WHITE PAPER

Training and Simulation
Virtual Reality

Using Virtual Reality as an Effective Corporate Training Tool

Learn how Intel deployed a scalable and effective virtual reality (VR) corporate training solution with a high return on investment

Authors

Adva Goldman
Global Environmental, Health & Safety Learning & Development Program Manager, Intel Corp.

Rodrigo Tamellini
Director of Commercial VR, Intel Corp.

Contributors

Richard Crowley
Software Apps Engineer, Intel Corp.

Verity Gould
Training Program Manager, Intel Corp.

Sensen Li
Instructional Designer, Intel Corp.

Patty Mckay
Training Manager, Intel Corp.

Joshua Miller
Media and Technology, Intel Corp.

Ken Phillips
Corporate Environmental Health and Safety Electrical Owner, Intel Corp.

Roland Richards
Media and Technology, Intel Corp.

Nathan Shehorn
Instructional and System Designer, Intel Corp.

Jamie Sherman
User Experience Research Scientist, Intel Corp.

Lawrence Soto
Automation Training Program Manager, Intel Corp.

Executive Summary

Intel recognizes the compelling potential benefits of virtual reality (VR) for enterprises. In this project, Intel designed and deployed a large-scale, results-oriented VR training solution that will complement its existing industry-leading training offerings. Using Intel's Electrical Safety Recertification course as a starting point, we collaborated with an independent software vendor (ISV) to successfully develop VR content, integrated it into our existing infrastructure and processes, and completed a 10-day testing phase. After some minor modifications, we plan to roll out the new course to additional sites and develop additional courses.

VR can help achieve the following enterprise benefits:

- Reduce training total cost of ownership (TCO)
- Increase trainee retention and motivation
- Increase training return on investment (ROI)

Trainee response to the new VR-based course was very positive—94 percent asked that more VR-based courses be made available—and ROI calculations indicate that by better matching required courses to employee job roles, the five-year ROI of just this one course could be as high as 300 percent. Read on to find out more about methodology, best practices, and results.

Introduction

Corporate training is a high priority across all industries—in the U.S. alone, companies spent about USD 93.6 billion on training and training components (payroll, equipment, travel, and outsourcing) in 2017—a 12.25 percent increase over 2016.[1] According to the Association for Talent Development, large companies spent about USD 1,200 per employee per year in 2016, spread over 34.1 hours per employee (4th year of increase).[2] In today's training environment there are multiple challenges that require leadership and development (L&D) teams to look for solutions:

- Changes in target audiences, budget, and skills needed to introduce new technologies
- Growing headcount and globalization (more international sites, different cultures, and many languages)
- The internet and YouTube* model sets the bar for presenting content and information in a short, crisp, and direct way

New technologies can help address those challenges.

Table of Contents

The Potential of Virtual Reality

Companies are exploring virtual reality (VR) as an effective learning tool to increase employee engagement, and return on investment (ROI) is important. Because VR is an emerging technology, data is scarce about exactly how much immersion and realism improve the learning process and content retention. Many seem to take it for granted that VR could be an excellent training tool, but until now few have moved beyond small pilot projects, and even those have not generated substantial quantifiable data.

Other challenges associated with implementing a VR training program include lack of familiarity with the various adjacent technologies—hardware and software. Instructional designers and training teams need to learn new skills while IT needs to accommodate new requirements. Integrating a new technology into existing training processes and corporate policies can be complex. For example, just a decade ago it took companies time to integrate web-based training (WBT).

On the other hand, VR offers a wide array of benefits. Realistic immersive simulation allows trainees to learn in a safe environment, with no physical danger or potential costly damage to equipment. "Freedom to fail" can improve outcomes, while the immersive experience increases learner engagement, which in turn increases motivation to learn and retain and may improve job satisfaction. VR lends itself to self-paced learning, making it convenient for both trainees and trainers.

Most importantly for calculating the ROI for a VR project, VR facilitates learning by doing. According to the cone of learning from Edgar Dale, after two weeks, the human brain tends to remember 10 percent of what it reads, 20 percent of what it hears, but 90 percent of what it does or simulates.[3]

Image based on Edgar Dale's "cone of learning."

A more recent study carried out by the National Training Laboratory revealed that retention rates for lecture-style learning were at 5 percent and reading rates were at 10 percent, while immersive, hands-on learning had a retention rate of 75 percent.[4] VR may speed learning as well; a 15-minute VR experience can produce the same amount of learning as from a 1.5-hour documentary.[5] VR offers a way to reduce training total cost of ownership (TCO) and/or increase training ROI through better and faster content delivery and longer content retention.

Because the potential enterprise benefits of VR are compelling, we at Intel decided to use our considerable training expertise to design and deploy a large-scale, results-oriented VR training project that could complement our existing industry-leading training offerings. This white paper shares our methodology, key learnings, and results.

An Overview of Intel's Training Environment

Intel's Corporate Services Talent and Solutions (CSTS) team, in partnership with the Corporate Environmental Health and Safety (EHS) team, manages the EHS training needs for Intel around the world, providing WBT, instructor-led training (ILT), on-the-job training (OJT), video, and job aids to over 81,000 trainees. We offer 120 EHS courses, with an average of 300,000 training hours per year. Most EHS courses are regulatory-driven and must comply with either the U.S. regulations, local regulations, or corporate policy.

The corporate EHS standards include five Fatality Prevention Programs. The courses included in these programs require higher focus, more attention to detail, and are associated with greater potential risks. Each Fatality Prevention Program comprises one to eight courses using either ILT, WBT, or OJT.

Improving Electrical Safety

Intel takes employees' safety very seriously. We saw VR as a way to improve our existing high-quality safety courses. After considering several topic possibilities, we settled on the Electrical Safety Recertification course.

This course belongs to the "Electrical Safety" Fatality Prevention Program. Over 11,000 Intel employees and contractors are required to take this course every year, at 13 different sites around the world, in 11 languages. This large target audience is required to understand theoretical knowledge and many of them perform daily electrical-related tasks. While the immediate risk of employee injury or death due to electrical causes is known, it is challenging to ensure that employees are highly skilled for the different levels of activities. There are eight courses in the "Electrical Safety" program, and we specifically chose the "Recertification" course because the content is highly relevant:

- Students are required to present knowledge and understanding as well as skills and competency by executing daily tasks safely.
- Electrical accidents are considered one of the deadliest workplace accidents; even 1/10th of an amp can stop a human heart. The Occupational Safety and Health

Administration (OSHA) indicates that electrical accidents result in fatal injuries with a ratio of 1:10, whereas the fatality ratio rate in other Fatality Prevention Programs is 1:300.[6]

Intel's core value is to keep our employees safe. Unfortunately, electrical-related incidents and near misses happen. From 2015 to 2017, there were 24 reported electrical incidents and about the same number of near misses at various locations at Intel. About 90 percent of the root causes for electrical-related incidents are behavioral-based (not following procedures). The Electrical Safety Recertification course covers causes for at least 65 percent of these known incidents. Note that we cannot guarantee that VR or any training will eliminate those incidents, but we believe education is the best prevention tool and VR is driving this education experience to another level of immersion/realism.

Every incident or near miss has many associated direct and indirect costs (injuries, absences, system time down, insurance premiums, and so on). The number of reported electrical-related incidents at Intel during 2015-2017 translates to over USD 1 million (based on internal calculations using an industry calculator and the amount of incidents Intel experienced during 2015-2017).

Defining Project Goals and Key Considerations

Intel employees have access to thousands of high-quality training courses created and delivered by our instructional designers and training teams. As we added VR to our existing corporate-training toolset, we specified the following goals:

- Influence hands-on behavioral change among relevant audience.
- Balance cost and effectiveness to maximize ROI.
- Develop best-known methods for adopting VR in a real-world corporate environment.
- Define clear metrics for measuring VR training effectiveness.
- Establish a scalable and repeatable process.

When we considered what makes training "effective," we examined effectiveness from several perspectives:

- **Content relevance.** We wanted to choose a topic that applied to a broad set of employees and that could make a quantifiable difference in employees' lives—something that was interactive, on-the-job, high risk/hazard potential or mission critical. See Improving Electrical Safety for details on the topic we chose for our VR project.
- **Quality of immersive experience.** There are several ways to implement a VR experience; because our project focused on safety and an excellent learning process, a core pillar of the project was to guarantee a high-quality experience. High-quality VR should replicate a realistic working environment that provides the trainee with a genuine experience while performing a specific procedure or task. While cost was a factor, we needed to balance that consideration with the fact that poor VR experiences (jitter, poor images, and so on) can prevent trainees from benefitting from the learning experience.

  Quality is affected by more than visuals—it also includes the sounds, user interface (UI), the sharpness and accuracy of movements and controllers, and a room-scale solution that lets the trainee approach a tool and realistically perform the required tasks. We wanted to replicate the experience that OJT would provide but eliminate the need for a trainer, thereby reducing cost and time. The safety net provided by VR allows us to show consequences of key mistakes and deliver more challenging scenarios, which increases the depth of possibilities and tasks.
- **Ease of measurement.** We needed to be able to use telemetry to compare VR learning results with a baseline from the existing WBT. As stated earlier, most people take for granted that a VR-based immersive learning experience drives results, but the fact is VR is still not widely available. We saw some activity around VR training in the industry in the past two years, but most information was not publicly available. Results, ROI, and TCO are crucial elements to garner stakeholders' support and sponsorship for new technology adoption. So, we needed to look back at WBT (to establish a baseline) and forward to VR-based training and design a full set of telemetry to explore the economics behind VR. We aimed to collect both qualitative and quantitative data about the VR learning experience and compare that data with traditional web-based tools.
- **User friendliness.** To increase ROI, we primarily used self-paced training so that human guidance is not necessary. But, we realize that not everyone is an early adopter of technology; in fact, most of our trainees have little to no experience with VR. We wanted our training course to be easy to use for both technically savvy employees and employees who may have never used a VR system before. One of the success criteria for our VR project is to provide a frictionless solution (for both trainee and to the training team) that brings the trainee up to speed quickly, so they feel comfortable with VR and can quickly focus on the core learnings of the course.
- **Corporate friendliness.** Intel, like any other big corporation, has policies that must be followed. Whatever we developed had to seamlessly integrate with a wide range of existing corporate processes and policies, even though these processes and policies were formed with no consideration for VR use cases. Our solution had to work at any Intel facility and provide an identical experience to every trainee regardless of the training location. We had to integrate with HR, legal, security and not least of all IT. Infusing new hardware and software into a secure network had its challenges, as did securing the connection between the new software application and our existing learning management system (LMS). We had to consider even the most unlikely scenarios and ensure we had a mitigation plan in place so neither the company nor the trainee was compromised.

Our Solution: Implementing Immersive Corporate Training at Scale

We took a phased approach to building our VR-based corporate training solution. The entire project took about eight months from stakeholder approval to our recent 10-day testing, and involved close collaboration with a strategic independent software vendor (ISV) to develop the solution. The testing is complete, and based on the results, we are making minor final adjustments to the course content and user experience (UX). We anticipate bringing the course to production during Q4 of 2018.

The following sections describe the best practices we developed as we progressed through content creation, deployment, integration, and measurement.

Content Creation

Content creation is a key concept when developing a VR-based corporate training solution and involves several factors such as instructional design strategies, content structure, storyboarding, VR modeling, and content validation.

VR-Based Instructional Design Challenges

Proficiency in performing tasks in a virtual environment requires mastering the VR gadgets to control and manipulate the learning experience. Instructional designers may often assume that learners will encounter few challenges as they familiarize themselves with a virtual environment and can fluently translate their prior experiences, if any, into the learning activities we design. This is not necessarily true; we must realize that learners are still accepting and adjusting themselves to the new immersive environment. To address this concern, we grounded our work in the Knowledge Progression Framework[7] as we designed and developed the storyboard to illustrate game logic.

Since VR enables a user to physically perform tasks (compared to the traditional WBT environment, which primarily focuses on theoretical knowledge), we had to work closely with the subject matter expert (SME) to translate theoretical corporate electrical safety principles into measurable actions. This is a critical step because it helps define expected performance at the workplace, instead of dumping policies on learners and asking them to memorize them. In a well-designed virtual environment, learners are exposed to a stream of scenarios and the focus becomes "what to do" instead of "what to know." Instructional designers need to create sufficient interactive scenarios so that learners can effectively utilize the capabilities of VR to support the desired learning outcomes.

Instructional Design Strategies

We used these best practices as we designed our VR content:

- **Define action-driven learning objectives.** In our case, the purpose of this virtual learning experience was twofold:
  - Allow learners to practice specific electrical working instructions in an injury-free environment
  - Examine learners on various safety and operation procedures, such as troubleshooting and maintenance

  Therefore, we had to identify the most critical performance that learners should demonstrate in reality and narrow that down to actionable items that could be measured in a quantitative way.
- **Think as a learner and think for the learner.** VR is all about the trainee's experience. Instructional designers need to consider how the content engages learners, draws them in, and stimulates their senses. It is important to recognize that learners drive their own learning process because they can design, change, and manipulate their experience, as well as have emotional reactions, such as fear and excitement. On the other hand, learners can fail without risk, which encourages them to explore new solutions and be creative. They can also seek an alternative approach to completing a task, one that might prove to be faster or more productive than a previously successful attempt. The combination of all of this can trigger curiosity and reflection in a learning environment.
- **Use "what-if" scenarios to stimulate thinking.** What-if scenarios represent situations in which learners need to perform actions based on the pre-defined conditions and are a key indicator of their problem-solving skills. This element is critical because incorporating desirable difficulties into learning scenarios can foster significant improvements in long-term learning retention.[8]
- **Use feedback loops to provide scaffoldings.** The final essential component of the learning design is a feedback loop. In the absence of facilitators in the virtual environment, redirection provides learners with formative feedback and guidelines throughout the scenarios. During this process, critical learning and problem solving are reinforced. Moreover, incorporating timely and targeted feedback provides learners with information when incorrect decisions are made, and further cue learners to progress through the scenarios.

Content Structure

Guided by the Knowledge Progression Framework and design strategies we identified above, we proposed the following learning structure:

- **Level 0 Setup.** Get familiar with the VR gadgets and environment. At this level, learners are expected to learn the basic skills to use the VR gadgets, such as how to select an object and navigate in the virtual environment. Simple tasks should be in place for them to practice.
- **Level 1 Basic.** Guide learners through the procedure with tailored feedback. At this level, learners are guided through each step in the workflow. UI indicators and context-sensitive "hints" help learners understand how to perform the current step, know which step they are in, and how many steps remain. They are presented with short explanations for each step in the workflow. Each mistake is followed by feedback and "hints" about how to complete the step correctly. Learners can retry each step several times and review the explanations again.
- **Level 2 Intermediate.** Allow the learner to explore what-if scenarios (see next page).
- **Level 3 Advanced.** Scope creep scenarios.

Level 2 and Level 3 simulate real-life scenarios. There is no UI indication for the learner's current stage, and learners receive only generic feedback and limited guidance. The VR system can simulate the consequence (that is, what may happen in reality) in case of incorrect actions. Learners have the flexibility to determine where they want to go, what they want to do, and in which order they want to perform tasks.

At the end of each level, it is important to provide a performance summary and feedback for improvement. The VR system should record all the trainee's activities during the session; this information can then be used for analysis, debriefing, and reports. The score is configured by time spent on that level and the number of deviations from the correct workflow.

VR Storyboarding

The difference between VR and traditional training approaches is the sense of immersion. VR training engages learners and stimulates their senses. Learners must demonstrate their understanding in action, receive immediate feedback, and adjust their behavior accordingly. In contrast, traditional training is more like a one-way approach where learners can only passively accept information. It is difficult to determine how learners interpret the knowledge without giving them a quiz.

As mentioned earlier, VR-based training focuses on what you do, while the traditional approach focuses on what you know.

We found that simply translating a traditional word-based storyboard to VR training left many loose ends that required additional fine tuning. There is a need to create detailed environments and attention to details is very important. As we worked with the ISV, we used more images and videos than are typically used for storyboarding. Providing this extra level of visual detail during the briefing and debriefing phases helped close the storyboarding gaps. Also, because VR is an open-ended scenario, this level of guidance helped keep the ISV focused on the core elements that need to be included.

VR Modeling

We worked with a studio (SkillReal* by Compedia) to build this realistic and immersive experience. This ISV specializes in training and simulation and helped us to shorten the time it took to develop the course. It also kept our L&D training specialists focused on the content itself, not on learning VR programing capabilities. Another reason we chose this path was our original commitment to improve the quality of the UX and UI. Working with Intel's Corporate Service media team, we shared 221 high-resolution images with SkillReal, and they captured an additional 558 images. We also created four videos and a sound track from actual Intel factories, allowing SkillReal to build a photorealistic training environment (see Figure 1).

In agreement with the ISV, we divided the content delivery into two major stages (10 weeks of development each). Although it may seem like developing the whole course at once would have been faster, our experience revealed that smaller chunks of material and additional validation steps produced better content and prevented costly and time-consuming re-work.

During the first stage, we worked with the ISV for the first two weeks planning and establishing the 3D workflow and designing and creating the Level 0 floor (Tutorial Mode). The ISV used regular office references (desk, cabinet, chair, and so on) for the modelling and texturing, in order to create a standard office environment. Once the tutorial level was complete, they spent another two weeks collecting references of a typical electrical environment and drawing blueprints, resulting in a 3D prototype of the entire Level 1. The prototype helped identify all the 3D elements that needed to be modeled.

Using the prototype as a guide, the ISV spent about a month creating approximately 40 objects. Finally, they spent another three weeks creating the entire Level 1 in the game engine, adding lights, animations, shaders, and so on. See Appendix for some visual examples of creating the Level 0 and Level 1 content.

Ongoing interaction with the ISV was crucial to find the ideal balance between UX, realism, and final cost implications. The key learning was that while a realistic simulation was important, requiring too many factors to create realism compromises the UX. For example, to perform some procedures, technicians must wear specific protective gear. And although wearing protective gear is crucial in real-life situations, in a VR environment, making them go through the motions of putting on gloves and other protective gear can be tedious and doesn't add any real learning value. Actually, this level of detail would probably just add cost to the project since those interactions and renderings would consume project coding resources.

Another UX trade-off was considering whether to use VR teleporting. Teleporting is a common method for shortening the walking distance between objects and making the overall experience more fluid. However, we decided not to use teleporting because moving carefully between electrical cabinets is important to the actual experience. We also didn't want accidental teleporting to place trainees too close to an energized piece of equipment. Additionally, if the trainee forgets something during a task, we want them to be able to walk back and figure out what they missed. Finding the right balance between "too much detail" and "too shallow" was challenging and will be different for every course created.

Figure 1. High-resolution images, combined with sound tracks, provide a realistic experience for trainees.

Another important decision was the delivery method, because VR-based training can be delivered in several ways. The trainee can remain seated, stand in one place, or have access to a room-scale experience. Trade-offs are often required between interactivity and ease of deployment. Real estate availability is also a relevant criterion when planning for scale-up. Since we had a fairly high interaction with electrical equipment and experiencing the environment's sounds is relevant for the content scope, we decided for a room-scale approach (see Deployment for more details).

Content Validation

A final learning to share about VR content creation may sound obvious but it was surprisingly challenging. During course development we used a combination of VR experts, content experts, and trainees from widely different age, gender, technology familiarity, and knowledge backgrounds to validate the UI and technical content. We created a test script that could capture trainees' feedback that enabled us to map bottlenecks in the training flow. We let the trainees vocalize their thought process (what they understood, what they thought they should do next, what they were confused about) while they experienced the training. Their insights were recorded on top of the storyboard.

This approach made it easier to structure and consolidate feedback and helped us list all changes required (both to UX and content). We used a set of criteria to evaluate the feedback to identify which suggestions should or should not be implemented.

Deployment

We decided to roll out and fine tune the VR-based corporate training solution at a single site, then scale it to a second international site after a few months. Initial deployment steps included identifying the number of potential trainees, estimating the time required to complete the training, and deciding how many systems/licenses would be required to deliver the training.

We used this information to work ahead of time with a wide variety of stakeholders, including representatives from HR, legal, security, safety, IT, facilities and signage, internal affairs, technical support, and factory site teams. This holistic approach minimized roadblocks and unforeseen scenarios. This was an important step. In our experience, getting everyone on the same page was at least as difficult as surmounting challenges around creating the VR content. For example, without close collaboration with IT, integration of the new VR course with Intel's enterprise-wide LMS would have been impossible. Safety personnel can help ensure that the VR room is as risk-free as possible. Facilities experts can help find the location for the training room that includes badge-controlled entry. HR and the communications team can help raise awareness of the new training option and its benefits.

Another aspect of solution deployment included ease of use. We developed end-user instructions that covered the badge-controlled entry and login, hygiene, and more. The simple instructions, posted on the training room wall, can be used by all employees whether they are VR experts or neophytes. We designed the solution to be self-paced. Employees can schedule a convenient training time (using an internally developed room-scheduling tool), go to the training room, and swipe their badge to get in. Once they have concluded the training, they can simply exit the room. No additional personnel are necessary to guide the training.

Figure 2 shows our dedicated training room blueprint; more details are provided below.

1. **VR-ready systems.** We used two high-end desktops powered by Intel® Core™ i7 processors. Those system specs are aligned with Intel's recommended specs for VR content consumption (see Table 1 on the next page).
2. **Virtual fence and feedback mats.** Besides the virtual fence setup (standard in VR deployments) we provided an extra layer of user feedback using special mats on the floor.

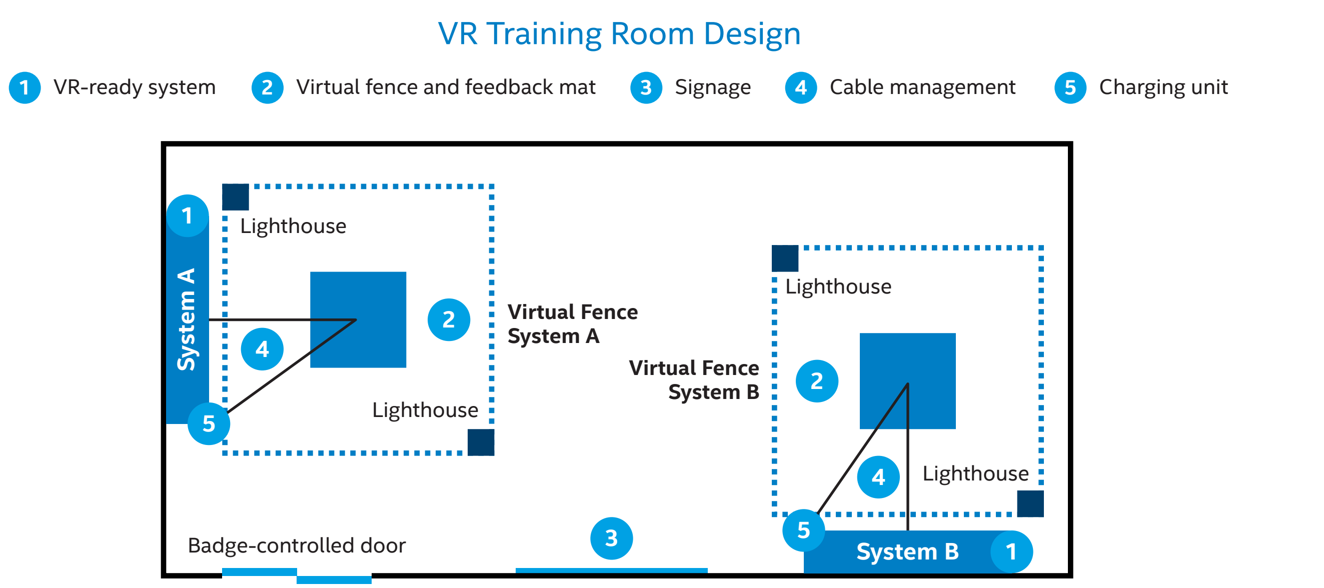


Figure 2. Our virtual reality (VR) training room is badge-controlled and can accommodate two trainees at a time.

Therefore, besides the visual clue of the blue virtual safety grid, the trainee can physically feel when they step out of the safety boundaries.

3. **Signage.** As mentioned earlier, instructional posters help trainees proceed step-by-step, such as how to adjust the VR headset and how to launch the VR course.
4. **Cable management.** The VR headset cord was suspended using retractable cable systems, minimizing the chance of accidents or entanglement.
5. **Charging unit.** To keep controllers properly charged at all times, we installed a special set of chargers and holders to connect controllers and headsets after each training session.

Integration

In order to scale, any new technology needs to comply with corporate policies. One of those checkpoints goes through IT, and VR has its own challenges from that perspective. The VR software ecosystem is fairly new, and updates are quite common. On the other hand, a corporate software image, used worldwide by thousands of employees, requires high standards of stability and security. It's common for corporations to install their own bug and security patches, rather than use the latest versions of software.

We faced three major challenges during our integration:

- **Preventing repeated calibration** of the VR system every time a new trainee logged into the training system. Recalibration is a time-consuming and difficult process, but IT policies require a standard corporate software image on the desktop PC in the training room. Our challenge: we couldn't modify the software image to avoid recalibration.
- **Software incompatibilities** between the standard security software that is automatically pushed to every desktop PC at Intel and the VR solution caused random reboots and system crashes.
- **Insufficient content controls** in the standard content distribution system, which was designed for consumer use, not enterprise use, did not meet Intel's information security and personal use policies.

We found that multiple layers of protection could help us comply with Intel's policies. To address the repeated recalibration issue during the testing phase, we added a layer to the login process, keeping the desktop PC logged in at all times to avoid triggering recalibration and ensuring trainees log in at the application level. This approach requires some additional environment security measures. When the course moves into production, we will use a kiosk corporate software image.[9]

At the outset of the project, there was not an existing solution that could solve the software incompatibility and content control challenges, so we collaborated with HTC to roll out VIVE* Pro's enterprise-grade platform (part of the VIVE Enterprise Advantage and Advantage+ program). This gave us the flexibility and control we needed to manage software deployments and updates easily and securely. HTC's Device Management System* monitors the VIVE installations, allowing us to deploy and manage software and drivers for all devices behind a firewall.

We worked with IT to verify that our VR system met all policy requirements for connection to the LMS, our internal network, and the privacy expectations for our employees. For the LMS, we created an application (using internal application developer resources) to handle the connection. The application automated many aspects of the training data (user login, course eligibility, scores, certificates, pre- and post-tests, and evaluation). We also used this application to launch additional support tools (such as tutorial videos required for the solution deployment) and it can accommodate additional VR classes in the future.

Table 1. Training Reference Architecture for Commercial Virtual Reality (VR)

		Use Case: Content Creation	
	Use Case: Content Consumption		
	Good	**Better**	**Best**
Processor	Intel® Core™ i5/i5+ processor 7th or 8th Gen S/H Series	Intel Core i7/i7+ processor 7th or 8th Gen S/H Series	Intel Core X-Series processor or Intel® Xeon® processor – Professional or Intel Core i9/i9+ processor H Series
Storage and Memory	Intel® SATA SSD + HDD with Intel® Optane™ memory 32 GB recommended	Intel® PCIe* SSD + HDD with Intel Optane memory 32 GB recommended	Intel Optane SSD 900P/905P Series + HDD with Intel Optane memory 64 GB H Series Intel Optane SSD 800P + HDD with Intel Optane memory 64 GB
Other Components	NVIDIA GTX* 1060/Radeon RX* 580 (equivalent or better) Intel® vPro™ technology	NVIDIA GTX 1070/Radeon RX Vega 56 (equivalent or better) Wireless VR Intel vPro technology	NVIDIA GTX 1080/Radeon RX Vega 64/ Quadro P4000 (equivalent or better) Wireless VR Intel vPro technology

SSD = solid state drive; HDD = hard disk drive

Measurement

As mentioned earlier, one of our main goals was to generate both qualitative and quantitative results regarding the efficiency of learning and cost of VR-based corporate training. We used telemetry and analytics to gather data, then performed rigorous A/B testing, comparing data collected during the VR training to our extensive baseline of data about WBT performance and retention. That comparison helped us define a per-user cost and final ROI (see Results and Key Learnings).

Table 2 shows the various metrics we tracked using telemetry and other feedback mechanisms.

Results and Key Learnings

After two rounds of pre-testing, which included validating both the content and the UI as well as the UX, we rolled out an official testing period of 10 days. The objective was to evaluate the solution as a whole, capture data, and finalize the VR room blueprint to scale the solution to additional sites.

The testing proposal was to capture insights from self-paced training observation and additional data from our telemetry; the target audience consisted of Intel employees who were officially required to take the course and had already successfully obtained credit for all pre-required courses.

The test would include a post-test (as the traditional WBT course does) measuring trainee content understanding and granting them the credits, once approved.

Initial Observations

We made the following observations during the 10-day testing period.

Theoretical versus Practical Knowledge

There are four courses that the required target audience must successfully complete before they can take the annual Electrical Safety Recertification course, in any of its forms (WBT or VR). The tested audience, most of whom have worked at Intel for years, are used to taking the recertification course in a WBT format.

After taking the VR course, our observations indicated that the vast majority (about 75 percent) of the trainees struggled to complete the required training electrical procedures. Their limitations were primarily associated with properly and safely performing the hands-on tasks (lack of experience with equipment, low familiarity with tools, and no clear understanding of the proper sequence for task execution). After taking the initial prerequisite theoretical courses and the WBT recertification course for multiple years, when asked to perform real-life tasks, the procedural and safety gaps were exposed. Our post-experience interviews clearly indicated that most of this audience never had and never will have (occasionally or on daily basis) a need or opportunity to execute those tasks.

Table 2. Virtual Reality (VR) Corporate Training Metrics

Educational perspective | E2E deployment | User perspective

Metric	Reason	Definition
VR training conversion rate	Understand trainees' willingness to try VR-based training vs. traditional web-based version.	Percentage of trainees who chose to take the VR option out of all those who were required to take the course.
VR usage learning curve	Understand how long it takes the user to get familiar with controls.	Impact of VR solution on training execution. Is it easy to use?
Training time	Time spent on training/out-of-role time for managers. Understanding if VR-based training can minimize the total time under training is a relevant factor.	Time required to perform the full course.
VR learning efficiency	Understand the impact of VR on content retention.	Compare both training versions (VR and web-based) using L3 approach.
Pre- and post-test exams	Bring quantitative measurement to learn effectiveness.	Specific measurement to assess learning curve of VR vs. web training.
On-the-job (OTJ) trainer feedback	Senior peers usually help with OTJ training, understand their perception/advocacy of new training. Method and impact on the job.	Qualitative feedback coming from peer trainer to evaluate performance change.
System usage rate	Understand the system usage rate for several outputs (TCO, ROI, roll-out metrics, and voluntary retaking of course).	System usage hours vs. student universe.
Map development/ deployment effort	Understand if/how VR-based content development affects additional team dedication.	Measure hours required to develop and deploy (ISD, SME, deployment).
IT issues	Measure impact on IT system to share BKMs on blueprint.	Compare the number of HR tickets associated with VR training to the number of HR tickets associated with web-based training (WBT).
User feedback	Understand user perspective on VR learning experience.	Quantitative and qualitative feedback on training experience.

Technology Familiarity

As expected, an overwhelming majority of the audience (over 90 percent) had very limited or no prior VR experience. Getting to know the controllers, adjusting the headset, and being able to interact with elements in the VR experience was a learning curve. After a few minutes of experience, most of them gained the minimum level of dexterity (the experience requires using both hands to manipulate at least four buttons and ideally the capability to use body movements aligned with controller and head movements). Only 10 percent of the audience experienced difficulty getting familiar with the equipment.

Physical Comfort

To complete all stages of the course, the average time inside the VR experience was about 42 minutes. However, due to lack of procedural knowledge and unfamiliarity with controllers and the VR experience, or failure to safely complete a task (necessitating the repeat of some steps), some users had a much longer VR exposure (in some cases over 90 minutes); we could discern a higher level of fatigue in those cases.

Only 10 percent of trainees reported some level of physical discomfort, with only 5 percent feeling a higher level of nausea or dizziness that prevented them from completing the training. We noticed that some of the physical discomfort reported was more prominent within the 30 percent of trainees who were wearing or supposed to be wearing glasses. Some were able to fit the head-mounted display (HMD) over their glasses, while some chose to take their glasses off. This specific audience also reported difficulties reading some instructions.

Users also reported that they felt uncomfortable when pop-up messages appeared too close to them or when a moving element of the environment (an opening door or a moving cart) "touched" them.

To perform tasks, trainees sometimes needed to get on their knees, which was challenging for a small segment of the participants.

Pre- and Post-Tests

We applied the same tests for WBT and VR-based trainees. Our original plan was to use these tests to measure VR's test scoring impact. By comparing the pre-test and post-test (same subset of questions), we noticed an improvement of 19 percent in the post-test scoring compared to the pre-test scoring.

Because the Electrical Safety Recertification course is part of a Fatality Prevention Program, the minimum score to be approved is 90 percent. Intel allows trainees to retake the final test as many times as they need to reach the qualifying score. Consequently, most trainees take the post-test several times prior to being approved. When we explored VR-based and WBT-based individual scoring and overall approval rate success, we couldn't capture a significant advantage of one method over the other—both VR and WBT had similar scoring with a 5 percent VR advantage on approval success rate. Based on the audience mismatch (remember, our post-experience interviews revealed that most of the trainee population had never performed electrical-related tasks and were not likely to) and the gap between theoretical and practical knowledge, we are investigating how to improve the post-test to better track audience proficiency.

User Feedback

Virtual reality (VR) was overwhelmingly approved by trainees—94 percent requested that more VR-based training be made available. Trainees indicated during the post-experience interviews that web-based training (WBT) had become a simple click-through process; they were not paying much attention and were unable to perform the procedures. They acknowledged that being able to focus on the tasks, seeing the consequences of their decisions, and physically performing the procedural steps was a great contribution to the course. Here are just a few of the comments we received during the post-experience interviews:

"Oh… I died. I am going to remember that."

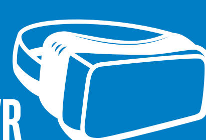
"The WBT is just a click-through process, nobody really pays attention to that."

"The situation is real enough that I feel the same kind of feelings as when I am next to a panel."

"This is definitely practical for fall protection, pallet jack, fork lift… oh yeah."

"The hardest thing for me is just the movement. After that I was ok."

94% OF TRAINEES WANT MORE VR



94% of trainees who took the VR-based course requested that more VR-based courses be made available.

300% VR ROI

Our first VR-based corporate training course has an estimated potential 5-year ROI of 300%.

Return on Investment

We have started to model the ROI and net present value (NPV) figures for our VR solution. Our model covers the variables shown in Table 3.

Based on existing incident reports, if we make an assumption to reduce incidents by 25 percent, we can project an ROI of 28 percent over five years. Our team considered a conservative figure since the course scope covers about 65 percent of reported incidents and our data indicate that the vast majority of those incidents were due to procedural mistakes.

This ROI figure should also improve based on the findings of our 10-day testing period. The pilot project team is suggesting significantly reducing the number of employees who are required to take this training (eliminating those who are not exposed directly or indirectly to any electrical hazard and are not required to perform any electrical procedures). If we reduce the trainee base to 50 percent of the existing demand, the ROI goes up to 300 percent over five years.

Whether the ROI is 28 percent or 300 percent, we considered only a single course in VR. In reality, the usage rate of the VR systems per site allows more courses to be offered with the same structure. Therefore, some fixed costs, such as equipment, training room real estate, and maintenance could be diluted with other courses—thereby further improving the final project ROI.

Table 3. Variables for Calculating Return on Investment (ROI)

Costs	Benefits
• Development • Install at site • Licensing per site • Sustainability (hardware maintenance) • Incremental time per employee (dislocation to VR training room) • Training room (real estate) • Training time (current methods compared to VR)	• Expected incidents deduced per course • Cost incurred per incident • Expected incidents savings per course

Conclusion

After a final round of minor adjustments on product and process, we plan to move into production at the first site and replicate the blueprint at an additional site.

Our set of recommendations based on the test will be validated during this production phase. We will collect additional data and develop a final global deployment plan. The ROI figures give us a high level of confidence in the course rollout and the learnings we have observed so far will help us shape a broad VR-based training program at Intel.

We hope this document helps other industry players to embrace VR technology and we look forward to sharing best-known practices not included in this document scope. For organizations just starting to consider VR training, see Figure 3 for a quick summary of steps based on our own experience.

To learn more about virtual reality and how Intel can help with VR solutions, visit **intel.com/VirtualReality**.

Corporate Training Step-by-Step Overview

Understand training needs	Identify the ISV partner profile	Define key content concepts	Work around deployment challenges	Measurement
Select a training scenario where immersive experiences add value to the learning process: • Interactive • On the job • Dangerous • Mission critical	**Studio vs. Platform** Studio Advantages: • Low VR expertise • Shorter TTM Studio Disadvantages: • Scale cost • Low customization Platform Advantages: • Scalable • Customizable Platform Disadvantages: • Higher internal capabilities	Define (with ISV support) some key content concepts: • Realism vs. UX vs. cost • Learning method • VR-ready storyboard and briefing/debriefing process • Seating vs. standing vs. room scale	Plan the interface in advance with other key organization partners (HR, Legal, Security, IT, Corporate Services, Internal Affairs, Tech Support, site teams). Forecast the system quantity need and roll-out in stages.	Plan to capture relevant KPIs and data to a data-driven ROI approach (some should be built in the training itself such as telemetry data).

Figure 3. A step-by-step, phased approach can help deliver virtual reality (VR)-based corporate training at scale.

Appendix: Real-World Examples of Creating VR Content

The images and captions in this appendix provide visual detail and examples about the various steps involved in creating Level 0 and Level 1 virtual reality (VR) content for our VR-based "Electrical Recertification" course.

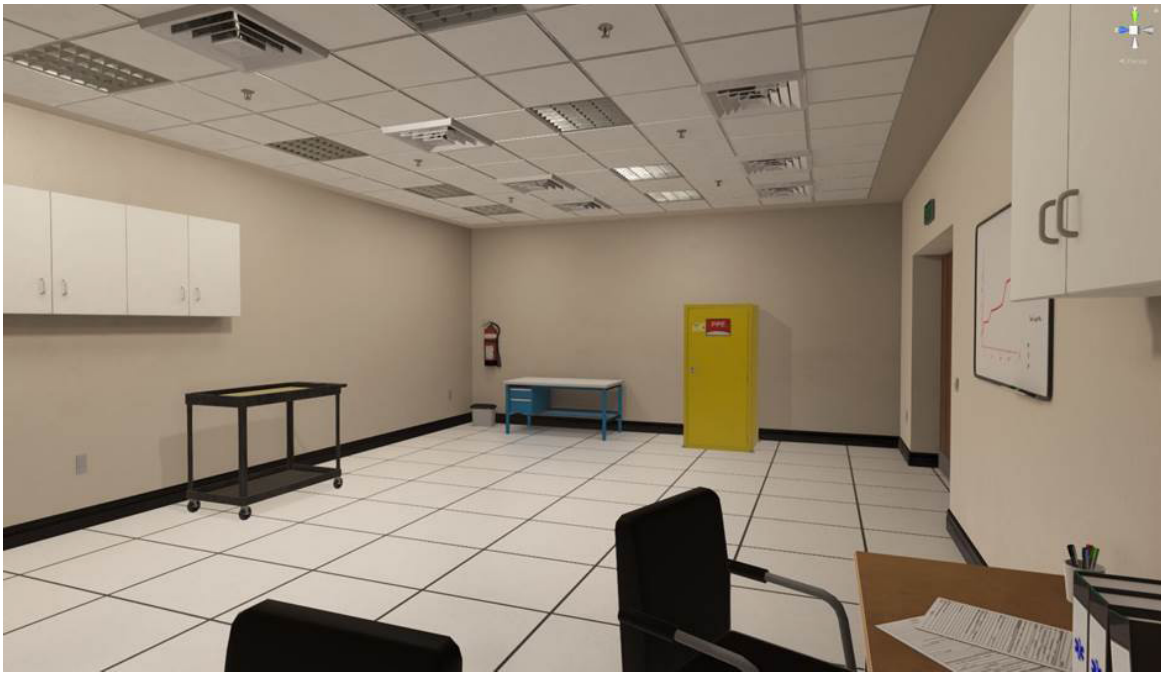


Figure 1. Using standard office equipment references in the Tutorial Mode (Level 0) creates a comfortable environment as the trainee gets accustomed with the virtual reality (VR) equipment.

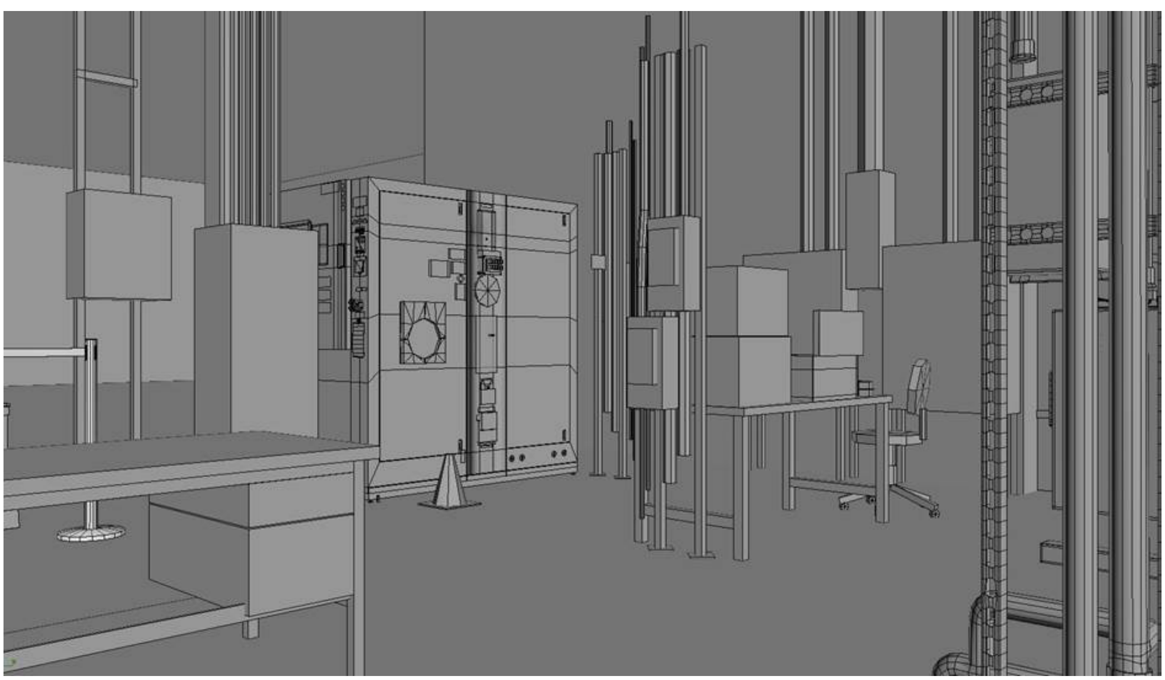


Figure 2. A detailed 3D prototype of the Level 1 content identifies all the necessary 3D elements that need to be modeled.

Figure 3. Once the 3D prototype is complete, modeling of each object can begin. Here, we are modeling an electrical tool.

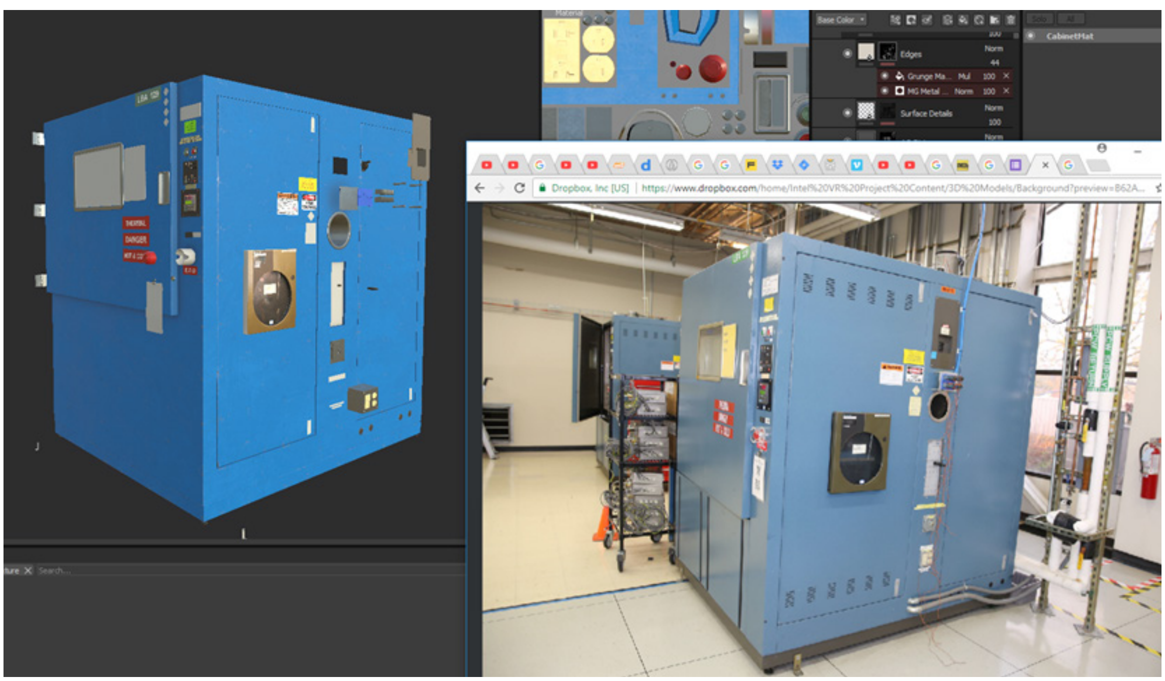


Figure 4. Here is another example of modeling an object—in this case, an electrical cabinet.

Figure 5. The final step is to create the entire Level 1 content in the game engine, adding lights, animations, shaders, and so on.

Figure 6. Here is another example of the final content, displaying its high level of photorealism.

Solution Provided By:

Learn More

You may find the following resources useful:

HTC VIVE* vive.com/us

SkillReal* from Compedia skillreal.com

Intel® Core™ i7 processors intel.com/corei7

VR-ready PCs intel.com/devices

[1] Statista, "Total training expenditures in the United States from 2012 to 2017 (in billion U.S. dollars)." statista.com/statistics/788521/training-expenditures-united-states

[2] Association for Talent Development, "2017 State of the Industry." td.org/research-reports/2017-state-of-the-industry

[3] Unimersiv, "We create great VR Training & Educational experiences." unimersiv.com/about-us

[4] The Learning Pyramid, thepeakperformancecenter.com/educational-learning/learning/principles-of-learning/learning-pyramid

[5] Unimersiv, January 2015. "Virtual Reality as a Learning Tool." unimersiv.com/virtual-reality-as-a-learning-tool

[6] E-Hazard, October 2014. "Why Electrical Safety Training Is Important For Supervisors." e-hazard.com/blog/why-electrical-training-is-important-for-supervisors

[7] Brophy, S. P. and Li, S. (2010), "A Framework for Using Graphical Representations as Assessment of Engineering Thinking": (Proceedings of the 2010 American Society of Engineering Education Annual Conference & Exposition, Louisville, KY.). This framework highlights the co-development of both tool literacy and domain knowledge. It demonstrates how learners with various knowledge skills can develop their conceptual understanding of tools and domain knowledge.

[8] Smith, J.K.; Brown, P.C.; Roediger III, H.L.; and McDaniel, M.A. "Make It Stick. The Science of Successful Learning." makeitstick.net

[9] A kiosk corporate image is a software image (OS and applications) that is open to a general internal audience. It is more restrictive than a user-specific software image (for example, users cannot add applications or send email from it). Often, kiosks provide Internet access in an open working area; our VR solution works similarly, but provides VR access instead. For more information on this topic, visit howtogeek.com/173562/how-to-easily-put-a-windows-pc-into-kiosk-mode-with-assigned-access.