High-Fidelity Training on Demand via the Cloud

Lisa Jean Bair
SAIC
Norfolk, VA
lisa.j.bair@saic.com

John R. Fairchild
SAIC
Winter Park, FL
john.r.fairchild@saic.com

Stephen A. Elkins
SAIC
McLean, VA
stephen.a.elkins@saic.com

ABSTRACT

Current simulation-based training focuses on hardware-based capabilities installed at forward deployed and designated military and civilian training sites. Learners must conform to training center schedules and resource limitations. These individual site installations require dedicated support for trainer operations, maintenance, network, and information assurance. Moreover, software updates and configuration changes are difficult and expensive to coordinate, given dispersed installations. Geographically dispersed learners need access to training more rapidly with reduced overhead and lifecycle costs. Ideally, these learners would have access to a broad-spectrum of training media, such as simulations, at their home-stations or training sites without the extensive infrastructure to support full simulation systems. The "cloud," networked remote-servers accessed via the internet, may solve this problem by providing broad access while localizing infrastructure—Training on Demand (TOD). This paper gives a brief review of the current state-of-the-art in providing simulation-based training and the challenges in moving it to the cloud. We describe a solution that allows for platform-independent deployment of simulation and game-based training—from tablets to personal computers—over cellular, WIFI, and broadband network connections, whether government- or commercial-based. We conclude with use-case results and a discussion of future development-research required.

ABOUT THE AUTHORS

Lisa Jean Bair is a Solutions Architect and Technical Fellow for SAIC's training and simulation service line, serving as its Training Enterprise Market Initiative lead. She has over 19 years of experience in operations analysis, with over 20 peer-reviewed publications and a 2013 I/ITSEC best paper nomination. She has led research and development, analysis and support tasks completed by project teams consisting from individual contributors to small teams containing a wide range of expertise levels, from entry-level research assistant to PhD qualified subject matter experts. She has engaged in all aspects of company management, including technical and programmatic management, customer engagement, and business development and is active in the modeling and simulation (M&S) community, currently serving as chair of the Communications, Outreach, and Public Affairs committee for the NMSC. Ms Bair's areas of expertise include M&S validation, simulation supported analysis, agent-based simulation, multiple objective decision analysis, multi-attribute utility theory, and analysis. Her experience includes concept development and experimentation; analyses of alternatives; complex decision problems; M&S planning use; test and evaluation; and validation. Her original research established a comprehensive multi-agent system taxonomy and foundational principals and a framework for M&S validation. Her current research interests lie in developing multi-modal education media. Ms. Bair earned an MS in Operations Research from The College of William and Mary and a BS in Applied Mathematics from ODU.

John Fairchild is a Game Designer in SAIC's Training and Simulation Service Line. Since joining SAIC in 2007 he has worked primarily with the Army Game Studio (Redstone Arsenal, Huntsville, Alabama) developing the America's Army game and numerous other serious-games projects for training, simulation, education and public outreach. Mr. Fairchild has worked with game-based technology since he graduated from Full Sail University, a digital arts college in Orlando, FL and is currently leading a strategic partnership between SAIC and Full Sail, pursuing serious games, interactive instruction, synthetic training environments and other advanced game-based technologies initiatives. Mr. Fairchild is the technical lead for SAIC's Training on Demand Independent Research and Development (IR&D) effort. He is interested in developing serious-games with demonstrable benefits that provide engaging, interactive experiential learning and is interested in evolving educational and instructional standards to meet changing technology.

Stephen Elkins is a Solutions Architect for the SAIC Education and Training Directorate. He previously served 20 years in the U.S. Navy (retired 2004) and joined the SAIC team as a Mobile Tactical Training Specialist. He held positions as Assistant Project Manager and Project Manager for the development of Antisubmarine Warfare training systems for the U.S. Navy. Currently, he manages SAIC's Training on Demand IR&D project and participates in the development of proposals for SAIC's education and training offerings. Mr. Elkins holds degrees in Workforce Education and Development (Southern Illinois University) and Management (Embry-Riddle Aeronautical University).

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INTRODUCTION

Over the ages, the commercial market has viewed growth in technology as an opportunity to improve education, with varying degrees of support and skepticism in the research, teaching, and public arenas. The advent of personal computing and the rise of the internet has proved no different. The potential changes and influences these technologies could make were there for those with enough vision to see. In 1969, a UCLA press release quoted Leonard Kleinrock as saying in response to the then-forthcoming ARPANET:

> As of now, computer networks are still in their infancy. But as they grow up and become more sophisticated, we will probably see the spread of ‘computer utilities’ which, like present electric and telephone utilities, will service individual homes and offices across the country. (Kleinrock, 2003)

This prophetic statement heralded the *Information Age* and recognized the power of the internet that the 21st century will see realized. Some estimate that corporate spending on cloud computing represent approximately 5% of total information technology spending, or $100 billion dollars—Amazon Web Services adds sufficient infrastructure each day to power the company of ten-years ago. Corporate reluctance to adopt cloud services stems from perceived cost savings by keeping the services in-house and worries about data security (“Silver lining,” 2014). This growth is across all business sectors with some estimates saying that 69% of enterprises have adopted some form of cloud-technology (“Cloud Computing Adoption Continues Accelerating In The Enterprise,” 2014). The military sector is no different. The US Department of Defense (DOD) Cloud Computing Strategy (Takai, 2012) encourages the adoption of cloud services not only from internally provided DOD sources but also from commercial vendors that can meet mission requirements and information assurance, security, and other policy requirements. Further, the North Atlantic Treaty Organization (NATO) Science and Technology Organization (STO) (NATO STO, 2015) evaluated and provided recommendations for adopting these service oriented architectures to aid its member warfighters to access high-fidelity training on-station, receive en route mission rehearsal, and benefit from up-to-date and highly accurate real-time decision aides in the field “without the full investment in hardware, software, personnel and infrastructure.”

A Brief History of Education and Technology

In New York City, August 1987, during the American Psychological Foundation's Distinguished Teaching Award Address at the annual meeting of the American Psychological Association, Ludy T. Benjamin, Jr spoke of the history of teaching machines (Benjamin, 1988). In this fascinating history, he notes that while the public press credited B.F. Skinner with the origination of "teaching by machine," patented educational devices and teaching machines have existed since at least the 19th century. One early inventor, Sidney Pressey, saw technology as the solution to solve the ills in education:

> Work in the schools of the future will be marvelously though simply organized, so as to adjust almost automatically to individual differences and the characteristics of the learning process. There will be many labor-saving schemes and devices, and even machines—not all for the mechanizing of education, but for the freeing of teacher and pupil from educational drudgery and incompetence. (Pressey, 1933)

Benjamin relates that despite his enthusiasm, Pressey's teaching machines did not gain traction in schools. Despite efforts by Skinner in the 1950's and international discussions and popular press interest in the 1960's, technology in the classroom still failed to take hold. Concerns included skepticism over and ability to teach and their impact on teachers in the classroom, such as teacher-student ratio. Assessing the effectiveness of teaching machines was an early area of academic research for doctoral students, even prior to Skinner's appearance in the field, with the 1960's seeing contributions developing criteria and methods for assessing their effectiveness. The effect of corporate influence, with profit as a motivator, on teaching in the classroom also manifested in public discourse. Familiar themes, both military and industry were interested in their use, particularly for training, and there were concerns about the ability to provide teacher training on the use of these technologies, reducing their effectiveness.

The rise of computers

Concerns in the 1960's about the presentation of instructional material by teaching machines, the lack of quality educational software, teacher familiarity and understanding of their use, and teacher fears of being supplanted may have affected early adoption and integration of computers into the classroom in the 1970's and 1980's—teachers viewed computers as a teaching aide rather than integrally part of the instructional process itself (Benjamin, 1988). This led, Benjamin to speculate in the late 1980's that "if past behavior is a predictor of future behavior, then it seems unlikely that computers or any other teaching machines will play more than a supporting role in the classroom" (Benjamin, 1988, p. 711). Studies in the early 1990's assessed the truth of this predication. Cuban (1993) noted that number of schools using computers for instruction increased from 16% in 1981 to 98% in 1991, with the computer-to-student ratio dropping from 125:1 to 18:1. Still, students' educational use of computer-technology was uneven: variances in time-per-week spent on educational-related activities, access based on income and native language, and use by low-achieving students. This rise however positively affected instructional access in special education and for disabled students. His analysis concludes that culture attitude about teaching, learning, valuable knowledge, and appropriate school and classroom organization drive lackluster adoption of classroom technology, not funding, teacher preparedness, or administrator indifference. A follow-up study on behalf of the American Educational Research Association found little difference a decade later, finding that access did not lead necessarily to use, with most teachers rarely, if ever, making use of the available technology. In fact, teachers primarily used computers for administrative-related activities rather than altering their teaching patterns—an eerie echo of Benjamin's foretelling. Slow-adoption of change, slow revolution due to inertia, could be the reason (Cuban, Kirkpatrick, & Peck, 2001). Alternatively, they speculate that institutionalize classroom structures, time constraints, unforgiving curricula and curricula-pacing, and inadequate infrastructure support—wiring, reliable equipment and software, obsolescence—all contribute to poor and slow adoption of available computer-supported instruction. To achieve successful technology integration within the classroom they see the need for fundamental changes in school organization, allocation of instructional time, and methods used in teacher class preparation—without which, "*New technologies will, paradoxically, sustain old practices!* [emphasis added]" (Cuban et al., 2001, p. 830)

The internet: distance and online learning

The birth of the ARPANET transformed into the internet in the late 1990's and early 2000's has revolutionized communication and information dissemination and access across the globe (Leiner et al., 1997). This technology growth espouses the characteristics of *nomadicity*, available to the user during daily activities, regardless of place; *embeddedness*, connectivity through intelligent devices; and *ubiquity*, global, widespread deployment (Kleinrock, 2003), and the information available to users has exploded to exponential proportions (Royal Geographical Society with the Institute of British Geographers (RGS-IBG), n.d.). This unprecedented capability to collect and record data—shopping habits, birth records, medical information, financial records, viewing habits, phone calls, internet searches—has simultaneously resulted in consumer convenience and understandable unease about information privacy (Sweeney, 2001). The internet's rise has facilitated educational access through distance learning and online-instruction—estimates suggest over a million K-12 students receiving instruction this way! Distance learning includes earlier modalities, such as correspondence courses and video-conferencing—little different than a traditional classroom—and newer technologies, such as online instruction. For the latter, research shows that blended learning options that include instructor involvement, student goal-setting for learning outcomes, and two-way interaction between instructor and student have the best student outcomes (Means, et al., 2009).

Massive Open Online Courses (MOOCs) bring together distance learning concepts and the internet and has seen speed increases across standard cable broadband of 2450% since 1999 (National Cable and Telecommunications Association, n.d.). These online courses, sometimes available at no cost, range from recorded video of instructor-led lecture and self-paced or narrated PowerPoint to online laboratories and discussion forums, incorporating some or all of these elements and more. Funding powerhouses like the Bill and Melinda Gates Foundation are funding research into this delivery mode through organizations like MOOC Research ("MOOC Research," n.d.). EdX, the consortium between MIT and Harvard, launched its first MOOC in 2012, *Circuits and Electronics 6.002x*. This course included video lectures, interactive problems, online laboratories, and a discussion forum and had over 150,000 registrants (Breslow et al., 2013). Education is literally at a learner's fingertips—all across the world.

21ST CENTURY TECHOLOGIES

The Horizon Report (Johnson, et al., 2010) notes key technology trends in mobile computing, gesture-based computing, and others with the potential to create significant change in teaching and learning with cloud-computing at the core for much of this potential—and the future is now! Cloud-computing holds the promise of providing broad access to broad-spectrum, training media wherever the learner may be, without the need for extensive infrastructure. The hope is that networked remote-servers accessed via the internet can provide dispersed learners with access to training more rapidly with reduced overhead and lifecycle costs. Maintenance would be localized, both reducing overall costs and promoting improved currency of software with better consistency across users, and information security limited to the networked servers and the connections to them (Jula, Sundararajan, & Othman, 2014).

The Cloud

Kleinrock's analogy that likens obtaining computing services similarly to acquiring essential utilities services is illustrative. In this 21st century computing model, providers expose services through virtual machines customized to meet their users' needs, more formally defined by the National Institute of Standards and Technology (NIST):

> Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort or service provider interaction. (Mell & Grance, 2011)

There is significant interest in understanding the challenges, benefits, and marketplace of cloud computing (Armbrust et al., 2010). Ease of access and update are compelling reasons for cloud migration. Anticipated benefits include no upfront investment, lower operating costs, scalability, and reduced business expense and maintenance costs. However, there are research challenges in many areas, including automated service provisioning, virtual machine migration, and data security (Zhang, Cheng, & Boutaba, 2010). This culminating, transformative vision has its price and own challenges, though. Data confidentially and security are obvious concerns (Fleener, Zou, & Eddy, 2014). From a simulation perspective, benefits include improved interoperability, enhanced sharing of resources, and improved deployment and accessibility (Siegfried, et al., 2014), while the technical challenges grow to include required mindset shifts in infrastructure, management, pricing, and personnel (Rieger, 2014)

Selecting Cloud-Services

Providing an a priori optimized cloud-service design is an intractable problem, suffering from two primary challenges: (1) identification of needed services and (2) optimal selection of the required services that meet the desired quality of service attributes (Jula et al., 2014). It may be argued, convincingly, that the first is a question of scoping and requirements identification. Further, one can easily accept that development requires setting an initial starting point. Growth to meet emerging objectives, then, must come at the expense of inefficacies from a solution considered "sub-optimal" had those future requirements been known at the outset. Thoroughly discussed in Jula

(2014), the second challenge—an NP-hard decision-problem—is less easily dismissed. Needed is a solution taking advantage of its structure that meets the needs of the cloud community. Nonetheless, computing, data, analytics, and information services are migrating to the cloud—as are modeling and simulation (M&S) services. Currently, these selections rely on best practices and selecting among service composition packages within various service pools.

Simulation and the Cloud

From a user perspective, usability is a concern, where existing workstation-driven interfaces could potentially overshadow considerations for effective and friendly user-interface design, where communication over an API is preferable to direct communication with a simulation, that would otherwise prevail (Zehe, et al. 2015). Other technical research-issues have appeared as M&S Grand Challenges at the Winter Simulation Conference (e.g., 2012-2014), among them are significant challenges in executing effective large-scale parallel, REMOTE, cloud-based simulation. The typical, application-driven, quick-delivery of small message-packets is at odds with the cloud-environment's strength of fewer, larger messages requiring high bandwidth. The result is latency.

To address some of these issues, the NATO M&S Group (MSG) developed an M&S as a Service (MSaaS) architecture to aid members in the use of and migration to a service oriented architecture for simulation and to enhance NATO's ability to exploit M&S and improve cost of and access to high fidelity training (NATO STO, 2015). Three key characteristics drive its service orientation: (1) communication following standards among actors, (2) loose coupling of components, and (3) component interoperability. MSaaS includes model development, verification and validation, certification, and training services. From a training perspective, flexibility and scalability of service options and worldwide accessibility are core advantages to using MSaaS. Identified perceived-drawbacks include development time, software and costs required to migrate to a cloud infrastructure, network performance and vulnerability risks, and the potential loss of face-to-face team contact as services become more remote.

Composability and Interoperability of Simulation in the Cloud

If it were correct to view simulation as another service available in the cloud, then it is necessary to consider where that service lies. It is only at the M&S-application level, or does it also apply to its component models? Just as the cloud-services selection problem is NP-hard, the simulation-component selection problem also falls into the set of NP decision-problems; NP-complete or NP-hard depending on whether it is known which objectives the components meet (Petty, Weisel, & Mielke, 2003). Further, Page and Opper (Page & Opper, 1999) have demonstrated that the general problem of determining which objectives a component meets is undecidable. These two results together require that the M&S community determine and exploit characteristics of this problem and develop semantic descriptions that simulation-component objectives descriptions and mappings in order to realize component-based simulation development. Migrations to cloud-enable architectures do not eliminate this need and may exacerbate it. Looking past the shackles cast by modern digital computers, with less computing power than a Turing machine, Martinez-Salio and Lopez-Rodriguez (Martinez-Salio & Lopez-Rodriguez, 2014) describe some of the challenges resulting from existing heterogeneous standards within the M&S community—a byproduct of add-on, meet-to responses to key interests and issues arising through natural expansion and use of technological capabilities within the live, virtual, constructive (LVC) simulation development cycles. They provide recommendations to address this and other issues and recommend an architecture for implementing MSaaS.

PROFESSIONAL MILITARY EDUCATION AND TRAINING

In the late 1970's, leaders in education recognized that the learning style of the student mattered—when instructional and learning styles match, student motivation and achievement improve (Dunn & Dunn, 1978). Ground breaking research included development of an Index of Learning Styles© with validated and peer-reviewed assessment instruments to help determine an individual's learning style preference and matching teaching methods to aid in instruction (Felder & Silverman, 1988; Litzinger, Lee, Wise, & Felder, 2007). Moreover, studies have shown that multisensory instruction can be more effective than other traditional delivery modes (e.g., lecture, slides) so long as it maintains sensory-congruency (i.e., stimuli maintains the natural, or expected, relationships between sensory inputs) (Shams & Seitz, 2008). In 1990, and since updated the APA codified this research into a set of 14 Learner-Centered Psychological Principles (Learner-Centered Principles Working Group of the American Psychological Association's Board of Educational Affairs, 1997).

While K-12 education only slowly has accepted technology incursions in its domain, the same cannot be said for that of post-secondary school education—where trade schools, colleges, and universities may have motives or prestige, profit or mission—or that of military education and training—where student volume, no doubt influences the decision. Gorman's Matrix partitions the components of military training by *who is trained* and *where training occurs*, allowing the description of training by function, or objective and form (Fletcher & Chatelier, 2000). The former is a function of *who* and the latter of *where*. An early adopter of distance learning, the DOD submitted its Strategic Plan for Advanced Remote Learning to the 106th Congress in 1999; the military has embraced the concept of differentiated instruction (Wisher, Sabol, Moses, & Ramsberger, 2002). One doubts that this is in an effort to better motivate its learners. *No—matching instructional methods, content, and media to the learning styles and skill levels of its soldiers, sailors, marines, and airmen enhances acquisition, understanding, application of what they learn!* The military has recognized the need for and the power of online technologies to provide instructional materials adapted to the learning style of learners (Bonk & Wisher, 2000). The military's pursuit of technologies that enable comprehensive learning strategies that blended-learning solutions and experiential learning through simulation intrinsically recognizes the warfighter learns more when spending more time and using more senses when learning subject matter. For the warfighter, recall must be automatic, not learned for a test and soon forgotten.

TRAINING THROUGH THE CLOUD: TRAINING ON DEMAND (TOD)

Current simulation-based training focuses on hardware-based capabilities installed at forward deployed and designated training sites. Learners must conform to training-center schedules and resource limitations, and software updates and configuration changes are difficult and expensive to coordinate across installations. Infrastructure and other costs required for sophisticated, experiential-based learning provided by simulations and games is expensive and can create a barrier to entry. Requirements for maintenance and upgrade can be more prohibitive, particularly when multiplied by several locations. These sunk costs include not only network, hardware, and software but also data collection and verification, configuration, required travel, and instructor support. Cloud technologies can distribute digital training to hardware already owned by trainees, providing viable cost effective training and performance-data collection capabilities, connecting to metrics and remote instructors, when needed. Faced with shrinking DOD-training budgets and increasing needs for training across industries, cloud technology has the potential to wreck the neat partitioning of Gorham's Matrix of training by individual-units and residence-operational units, stressing both its form and function and reducing the constraints faced by our soldiers, marines, sailors, and airmen posed by current training-site, infrastructure, and travel-budget limitations. Using cloud technologies for training could stretch the boundaries of Gorham's categorization. TOD capabilities can supplement and optimize traditional training by providing innovative part-task-training to the point of need, on consumer grade hardware and platforms, over preexisting digital distribution infrastructure using cloud-services for data collection, processing, retrieval and authentication, and synchronous multi-user virtual interactivity. Ultimately, the goal is to centralize processing for the simulation engine, distributing only that which the end-user for meaningful simulation interaction and training. This centralized processing and tailored distribution opens possibilities for training on personal computing devices, including those handheld. This would enable organizations delivering instruction or training to reach a larger training audience with less infrastructure investment.

Use Case: Firearm Speed and Accuracy Drill

Our use case focused on developing training game running a basic scenario from cloud servers to remote platforms to 1) identify technical hurdles and measure training effectiveness for future development and 2) demonstrate the effectiveness of a cloud delivery methodology in a realistic training environment. We created a traditional simulated training environment with high fidelity graphics run locally on mid- to upper-tier hardware, for the purpose of distributing training to areas where large local systems are not feasible or economical. We selected speed and accuracy drill with a firearm, moving and firing along a predefined course, using the Warrior Competition, and annual Special Forces competition held and set in the King Abdulla II Special Operations Training Center (KASOTC) in Amman Jordan ("7th Annual Warrior Competition, April 19th – 23rd , 2015," n.d.). This drill requires onsite participation, using live firearms and other equipment. As a task learned by doing, typically expensive to train live and requiring custom hardware for virtual training, it met our desired characteristics. Since portability and scaling of high-end simulation to lower-end devices is core to the TOD concept, we also integrated two pieces of cutting-edge high-end hardware: the Oculus Rift VR-HMD and the MAGII AR-input device, usually used for first-person-shooter games and selected for its availability over other motion controller options. Similar technology is used in virtual fire trainers and would not be available to remote users.

Training-Modes

Rather than attempting to recreate the entire training, as it would be experienced on a proprietary simulator or training-system, we wanted to focus on the strengths of the target platform while mitigating weaknesses. A workforce largely having smartphones and tablets or low-end laptops and workstations requires delivered at the point of need, suitable for their technology at hand. *Cloud delivery without access fails as a solution.* Therefore, our design and implementation explicitly consciously choose to create a version of the training, restructuring it to produce courses and exercises suited to those devices. *Technology must meld with instructional systems design and training practices known to be effective.* In the context of KASOTC, a speed and accuracy live fire simulation, we focused on lessening the learning curve for would-be users of the high-end training system rather than attempting to recreate that capability in its entirety on a mobile device. Organizations need to maximize the value of limited time spent by trainees using high-end systems while minimizing the travel, support, and other costs associated with using them. *Using pre-learning and scaffolding strategies as part of a holistic part-task training strategy maximizes the learning value from simulators, virtual simulations, and live exercises and reduces learning-curve bottlenecks.*

Using our existing Cyber Security Edge™ cloud-infrastructure and commercially available products, we implemented two cloud-based alternatives to alternate methods, operating with geographical separation and reduced hardware specifications, to compare and contrast potential strengths and weaknesses from user interaction with the simulated environment. We implemented three end-state training-modes:

1. LOCAL system supporting high-fidelity graphical rendering and other capabilities for virtual training
2. REMOTE system with diminished capabilities but with added remote multi-user offerings
3. THIN-CLIENT system, allowing connectivity at distance on clients with a minimal hardware specifications

For the training simulation environment, we built a virtual section of KASOTC using with Epic's Unreal Engine 4 developed to port to all three client specifications (training modes). The game engine provided core functionality such as rendering, networking, user input, physics, artificial intelligence, virtual reality, synthetic environments, advanced peripherals, and multi-platform simultaneous development and porting—*develop once … distribute to many*. We developed it to be portable to a laptop and tablet, with fidelity automatically scaled to platform capabilities, using common hardware input methods (mouse and keyboard, touchscreen). A common cloud database captured data from and served multiple platforms via our High Fidelity Cloud Network™ (HiFiCloudNet™). Using inputs from instructional systems designers and subject matter experts, we developed the part-task training tailored to strengths of each running platform, allowing results to be reviewed locally. System specifications required that each configuration-mode must be compatible with the configuration that follows in the list: LOCAL must be able to REMOTE and both LOCAL and REMOTE must be able to run the application(s) designed for the THIN-CLIENT. The reverse relationship does not apply. However, the THIN-CLIENT did need to be able to connect to services tied to data being by the primary (LOCAL) system. LOCAL provides LAN-based high-fidelity virtual-training, supports cutting-edge hardware peripherals, REMOTE provides WAN-based virtual-exercise with moderate fidelity on consumer-grade hardware, and THIN-CLIENT has the lowest fidelity, running on iOS, for greater distribution, provides WAN-based distance learning, rehearsal and mission preparation.

Implementation

Accessing the benefits of game technologies in cloud-based games and graphics-intensive simulations, which suffer from network, bandwidth, and other infrastructure limitations, historically has been challenging. To make remote training useful a training audience, training objectives and scenarios must be synchronized, a challenge with asynchronous training. While cloud-technology, itself, is no longer new, fully adopting it for the delivery of high fidelity applications via the cloud to low end platforms required a solution to virtualize GPU processing. We built wrappers around COTS cloud migration software for the TOD system to solve this problem. Several server components providing services for multi-platform clients comprise the TOD) system (**Figure 1**). Cloud servers store data from local and remote exercises, serve data and metrics to and from all clients, instantiate servers as needed by remote clients, and manage server-list remote and connectivity. The data server provides data management tools to handle account creation, validation, and training data processing in support of the KASOTC game simulation-client. It accepts training data for data processing from the game simulation client to form metrics, reports, and other aggregates, stores it in a standard relational database system, and serves this data to authorized clients and users. Any loader application, game simulation client, and web-based (HTML5) clients can retrieve data. We developed application instantiations for multiple platforms from a single common codebase, tailoring them to run on lowest-common-denominator systems while still taking advantage of powerful graphics processing hardware. LOCAL runs the local LAN Client for exercises, hosts LAN server instances (listen server), stores data from local exercises, pulls and pushes data and metrics to and from the cloud, can accept REMOTE client connections, and can access LOCAL data for THIN-CLIENT mode. REMOTE stores virtual environment locally, runs THIN-CLIENT for virtual

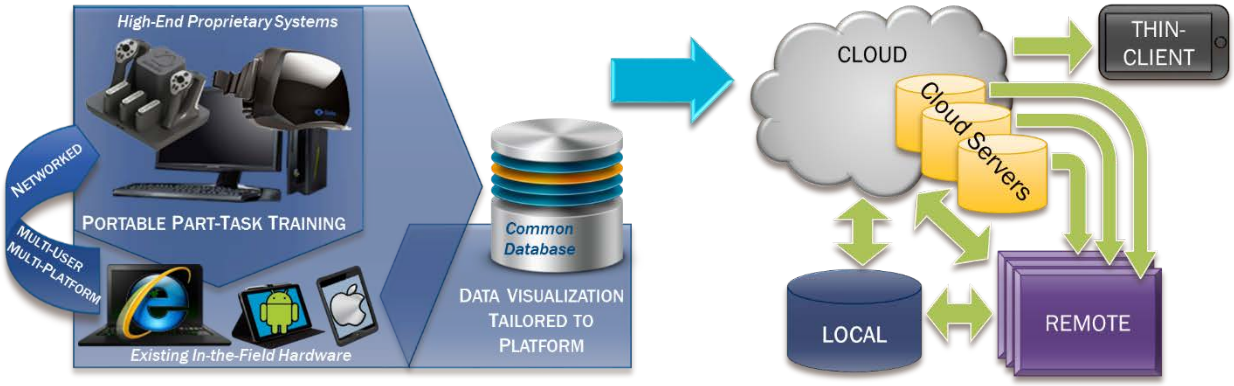

Figure 1. Training on Demand Concept

exercises, may request a cloud-server, provides multi-user capabilities via cloud-servers, processes input and rendering locally, pushes data and metrics to the cloud, can connect to LOCAL as a server, and can access cloud data for THIN-CLIENT mode. THIN-CLIENT stores environment locally, runs virtual walk-through, pulls data and metrics from the cloud-server, and uses data for after-action reporting and replay. A firewall with limited access to support client and web-browser connections protects the server network. A database further protected by a second firewall that allows only local network access from the TOD data-server process stores the data itself.

From the LOCAL client, a user can run a combat shooting drill, and the system saves entire run for playback. During the run, collected data and metrics includes shots fired, hits and misses, accuracy, target acquisition time, re-fire rate, and course completion time, which LOCAL stores and pushes to the cloud server. From the REMOTE client, users can run the combat shooting drill as described for the LOCAL client with data and metrics pushed to cloud storage. With LOCAL, it also supports multi-player mode with a secondary user connecting in real-time. This user can connect in an instructor or trainer role, freely control a ghost camera, snap to either a first- or third-person perspective, locked to the primary user, communicate via VOIP and text during and exercise, and enact special instructor capabilities such as pause or reset. The LOCAL client also supports walkthrough mode via the THIN-CLIENT. This capability allows the user to learn the area (buildings, sightlines), identify targets (locations, order), practice the route and target sequence, review saved exercises from LOCAL or REMOTE systems, and review saved data and metrics. With the multi-participant networked capabilities, remote instructors can moderate virtual exercises in real-time, providing a cost effective way to interact between geographically separated participants.

Developing metrics visualization and review followed the same principles as the cloud-client capabilities. HTML5 technology, commonly found in the field on hardware owned by would-be trainers, provided the means for tailoring and visualizing data. The system collects data and allows visualization to and from any device. It provides advanced after action review capabilities for high-end systems (e.g., playback) with traditional, and simpler, top-down two-dimensional modes and spreadsheets. Users can visualize data via a webpage showing a top-down layout of the modeled area. It shows each firing position with a first-person view from the user's perspective of the location and a close-up image of the target itself. It displays each target in conjunction with user-location when firing and places target-hit locations at impact detection. In the event of a miss, a trajectory is overlaid in red with "missed" displayed as text on the target. Additionally, there is an overlay giving weapon-discharge time and location in table layout.

Evaluative factors for the system included model execution rate (update rates, frame rates), interface responsiveness, user experience, end user game-performance (goals accomplishment), including starts, aborts, and successful completions. During I/ITSEC 2014, we conducted an informal user-evaluation of the fully functioning system based on walk-up-participant use. The system had a high-end KASOTC-client (LOCAL) running on a virtual machine, playable via a Chrome-book (REMOTE) having only an integrated graphics card. We set up a local server to mitigate risks of congested bandwidth, cost and other factors related to trade-show connectivity to the World Wide Web. This provided us with a local-server test case for comparison. Users entered the training with variety of skill levels from novice to expert. Participants using the REMOTE TOD components before attempting the high-end system consistently scored better, regardless of prior knowledge, raising user confidence-levels in those initially intimidated by the larger, more demanding trainer. Those originally reluctant to attempt the more complex training were more likely to use it after successful completion of the REMOTE version (iPad or laptop). Generally, those using the REMOTE version first performed difficult tasks more readily and had considerably higher scores. Confidence gained in pre-learning activities—getting to "know the course"—had a positive attitude to the task, manifested by verbal banter in competition with others. Performance testing included locations in Michigan, Florida, and Alabama connecting to an ad-hoc Seattle data server. We recorded no notable inconsistencies as compared to local server operation when running these instantiations, although this testing did result in some minor adjustments in the developed implementation to parameters such as server time-out errors and transferred image sizes.

Development Considerations

Fully recreating high end training scenarios, digitally on consumer devices is still impossible. Consumer devices, while becoming more and more powerful, still cannot perform to the benchmarks of custom-built system configurations. Latency is inherent to all networked activities, and limitations in rate of data transfer are defined by distance and the speed of light. The TOD concept helps to optimize performance and effectiveness of traditional training systems, not by replacing legacy training but by supplementing it. When applying these technologies avoid the objective of trying to recreate the high-fidelity training experience for REMOTE digital methods. Instead, create a version of the training suited to available technologies that meet learning objectives that both the technologies can support and make sense to train outside of the legacy system. This can require employing a different style or method to make it suitable to the target platform and objective. Design should consider potential Training-on-Demand requirements, identifying material that students could pre-learn before engaging more complex trainers, and assess system requirements for pre-learning, distance training, local participation, remote instruction, online data accessibility, review, and visualization. Proficiency degrades over time when skills go unused, such as contingency actions, uncommon repair and maintenance, or job tasks not needed immediately. Design can include methods such as gamification, specialized user-experiences, and other techniques proven to aid retention.

While game and cloud technologies have many virtues, these technologies come at a price. Technologies like Unreal Engine, Oculus Rift and cloud digital-distribution services are simultaneously in development. We cannot assume backward-compatibility. Also, our use of these can find unknown bugs, requiring updates to fix. These can require updates to the implementation and render other capabilities inoperable. This means we must use Agile or flexible development practices to utilize new updates and breakthroughs to the advantage of the final product. Effective planning needs to build time into the schedule to understand and correct any issues that may arise.

Benefits and Future Work

Leveraging game-technology provides access to online multi-user virtual worlds capabilities. Two students can train together and an instructor can join a session, 1-1 or 1-many, to facilitate training objectives in an immersive, and increasingly realistic, virtual space. The cloud provides an efficient delivery means that allows for centralized control of software baselines and reduces system reconfiguration and setup time and requirements simulation based events and minimizes the need to maintain high-end infrastructure. In turn, this reduces the operational tempo of exercises and the costs associated with them. This provides central control and efficient development of applications and data sharing, while putting games into the hands of the learner, immersing and engaging them within the context of the training scenario. Cloud technologies delivering to multiple learning modalities can help organizations move from episodic training to ongoing training. The focus of future work will to improve usability of the infrastructure and its ability to fit within existing training infrastructures and technology. We will add capabilities to increase the TOD ability to distribute to other consumer devices and to connect remote instructors to synthetic training environments in real time. We will also develop the additional means to provide instructors access to metrics and monitoring and expect this to enable a single instructor to facilitate simultaneous, multiple training sessions globally.

CLOSING THOUGHTS: CHANGING THE GAME

On 29 June 2013, an article in *The Economist* said the following:

> The promise in all this [cloud technology] for teachers is less drudgery, since some of their duller tasks can be automated, and interesting new challenges as they work out how to reorganise [sic] their classes. If the technology can be used as an extra pair of hands in the classroom, teachers will find it possible to do more. ("Catching on at last," 2013)

Pressey promised nearly the same in 1933. If we are to inure ourselves against renewing old promises and expecting different outcomes, we need to recognize that embracing this technological change in education is more than additional funding, better tools, and more teacher-training. Cloud computing may finally make Pressey's promise possible, but its cost may be drastic transformation of the educational and training landscapes. Adoption of technology integrated in the classroom may be equivalent to cultural change in the educational institution itself. A century of experience suggests that anything less results in technology as an adjunct to teaching instead—unneeded, and, perhaps, unwelcome. As in many other instances of transformation, the military services already may be sowing the seeds of cultural change. In the end, though, such transformative opportunities may pass by mainstream education. Through the cloud, learners can select and use multi-media learning products, based in authoritative data vetted by experts, tailored to their personal learning styles and rated by their peers, meeting the learner's own schedule and pacing needs, available anywhere in the world. MOOCs are powered by world-recognized universities, like Harvard and MIT, and by funding sources such as the Bill and Melinda Gates Foundation. Under these circumstances, students may opt-out of traditional education, leaving the one-room schoolhouse go the way of the buggy whip and modern schools the way of the typewriter. In the future, not just the military but all institutions of learning will be able to embrace true blended-learning that fully integrates technology into the curricula rather than treating it as a supplement.

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