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14. ABSTRACT The increasingly complex environment of the 21st century demands unprecedented knowledge, skills and abilities for people from all walks of life. One powerful solution that blends the science of learning with the technological advances of computing is Virtual Environments. In the United States alone, the Department of Defense has invested billions of dollars over the past decade to make this field and its developments as effective as possible. This 3-volume work provides comprehensive coverage of the many different domains that must be integrated for Virtual Environments to fully provide effective training and education. Vol 3, Chapter 36, discusses a vision for the future which emphasizes the capabilities of operators, not simply the hardware that confines them. Future Air Force training will be driven by expected operational requirements involving personnel extensively connection to their weapons systems, other operators, and coalition forces in a global environment. The authors discuss live, virtual, and constructive entities.			
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FUTURE AIR FORCE TRAINING¹

Daniel Walker and Kevin Geiss

Aviation pioneer Wilbur Wright (1900) stated, “It is possible to fly without motors, but not without knowledge and skill.” Our vision for the future emphasizes the capabilities of operators, not simply the hardware that confines them. Future air force training will be driven by expected operational requirements involving personnel extensively connected to their weapon systems, other operators, and coalition forces in a global environment. From a research perspective, we observe weapon systems that are increasingly capable and complex. Reflecting these advances, the future of air force training is live, virtual, and constructive (LVC): “live” personnel and equipment, “virtual” simulated adversaries and environments, and “constructive” computer-generated entities.

OPERATIONAL CONTEXT

Operational Roles, Policy, and Doctrine

Transformation, evolution, adaptation—the operational roles of air forces—are adjusting along with the nature of conflict. The Department of Defense (2006) Quadrennial Defense Review reemphasized the necessity and value of transforming training to account for the shifts from conventional or symmetric conflicts to asymmetric and unconventional engagements that go beyond traditional kinetics based operations and now focus on such areas as cyber warfare and humanitarian operations. Robust training systems must accommodate future weapon systems along with the makeup and tactics of future adversaries in diverse global operational contexts. The exact makeup of adversaries 20 years hence is unknown, but we do know that technology will advance the capabilities of our forces, as well as those of our adversaries.

To enable effective operations, training methodologies require incorporation of advances in both technology and doctrine. In this context, air force personnel participate in military operations through a variety of weapon systems beyond

¹Disclaimer: This manuscript reflects independent views of the authors and is not an official opinion of the U.S. Air Force. Approved for public release WPAFB 08-0027.

inhabited aircraft to include autonomous and semi-autonomous aircraft, space, missile, and ground systems. These systems are further functionally integrated with special operations, stability operations, and information operations. Distributed mission operations are discussed elsewhere in Volume 3 (see Andrews and Bell, Volume 3, Section 1, Chapter 8) and reflect a key evolution in the operational framework.

System Attributes and Capabilities

Military weapon systems continue to separate individual operators from ultimate mechanical events. Pilots no longer push a stick connected to a wire for manipulating a wing aileron, but rather they manipulate electronic interfaces sending digital commands to control uninhabited vehicle systems. The essential competencies required for such tasks may differ. However, for some systems, physical separation is mirrored by cognitive integration that imbeds humans in technological systems. The manner by which work is divided between human and machine is increasingly complex. A recent National Research Council report (2008, p. 30) asserts that for "today's aircraft" it is now impossible to precisely assign "the percentage of responsibility to humans or machines." Thus, careful analysis is required to determine for which tasks the human must be trained and how the human is integrated into the virtual environment (see Barnett, Volume 3, Section 1, Chapter 3).

Air force weapon system technologies are becoming so diverse and powerful that training, testing, and skill maintenance will increase demands on training and simulation systems. Ackerman (2006) describes one such weapon system, the F-35 joint strike fighter (JSF). JSF targeting capabilities utilize substantial sensor and information fusion, including electro-optical targeting and scanned array radar. The JSF tracks all aircraft within a 10 mile radius and integrates information from 1,000 independent scanning radar arrays, which may be tracking unmanned aerial vehicles (UAVs), missiles, or moving ground targets. To support the currency needs of the JSF operator, training systems must provide innumerable variants on key dimensions (for example, weather, adversaries, and weapon systems). The JSF ultimately requires pilots to take on the additional duty of "chief information officer." Through interacting with other JSFs, one aircraft has the ability to perform a mission by relying substantially on information provided by a second aircraft (Ackerman).

Resource Constraints

Two main resource constraints are driving greater implementation of virtual and constructive simulations for training. First, with weapon system capabilities, such as the JSF, it is difficult to put enough real assets in play to fully train a pilot. There is neither sufficient airspace nor enough capable live adversaries routinely available to enable training operations for the pilot of such aircraft, and certainly not for a whole squadron. Second, military operations are costly and fuels are

precious commodities. Using funds or fuel for training rather than operations becomes a difficult decision. The cost-benefit/effectiveness analysis presented by Moor, Andrews, and Burright (2000) indicates that simulator based aircrew training is a valid alternative for the development of training strategies and requirements in light of these resource constraints.

APPROACH

Creating the training tools and strategies to improve warfighter performance using LVC operations demands development in five areas: competency based assessment, performance measurement, continuous learning, cognitive modeling, and immersive environments.

Competency Based Assessment

Consistent with other armed services, air force personnel receive primary training via traditional formal instruction courses. Advanced and continuation training is often administered using different approaches. For example, in the Ready Aircrew Program (RAP) discussed by Colgrove and Bennett (2006) aircrews train with a frequency and event based system to maintain proficiency through specified numbers and types of events.

One consequence of a RAP for performance improvement or maintenance is its limited assessment capabilities. The assessment is conducted in two often uncorrelated parts. The primary assessment is conducted by tracking event numbers and frequency. Personnel could be deemed not mission ready by virtue of completing too few events or by exceeding a predetermined period between events. The second part of the assessment is a subjective evaluation of crew member mission competency. If the required events are not performed well, or the crew member appears incapable of succeeding in a designated mission, a supervisor could disqualify him or her. Simply performing the required events in the appropriate time period may be indicated as satisfactory training. A crew member might be deemed mission ready without any linking to qualitative assessment, since poor performance is not tracked by this method. In practice, these subjective assessments are not regularly conducted, and other methods, such as supervisor observation or self-reporting, are required to validate a need for further training.

An alternative for aircrews is to use a competency based system versus simply accomplishing a required number of events. Competency based assessment requires detailed mission essential competency² (MEC) evaluation, which is being instituted for many aircrew combat specialties. The MEC process determines the knowledge and skills, not just tasks, required for proficiency in a mission. Research presented by Colgrove and Bennett (2006) showed that MEC based training produces favorable results. For example, one aerial defense

²The phrase mission essential competency, mission essential competencies, and associated acronyms have been service marked. Air Combat Command, Air Force Research Laboratory, The Group for Organizational Effectiveness, Inc., & Aptima, Inc. are the joint owners of the service mark.

scenario study of MEC based training effectiveness showed 63 percent fewer enemy bombers reached their target, 24 percent more enemy fighter aircraft were killed, and friendly aircrews suffered 68 percent fewer simulated mortalities. Ensuring aircrews can perform such skills requires improving the measurement system.

Performance Measurement

Technological advances, fielded and under development, provide promise to capture the objective metrics to enable meaningful evaluation and tailored training. One advancement is evident in simulator based training; high fidelity simulation testbeds collect over 750 different performance parameters every 50 milliseconds. This dense data environment provides one component of a performance evaluation and tracking system. Schreiber, Watz, Neubauer, McCall, and Bennett (2007) describe this system as an emerging set of performance measurement strategies and tools to support competency based continuous learning. It includes subject matter expert observer assessments using behaviorally anchored grade sheets and objective measurements based on data from simulation or live operations.

Robust and extensively instrumented live training would enable data collection similar to simulator environments. Important parts of this future environment for collecting objective performance data are available within the weapons system, but not generally transmitted on instrumented training ranges. Efforts are under way to develop live, virtual, and constructive techniques to capture those data, such as internal cockpit switch positions. Gathering comparable performance data from virtual and live experiences will enable seamless training for aircrews irrespective of domain. When procedures are in place to gather detailed performance data in all training events, then it will be possible to more efficiently tailor training to specific individuals rather than the "one size fits all" approach of many continuation training regimens. For further discussion of aviation training, see Schnell and Macuda, Volume 3, Section 1, Chapter 12.

Continuous Learning

A recent Defense Science Board report (Department of Defense, 2003) recommended that traditional schoolhouse training be replaced with continuous training employed on-site with the individual. LVC environments introduce the concept of the transparent venues with an added opportunity that such tools could support both training and operations, allowing personnel to take advantage of nonmission time for training. The continuous learning strategies we foresee go beyond simply "on-the-job training" and should become a standard feature of military systems.

Conventional job based training reflects learning during the course of normal duties rather than a situation where the operator is unable to discern the training events from normal mission events. Admittedly, even laboratory experiments

have not achieved completely seamless integration of simulation and operations for complex weapon systems, yet the value of continuous training and performance assessment is apparent. Hancock and Hart (2002) discuss one simplistic example of the integration of training, competency assessment, and operations. The Transportation Security Administration uses the Threat Image Projection software program where the performance of individual screeners in detecting weapons and explosives by X-ray imaging is evaluated continuously. This approach also allows the system to integrate up-to-date intelligence on specific threats. Likewise, the power of constructive simulations would allow training system designers to incorporate the latest information (for example, threats or terrain data) into training.

Cognitive Models

Cognitive models for replicates and imbedded tutors are additional elements for enhancing mission-effective performance training. Cognitive model products are projected to shape service training. One approach is to develop models for performance prediction. Research models can account for the effect of training frequency on models of memory and may allow commanders to predict performance for specific training regimens. Jastrzembki, Gluck, and Gunzelmann (2006) propose that these predictions could then be used to determine effective application of limited training resources while having the greatest impact on improving individual crew member performance.

Ball and Gluck (2003) present one pathfinder effort for advancing computational replicates, the development of a Predator UAV pilot computational model. The researchers first created a synthetic task environment (STE) tool to simulate operation of the Predator aircraft. The STE includes aircraft performance simulation and three synthetic tasks: basic maneuvering, landing, and a reconnaissance problem requiring sensor positioning over a target within given constraints (for example, wind, cloud cover, and flight path restrictions). In this STE, various cognitive models were developed in an effort to replicate human performance in dynamic and complex tasks. As this foundational work is expanded, future training strategies will include models of synthetic adversaries and allies.

Well-developed models will provide a richer training experience than current rule based constructive simulations. Synthetic adversaries and allies will continue to be an important part of air force training for a number of reasons. As discussed above, modern weapon systems need large, complex scenarios to fully exercise their capabilities. Live adversaries and allies are expensive and less available due to shrinking force structure. Also, peacetime training restrictions (for example, range, space, and speed) decrease the effectiveness of live adversaries when matched against our most advanced systems. As Gluck, Ball, and Krusmark (2007) contend, computational replicates, when fully developed and deployed, offer greater flexibility as they can be modified more cheaply and perhaps more effectively than hardware-intensive live weapon systems.

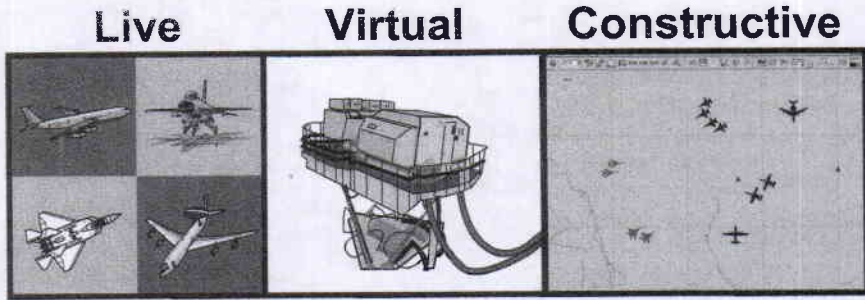


Figure 36.1. This graphic depicts three elements of future air force training technology systems—live, virtual, and constructive.

Immersive Environments

As weapon systems continue to diminish the barriers between human and machine, training systems must follow suit. Continued advancements in training technology toward LVC environments (see Figure 36.1) can provide enhancement of immersion through sensory fidelity. Maximizing this fidelity by using more operational equipment may obscure the perception of an active training environment versus an actual mission. Mixing live and simulated entities in the same domain can challenge the situational awareness of participants, although preliminary research has discovered effective mitigation techniques. For instance, Hughes, Jerome, Hughes, and Smith (Volume 3, Section 2, Chapter 25) discuss aspects of integrating terrain data in simulations. Other concerns relate to operating with differing security levels, simulation hardware, and fidelity requirements. Governments and industry will have to continue to work toward standards for data protocols and multilevel security in order to realize an effective coalition immersive environment.

CONCLUSION

We have seen increasingly immersive operational environments, such as the merged information stream for the JSF pilot. Because of the data sharing capabilities of the JSF (sensor data and information provided from one platform to another), the pilot may never actually see the target before or after weapon deployment. Thus, in a training scenario, a virtual adversary may be inserted that cannot be distinguished from a live asset. Conceptually, what we are describing is a convergence of perceived experience: a training environment that increasingly incorporates both constructive and real entities, and likewise, a real world activity that is integrated with simulation and training-specific tasks. The future of air force training will be enabled by continued advancements in live, virtual, and constructive environments.

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