STRATA: DARWARS for Deployable, On-Demand Aircrew Training

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ABSTRACT

Current practices in team training rely either on coordinated scheduling of personnel local to a base or ship (which limits the availability, breadth, and consistency of training), or on TDY training at a dedicated facility (which presents few opportunities, risks rapid skill degradation, and incurs high costs). To overcome these limitations we are developing *Synthetic Teammates for Realtime Anywhere Training and Assessment* (STRATA). STRATA is supporting DARPA's Training Superiority ("DARWARS") program and its vision for persistent, on-demand distributed mission training. STRATA integrates several innovative technologies that, for the first time, allow users to interact in challenging, engaging scenarios with distributed human and synthetic players, executing realistic missions at varying challenge levels. Our goal is to achieve considerable improvement in user performance by combating skill decay, to afford on-demand practice of both individual and team-level skills, and to provide tools that enable designers to create innovative training that is fully deployable with minimal equipment requirements.

A central feature of STRATA is the use of intelligent, interactive synthetic teammates that communicate verbally with users and exhibit realistic task and team behaviors. STRATA also affords instructor-optional training, through the use of advanced capabilities for automated mission briefing, individual and team performance measurements, and automated after-action review (AAR). STRATA is being demonstrated in the context of Close Air Support training. More broadly, the combined capabilities of synthetic teammates and automated instruction affords team training that is truly on-demand.

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SYNOPSIS

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STRATA is part of DARPA's Training Superiority ("DARWARS") program and fully supports its vision for persistent, on-demand distributed mission training. STRATA integrates several innovative technologies that, for the first time, allow users to interact in challenging, engaging scenarios with distributed human and synthetic players, executing realistic missions at varying challenge levels. Our goal is to achieve considerable improvement in user performance by combating skill decay, to afford on-demand practice of both individual and team-level skills, and to provide tools that enable designers to create innovative training that is fully deployable with minimal equipment requirements.

A central feature of STRATA is the use of intelligent, interactive synthetic teammates. These agents communicate verbally with users and exhibit realistic task and team behaviors. The variability of behavior and modeling of error modes makes these agents well-suited for team training. Their ability to stand in for missing team members enables a user to engage in team training without the team being present.

STRATA also affords instructor-optional training, through the use of advanced capabilities for automated mission briefing, individual and team performance measurements, and automated After-Action Review (AAR). Cognitive models drive the performance of the synthetic teammates and help track user performance and detect errors. A suite of performance measures monitors user and team actions, logging the measures for subsequent AAR and notifying the synthetic teammates (whose actions are influenced dynamically by user performance).

STRATA is being demonstrated in the context of Close Air Support training. More broadly, the combined capabilities of synthetic teammates and automated instruction afford team training that is truly on-demand.

TRANSFORMING "LAST METER" TRAINING

Current Practices in Aviation Training

Assured readiness of military forces depends crucially on the ability to maintain both individual operator skills and a team's capability to fight together. Emphasis on network-centric warfare and joint operations is transforming conventional notions of "team" toward a more distributed view, and efforts to sustain force readiness must be responsive to such trends. Despite the force projection importance of the Navy air wing and USAF Air Expeditionary Wing, aviators have few opportunities to practice with other air wing elements and hone teamwork or integration skills, presenting a potential impediment to readiness.

Current practices in team training rely on coordinated scheduling of personnel local to a base or ship, or require a unit to participate in Temporary Duty (TDY) training at a dedicated facility. In the Navy, for instance, the Naval Strike and Air Warfare Center (NSAWC) air wing training detachment offers training in air wing integration skills, but it is the only opportunity naval aviators have for this type of team training. Large-scale exercises and dedicated facilities, while valuable, present limited opportunities and incur high costs, and are therefore not well-suited as a primary resource for team training. In addition, skills acquired during such exercises are subject to rapid degradation in the absence of continued practice, and are acquired in contexts detached from a unit's operational environment. This problem has been exacerbated in recent years by attrition of mid-level officers. In the Navy, for example, this attrition has resulted in a greater proportion of the air wing who are recently out of the Fleet Replacement Squadrons. Thus, training approaches are needed to impart integration skills and training strategies that junior air wing members can access on-demand.

Localizing training at the unit level introduces inconsistencies and relies on instructors with widely varying qualifications and experience (if instructors are available at all). Unit-level training also imposes limits on the breadth of training available to any individual warfighter or team. And individual warfighters cannot be scheduled for team training in the absence of compatriots to assume the other roles within the team. Force readiness is being exposed to additional stressors such as political imperatives for presence in multiple theaters, asymmetric, transnational threats, and rapid changes in information, sensor, and weapons systems. These changes further tax the ability of current training mechanisms to sustain warfighter readiness.

Last Meter Training

Although training exercises, such as those conducted at NSAWC, are measurably valuable, they do not address the need for on-going refresher training. Skills are subject to decay over time in the absence of practice (Arthur, Bennett, Stanush, & McNelly, 1998). Opportunities for stand-alone skill practice are far more abundant than opportunities to practice coordination skills such as communications, coordination, and replanning. The need for ongoing training is made more urgent by rapidly changing tactics, threats, rules of engagement, doctrine, weapons systems, equipment, and conflict regions.

DARPA's Training Superiority program (DARWARS) seeks to transform military training by providing continuously available, on-demand, mission-level training applications for all forces at all echelons (Chatham & Braddock, 2001). These are called Last Meter Training Systems (LMTSs) since they are intended to address the "last meter" problem of getting training devices into the hands of users whenever needed.

In this paper we present the STRATA, an LMTS aimed at achieving significant improvement in readiness by creating deployable, on-demand individual and team training.

Deployable On-Demand Team Training

For individual and team training to be truly "on-demand", three important requirements must be met. First, the training must be accessible when and where the user needs it. For deployed forces, training must therefore be portable and readily *accessible*. Second, the presence of an instructor must be optional. Even for remote, networked training, arranging common meeting times between user and trainer establishes systemic barriers to on-demand training. Third, the presence of teammates and adversaries must be optional. Providing team training to individuals currently requires that all teammates participate synchronously; training exercises similarly employ human confederates to act in OPFOR roles such as aggressor squadrons at NSAWC.

These three characteristics have important implications for how a training application must be designed. As a fully-accessible training environment, the application should be deployable on low-cost, low-footprint computational devices with minimal specialized equipment. As an instructor-optional trainer, the application requires robust performance measurement, mission replay, and AAR, as well as learning management tools to help instructors define, catalog, and select scenarios. As a team-optional trainer, the application must provide training of communication and coordination skills through realistic interaction with other entities, such as other strike elements, command and control (C2) assets, or tactical air-ground controllers.

STRATA TECHNICAL APPROACH

To achieve on-demand team training, STRATA provides a high cognitive-fidelity simulation environment, performance measurement and debrief, and intelligent, speech-interactive synthetic teammates.

STRATA and Cognitive Fidelity

A guiding principle of STRATA is that, for any given set of training objectives, there exists a range of acceptable simulation fidelities (NRC, 1997; Isdale, Fencott, Heim & Daly, 2002). Simulation-based training must be designed so that training objectives are carefully aligned with the level of fidelity needed to practice and master those objectives (Salas, Bowers & Rhodenizer, 1998; Hays & Singer, 1999; NAVAIR Orlando TSD, 2002). In the case of STRATA, our focus on communication, coordination and decision-making implies a strong need for *cognitive fidelity*, meaning users should be immersed in environments that elicit decision-making and team behaviors that closely match the mental processes they apply in actual practices. The visual and physical fidelity requirements associated with airmanship "stick and throttle" training are less stringent for STRATA but must be adequate to present a realistic and challenging environment that requires the integration of multiple skills and that meets end-user criteria.

Traditionally, flight training devices used for military training offer simulation with high visual and physical, complete with wide field-of-view projection, detailed terrain, and actual flight controls and instrument panels. Such devices are very costly to acquire and maintain, require dedicated hardware and personnel, and are severely limited in number. As a result, users can train only in specific locales and during assigned time slots.

Desktop flight simulators seem to offer an obvious solution to cost and access barriers by providing greater numbers of flight trainers with low hardware overhead. However, for many flying tasks, such devices provide inadequate levels of fidelity and instructors and students thus prefer higherfidelity devices (Dennis & Harris, 1998). This bias carries over into tasks that are flying-related but which do not emphasize airmanship (such as those in STRATA, namely, communication, team coordination, and cognitive decision-making). An unfortunate consequence is that desktop PC-based simulation, when used in the military at all, has been employed for relatively rote, procedural training (Wiggins & Crognale, 2003) that fails to exploit the potential of this medium.

The dialogue between advocates of lower-cost, PC-based simulation devices and pilots historically wary of reduced-fidelity simulation has made steady headway as simulator technology has advanced. Numerous studies conducted during past decade point to a trend of greater acceptance among pilots of medium fidelity, PC-based training, both among pilots in general (Beringer, 1994; Jentsh & Bowers, 1998) and among military pilots (Rogers, 1991; Baker, *et al.*, 1993).

Simulation Environment: Deployability, Access

On-demand training is supported in STRATA by developing sophisticated simulation-based training on low-cost, low-footprint, portable computers. The underlying simulation is implemented with a high-end COTS flight simulation product called Airbook USA, a PC-based linked mission trainer currently in use or under evaluation at several military training sites by the Navy, Air Force, Army, and Air National Guard. In addition to detailed terrain and entity models, the system provides highly accurate F/A-18 weapons, sensors, physics, and visual displays.

Augmenting this simulation capability is technology to integrate the Airbook environment with standards-based interoperability protocols (via HLA), both to communicate with other simulations and to establish a seamless link with the synthetic teammates and automated performance assessment modules.

The ability to execute the simulation in standalone or networked mode, on standard laptop computers, with little sacrifice in visual fidelity, helps advance STRATA's objective of on-demand team training.

Instructor-Optional Training

A second requirement for on-demand access to individual team training is that the instructor need not be present. STRATA therefore performs the three principal functions of a live instructor: pre-mission brief, performance measurement and assessment during the mission, and AAR. STRATA will also provide learning management capabilities such as scenario tailoring and interoperability within a broader training management architecture called DARWORLD, being developed as part of DARWARS.

STRATA's pre-mission brief presents the content needed to prepare a user for the training mission. For Close Air Support, this content includes scenario training objectives, intelligence reports, weather conditions, control procedures, aircraft configuration, communications plan, flight plan, maps, and other information. STRATA will extract these data automatically from scenario definition parameters, and customize them to the role and experience level of the user.

STRATA's performance measurement system activates measures that pertain to the user's training objectives and the scenario training conditions (*e.g.,* night flight, threat levels). These measures concern mission effects (*e.g.*, number of targets destroyed), taskwork, and teamwork. Taskwork training provides instruction and practice in the procedures and decision-making required of an operator of a particular crew station. Teamwork training reinforces the inter-relatedness of each member's responsibilities, emphasizing communication and coordination (see Smith-Jentsch, Zeisig, Acton & McPherson, 1998, for an example framework for teamwork training). As each performance measure is taken, STRATA assesses the measure's value against performance standards and stores the results for use in AAR. When integrated with the DARWORLD training management system, STRATA will use data from a user's training jacket (training records) to fully automate measure selection and parameterization.

Finally, STRATA presents a rich and innovative AAR. This AAR supports the traditional replay of the scenario over a map. Users typically employ this view to reconstruct the mission narrative, diagnose problematic actions, and review their successes. STRATA goes beyond most existing training simulations by presenting communications transcripts synchronized to the map replay. The STRATA AAR also presents a summary of assessments on training objectives; selecting one (e.g., "Conform to weapon release protocol"), advances the tactical replay to the appropriate moment in the scenario (e.g., weapons release over the target). Thus, users can navigate the scenario by topic, as well as time. Plans for the next generation AAR will present expert feedback based on user assessments and integrate data concerning user performance in previous scenarios into the AAR to show progress (or regress) over time.

Team Training for Individuals

As much as COTS simulation technologies can provide low-cost practice opportunities with fidelity that is adequate for many training needs, simulation-based "training systems" largely ignore the sophisticated tutoring and assessment required to address training of real-time decision making in complex situations. In fact, using simulations in the absence of appropriate instructional feedback, such as could be provided by an intelligent tutor, can have a negative impact on performance (Means, Salas, Crandall & Jacobs, 1993). Simulators that are also devoid of speech understanding capabilities are unable to train skills related to communications, such as radio procedures. Finally, current COTS flight simulators lack the cognitive and pedagogical infrastructure to perform training management tasks such as presenting scenarios that optimally expose the trainee to skills in greatest need of practice, or reporting student performance. These limitations are not unique to PC-based COTS simulators; high-fidelity, multi-million dollar trainers seldom include native assessment, intelligent tutoring, or speech interaction.

The constraint that team members must be present together to participate in team training undermines efforts to make training *on-demand*. Synthetic teammates offer a solution by providing intelligent entitites to fill the role of human teammates absent from a given training session. To be effective in team-training, synthetic team members require the following capabilities:

(1) simultaneous execution of: taskwork (flying the airplane, working the console); teamwork (interacting with other members of the team); and instruction (providing assessment and feedback);
(2) interaction via spoken language (required for team training in verbal environments); and
(3) modulating behaviors to replicate various error modes, to allow for varying the proficiency of the synthetic team members (important in team training).

In previous work, we have demonstrated synthetic teammates meeting these requirements (Zachary, Santarelli, Lyons, Bergondy & Johnston, 2001). In this effort, we developed a simulation-based practice and training environment in which a human E-2C tactical crewmember can train in coordination skills by interacting with synthetic teammates, both on and off the E-2C. The synthetic teammates interact in spoken language and possess rich models that enable robust cognition and behavior. The models are created with CHI System's iGEN™ toolkit for constructing cognitive agents which is derived from a conceptual framework for representing real-time expert decision making with multiple attention demands (Zachary, Le Mentec, and Ryder, 1996). A synthetic team member acting as a tutor also possesses an internal model of the trainee, enabling tutorial monitoring and intervention with timely, relevant feedback, and providing an opportunity to train meta-cognitive skills in context.

Synthetic teammate actions can be modulated to replicate and reliably model various error modes (Bell & Scolaro, 2003). Modulating performance errors is of great importance in team training, allowing the human trainee to experience high, moderate, or low proficiency team-members, providing a unique capability to train cognitive performance in team skills under varying conditions.

CLOSE AIR SUPPORT EXAMPLE

STRATA is being demonstrated in the context of Close Air Support (CAS) training, because this mission presents an on-going training requirement and offers a representative domain for evaluating innovative training technologies. CAS involves air strikes against enemy targets located in close proximity to friendly ground forces (JCS, 2003). It is a mission with inherent complexity and risk and where the consequences of an error can be very high (Jansen, et al., 2003).

Current CAS training practices

Training for the terminal components of a CAS mission (i.e., aircraft check-in, orbit, ingress, weapon delivery, and egress) normally involves exercises at training ranges employing live ordnance.

Equipment, personnel, and range access must all be orchestrated in advance to facilitate live training. Fixed-wing CAS sorties, for instance, are usually flown in groups of two to four aircraft. Command and Control elements such as a Direct Air Support Center (DASC) may be required. Finally, the terminal attack controllers, such as a Joint Terminal Attack Controller (J-TAC) or Forward Air Controller (FAC), must be pre-arranged and in-place.

Figure 1 details one form of the CAS process, the *immediate* CAS request process, as defined by the Joint Tactics, Techniques, and Procedures for Close Air Support (CAS) doctrinal publication (JCS, 2003). STRATA's training focus begins at stage 9 where the DASC instructs the lead F/A-18 to proceed to a Contact Point (CP) and contact the FAC using a specified callsign and radio frequency. At stage 11, the lead F/A-18 checks in with the FAC at the CP and completes an authentication process. The FAC provides a briefing regarding the location of the Ingress Point (IP), the position of the target, the target itself, how the target will be marked, the location of any friendlies, and how to egress from the target. This "nine-line" briefing is based on a standard nine-line format to promote brevity and accuracy, After providing the nine line briefing, the FAC may provide a time on target to the lead aircraft. By the time the aircraft cross the IP the lead and wingman have established necessary separation. At this stage the controller will coordinate any marking (*e.g.*, smoke, laser designator) with the lead pilot to pinpoint the target and, if the lead aircraft appears aligned correctly, will give a "cleared hot" indication. Once cleared hot, the lead delivers the ordnance and the controller makes a battle damage assessment. In this scenario the process would then be repeated for the wingman.

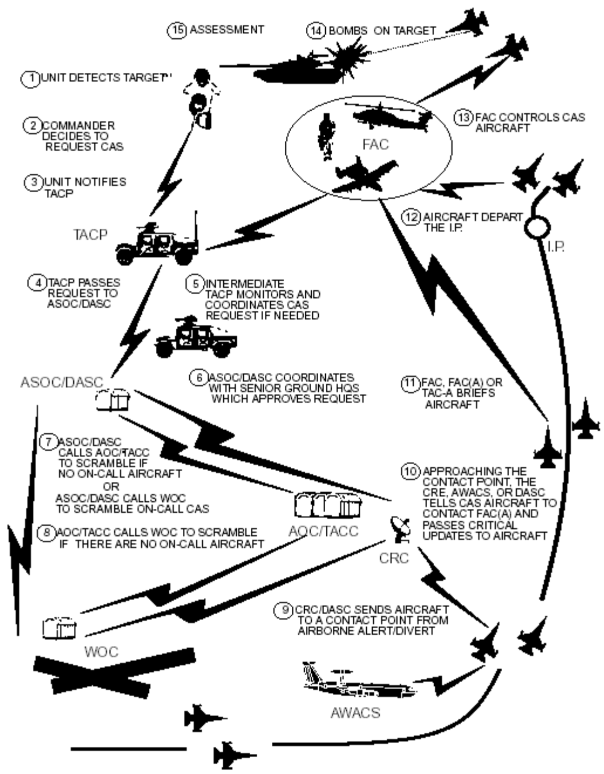

Figure 1. Immediate CAS process (JCS, 2003)

Although CAS is relatively structured and has well-defined conditions and communications that govern transitions from one phase to the next, opportunities to practice CAS are limited because of the need for a team of personnel and an appropriate range. Thus, training and readiness to perform CAS missions can decay during deployment cycles. Using synthetic teammates and a simulated CAS environment, STRATA provides mission scenarios focused on the terminal components of a CAS mission that can be used anytime, anywhere.

STRATA Scenario Example

The STRATA CAS scenario is instantiated by a scenario generator that tailors scenario templates based on the user's training jacket and on specific training objectives specified by the DARWARS training management system. In this brief example, the scenario begins with the user viewing a mission brief; however, prior to reaching the briefed CP, the (synthetic) DASC re-tasks the user (to create opportunities for "adaptation to re-tasking" practice and assessment).

Upon reaching the new CP, the user checks in with the FAC and receives the nine-line. Figure 2 shows the cockpit view at this point. In this instance, the FAC's brief includes an error: friendly positions are incorrectly given as too close to the target (recall that the synthetic teammates can exhibit realistic error behaviors). The user is thus assessed on situational awareness of target and friendly locations as well as adherence to briefed weapons release parameters. If the user fails to detect the error, the synthetic wingman reports to the lead that the friendlies are too close to the target. The FAC then corrects the nine-line and gives a time-on-target (TOT). Once again, the FAC commits an error and the user must recognize that the strike aircraft cannot make the specified TOT. If the user fails to notice these errors, the wingman again provides backup and prompts the lead to ask the FAC for more time. The user then pushes to the IP, lines up on the proper attack heading, receives a "cleared-hot" from the FAC, and releases the ordnance (Figure 3). The process then repeats for the wingman, who executes the attack run while the user (flying the lead) performs an egress.

Figure 2. Cockpit view early in CAS scenario

This brief example is just one of many variants that can run in STRATA; since the synthetic teammates are dynamic and not scripted, scenarios are responsive to the user's actions. Moreover, STRATA can train two users simultaneously (one flying the lead position and the other flying the wingman aircraft) and can dynamically "hot-swap" human and synthetic players. Any player in the scenario can be replaced by a human user; for example, STRATA could be readily adapted for use in training tactical air controllers.

CONCLUSION

To maintain readiness of perishable skills and provide a broad range of missions and situations, a realistic simulation-based training system is needed that is truly on-demand; it must be readily deployable, usable with or without the presence of an instructor, and adaptable to whatever users are available to train at the time. STRATA introduces training that meets these requirements. Performance assessment and automated AAR offer interactive, adaptive, instructor-less training. Intelligent entities appropriate to the scenario interact in spoken language, and exhibit realistic, responsive, adaptive behaviors. These agents thus provide on-demand access to coordination and communications training. Finally, STRATA provides a high-Cognitive Fidelity simulated environment for practicing and assessing decision-making, communications, and coordination, perishable skills most at risk of decay during deployment cycles.

ACKNOWLEDGEMENTS

STRATA is supported by the Defense Advanced Research Projects Agency through Office of Naval Research Contract N00014-03-C-0300. The authors gratefully acknowledge the support and guidance of Dr. Ralph Chatham of DARPA, Dr. Harold Hawkins of ONR, and LCDR Sean Biggerstaff of NAVAIR PMA205.

Figure 3. Weapon release showing bomb on target and FAC's smoke mark (right of target)

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