

# DARWARS: An Architecture That Supports Effective Experiential Training

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## The DARWARS Vision

Initiated in 2003, the DARWARS Project is part of DARPA's *Training Superiority Program*. The program's goal is to transform military training by introducing a new kind of cognitive training experience for units and individuals. These low-cost, mobile, on-line, simulation-based training systems take advantage of the ubiquitous presence of the PC and of new software technologies, including multi-player games, virtual worlds, off-the-shelf PC simulations, intelligent agents, and on-line communities. *Experiential* lightweight simulation systems create immersive training environments for a wide range of domains, from language training to battlefield strategy, and often offer automated, on-target feedback for each student and team.

This investment in new training technology addresses several identified military training problems, including the need for more training in team coordination throughout the services; more opportunities for joint operations training; more training for Reserves and Guard units; refreshing combat skills that have decayed after schoolhouse training; and the ability to schedule last-minute training just before and during troop deployments. Because they are motivating to the student and are available anywhere, anytime, DARWARS training systems are the key to unparalleled training effectiveness.

BBN Technologies is the architecture and integration lead for DARWARS, coordinating the work of several R&D contractors including Aptima, Inc and MÄK Technologies. Together, they are developing an architectural framework, the DARWARS Core, which includes a broad set of web services, tools, and system interface definitions to facilitate the development of advanced Training Systems of all types, and their deployment and use by instructors over a global training network. The DARWARS Core is scalable; it supports training for individuals, teams, and teams of teams (involving hundreds of students at PCs all over the world interacting in a virtual environment). Training Systems keep track of what each student does in the simulation in order to offer individual and group feedback. The program supports on-line communities of students, instructors and developers around the DARWARS family of Training Systems. In the coming months, DARWARS will be able to interact with Learning Management Systems to coordinate student record management, curriculum development and integration of didactic and experiential training.

In addition to providing a technological architecture for training systems, DARWARS pushes the envelope of training science by providing a general pedagogical framework for simulation-based instruction – linking training objectives to students' experiences in simulations and virtual worlds. DARWARS *trainees* are able to find what training experiences are available to them; choose ones that match their needs; review their performance in specific training experiences; track their progress over time; and estimate their readiness for the next training experience or real-world event. DARWARS *trainers* will schedule training sessions based on the training objectives of individuals and teams. They will have access to performance information to enable the development of new curricula; tools to provide individualized real-time coaching; and applications that will allow them to conduct effective After Action Reviews (AAR). DARWARS supports all of these features in its single, unifying framework of specified objectives, conditions, and measures.

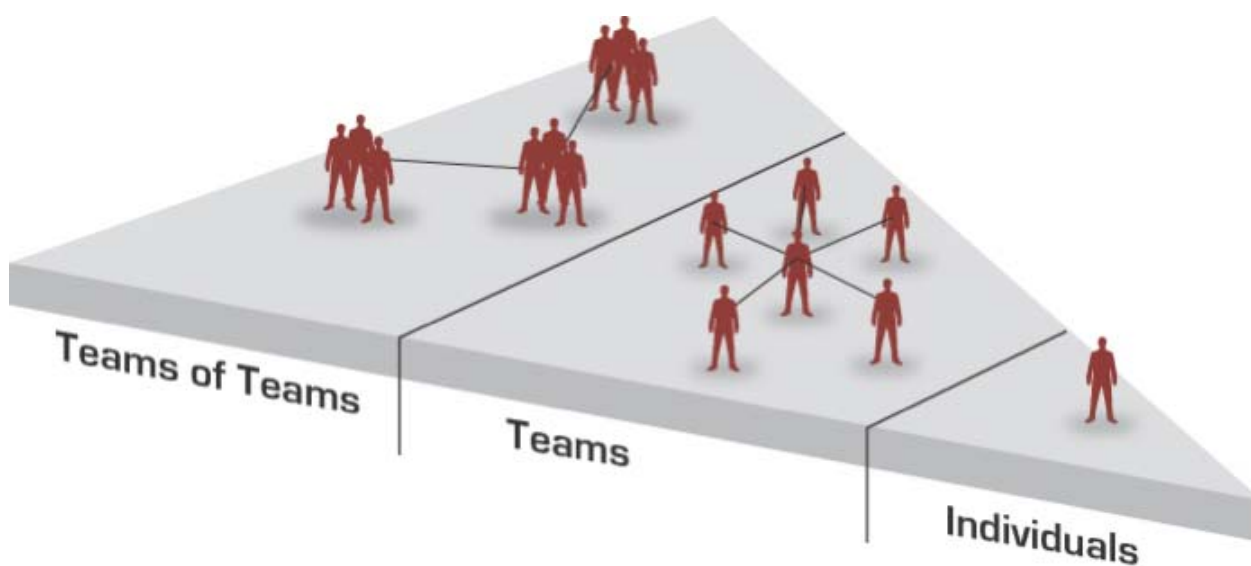
This framework for tying training objectives to experiential training is the subject of this white paper. It will provide an overview of the key training features and services in the DARWARS Core and illustrate how the framework will

facilitate interoperability between Training Systems. It will also discuss the pedagogical challenges and opportunities involved in developing an integrated simulation-based training environment.

## The Current State of the Art in Simulation-based Training

Educators recognize that simulation-based instruction – immersive, situation-based training occurring in a complex virtual environment – offers great opportunities for learning. However, the majority of existing simulation-based training systems do not realize the full pedagogical potential of their technology, particularly for large-scale training efforts.

Current simulation-based training systems favor small scale, relatively homogenous teams with single applications, and often require a cadre of support and training staff. Simulation development is typically focused on building a high fidelity, realistic simulated world with little emphasis on measurement or assessment of performance. Scenarios are developed by Subject Matter Experts (SMEs) who have the greatest knowledge of the target domain. The same SMEs observe training, facilitate the AAR discussions, and modify scenarios to address individual trainees’ needs. Thus, a large part of simulation-based training is currently mediated by human experts and must be scheduled when they are available. Similarly, training goals and objectives are often implicit and are contingent on SME expertise. Trainee performance is evaluated qualitatively, rather than being measured by actions within the simulation and assessed with regards to overall objectives.



*Figure 1. The spectrum of training in DARWARS: Ranging from focused skills training for individuals, to team coordination drills, to massive joint operations virtual exercises. The examples mentioned are part of the family of DARWARS training systems, which are described on-line at [www.darwars.net](http://www.darwars.net).*

This SME-intensive approach to simulation-based training is well suited for training and debriefing small, homogeneous, co-located teams. With a single team (Figure 1 – middle), trainers can review overall mission performance in general terms and point out the role of individuals (Figure 1 – bottom right) in support of those objectives. Or, trainees can debrief themselves by recalling and discussing their experiences and assessing what worked well, where problems occurred, and how to improve their performance. In small homogeneous groups that are experienced in interacting with one another, individuals are likely to intuit their function in the mission. Trainers can point out lessons learned at a relatively low level, and individuals benefit from this direct expert feedback.

The model described above is not sustainable, however, as the number of participants is increased, and when multiple, diverse, geographically distributed teams of teams must be coordinated to meet mission objectives (Figure 1 – top left). With hundreds of trainees from different backgrounds, different services, and different platforms (a typical joint

mission), the SME trainer will not be able to provide individualized feedback to every participant. Specific individuals may not be able to determine their role in achieving overall mission objectives, and thus will not reap the full benefit of a high level mission performance AAR. It is possible to remedy this problem by employing many SME trainers to observe performance at multiple levels, each giving individualized feedback to a subset of the total participants. However, this solution requires the availability of a large number of experts, and may be difficult to achieve in geographically distributed exercises. In order to deliver meaningful feedback that maximizes learning for large, diverse teams of teams, explicit representation is needed for training objectives; for the types of conditions in which those objectives must be met; and for the measures of performance that reflect behavior in those objectives.

## The DARWARS Training Framework

The challenge for DARWARS is to deliver tailored, relevant feedback at each level of the spectrum, from individual to team to diverse teams of teams. DARWARS is being designed to maximize the effectiveness of distributed, simulation-based training by supporting the full potential of such systems. To accomplish this goal, explicit representations of the training objectives, simulation conditions, and performance measures will enable trainers to tailor training and AAR to individuals or smaller subsets of the larger team, while simultaneously evaluating overall mission performance.

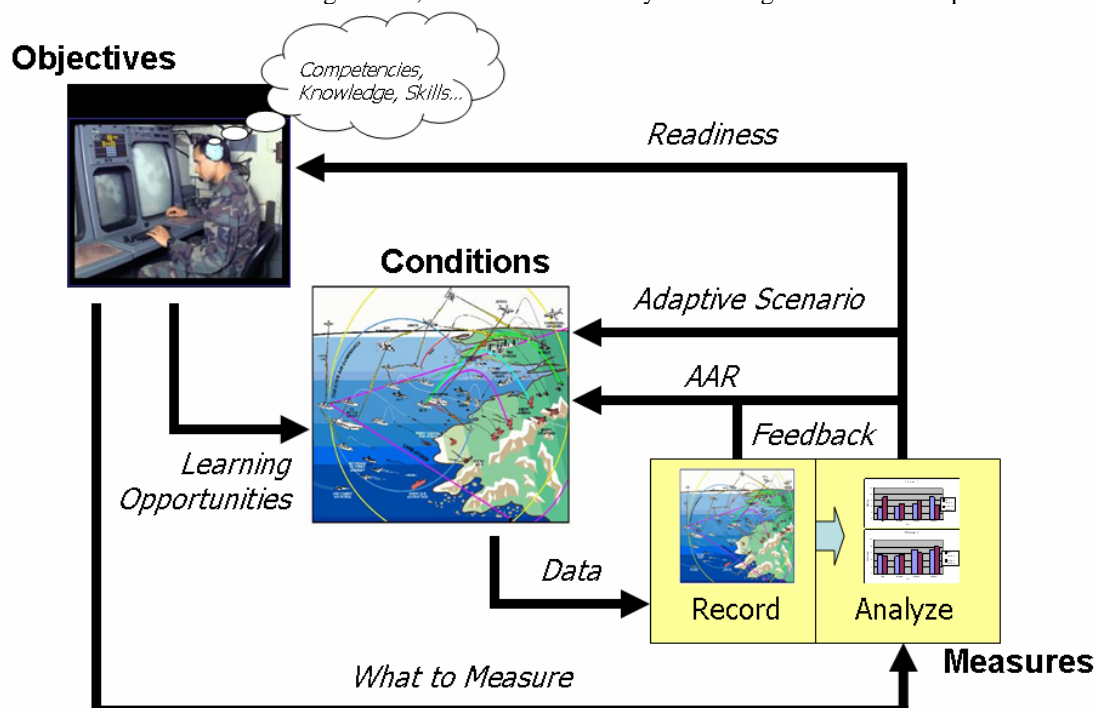


Figure 2. The role of Objectives, Conditions and Measures in simulation-based training.

This explicit representation of pedagogical elements is what is being developed for DARWARS (Figure 2). Trainees have specific learning *objectives* to gain competencies, knowledge, or skills in specific subjects or domain areas. They are then matched to the appropriate training experience (e.g., taking a particular role in a specific scenario) based on these *objectives*. Trainers have the ability to craft a virtual world to help the trainee meet those *objectives* by specifying the characteristics or *conditions* of the virtual environment with more precision and control than is possible in the physical world. Trainee responses within the simulation can be recorded and contextualized in terms of the learning *objectives*. Meaningful *measures* can be made based on trainee performance, recorded, and then extracted to provide assessment and feedback to trainees both during a training session (in the form of coaching) and after a session (in the form of an AAR). The measures give trainers insight into trainee progress with regard to the *objectives*. Diagnosis of these measures enables the next match between training experience and trainee. The detailed record of performance in the simulated world may allow predictions about trainee readiness in the real world.

Explicit representation of *measures* with regards to *objectives* also allows trainers to interpret performance efficiently, diagnose the trainees' needs, and to personalize the training curriculum—all the while updating a record of the trainee's

remaining objectives. Similarly, the performance of teams and other groups of people can be evaluated based on performance within the simulator and assessed in relation to past performance and established criteria. Over time, information about the progress of many DARWARS users through multiple training experiences may reveal trends that can be used for scenario and curriculum development.

The training framework developed for DARWARS explicitly represents *objectives*, *conditions*, and *measures*. However, it is the explicit representation of the relationships among these elements that will allow DARWARS to provide users with the highest caliber training functionality.

## Objectives, Conditions and Measures

As described above, the main pedagogical parameters identified to increase training effectiveness in simulation-based learning environments are *objectives*, *conditions*, and *measures* (see Figure 3). Each is described below.

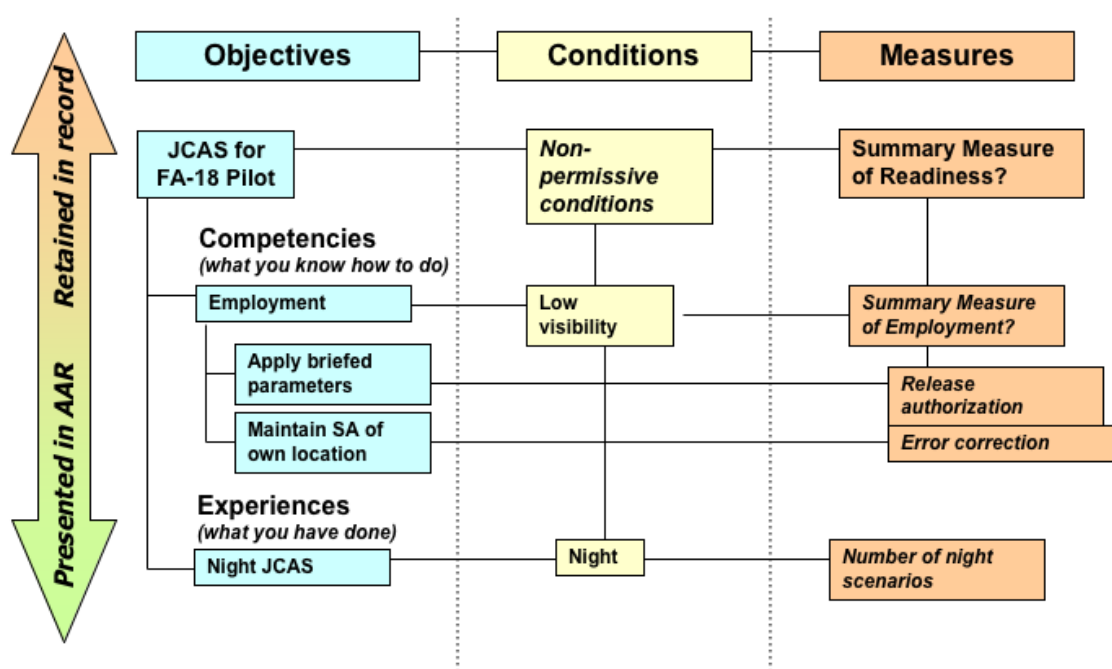


Figure 3. The three main pedagogical parameters for specifying training:  
Examples for training a JCAS F/A-18 pilot.

**Objectives** are what the trainee will need to be able to do or know after participating in a training event. An *objective* may be the description of a task or activity, and can be hierarchical. For example, the *objective*: “Operate a vehicle in a convoy” may have nested sub-objectives, such as “Observe, assess, prepare for ambush” and “Respond to ambush.” A particular training event may have multiple *objectives*.

**Conditions** describe the specific configuration of parameters within a Training System that have implications for learning. For instance, within a flight simulator Training System, the weather conditions and number of players may vary. **Conditions** also include the fixed parameters of a Training Systems, such as the air platform (F-18, helicopter, commercial aircraft). These fixed and changing parameters constrain the types of *objectives* that can be addressed, and are consequently fundamental to training. For example, pilots must acquire knowledge of flying under a variety of conditions, such as adverse weather and low visibility, before they become fully competent.

**Measures** are behaviorally anchored, observable actions within the Training System that can be calculated and linked to a particular *objective* (or sub-objective) to demonstrate mastery of a task (or competency, knowledge, skill) in a particular set of *conditions*. In this way, the *objective* is operationalized; the *objective* being met is defined by the

*measures* employed. Thus, the choice of *measures* is important to both instructors and trainees. For a Training System to be maximally effective, the measures should clearly relate actions to objectives.

The same training *objectives* can be addressed using different approaches to measurement. Many existing simulators – including potential elements of DARWARS – are experiential in nature; trainees participate in many simulated missions and learn implicitly over time through exposure to the diverse conditions presented to them. *Objectives* in this type of simulation can be characterized as *experiential*. For instance, a civil aviation Training System may have a training *objective* such as “Master take-offs and landings.” A trainee’s experience can be roughly gauged by capturing their *exposure* to developmentally important experiences. In this case, a trainee’s progress for the *experience objective* is simply the number of take-offs and landings they have successfully accomplished within the training system—their total *exposure* to those events.

Alternatively, some Training Systems may explicitly lay out training objectives that specify the quality of performance (e.g., novice, intermediate, expert). For instance, *competency* in a foreign language can be assessed using explicit *measurements* of vocabulary, grammar, pronunciation, and cultural knowledge. At any point during training, the level of *proficiency* can be calculated based on these *measures*. The *competency objective* denotes the desired end state of training. Returning to our example from civil aviation, if the objective is “Master take-offs and landings,” the Training System may measure the altitude and speed of the aircraft in addition to procedural knowledge to determine the level of *proficiency*.

One challenge that DARWARS must manage is the “roll-up” of measures to higher-level indicators of performance. To illustrate, consider the high school classroom. In a single course, individual grades on homework and test scores may be combined into a single grade that reflects course performance. Grades from multiple courses are then combined to indicate overall achievement in high school. In the high school system, *measures* roll up in an explicit and consistent manner. Within DARWARS, this type of roll-up poses a challenge: How do low-level *measures* translate to overall performance? It is not the goal of the DARWARS Training Impact Group to dictate assessment schemes. Instead, it will be up to individual Training System developers to determine if and how *measures* can be meaningfully combined to produce aggregate indicators of performance. DARWARS will allow multiple assessment schemes to be applied to the same set of competencies in order to express differing judgments of how lower level competencies combine to produce higher level indicators of performance or readiness.

## Implementing the Framework

Implementing the DARWARS framework requires making connections among the objectives and measures established for a particular configuration of training systems, called a Training Packages (TP). Doing so enables movement from one training experience to another. Figure 4 illustrates how such interoperability between different TPs might be accomplished, as supported by the pedagogically-grounded infrastructure provided by DARWARS.

SGT Ronald Davis is in the 171<sup>st</sup> Quartermaster Squadron which is about to be deployed to Iraq. He will be involved in supply operations, and will have squad leader responsibilities. Although he will be in a part of the country that is secured, recent events have shown that military supply lines are often targeted by insurgents. The squad leader and his squad mates need to be capable of following their commander’s guidance when it comes to effective convoy tactics, techniques, and procedures (TTPs) and standard operating procedures (SOPs). These warfighters should also have a rudimentary understanding of the culture in which they will be deployed and need to be able to effectively deal with situations that might arise during normal convoy operations.

Fortunately, there are DARWARS Training Packages (TPs) that address the objectives SGT Davis requires. TPs are denoted as rectangles in Figure 4. Some TPs are designed for multiple trainees filling multiple roles (represented as a stack of rectangles) and some designed for individual performance (represented as a single rectangle). Multi-trainee TPs could include different simulation engines or training systems interacting (indicated by different colors in the TP stacks. SGT Davis’ Platoon Sergeant has assigned him and some of his squad mates the Basic Convoy Operations Objective, and has set up an event in which he participates in a DARWARS TP “TTPs and SOPs.” SGT Davis will take on the role of a convoy driver in a five vehicle convoy, and will be required to navigate safely through both urban and open terrain. There is some didactic content – available through an LMS – that will help him review the pertinent information about convoy TTPs and SOPs. Didactic

content is denoted by ovals in Figure 4. In this case, we can imagine that recent field lessons are available as content presentable by an LMS. DARWARS will be able to connect to different types of didactic content.

SGT Davis then participates in the event – the team is able to reach their destination in the virtual environment, avoiding or prosecuting targets that would impede their path. After participating in the event, a few things are known to DARWARS. DARWARS knows how SGT Davis did – that he accomplished his mission goals (safe arrival at a waypoint). Based on his performance, his Platoon Sergeant feels he is ready to move on to a new objective: “Intermediate Convoy Operations.” The first TP that addresses the Intermediate Convoy Operations Objective is the TP “Crowd Control in Iraq” In this package, the convoy’s path is blocked by protesters. SGT Davis and his squad must interact with the crowd until they disperse peacefully. At the same time, SGT Davis and his squad mates must demonstrate the skills they practiced in the “Convoy TTPs and SOPs” TP.

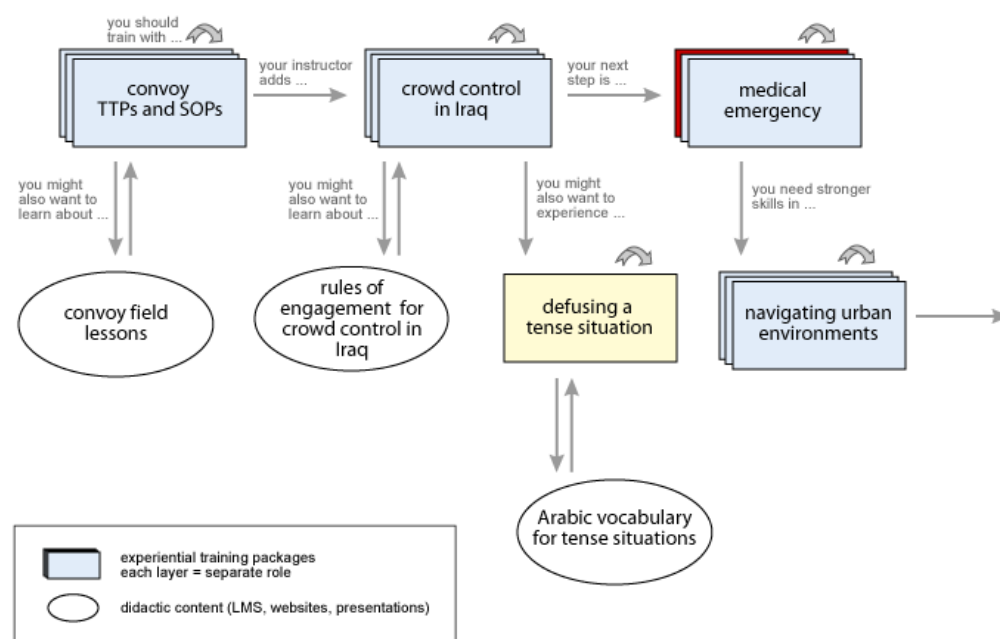


Figure 4. An illustration of dynamic curricular development in DARWARS. Shape indicates type of training (rectangle = experiential; oval = didactic). Colors indicate different Training Systems.

As before, there is some didactic content that is appropriate, such as the “Rules of Engagement for Crowd Control in Iraq.” In this case, there is a link from the TP Brief to a web page that will facilitate progress through the experience. Since DARWARS is web-based, this type of linking is easy to implement. During the TP, SGT Davis’s team is required to interact with the populous, which required cultural knowledge. Using objectives common to multiple TPs, DARWARS can suggest that a culture and language objective be added to his list of objective assignments. SGT Davis’s platoon commander thinks that it is a good idea, and follows the suggestion. Based on SGT Davis’s performance in the simulation, a new TP can be run – “Defusing a Tense Situation” – which addresses the new objective. Also based on performance in the “Crowd Control in Iraq,” an additional TP can be found that addresses the Intermediate Convoy Operations” objective – “medical emergency.” After practicing in that TP, his performance suggests that he needs some additional training in urban navigation. He launches a different TP, and then moves on to additional experiences – which may require the addition of other skills. Of importance here is this: SGT Davis’s particular path through training experiences is tailored to his performance, dynamically generated, and different from other warfighters who have similar objectives.

The connections made in the above story are made possible by the development of an infrastructure of objectives, conditions, and measures that support this dynamic progression through experiential training. Additional DARWARS

structures and features, such as training packages, role descriptions, and roll-up scores, facilitate this further. For each of the connections mentioned in the story, there will be structures implemented in the DARWARS core, as shown in Table 1. Some of these are already implemented, and some are near-term plans. Note that these connections among TPs are motivated by individual and team training needs and requirements. This leads to higher efficiency and higher potency training.

Table 1. Implementation of Key Connections in the DARWARS Core Pedagogical Infrastructure

<b>Connection</b>	<b>Implementation</b>
<b><i>Your next step is...</i></b>	<b><i>Progression via Objectives addressed by Training Packages</i></b>
<b><i>You should train with...</i></b>	<b><i>Training Packages with multiple roles designed to address different Objectives</i></b>
<b><i>You might also want to learn about...</i></b>	<b><i>Objectives common to TPs and Didactic Content</i></b>
<b><i>You might also want to experience...</i></b>	<b><i>Objectives common to different Training Packages</i></b>
<b><i>You need stronger skills in...</i></b>	<b><i>Low scores against Objectives trigger new Objective Assignments</i></b>
<b><i>Your trainer adds.../You add...</i></b>	<b><i>Trainers or Trainees assign Objectives or schedule Training Events</i></b>

*A large part of the DARWARS vision is to make Training Systems into effective training environments for individuals and teams. We believe part of this will be accomplished by supporting connections among different training experiences, as shown above. This allows the warfighter to participate in those events that help him or her practice, improve, and hone one's skills, and then carry that knowledge into theatre when it is demanded of them.*

## Next Steps

The goal for this white paper was to explain the benefits of an articulated training framework and describe the requirements needed for such a framework to be effective. DARWARS can make possible the move from an expert-dependent Training System without clear objectives to a scaleable simulation-based Training System with explicit objectives. A structure of inter-linked objectives, conditions, and measures facilitates this move, and makes possible a host of activities that would improve training effectiveness. DARWARS is working closely with Training System developers and LMS vendors to propagate these ideas.

It is the DARWARS Training System developers and their transition partners who will drive DARWARS towards its potential. We will continue to work closely with them to foster a better understanding of how training in different systems unfolds. It is likely that the framework being developed will continue to evolve. We are also seeking other developers to adopt this approach to training and integrate their systems with the DARWARS Core functionality.

This paper provides an overview of the key training features and services in the DARWARS architecture, and illustrates how the framework will facilitate all phases of the training cycle. It is also intended as a vehicle to communicate to Training System developers and to convince them that the effectiveness of training can be enhanced by augmenting their applications with a rich pedagogically-motivated set of tools supplied by DARWARS.

It is hoped that this white paper will broaden the dialog with current and future DARWARS stakeholders. With input from many Training System developers, the framework will be refined further, and the fundamental elements populated with information from existing systems to test their utility. Through close collaboration, potential problems will be addressed and apparent incompatibilities overcome. The results will raise the bar for simulation-based training for years to come.

*For more information, please visit the DARWARS website, <http://www.darwars.net>, or contact us at [info@darwars.net](mailto:info@darwars.net).*