

A Tactical Decision Trainer for Cross-Platform Command Teams

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ABSTRACT

Warfare with near-peer adversaries will require extraordinary integration between warfare domains. For the Navy, this means that commanders of air and sea platforms must coordinate sensors and weapons through informed, timely, and decisive tactical command.

Cross-platform command training is rare, so are simulations to support it. Virtual simulations enable operators to execute tactics on one platform, but the cross-platform challenge requires training in command (not execution) between (not within) aircraft and surface vessels. Constructive simulations represent multi-platform battles, but they generally do not enable trainees to coordinate realistically over decisions or manage the execution of complex orders; nor do they typically measure decision making and its effects, or directly support well-specified instructional strategies.

A system of instructional techniques and technologies was developed to train cross-platform teams in tactical decision making. This solution consists of: (1) an instructional strategy in which users from air and sea platforms view the battle, argue their tactical options, and issue orders; (2) a graphical user interface on which students issue those orders simply by specifying the asset(s) and tactic(s) to apply to emerging threats; (3) the Next Generation Threat System (NGTS) simulation of the battle assets (platforms, sensors, weapons) and the battlespace; (4) an executive agent that transforms trainee orders into simulator commands without human control; (5) an engine that measures and assesses decisions and their effects; and (6) an After Action Review (AAR) system that reports events over time, reports performance on decision skills, and recommends discussion points during AAR. The Navy is putting this technology to work in training in 2016. This paper describes the instructional strategy, aspects of the system that supports it, and feedback from users of the system.

ABOUT THE AUTHORS

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THE CHALLENGE OF CROSS-PLATFORM TEAM TRAINING

Warfare with near-peer adversaries will require extraordinary integration between warfare domains, referred to by the Navy as Integrated Warfighting Capabilities (IWC). Commanders of air and sea platforms will have to coordinate sensors and weapons through informed, timely, and decisive tactical command, and do so at a level never seen before. Currently IWC coordination training occurs late in the pipeline, largely at live exercises. This is a relatively high risk training strategy. The next evolution of IWC training must address two requirements. First, the training pipeline must be reconfigured to provide more cross-platform training earlier, at increasing levels of fidelity and complexity. Second, simulation technology must be developed to support that training.

A recent Naval Aviation Training Systems (PMA-205) program manager, CAPT Craig Dorrans, has said of the requirement to increase cross-platform training that, "Instead of single stove-piped capabilities, we have networked systems, all contributing to a warfighting capability that requires you to train as a team instead of an individual" (as cited in Mattingly, Bolton, Walwanis, & Priest, 2014). Training between platforms -- specifically air-to-air and surface-to-air -- is provided rarely and late in Navy training. Training pipelines are owned and developed within each platform, and training technologies (e.g., virtual flight simulators) are under the umbrella of separate offices for surface, aviation, and subsurface programs. While there are organizations within the military that address integrated (i.e., cross-platform) capabilities, the requirements for each platform typically fall to the platform or domain project teams and are, therefore, traditionally focused on one platform and, slightly outward, to its immediate interactions with other platforms and their technologies. These circumstances make the shift to cross-platform training difficult.

To make cross-platform training available earlier in the pipeline means filling a gap at the crawl and walk levels of Navy training prior to the run level of exercises. Navy training (like most service training) is delivered at several levels: crawl, walk, and run. For example, at the crawl level, a pilot may first concentrate on the basic information they may need at the individual level in the classroom, then move to a part task trainer to learn button pushing skills. Following the mastery of these skills, the pilot may graduate to a simulated operational environment at the walk level, where they practice both the button pushing and the more complex, cognitive skills needed in collective, tactical operations, working up from wing to lead and squad level training. The run phase of training is often a live operation for IWC, because of limitations of simulators for cross-platform operational training. In live exercises, participants lead and interact within operational environments, within squadrons and across platforms.

Trainees who have advanced to the platform configuration are positioned to practice and coordinate at an integrated level. However, this rarely occurs before live training. Each platform typically flows through the crawl and walk at their own pace with their own trainers (for the most part), but platforms rarely, if ever, train together before the run phase. Such stovepiped training pipelines largely satisfied the requirements of the Fleet before IWC. However, IWC requires crawl, walk, run training specifically for cross-platform level skills and knowledge. This training does not exist, as illustrated in Table 1. Higher level skills such as command decision making and mission coordination are

largely learned on the fly in operational or live, cross-platform exercises, late in the training process, without early benefit of simulations and training technologies.

Table 1: A training and training technology gap exists at the crawl & walk levels of Navy IWC training

Training type & level	Crawl	Walk	Run
Within-platform training	Training exists	Training exists	Training exists
Cross-platform training	Training gap		Training exists

New techniques and technologies are needed to provide early (run, walk) cross-platform decision training. Current technologies are generally not sufficient to deliver cross-platform, cross-domain live, virtual, and constructive training. Current virtual simulations typically enable operators to practice execution of tactics on one platform. For example, aviation simulators may be networked to each other, but rarely if ever does aviation based virtual training involve surface counterparts at a lower level. The cross-platform challenge requires training in coordination and decision making, not just execution, across multiple platforms. Constructive simulations (e.g., Next Generation Threat System (NGTS); Joint Semi-Autonomous Forces (JSAF) represent multi-platform battles, but they generally do not enable trainees to coordinate realistically over decisions or manage the execution of complex orders; instead they provide semi-autonomous support for platform centric virtual trainers. Furthermore, virtual and constructive simulations do not traditionally provide mechanisms to measure decision making and its effects, nor are they designed specifically to support well-specified instructional strategies, both of which are important elements of training effectiveness (Freeman, Stacy, & Olivares, 2009; Vincenzi et al, 2007).

This paper describes a new tool that fills the gap in early, crawl-level training in decision making and coordination across platforms for IWC. The tool enables students to exercise new integrated tactics, visualize how they play out, and efficiently identify and learn from their successes and failures. The Cross-Platform Mission Visualization Tool is built upon prior work sponsored by the Office of Naval Research (ONR) Future Naval Capabilities (FNC) Live Virtual and Constructive Training Fidelity program (LVC-TF). The initial capability (Phase 1) was delivered as a demonstration for the Navy community to illustrate the application of instructional technology for classroom, cross-platform visualization and decisions making. A follow on capability (Phase 2) was recently delivered for use by a Navy training organization, and additional capability (Phase 3) should be in development shortly.

A SOLUTION FOR CROSS-PLATFORM DECISION TRAINING

The Cross-Platform Mission Visualization Tool supports classroom training exercises in decision making for IWC. It was created efficiently, by building on the NGTS simulator (a Navy program of record), and ONR LVC products such as the Performance Measurement Engine and Training Executive Agent (all described below). Specifically, the training system consists of these components (illustrated in Figure 1): (1) an instructional strategy in which users from air and sea platforms view the battle, argue their tactical options, and issue orders; (2) a graphical user interface on which students issue those orders simply by specifying the asset(s) and tactic(s) to apply to emerging threats; (3) the NGTS simulation of the battle assets (platforms, sensors, weapons) and the battlespace; (4) an executive agent that transforms trainee orders into simulator commands without human control; (5) an engine that measures and assesses decisions and their effects; and (6) an After Action Review (AAR) system that reports events over time, reports performance on decision skills, and recommends discussion points during AAR. Below, we describe these components of the system.

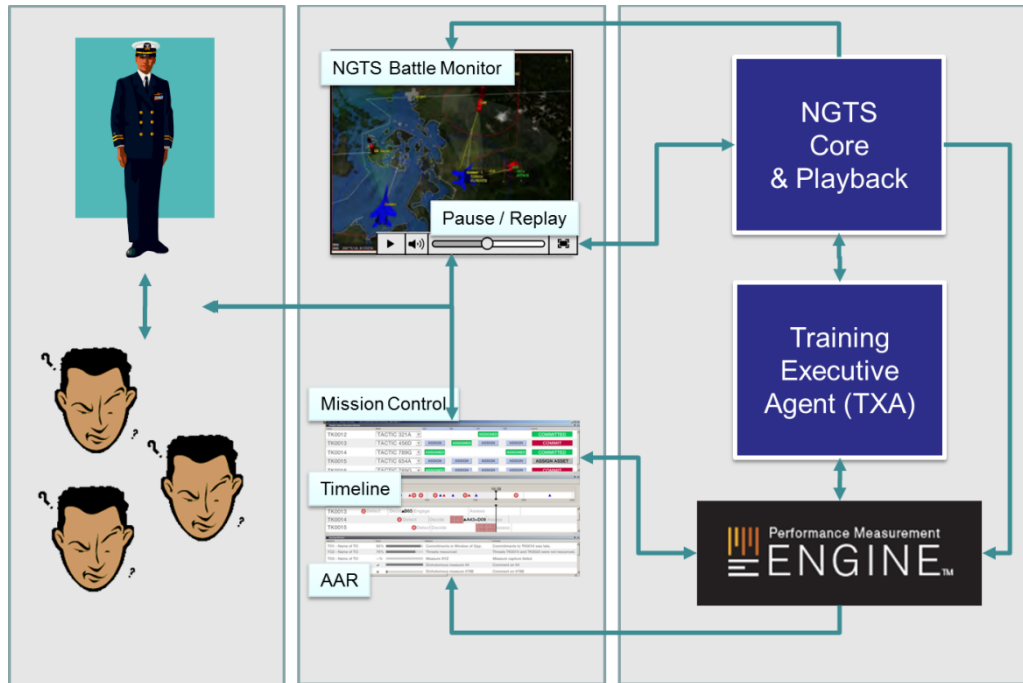


Figure 1. The architecture for the cross-platform decision trainer engages operators in dialogue concerning a tactical picture and tactical actions. Measurement and scenario control technologies drive the simulation.

Instructional Strategy

Training simulators are typically designed to fulfill requirements concerning the fidelity of platforms, weapons, sensors, and the environment. While the overall purpose of simulators is to support instruction, it is rare for a training simulation to be designed to support a highly specific instructional strategy. The unusual training objectives of this program drove us in this productive direction. There were three such objectives. First, the training must build awareness of technical and tactical capabilities across air and sea platforms. Second, it must build awareness of the practical constraints on those capabilities. These constraints are often subtle, and typically learned by direct experience of platform operators. They include the time cost of executing specific tactics, the perceived risk of engagements, and the opportunity cost (“If we pursue threat X, we cannot return to the fight for Y minutes to handle threat Z.”; “If we expend limited weapons on X, we will be vulnerable to threat Z later.”). We believe that real-time discussion between platforms about tactical problems will transfer this knowledge between platform operators. Third, the training must build trust between platform leaders to promote coordination.

Dialogue and practice are the central elements of the instructional strategy that will be used with this system and drove its design. The system enables dialogue by situating the trainees -- representatives from each platform -- together with the instructions to: (1) collaborate over the decisions that arise during scenario execution, and (2) debate those decisions during After Action Review (AAR). The system enables practice in decision making by presenting an interface that supports only that task. The UI enables trainees to gather essential tactical information (e.g., the identity and kinematics of a track), and to issue orders to assets. Automation translates those orders into tactical maneuvers that are displayed on a view of the battlespace, and this provides an active demonstration of decision outcomes (Rosen, Salas, Pavlas, Jensen, & Lampton, 2010).

In practice, training plays out as follows: As a session begins, representatives from each platform (air and surface) sit side-by-side before a single keyboard and dual displays, one depicting the battlespace, and the other presenting a dynamic menu of assets, tactics, and threats. The instructor describes the cross-platform capabilities and tactics about which they will make decisions, briefs them on the mission at hand, and tells them to talk through all decisions before issuing commands on the “Mission Control” GUI (described below). One trainee is assigned to

issue orders on the GUI. The instructor starts the simulation. As the trainees spot threats, they raise tactical options and argue their merits and costs. One trainee then issues the consensus commands and the simulation continues as own forces execute the commands. New threats periodically arise to trigger further decision making. At the scenario's end, the instructor presents additional displays that document the time course of commands and events, and enable replay. In addition these displays summarize trainee performance with measures and guidance concerning decision successes, failings, and tradeoffs between the tactical options. The instructor uses those measures and guidance to spark discussion.

User Interface

Because this system trains tactical decision making, not tactical execution, the user interfaces provide only the tactical picture that is the input to decisions, plus a simple interface for building, monitoring, and managing commands. The students do not directly control the assets that execute their commands, thus they are not presented with an interface for executing tactics.

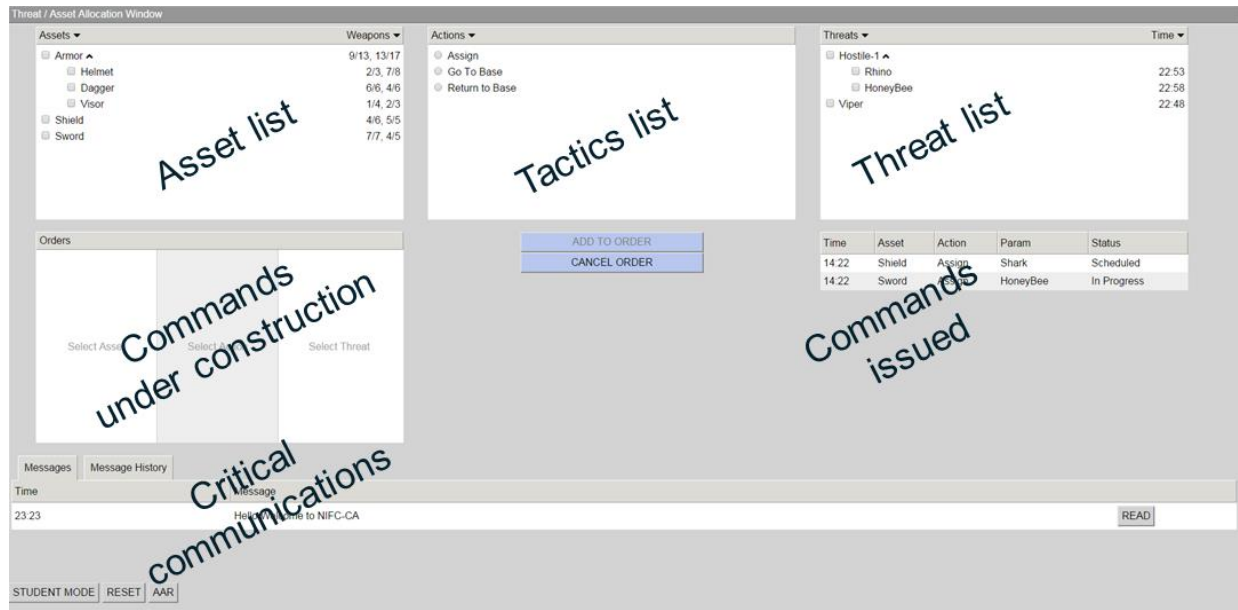


Figure 2. The Mission Control GUI enables trainees to construct, monitor, and cancel commands.

The Mission Control GUI enables the user to build an order by selecting specific assets, tactical actions, and threats. Trainees specify these elements of a command on the top of the simple display (see Figure 2). The system aggregates the current selections into a box of commands under construction (lower left). The student then issues the command with a button click that simultaneously transfers the command to a list of issued commands that are in process (lower right). The instructor and trainees can use that list to monitor the current state of tasking, and they can cancel commands on that list as new threats emerge. (For example, the trainees may cancel a command to approach and visually identify a track in favor of executing a new command to destroy a confirmed threat, or retreating to escape it.) At the bottom of the display is a simple message report that conveys critical information (cast as communications) such as changes to the Rules of Engagement (ROE).

The Mission Control display scales well to complex scenarios. First, assets and threats are organized into packages that are displayed using hierarchical menus (e.g., asset package X contains assets X1, X2, ... Xn). Second, the tactical actions available at any one moment are automatically trimmed down to those that are feasible. By design, that list typically contains tactics that are attractive but unwise, to spur discussion and test knowledge. The Mission Control GUI is implemented as a web interface, so it can be distributed via standard browsers.

Next Generation Threat System

The foundation of this training system is the Next Generation Threat System (NGTS), a synthetic environment generator used to support training, testing, research, development and analysis. NGTS models threat and friendly aircraft, ground and surface platforms and their corresponding weapons and subsystems.

NGTS consists of three main components as shown in Figure 3. The Database contains parametric data of platforms, weapons, and subsystems. The Simulation Engine models platforms, weapons, and subsystems. The user sees the product of these interacting components on the Battle Monitor. It displays entities in the synthetic battlespace and their parameters (e.g., speed). Users can adjust the 3D view of the battlespace, visualize radar coverage, obtain platform parameters, and take other informational actions using the Battle Monitor. (NGTS also provides maneuver and system controls for many platforms, but these are not accessible to the users of this training.)

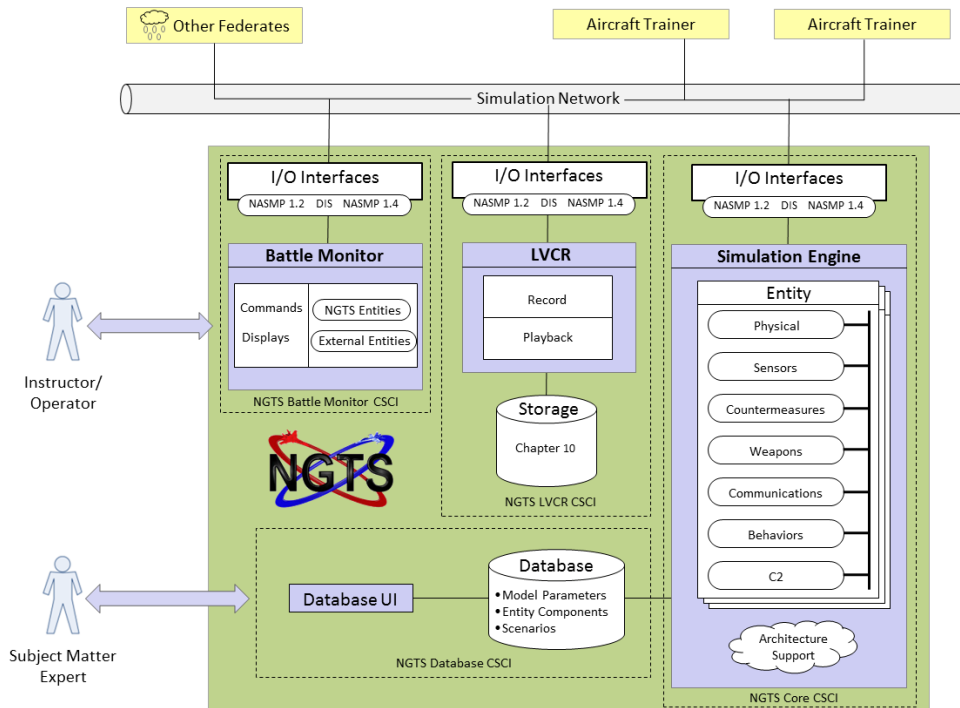


Figure 3: The NGTS architecture.

NGTS provides a graphical behavior editor with which the authors of NGTS training and test missions can define the tactical behaviors of friendly entities and near peer threats. Offensive and defensive doctrine and tactics defined in this editor execute dynamically at runtime. Those tactical behaviors can be defined to represent expert or inexperienced aircrew skill and awareness of opposition capabilities. Further, the behaviors interact with entity subsystems (radar warning receivers and dynamic weapons selections, etc.) based on the tactical environmental changes. In our cross-platform training system, behaviors are defined using this editor, and then parameterized and managed during execution by a Training Executive Agent (TXA) (see Figure 1, and the description below), to fulfill the commands issued by trainees.

Training Executive Agent

The TXA middleware translates and composes trainees' commands into NGTS behaviors that fit the current state of the battlespace and supported behaviors. The mission visualization system described here presents an extreme test of this capability, because TXA must control multiple platforms in complex scenarios with no intervention from a human operator. The TXA is designed to aid the instructors who deliver training by adapting scenarios "on the fly",

thus reducing operator workload and presenting a more realistic and complex situated training (Wray, Bachelor, Jones, & Newton, 2015).

Complex scenarios often require entwined (or even conflicting) constraints to be satisfied by the behavior of semi-autonomous forces within the simulation. For example, in the air domain, even a simple request to engage targets or identify a bogey may have wildly different meanings depending on previous relevant task orders or ROE. Developing entity-level behaviors to handle each case individually is tedious and combinatorially prohibitive. Requirements for training events or exercises may interact with doctrinal behavior requirements, further increasing the combinatorial requirements for fully-adaptive behaviors (Wray, Priest, et al, 2015).

As an example, consider a trainee decision that requires the timely execution of multiple steps. Some of the trainee commands require certain stipulations to be satisfied by other in-progress commands. These are placed in a monitoring state; they proceed only once execution conditions have been satisfied. For example, a target may need to reach a designated minimum distance before an asset can be fired on it. These details are not important to trainees in this training domain because the focus is on helping them make a decision and see it play out, rather than the low-level execution of specific actions in the simulation. The TXA's monitoring/action mechanism sequences and operationalizes all the "buttonology," allowing trainees to ignore platform minutiae and focus on high-level decision-making.

Consider another example. A trainee may issue multiple commands utilizing the same blue platforms. TXA, using behavior coordination algorithms, detects when trainee commands can be proceed in a merged, but equivalent, form. However, when trainee commands are immiscible, commands are sequentially executed. The trainee's first command is completed before allowing subsequent commands to proceed. An example of both cases can be seen in air-to-air targeting: suppose a student issues blue actions against red targets T1 and, later, decides to also engage T2. Blue air may be able to prosecute both targets at once if they are geographically close. In this situation, the TXA directs the behavior to attack once, engaging target T1 and amending for T2 as appropriate. If T2 is far away, or if blue air is ending its engagement against T1 as the student issues the command, the TXA ensures that the engagement against T1 is consummated before engaging T2.

In sum, the TXA allows the cross-platform trainer to automatically meld disparate actions into a single composite picture, even when the actions are not in harmony, and regardless of the composability of underlying platform behaviors.

Measurement & Assessment System

The training system is designed not just to enable practice in tactical decision making, but to measure tactical decision skill. Such measurement generates evidence with which instructors can drive home training points and spark discussion. It ensures that instructors can assess trainees, and that institutions can assess training (Freeman et al, 2009). Finally, automated measurement reduces the load on instructors and observers; only one instructor and no observer/controllers are needed to measure and assess performance with this system.

The measurement system captures orders and simulation data in real time. It translates them from button presses and object interactions into the Human Performance Markup Language (Stacy, Ayers, Freeman, & Haimson, 2006). HPML is an open source, XML schema-based language designed to formally express, measure, and assess key aspects of human performance from data captured from simulations, observer reports (on tablets), and neuro-physiological measurement devices. HPML specifies the data, metrics, and computations required to generate measurements and assessments. Those computations can be executed by any technology that processes HPML. In this system, that technology is the Performance Measurement Engine (PME).

The PME performs several functions within this cross-platform decision trainer. First, PME communicates measures that represent trainee commands to TXA (described above), which dynamically configures the simulation to execute those commands. Second, PME computes measures from NGTS simulation data. These measures on training objectives are abstract relative to the simulation data. For example, a measure of "battlespace management" aggregates, across all threats, the latency between the emergence of a threat and the command that responds to it.

The aggregated measure and the instances that comprise it (not shown here due to the sensitivity of the data) are all available for use in AAR, as we discuss below. Third, PME computes scores and delivers feedback to the trainees and instructor concerning the tactics and assets that trainees select on the Mission Control GUI, shown at the bottom of Figure 2 once the scenario is complete. It does so by drawing from a matrix, composed by domain experts, that defines each potential command combination of a threat package, tactic, and asset package; a score on the quality of each command; and guidance concerning the strengths, weaknesses, and tradeoffs of that command.

After Action Review

The After Action Review (AAR) interface is designed to enable students to conveniently inspect both the history of scenario play, and system's automatic assessment of that play against training objectives. The AAR is also designed to help instructors spur discussion about decisions and their costs.

Two components comprise the AAR. A timeline presents the history of the scenario in compact format and an expanded format that shows additional detail. The compact view (below the video controls in Figure 4) denotes threat detections, commands (commits), fires, and kills on a single band. Roll-over boxes provide detail. Counters indicate when multiple events occurred simultaneously. The expanded view presents the same information by threat package (one per row), as well as the terminal distances between the threat and a vital asset (such as an aircraft carrier). (The distances illustrated here are not tactically sensitive).

Replay controls (above the timeline) enable the instructor or trainees to start, play (at several speeds), and stop a recording of the tactical picture from any time selected with the black time bar.

The assessment interface (not shown because of classification levels) presents training objectives, such as managing battlespace, and managing sensors. For each training objective, the interface defines a measure (e.g., the number of threats resourced, the minimum distance of threats to the valued asset), and lists a score on that measure aggregated over all instances. Users can drill down from the aggregate score to inspect the score on each, individual threat or event. This interface also presents comments that help instructors to spur discussion typically concerning tradeoffs inherent in a given tactic, opportunity costs, and specific failures on training objectives.



Figure 4: The playback control (top), compact timeline (middle), and expanded threat timeline (bottom).

USER FEEDBACK

The first phase of this effort, completed in 2015, produced a demonstration of this cross-platform mission visualization tool for a representative training use case. Potential users provided anecdotal feedback. That feedback was positive and supported the development of further capabilities. That feedback indicated that the system could reduce instructor and operator workload; increase basic cross-platform knowledge, coordination and communication

skills, and trust across platforms; and fill a Fleet training gap with a low cost, flexible capability to instruct IWC coordination, make tactical decisions, visualize those decisions as they play out, and debrief across platforms. The second phase, completed in summer of 2016, produced a standalone instructional capability for a staff level school house. A third phase is planned for FY17 and will provide transfer of training and effectiveness data to verify user feedback and expected learning gains using the mission visualization tool. Future research will deliver objective, empirical evidence of training effects.

CONCLUSION

The cross-platform mission visualization tool is a useful and necessary product for closing the Fleet training gap and improving operational readiness along multiple fronts. The tool has several valuable attributes. First, it provides practical benefits at low cost, because it leverages existing ONR and Navy components: NGTS, TXA, and PME. Second, the tool supports the Navy paradigm of building skills using a crawl, walk, run curriculum (cf. Merrill, 2002). It provides an initial crawl capability for developing cross-platform knowledge and decision skills. More complex LVC training systems can advance the training pace to walk and run. However, this tool is not sufficient to solve the challenge of cross-platform, cross-domain IWC training. The Navy is also developing an integrated LVC solution (or a solution that combines a subset of the three). The current effort can feed into that development by providing both 1) a complete, relatively low fidelity, simple solution to initialize IWC decision making and coordination skills; 2) specific training content and components for mission simulation, executive control of constructive entities, measurement, and AAR; and (3) an instructional strategy that leverages the science of learning for training teams and multi-teams in decision making and coordination. This strategy intertwines dialogue, practice, active demonstration (i.e., presentation of automated scenario play), and cross-platform debriefs on measured performance against training objectives. The technology and instructional strategy developed here should help the Fleet to meet training needs efficiently, by ensuring early gains in knowledge and skill that previously accrued only during late, large, live, and costly exercises.

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