# Learning from the First Victories of the 21st Century: Federating Simulations for Reconstruction and Exploration

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**ABSTRACT**

In October 2001, the United States response to terrorism included insertion of Special Operations Forces (SOF) teams into northern Afghanistan to operate with indigenous opposition forces as part of Operation Enduring Freedom. Initial success came with the defeat of Taliban forces controlling Mazar-E Sharif, the key hub in the lines of communication for all northern Afghanistan territories. Northern Alliance horse-mounted cavalry, allied with small teams of SOF, overpowered and routed defending Taliban infantry and armor forces. Victory here depended on a unique marriage of 18th century close combat tactics with 21st century communications, synchronization and precision munitions. Air Force, Marine Corps and Navy strike aircraft using GPS- and laser-guided ordnance, provided critical indirect fires under the direction of on-ground SOF who synchronized cavalry charges to secure objectives. These operations hold many lessons for the transforming United States military that can be presented and studied in simulation using combinations of immersive and constructive systems. DARPA is developing a simulation federation to capture these operations, both as a reconstruction of fact and as a laboratory for exploring possible alternatives. This paper describes the architectural design and associated implementation of a federation of simulations to represent important aspects of the Enduring Freedom operations including weather, information operations, communications, and the unprecedented mixture of forces and capabilities. The Enduring Freedom reconstruction effort highlights an approach to overcoming several technical challenges including the mixture of simulation free play ("what-if" excursions) with historical presentation of fact. Finally, we exemplify potential uses of the architecture and implementation to stimulate real-time command and control environments.

## ABOUT THE AUTHORS

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## INTRODUCTION

The United States' military forces are transforming. Former emphasis on heavy forces, designed to survive and win on the battlefields that appeared the most threatening during the Cold War period, has been replaced by a focus on joint and combined operations using forces that are far more flexible and easily deployed. Some have argued that this type of military will not be capable of success in conflicts that seem likely to come. While this debate will continue into the future, the operations that occurred in Afghanistan in late 2001 provide a clear example of light force capabilities, even when outnumbered and facing a defensive force armed with significant armor and artillery assets.

In October 2001, the United States' response to terrorism included insertion of Special Operations Forces (SOF) teams into northern Afghanistan as part of Operation Enduring Freedom. The small SOF detachments were linked with indigenous opposition forces and were able to apply joint and combined operations to destroy Taliban strongholds in and around the communications hub of Mazar-E Sharif. Victory came rapidly, despite the many advantages that the Taliban defenders enjoyed.

The Taliban had occupied northern Afghanistan for several years and were able to prepare defenses without serious interruption throughout the area. Coalition forces were dispersed and did not enjoy centralized operating bases. The Taliban forces were motorized and proficient with use of their Soviet armor, artillery, and air defense systems (principally T-55 tanks, D-30 artillery, and ZSU-23-2 guns). The Coalition forces were a mix of horse-mounted cavalry and infantry whose main weapons were small arms and a few mortars. The Taliban were government supported and relatively well supplied. The Coalition forces "lived off of the land" and were in need of basic subsistence supplies, both for men and animals. The Taliban had superior numbers and included foreign "professional soldiers" many of whom were religious zealots. The Coalition forces were largely a force of local militia.

Taken at face value, these opponents could hardly engage in anything but a strictly one-sided contest; however, the SOF presence on the battlefield radically changed the balance of combat power. The battle did become a one-sided affair, but not as one might expect. The Taliban, despite their arsenal of Cold War era might, proved no match for Coalition forces.

The campaign to secure Mazar-E Sharif holds many lessons regarding the application of joint and combined operations with a light, highly mobile military force. The operations must be analyzed and their lessons promulgated, studied and learned. In mid 2002, the Defense Advanced Research Projects Agency (DARPA), at the request of the United States Central Command (CENTCOM), began to reconstruct the salient facts and operations of the Mazar campaign. The reconstruction is presented using a federation of simulations, a flexible approach that permits both high-level analysis and very detailed examination of the recorded fact. This paper describes the architecture of the Enduring Freedom Reconstruction federation, highlights the constructions used to overcome the many novel challenges encountered, and describes the architecture's potential to support simulation free-play, blending "what-if" analyses with presentation of historical fact. Potential uses for real-time command and control are also discussed.

## CHARACTERISTICS OF THE CAMPAIGN

The campaign for Mazar was unlike previous military actions that have been the focus of simulation reconstruction efforts. As an example, the successful reconstruction of the Battle for 73 Easting from Operation Desert Storm depicted a company-sized armor battle that lasted several hours, was fought over a relatively small land area, and was recorded on audiotape by one of the participating tank crews (Orlansky and Thorpe, 1992). In contrast, the campaign for Mazar included a series of coordinated air – ground actions that unfolded over a 25-day period. These actions were not recorded in faithful detail and were conducted by a diverse set of forces including USAF, USN and USMC air compo-

**Figure 1.** SOF and Afghanistan Militia, "Movement to Contact"

nents, Army SOF, and groups of Afghanistan militia fighting against Taliban regulars and irregulars. Key weapons and equipment were diverse and included armor, artillery, commercial vehicles, animals, aircraft carriers, and numerous air platforms from several countries. The theater of operations spanned an area extending from Diego Garcia in the southeast to Ramstein Air Base in the northwest. In short, the 73 Easting reconstruction focused on a single battle. The Enduring Freedom reconstruction must capture and present facts surrounding many engagements that were small parts of an overall, near-global campaign.

Key events occurred both on the ground and in the air. The ground events take place largely at the individual soldier level rather than the platform level. These forces utilized modes of transportation not normally available in current simulations (e.g., commercial pickup trucks, all-terrain vehicles, antiquated Soviet vehicles and horses). Many of the campaign participants were akin to $18^{th}$ century armies, traveling from battle to battle on horseback or on foot (see Figure 1). In stark technological contrast, attacks against Taliban defenders were coordinated joint and combined efforts that relied heavily on ground-aided precision attacks.

Important air events included delivery of multiple types of munitions. These included conventional ("dumb") bombs, JDAMS, laser-guided bombs, and occasionally 20 mm cannon delivered in strafing runs when American ground forces were in imminent danger. Altitude restrictions on aircraft operations were in force. Most of these munitions were delivered from altitudes at or above 20,000 feet (ASL). At critical junctures, however, fighter aircraft broke the "hard deck" and strafed ground targets. In-flight refueling was a major component of the air operation.

Weather proved to be an important factor throughout the campaign. Aircraft were often unable to operate because of very restricted visibility. In fact, adverse weather conditions caused the original insertion of the SOF detachment to be delayed several times. Even after the successful insertion, there were occasions when ground fog prevented the SOF from acquiring targets and thus from controlling air strikes.

These examples represent some of the key events derived from historical record that must be represented in the reconstruction. Each holds implications for the systems that will be applied; however, the events themselves are not the only source of constraints and requirements.

## RECONSTRUCTION REQUIREMENTS

The characteristics described above imply many requirements for the systems taking part in the reconstruction. The purpose of the reconstruction effort itself implies additional requirements. The goal is to create a resource that can be used to enable analysis, study, and learning based on a complete record of events surrounding the Mazar campaign.

Available records for the campaign are incomplete. Precise knowledge of every platform and soldier is simply not available, regardless of centrality to the operations. Thus, a significant amount of the record has to be completed by filling in with plausible action, given a specific operational context. Simulation plays a vital role here. As an example, historical record might indicate that a particular aircraft refueled at location $L_I$ and time $T_I$ and that it struck a ground target at $L_J$ and $T_J$. We can use simulation behavioral rules to identify plausible aircraft behaviors (and thus locations) between these two known points.

The reconstruction must not only represent the historical record, but it must also present that record in a manner that facilitates learning and analysis. Thus, the reconstruction must be available for "replay" at any time. It must consistently present the same events on each viewing, but allow examination from a variety of viewer-specified perspectives. Perspectives might differ based on the location of the viewer in time or space, or the level of force aggregation for entities in the replay. Both a "God's-eye" plan view of actions and an on-ground "out-the-window' view should be available. Again, simulations offer mechanisms to meet these requirements. In particular, virtual simulations that offer a variety of viewpoints for examining the replay of logged activity are very appropriate for presenting dynamic "out-the-window" portals into that activity. These can be presented in concert with plan-view displays of the same events.

Immersive simulations offer yet another key capability. As noted above, terrain played a major part in determining the character of the campaign. Immersive simulations that include geospecific terrain models can provide a digital terrain walk, long recognized as a vital component in the study of military operations.

Clearly, the simulation of historical fact surrounding the Mazar campaign has demanding requirements, implied by both historical fact and intended use. In summary, the reconstruction must be able to:

- work with a wide variety of platform types, both old and new, including aircraft, armor, ships, military vehicles, and commercial vehicles
- work with a variety of animate entities, both as groups and as individuals, including SOF, regular forces, militia, horses, and pack mules
- illustrate the cooperation between ground-based controllers and air platforms
- include a geospecific, high-fidelity, terrain model that supports terrain familiarization for the viewer and accurate mobility and line-of-sight calculations for operational analyses
- permit dynamic changes in the terrain model
- portray significant weather events and their operational impact
- permit fine control (fully scripted) of entity actions when the historical record of events is complete and must be followed exactly
- permit mixing simulated actions with scripted actions so that the simulation can fill-in gaps in the historical record with plausible events
- play back simulation events consistently, but from a variety of viewing perspectives

No single simulation can meet this diverse set of requirements. Accordingly, we have designed the reconstruction architecture as a federation of multiple systems. This approach simplifies the problem greatly. While the federation as a whole will address all aspects of the problem, each individual federate can concentrate in a single area.

## SELECTING FEDERATES

Federations of simulations rely on synergy to address complex problems. The cost is that of integrating the systems themselves, so that they can cooperate in a single exercise. While the payoff is high, integration costs can also be significant. Fortunately, federation of systems is no longer a novel approach to meeting diverse simulation requirements. When possible, reuse of proven federations offers the potential to greatly reduce integration costs while achieving the same power of synergy.

Joint Forces Command (JFCOM) has been using federations to fulfill their experimentation mission for several years (Ceranowicz et al, 2002). Their Millennium Challenge 2002 experiment series featured a very large federation that included several systems capable of addressing parts of the reconstruction problem. Some of the same systems also participated in the Defense Modeling and Simulation Office (DMSO) Environment Federation, a demonstration program focused on illustrating the importance of including realistic environmental representations in simulations (Lutz and Richbourg, 2001). These systems included:

- Joint Semi-Automated Forces or JSAF (Lockheed-Martin Information Systems): an entity-level, real-time computer generated force (CGF) combat simulation featuring entities that respond with lower-level behaviors given higher-level, real-time mission assignments as specified by human operators.

**Figure 2.** ModStealth View of Captured Taliban Defensive Position

- ModStealth (Lockheed-Martin Information Systems): a real-time, three dimensional visualization system often teamed with JSAF to provide "out-the-window" views from a variety of user-controlled perspectives.
- Dynamic Terrain Simulator or DTSim (Lockheed-Martin Information Systems): a system that functions with JSAF to make run-time changes in the simulation terrain. Typical use includes surface cratering and building destruction subsequent to bomb impact and the addition of engineer works, on command.
- Ocean, Atmosphere and Space Environmental Services or OASES (Northrop Grumman Information Technologies): a system that can ingest authoritative meteorological and oceanographic data, reformat and make real-time edits to that data, and serve the data to federation consumers.
- hlaResults (Virtual Technology Corporation): a federation data management utility that can both record and play back interactions in an HLA federation.

These systems have proven capable of interoperation during High-Level Architecture (HLA) federation exercises. In particular, the Environment Federation was founded on their combined capabilities. OASES served historically accurate, geospecific weather to the federation, impacting many JSAF operations. As an example, low-lying fog greatly impaired line of sight for entities on the battlefield. DTSim proved valuable in providing defensive fortifications and engineer works that demonstrably improved survivability of JSAF forces, including armor and dismounted soldiers. ModStealth effectively rendered visual representations of weather effects (e.g., blowing smoke, haze, and precipitation), terrain, and simulation entities, immersing viewers in the battlefield action. hlaResults recorded and played back all system interactions so that the experiments could be reviewed as desired.

Clearly, these five systems have demonstrated the ability to satisfy many of the reconstruction requirements as discussed above; however, some key requirements remain to be addressed. First, coordination between ground controllers and in-flight strike aircraft was essential to success in the campaign. JSAF does model individual soldiers and many types of aircraft, but does not specifically represent their coordinated efforts. TacAir-Soar (Soar Technology, Incorporated) is a capability built on JSAF base libraries that does model such interaction. TacAir-Soar also provides behaviors for most common air platforms and missions, including direct strike air-to-ground, reconnaissance, and refueling. All of these air missions occurred during the campaign and must be represented. TacAir-Soar fundamentally relies on JSAF for many runtime services, including any that are required for integration into a federation. As a result, integrating TacAir-Soar into a federation that already includes JSAF is trivial.

Figure 2 illustrates the interaction of these systems. This is a ModStealth out-the-window view of a Taliban defensive position, subsequent to an air-ground precision strike. The vehicles and defending infantry are JSAF entities. Remotely-located SOF provided laser designation of the targets, allowing SOAR aircraft to strike using laser-guided munitions. DTSim dynamically modified the terrain to depict bomb craters (and infantry trenches as well). Simulated Afghanistan militia forces occupied the hilltop as wind drove smoke from the burning vehicles across the battlefield.

Figure 2 also includes simulation entities generated by an additional system used to address a second area of new requirements. While JSAF does represent individual soldiers, the focus of the simulation has historically been placed on modeling crew-served weapon systems (e.g., tank crews). Neither JSAF nor ModStealth have capabilities to model horse-mounted cavalry, militia, or forces that fight using unconventional styles or transportation modes. Further, JSAF does not have a scripting capability that allows completely deterministic control over the simulation entities. The DI-Guy simulation and DI-Guy Scenario (Boston Dynamics) allow full scripting for highly articulated and visually realistic models of individual soldiers. Their technologies are readily extensible to model other characters as well, including horses. Further, they provide an application program interface that has been incorporated into both JSAF and ModStealth, making all DI-Guy characters and movements available for both simulation and visualization. Integrating these components into an HLA federation is a key remaining task. Figure 3 illustrates some of the BDI characters created to support the reconstruction program.

Finally, the replay of the campaign will require more viewpoints than can be provided by ModStealth out-the-window visualizations alone. As an example, examining the theater-wide air picture would be very difficult using out-the-window displays. Plan-view displays of individual or aggregated forces are more appropriate in this and many other instances. Further, the vast physical extent of Coalition air operations, spanning the area from Germany to Afghanistan to Diego Garcia, implies the need for multiple resolution terrain models. The JSAF editor does include a plan-view display that could model this expanse of terrain, but the display is inherently two-dimensional. As part

**Figure 3.** Boston Dynamics Models of SOF and Afghanistan Militia

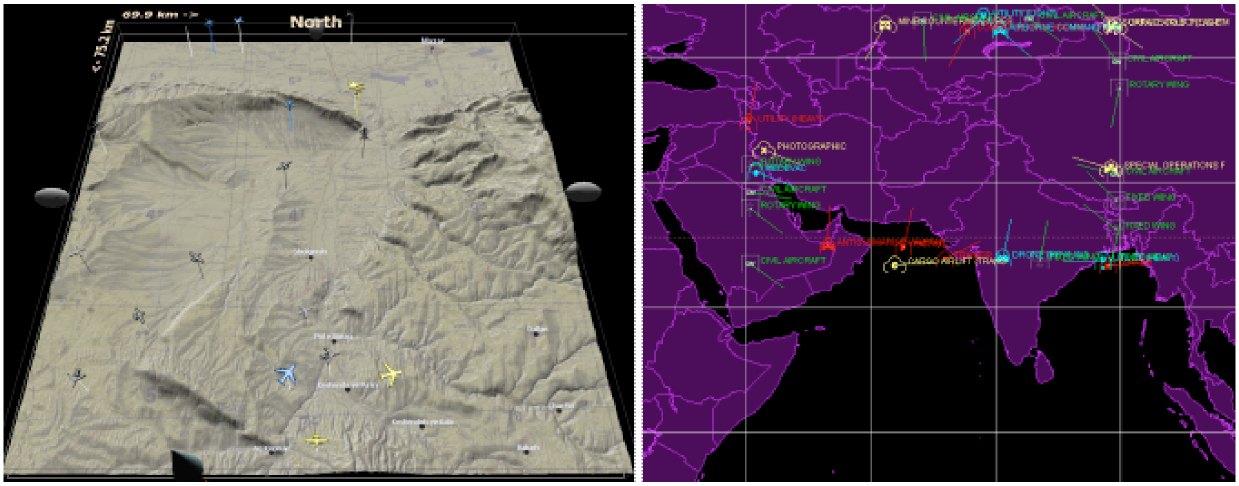


**Figure 4.** CommandSight and XIS Presentation of the Operational Picture (different scales)

of the Command Post of the Future (CPoF) program, DARPA is sponsoring development of other display systems that can represent time varying, three-dimension representations of extended battlefield areas. In particular, CommandSight (Oculus Info, Incorporated) provides all these desired display capabilities. While CommandSight displays are able to quickly convey large amounts of information, they could appear unfamiliar to viewers more accustomed to the status screens used in modern Combined Air Operations Centers (CAOC). Another DARPA-sponsored system, XIS (eXtensible Information System, Polexis, Incorporated) has been used with CommandSight in the past and provides a more conventional representation, using standard (MIL-STD-2525) symbols. Thus, both XIS and CommandSight are used to provide complementary operating pictures. These components are integrated into the federation using another DARPA-sponsored software product, Commander / Crossbow (Global InfoTek, Incorporated). Figure 4 illustrates typical CommandSight (left side) and XIS (right side) portrayals of (fictional) operational pictures.

## IMPROVING SOURCE DATA

Preceding sections note that available source data does not provide a complete account of the Mazar campaign in sufficient detail to fully script all simulation events. Event descriptions have been taken from interviews, planning data, operational situation briefings, air mission reports, some periodic AWACS capture of air activity, and a physical survey of the battlefields (conducted during a site visit about one year after the campaign). Many different approaches were used to resolve conflicts between data sources and to complete the record of events prior to final scripting. As an example, terrain analyses were useful in adding detail to high-level accounts of ground actions.

One of the Combat Controllers described his operations just before the capture of Mazar. "*When we climbed to the top of that hill, we could see the Taliban on the other side, regrouping for their final attempt to stop us. They were setting up fixed positions – bunkers with Y-shaped fighting trenches – on the northern side of the pass. It works against tanks, but its plain stupid in this terrain. We had unrestricted movement into the pass, which gave us the high ground*" (Pelton, 2002). Other interview information provides the number of Taliban bunkers, the force arrays, and the sequence of events; however, only approximate locations for all forces are available. Application of line-of-sight analyses, weapons constraints, and typical deployment configurations led to the specification of plausible locations for all participants. Figure 5 shows the resulting operational picture (left side) and the ModStealth view (right side) of the area from the SOF air controller location on the eastern hilltop.

Constructive simulation provided another method to specify necessary detail from the incomplete accounts that were available. Reconstruction of the exact routing and activities that formed the air picture required application of production rules. After manual analysis and fusion of the various source data, a set of known locations, and in some cases, times, were derived for each flight. Each flight was also characterized with other, less well-specified activities. As an example, strike aircraft would be described as "loitering near the battle area" before known strikes, "holding in refueling patterns" or "moving through air corridors" while in transit, and other activities that did not associate exact locations and times with the flight. If these locations

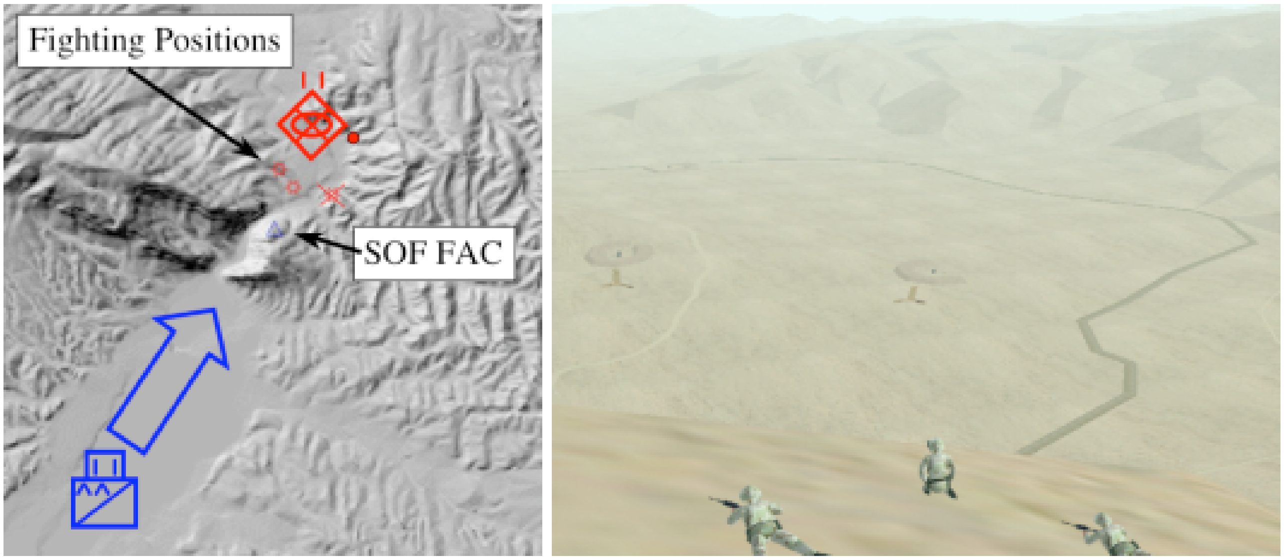


**Figure 5.** Daybreak at the Tiangi Pass as Morning Fog Lifts

were simply connected to specify a flight path, aircraft would often be shown as flying at speeds well below the minimum necessary to maintain lift. Constructive simulation algorithms, referencing established aircraft operational characteristics and specific locations and times, were used to determine the number of orbits an aircraft would make while loitering or refueling, apply routing through air corridors, group individual aircraft into flights, and so on. These processes provided sufficient detail to get the aircraft into the battle at the right time and place. They also served as scripts of behaviors for each aircraft. These scripts provided a starting point for using the federation to integrate the air and ground activities into a single, coherent picture.

## UTILIZING THE EVENT SCRIPTS

The campaign for Mazar-E Sharif began on 19 October 2001 and ended on 9 November 2001 when Taliban resistance in the area was crushed at the Tiangi Pass. There were many periods in this interval where ground forces remained relatively static and key activities were conducted as air operations. For these periods, the reconstruction did not require simulation beyond the constructive stage. Event scripts, created using expanded processes similar to the above, were sufficient to represent the key events. The problem here reduced to finding a method that could reproduce the scripted behaviors in JSAF, a non-deterministic simulation that does not, per se, accept input scripts at the requisite level of detail. JSAF was designed to have a "mind of its own", so that the JSAF entities could respond independently and plausibly in numerous operational situations. This is clearly a desirable trait when JSAF supports most simulation exercises; however, this characteristic can be counterproductive when the goal is to recreate an accurate version of historical fact.

One possible method of using JSAF in a historical reconstruction requires careful management. This approach would feature a human operator reading the scripts, determining initial force arrays, creating JSAF scenarios, and starting the simulation. When the simulation deviated from scripted events during the course of battle (due JSAF independent reasoning and behavior), the simulation would be stopped. The JSAF operator would inject a new factor, change a mission assignment, or make some other change in the scenario to alter the outcome. The process would be repeated until the simulation followed the desired script.

Clearly, this approach has significant drawbacks. The process is tedious, error prone, and may not produce a faithful reconstruction in all detail. A more innovative approach exploits the fact that no "simulation" to create behavior is required in fully scripted case, only a "playback" of known activities. This is exactly the JSAF behavior when it displays simulation entities "owned" by a different JSAF (or other systems) that participate in the same federation. Similarly, JSAF exhibits this "display only" behavior when hlaResults plays back a record of federation interactions (that had been recorded earlier). In this instance, hlaResults acts as the "owner" of the simulation entities.

Thus, transforming the scripts of behavior into a form that hlaResults can play to the federation is a conceptually elegant solution to this problem. It also turns out to be readily achievable. When hlaResults records

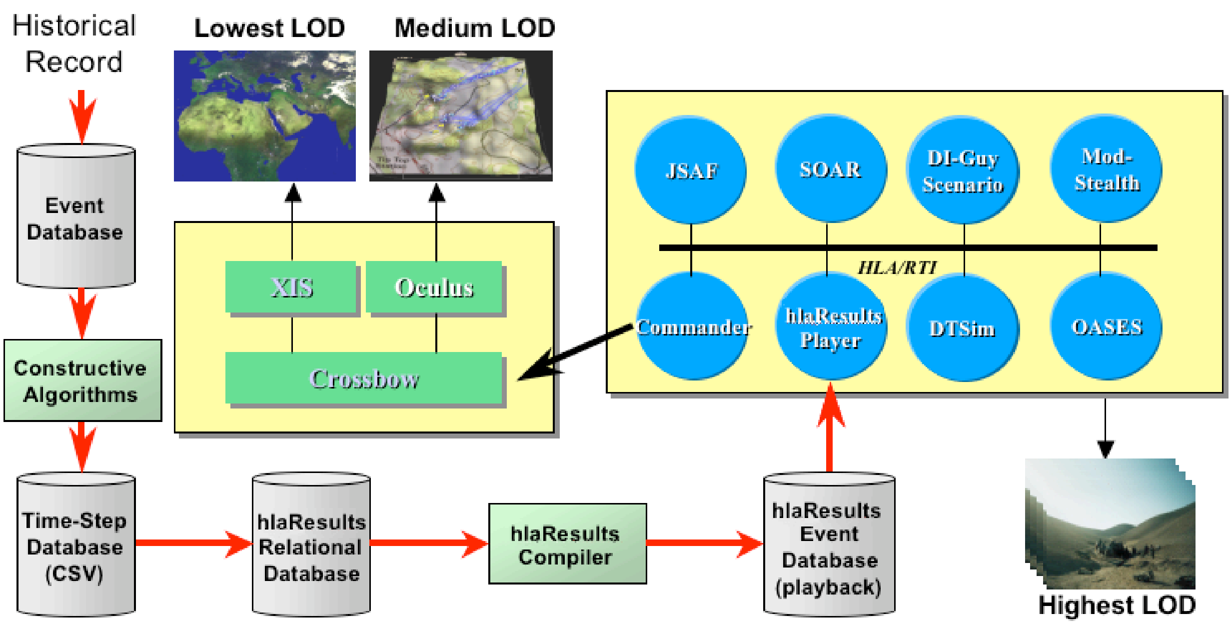


**Figure 6.** Systems Architecture for Replay of Scripted Events

federation interactions, it creates a relational database to store all information. (This database is compiled into a more efficient format prior to actual playback.) The simulation's Federation Object Model (FOM) determines the exact format of the relational database. Accordingly, we expanded our constructive algorithms to also compute all data specified in the FOM and to format the output scripts to permit ingest into hlaResults' relational database. Subsequent hlaResults playback to the federation produced the desired result. Figure 6 illustrates this partially manual, but highly-automated process as an architecture diagram.

## SCRIPTS AND LIVE SIMULATION

Two days in particular, 5 and 9 November 2001, proved to be pivotal to the success of the Mazar Campaign. By the 5th, Coalition forces had perfected and began to employ tightly coordinated air-ground tactics, allowing them to rapidly move into and through Taliban strongholds in the Darya Suf valley. By the 8th, they had advanced approximately 80 kilometers and were poised to secure victory at the Tiangi Pass the next day. These two days included several key ground-force events that have been reconstructed in virtual simulation. The live simulation of these specific events must be seamlessly interwoven with fully scripted events surrounding them in time and space. As an example, suppose a strike aircraft takes off from a distant base, refuels several time en-route, assumes a loitering orbit near Mazar, and then delivers laser-guided ordnance in coordination with on-ground controllers. After the strike, the aircraft departs the target area and refuels from tanker aircraft several times as it returns to home base. This flight would take several hours and cover a large expanse of the Theater. There is no need to represent the entire flight in real-time, virtual simulation. Assuming the strike is part of the 5 or 9 November activities, the portion of the flight immediately surrounding the strike event should be part of the virtual simulation to ensure that the air-ground coordination is fully modeled and represented seamlessly.

Integration of the scripted and live simulations in this example begins with examination of the scripted record for the strike aircraft. The first step is to identify two convenient handoff points, where control of the aircraft should pass between live and scripted simulation. The handoff points could be spatially determined by identifying the intersection (in two dimensional space) of the ingress and egress flight paths with a boundary of the strike area terrain model supporting the virtual simulation. The handoff points could also be chosen based on time, the first at some time prior to the strike event and the second following the strike as an example. Once the handoff points have been identified, the script of activities for the strike aircraft is segmented into three parts. The first part extends from aircraft launch up to the first handoff point. The third extends from the sec-

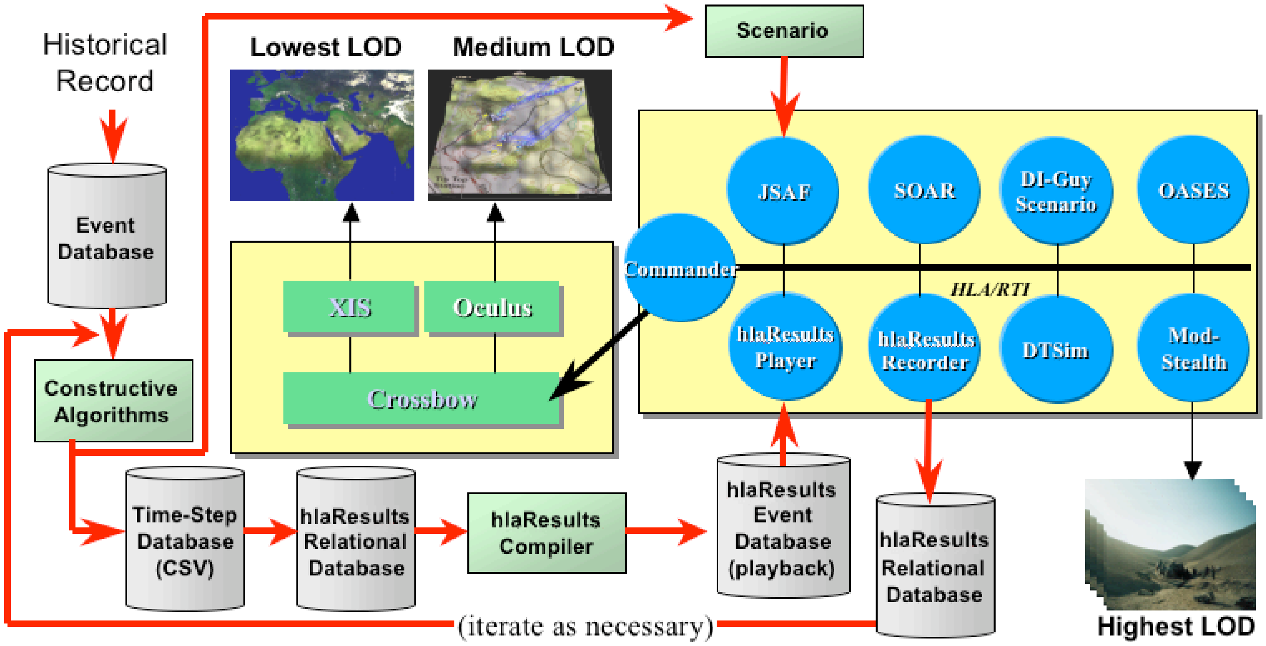


**Figure 7.** Systems Architecture for Mixing Scripted and (Live) Simulated Events

ond handoff point to aircraft recovery. The middle part of the script can be deleted and replaced with live simulation events. A JSAF entity corresponding to the same aircraft is instanced, in flight, in the virtual simulation, using the location, speed, altitude, and heading specified at the first handoff point. JSAF now "owns" the aircraft and the live simulation plays out the attack as ground controllers (also live simulation entities) use SOFLAMS to designate the target. After striking the target, the JSAF aircraft is commanded to exit the area, heading towards the location of the second handoff point. As the aircraft approaches that location, it is deleted from the live simulation.

The above discussion provides the conceptual model for integrating scripted and live simulation of a single entity. In practice, identification of the handoff points is completed as an off-line process and provides data for instancing and deleting multiple simulation entities. This process can be completed concurrently with application of the constructive algorithms that produce the original script. Adding an hlaResults recorder to the federation shown in Figure 6 allows the physical integration of all events. That is, an hlaResults player serves scripted activities to the federation. Scripted entities disappear given the appearance of corresponding JSAF entities. The JSAF entities disappear when their role is complete and in conjunction with the reappearance of corresponding entities in the script. The hlaResults recorder captures interactions from both the hlaResults player (scripted entities) and from JSAF (live simulation entities) to create a single, integrated record of all events. This process works transparently when "things go smoothly" at the second handoff point.

Note that, by design, transition difficulties at the first handoff will be rare. Problems could arise at the second handoff if JSAF does not complete its assigned task exactly as intended. In such cases, two approaches are available to smooth the transition, both of which are completed as off-line processes applied to the hlaResults recorded database. If the problems are minor, the database can simply be edited by hand. For more severe cases, the constructive algorithms applied to create the original script of events can be applied to mesh the JSAF aircraft with the scripted activities that occur after the second handoff. In either case, the repaired hlaResults record can be compiled and played back as a single, integrated record of events. Figure 7 illustrates the complete architecture.

## ADVANCING THE CAPABILITY

There are many advantages to mixing historical fact with live simulation. Here, we have focused on using simulations to provide plausible, doctrinally correct actions as data that fills in an incomplete record. Another way to view the interweaving of historical fact and live simulation is that it provides an accurate basis (history) for branching off into "what-if" analyses (live simulation). One value of such an approach is a decreased uncertainty in evaluating simulation results because as much of the result as possible has been derived from known performance.

There is no claim that the Enduring Freedom Reconstruction has achieved the ability to freely mix what-if analyses with historical fact. Simulation use was tightly constrained and controlled to ensure a specific result. Also, the process we have described above includes some undesirable manual components. At best, this is a "semi-automated what-if capability" when the real need is to have a fully-automated process. The hurdles to achieving automation here are really those that have already been discussed above. These include circumscribing the context of the live simulation event, effecting transfer of ownership, and meshing the simulation result with historical record. It seems that only one of these poses a challenge. The same constructive algorithms used in this effort can also serve to mesh results in other cases. Automating transfer of entity ownership also appears straightforward, given the capabilities described above. Automatically circumscribing the events that might change is a much more difficult problem. To illustrate this problem, consider two possible examples of altering events.

One split element of the SOF detachment was nearly overrun and lost during operations on the 5th. How would subsequent events have been different if the Taliban had succeeded here? As a second example, suppose that a B-52 missed its target on a first bombing attempt and required a second pass to destroy the target. If the target had actually been destroyed on the initial pass, how would subsequent events differ? In the first example, the impact would likely be widespread and might require transferring ownership of all entities to the simulation. The second example is far more benign and limited in sphere of influence. The problem is one of automating this judgment.

If the automation can be achieved, how will that be a benefit? There are clear implications for improving command and control. That is, the current operational situation could be "scripted" into the system and thus form an accurate basis for course of action analysis in real-time. Such a possibility is very achievable, given the architecture now in place. The CommandSight and XIS tools are designed to be assets that will be available in future command posts. As illustrated in Figure 7, communication to these systems is one-way, always coming from the federation. CommandSight and XIS are simply used as displays. Implementing two-way communications along this link will allow these command and control interfaces to send commands back into the federation, a much more powerful use of the participating systems and one that will be the subject of future effort.

## CONCLUSION

We believe that basing simulation exercises on historically accurate events offers several advantages. Chief among these is that the results derived from such exercises offer improved confidence. This reconstruction effort provides the existence proof that such use is possible; we can blend historical fact with simulated events. Further, the scope of this type of blended simulation can extend over large intervals in time and space and can encompass both constructive and virtual systems. While the program as completed used several manual processes to achieve this end, the architecture facilitates greater levels of automation, a necessary step to generalizing the capability. Such advances offer potential to influence future simulation efforts for training and analytical uses. The architecture also has potential applicability to planning (course of action analyses) and execution monitoring for real-time, command and control systems. Realizing this potential requires advances in the ability to manage long-standing problem areas, including context management. The existence of an "all-or-none" solution to the context management dilemma proves that a solution is possible. Feasibility of this solution and possibility of improvement to it remain to be explored.

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