DEVELOPING JOINT OPERATIONS ON URBAN SYNTHETIC TERRAIN (JOUST) TECHNOLOGY

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The Services currently have very limited opportunity to conduct live joint urban operations training and testing due to facility limitations and range safety and environmental concerns. Since the US military is increasingly likely to conduct operations on urban terrain, this deficiency must be addressed. Developing a distributed range capability for urban operations appears to provide the best solution to this problem. The Services have separate initiatives totaling over $200M beginning in FY04 to build separate Service-unique urban operations facilities. At this time, the plans for these facilities are not well integrated and no concept currently exists to integrate live, virtual, and constructive training assets in a way that provides meaningful training.

The Defense Modeling and Simulation Office (DMSO) is conducting research into integration of simulation technology and distributed range capability for urban operations. The overall objective of JOUST is to allow the joint warfighter to conduct training and testing for urban warfare using distributed live test and training capabilities as well as distributed simulation technology. JOUST will integrate Naval, Air Force, and Army assets in a mixture of live-fire ranges, military operations urban terrain facilities as well as, virtual and constructive simulations.

This paper focuses on the challenges of creating a cost affordable solution for distributed joint urban operations testing and training. The keystone issue here is to define a distributed system component architecture that will leverage DoD investments in both live-fire ranges and simulation technology. Our approach, to develop a prototype Joint Urban Operations Distributed Synthetic Range (DSR), is based upon working through various architecture alternatives and defining fundamental assumptions. We will also present our near term JOUST objectives along with a set of defined use cases for FY03 experimentation. The results of our efforts will be valuable in defining a reusable joint urban operations test and training environment.

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INTRODUCTION

This paper discusses the development of a Joint Urban Operations (JUO) training environment and the related research being conducted in the Joint Operation on Urban Synthetic Terrain (JOUST) project sponsored by the Defense Modeling and Simulation Office. Additional research participants include Joint Forces Command JUO Integrated Product Team, Office of Naval Research Virtual At Sea Trainer, and Dismounted Battlespace Battle Lab at Fort Benning. The initial research is on JUO training capabilities, however consideration of leveraging such capabilities for testing is important. Research on expanding the JOUST to JUO testing will be conducted later in the project. The need for a JUO training environment is based upon the following assertions:

1. The United States (US) continues to secure its national security interest throughout the world.
2. The US military provides a critical capability to support the national security policy, which requires more frequent military operations on urban terrain.
3. The world continues a steady urbanization, especially in developing nations which are the most likely candidates for US operations.
4. An integrated Joint and Service training environment that realistically represents the various roles and missions of JUO is required to better prepare Warfighters for execution of urban operations.

This paper provides supporting information for a JUO training environment, candidate training requirements, an emerging concept for addressing the training needs, and a technical approach to develop the training environment being addressed with the JOUST project. The next section discusses why JUO training capabilities is an emerging opportunity.

CASE FOR THE OPPORTUNITY

What constitutes an urban area? The Handbook of Joint Urban Operations defines an urban area as "any locale in which man-made construction and a large non combatant population are the dominant features, have

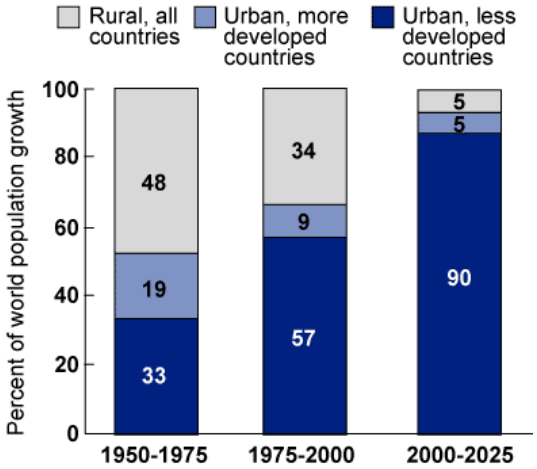

Figure 1. World population growth in urban and rural areas, less and more developed countries[1].

important operational and tactical implication,

[1] From "World Urbanization Prospects: The 1999 Revision (2000)", New York: United Nations, 2000.

and may have strategic significance" (Department of Defense, 2000).

The world population in urban areas is continuing to expand. "Virtually all the population growth expected at the world level during the next 30 years will be concentrated in urban areas" (M.P. Brockerhoff, 2000). The World Urbanization Prospect Report (2001) has estimated that world population in urban areas has risen nearly 47% between 1950 and 2000. Figure 1 illustrates that over the next 25 years urbanization in less developed countries will dominate world growth. By 2007, the United Nation projects that half of the world population will be living in urban areas. This trend in world population growth increases the potential that the US will be engaged in some type of urban operations in less developed countries. Figure 2[2] illustrates that the US has already been involved in several military operations involving urban areas since 1989. The urban environment presents many complex and challenging problems for the Warfighter. "Two key characteristics that make urban environments more complex than other environments are man-made construction and density of noncombatants" (Department of Defense, 2000).

The complexity of the environment is compounded because most operations involve more than just the US military, such as coalition, non-combatants and non-governmental organizations (NGO) (e.g., Red Cross). The US has begun to recognize the importance of urban operations as a critical part of our national security strategy and is reflected in key national security documents, defense panel recommendations, independent analyses, and joint and unilateral service doctrine. All are emphasizing that urban operations have held and will hold a central plan in US national security policy. This has lead to language in the Defense Planning Guidance: FY2000-2005, which states that: "To ensure the US military has the ability to effectively operate on the urban battlefield, the CINCs and Services must continue to expand their present efforts of study and understanding of the urban environment and must develop an integrated approach that optimizes key warfighting capabilities for future

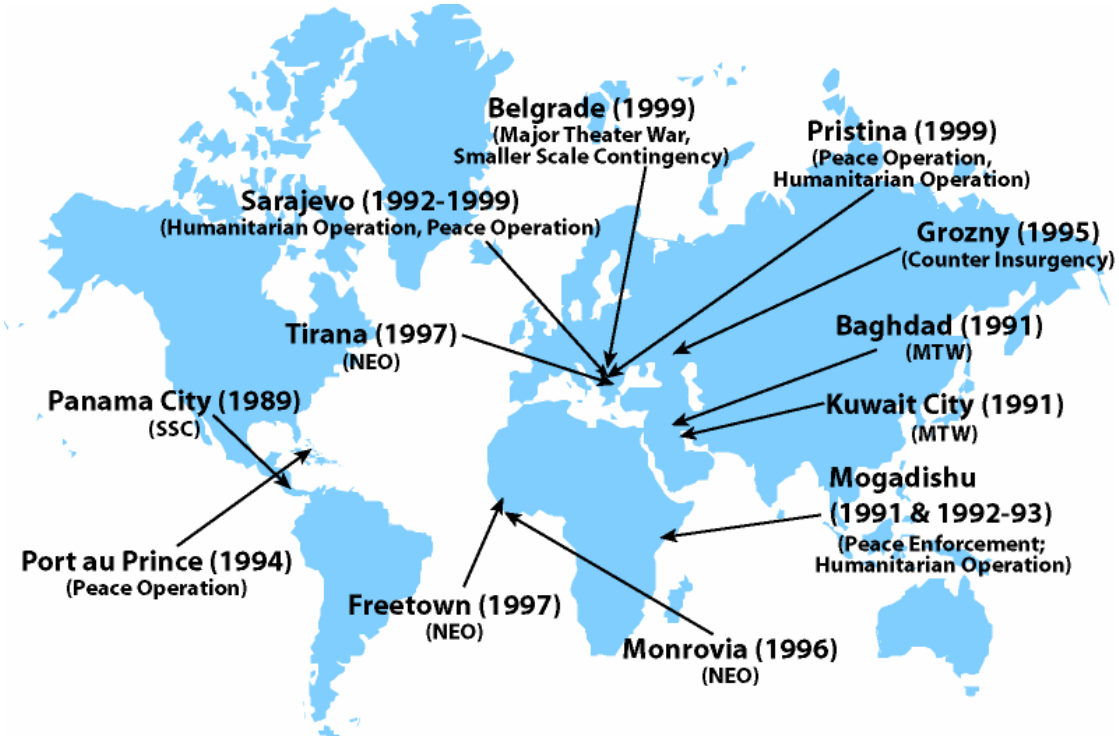

Figure 2. This map illustrates the various Joint Urban Operations the US military has participated in since 1989.

[2] From Handbook of Joint Urban Operations (p. I-3), 2000, Pentagon.

operations on urban terrain" (Department of Defense, 2000).

Congress has recently recognized the magnitude of this problem, as documented in the Department of Defense Appropriations Bill 2000, "...the Committee is persuaded that efforts in this area must be substantially expanded in order to improve the readiness of U.S. forces for possible conflicts centered in urban environments" (Department of Defense Appropriations Bill, 2000). Since it is likely that the US will engage in urban operations, the US military must train for missions against an asymmetric opponent on urban terrain. Future adversaries will try to avoid confronting the US on open terrain with traditional forces where US technology, doctrine, and training are overwhelmingly decisive. An example of this behavior was in Mogadishu where the US military suffered the loss of 18 servicemen in a single operation. The military success achieved in the open terrain over Iraqi forces in Desert Storm did not translate onto the urban area mission in Mogadishu against an adversary employing simple, but effective asymmetric warfare strategies.

As the world becomes more urbanized, avoiding built-up areas is simply not possible. Future adversaries will exploit urban and complex terrain for sanctuary. To reduce its exposure and complicate U.S. targeting, the adversary will disperse and operate from areas of physical and moral sanctuary often located in complex, urban terrain, shielded by civilians and culturally significant structures. Humanitarian concerns will limit key attack options and impose an increased burden on Joint Force Commanders (JFC). Because urban operations offer a multitude of challenges that may vary between humanitarian and combat, it is essential that urban operations be undertaken as a joint effort among the Services, Coalition, and other essential organizations and that the Warfighter be trained to be agile as well as identify and adapt to changing conditions. The information previously stated supports the need for a Joint training capability.

The objective of the JOUST research is to define how best to provide this capability. We need to understand potential training needs in order to define JOUST requirements. The next section discusses those training needs.

JUO TRAINING CAPABILITIES

To determine JUO training needs, it is important to understand some basic concepts and terms. The Joint Training Manual divides training into three levels: joint training, joint interoperability, and service training. All three are very important, however the focus of JOUST is joint interoperability training that is described as "tactical forces work together to execute …under the direction of a Joint force commander" (Joint National Training Report, 2002). This will require the Joint Force Commander (JFC) to "train interactively from the task force level down to the lowest tactical level with these joint assets" (Handbook for JUO, 2000).

Joint training is defined as "military training based on joint doctrine or joint tactics, techniques, and procedures (TTP) to prepare joint forces and/or joint staffs to respond to strategic and operational requirements deemed necessary by combatant commanders to execute their assigned missions. Joint training involves forces of two or more Military Departments interacting with a combatant commander or subordinate joint force commander; involves joint forces and/or joint staffs; and is conducted using joint doctrine or joint tactics, techniques, and procedures (Joint Staff, 1999)".

What are the likely types of training capabilities for JUO? A JUO training capability will need to integrate operational with tactical level training. Based upon information in the JUO Handbook (Handbook for JUO, 2000), the operational level training of the Joint Task Force (JTF) may span several types of urban operations such as isolating, retaining, containing, denying, and reducing. Isolating requires the separation of hostile forces in an urban area from other forces; the Battle for Grozny is an example of isolation. Retaining is effort to keep an urban area from falling into hostile forces control. Containing requires the JTF to prevent hostile forces from leaving an urban area. Denying positions JTF forces outside the urban area to prevent hostile forces from entering the area. Reducing is the use of offensive forces to remove a hostile force from part or all of an urban area. At the operational level the Joint Force faces the challenges of planning, directing, coordinating, and controlling the

execution using the best mixes of available ground, air, and maritime capabilities to meet strategic objectives. At the tactical level, each Services' will plan and execute their mission using capabilities deployed in the area of responsbilitiy. The integration of information between the operational and tactical level is dynamic. This was evident in United Nation Operation Somalia II (UNOSOM II) as the mission transition from peace operations to a peace enforcement that constituted a change in command and control. A major observation from UNOSOM II was the need for the JTF to have a well integrated C2I capability for "rapid dissemination of information and intelligence to the forces engaged in the urban fight" (Handbook, 2000). In summary, the JUO training capability must integrate with the tactical level training to provide the JTF with the ability to plan, direct, coordinate, and control in a dynamically changing environment. At the tactical level, forces engaged in an urban operation will execute their assigned mission, but will need to rely upon other Joint team elements for support if and when the operation changes. The flow of C2I between the operational and tactical level is critical in the urban environment. Training in JUO will be a key factor for US military to be able to successfully operate in an urban environment. The training must represent the nature of the JUO, which requires the integration of both operational and tactical level training in a meaningful manner. The next section will discuss a research concept for a JUO training environment.

TECHNICAL APPROACH

The previous sections have established a foundation on the need for an integrated JUO training environment to support the US military. In the succeeding pages is a discussion of the research to develop a JUO training concept that integrates Live, Virtual, Constructive (L, V, C) simulations which provides value added training to Joint as well as Service Warfighters.

A proposed JOUST operational use case is shown in Figure 3 to help illustrate the needs of JUO training capabilities. This use case is intended only as a high level representation of the problem space. The purpose of this operational use case is to articulate the possible operational users and their interactions that would constitute requirements for a JUO training capability. The use case also demonstrates the complexity associated with both the problem space and developing a capability based training environment. The following table represents the numbered actions depicted in Figure 3.

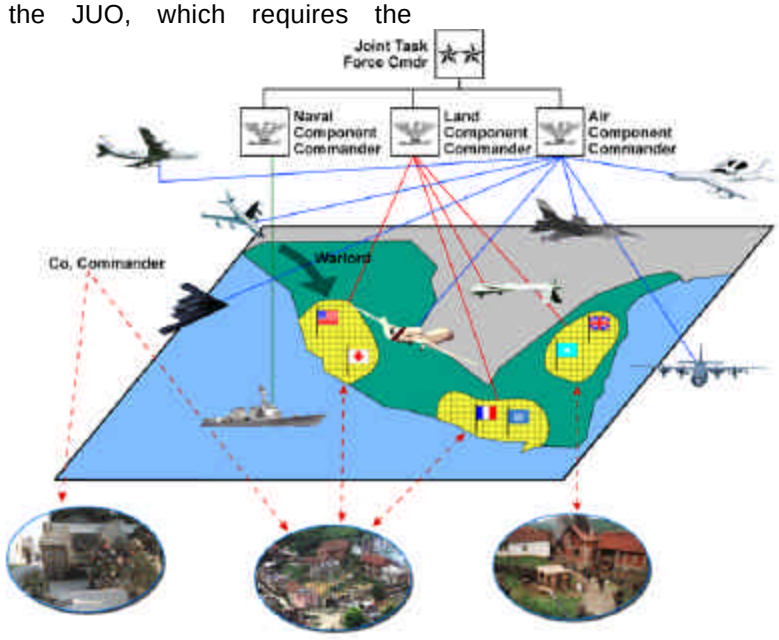

Figure 3. Proposed operational use case for JOUST to support defining functionality. The use case identified participants and possible interactions.

Table 1. A sequence of events for a potential use case involving operational users and their interactions in a JUO mission.

No.	Activity
1.	JTF plans a Joint Urban Operation deployment for a humanitarian mission into several urban areas.
2.	An unfriendly Warlord moves to the key food and medical supply urban area to disrupt and confiscate materials for profit.
3.	JTF Commander directs a Ranger company to take up position in urban area to protect NGOs and relief workers as well as confront and disarm Warlord fighters.
4.	Warlord knows the Ranger company is being deployed and decides to move some of his light armor and mortars outside of South East urban area.
5.	JTF Intel spots the movement via UAV and authorizes an F16 strike on the outskirts of the city to halt the armor movement.
6.	1st Platoon, Ranger Company, encounters stiff indirect fire from Warlord fighter at the North East section of the city.
7.	2nd Platoon, Ranger Company, locates the Warlord indirect fire (mortars) position and requests indirect fire support from JTF.
8.	The JTF directs a Naval destroyer patrolling the channel, to conduct a fire mission using 2nd Platoon as forward observer to adjust fire.

There are many technical challenges both at the tactical and operational level of training. The focus of our technical approach is to develop a concept that provides the ability to dynamically adjust the operational scenario via tactical command and control to incorporate randomness and therefore add complexity to the training event. A dynamic training environment creates the conditions in which the joint staff and warfighters are not able to anticipate or game the outcome. This capability to include realistic random events to dynamically affect the operation more closely represents the stressing factors in an urban operation for both the operational and tactical level. Referring back to the proposed operational use case, Figure 3, the joint staff must be ready to deal with multiple changing situations that have spatial and temporal difference. These changing conditions at the operational level affect the events at the tactical level that require the JTF to rapidly re-plan and direct forces to changing situations and conditions in the urban operations. These dynamics are not simply one-way with the operational only affecting the tactical because actions at the tactical level flow stressing conditions up to the operational level with such events as a unit being engaged by indirect fire and needing other Joint team assistance. Effective JUO capability based training requires the coupling of both the operational and tactical levels.

The JOUST research has focused on the integration of L, V, and C to create this dynamic JUO training capability. There are other solutions, which we will briefly address.

A JUO constructive simulation environment is an attractive solution since it may have the lowest recurring cost. Additionally, the Department of Defense (DoD) has invested in programs such as Joint Conflict and Tactical Simulation (JCATS) and Joint Simulation System (JSIMS), however there are weaknesses in constructive simulation performance in urban operations. The Army's Materiel Systems Analysis Activity (AMSAA) made a recent assessment of current Army models and their ability to represent operations in an urban area" (S.T. Crino, 2001). Their assessment addressed six focus areas; indirect fires, tactical communications, mobility, direct fire, wide area surveillance, and search and target acquisition. In these six focus areas they assessed basic knowledge, algorithm, and data. The only focus area that achieved a green or good rating was indirect fire with only basic knowledge and algorithm assessment meeting that rating. The other five focus areas were either yellow or red. The Army has used this information to organize a Focus Area Collaborative Team to bring experts together to address these weaknesses. But are detailed algorithms and data needs assessed by AMSAA required to support joint urban operations training? Some will certainly argue that such details are not necessary for a constructive JUO simulation, however the tactical level effect of maneuvering, communicating, and sensing produce direct effects on the operational level.

Task Force Ranger provides an example of this relationship where effects of urban environment directly affect the operational level C2. The Ranger's tactical communication was not effective. They had the most advanced equipment available, but it required line of sight, which in the urban area of Mogadishu restricted their effectiveness (F.H. Akers Jr and G. B. Singleton, 2000). In that same environment, their adversaries simply used drums to communicate between themselves to maneuver forces to engage and harass the Rangers. Because of the communication problems at the tactical level, the JTF did not have a clear picture of quickly evolving situations and therefore was not able to dynamically adjust plans and direct forces to support the Rangers. Therefore, having detailed performance data in an urban area is important for a JUO training capability. A JUO training capability based only on constructive simulation is not an effective solution. Constructive simulations play an important role in our concept for a JUO training capability, but the integration to the virtual and live simulation is essential. The constructive simulation provides the operational level context or "common operational picture" needed by the JTF for urban operations. An example of the common picture can be taken from the operational use case in which the movement of Warlord fighters into two separate urban areas, which has operational and potentially strategic impact and requires a JTF response. Just as an all constructive JUO environment may not be practical, neither is an all virtual or all live. The latter two conditions would involve many Warfighters, large training space, be costly, and because of these factors occur rarely. The US Marine Corps created an innovative approach by using a US city, North Little Rock, to conduct urban operations training. This provides realism not found in typical training ranges and helps them to prove or disprove what they developed conceptually in the training ranges and worked out in a real environment. What this environment lacks for JUO is ability to integrate other Service capabilities needed for a joint operation, such as Naval fire support. Also the city based JUO training has time and size restrictions. Integrating a city within L, V, C JUO would provide an excellent opportunity, but challenging. Those challenges include instrumentation of the city operating area, data correlation of the city terrain with simulation, and networking of instrumentation in the city. Solutions to these challenges are available, but it must be cost affordable, flexible, and highly mobile. The JOUST research supports a system of systems architecture for a JUO training environment as the most suitable approach. A suggestion offered by the Joint Urban Training study was that "a distributed simulation linking live training with constructive simulations is desired to provide for JUO" (Department of Defense, 2001). Figure 4 is an illustrative example of how to construct a JUO training capability and Table 2 represents the numbered actions depicted in Figure 4. The integration of distributed simulations is not a new or innovative concept so what makes JOUST any different? Figure 4 could represent any System Architecture for a current training event. At the overview level, it

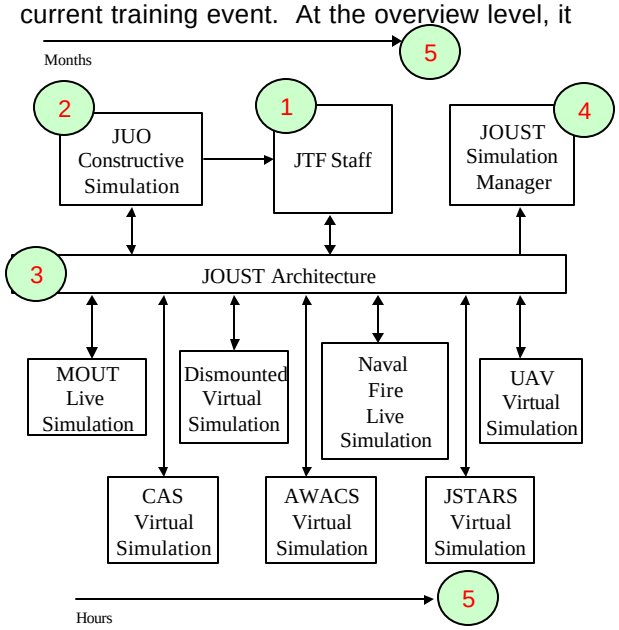

Figure 4. This is a top-level view of the possible training systems composing a JOUST training capability. The integration between the operational level and tactical level training simulation would be the JOUST Architecture.

would be difficult to distinguish this from any other simulation training event, however the complexity of the urban area, synchronization of live and simulation environments, and dynamics between operational and tactical operations. A closer investigation into the architecture is needed to understand what makes the JOUST concept an innovative approach for JUO training. The scenario thread included in Figure 3 is essential to

decompose the problem into a technical discussion of the complexity.

Table 2**.** An example sequence of top level interactions between operational and tactical level simulation to support a JOUST training capability.

No.	Activity
1.	JTF staff is provided relevant information on JUO.
2.	Constructive simulation provides JTF staff with integrated picture of JUO. It includes an opposing forces simulation.
3.	The JOUST network provides both voice and data communication between JTF staff training and Service training.
4.	The JOUST simulation manager supports set-up and monitoring of the exercise.
5.	The operational time lines for the JTF is scaled to months while the Service level training is scaled at hours. The Service level training would be conducted at various times within the JTF timeline.

At the operational level the constructive simulation is used to stimulate the staff to plan, direct, and control urban operations of the JTF. The staff is concerned with intelligence from various sources on Warlord forces, logistics of the peace keeping operations, coordination with NGO and coalition forces, and coordination with the tactical operations. The JTF forces have been deployed to conduct various missions. At the tactical level, these missions will be conducted in virtual and live simulation environments. Units receive their operational orders and plan their mission accordingly. As these units begin to execute their mission, this creates dynamic effects in the urban operations. As units deploy, the Warlord's own intelligence determines there is a potential opportunity to steal some relief supplies that can be sold to support his ongoing operations. The Warlord moves forces to steal these relief supplies. The movement of the Warlord forces is detected by the JTF staff, which needs to redirect available forces to intercede and prevent this from occurring. Here begins the first stages of the dynamic nature of the training environment. The JTF directs ground forces to deploy into another section of the city to deny Warlord forces access. The tactical forces must immediately replan their mission and deploy forces for a new mission. Effecting changes in the live environment is limited. Real-time modification or construction of a very large MOUT facility, on the order of ten square miles, would be required to present a change in location, but this is currently not available. Using a real city for JUO does offer a more practical solution with the ability to move forces to various locations. Even this solution has challenges such as mobility of instrumentation and data communications. In the near term, a solution must be developed which is practical to accomplish this perceived movement. The solution will not change the Warfighter's physical location, however in the JTF picture and other virtual simulation participants, the Warfighters will be shown moving to a new area. Therefore, the JOUST system must incorporate a dynamic coordinate translation application that transposes the location of the Warfighters and systems in a fixed Military Operation on Urban Terrain (MOUT) facility to a new area for other Joint team participants. This information will be propagated at both the tactical and operational level. The movement effect is simpler in a virtual environment and can be addressed by changing the terrain and visual databases. JOUST also provides the opportunity to integrate instrumented live fire ranges. Two potential opportunities are Naval fire support (NFS) and Close Air Support (CAS). The challenge is synchronization of the live fire range and the live training environment. For initial experiments NFS and CAS will have limited interactions among themselves or with the MOUT facility relegating their interaction to virtual and constructive simulations. An example from our operational use case is a soldier in a dismounted virtual environment identifying a Warlord constructing an indirect fire position. The Warlord position is outside the urban area and well protected. From the virtual environment the dismounted unit issues a spot report and requests a call for fire mission to JTF, which directs a Naval ship to provide fire support. The Naval ship is on a live fire range and will engage a virtual target, Figure 5.

A forward observer in the virtual environment transmits the target type and coordinates to the real Naval ship on range. The ship fires a

salvo at the target coordinates that have been translated to local coordinates within the range. The range instrumentation detects the impact point of the live fire rounds and calculates the coordinates of where those rounds would have impacted on the virtual terrain. The impact coordinates are transmitted near simultaneously on the JOUST network to the virtual environments. The target impact is seen by the solider in the virtual environment, which adjusts fires to the Naval ship. This interaction demonstrates the complexity of linking a live fire range with virtual environment. There are simulation data correlation and translation requirements as well as tactical voice and data requirements. Additionally each live range has their unique data message format. The US Army's Simulation Training & Instrumentation Command (STRICOM) is developing a common architecture for Military Operation on Urbanize Terrain/Restrictive Terrain (MOUT/RT) facilities that will be included in the research to develop a JOUST technical architecture. Table 3 represents the numbered actions depicted in Figure 5.

Table 3. A sequence of events for the Naval Gun Fire use case involving virtual and live fire simulations.

No.	Activities
1.	Soldier in virtual environment requests fire support to higher headquarters. Communication is packaged and transmitted.
2.	Naval ship on live fire range receives fire mission. It directs live range at virtual target coordinates. The range calculates impact coordinates.
3.	Near simultaneously the impact is displayed in the dismounted simulation. The soldier adjusts fires.
4.	UAV simulation also displays the impact and provides Battle Damage Assessment.

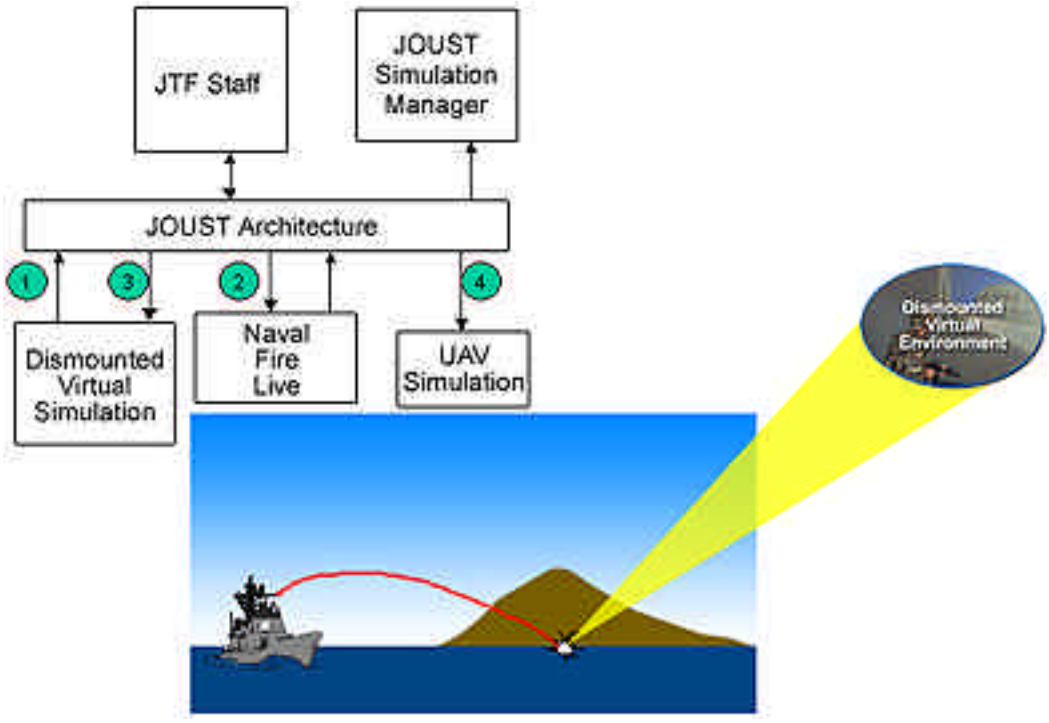

Figure 5. An example illustration of a virtual and live fire simulation integration. JOUST architecture provides the asynchronous and synchronous integration of data and voice communications.

These various different architectures to integrate for JUO training capabilities

Table 4. A sequence of events for integrating Live, Constructive and Virtual simulation through the JOUST architecture.

No.	Activities
1.	Position data and communication is provided to JOUST bridge.
2.	JOUST bridge translates and transforms position data to synchronize live environment with V, C simulation. Voice data is packaged for distribution on JOUST network.
3.	JOUST Simulation Manager passes control data to instrumented devices such as indirect fire pyro-techniques.
4.	Communications from other simulations is passed to MOUT facility.

creates a requirement on JOUST to be a System of Systems architecture with software framework that enables the handling of multiple message protocols to integrate the various simulation environments and tactical communications. The technical approach for JOUST is to integrate the operational and tactical level simulations. This is accomplished with an architecture that separates the integration from the simulation logic such that the integration logic is a component of the JOUST framework. This logic component is the JOUST bridge. Figure 6 is a top level description of capability that the JOUST architecture must provide to support JUO training. For the specific example in Figure 6 the MOUT/RT architecture provides a common interface to site-specific capabilities. In this example, the JOUST bridge provides the integration logic between the JOUST system and the MOUT simulation. By embedding the integration logic into the JOUST architecture we will enhance adaptability and reuse. Table 4 represents the numbered actions depicted in Figure 6.

Other ranges such as the Nellis Training Initiative, which provides close air support, or a Naval live fire training range for urban operations have their own architecture to integrate. To facilitate the integration of ranges and simulations, the JOUST architecture will consider using the High Level Architecture and/or Test & Training Enabling Architecture (TENA) middleware for the JOUST bridge component. Research is

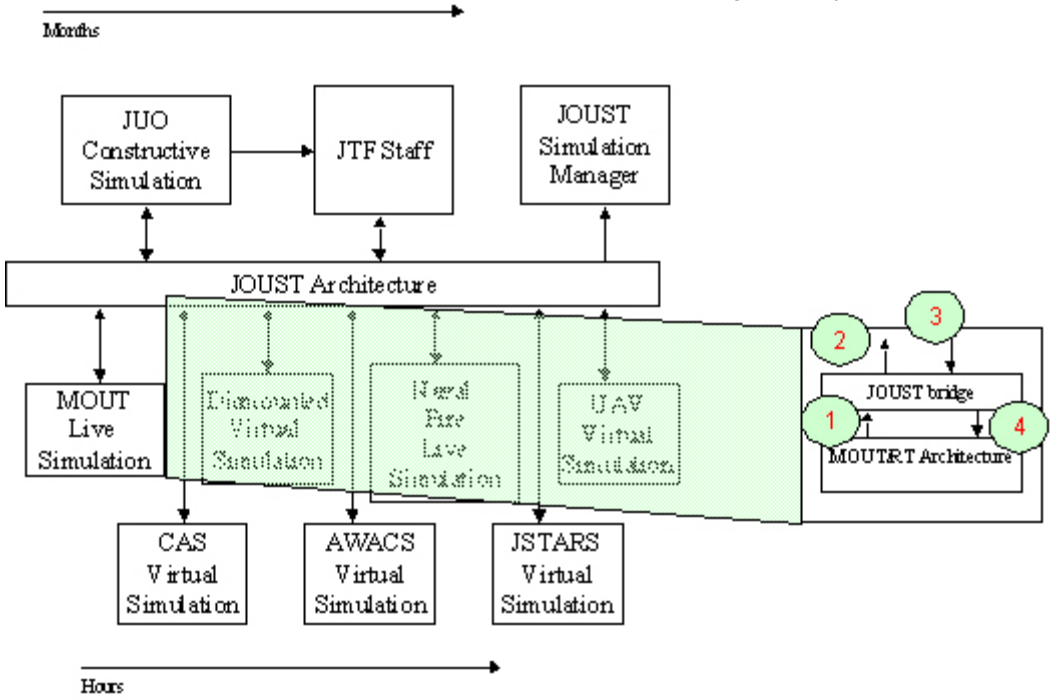

Figure 6. An example of a system of systems architecture for JOUST, which must integrate various live, virtual, and constructive simulation environments.

continuing into the specific use of these two architectures within JOUST. The services required from HLA and TENA middleware will be identified as the research progresses into the design of the component framework to support tools and system architecture integration for JUO training.

The technical approach and methodologies described in this paper are being implemented on JOUST to provide an architecture and integration strategy for a live, virtual, and constructive environment to support JUO training operations. The JOUST architecture will provide the capability to immerse the Warfighter into a realistic dynamically changing environment that will stress his skills in order to effectively train for operations against an asymmetric threat in an urban environment. This initial phase of the program will deliver an architecture design at the end of FY02. The architecture will be used to develop a prototype Joint Urban Operations Distributed Synthetic Range (DSR). Current plans are being developed to test JOUST through a set of experiments using L, V, and C simulation from the Joint and Service organizations.

SUMMARY

A need does exist for a comprehensive JUO training capability. Joint Urban Operations present many challenges to the US military. To become proficient in conducting operations in urban areas requires quality training. Effort is being invested by the Services in enhancing and developing their MOUT training capabilities, however this does not necessarily benefit Joint team training. The research being conducted by DMSO is to address the nature of a distributed training capability linking together live, virtual, and constructive simulations. The JOUST project has been created to conduct needed research to define an architecture that will support a Joint test and training capability for urban operations. To understand the needs for a JUO test and training capability an operational use case is defined that identifies the potential systems and interaction expected for a JOUST. Testing of the JOUST architecture will be accomplished by conducting a set of experiments during FY03. The results of DMSO efforts will be valuable in defining a reusable joint urban operations test and training environment.

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