# Holistan Revisited:

## *Development of a Demonstration Scenario for Future Military Coalition Operations*


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3rd March 2008

# Report Documentation Page

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|---|---|---|---|
| **Report Title:** | Holistan Revisited | | |
| **Report Subtitle** | Development of a Demonstration Scenario for Future Military Coalition Operations | | |
| **Project Title:** | ITA | | |
| **Number of Pages:** | 47 | **Version:** | 1.0 |
| **Date of Issue:** | 03/03/2008 | **Due Date:** | 14/03/2008 |
| **Performance Indicator:** | EZ~01~01~29 | **Number of References:** | 14 |
| **Reference Number:** | ITA/P12/HolistanScenario | | |
| **Report Availability:** | APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED | | |
| **Abstract Availability:** | APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED | | |
| **Authors:** | Paul Smart | | |
| **Keywords:** | Ontologies, Semantic Web, Coalition Operations, Scenario, Scenario Development, Military Coalitions, Technology Demonstration | | |

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**Abstract:**

As a fundamental research program, the International Technology Alliance (ITA) endeavours to research and develop solutions to some of the problems confronting US/UK military coalition forces. Fundamental research programs can, however, deliver scientific and technical outcomes whose immediate practical relevance and exploitation potential is sometimes not immediately obvious to members of the end-user community. To address this problem we have often found it useful to demonstrate capabilities using a combination of domain scenarios and technology demonstrators. The current report describes our efforts to develop a domain scenario and technology demonstrators within a specific component of the ITA initiative, namely Project 12 Task 1 (P12T1). P12T1 is concerned with the development and evaluation of solutions that support the large-scale integration of information from multiple sources within a distributed network environment. It also focuses on the development of knowledge accessibility solutions that support both the retrieval of task-relevant information and the monitoring of battlefield information. To provide practical demonstrations of these capabilities we have developed a pseudo-realistic domain scenario that features US and UK coalition forces jointly involved in humanitarian relief and conventional warfighting operations. The scenario provides the narrative backdrop for a number of technology demonstrations. These include the identification, integration, and retrieval of information relevant to the planning of humanitarian relief efforts; the alignment and integration of nation-specific data repositories for the purposes of improved coalition interoperability; the acoustic detection and classification of military vehicles using data fusion algorithms; and the detection of mission-critical information from battlefield event streams. All these technology demonstrations are described in the report and presented alongside the aforementioned domain scenario. The report also identifies and describes a number of collaborative linkages between P12T1 and other ITA projects. These linkages reflect the fundamental inter-dependency of research efforts within the ITA program, and they are an essential ingredient of our technology demonstration goals.

| **Classification of Report:** | **Classification of Abstract:** | **Classification of this Page:** |
|---|---|---|
| UNCLASSIFIED | UNCLASSIFIED | UNCLASSIFIED |

# Acknowledgements

The research that is the subject of this report was sponsored by the U.S. Army Research Laboratory and the U.K. Ministry of Defence and was accomplished under Agreement Number W911NF-06-3-0001. The views and conclusions contained in this document are those of the author(s) and should not be interpreted as representing the official policies, either expressed or implied, of the U.S. Army Research Laboratory, the U.S. Government, the U.K. Ministry of Defence or the U.K. Government. The U.S. and U.K. Governments are authorized to reproduce and distribute reprints for Government purposes notwithstanding any copyright notation hereon.

# Abstract

As a fundamental research program, the International Technology Alliance (ITA) endeavours to research and develop solutions to some of the problems confronting US/UK military coalition forces. Fundamental research programs can, however, deliver scientific and technical outcomes whose immediate practical relevance and exploitation potential is sometimes not immediately obvious to members of the end-user community. To address this problem we have often found it useful to demonstrate capabilities using a combination of domain scenarios and technology demonstrators. The current report describes our efforts to develop a domain scenario and technology demonstrators within a specific component of the ITA initiative, namely Project 12 Task 1 (P12T1). P12T1 is concerned with the development and evaluation of solutions that support the large-scale integration of information from multiple sources within a distributed network environment. It also focuses on the development of knowledge accessibility solutions that support both the retrieval of task-relevant information and the monitoring of battlefield information. To provide practical demonstrations of these capabilities we have developed a pseudo-realistic domain scenario that features US and UK coalition forces jointly involved in humanitarian relief and conventional warfighting operations. The scenario provides the narrative backdrop for a number of technology demonstrations. These include the identification, integration, and retrieval of information relevant to the planning of humanitarian relief efforts; the alignment and integration of nation-specific data repositories for the purposes of improved coalition interoperability; the acoustic detection and classification of military vehicles using data fusion algorithms; and the detection of mission-critical information from battlefield event streams. All these technology demonstrations are described in the report and presented alongside the aforementioned domain scenario. The report also identifies and describes a number of collaborative linkages between P12T1 and other ITA projects. These linkages reflect the fundamental inter-dependency of research efforts within the ITA program, and they are an essential ingredient of our technology demonstration goals.

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# 1 Introduction

The advent of the Semantic Web provides a number of opportunities for military agencies to exploit the potential of modern information and communication networks. One opportunity is, of course, the ability to search for task-relevant information in a way that obviates some of the restrictions associated with simple keyword-based searches (e.g. their insensitivity to hyponymic relationships). Other opportunities include the potential for large-scale information integration, improved inter-agent collaboration, dynamic service composition, enhanced situation awareness (see Smart et al., 2007) and so on. One context in which these opportunities are being explored (and indeed realized) lies in the area of coalition military operations. Coalition operations are characterized by a reliance on information and communication networks, and many of the information exploitation challenges faced by coalition forces parallels those encountered in the context of the WWW (the traditional stomping ground of the Semantic Web community). Indeed, to the extent that military agencies occasionally exploit the technology infrastructure or information contents of the conventional internet, the information exploitation challenges of the military may be considered co-extensive (at least in some cases) to those currently being tackled in the network and Web sciences.

The potential value of semantic technologies to a broad spectrum of coalition military operations is being investigated as part of the joint US/UK International Technology Alliance (ITA) initiative, a collaborative partnership of industry, academic and government stakeholders[1]. Our research within the ITA (particularly within Project 12, Task 1 - hereafter referred to as P12T1) aims to investigate the contribution of semantic technologies to a number of coalition-relevant capabilities. These include:

1. the role of semantic technologies in effecting complex forms of information aggregation and integration from semantically heterogeneous and physically disparate sources;
2. the role of semantic technologies in providing a representational substrate for the realization of advanced problem-solving capabilities, some of which may be distributed across multiple agencies in a network environment;
3. the role of semantic technologies in enabling rapid access to task-relevant information in a way that respects the kinds of semantic abstractions made over distributed information content; and
4. the role of semantic technologies in supporting information quality assessments.

These research activities are ongoing, and we are already beginning to see considerable progress in the areas of information integration (Smart & Shadbolt, 2007) and information retrieval (Russell et al., 2008). There is, however, a growing consensus that if we are to fully engage with the military stakeholder community then we will need to do more than simply push ahead with our research and technology development program. Academic publications and technical reports provide insight into the technical and scientific merit of a research project, but they seldom highlight the practical value of research outcomes in a way that is understandable to the end-user community. For this reason we aspire to provide practical demonstrations of P12T1 research outcomes in a pseudo-realistic military coalition scenario.

[1] http://www.usukita.org/

This report explores the opportunities for technology demonstration in respect of P12T1 research. It follows a review of P12T1 research goals and is based on a number of discussions with members of the ITA community, particularly with members of the Project 8, 9, 10, 11 and 12 teams. The primary aim of the report is to coordinate the efforts of the P12T1 team; however, the demonstration scenario and technology components described herein form part of a common Technical Demonstrator System (TDS) that brings together the research and technology outputs of all TA4 projects (as well as some TA3 tasks). As such, the contents of this report are broadly relevant to all those involved in the effort to build a common demonstrator by the conclusion of the ITA Biennial Program Plan (BPP) (i.e. May 2009).

The structure of this report is as follows. Section 2 provides an overview of the scenario, highlighting the operational context and key entities of interest. Sections 3 through 6 then present successive phases of the demonstration scenario. The scenario is broken up into 4 distinct phases as follows:

- **Phase I: Mission Planning:** features the collation, integration and analysis of plan-relevant information as part of the coalition planning process (see Section 3).
- **Phase II: Force Deployment:** features the analysis of sensor data as coalition forces are deployed to target areas (see Section 4).
- **Phase III: Situation Monitoring:** features the creation of situation monitors that can be used to monitor incoming information streams for operationally-significant information (see Section 5).
- **Phase IV: Combat Operations:** features the use of Python scripts to capture event streams from the Battlefield 2 (BF2) game environment. The event streams are serialized to RDF and the user is alerted to the presence of significant events (as defined by the aforementioned situation monitors) using filtered RSS feeds (see Section 6).

Within each phase, we highlight the opportunities for technology demonstration in respect of semantically-enabled capabilities. In Section 7 we discuss the project actions that need to be undertaken in order to realize these technology demonstration objectives. These actions from part of the 'Technology Demonstration' workpackage and the discussion here therefore extends the task decomposition associated with the P12T1 research agenda.

# 2 Demonstration Scenario

The demonstration scenario for P12 (and indeed for all ITA TA4 projects) centres on a Military Operations Other Than War (MOOTW) scenario featuring the use of US and UK coalition forces. This section provides an overview of the demonstration scenario, detailing the key features of the operational context and the Area of Interest (AoI).

## 2.1 Background Information

The scenario is set in a fictitious Middle-Eastern country called Holistan (Roberts et al., 2007). The country borders the land-locked country of Rugistan on the west, the Democratic Republic of Weighat to the east and the People's Republic of Sugaria in the far northeast. Holistan has been the focus of violent conflict in recent years, with religious fundamentalist groups mounting an insurgency (backed by the People's Republic of Sugaria) against Holistan government forces. In the face of continued unrest, and with the overthrow of the democratically-elected government looking imminent, US and UK forces are deployed to the country (under a UN mandate) to suppress the insurgency and stabilize the region. At the time of the scenario, coalition forces have been largely successful in their campaign. The majority of insurgent forces have been defeated; however, pockets of resistance remain in Mantristan, the northernmost province of Holistan.


*Figure 2-1: Holistan and neighbouring countries*

## 2.2 Event Timeline

On the 18th March 2008 at 15.10 hours a large earthquake devastates the region of northern Holistan, particularly the northern province of Mantristan. Isolated village communities in the mountains are hardest hit with large numbers of civilian causalities and major structural damage to settlement buildings. The region is declared a disaster area, and the international community calls on humanitarian agencies to coordinate a relief effort to resolve the crisis. Unfortunately, the recent conflict has resulted in the withdrawal of many members of the humanitarian community, and the agencies that remain in theatre are nervous about the security situation in Mantristan province. Until the humanitarian community can marshal sufficient resources to cope with the crisis, US and

UK coalition forces are called on to assist with emergency relief efforts and to improve the security situation for subsequent humanitarian intervention. The affected area is divided into a number of AoI, each under the command of a military coalition commander. The AoI that is the focus of this scenario (see Figure 2-3) comprises three mountain communities situated approximately 40 miles north of the provincial capital Astana. The region is under the control of a brigade sized military unit comprising logistical, infantry and airborne elements from the US and UK armed forces. During the past few months the force has been undertaking strategic operations against insurgent groups who operate from their hideouts in the mountains.

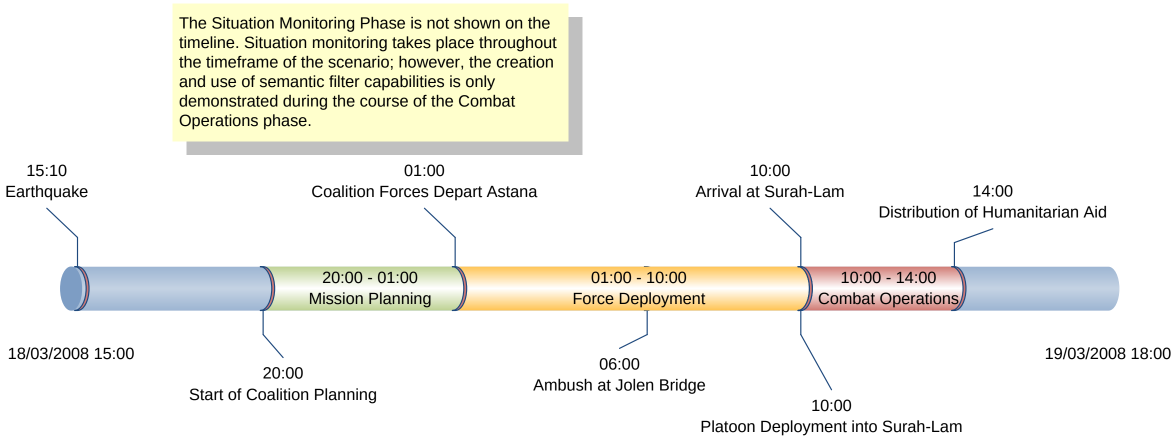


*Figure 2-2: Scenario Timeline*

Coalition forces commence planning at 20.00 hours. Unlike, the situation seen in previous MOOTW scenarios (Smart, 2005), the current scenario assumes that all initial relief operations fall under the jurisdiction of coalition forces. The humanitarian community establishes a separate emergency operations centre in Malekabad (the capital of Holistan), where longer-term relief efforts are coordinated[2]. Military planning focuses on the resource requirements (both military and civilian) of the mission, the potential threat posed to coalition forces by the security situation, the information and surveillance requirements of the mission, and the need to maintain communications with deployed forces at all times throughout the mission timeline. At 01.00 on the 19th March, coalition forces leave Astana en route to the mountain settlements. They are expected to arrive at their target locations by daybreak.

For the most part, the action within the scenario focuses on the largest of the three settlements: Surah-Lam. The bulk of military forces (Alpha Force) are committed to this town and they approach

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[2] A number of humanitarian aid organizations are operating in the region. The ERC (Emergency Relief Coordinator), in collaboration with the IASC (Inter-Agency Standing Committee), has appointed the UNHCR to serve as the lead agency (Humanitarian Coordinator) in coordinating and overseeing all long-term relief efforts. The UNHCR have established a significant presence in the west of country, setting up IDP camps, and they have also established a HIC (Humanitarian Information Centre) in Malekabad. The HIC is situated in a former embassy within Malekabad and serves as the focus point for information gathering, exchange and dissemination activities with respect to long-term relief efforts. In order to enable coordination and communication with military forces, MLOs are assigned to assist the humanitarian community with the planning of specific sectorial activities, e.g. food distribution. Their primary role is to ensure that plans for humanitarian action are fully deconflicted with coalition-led HA/DR operations (as well as other military operations). The MLOs act through the CJCMOTF (Coalition Joint Civil-Military Operations Task Force), which serves as the strategic command HQ for civil-military coordination on behalf of US/UK coalition forces.

it from the south via the Khevan Pass. Unmanned Aerial Vehicle (UAV) reconnaissance, performed as part of the joint planning operations on the previous day, has revealed that the Jolen Bridge has been damaged, and coalition forces are required to repair this bridge before they can continue to their target destination. It was assumed, by military planners, that the bridge was damaged by the earthquake; however, on arrival at the bridge it becomes apparent that the damage is due to explosives. Unbeknownst to the coalition, an insurgent group hiding in the mountains has targeted the bridge in the aftermath of the earthquake, assuming (quite correctly) that military planners will (mis)attribute the bridge damage to the earthquake and not suspect an ambush[3]. From their elevated position high above the Khevan Pass, the insurgents launch missile attacks against coalition forces and Alpha Force suffers a number of causalities requiring immediate medical evacuation. An urgent request for Close Air Support (CAS) is made to brigade headquarters (HQ), and, following a number of aerial assaults on enemy positions, it is assumed that the threat has been negated. Coalition forces finish repairing the bridge and continue to Surah-Lam.

As coalition forces approach the town, they suffer a temporary loss of communications due to the destruction of a UAV radio relay platform. In addition, acoustic sensors deployed to the north of Surah-Lam suggest the movement of multiple vehicles (suspected to be insurgent forces) moving south towards the town. By 10.00 hours, Alpha Force has reached the outskirts of the town, but, suspecting another ambush, they do not enter the town immediately. Instead, 3 platoons are deployed into the town to assess the security situation and negate any risk of attack. As they move into the heart of the town, they are engaged by insurgent forces and a firefight ensues. By 14.00 hours, the insurgents have been defeated and coalition forces begin distributing humanitarian aid.

## 2.3 Geography

Mantristan province is located in the north of Holistan. It borders the neighbouring countries of Sugaria (to the north and west) and Weightan (to the East). It is a mountainous region with many high peaks having permanent snow cover. There are two valley systems that dominate the landscape: the Natal Valley runs north from the city of Astana, while the Jan-Segal Valley sweeps down from the north-west border with Sugaria. The Gardak River runs along the bottom of the Jan-Segal Valley.

[3] Here we see an error of decision-making that is grounded in assumptions about the causal potency of the earthquake with respect to structural damage. Although the UAV imagery could not reveal the precise cause of the bridge damage, military planners failed to fully consider alternative explanations for the situation. A combination of confirmation bias and the priming influence of information about earthquake-induced structural damage, created the conditions under which the beliefs and expectations of military planners could be (easily) manipulated by enemy forces. Note that at any other time, damage to the bridge would have caused military planners to be suspicious about enemy activity.

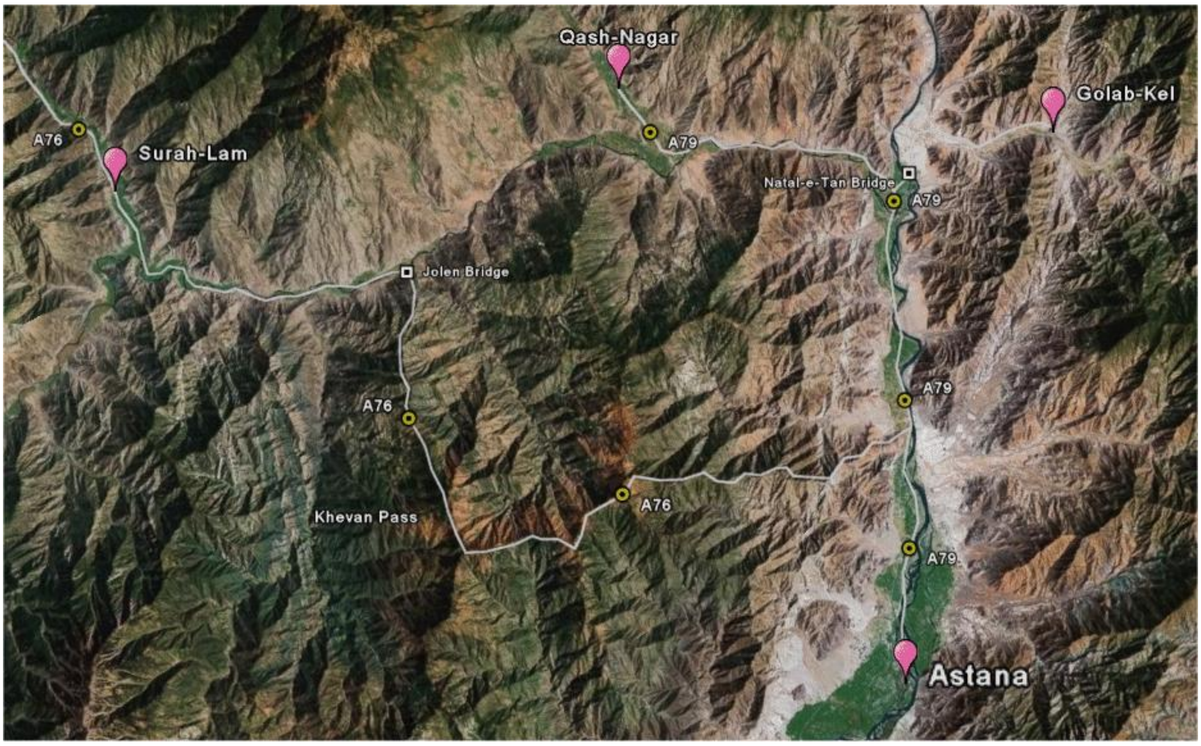


*Figure 2-3: Map Showing Settlements and Transport Routes*

The rugged terrain presents a number of problems for coalition forces. Firstly, it canalizes coalition forces into narrow mountain passes where they are vulnerable to enemy fire from insurgent groups. Secondly, the landscape prohibits direct line-of-sight communications. Communication networks thus need to be established using satellite communications or the use UAVs as radio relay stations.

## 2.4 Weather

During the timeframe of the scenario, the weather conditions are generally mild. Temperatures range from a high of 10°C to a low of -2°C. Low-lying fog reduces visibility on the morning of the 19$^{th}$ March, especially in the region north of Surah-Lam.

## 2.5 Settlements

Although the terrain of Mantristan presents challenges to human habitation, there are many villages and towns scattered throughout the mountains. These settlements are connected by a sparse network of roads and mountain passes that are occasionally blocked by landslides and (in Winter) avalanches. There are three mountain settlements which fall within the AoI assigned to the brigade commander (see Figure 2-3). These are the focus of the MOOTW operations to be undertaken during the course of the scenario. They include Surah-Lam (population 3000), Qash-Nagar (population 600) and Golab-Kel (population 150). To the south of the AoI lies Astana, the provincial capital of Mantristan. There is a small airport on the northern outskirts of Astana, and this serves as the command headquarters for coalition forces.

Surah-Lam is clearly the largest of the three settlements, and it is the primary focus of attention in the current scenario. The town lies near to the Sugarian border region, which represents one of the last strongholds of the insurgents; it is the most hazardous of the three settlements from a security perspective.


*Figure 2-4: View of Jan-Segal Valley (Looking West from Golab-Kel)*

## 2.6 Transport Routes

There are two routes into the mountains that can be used by coalition forces. The first of these is the A76, also known as the Khevan Pass. It connects Surah-Lam with the provincial capital, is approximately 60 miles long and has a crushed-rock surface. The second route is the A79. It is a robust tarmac road that leads into the mountains along the floor of the Natal Valley. It terminates at Qash-Nagar, and is approximately 40 miles long. Golab-Kel can be reached via a minor dirt road that branches off from the A79 at a junction approximately 1 mile from the Natal-e-Tan Bridge

*Figure 2-5: Jolen Bridge*

The A76 crosses the Gardak River in the Jan-Segal valley via the Jolen Bridge. In places, the Gardak River can be crossed on foot; however, such crossings are usually treacherous, particularly after heavy rain. The road continues through Surah-Lam towards the north-west border region with Sugaria. In places the crushed-rock surface of the road gives way to asphalt, particularly as one nears the Sugarian border. Since the border region is one of the last strongholds for insurgent forces, the road north of Surah-Lam is of great tactical significance. One concern of military planners in the scenario is that insurgent groups will use the route to deploy forces to Surah-Lam in anticipation of a coalition deployment.

## 2.7 Coalition Forces

Figure 2-6 illustrates the organizational structure of the coalition force (Task Force N) based at Astana. The force is a brigade-sized military unit that includes infantry, logistics and aviation elements. The specific composition of the coalition forces is as follows:

- Two US Infantry Battalions, providing general infantry capabilities. Each battalion comprises three Infantry Companies.
- One Holistan Infantry Battalion, providing general infantry capabilities. The battalion comprises three Infantry Companies.
- One US Artillery Regiment, providing artillery support. The Regiment comprises three Artillery Batteries.
- One UK Engineering Regiment. This is split into two Close Support Squadrons and an Explosive Ordnance Disposal (EOD) Squadron. The Close Support Squadrons can be used for (among other things) bridge repair and construction, while the EOD Squadron is typically involved in the detection and removal of hostile munitions. The EOD Squadron is split into three EOD Detachments.
- One UK Aviation Squadron. This comprises one US Reconnaissance Flight (rotary wing) and two UK Transport Flights (fixed wing).
- One US Logistic Battalion, providing logistics support. This comprises two US Transport Squadrons, one US Electronic Support (ES) Company, one UK ES Company, and one US Stores Squadron.

The majority of coalition forces are assigned to Surah-Lam. This is because it is the largest of the three settlements, and it is also poses the greatest security threat. The precise composition of the forces assigned to the three mountain settlements is undetermined at the start of the scenario. It is assumed that the composition of each force will be specified as part of the mission planning process based on mission-specific force requirements, e.g. EOD specialists in the case of mine hazards and engineering personnel for bridge repair procedures.

Although not explicitly specified as part of the coalition force structure, it is assumed that Task Force N has, at its disposal, multiple UAVs that may be used for photoreconnaissance and UHF/VHF communications relay. In particular, we assume the following UAVs are available for use in the scenario:

- One RQ-4 Global Hawk UAV equipped with an Integrated Sensor Suite (ISS) comprising a Synthetic Aperture Radar (SAR), electro-optical and infrared sensors.
- Two RQ-7B Shadow UAVs equipped with Tactical Common Data Link (TCDL) relay capabilities.
- One ScanEagle UAV fitted with high resolution visual spectrum and near infrared cameras.

We expect these vehicles to form part of the UK Aviation Squadron.

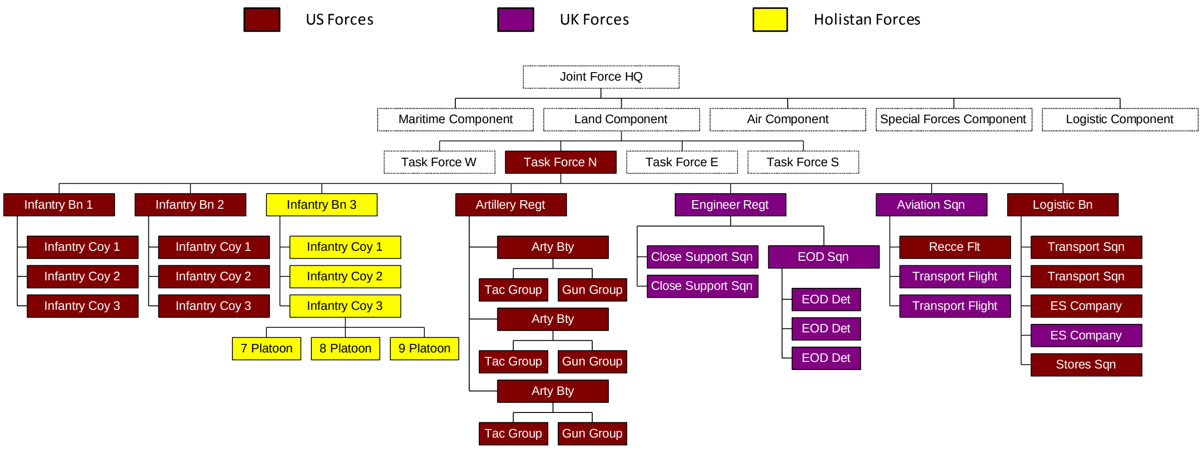


*Figure 2-6: Coalition Force Structure*

The scenario also includes the use of 2 Apache AH-60 attack helicopters, which are used for force protection purposes (see Section 4.1). These helicopters do not form part of Task Force N. Instead they are co-opted from external coalition force components. The evacuation of personnel following the attack on coalition forces at the Jolen Bridge (see Section 4.1) is supported by a medical evacuation team, again external to Task Force N.

## 2.8 Insurgent Forces

The hostile forces encountered in the scenario are all members of the Sugarian-backed insurgency. For the most part, the insurgents are equipped with light weapons, such as rifles, machines guns and mortars. However, it is known that the insurgents occasionally use more sophisticated weapons, such as Rocket-Propelled Grenades (RPGs), mostly of the RPG-29 Vampir variety. These weapons are believed to be supplied by Sugarian forces, who have some ideological affinity with the insurgents. The Sugarian regime is also believed to be responsible for supplying the insurgents with modified Sports Utility Vehicles (SUVs).

The tactics adopted by the insurgents are largely ones of guerrilla warfare: they tend to avoid direct confrontation with coalition forces, but they will attempt to exploit any ad hoc tactical advantage. They are also capable of constructing and deploying Improvised Explosive Devices (IEDs) and these have been used with some success to target coalition forces.

The insurgents are motivated by a profound religious zeal and hatred of Western culture. They are not averse to attacking innocent civilians, or indeed sacrificing their own lives, if they believe it will support their cause.

## 2.9 Humanitarian Organizations

Although many humanitarian organizations withdrew from Holistan during the height of the conflict, some have now started to return. A number of United Nations (UN) agencies have remained in theatre throughout the conflict, including, most notably, the UNHCR[4] which has established a number of Internally Displaced Person (IDP) camps in the west of the country. Other humanitarian agencies operating in Holistan at the time of the scenario include:

- ICRC[5] (International Committee of the Red Cross)
- WFP[6] (World Food Programme)
- OXFAM International[7]
- CARE International8
- MSF[9] (Médecins Sans Frontières)

[4] http://www.unhcr.ch/
[5] http://www.icrc.org/
[6] http://www.wfp.org/
[7] http://www.oxfam.org/
[8] http://www.care.org/
[9] http://www.msf.org/

# 3 Phase I: Mission Planning

## 3.1 Overview

This phase of the scenario takes place in the immediate aftermath of the earthquake, from 20.00-01.00 hours on the 18th March 2008. The overriding concern of coalition forces during this phase of the scenario is to create a mission plan that will coordinate military action in the subsequent deployment and execution phases. The planning stage requires the rapid retrieval, aggregation and integration of multiple types of information, and the time constraints imposed on military planners (especially the short notice period) obliges them to exploit whatever (trusted and reliable) sources of information are available for the purposes of plan development.

A number of technology demonstration goals are being pursued in this phase of the scenario. First and foremost we wish to demonstrate the use of knowledge access tools to facilitate the retrieval of task-relevant information (in this case, the retrieval of information that is relevant to the specification of a coalition military plan). Such tools are the focus of scientific and technology development efforts within P12T1, specifically within the 'Knowledge Representation and Accessibility' workpackage. They include a variety of graphical query designers (e.g. the NITELIGHT tool) and natural language query interfaces. What the use of such tools demonstrates is, we argue, the potential of semantic technologies (ontologies, semantic query languages, RDF triplestores, etc.) to contribute to situation awareness and information superiority in a situation where relevant information content is physically distributed (with respect to the network topology) and associated with a number of morphosyntactically-diverse representational formats (e.g. the use of different database schemas or XML languages). Our plan is to support the user with respect to information retrieval on the Semantic Web, while avoiding the complexities of both the underlying representation format, and (in some cases) the niceties of the semantic query language itself. As knowledge access mechanisms become progressively more efficient and easy to use, so their transformative potential for human cognition is, we argue progressively enhanced. In the extreme case, where network-enabled knowledge access is as easy and effortless as retrieving information from our own onboard memory systems, then we may confront a situation where it (perhaps) makes both scientific and subjective sense to see the extended knowledge environment (the knowledge distributed throughout a network) as an intrinsic part of our individual (or collective?) epistemic profile (see Clark, 2003). The panoply of knowledge access tools (query designers, natural language interfaces, semantic information browsers, etc.) currently under development are, we suggest, a move in this general direction, and they provide a technological framework within which network-enabled cognition or extended mind (Clark & Chalmers, 1998) accounts can be empirically evaluated.

A second, and not altogether unrelated, demonstration goal for this phase of the scenario is to illustrate how semantic enrichment can contribute to the integration of ostensibly disparate datasets from multiple information providers. One of the tasks confronting military planners in this phase of the scenario is to identify sensor assets that can be used to satisfy information and surveillance requirements throughout subsequent stages of the mission. This process of 'sensor-to-mission' matching is the subject of a specific sub-task within Project 8 (i.e. Task 1), and it relies on the use of semantically-enriched characterizations of both sensor platforms and information acquisition requirements (Preece et al., 2007). This match-making strategy works fine as long as the sensor assets are described using the same ontology, but what if the elements of a coalition force use different ontologies to describe their sensor systems? In this case, what is required is a means to map or align the ontologies so that semantically-equivalent sub-components (perhaps, for example, describing the same sensor type) can be identified. In other words, what we require is a semantic integration solution that can be used to support the process of sensor-to-mission matching with respect to multi-national (or multi-agency) coalitions. The demonstration opportunities for P12T1 should be obvious here, since one of the foci of P12T1 research is precisely to explore the mechanisms enabling the exploitation of semantic integration solutions. By co-opting such mechanisms into the sensor-mission matchmaking process we are seeking to provide a concrete demonstration of semantic integration/interoperability as well as supporting the P8T1 goal of optimizing the assignment of coalition sensor assets to specific mission contexts.

| Phase 1: Mission Planning | |
|---|---|
| **Military Objectives** | • Create a coalition plan to coordinate military action.<br>• Identify the resource requirements (both military and humanitarian) for the mission.<br>• Understand the constraints on military action imposed by the operational environment, e.g. the effect of weather on sensor selection and deployment. |
| **Demonstration Goals** | • Demonstrate the use of graphical query designers in enabling rapid access to task-relevant information.<br>• Demonstrate the use of natural language query interfaces in enabling rapid access to task-relevant information.<br>• Demonstrate the use of semantic integration and interoperability techniques in enabling the exploitation of distributed information content.<br>• Demonstrate the relative superiority of portable ontology alignment solutions, as opposed to conventional alignment solutions, in distributed network environments. |
| **Timeframe** | • 18/03/2008 20:00 – 19/03/2008 01:00 |
| **Demonstration Activities** | • Retrieval of Meteorological Information (see Section 3.2.1)<br>• Retrieval of Mine/IED Hazard Information (see Section 3.2.2)<br>• Semantic Integration of Sensor Ontologies (see Section 3.2.3) |

*Table 3-1: Overview of Mission Planning Phase*

## 3.2 Demonstration Activities

The focus for technology demonstration in this phase of the scenario is very much geared to the retrieval and analysis of information in support of coalition planning. As such, the demonstration activities we propose in this phase of the scenario are based on the use of knowledge access and retrieval tools, portable ontology alignment solutions, and semantic integration and interoperability solutions. Each specific demonstration activity is characterized in terms of the following:

- **Demonstration Goals:** an overview of the technology demonstrations goals; i.e. a specification of what needs to be accomplished by the demonstration.
- **Resources:** the resources that are required to realize demonstration goals. These include datasets, ontologies, and technical solutions.
- **Technologies:** the tools and technologies required for the demonstration.
- **Actions:** the actions that need to be undertaken by P12T1 staff in order to implement the demonstration.
- **External Collaboration:** the requisite links to projects and staff outside the P12T1 team.
- **Assumptions:** any assumptions upon which the technology demonstration effort is based.

### 3.2.1 Retrieval of Meteorological Information

The analysis of meteorological information is important because it shapes and constrains the opportunities for military action. In the current scenario, the retrieval of meteorological information is important because it highlights the kinds of resources that may be required in order to counter humanitarian challenges, e.g. low temperatures may mandate the need for extra blankets, fuel and power generators, while heavy rainfall may suggest a need for plastic sheeting and tents. Meteorological information therefore impacts on the resource requirements for humanitarian mission planning.

Meteorological information is also important because it affects the relative suitability of different sensor systems for information acquisition and surveillance missions. In the current scenario, for example, the forecast is for heavy fog in the region of the Khevan Pass, Surah-Lam and the Sugarian border region. This reduces visibility and militates against the use of electro-optic sensors for information gathering purposes. Faced with an urgent operational requirement to monitor insurgent activity in the region (recall the close proximity of Surah-Lam to the Sugarian border region – see Section 2.5), coalition forces need to adjust their sensor deployment plans based on the relative suitability of specific sensor platforms for the prevailing mission context (in this case the weather context). As we shall see (see Section 4), the integration of information about meteorological conditions and sensor capabilities supports the decision to rely on vibro-acoustic sensors along the route from Surah-Lam to the Sugarian border region (i.e. the A76 north of Surah-Lam).

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| **Demonstration Goals** | • Demonstrate the use of graphical query designers in enabling rapid access to task-relevant information.<br><br>• Demonstrate the use of semantic integration and interoperability techniques in enabling the exploitation of distributed information content. |
| **Resources** | • Meteorological Ontologies: at least two meteorological ontologies are required.<br><br>• Meteorological Data: at least two streams of meteorological data should be available. These should provide weather |

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| | forecasts for the next 48 hours within the target region of interest. No constraints on the actual weather conditions are specified here (although other ITA members may have specific requirements[10]). One exception, in our case, is for the presence of low-lying fog in the region of the Khevan Pass, Surah-Lam and the Sugarian border region on the morning of the 19th March. |
| **Technologies** | • Graphical query designers will be used to represent information retrieval interests in a graphical format. The tools will execute semantic queries against an RDF triplestore containing meteorological data. The query results will be converted to Keyhole Markup Language (KML) for display on a Google Earth (or similar) display.<br>• Semantic integration and interoperability solutions will be needed to effect the integration of meteorological information from multiple sources. These semantic integration solutions will be based on the rule- or query-based solutions being investigated as part of P12T1. They may, or may not, utilize the portable ontology solution also being investigated as part of P12T1. |
| **Actions** | • Acquire or create meteorological ontologies.<br>• Acquire or create meteorological data sets.<br>• Create sample semantic queries for the retrieval of meteorological information.<br>• Transform meteorology query results into appropriate presentation formats (e.g. convert query results XML to KML for Google Earth/Google Maps display). |
| **External Collaboration** | • The design and implementation of graphical query designers is supported by collaborative links between our team and members of the DIF DTC SEMIOTIKS initiative[11].<br>• Some collaboration with ITA projects may be required to support the creation of meteorological datasets. It will be important for any individuals working on weather-dependent elements of the scenario to communicate their data requirements to the P12T1 team. |

[10] In particular, it will be important to establish the requirements in respect of the plan specification activity (P12T2).
[11] http://www.ecs.soton.ac.uk/research/projects/semiotiks

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| Assumptions | We assume that there is a compelling reason to analyse meteorological data within the demonstration scenario. In particular, we assume that the analysis of meteorological data will contribute to the structure and content of coalition plans (e.g. the need for acoustic sensors rather than electro-optic sensors to monitor insurgent activity, and the need for extra blankets to deal with low night-time temperatures). |

### 3.2.2 Retrieval of Mine/IED Hazard Information

This demonstration activity is similar to that outlined for the retrieval of meteorological information. In this case, however, we are concerned with a different domain (information about the location of mine hazard areas) and the potential for IED attacks. The aim (for coalition forces) is to access information about the results of mine hazard impact surveys (maintained by humanitarian demining organizations) and coalesce this with information about recent IED incidents. Ultimately, military planners need to use this information to assess the risk posed to coalition forces both en route to the target settlements and also in the vicinity of the settlements themselves. The risk posed by minefields may limit troop deployment activities, or it may necessitate the recruitment of EOD specialists as part of the mission plan. In any case, we are assuming that the analysis of mine/IED hazard information is an important element of the coalition planning process.

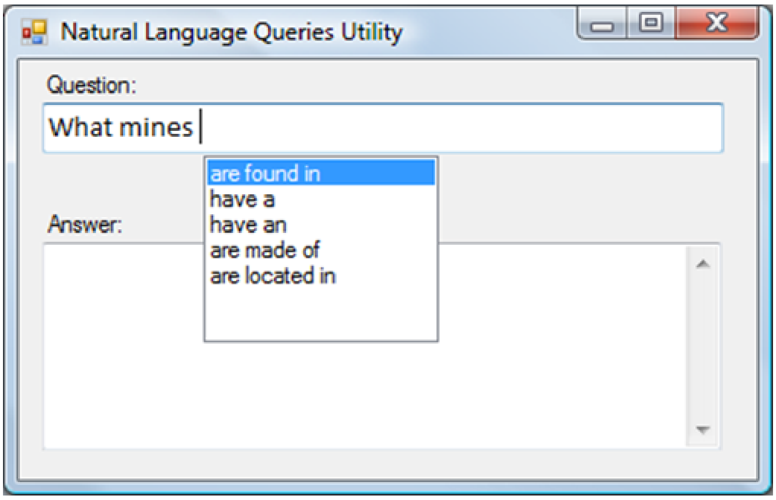


*Figure 3-1: Natural Language Question Answering Utility*

The key difference between this demonstration activity and that presented for the retrieval of meteorological information is the way in which information is actually retrieved. In the present case, we aim to demonstrate the use of natural language query tools that support the expression of information retrieval requirements in sentential (natural language or Controlled English) formats. Figure 3-1 illustrates one (admittedly simple) interface for the expression of information retrieval requirements, in this case using a question-answering format (see also Lopez et al., 2005)

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| Demonstration Goals | • Demonstrate the use of natural language query interfaces in enabling rapid access to task-relevant information. |

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| **Resources** | • Demining Ontology: at least one humanitarian demining ontology is required.<br>• IED Incident Ontology: at least one ontology of IED incidents is required.<br>• Mine Hazard Data: at least one stream of mine hazard data for the AoI is required.<br>• IED Incident Data: at least one stream of IED incident data for the AoI is required. |
| **Technologies** | • Natural language query interfaces will be used to support the retrieval of information. Natural language (or Controlled English) expressions will be converted to SPARQL queries and executed against an RDF triplestore. Query results will be represented in a graphical format on a map display. |
| **Actions** | • Acquire or create humanitarian demining ontologies.<br>• Acquire or create mine hazard data.<br>• Acquire or create IED incident ontologies.<br>• Acquire or create IED incident data.<br>• Create sample semantic queries for the retrieval of mine hazard/IED incident information.<br>• Transform mine hazard query results into appropriate presentation formats (e.g. convert query results XML to KML for Google Earth/Google Maps display). |
| **External Collaboration** | • The design and implementation of natural language query interfaces is supported by collaborative links between our research team and members of the DIF DTC SEMIOTIKS initiative. We also rely on the DIF DTC SEMIOTIKS project to provide us with demining and IED incident ontologies.<br>• Although we make no assumptions about the impact of query results on plan creation and execution, the information content of the ontologies may need to be adapted to suit the planning requirements of P12T2 (e.g. the presence of mine hazard areas may necessitate the inclusion of EOD experts as part of the coalition plan). As such, some collaboration with P12T2 is required by this demonstration activity.<br>• Some collaboration with other ITA projects may be required to support the content of the mine hazard ontologies, especially |

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| | the datasets. It will be important for any individuals working on mine/IED-dependent elements of the scenario to communicate their data requirements to the P12T1 team. |
| **Assumptions** | We assume that the analysis of mine hazard and IED incident data is both operationally-relevant and significant. For example, we assume that at least one mine hazard region is located in the vicinity of one of the villages. We also assume that one of the transport routes has a history of IED attacks on coalition forces. |

### 3.2.3 Semantic Integration of Sensor Ontologies

The use of ontologies within the ITA is not limited to Project 12. One also sees ontologies (and semantic technologies more generally) being used in at least two other projects: Project 8 (Task 1, Sensor-Mission Matching) and Project 9 (Task 2, Semantically-Mediated Data Fusion). In both cases, there is a compelling reason to incorporate (and demonstrate) the research outcomes of the projects within the current technology demonstration. The case for collaboration with Project 9 is made in Section 4; here we outline the interface between our own research and that undertaken by Project 8[12].

Project 8 Task 1 (P8T1) focuses on the optimal selection and assignment of sensor assets based on the fit between specific sensor characteristics and Intelligence, Surveillance and Reconnaissance (ISR) requirements (Preece et al., 2007). Ontologies are used to support sensor selection by providing a semantically-enriched characterization of sensor resources that can be exploited in a match-making process, a process that ranks available sensors in terms of their ability to satisfy specific information acquisition requests. Sensor ontologies come in multiple flavours, and SensorML[13] and OntoSensor (Goodwin & Russommano, 2006) represent just two distinct languages for the representation of sensor-relevant information. It is by no means clear whether extant sensor ontologies will (ever!) satisfy the representational requirements for sensor characterization in every conceivable exploitation context. The problem is not just the plethora of sensor types, configuration parameters and performance limitations, neither is it the rate at which new sensor devices are developed and made available to military agencies; rather it is that the kind of information needed for any particular task is likely to be somewhat specific to both the nature of the task, the perspective of the end-user engaged in that task, and the broader problem-solving context in which the task is embedded. The idea that one single monolithic sensor ontology could ever be developed (let alone maintained) to support the representational requirements of all stakeholders across every exploitation context is therefore (practically) untenable. What we confront here is a specific case of

[12] It is also worth mentioning here that there appears to be a significant basis for closer collaboration between P12T2 and P8T1 in the context of technology demonstration. The use of sensors within a mission is an integral part of the coalition plan. Sensor platforms represent a specific type of resource whose utilization needs to be carefully aligned with the spatio-temporal profile of coalition action. In addition, there will often be a rather delicate association (a dependency) between sensor-derived information and the decision points within a plan (the choice between action *x* and *y*, for example, may *depend* on the information provided by sensor *z*, and thus the tasking of sensor *z* needs to be sensitive to the temporal profile of *x* and *y* within the broader plan context).

[13] http://vast.uah.edu/SensorML/

a more general problem in the Semantic Web (and database) community. It is the problem of coping with the emergence of representational formalisms that are unified at the semantic level of analysis (i.e. formalisms that target a common domain of discourse), but whose morphosyntactic manifestations are both multifarious and (typically) heterogeneous. In the absence of any kind of representational scheme that might provide a semantic metric at the formal symbolic level, we are obliged to resolve the semantic integration problem by expressing ontology alignment solutions that make explicit the semantic correspondences between ostensibly disparate data representation frameworks.

The relationship between the projects of semantic integration (P12T1) and sensor-mission matching (P8T1) should now (hopefully) be clear. Given that we have a situation where multiple sensor ontologies are being used, and the resources they describe are intended for collective exploitation, we need to utilize semantic integration solutions that effectively combine the representational schemes of coalition forces in order to fully leverage the problem-solving potential of the sensor-mission matchmaking process. Such is the nature of our demonstration goal for this phase of the scenario. Essentially we seek to demonstrate the potential of semantic integration solutions for improving the exploitation of nation-specific (and perhaps even organization-specific) data repositories in the context of a sensor matchmaking processes that must (necessarily) transcend national boundaries.

One distinctive feature of the semantic integration solutions being investigated as part of P12T1 concerns their suitability for exploitation in a distributed network environment, specifically a network environment that features occasional disruptions in nodal connectivity and network topology. The challenges presented by such an environment are considerable:

> *"The key problem is that time-variant changes in network connectivity (or the differences in connectivity apparent from the perspective of physically distributed military agencies) results in the differential availability of nodes and their associated knowledge resources. This can contribute to a confusing situation picture because query results executed from one location in the network need not coincide with the results of the same query executed elsewhere. Moreover, the same query may return different results at different times based on the physical distribution of knowledge resources and the extent of intervening changes in network topology. The distributed nature of knowledge resources is a potential problem here because it complicates the possibility of establishing a common collective representation about the nature and implications of the current situation picture. Ultimately, we argue, this can attenuate shared situation understanding and situation awareness and undermine the potential for coalition inter-operability." (Smart & Shadbolt, 2007)*

To address concerns about the impact of coalition military networks on the viability of semantic integration solutions, we are actively investigating the use of portable ontology alignment solutions as part of the P12T1 research agenda. We assume, in this case, that the sensor ontology for one of the coalition partners, the UK say, is temporarily unavailable (due to a network outage) and that it is not therefore possible to access the ontology during the course of the semantic integration process. Fortunately, our dependence on the absent ontology is attenuated because we have a portable ontology alignment solution that captures the minimal set of ontology components that are needed to effect the integration or transformation of nation-specific sensor datasets[14].

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| Demonstration Goals | • Demonstrate the use of semantic integration and interoperability techniques in enabling the exploitation of distributed information content.<br><br>• Demonstrate the relative superiority of portable ontology alignment solutions, as opposed to conventional alignment solutions, in distributed network environments. |
| Resources | • Sensor Ontologies: we require at least two sensor ontologies. One ontology will be used by US forces and the other will be used by UK forces.<br><br>• Sensor Asset Data: we require two datasets providing information about sensor resources for US and UK forces. |
| Technologies | • The Potable Ontology Aligned Fragments (POAF) framework will be used to effect the integration of information from coalition sensor ontologies.<br><br>• The P8T1 match-making framework (Preece et al., 2007) will be used to select sensor assets based on information acquisition requirements. We assume that UAV platforms (from both nations) will be selected to provide information about the structural integrity of roads and bridges en route to the villages; however, in the case of monitoring insurgent activity north of Surah-Lam, the use of UAVs will be ruled out by the presence of fog (information derived from the aforementioned meteorological analysis). We assume that the P8T1 match-making process will be sensitive to this contingency and that it will recommend the use of alternative sensor assets, namely acoustic sensors, for the acquisition of information about vehicle movements along the A76. The manner in which the matchmaking process will be invoked and exploited in the context of the TA4 technical demonstrator is something that needs to be resolved in future discussions with the P8T1 team. |
| Actions | • Acquire or create sensor ontologies.<br><br>• Acquire or create sensor data sets. |

[14] It might be worth providing an empirical demonstration of the relative advantages of semantic integration using POAF as opposed to conventional semantic integration solutions at this point in the demonstration.

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| | • Create ontology alignment solution for sensor ontologies.<br>• Instantiate POAF-based solution to effect semantic integration of the sensor data sets.<br>• Liaise with members of the P8T1 team to understand sensor match-making requirements and incorporate sensor-to-mission match-making solutions in the technology demonstrator. |
| **External Collaboration** | • Significant collaboration is required with members of the P8T1 team. |
| **Assumptions** | We assume that there is a compelling reason for coalition forces to share their sensor resources. For instance, it may be that the US and UK possess UAVs that are differentially suited to particular information gathering activities (e.g. the acquisition of information about the structural integrity of bridges, buildings, roads or the movements of insurgent forces), as well as different information gathering contexts (e.g. night-time versus daytime operations, foggy versus clear visibility conditions, and so on). We additionally assume that the P8T1 match-making process can be sensitized to the impact of weather conditions on the suitability of sensors for particular missions. For example, we assume that there is an operational requirement to detect and recognize vehicle movements along the A76 north of Surah-Lam, and that the use of UAVs is invalidated by the presence of fog. The match-making process therefore needs to reject the use of UAVs and recommend the use of vibro-acoustic sensors in their stead. What this, in effect, requires is that the relationship between fog, ground-level visibility and the reliance of sensors on good visibility conditions be made explicit in the various ontologies. In particular, we assume that the causal relationship between fog and poor visibility, and the dependence of optical sensors on good visibility, is accessible to match-making processors and can be used to guide sensor selection/ranking decisions. Clearly, this requires the match-making processors to (automatically) detect the potential significance of meteorological information for sensor selection and to proactively query meteorological repositories for information about impending weather conditions. Alternatively, such information could be ‘manually’ input to the sensor match-making process as part of the initialization process. |

# 4 Phase II: Force Deployment

## 4.1 Overview

This phase of the scenario takes place from 01:00-10.00 on the 19th March. The phase is dominated by the transit of coalition forces to their mountain targets. For the most part, the action is centred on Alpha Force; the deployment of Bravo and Charley Forces is assumed to occur without incident[15]. The timeline for this phase of the scenario is illustrated in Figure 4-1. Alpha Force arrives at the Jolen Bridge at 06:00 hours. There they are engaged by insurgent forces hiding in the mountains around the Khevan Pass, and a fire fight ensues. Coalition forces request CAS support in order to support their attack on enemy positions, and such calls are duly answered by the arrival of 2 Apache AH-60 helicopters. Guided by the location information supplied by ground forces, the attack helicopters launch missiles at enemy positions above the mountain pass, and subsequently no further enemy fire is received. The insurgent groups are assumed to be destroyed, or at least sufficiently compromised so as to serve no further threat to coalition forces. A number of coalition causalities are sustained in the course of the fighting and these require immediate medical evaluation.

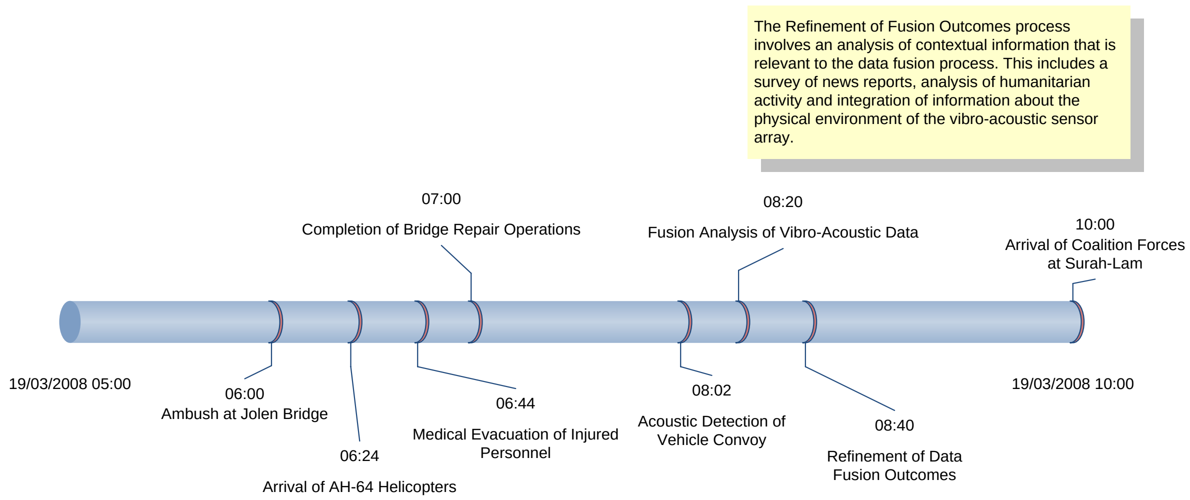


*Figure 4-1: Event Timeline for Force Deployment Phase*

By 07.00 hours coalition forces have completed repairs to the Jolen Bridge, and they cross the Bridge en route to Surah-Lam. Shortly after Alpha Force has crossed the Gardak River, vibro-acoustic sensors deployed north of Surah-Lam detect the transit of multiple vehicles heading south towards the town. Insurgent forces based in the Sugarian border region have heard the distant sound of gunfire in the mountains and (correctly) interpreted this as a signal that coalition forces have arrived at the Jolen Bridge. They now deploy a vehicle convoy to Surah-Lam in anticipation of coalition forces. The idea is that unsuspecting coalition forces will be ambushed upon entry to Surah-Lam thereby allowing the insurgents to inflict significant damage to the US/UK deployment.

[15] One may ask why we have opted to include Bravo and Charlie Forces at earlier stages of the scenario. The answer is that the inclusion of multiple target settlements presents a challenge to military planning in terms of the optimal allocation of coalition resources to specific missions. The need to determine the precise composition and capability of each force (in relation to the nature of the humanitarian challenge that each force must deal with) is intended to showcase the use of planning technologies currently being developed as part of P12T2.

Unfortunately (for the insurgents, at least), the transit of the insurgent vehicle convoy is detected by a number of strategically placed vibro-acoustic sensor arrays on the route to Surah-Lam. The sensor data is transmitted to brigade headquarters using a UAV drone (flying above Surah-Lam) as a radio transmission relay. Back at HQ, data fusion processes, in conjunction with domain ontologies, are used to analyse the acoustic data and compute vehicle type information. The output of the semantic data fusion process reveals a high probability of a number of vehicle types, including SUVs – the vehicle type most commonly supplied to the insurgents by their allies across the Sugarian border. The acoustic profile of the vehicles, in conjunction with vibration data, indicates that the vehicles are moving at about 20 miles an hour. Despite this, the estimated number of engine revolutions (as indicated by the acoustic sensors) is excessively high for the inferred vehicle type. This could reflect the fact that the vehicle is heavily laden, perhaps towing a trailer or carrying heavy equipment, or is negotiating difficult terrain (moving uphill, for example). Semantically-enriched descriptions of the region in which acoustic sensors are deployed indicate that the sensors are located next to a relatively flat and smooth stretch of road. The chances are, therefore, that the vehicles are carrying (or towing) large amounts of heavy equipment.

The outcome of the data fusion process suggests that heavily armed enemy militia may be moving into Surah-Lam; however, in order to support this conclusion, military analysts need to rule out alternative explanations. One such explanation is that humanitarian convoys are being deployed to Surah-Lam from within Sugaria. The presence of dense morning fog precludes the visual identification of the convoy, so military analysts search all networked information sources, including those from the humanitarian community, for any evidence that Sugaria may be participating in the relief effort. This search reveals no direct evidence of humanitarian deployments; however, a number of news agencies provide reports about Sugaria's intention to independently assist their fellow Islamists in the border region. As such, it is not possible for military analysts to rule out the possibility that the detected vehicle convoy is part of an ad hoc relief effort originating from Sugaria. Given the uncertainty about the true nature of the convoy, as well the potential political repercussions of a coalition attack on a Sugarian relief effort[16], coalition commanders decide against the use of air strikes to negate the potential threat posed by the convoy.

Alpha Force commanders are alerted to the presence of the convoy and are instructed to proceed with caution. They are informed that insurgents may have been deployed to the town and may be using the humanitarian crisis as cover for strategically-significant attacks on coalition forces. Alternatively, it is possible that Sugarian-backed humanitarian aid is being supplied to Surah-Lam, with or without the assistance of insurgent and/or Sugarian armed forces. As Alpha Force arrives at the outskirts of Surah-Lam, coalition commanders begin planning their tactical deployment into the town. It is decided that three platoons will be deployed to the town to reconnoitre the terrain and establish the true nature of the situation. Platoon commanders are briefed about the potential sensitivity of the situation and the negative impact of civilian causalities. They are instructed to avoid

[16] Even if the convoy could be reliably identified as military in nature, it is expected that Sugarian-backed insurgents will use the humanitarian crisis as cover for their military operations. In other words, the insurgents may claim that the convoy was part of a Sugarian relief effort, irrespective of its actual nature. One response of the Sugarian government could be to publicly decry the incompetence of coalition forces and declare their attack on Sugarian aid workers as evidence of an ideologically-motivated antipathy towards the Islamic community.

direct conflict with Sugarian government forces, but to engage and destroy armed insurgents. In general, armed confrontation is to be avoided unless coalition forces come under direct fire.

The Force Deployment phase clearly features a number of events that impact on the integrity of the original coalition plan. Perhaps even at this stage we could establish a case for the wholesale revision of the plan, reviewing and refining resource allocation commitments and the temporal profile of operational action. The phase also highlights the political complexities of modern warfare and the power of the media to cast coalition operations in a negative light. At a number of junctures in the scenario, it is clear that enemy forces are using the humanitarian crisis, as well as their knowledge about the likely response of coalition forces, to gain a strategic military advantage. It is not that insurgent groups or Sugarian forces necessarily expect to defeat coalition forces at Surah-Lam (they clearly do not because their deployments are small compared to the size of Alpha Force); what they do expect to gain is a psychological victory. By forcing coalition forces to demonstrate their military supremacy in a humanitarian crisis situation, they hope to win public support for the insurgency. It is hoped (and fully expected) that the martyrdom of a few insurgents can be used to garner political and ideological support, establishing a general sense of opprobrium and condemnation of US/UK tactics throughout the international community.

There are numerous opportunities for technology demonstration in this phase of the scenario. Perhaps the most compelling technology demonstration opportunity is the use of semantic technologies to support acoustic data fusion. This, at least, is the technology demonstration to be most fully explored in the current phase of the scenario (see Section 4.2.1). Other opportunities include:

1. The semantic retrieval of meteorological information to evaluate the use of electro-optic sensors in the visual identification of the acoustically-detected vehicle convoy (recall that the presence of fog rules out the use of photo-reconnaissance by UAVs). This capability was demonstrated in the Mission Planning phase (see Section 3.2.1) and will not be repeated here.

2. The semantic integration of information about the activities of humanitarian agencies. Recall that military analysts need to rule out the possibility that the vehicle convoy en route to Surah-Lam is humanitarian in nature. One way in which they can do this is by integrating information from disparate sources, e.g. the institutional websites of humanitarian agencies currently deployed in theatre, to check whether there are any public reports of planned humanitarian intervention. This demonstration opportunity is interesting because it highlights the use of semantic technologies to integrate information from multiple, disparate and, in this case, non-military[17], information sources. Having said that, the narrative structure of the scenario rules out any direct involvement of humanitarian agencies in Surah-Lam. If humanitarian agencies were contributing to the relief effort in Surah-Lam then

[17] The non-military nature of the information highlights the fact that military agencies will sometimes need to exploit information sources that are not under their direct control. Thus even if it was practical to assume that future military forces could standardize the totality of their information representation schemes at the international level, the problem of semantic heterogeneity would still persist because of the impracticalities associated with more global standardization efforts outside the military domain (consider the range of agencies – governmental, civilian, commercial, etc. – that might need to be co-opted into any large-scale information standardization effort).

a number of inconsistencies would be encountered. Why were humanitarian agencies initially reluctant to respond to the crisis, for example? This initial reluctance, recall, explains why coalition military forces are involved in the relief effort in the first place. In addition, the presence of humanitarian agencies in Surah-Lam would largely negate the possibility of combat operations later in the scenario (see Section 6). It is not even clear whether coalition forces would still be deployed to Surah-Lam in this case. In addition, the demonstration of semantic integration in respect of humanitarian activities requires the creation of relevant ontologies and datasets. This (unnecessarily) increases the burden on P12T1 staff to create scenario-supporting materials, e.g. datasets. For these reasons we do not intend to pursue this particular demonstration opportunity.

3. The search and retrieval of information deemed relevant to the process of identifying the intent of the vehicle convoy. In this case, military analysts need to identify any information that might shed light on the nature and intent of the vehicle convoy. One source of information is provided by news agencies broadcasting information about the proposed involvement of Sugaria in cross-border relief efforts. While this demonstration opportunity capitalizes on the potential for semantic technologies to make explicit the link between various news feeds and ongoing operational commitments, it is clear that the demonstration activity would require significant effort in terms of the creation of supporting resources, e.g. press releases, video broadcasts, RSS feeds and so on. For this reason we have decided not to exploit this opportunity as part of our technology demonstration activities.

| Phase 2: Force Deployment | |
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| **Military Objectives** | • Deploy coalition forces to humanitarian target locations.<br>• Monitor the progress of troop movements.<br>• Protect deployed forces and alert them to any potential threats. |
| **Demonstration Goals** | • Demonstrate the relevance of domain ontologies to data fusion processes.<br>• Demonstrate the use of semantically-enriched representations in improving data fusion outcomes, e.g. improving the confidence of entity classification estimates.<br>• Demonstrate the use of provenance information in supporting data fusion processes. |
| **Timeframe** | • 19/03/2008 01:00 – 19/03/2008 10:00 |
| **Demonstration Activities** | • Semantic Fusion of Vibro-Acoustic Sensor Data (see Section 4.2.1) |

*Table 4-1: Overview of Force Deployment Phase*

## 4.2 Demonstration Activities

As mentioned above, there is only one real technology demonstration activity that need concern P12T1 in this phase of the scenario – it is the use of semantic technologies to support acoustic data fusion (see Guo et al., 2007; Veres et al., 2006). As in Section 3.2, demonstration activities are described with respect to their demonstration goals, dependence on specific resources, need for external collaboration and so on (see Section 3.2).

### 4.2.1 Semantic Fusion of Vibro-Acoustic Sensor Data

The aim of the fusion process in the scenario is to identify the type of vehicles involved in the convoy. Such information is important because it contributes to an understanding of the intent of the convoy. The fact that the fusion process reveals information about the presence of SUVs is significant because it is known that this type of vehicle is used for insurgent activities, and it seems less likely that such vehicles would be involved in humanitarian action. Previous studies have revealed that vehicle type information can be reliably inferred from acoustic data (Xiao et al., 2006); the question is whether semantic information can contribute to the accuracy of these inference outcomes. Can semantic information improve the confidence associated with acoustically-mediated vehicle classification decisions?

The first thing to note in respect of this is that the acoustic profile of a vehicle is not invariant with respect to multiple recording contexts; instead, a variety of factors may influence (at least some) of the features comprising a vehicles acoustic signature. These include (among other things):

1. **Road Surface Type:** much of the sound generated by conventional automobiles derives from the road surface on which it travels. The same vehicle therefore makes different sounds depending on the material of the road surface on which it travels. Vehicles travelling on asphalt road surfaces may be expected to sound somewhat different than vehicles travelling across sand, gravel or concrete surfaces.

2. **Vehicle Speed:** the speed of the vehicle is typically determined by the rate of engine revolutions. This alters the acoustic profile of the engine (and vehicle).

3. **Environmental Context:** the external environment may contribute to the sound profile of an object, e.g. the presence of sound-reflecting surfaces.

To this list I think we can add the characteristics of the sensor device used to acquire acoustic data. Classification accuracy may differ widely if we have microphones with different transduction capabilities, e.g. differences in sensitivity. So, for example, if we have two microphones and one has an upper sensitivity of 15KHz, while the second has an upper sensitivity of 20KHz, then the latter will have greater discriminative ability if the key acoustic differences (from the perspective of classification) between the two sound profiles lies in the 15-20KHz range. If we did not have information about the sensitivity of the various microphones in this case, then we might assume that a vehicle could not be of a particular type simply because some high-frequency component was missing from the spectrogram of the 15KHz microphone. In fact, of course, we know that (relative to the features supporting a discriminative response) the sensor is simply incapable of making a correct classification decision. Here then lies one way in which semantic information may contribute to data fusion outcomes: ontologies can be used to capture contextual information that guides the classification process, informing fusion processors about the discriminative significance of particular features under different observation conditions.

One factor that is important in the context of the current demonstration is nature of the road (its gradient and surface characteristics) in the immediate vicinity of the acoustic sensor array. Road surface type, for example, is important because the P9T2 analysis focuses on the sound generated by vehicles under a limited range of road surface types. As such, if a vehicle (of a particular type) is recorded under the same conditions as those used to derive a classification solution, then we can be reasonably confident in the classification outcome (at least as confident as the classification solution permits). If, however, a vehicle is recorded with respect to a new type of road surface (one not studied under laboratory conditions), then we will only be able to rely on those features of the acoustic profile that are invariant with respect to road surfaces. This will affect (in a typically negative fashion) the certainty associated with the classification outcome. One use of semantic technologies is therefore to provide contextual information about the location of sensors: are they located next to a rock-surface road, a tarmac road or a dirt track. Other factors that may be relevant to the fusion process (at least in the context of the current scenario) are the characteristics of the vibro-acoustic sensors themselves (as derived from sensor ontologies), the proximity of reflective surfaces (contributing to echoic disturbances) and the meteorological conditions in the vicinity of the microphone array (e.g. humidity exerts a frequency dependent attenuation of acoustic energy with high frequencies being absorbed more than low frequencies).

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| **Demonstration Goals** | • Demonstrate the relevance of domain ontologies to data fusion processes.<br>• Demonstrate the use of semantically-enriched representations in improving data fusion outcomes, e.g. improving the confidence of entity classification estimates.<br>• Demonstrate the use of provenance information in supporting data fusion processes. |
| **Resources** | • Data Fusion Ontologies: one or more ontologies to support the process of acoustic data fusion. The contents of the ontologies will, in all likelihood, include information about vehicle types and vehicle characteristics (particularly those that affect the vehicle's acoustic signature), as well as features of the information acquisition context that might affect signal transduction (e.g. road surface type, prevailing meteorological conditions, microphone sensitivity, transfer function characteristics, frequency range, and so on). |
| **Technologies** | • We assume that members of the P9T2 project will take responsibility for the execution of data fusion processes, presumably using a separate application or utility, e.g. MATLAB. There is, therefore, no requirement for P12T1 to engage in any technology development for this phase of the |

| | |
|---|---|
| | scenario; our responsibilities are limited to the provision of ontologies supporting acoustic data fusion. |
| **Actions** | • Acquire or create data fusion ontologies. |
| **External Collaboration** | • Significant collaboration is required with members of the P9T2 team. |
| **Assumptions** | We assume that sufficient data will be provided to P9T2 (by ARL) such that they can investigate the genuine contribution (if any) of domain ontologies to acoustic data fusion processes. We also assume that no action (other than the provision of domain ontologies and associated collaboration) is required by P12T1 team members to support the demonstration of semantically-mediated acoustic data fusion. |

# 5 Phase III: Situation Monitoring

## 5.1 Overview

At this point in the scenario (19/03/2008 10:00) Alpha Force has arrived at the outskirts of Surah-Lam, and three coalition platoons are about to be deployed into the town. From the perspective of technology demonstration, this phase is a precursor to the use of the BF2 simulation environment, which is used to demonstrate the interaction between coalition forces and insurgent groups within Surah-Lam. Our primary aim in this phase is not, as the title of this section suggests, to actually monitor the unfolding situation in Surah-Lam; rather it is to establish the conditions under which specific events and contingencies can be monitored throughout subsequent combat operations. This involves two steps: the identification of 'markers' (e.g. events or situation contingencies) that indicate the overall status of the mission, and the creation of monitoring functions that actually detect the presence of markers from incoming information streams. In some cases, the markers may indicate the failure or invalidation of the current plan and thereby suggest the need for (dynamic) replanning.

What we aim to demonstrate in this phase of the scenario is the way in which an event ontology and a semantic query designer component can be used to specify situation markers deemed relevant to a commander's ongoing awareness of the current situation. To detect such markers, we clearly need a system capable of recording and generating events. In the real world we would assume that such events are captured and reported using military communication networks; however, in the case of the demonstration scenario we have to rely on a simulated environment, namely, the BF2 game environment. Fortunately, BF2 can be instrumented with Python scripts that are capable of capturing all the public events generated by the game. As a result, we can capture the dynamics of player interaction within the game and serialize this information to an RDF stream, pretty much as we would expect to happen in a real-world, semantically-enabled, military network environment. Of course, the range of events capable of being captured from BF2 is not the same as that which we would expect to see in real-world combat situations. In particular, BF2 provides accurate, timely and high-resolution information about the changing status of all battlefield entities – clearly, not something we would expect to find in the real-world. The key purpose of the current demonstration is not, however, to show how semantic technologies contribute to the type or quality of information communicated on a network, it is merely to show that semantic technologies can be used to selectively filter, query and reason with dynamic information streams that provide *at least some* information (whether accurate or inaccurate) about a particular situation[18].

| Phase 3: Situation Monitoring | |
|---|---|
| Military Objectives | • Identify situation contingencies that indicate the overall status of the mission and the need for additional command and control activities (e.g. replanning).<br><br>• Create situation monitors that will alert commanders to the |

[18] The fidelity of BF2-derived information could be deliberately compromised, if required, e.g. we could introduce errors into the BF2 event stream.

| Phase 3: Situation Monitoring | |
|---|---|
| | occurrence of specific battlefield events. |
| Demonstration Goals | • Demonstrate the use of graphical query designers in enabling rapid access to task-relevant information. |
| Timeframe | • 19/03/2008 10:00 |
| Demonstration Activities | • Creation of Situation Monitors (see Section 5.2.1) |

*Table 5-1: Overview of Situation Monitoring Phase*

In summary then, the key focus for technology demonstration in this phase of the scenario is to identify a set of plan-specific information monitoring requirements, e.g. monitoring damage to particular vehicles or injury to particular personnel, and then provide a mechanism for the creation of semantic queries that will execute continuously against the BF2-derived event stream. We will aim to demonstrate a particular semantic query tool in this phase of the scenario, namely the NITELIGHT semantic query editor (Russell et al., 2008).

## 5.2 Demonstration Activities

There is only one technology demonstration activity that need concern P12T1 in this phase of the scenario – it is the creation of semantic queries to support event monitoring in the BF2 game environment. As in Section 3.2, demonstration activities are described with respect to their demonstration goals, dependence on specific resources, need for external collaboration and so on (see Section 3.2) .

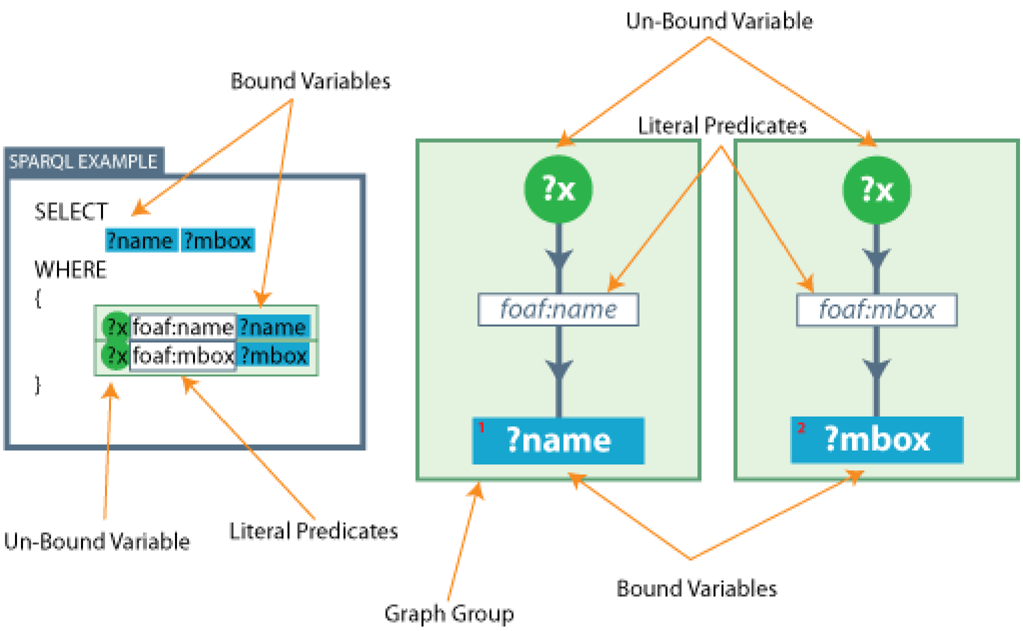


*Figure 5-1: vSPARQL Graphical Notation*

### 5.2.1 Creation of Situation Monitors

As stated above, this activity involves the use of the NITELIGHT semantic query tool to create SPARQL queries using the vSPARQL graphical notation syntax (see Figure 5-1). The queries will be generated with respect to a battlefield event ontology, based on the BF2 event model. Users will be able to browse the ontology and select elements that represent their specific situation monitoring objectives.

| | |
|---|---|
| Demonstration Goals | • Demonstrate the use of graphical query designers in enabling rapid access to task-relevant information. |
| Resources | • BF2 Event Ontology: an ontology describing the events and their associated properties that can be captured from the BF2 game environment. |
| Technologies | • The NITELIGHT semantic query editor is used to construct semantic queries. The queries are used to support the creation of filtered RSS feeds. |
| Actions | • Create BF2 Event Ontology.<br>• Create sample situation monitors using the vSPARQL notation.<br>• Implement a solution to convert query results format to RSS feeds. |
| External Collaboration | • Some collaboration is required with members of the DIF DTC SEMIOTIKS team. |
| Assumptions | None. |

# 6 Phase IV: Combat Operations

## 6.1 Overview

This phase of the scenario sees the entry of coalition forces into Surah-Lam. The BF2 simulation environment is used to demonstrate patterns of troop behaviour and communication as they reconnoitre the town for evidence of insurgent activity. Eventually, the troops encounter insurgent forces and a firefight ensures. In addition to the video and audio feeds providing by BF2 during this phase of the scenario, we see much of the action being serialized to RDF event streams. Such streams provide valuable information about the temporal evolution of the situation picture and the occurrence of specific events.

| Phase 3: Mission Execution | |
|---|---|
| Military Objectives | • Identify enemy positions.<br>• Understand the threat to coalition forces.<br>• Destroy enemy forces.<br>• Minimize civilian causalities. |
| Demonstration Goals | • Demonstrate the value and relevance of semantic technologies to coalition military operations.<br>• Demonstrate the use of graphical query designers in enabling rapid access to task-relevant information. |
| Timeframe | • 19/03/2008 10:00 – 19/03/2008 14:00 |
| Demonstration Activities | • Monitoring of Battlefield 2 Event Streams (see Section 6.2.1) |

*Table 6-1: Overview of Combat Operations Phase*

The technology demonstration goals for P12T1 in this phase of the scenario are relatively straightforward. Having defined the kind of events and contingencies that we need to monitor (see Section 5), we simply need to monitor BF2 RDF event streams and periodically execute semantic queries corresponding to situation monitoring/awareness goals. As discussed in the previous section, such goals are captured by the use of semantic queries created using the vSPARQL graphic notation language and the NITELIGHT query editor tool (see Russell et al., 2008).

## 6.2 Demonstration Activities

There is only one technology demonstration activity that need concern P12T1 in this phase of the scenario – it is the monitoring of BF2 event feeds and the provision of situation-relevant combat information to military commanders. As in Section 3.2, demonstration activities are described with respect to their demonstration goals, dependence on specific resources, need for external collaboration and so on (see Section 3.2) .

### 6.2.1 Monitoring of Battlefield 2 Event Streams

BF2 is a first-person shooter game in which players fight in a virtual battlespace (see Figure 6-1). The game is the focus of considerable attention in the ITA, where it is being used as a research tool to investigate the communicative and coordinative dynamics of team player behaviour. BF2 can be instrumented by means of Python scripts, which allow a degree of interoperation between the game environment and external software components. For example, information about events in the game (e.g. the death of team members, the destruction of vehicles and entry into a particular area) can be captured and made available to external programs (see Masato & Norman, 2007). The ability to access information about events in the game provides a valuable technology demonstration opportunity for P12T1. The aim, in essence, is to capture game events using Python scripts and serialize these to a network-accessible RDF stream. The stream will be processed and presented to the end user in the form of RSS feeds that the user can access using conventional RSS readers. Because the range of possible events that can be captured in this fashion is extremely large, especially when one considers the generation of event streams for each player and vehicle within the game, it will be important to provide a means for end-users to filter incoming RSS feeds. One possibility is to support a taxonomy of feeds that parallels the event typology for the BF2 environment[19]; another is to selectively filter incoming streams using semantic queries. The advantage of this latter, query-based solution is that it provides the end-user with complete control over the way in which incoming event streams are filtered. Users can essentially use the semantic queries as a means of representing their situation monitoring and situation awareness requirements. In addition, because game events are represented in a semantically-enriched format, we can support various forms of semantically-driven analysis or decision support.

[19] http://bf2tech.org/index.php/Event_Reference

*Figure 6-1: Battlefield 2 Screenshots*

| | |
|---|---|
| **Demonstration Goals** | • Demonstrate the value and relevance of semantic technologies to coalition military operations.<br>• Demonstrate the use of graphical query designers in enabling rapid access to task-relevant information. |
| **Resources** | • BF2 Event Ontology: an ontology describing the events and their associated properties that can be captured from the BF2 game environment. |
| **Technologies** | • Python scripts to capture and serialize BF2 events are required. |
| **Actions** | • Create Python scripts to capture and serialize BF2 events. |
| **External Collaboration** | • Some collaboration with members of the Project 10 team is required. |
| **Assumptions** | We assume that is possible to capture game events in a manner that does not deleteriously affect the performance of the game environment. We also assume that P10 will assume primary responsibility for game setup and execution. |

# 7 Summary

This section provides a summary of the demonstration scenario and technology demonstration activities described in this report.

## 7.1 Demonstration Scenario

A comprehensive demonstration scenario is presented in the current report. The scenario is based on an earlier and more general scenario developed by Roberts et al (2007). It involves US and UK coalition forces engaged in humanitarian relief and close combat operations with insurgent forces. Four phases of the scenario are described:

- **Phase I: Mission Planning:** This phase features the occurrence of an earthquake and the emergence of a humanitarian crisis. Coalition forces are enlisted to assist with the humanitarian relief effort, and they begin planning for the distribution of humanitarian aid. This phase of the scenario features the collation, integration and analysis of plan-relevant information as part of the coalition planning process (see Section 3).
- **Phase II: Force Deployment:** This phase sees coalition forces deployed to target settlements in a mountainous region. The largest of the three forces (Alpha Force) comes under heavy fire whilst en route to the target settlement of Surah-Lam. The phase features the analysis of acoustic sensor data as part of a semantically-mediated data fusion process (see Section 4).
- **Phase III: Situation Monitoring:** This phase entails the specification of situation monitors to monitor incoming information streams for operationally-significant information (see Section 5).
- **Phase IV: Combat Operations:** This phase features the use of Python scripts to capture event streams from the BF2 game environment. The event streams are serialized to RDF, and the end-user is alerted to the presence of significant events (as defined by the aforementioned situation monitors) using filtered RSS feeds (see Section 6).

## 7.2 Demonstration Activities

A number of demonstration activities are presented throughout this report. Table 7-1 provides a brief review of these activities.

| Activity | Description |
|---|---|
| Retrieval of Meteorological Information | This activity demonstrates the use of ontologies and semantic queries to retrieve meteorological information from at least two separate information sources. The information sources are assumed to use different ontologies, and this requires the use of a semantic integration solution to combine meteorological data. Semantic queries are created using a graphical editor that supports novice users with respect to the retrieval of task-relevant information. |

| Activity | Description |
|---|---|
| Retrieval of Mine/IED Hazard Information | This activity demonstrates the use of natural language interfaces in accessing information about mine hazard regions and IED attacks on coalition forces. The activity uses ontologies for both demining and IED incidents, and it exploits a tool that serializes natural language expressions into SPARQL semantic queries. |
| Semantic Integration of Sensor Ontologies | This activity demonstrates the integration of information about coalition sensor systems as part of a sensor-to-mission matchmaking process. The activity exploits an ontology alignment solution between multiple sensor ontologies. It also utilizes the portable ontology alignment solution being developed as part of P12T1. |
| Semantic Fusion of Vibro-Acoustic Sensor Data | This activity demonstrates the contribution of semantic information (in the form of domain ontologies) to acoustic data fusion processes. The aim is to develop data fusion ontologies that support the acoustically-mediated vehicle classification solutions being developed by P9T2. |
| Creation of Situation Monitors | This activity demonstrates the use of a graphical query editor to create monitoring functions that alert coalition commanders about the occurrence of operationally-significant events in the combat phase of the scenario. Situation monitors are defined in terms of a BF2 event ontology that describes the type of events that can be captured from the BF2 simulation environment. |
| Monitoring of Battlefield 2 Event Streams | This activity demonstrates the execution of situation monitors and the filtering of BF2 event streams. Information about events captured from the BF2 simulation environment are posted to a network-accessible RDF stream and then filtered according to a commander's situation monitoring requirements. Filtered event streams are presented to commanders in the form of an RSS feed. |

*Table 7-1: Technology Demonstration Activities*

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# Appendix A Acronyms & Abbreviations

| | |
|---|---|
| AoI | Area of Interest |
| ARL | Army Research Laboratory |
| BF2 | Battlefield 2 |
| BPP | Biennial Program Plan |
| CAS | Close Air Support |
| DIF | Data and Information Fusion |
| DTC | Defence Technology Centre |
| EOD | Explosive Ordnance Disposal |
| ES | Electronic Support |
| HQ | Headquarters |
| ICRC | International Committee of the Red Cross |
| IDP | Internally Displaced Person |
| IED | Improvised Explosive Device |
| ISR | Intelligence, Surveillance and Reconnaissance |
| ISS | Integrated Sensor System |
| ITA | International Technology Alliance |
| KML | Keyhole Markup Language |
| MOOTW | Military Operations Other Than War |
| MSF | Médecin Sans Frontières |

| | |
|---|---|
| POAF | Portable Ontology Aligned Fragments |
| RDF | Resource Description Framework |
| RPG | Rocket-Propelled Grenade |
| RSS | RDF Site Summary |
| SAR | Search And Rescue |
| SEMIOTIKS | SEMantically-enhanced InformatiOn exTraction for Improved Knowledge Superiority |
| SPARQL | Simple Protocol and RDF Query Language |
| SUV | Sports Utility Vehicle |
| TCDL | Tactical Common Data Link |
| TDS | Technical Demonstrator System |
| UAV | Unmanned Aerial Vehicle |
| UHF | Ultra High Frequency |
| UN | United Nations |
| UNHCR | United Nations High Commissioner for Refugees |
| VHF | Very High Frequency |
| WFP | World Food Programme |
| WWW | World Wide Web |
| XML | eXtensible Markup Language |