

NAVSEA
Naval Surface Warfare Center
110 Vernon Avenue
Panama City, FL 32407

Design Description For Team-Based Execution of Autonomous Missions (TEAM), Spiral 1

CDRL A002,
Contract No: N00014-08-C-0142
November 18, 2008



Lockheed Martin Systems Integration
Owego, New York

Distribution Statement A

- a. This statement may be used only on unclassified technical documents that have been cleared for public release by competent authority in accordance with DOD Directive 5230.9. Technical documents resulting from contracted fundamental research efforts will normally be assigned Distribution Statement A, except for those rare and exceptional circumstances where there is a high likelihood of disclosing performance characteristics of military systems, or of manufacturing technologies that are unique and critical to Defense, and agreement on this situation has been recorded in the contract or grant.
- b. Technical documents with this statement may be made available or sold to the public and foreign nationals, companies, and governments, including adversary governments, and may be exported.
- c. This statement may not be used on technical documents that formerly were classified unless such documents are cleared for public release in accordance with DoD Directive 5230.9.
- d. This statement shall not be used on classified technical documents or documents containing export-controlled technical data as provided in DoD Directive 5230.25.

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 18 NOV 2008		2. REPORT TYPE		3. DATES COVERED 00-00-2008 to 00-00-2008	
4. TITLE AND SUBTITLE Design Description for Team-Based Execution of Autonomous Missions (TEAM), Spiral 1				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Lockheed Martin Systems Integration,Owego,NY				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 40	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

Lockheed Martin Systems Integration – Owego
1801 State Route 17C Owego, NY 13827-3998
Telephone 607-751-2000



In Reply Refer To: 2008-ONRTEAM-0008

13 November 2008

NAVSEA Naval Surface Warfare Center
110 Vernon Avenue
Panama City, FL 32407

Attention: James S. Taylor, Program Officer

Subject: CDRL A002, Contract Data Requirements List (CDRL), Description Design
Contract No. N00014-08-C-0142

The enclosed data is submitted in accordance with the Contract Data Requirements List (CDRL):

CDRL Information:

-	CDRL:	A002
-	Data Item Title:	Description Design

Enclosed please find the subject CDRL submittal. Consistent with contract requirements, this submittal is being made electronically. An updated submittal to this requirement will be made during Spiral 2.

Any technical questions concerning this submittal should be directed to John Deopuria at (607) 751-3667 or via e-mail at john.deopuria@lmco.com.

Any other questions should be directed to the undersigned at (607) 751-2919, fax at (607) 751-3910 or via e-mail at Bob.Rieg@lmco.com.

Sincerely,

A handwritten signature in black ink, appearing to read "Robert B. Rieg".

Robert B. Rieg
Contracts

RBR/dlg

Enclosure: Design Description, dated 13 November 2008

cc:	Mr. K. Wallace	DCMA/ACO	(Letter only)
	Ms. N. Kochinsky	Owego/0532	
	Mr. J. Deopuria	Owego/0902	
	Director, Naval Research Lab	Washington, DC	
	DTIC	Ft. Belvoir, VA	(1 CD)

Title: Design Description For Team-Based Execution Of Autonomous
Missions (TEAM), Spiral 1



Doc. #:
Version: 1.0
Date: November 18, 2008

Change History			
Date	Version	Change Summary	
14 NOV 2008	1.0	Initial draft version	

Table of Contents

1	Introduction	5
1.1	Objective.....	5
1.2	Program Overview.....	5
2	References.....	7
3	Design Description.....	8
3.1	Context	8
3.2	Architecture.....	9
3.3	Software Component Descriptions.....	12
3.4	Service Descriptions.....	15
3.5	Data Models and Management	17
3.6	Behaviors.....	18
3.7	Simulation Environment.....	37
	Glossary	38

Table of Figures

Figure 1 Management of Manned and Unmanned Assets in Teams	6
Figure 2 Context of TEAM with other LCS and Mine Hunting Components.....	8
Figure 3 Example Service Composition.....	9
Figure 4 Example Simple Workflow	10
Figure 5 Representative TEAM and Supporting Services	11
Figure 6 Integration Infrastructure.....	12
Figure 7 Collaborative Mission Planning Overview	13
Figure 8 Contingency Management Overview.....	14
Figure 9 HMI Context.....	15
Figure 10 UCORE Based Data Hierarchy	18
Figure 10 Use Case Diagram	19
Figure 11 Mission Change Activity Diagram.....	21
Figure 12 Review Mission Activity Diagram.....	23
Figure 13 Representative Review Mission Screenshot.....	24
Figure 14 Schedule Tasks Activity Diagram	26
Figure 15 Review Task Schedule Activity Diagram	28
Figure 16 Representative Review Schedule Screenshot	29
Figure 17 Plan Routes Activity Diagram	31
Figure 18 Review Mission Plan Activity Diagram	33
Figure 19 Representative Route Review Screenshot.....	34
Figure 20 Review Assets Activity Diagram	36
Figure 21 Representative Screenshot (Focus on Asset Display).....	36
Figure 22 Data Model Overview	37
Figure 23 Simulation Environment.....	37

1 Introduction

1.1 Objective

The Design Description for the TEAM program describes the structure and behavior of the components in the system and their interrelationships and principles. The TEAM program is broken into two spirals. This document describes the design for Spiral 1, which focuses on mission planning. Spiral 2 focuses on mission execution. The design will also be updated in Spiral 2 and there will be revisions to this document.

1.2 Program Overview

1.2.1 Background

The improvised explosive devices in land warfare serve as a reminder of the asymmetric threat posed by mines in general. The sea lines of communication are threatened by mines just as land lines. In addition, adversaries can deny forces entry to coastal regions. These regions are often in the littorals requiring shallow draft vessels to defend them. To face this threat, the new Littoral Combat Ship (LCS) will be able to be equipped with a mine countermeasures (MCM) mission module.

Like the land mine problem, the sea mine problem is a difficult one. Mines can be found in various regions of the water column, and these regions present different challenges to the tasks of searching for and neutralizing mines. As such, various assets are utilized in these challenges, air and sea, manned and unmanned.

Currently there is minimal coordination between air and sea assets and between manned and unmanned assets. Yet these assets play vital and complementary roles in the MCM problem. What coordination there is takes place in between sorties. This means that they cannot compensate for contingencies that take place during sorties. This may lead to losses in mission effectiveness.

Furthermore, each asset has its own command and control systems and personnel with specialized skills. This can lead to inefficiencies in the already challenging workload aboard the LCS.

Lockheed Martin performed preliminary analyses of improvements in mission performance by employing the TEAM concepts. In those analyses, there was a substantial reduction in time to first neutralization utilizing 2 unmanned vehicles and a manned helicopter versus a helicopter independently. Furthermore, the analysis of multiple helicopters teaming for an upper water column mission showed a substantial reduction in time to first neutralization and a substantial increase in the number of mines neutralized. The analyses also indicated a potential decrease in workload through the use of common command and control enabling better load balancing across operators.

In these analyses, various simplifying assumptions were made. If, however, even a fraction of the improvements indicated can be realized, this represents a great opportunity for improving mission effectiveness in the MCM mission. Although this effort is currently limited to a single LCS, the analyses indicate greater improvements with multiple LCSs.

1.2.2 Program Description

One of the critical issues for Mine Countermeasures (MCM) missions aboard the LCS is the simultaneous management of multi-vehicle (both manned and unmanned) teams. Optimizing tactical performance of a limited crew by reducing workload requirements across all mission phases (pre-launch, launch, transit to operations area, execution, recovery, and post-recovery) is currently not feasible since each platform generally maintains its own management and control solution (a *vehicle-centric* approach). Two key methods to reduce LCS MCM workload through advanced mission management technologies are: (1) Increase the autonomy of specific tasks currently done by human operators, and (2) Standardize mission management functions across all vehicle types and mission segments to reduce the need for skill

specialization. As such, the main objective to meet the requirements of future LCS missions is to change from a *vehicle-centric* to a *mission-centric* paradigm (Figure 1).

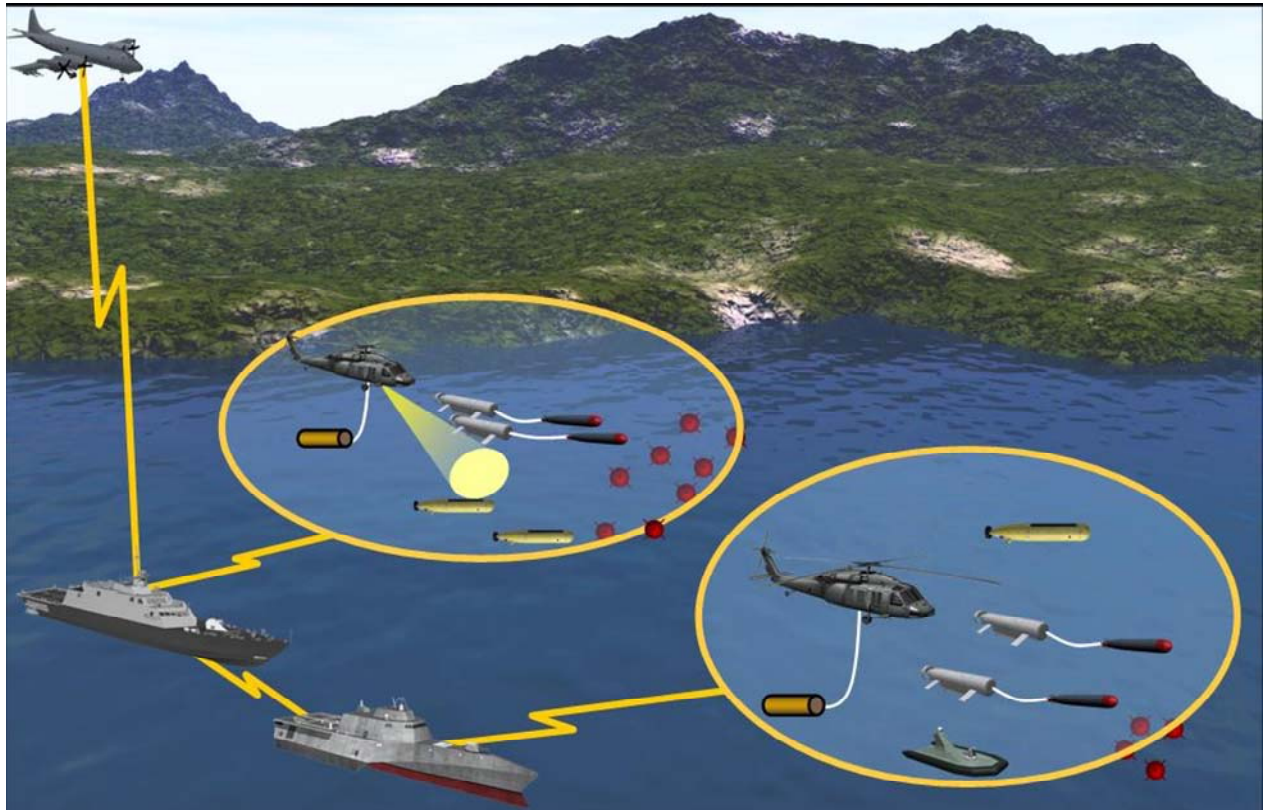


Figure 1 Management of Manned and Unmanned Assets in Teams

Mission centric planning means optimizing over multiple vehicles and multiple objectives. Automated decision aids are helpful in this. Mission centric execution means doing so during mission execution. Automated decision aids are essential for this.

Mission execution includes replanning in the face of the unexpected. Loss of subsystems or entire assets, discoveries about the environment and enemy actions can break the best plan. TEAM seeks to recover from these by incorporating the mission planning process in the mission monitoring process transforming it from a passive to an active process.

The objective of this phase of the TEAM program is to demonstrate technologies that can plan and execute mine countermeasures missions using the various assets available to it. TEAM seeks to combine these technologies using an open standard methodology to enhance configurability and extensibility. Finally, it seeks to plan the transition of these technologies to the fleet.

2 References

<u>Reference Number</u>	<u>Reference Name</u>
ISO 19136	Geography Markup Language (GML) 3.2.1
	Universal Core (UCORE) 1.0

3 Design Description

3.1 Context

TEAM exists in the context of other LCS and mine hunting components. These are illustrated in Figure 2.

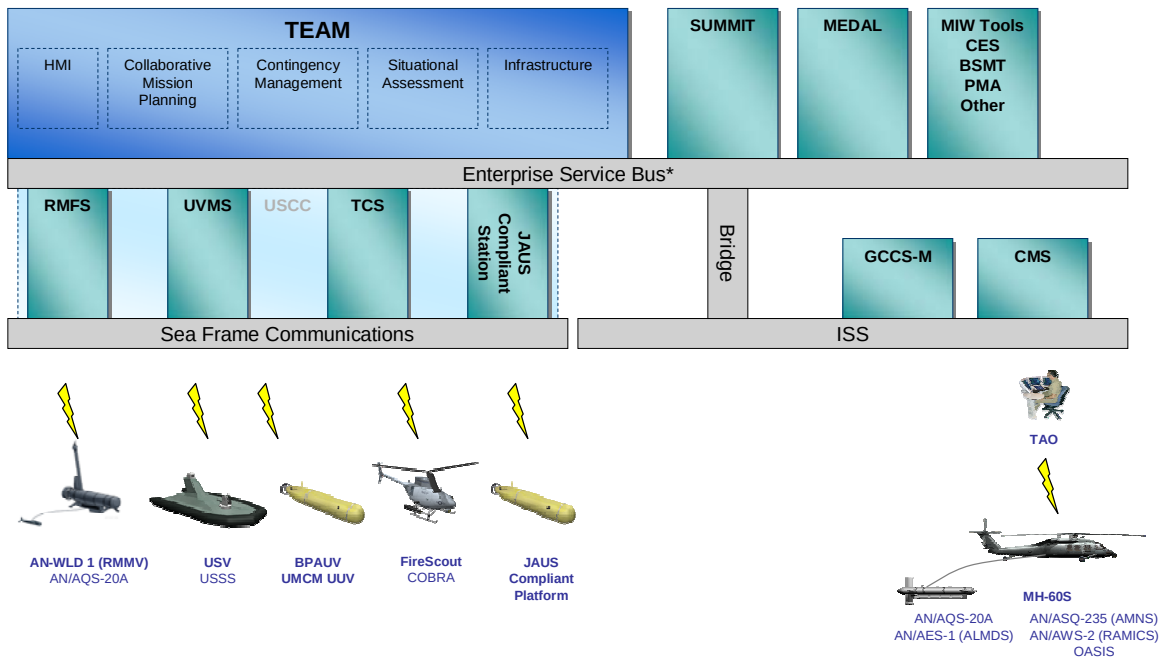


Figure 2 Context of TEAM with other LCS and Mine Hunting Components

Like the land mine problem, the sea mine problem is a difficult one. Mines can be found in various regions of the water column, and these regions present different challenges to the tasks of searching for and neutralizing mines. As such, various assets are utilized in these challenges. The MH-60S is a key platform in the MCM challenge and will be utilized on the LCS. The Airborne Mine Countermeasures (AMCM) program is implementing the employment of five MCM systems, the AQS-20A towed sonar array, the Airborne Laser Mine Detection System (ALMDS), the Airborne Mine Neutralization System (AMNS), the Rapid Airborne Mine Clearance System (RAMICS), and the Organic Airborne and Surface Influence Sweep (OASIS), on the MH-60S.

In addition, there are various surface and subsurface unmanned vehicles deployed or in development to address this problem. Of particular note is the Remote Minehunting System (RMS), the AN/WLD-1(V)1, featuring the Remote Multi-Mission Vehicle (RMMV), a semisubmersible unmanned vehicle capable of towing a variable depth sonar (VDS), the AN/AQS-20. There is also the Battle space Preparation Unmanned Autonomous Vehicle (BPAUV) and the Vertical Take-off and landing Unmanned Aerial Vehicle (VTUAV).

Analysis of the battle space and planning the MCM missions is performed with the assistance of the Mine Warfare and Environmental Decision Aids Library (MEDAL). Missions for the various assets are generated and distributed to them for detailed mission planning. After hunting missions have been

completed, data is collected for post mission analysis (PMA) after which MEDAL is utilized to generate new missions, searching, identifying, neutralizing, or sweeping.

Furthermore, programs under development, like Supervision of Unmanned Mission Management by Interactive Teams (SUMMIT) and Commander's Estimate of the Situation (CES) can provide benefit to and can benefit from TEAM capabilities.

TEAM infrastructure and services are targeted to be part of the next generation MCM ecosystem. The services and planning capability provide a solid foundation upon which future mission capability can be built.

3.2 Architecture

3.2.1 Approach

In general, TEAM's architecture is Service Oriented Architecture (SOA). Newly developed code, legacy code, third party code, and future code can be wrapped by service interfaces (Integration Application Programming Interface [API]) that communicate via a service bus. This is illustrated in Figure 3.

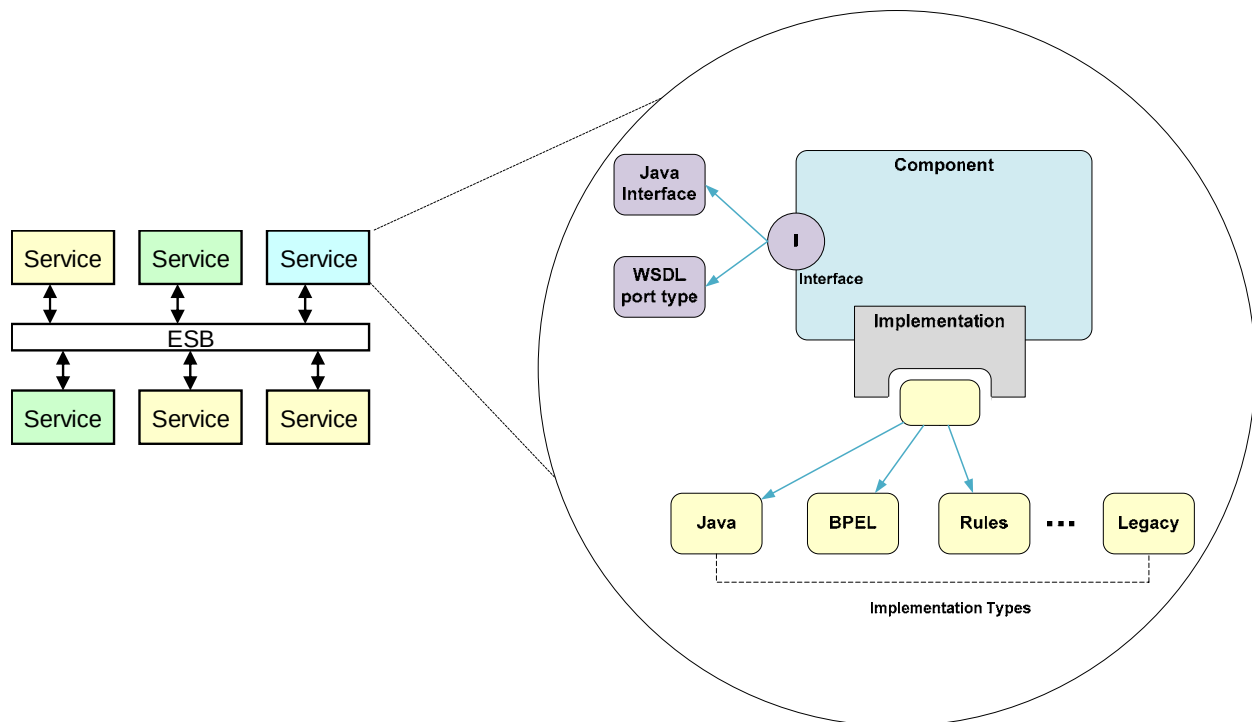


Figure 3 Example Service Composition

These services in their simplest form are quite useful, but their real power is revealed when they can be used to perform more-complex processes. Work has been under way for years to develop the technologies and standards that would support such a requirement. BPEL has emerged as the de-facto

standard. Where appropriate mission processes are represented as BPEL-compliant processes in TEAM. These processes emphasize orchestration of services whereas the services provide atomic functions.

Figure 4 shows a simple example workflow where an application sends data to a service, which performs a function and then sends processed data to the same or other application. In addition, the application may be an aggregate service, a service consisting of other services, a construct for many applications that provides convenience without disrupting reusability and configurability of the constituent services.

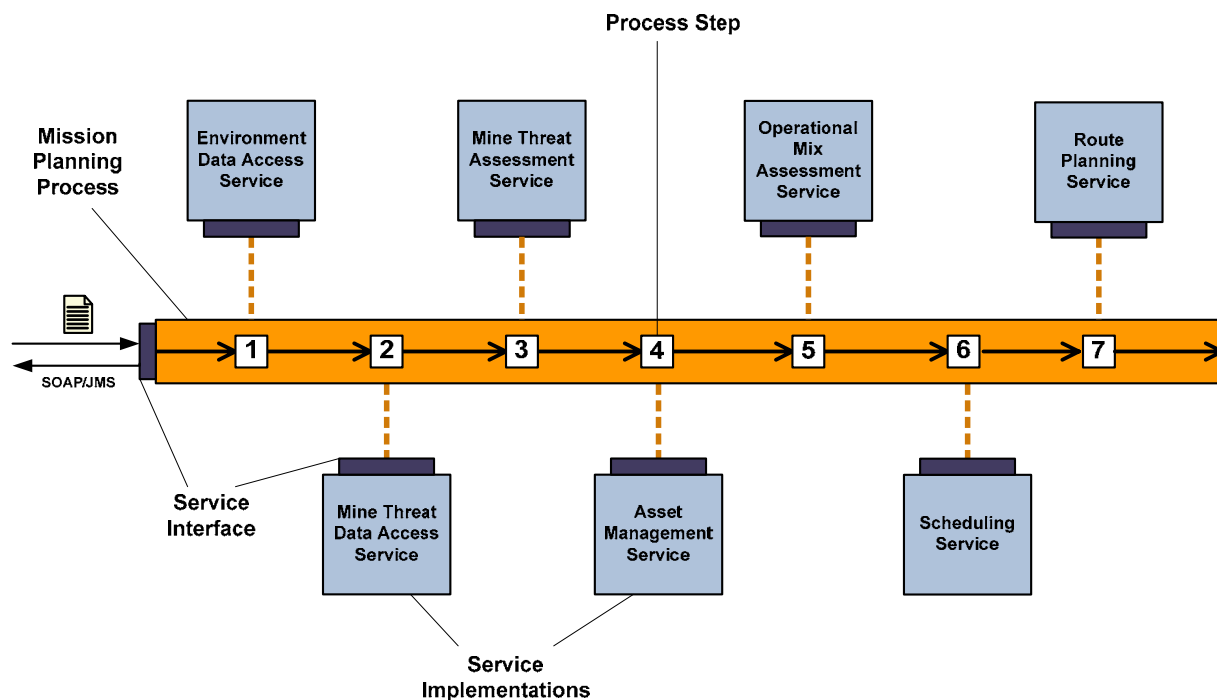


Figure 4 Example Simple Workflow

This approach is applied to the context of Figure 2 in a demonstration environment and Figure 5 emerges. In Figure 5 TEAM is divided into groups of services for convenience. Note that Figure 5 shows the grand vision for the entire program and beyond, not limited to Spiral 1. As a result, not all services shown are described later in this document. For example, the MEDAL services are displayed as they are expected from the forthcoming MEDAL EA effort. This, too, is beyond the scope of this work, but is included here as an example. Spiral 1 focuses on mission planning, so services in the Collaborative Mission Planning section as well as the Human Machine Interface (HMI) are described.

In Figure 5, the supporting services shown below the Enterprise Service Bus are not part of TEAM. These services are used to provide the necessary infrastructure to support the TEAM. For example, vehicle and sensor services provide handles to avatars in the demonstration environment. While these might become handles to vehicles in a deployed system, this is beyond the scope of this work.

The enterprise service bus itself is not part of the system per se. While an ESB is used to demonstrate TEAM services, no assumption is made that this is the service that will forever be used. It is intentionally

so to force compliance to standards. It also enables the government to utilize the ESB of its choice. While this is unlikely to result in zero effort to accommodate, the effort is anticipated to be much lower than if TEAM were tightly coupled to a particular ESB.

The MEDAL services are displayed as they are expected from the forthcoming MEDAL EA effort. While this is not part of this effort, it is targeted to be accommodated. Furthermore, other efforts are shown as able to expand, but such expansion is beyond scope.

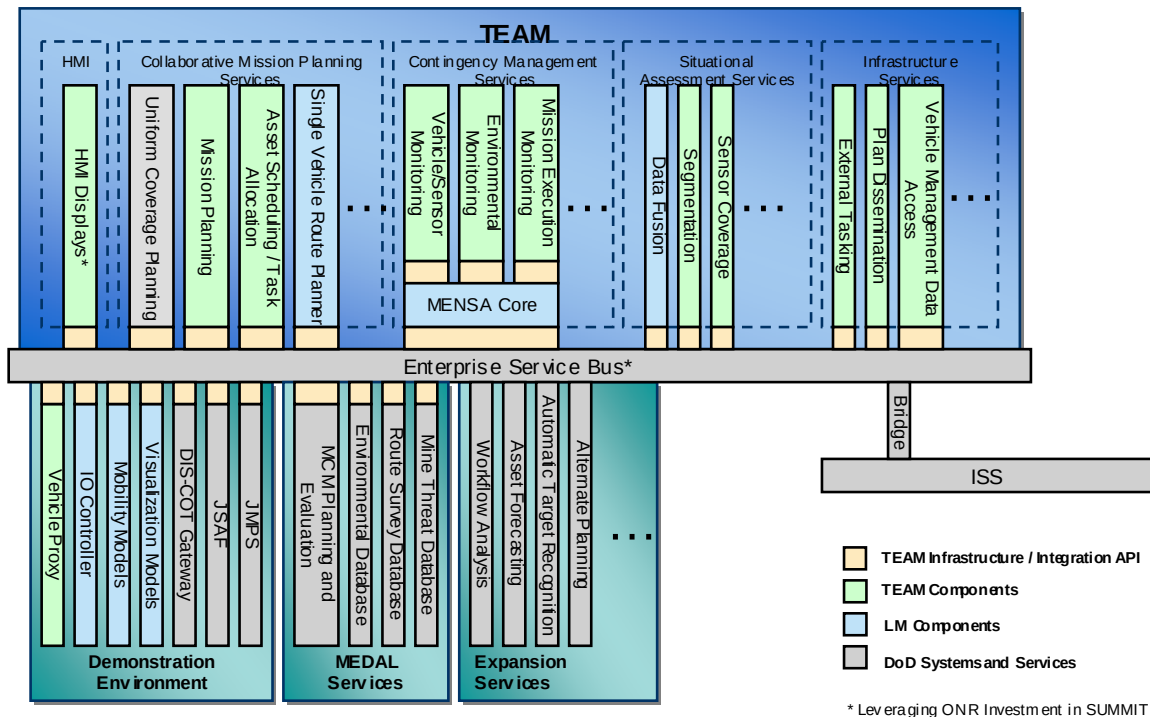


Figure 5 Representative TEAM and Supporting Services

3.2.2 Integration Infrastructure

This infrastructure in Figure 6 enables the integration of services through the introduction of a reliable set of capabilities, such as intelligent routing of data and control flow, protocol mediation so that services need not implement the details of the protocol, rules management to ease configurability and tailoring of logic, and process engine to make to whole system come together.

The use of third party, standards-based software facilitates openness. This openness enables future users can substitute other developed or third party solutions to suit their needs.

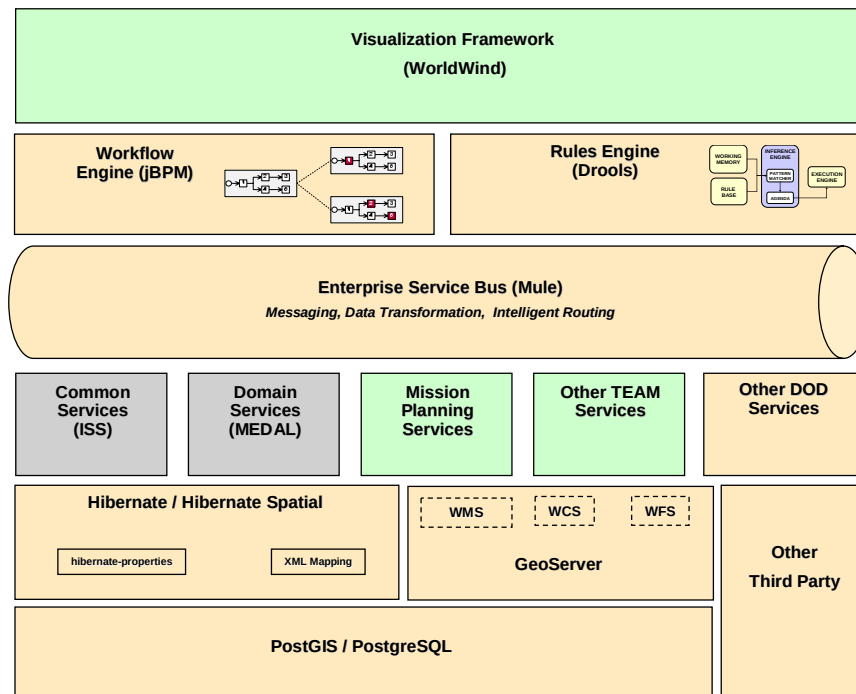


Figure 6 Integration Infrastructure

While the ESB is beyond the scope of the TEAM program, the Mule[®] service bus is utilized as a reference bus in lieu of a government selected bus. In addition to Mule[®], a number of open source solutions are also utilized as references in place of government selected solutions. Neither these nor Mule[®] are deliverable, but the government may opt to use them if it so chooses. jBPM, java Business Process Management, is used as a reference workflow engine. This provides a programmatic method for design and execution of workflows. Data is managed using PostgreSQL with PostGIS providing geographic data management on top of it. GeoServer is an open source service for publishing and editing georeferenced data providing Web Map Service (WMS), Web Coverage Service (WCS), and Web Feature Service (WFS). Because these interfaces are not always necessary and desirable, Hibernate/Hibernate Spatial is also used for providing these data. Finally, Drools is targeted as the rules engine.

By embracing open standards (such as JSR-94, a rules engine API, and UCORE, a data format standard already embraced by some government agencies) and not assuming a particular solution, the program intends to be compatible with whatever solutions the government brings to bear for these issues. In addition, it facilitates additional functional solutions the government chooses to use in the future.

3.3 Software Component Descriptions

3.3.1 Collaborative Mission Planning

Collaborative mission planning is tasked with converting mission objectives into an actionable plan across team assets. It takes geometry and performance parameters from MEDAL and decomposes those into tasks to be performed by available individual vehicles. For example, TEAM might be issued a bottom

mine hunt task in area A and a neutralization task for surface targets Mike-1, and Mike-2 also in area A. In this case, tracks for RMMV uniform coverage might be developed and divided into one set of tracks for each RMMV, while neutralization tasks (transit, reacquire, neutralize) might be developed for the MH-60S. The MH-60S might even be assigned tasks to refit with AQS-20 and some of the hunt tracks. The tracks might be scheduled to perform those most distant from Mike-1 and Mike-2 first in order to minimize risk to the assets. Accounting for the vehicles' characteristics (e.g. effective at needed depth) and the operating parameters, it then schedules those tasks to the vehicles performing them. Given that schedule and the vehicles' mobility parameters, it then generates routes for the vehicles. Figure 7 shows an overview of the data flow and centers of processing that are used to accomplish this.

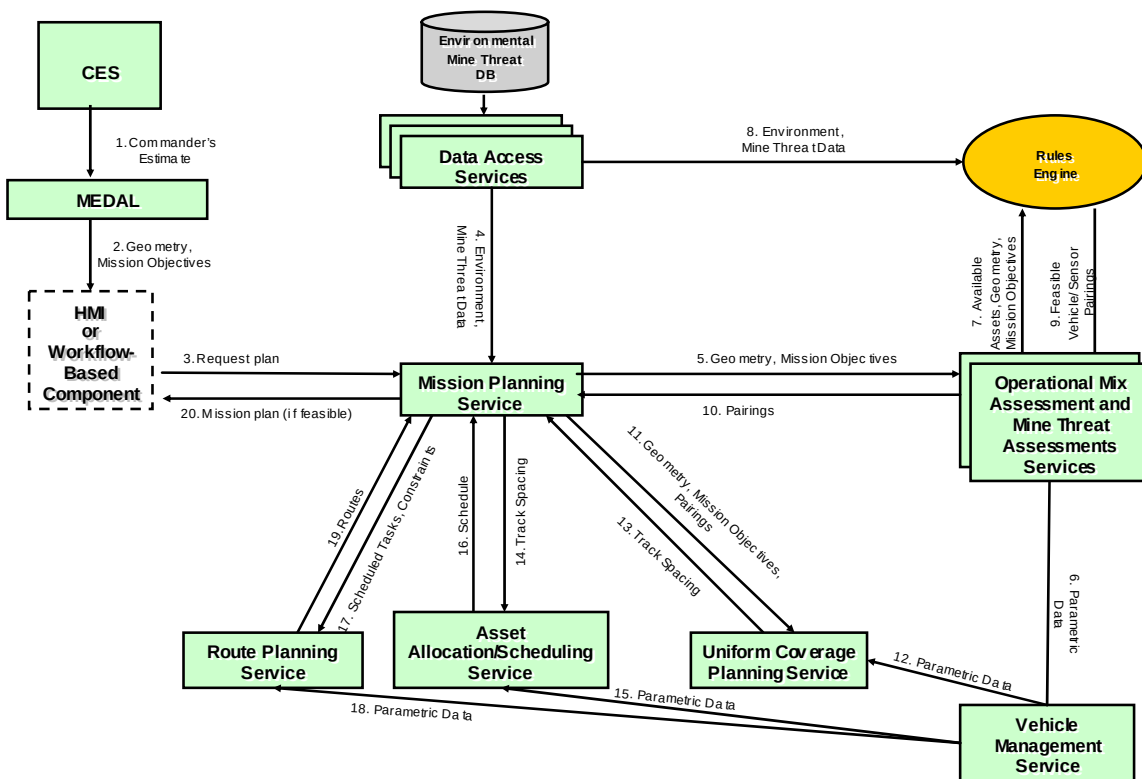


Figure 7 Collaborative Mission Planning Overview

3.3.2 Contingency Management

Contingency Management's task is to monitor the situation and the progress of the mission and decide when a plan modification is necessary. Most of this functionality is utilized in Spiral 2, but it is important to consider the approach during Spiral 1.

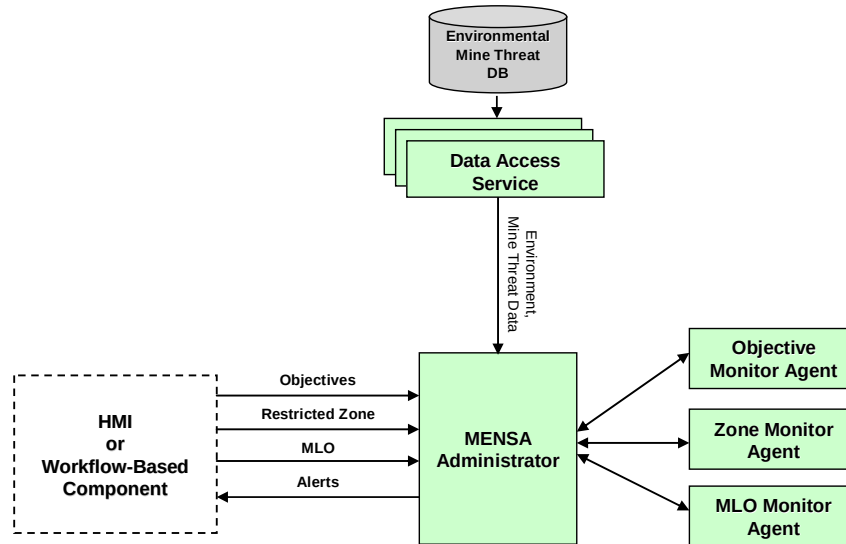


Figure 8 Contingency Management Overview

3.3.3 Human Machine Interface

The Human Machine Interface (HMI) serves as the exclusive interaction with the operator. It provides a tactical situation display on which geographic information appears. Overlaid on the tactical situation display appear objective geometries and routes. Also appearing in the HMI is information on the available vehicles and scheduling information on tasks. From here the operator has the ability to display information on these items and the ability to accept or edit data such as waypoints.

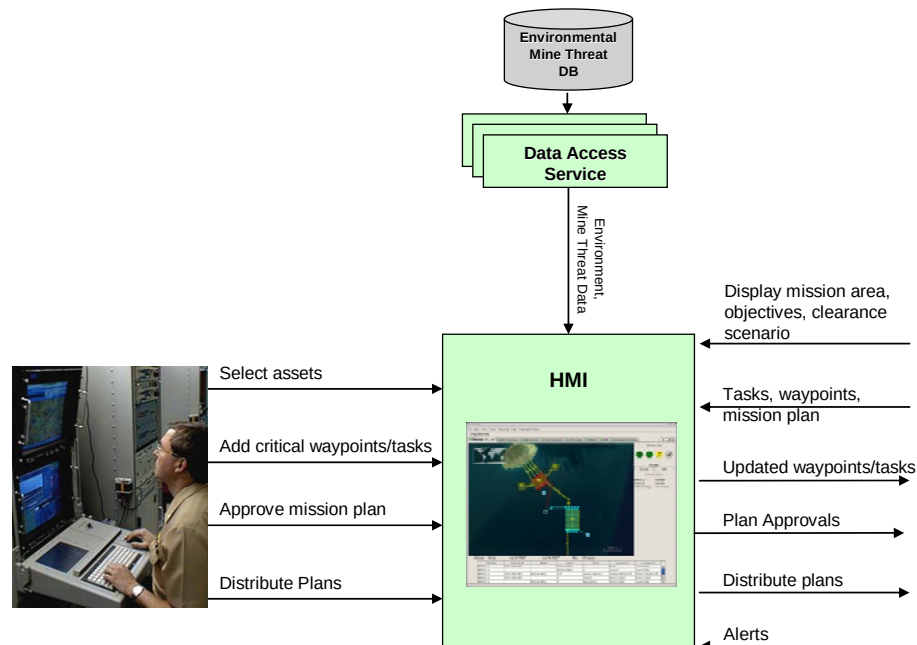


Figure 9 HMI Context

3.3.4 Situational Assessment

Situational Assessment is deferred to Spiral 2.

3.4 Service Descriptions

3.4.1 Asset Allocation/Scheduling Service

This service assigns assets to tasks and schedules those tasks for the assets. It takes a mission specification and decomposes it into task specifications. Continuing the previous example, given two RMMVs and a MH-60S each with an AQS-20, the tracks might be allocated evenly across those vehicles, allocated according to their endurance and speed capabilities, or allocated to the RMMVs with the MH-60S held in reserve with a neutralizer package.

It assigns and schedules tasks to assets, adding deconfliction constraints to the tasks specifications and applying task templates as appropriate. Continuing the example, an AQS-20 search task may require an alignment task preceding and following it constituting additional scheduling constraints. In addition, the first such task may require a streaming task preceding the alignment task and the last such task a sensor recovery task following the alignment task. These tasks would be added to the hunt task scheduled to proceed and follow it.

Deconfliction constraint examples include ensuring that search tasks by one vehicle maintain a standoff distance from a neutralization task and ensuring that transit tasks by two different vehicles be separated

temporally. Thus, in the example, RMMV 1 might be launched a period of time before RMMV 2 to ensure a minimum separation in space. In addition, its first track might be the track most distant from RMMV 2's first track. In contrast, there need be no delay between RMMV 1's launch and MH-60's launch because there is no risk of collision.

3.4.2 Environmental Data Access Service

This service maintains information about environmental data. This is represented as gridded data. Data can be requested at a specified point or a specified grid. Supported data types are bottom depth and bottom type. Data may not be available for some or all of these types and a subset of the requested region. If the data are available, they are returned for the requested region.

3.4.3 External Tasking Translator

This serves as the interface to tasking applications beyond the system boundary. In particular, this is intended to receive MEDAL information and convert it to the internal representation, decoupling the external tasking representations from the internal representation.

3.4.4 Human Machine Interface

The Human Machine Interface (HMI) provides the sole interaction with operators. It displays environmental data. Supported environmental data include bathymetry and bottom type. It displays mission objective geometry and accepts operator changes to it. It displays vehicle status information. It displays task schedule information and accepts operator changes to the tasks. Supported changes include vehicle assignment. It displays vehicle route information and accepts operator changes to it. Supported changes include waypoint addition, deletion, or movement. It also displays alerts when a plan is infeasible, when the mission objectives cannot be achieved with the assets available, when the task schedule is infeasible, when the routes are infeasible.

3.4.5 Image/Video Service

This service manages collections of images and video. For demonstration purposes, this provides simulated snippets and video for viewing by the operator. In a deployed system, it might be used for reference materials or to review previously collected images or video. This service is a Spiral 2 artifact.

3.4.6 MENSA Administrator

Mission Effectiveness and Safety Assessment (MENSA) is a legacy system for monitoring and assessing situation data. The MENSA Administrator offers a framework for an extensible set of monitoring and assessment agents.

3.4.6.1 Objective Monitor Agent

This function monitors changes in mission objectives and determines when the plan needs to be changed to accomplish the given objectives.

3.4.7 Mine Contact Data Access Service

This service accepts, manages and provides data on contacts. Contacts are spot reports of entities that may or may not be objects of interest. In particular, they may be mine like echo contacts (MILECs), mine like objects (MILCOs), or mines of different types.

The service definition provides for operations for requesting all contacts in a specified region and for a specific contact. In addition, they are made available through publish/subscribe. Furthermore, it provides operations for adding and modifying contacts.

3.4.8 Mine Threat Assessment Service

This service maintains data about mine threats. This is not information about a particular mine or mine like object, but information about a type of mine. Supported information includes operating characteristics such as minimum and maximum case depth, physical characteristics such as mine case size and shape, countermeasures type, and mine class. The service provides these data, if available, upon request.

3.4.9 Mission Planning Service

This service is a composite service that guides data through other services. In particular, this takes mission objectives and guides them through the task scheduling and route planning services to produce comprehensive mission plans.

3.4.10 Operational Mix Assessment Service

This service finds the feasible vehicle/task pairings. It takes in objectives and an available vehicle list with asset capabilities and matches vehicles to objectives.

3.4.11 Plan Dissemination Service

This service provides plans to interested parties beyond the system boundaries, decoupling those parties' plan representations from the internal plan representation. It provides Common Route Definition format documents for use by JMPS and vehicle formats for dissemination to vehicles. For demonstration purposes, this is a simple interface. In a deployed system, this might be a JAUS compliant interface. While this service is a Spiral 2 artifact, it is useful to consider in Spiral 1 design.

3.4.12 Vehicle State Data Access Service

This service maintains status information about assets. The information schema is an extension of UCORE, leveraging many of the data structures defined there. It extends UCORE by adding information about subsystems such as engines and optional sensors or neutralizers. The service provides these data, if available, upon request. In the future, the information will be updated based on communications from the assets.

3.4.13 Route Planning Service

This service plans routes between scheduled tasks for an asset. It respects spatial and temporal constraints in the given task specifications and the performance capabilities of the given asset.

3.4.14 Track Service

This service maintains information on objects in the battle space. These include friendly, unfriendly, unaffiliated, and obstacle objects. The service provides these data, if available, upon request.

3.4.15 Uniform Coverage Planning Service

This service decomposes mission-level objectives into tasks to be performed by assets. For example, an objective to hunt in a given area of mines to a given clearance level might be decomposed into a number of tracks to be traversed by an AQS-20 sensor at given speed and depth. It wraps the legacy UCPLAN functionality.

3.4.16 Vehicle Class Data Access Service

This service maintains information about assets. This is not state data, but rather static performance data such as maximum speed. It also includes information about what subsystems can be employed by the asset. The service provides these data, if available, upon request.

3.4.17 Vehicle Management Service

This service maintains information on what vehicles (not vehicle classes) are available.

3.5 Data Models and Management

TEAM leverages community of interest and industry adopted schemas.

It is based on UCORE, a universal core data schema that enables information sharing with ways to describe "what, when, where, who" types of information using a minimal set of terms in the core, agreed to by DoD and intelligence community and extensible by communities of interest and systems as needed.

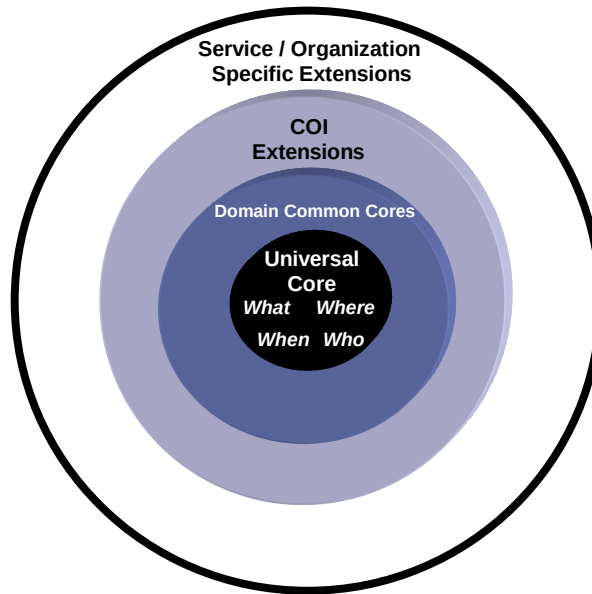


Figure 10 UCORE Based Data Hierarchy

UCORE makes heavy use of other common standards, including Geography Markup Language (GML), a XML grammar defined by Open Geospatial Consortium, Inc. ® (OGC) to express geographical features used for representing geospatial data as well as an interchange for format for that data.

3.6 Behaviors

This section describes the behaviors of the TEAM system for the Spiral 1 demonstration.

3.6.1 Use Cases

Use cases are a useful way of describing the fundamental ways in which a system interacts with its users and environment. Figure 11 shows the use cases identified for Spiral 1. There is at least one activity diagram associated with each use case in the following sections.

Activity diagrams are a useful tool for showing behavior between and within system components. Each swim lane in an activity diagram represents a component in the system and each line between swim lanes represents an interface. Otherwise, they look much like convention flow charts.

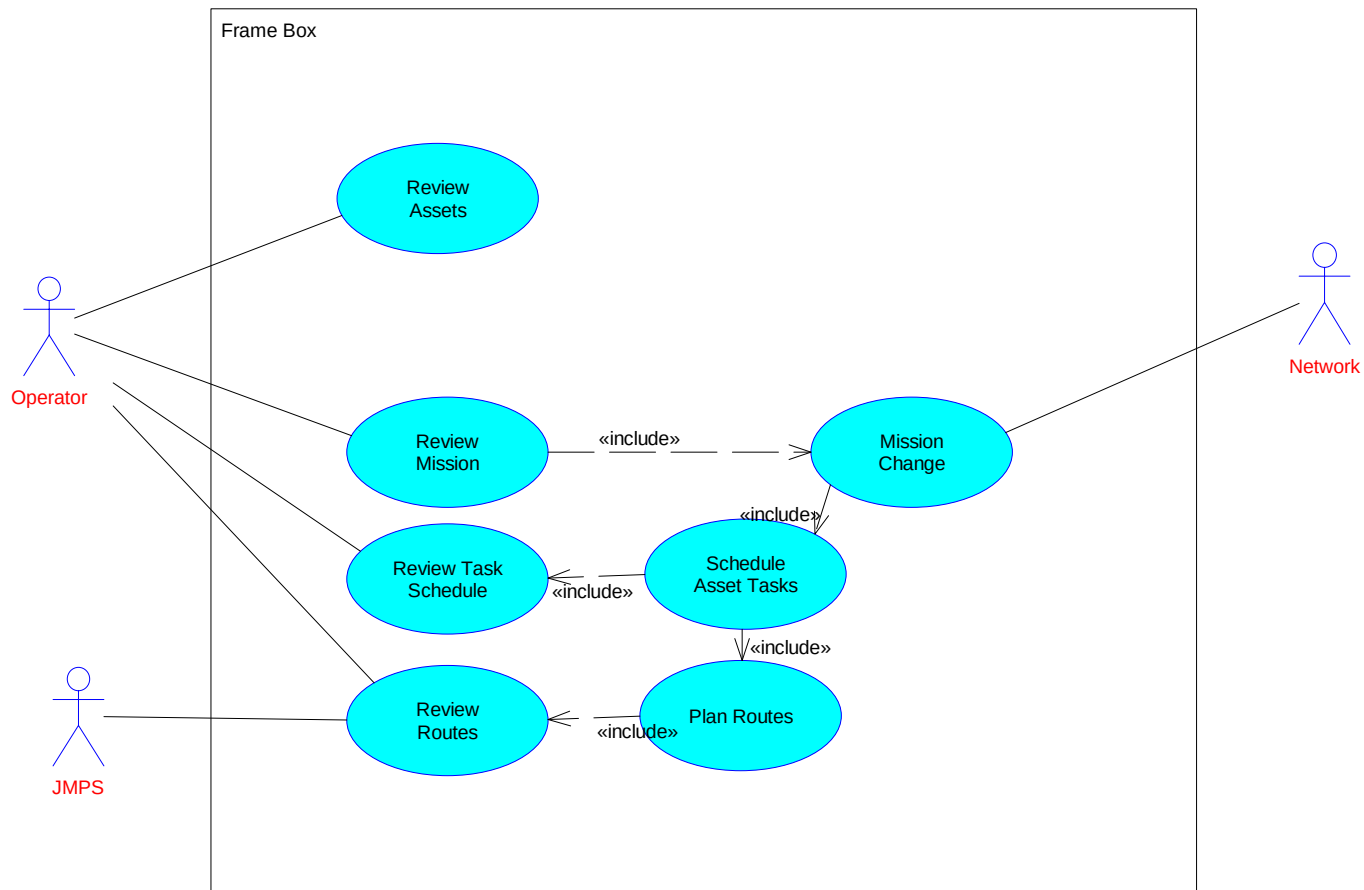


Figure 11 Use Case Diagram

3.6.2 Mission Change

Figure 12 shows the sequence of events that take place when a mission change is received. The change may come from the network (representing higher command authority). Alternately, it may come from the operator station.

Mission objectives arrive from the network actor and are translated into an internal representation including geometries and task types to be performed within those geometries as well as mission constraints such as restricted areas. These can be reviewed by the Operator in a separate use case. These objectives are validated (checked against any constraints). Validated objectives are then checked against the current plan to see if they can be accommodated without change. If not, planning proceeds.

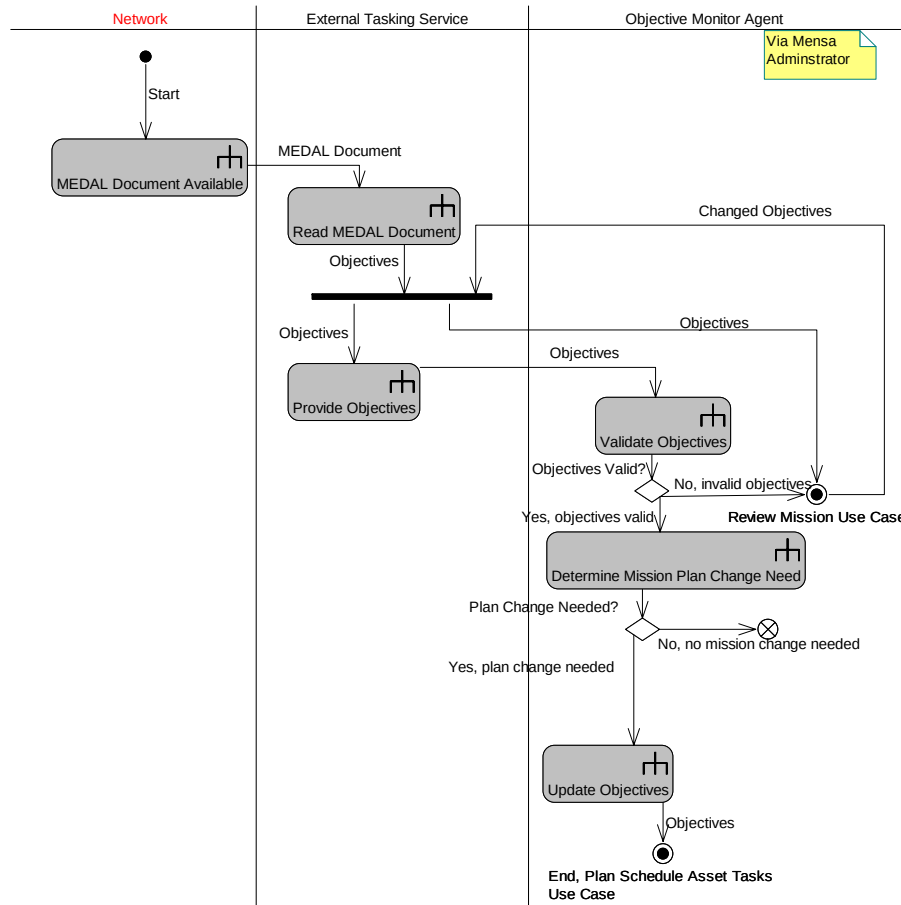


Figure 12 Mission Change Activity Diagram

3.6.3 Review Mission

This use case permits the Operator to review and alter objectives (Figure 13). This may be arrived at through a change in objectives, the discovery of invalid objectives, or the infeasibility of the objectives given constraints later in the planning process (e.g. availability of assets).

If it was arrived at from a change in objectives, the Operator may have configured the system to proceed without Operator intervention. This behavior is useful for testing later behaviors. Otherwise the human machine interface's state is set and the Operator is presented with the objectives. If he or she makes changes, the revised objectives are sent back and handled in the Mission Change use case. In any case, state is reset before proceeding.

Figure 14 shows a representative screenshot of the Operator's view during this use case.

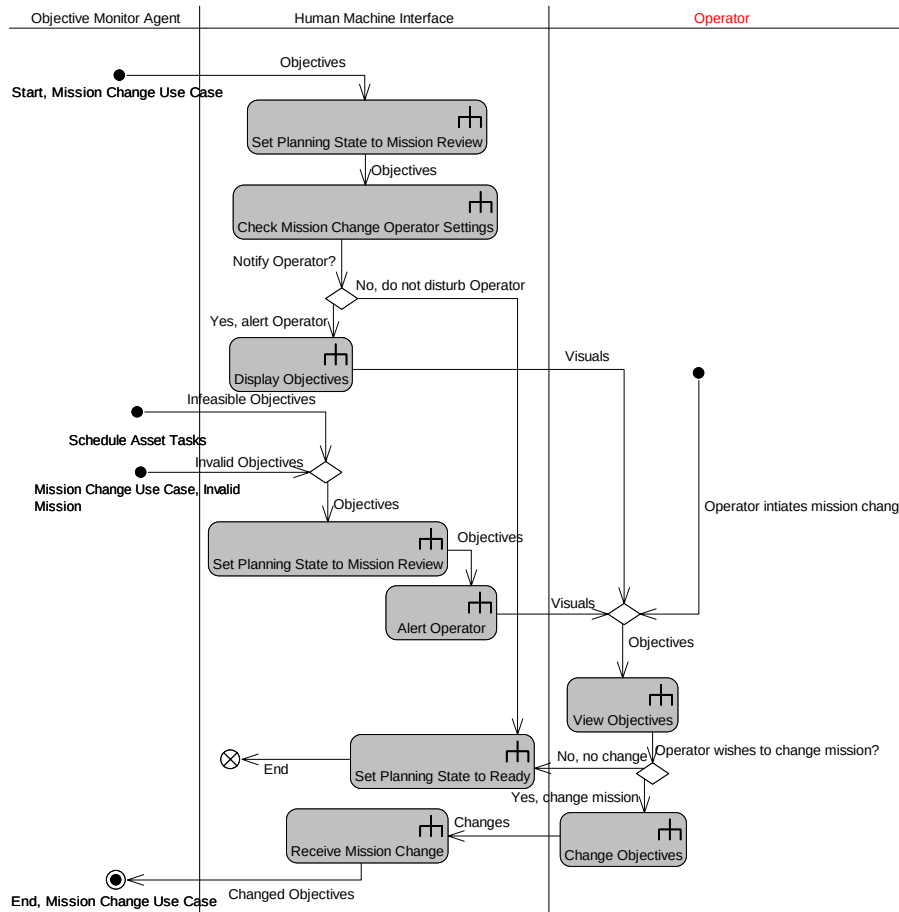


Figure 13 Review Mission Activity Diagram



3.6.4 Schedule Tasks

Figure 15 shows the process for defining the mission schedule. Given the objectives, information is gathered about the current situation (e.g. constraints on vehicle availability and on their capabilities, environment constraints on the objectives and the vehicle capabilities [e.g. bottom type may render vehicle hunting capabilities ineffective for certain regions], known mine like echo contacts, mine like objects and mines [these may be the targets of tasks or objects to avoid for other tasks]).

Given these conditions, the system develops the vehicle-task pairings. If tasks require uniform coverage planning, that is invoked for each of the pairings. Each of the resulting tracks may be considered a task to be scheduled along with identification and neutralization tasks. Additional scheduling constraints are added (e.g. launch windows and arrival windows to avoid collisions) and the tasks are scheduled if feasible. Of course, it is entirely possible that the problem is over constrained such that no solution is feasible. In this case, the results are sent back for mission review. Otherwise, they are sent for schedule review and route planning.

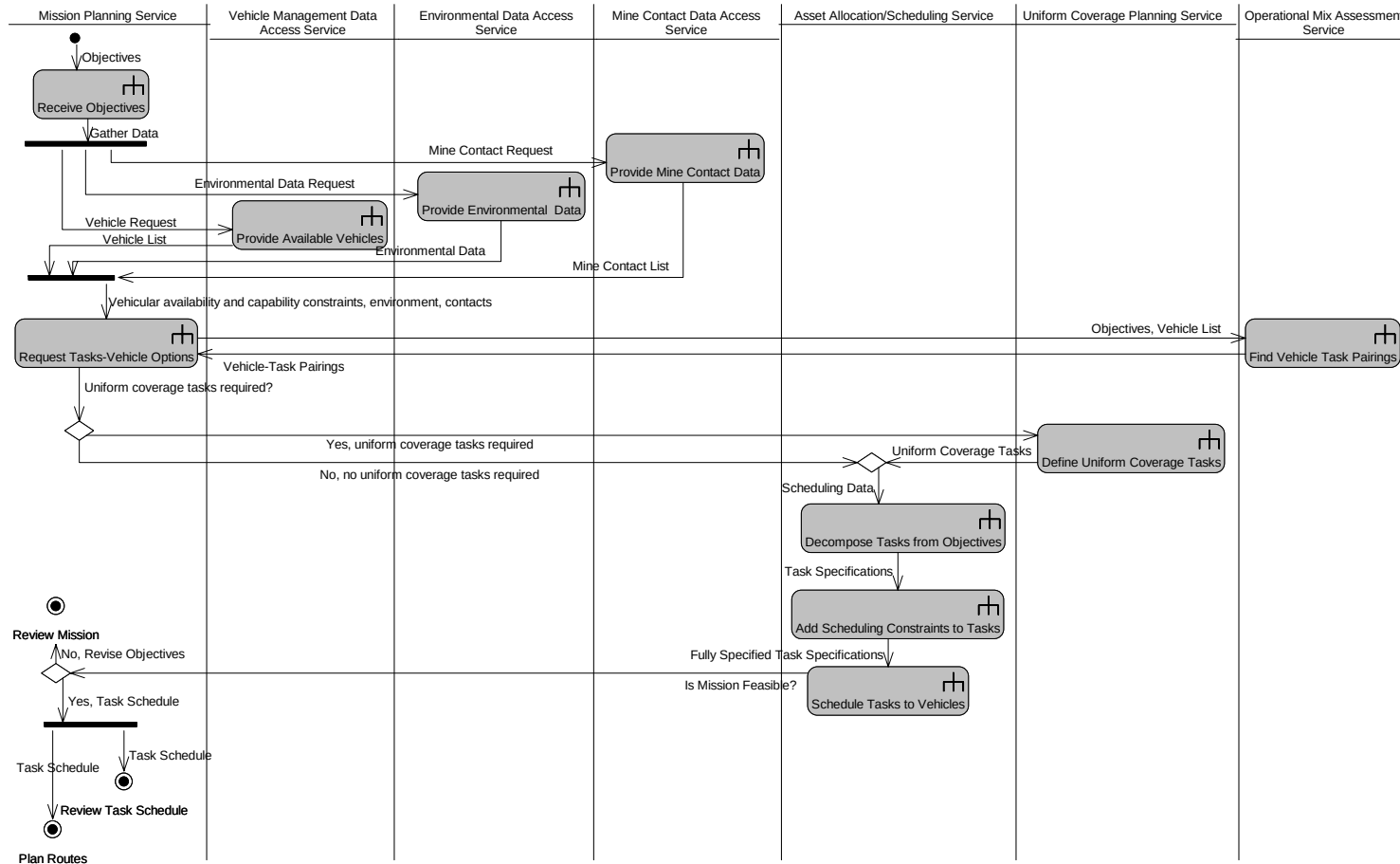


Figure 15 Schedule Tasks Activity Diagram

3.6.5 Review Task Schedule

Figure 16 shows the activities in the Review Task use case. Here the Operator is given an opportunity to review and alter the developed vehicle task schedule. This can be reached as a result of a new scheduling case, discovery of an invalid schedule, or an infeasible schedule discovered during routing.

Like the Mission Review use case activity diagram, state is set upon entry and reset upon exit. Also, the Operator may have set the system to proceed without intervention, in which case this process is exited. Otherwise the Operator is presented with the derived schedule and may accept or alter it. If it is altered, it is validated. If the validation fails, the Operator is presented with the schedule for revision.

Figure 17 shows a representative screenshot of the Operator's view during this process.

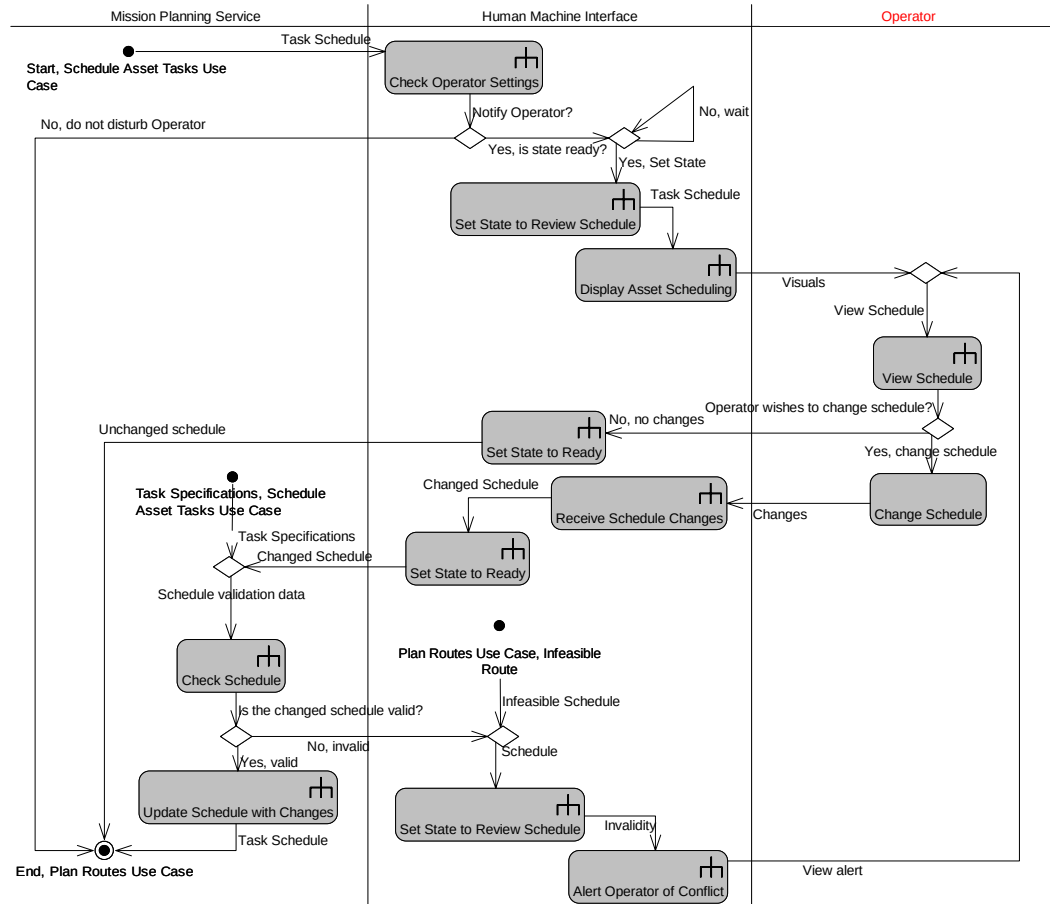


Figure 16 Review Task Schedule Activity Diagram

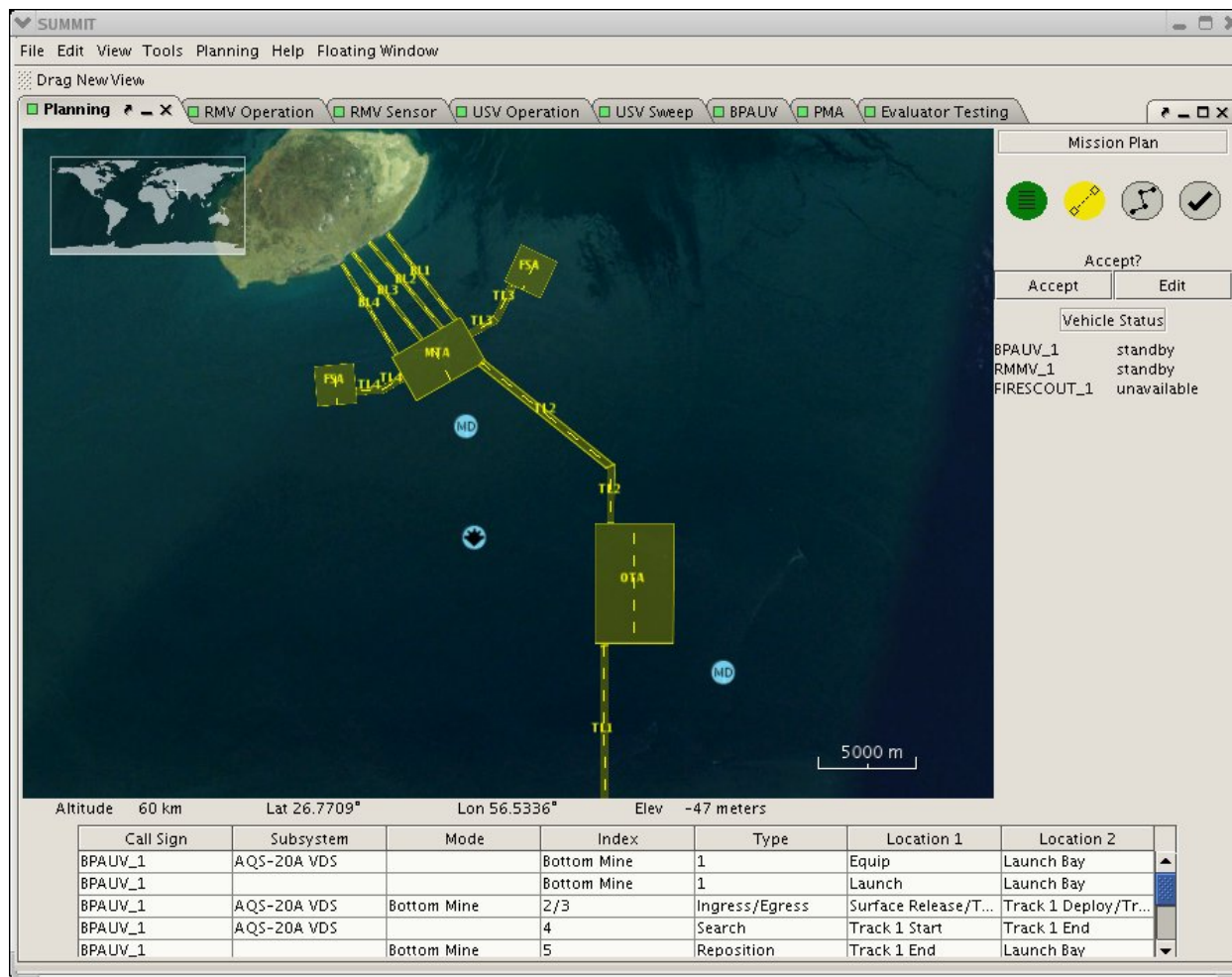


Figure 17 Representative Review Schedule Screenshot

3.6.6 Plan Routes

Figure 18 shows the activities in the Plan Routes use case. Routes are planned for assigned vehicle to traverse between tasks in schedule order conforming to constraints in the task specification. If routes are infeasible, they are sent back for the Operator to relax constraints. Otherwise the mission plan is compiled and stored.

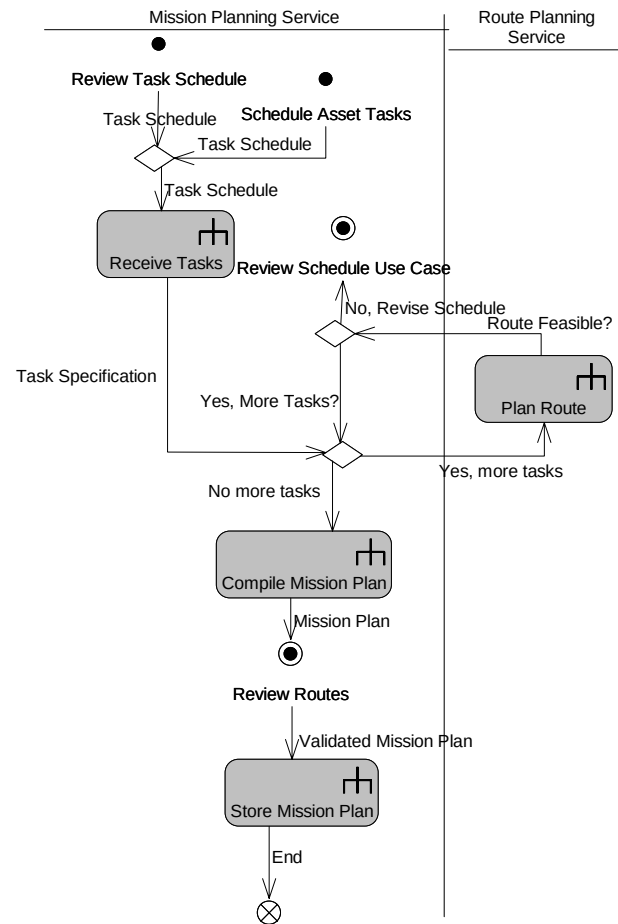


Figure 18 Plan Routes Activity Diagram

3.6.7 Review Mission Plan

Figure 19 shows the activities involved in reviewing the routes developed by the system. This process may be reached by the development of new routes. The process is similar to other review use cases in that state is set upon entry, and reset upon exit, the Operator may opt out of review, review, or change, any changed are checked for validity and presented to the Operator if invalid. In addition, this activity diagram shows the ability to display routes in the Joint Mission Planning System (JMPS) to show interoperability with a legacy system as well as the ability to work with other operator interfaces in general.

Figure 20 shows a representative screenshot of the Operator's view during this process.

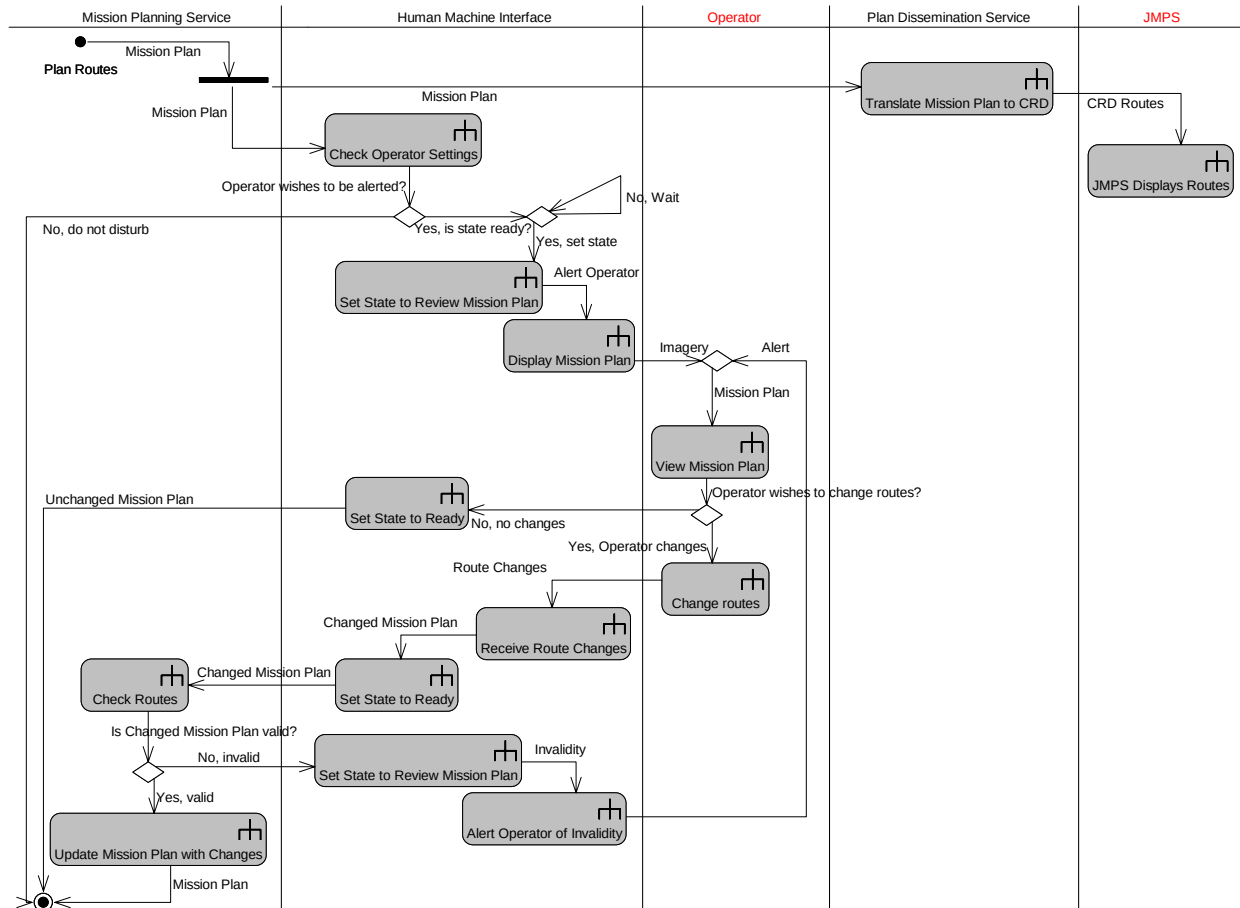


Figure 19 Review Mission Plan Activity Diagram

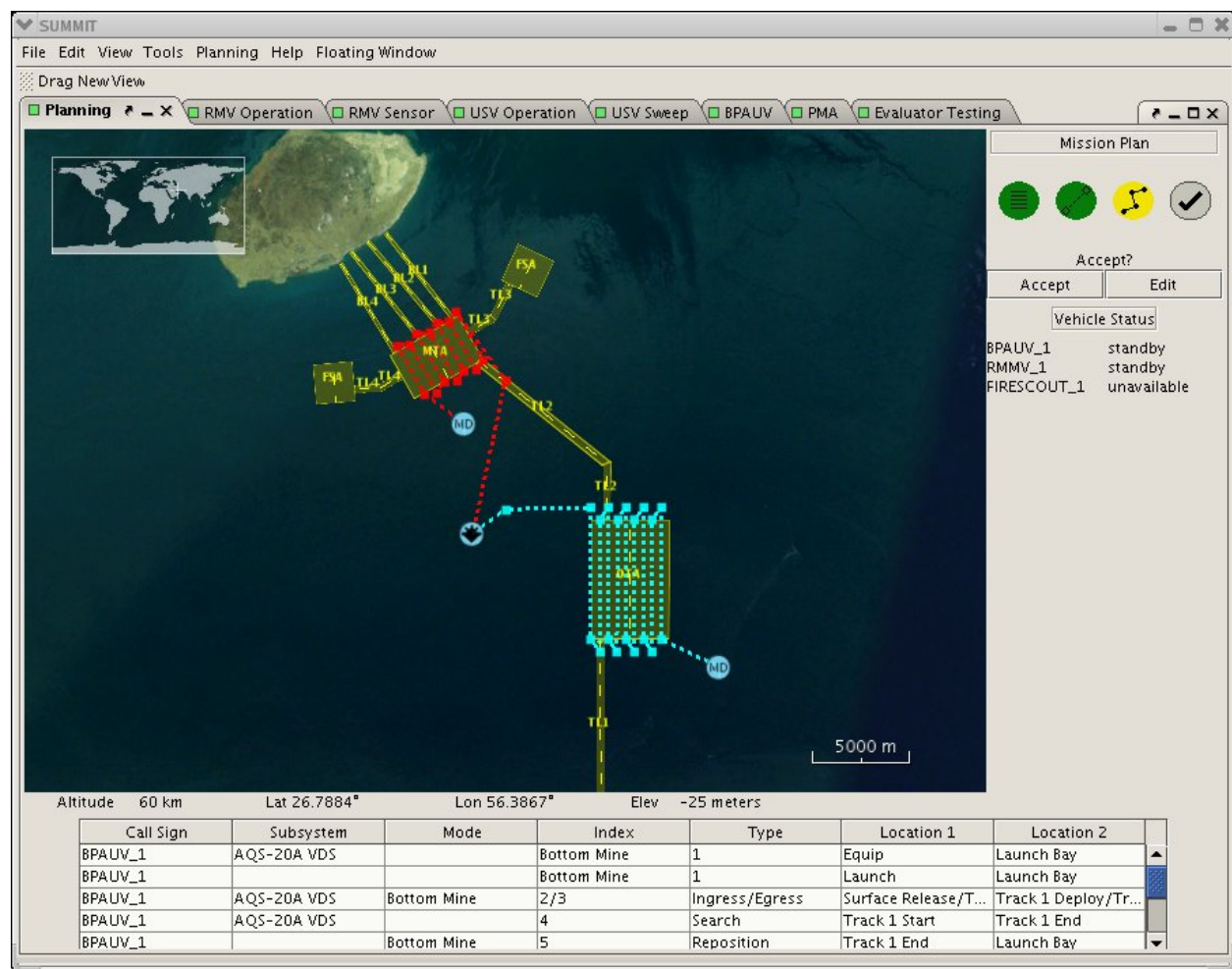


Figure 20 Representative Route Review Screenshot

3.6.8 Review Assets

Figure 21 shows the activities in the Review Assets use case. This is a fairly straightforward case in which, on demand, data are collected and displayed to the Operator.

Figure 22 shows a representative screen of the Operator's view of this (with the relevant data highlighted).

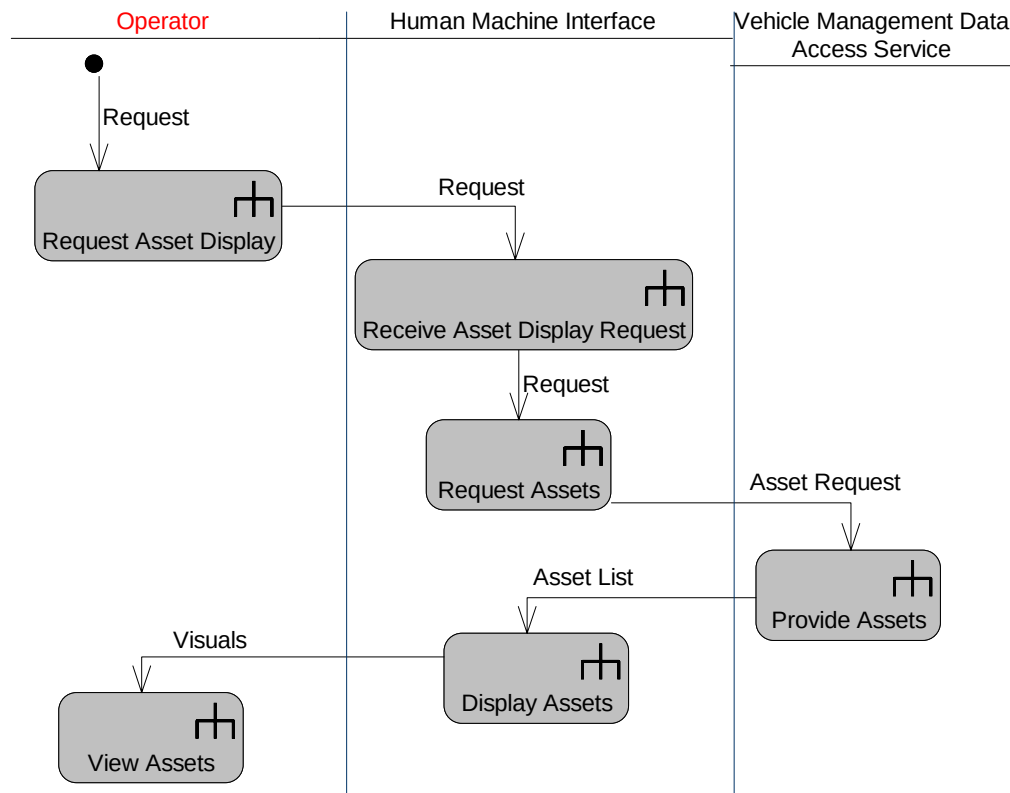


Figure 21 Review Assets Activity Diagram

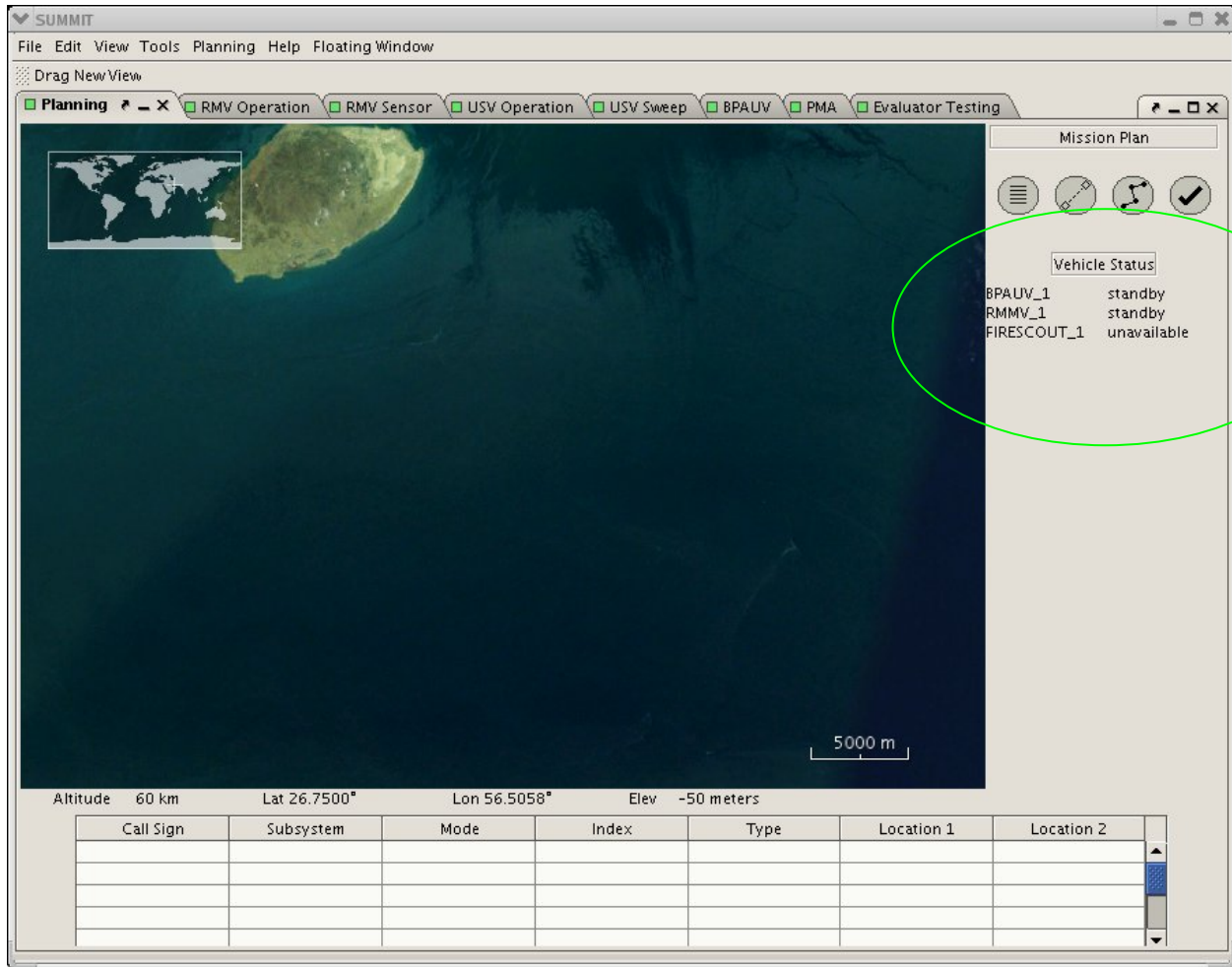


Figure 22 Representative Screenshot (Focus on Asset Display)

Figure 23 Data Model Overview

3.7 Simulation Environment

While not part of the design, it is useful to be aware of the intent of the simulation environment in which this design is expected to operate.

Figure 24 shows additional detail for the vehicle and sensor simulation. Note that some of these items are beyond scope, but expect to be incorporated under synergistic investment. In general, there are vehicular models that convert route plans to DIS packets. These packets are used by the JSAF environment to update the positions of the vehicles. JSAF maintains a unified model of the true state of the simulation and provides DIS packets with those. These are converted to GML moving object for use by the sensor models to provide TEAM with sensor reports and state reports.

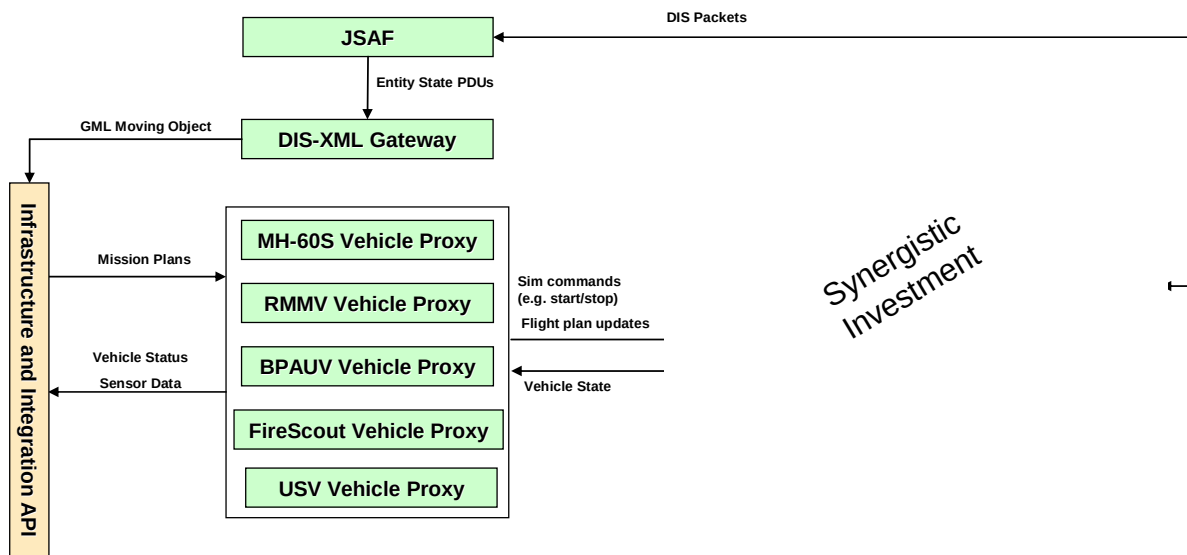


Figure 24 Simulation Environment

Glossary

Term	Description
ALMDS	AN/AES-1 Airborne Laser Mine Detection System
AMNS	AN/ASQ-235 Airborne Mine Neutralization System
API	Application Programming Interface
AQS-20A	Towed Sonar Array (VDS)
ATR	Automatic Target Recognition
BPUAV	Battlespace Preparation Underwater Autonomous Vehicle
CAD/CAC	Computer-Automated Detection/Classification
CES	Commander's Estimate of the Situation
COI	Community of Interest
COT	Cursor on Target
CRD	Common Route Definition
DIS	Distributed Interactive Simulation
DoD	Department of Defense
EOID	Electro-Optic Identification
ESB	Enterprise Service Bus
GCCS-M	Global Command and Control System – Maritime
GML	Geography Markup Language
HMI	Human Machine Interface
JAUS	Joint Architecture for Unmanned Systems
jBPM	Java Business Process Management
JSAF	Joint Semi-Automated Forces
JMPS	Joint Mission Planning System
LCS	Littoral Combat Ship
LM	Lockheed Martin
MCM	Mine Countermeasures
MEDAL	Mine Warfare and Environmental Decision Aids Library
MENSA	Mission Effectiveness and Safety Assessment
MH-60S	Naval Helicopter
MILCO	Mine Like Object
MILEC	Mine Like Echo Contact
MIW	Mine Warfare

Term	Description
MIWC	Mine Warfare Commander
MLO	Mine Like Object
NCA	National Command Authority
OASIS	AN/ALQ-220 Organic Airborne and Surface Influence Sweep
OGC	Open Geospatial Consortium, Inc.®
PMA	Post Mission Analysis
RAMICS	AN/AWS-1 Rapid Airborne Mine Clearance System
RMMV	AN/WLD-1(V)1 Remote Multi-Mission Vehicle
RMS	Remote Minehunting System
SOA	Service Oriented Architecture
SUMMIT	Supervision of Unmanned Mission Management by Interactive Teams
TEAM	Team-Based Execution of Autonomous Missions
UCD	Use Case Diagram
UCORE	Universal Core
USW	Undersea Warfare
UPC	Unique Planning Component (JMPS)
USCC	Unmanned System Common Controller
VDS	Variable Depth Sonar (AQS-20)
VSS	Volume Search Sonar
VTUAV	Vertical Take-off and Landing Unmanned Aerial Vehicle
WCS	Web Coverage Service
WFS	Web Feature Service
WMS	Web Map Service