Information Requirements for MCM and ISR Missions

PUMA Phase II

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Glossary of Abbreviations

AT/FP	Anti-Terrorism / Force Protection
DCDT	Dynamic Contextual Decision Tree
H&S	Health and Status
HBI	Harbor Bottom Image-Mapping
ISR	Intelligence, Surveillance and Reconnaissance
LCS	Littoral Combat Ship
MCM	Mine Counter Measures
MTI	Moving Target Indicator
PUMA	Plan Understanding for Mixed-initiative control of Autonomous systems
SOF	Special Operations Forces
STUAV	Small Tactical Unmanned Aerial Vehicle
UAV	Unmanned Aerial Vehicle
UGV	Unmanned Ground Vehicle
USV	Unmanned Surface Vehicle
UUV	Unmanned Undersea Vehicle

Introduction

This document contains display requirements for Littoral Combat Ship (LCS) control station displays to be used by unmanned vehicle units in support of heterogeneous unmanned vehicle missions (such as Special Operations Force (SOF) insertion). The method used for generating the requirements was that of a Hybrid Cognitive Task Analysis (CTA)[1] which entails describing a scenario overview of a representative mission, generating event flow diagrams, and depicting decision ladders for the key decisions identified in the event flow diagrams. These steps are then used together to generate an informational requirements summary which includes the situational awareness requirements that are derived from the event flow and display requirements of the decision ladders. This method was developed in Phase I of the PUMA (Plan Understanding for Mixed-initiative control of Autonomous systems) project[2]. In PUMA I, the mission scenario primarily consisted of Intelligence, Surveillance and Reconnaissance (ISR) tasks. For PUMA II, the scenario has been expanded to include Mine Counter Measures (MCM), Harbor Bottom Image-Mapping (HBI), and Anti-Terrorism / Force Protection (AT/FP) mission types. There is a specific emphasis on the MCM and ISR missions to highlight the informational requirement differences between the two task types. This document incorporates the expanded vehicle and mission type heterogeneities that are present in PUMA II in order to develop a cohesive set of informational requirements necessary for such a complex mission.

Scenario Overview

The following analysis pertains to a scenario where an operator unit aboard a futuristic LCS is required to supervise multiple autonomous vehicles with the objective of safely inserting an SOF team deep within a coastal bay. Hindering this insertion could be a host of threats present in air, on land, below the ocean surface, and/or above the ocean surface. In order to ensure the safe transport of the SOF team, the harbor sea floor must be mapped to determine sea floor heights and obstacles (HBI), potential mines must be located and destroyed (MCM), potential threats within the harbor must be located and monitored (ISR), and the LCS as well as the SOF team must be protected from potential targets (AT/FP). The completion of the four task areas (HBI, MCM, ISR, and AT/FP) by the available autonomous vehicles will be supervised by an operator unit present within the LCS. The analysis presented in this document is focused on MCM and ISR aspects of the overall mission; nonetheless, many of the resulting requirements also pertain to HBI and AT/FP tasks as well. If HBI and/or AT/FP requirements are necessary in the future, additional analysis could be conducted.

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[1] Nehme, C.E., Scott, S.D., Cummings, M.L., Furusho, C.Y., "Generating Requirements for Futuristic Heterogeneous Unmanned Systems", Proceedings of HFES 2006: 50th Annual Meeting of the Human Factors and Ergonomic Society, San Francisco, CA, USA, October 16-20, 2006.

[2] Scott, S.D., Cummings, M.L., Cognitive Task Analysis for the LCS Operator. (HAL2006-01), MIT Humans and Automation Laboratory, Cambridge, MA.(2006)

As the details of an SOF insertion, such as the number of vehicles and operators available, will likely differ from one mission to another, the event flow diagrams are generic. The vehicle heterogeneity has been abstracted out of the mission scenario so that no assumptions have to be made based upon the number or type of vehicles being supervised. Instead, the event flow diagrams are based on the vehicle task (HBI, MCM, ISR of AT/FP). For instance, in one example, an SOF mission may be completed using a team of 3 UUVs, 2 STUAVs, and a SUV, all supervised by a single operator aboard the LCS. An alternate SOF mission however could require a team of 4 UUVs, 1 STUAV and a USV with one operator supervising the amphibious vehicles and a different operator supervising the non-amphibious vehicles. The same event flow diagrams can be used to represent the operators in both of these mission instances. By generating display requirements that are independent of the exact team configuration, the following analysis can provide functional and information requirements that apply across the task areas, regardless of the exact team configuration. Additionally, more than one operator can be tasked with controlling the same vehicles. For this reason, the term operator in the remainder of this document refers to an operator unit regardless of the unit's size.

Event Flow Overview

The event flow diagrams (Appendix A) are based on the idea that operators have been given global tasking orders to follow for the duration of the mission. Therefore, the main event flow diagram begins by describing an operator following the first assigned global tasking order (Figure A.1). This global tasking order is in turn broken into a set of local tasking orders which primarily require the operator to complete imaging and monitoring activities (Figure A.2). These activities include checking for new data/images, assessing the quality and content of those data/images, monitoring the vehicle paths and schedules, as well as assessing if there are any zones that have not been covered by a vehicle or zones that need additional data/images.

Decisions (represented by diamonds) and processes (represented by rectangles) in the imaging and monitoring loop might result in the operator entering one of four functional areas loops (represented by circles): Mine Neutralization (Figure A.3), Target Monitoring (Figure A.4), Reallocation of Vehicles (Figure A.5), and Path Planning Supervision (Figure A.6). These four loops represent functions that the operator might be required to complete in order to satisfy the overall mission objectives.

Independent of which loop the operator is in, it is always possible for the operator to follow a preemption path, where the operator halts their current task and instead attends to an alert either regarding the health and status of a vehicle or the detection of a potential target. When preemptive alarms are raised, the operator has the option to temporarily delay the response to the alarm. The operator could decide to delay the alarm response if, for instance, a non-critical health and status alert arises as the operator is engaging with a target. There are many different mission pre-designated circumstances that could arise where the operator would want to delay an alarm.

Also modeled in the event flow diagrams is a process, named the "What is the next task?" loop (Figure A.7), that represents the transition an operator makes from one task to the next. Such support can be useful whenever the operator has finished responding to an emergent unplanned event, and then must determine what task to attend to next, or when the operator completes a specific task in one of the four functional area loops. In either scenario, the operator has been interrupted from his or her imaging and monitoring tasks which in general are the primary tasks. For this reason, any task that causes operators to interrupt their primary task is known as an interruption task in the scope of this document. The process operators utilize when determining which task to attend to next is described in more detail in a subsequent section of this document. Once the operator determines which task to attend to, he or she will exit the "What is the next task?" loop and immediately attend to this task.

When all local tasking orders have been completed, the operator will return back to the mission execution loop where he/she will determine their next global tasking order until all global tasking orders have been fulfilled.

Decision Ladder Overview

This document contains two decision ladders corresponding to mission critical decisions (Appendix B). The decision ladders provide a means for determining key requirements for the operator display for complex decisions that contain multivariate data with associated uncertainty. These decisions are highlighted in the event flow diagram with gray shading. The first ladder, "Is target a potential threat?" (Figure B.1), represents a decision process that is required if a target has been acquired and the operator needs to determine if the target is a potential threat. The operator analyzes the data/information regarding the target, potentially requesting further details and information until s/he is able to determine the nature of the target. This information is stored for future reference in order to be used by the operator or the mission stakeholders. The decision ladder is exited when the operator changes the status of the target. This decision point occurs both in the "Mine Neutralization Loop", and on the "Target Monitoring Loop" (Figures A.3 and A.4). This decision process is the same for both ISR and MCM, however the display and information requirements are different. The informational requirements for determining if a target is a threat, while an operator is occupied in ISR-oriented tasks, are depicted in Figure B.2 while those for an operator occupied in MCM-oriented tasks are displayed in Figure B.3. Key differences between the sets of information requirements involve the information regarding the target that the operator will need to obtain in order to correctly identify the type of target present.

The second ladder (Figure B.4), "Which vehicle is optimal for reallocation?" originates from the "Reallocation of vehicles Loop" event flow diagram (Figure A.5). During this portion of the event flow, operators are attempting to acquire new or additional vehicles for a specific task. Before determining which vehicle is optimal, the operator will

pinpoint the desired vehicle functionality and geo-spatial location of the task in question. A computer generated list is then compiled of all vehicles of similar functionality in or near that location for the operator to compare and choose from. If there is only one vehicle with the correct specifications, then the operator will obviously employ that vehicle and skip the majority of the decision ladder steps. In all other cases, however, the operator will first select vehicles with the greatest loitering time, then vehicles that have a similar or lower task priority. Figure B.5 depicts the decision ladder with the display requirements.

Although this study is not meant to address collaboration between multiple operators (including handing off vehicles), locations have been identified within the reallocation loop and its associated decision ladder where there likely will be a need to share vehicles between multiple operators. Additional work would be needed in order to generate requirements to support operator collaboration.

Requirements Overview

Information requirements were developed in a series of steps. Situational awareness (SA) requirements (Appendix C) were first derived from the event flow diagrams. Each requirement was linked to the decision and process blocks from which it was derived. These requirements fell into one of three SA levels: Perception, Comprehension and Projection. Next, information requirements were identified within each of the decision ladders. Together, these two sets of requirements were combined and then grouped by their functional category into a final listing of informational requirements (Appendix D). For instance, there is a group of requirements that are pertinent to the communications functionality and another group that are pertinent to vehicle location functionality.

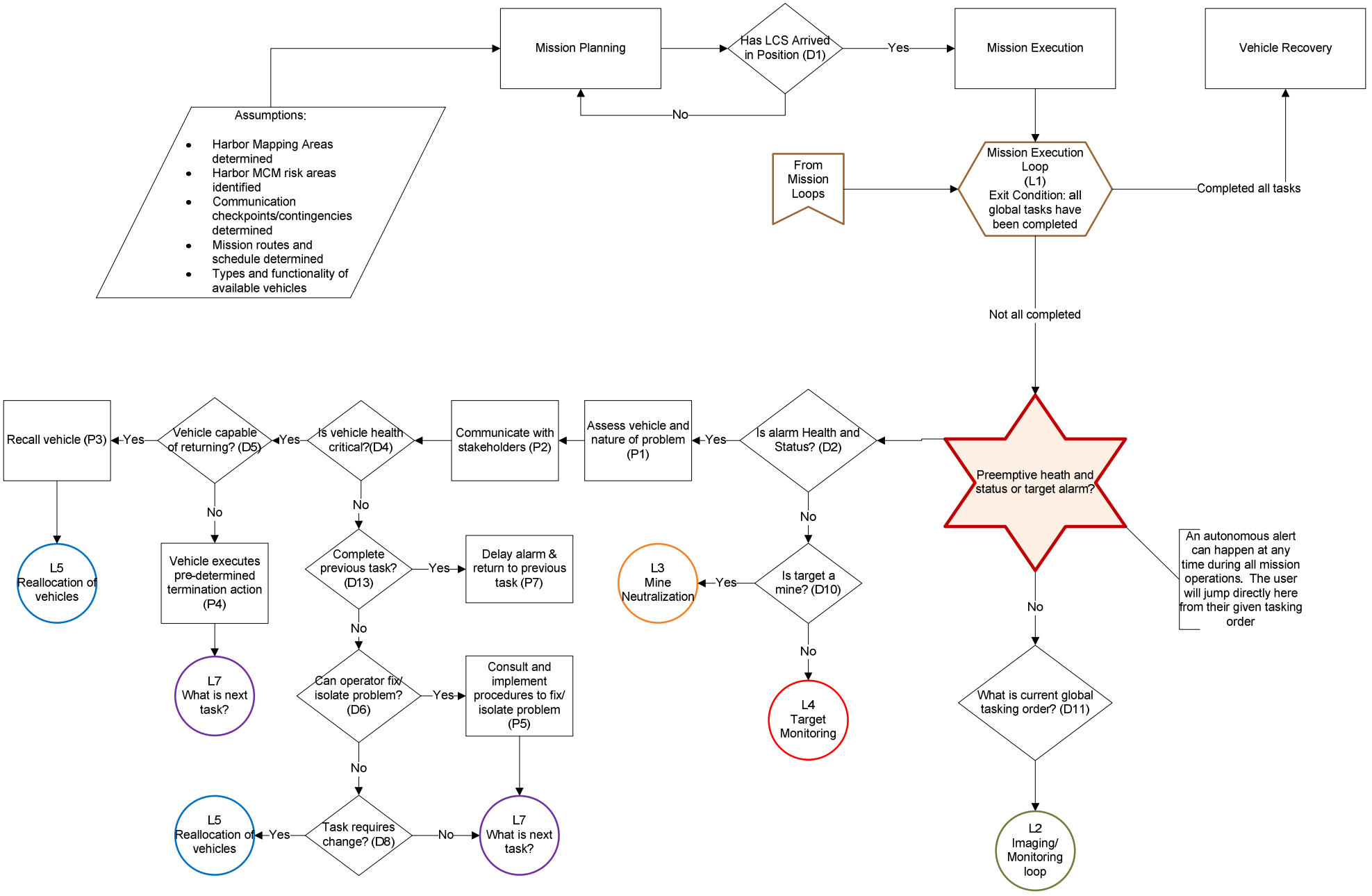
Within each of these groups, requirements either need to appear at all times, or are needed whenever a specific condition occurs, such as the requirements that are needed when a communications link is activated. For example, under communication aspects, operators will need to know the communications link coverage and schedule at all times, but will only need to know the duration of a communication link, and the probability of a communication link success if there is a link that is activated. The requirements that are conditional have their pre-conditional actions specified. These preconditions are determined by combining information from the event flow with the SA and informational requirements that occur at various points within the event flow. The requirements that have preconditions are grouped together under their pre-conditional event(s).

The final listing of information requirements for the mission is included in Appendix D. In total, there are 15 functional groupings. Seven of these groupings are required at all times within the mission (Vehicle Location Information, Geo-spatial Boundary Information, Vehicle Coverage, Communications Aspects, Global and Local Tasking Orders, Schedule Information, and Vehicle Specific Information). In addition there is a functional grouping for preemptive alerts, as well as a grouping dedicated towards the

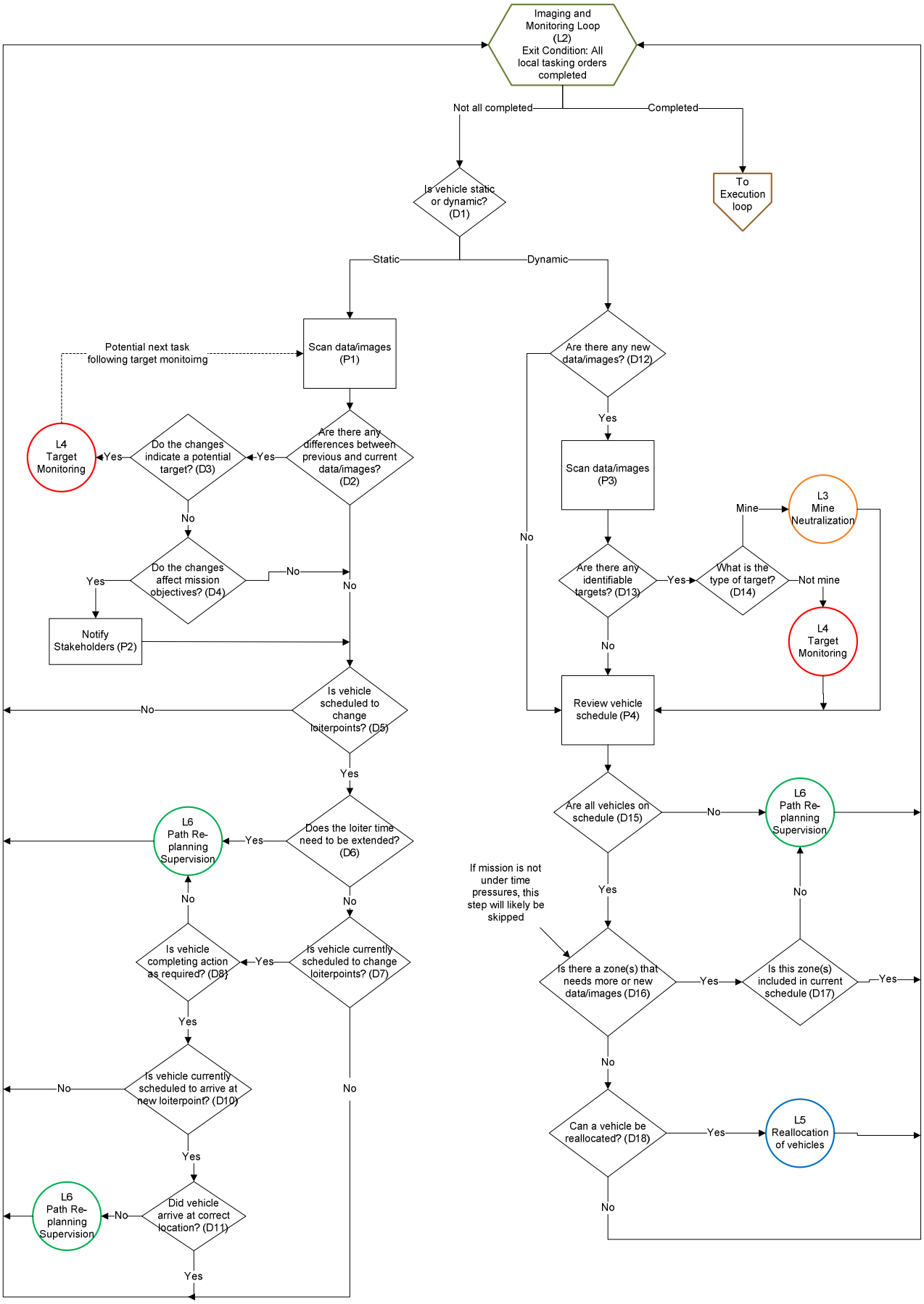
information necessary when an operator is transitioning between tasks. The other six functional groupings represent a departure from the mission execution loop into the imaging and monitoring loop, or into one the other four functional loops.

Overall there are 135 information requirements that must be met at some point during the duration of the mission. The information requirements an operator will require will ultimately depend upon the specific global and local tasking orders an operator is given for that specific mission.

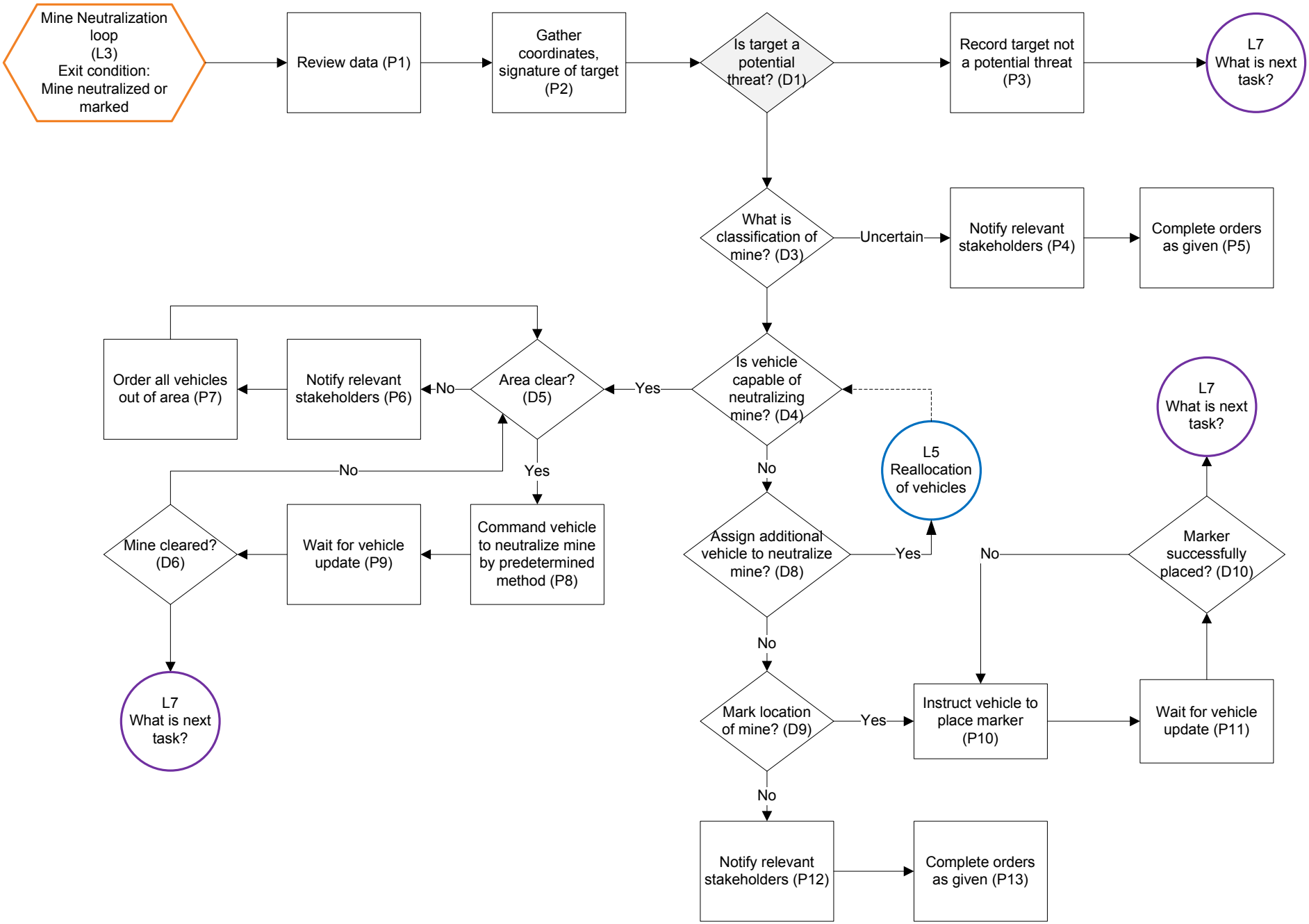
Appendix A: Event Flow



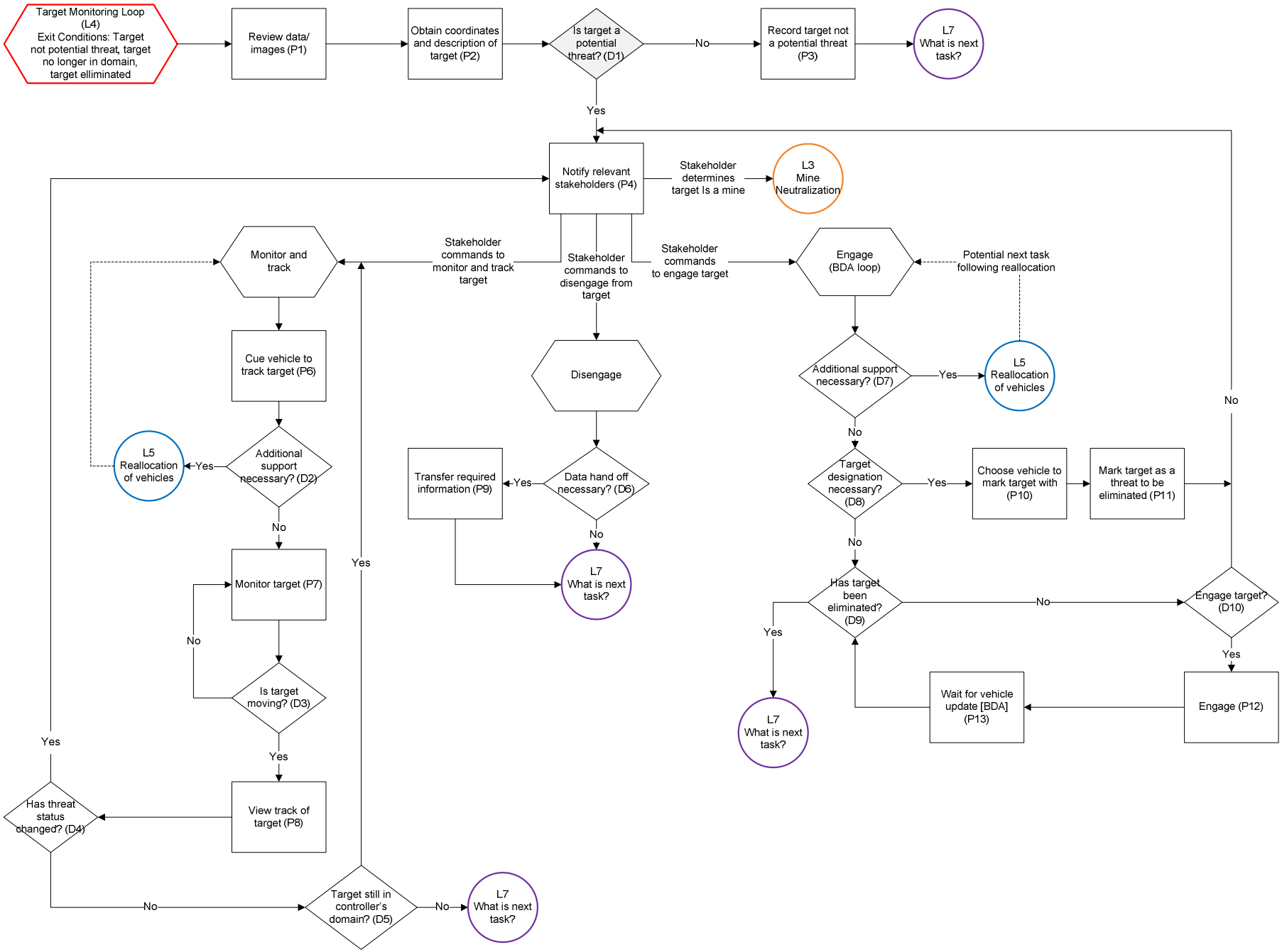
A.1 Mission Execution Loop



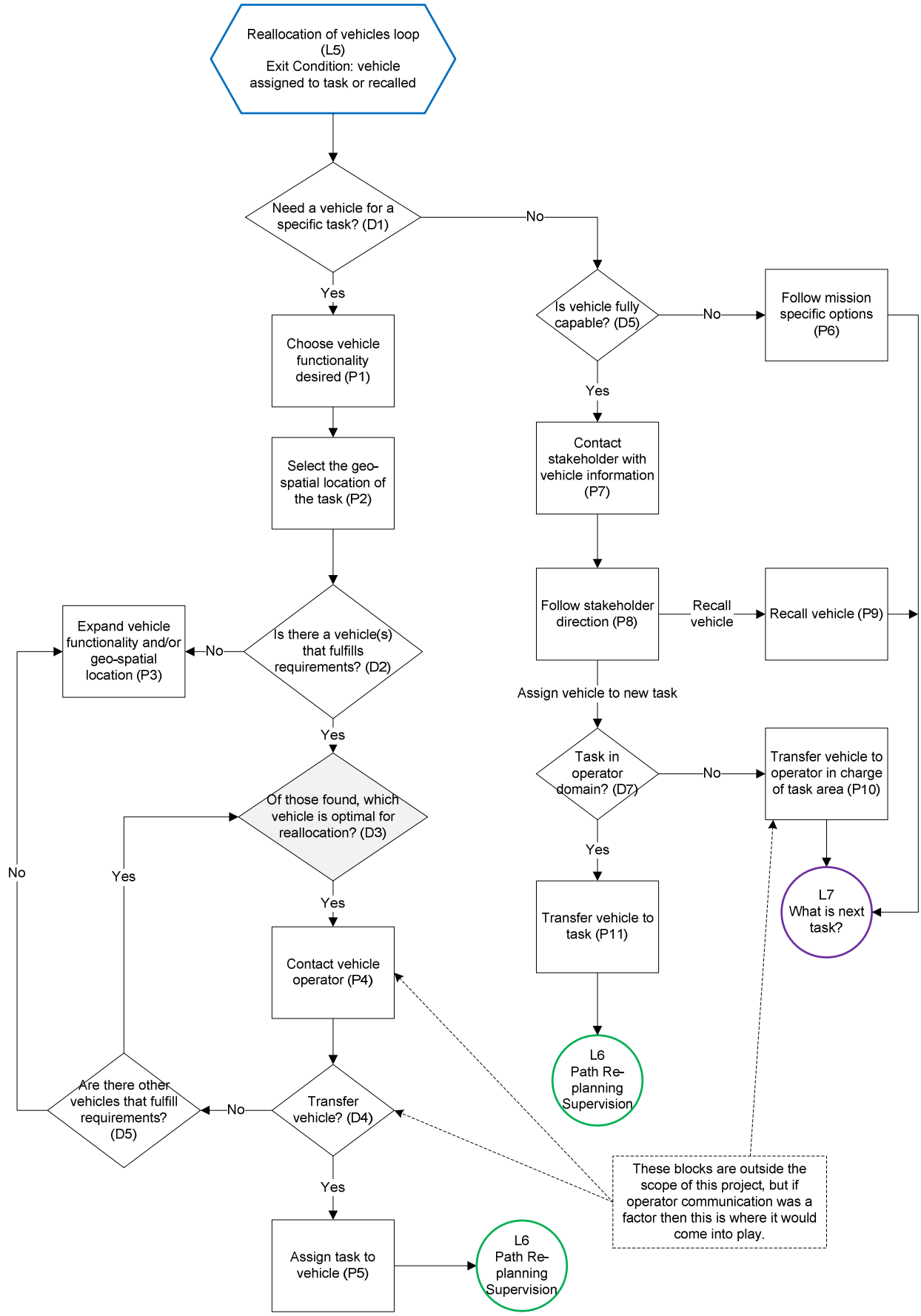
A.2 Imaging and Monitoring Loop



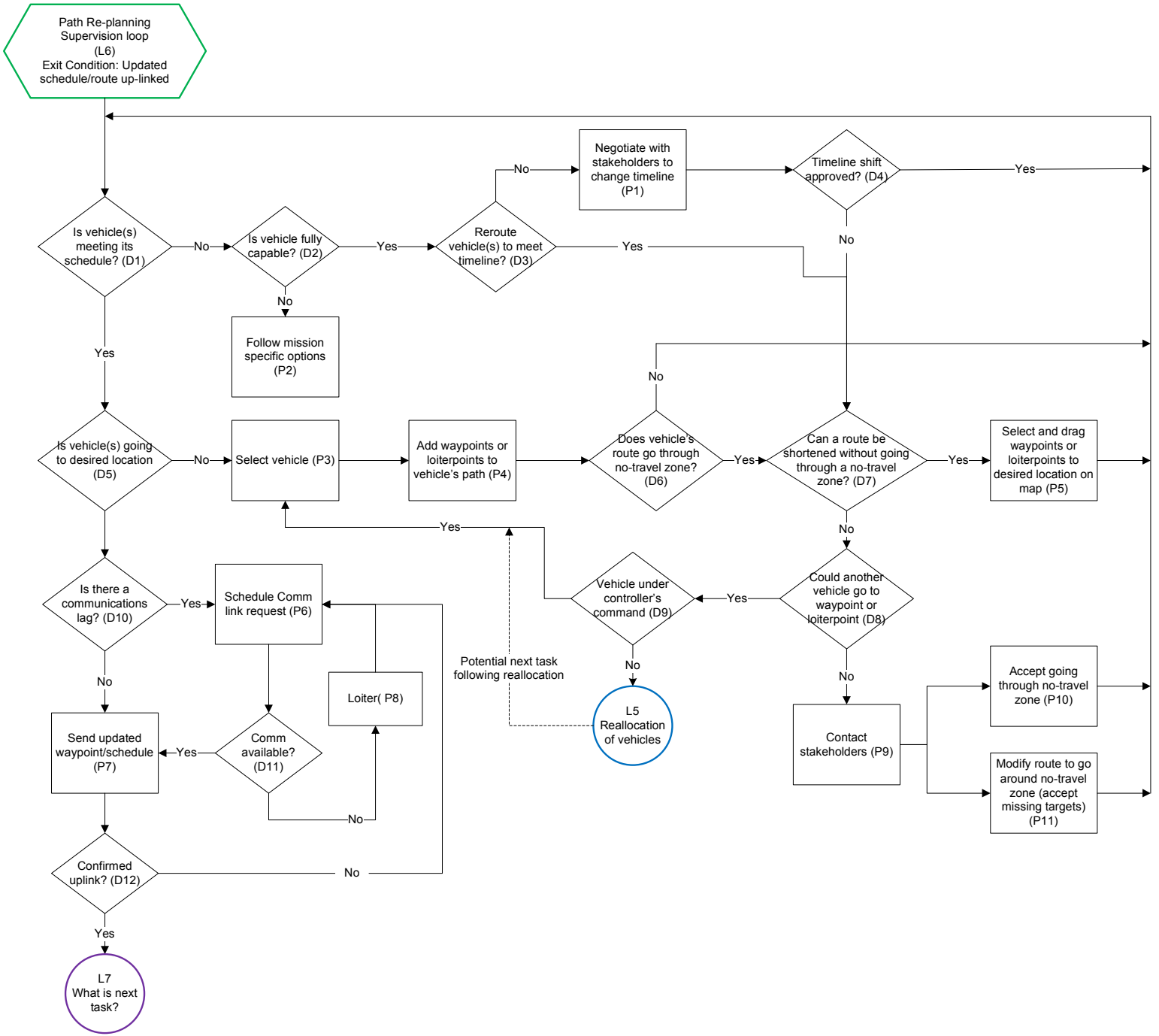
A.3 Mine Neutralization Loop



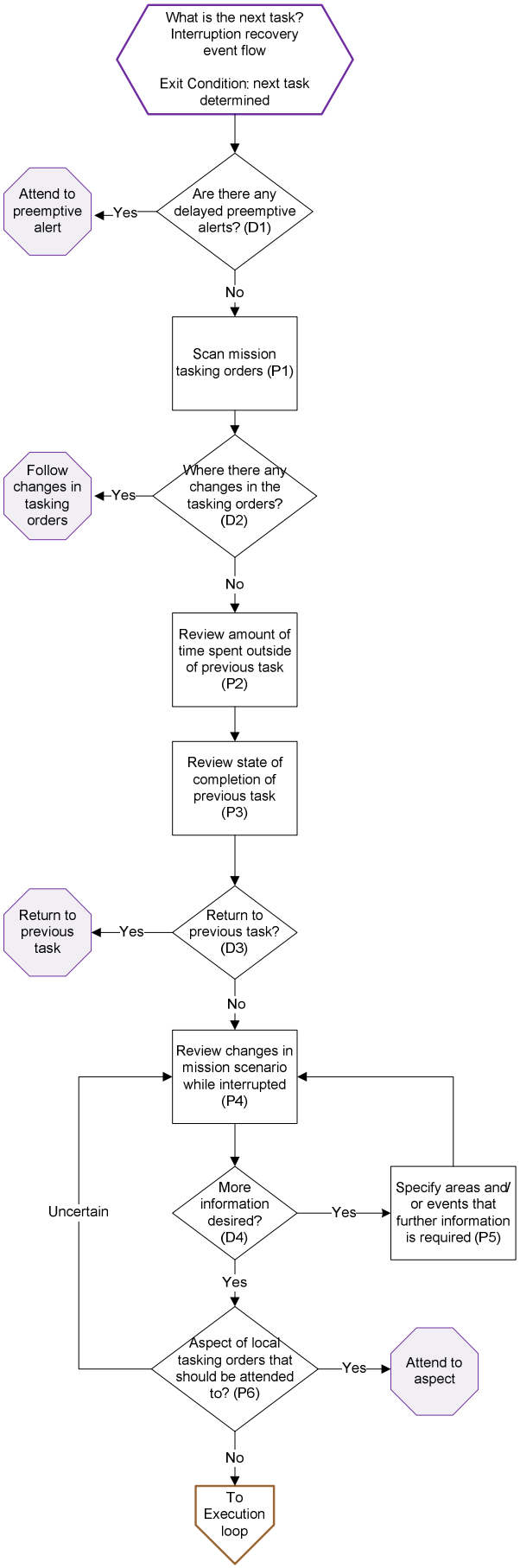
A.4 Target Monitoring Loop



A.5 Reallocation of Vehicles Loop

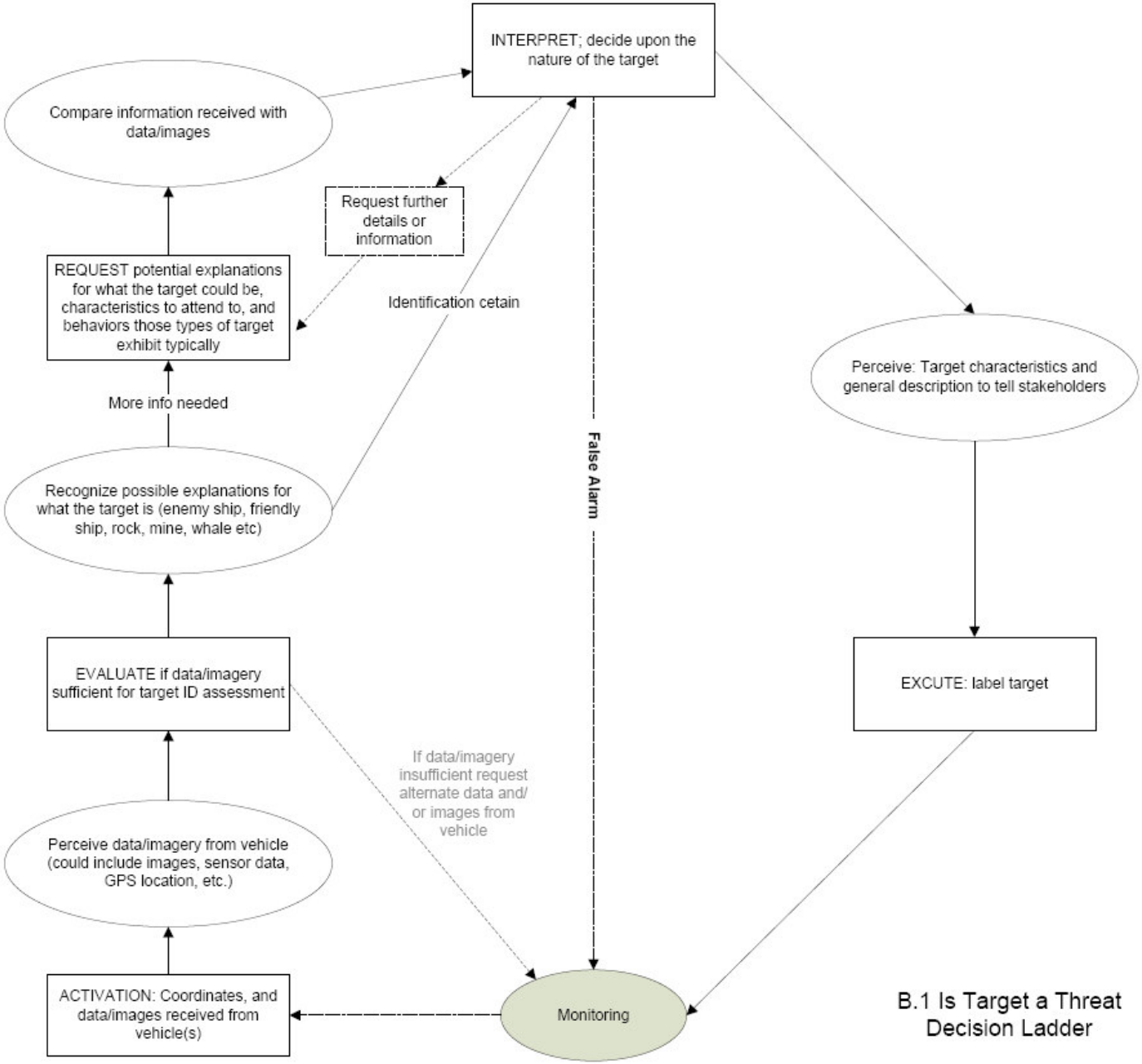


A.6 Path Re-planning Supervision Loop

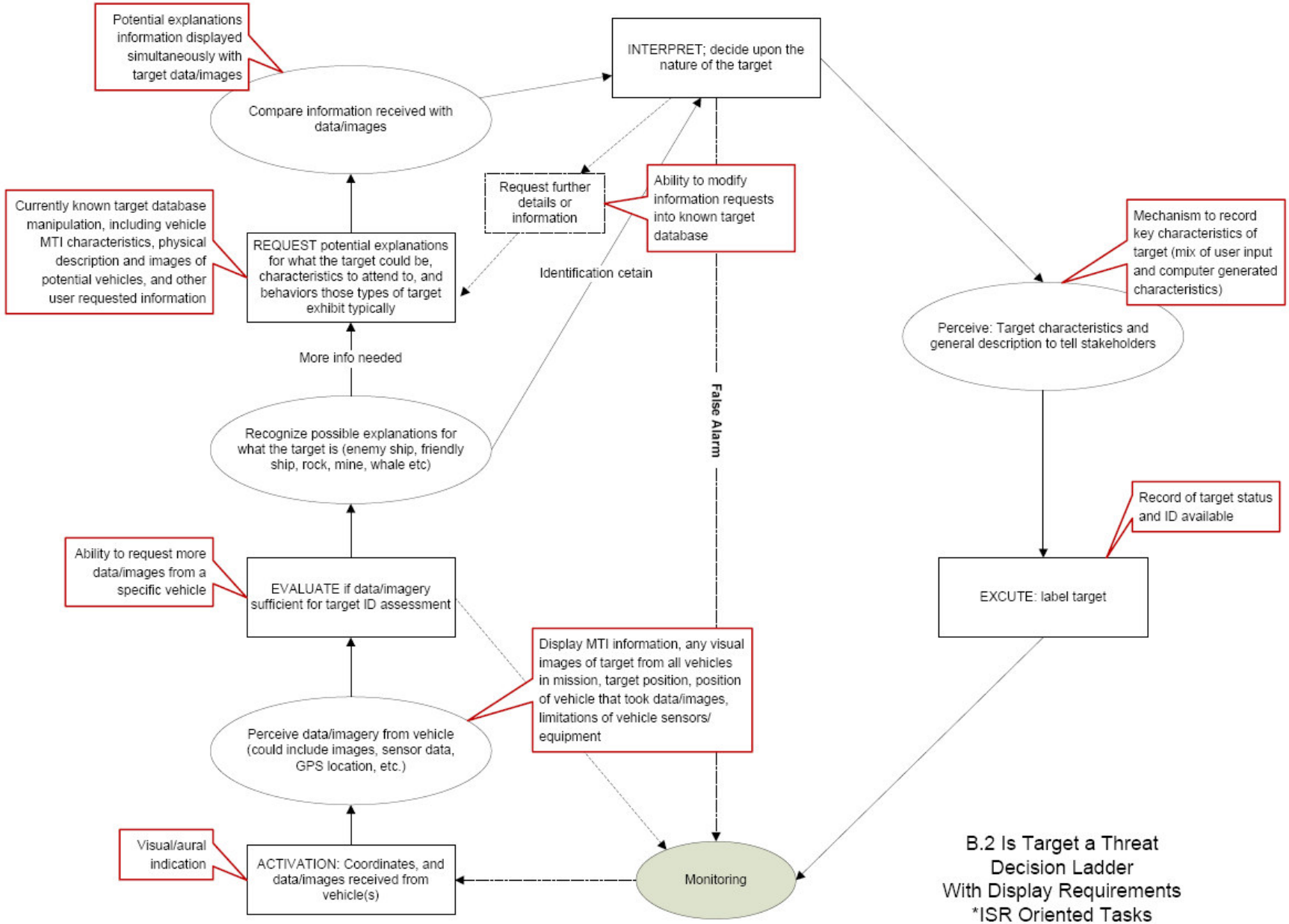


A.7 What is the next task? Interruption recovery event flow

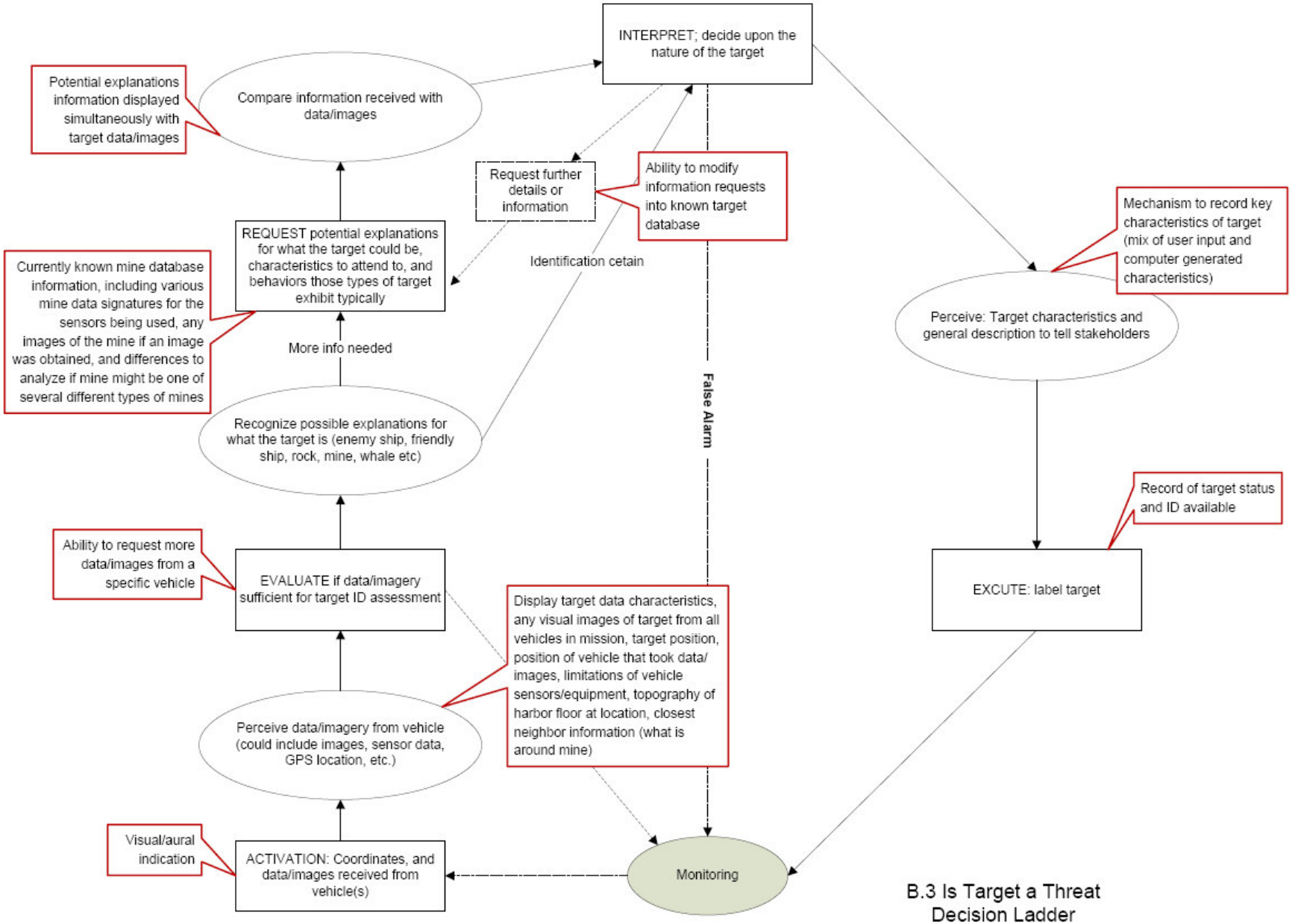
Appendix B: Decision Ladders With and Without Display Requirements



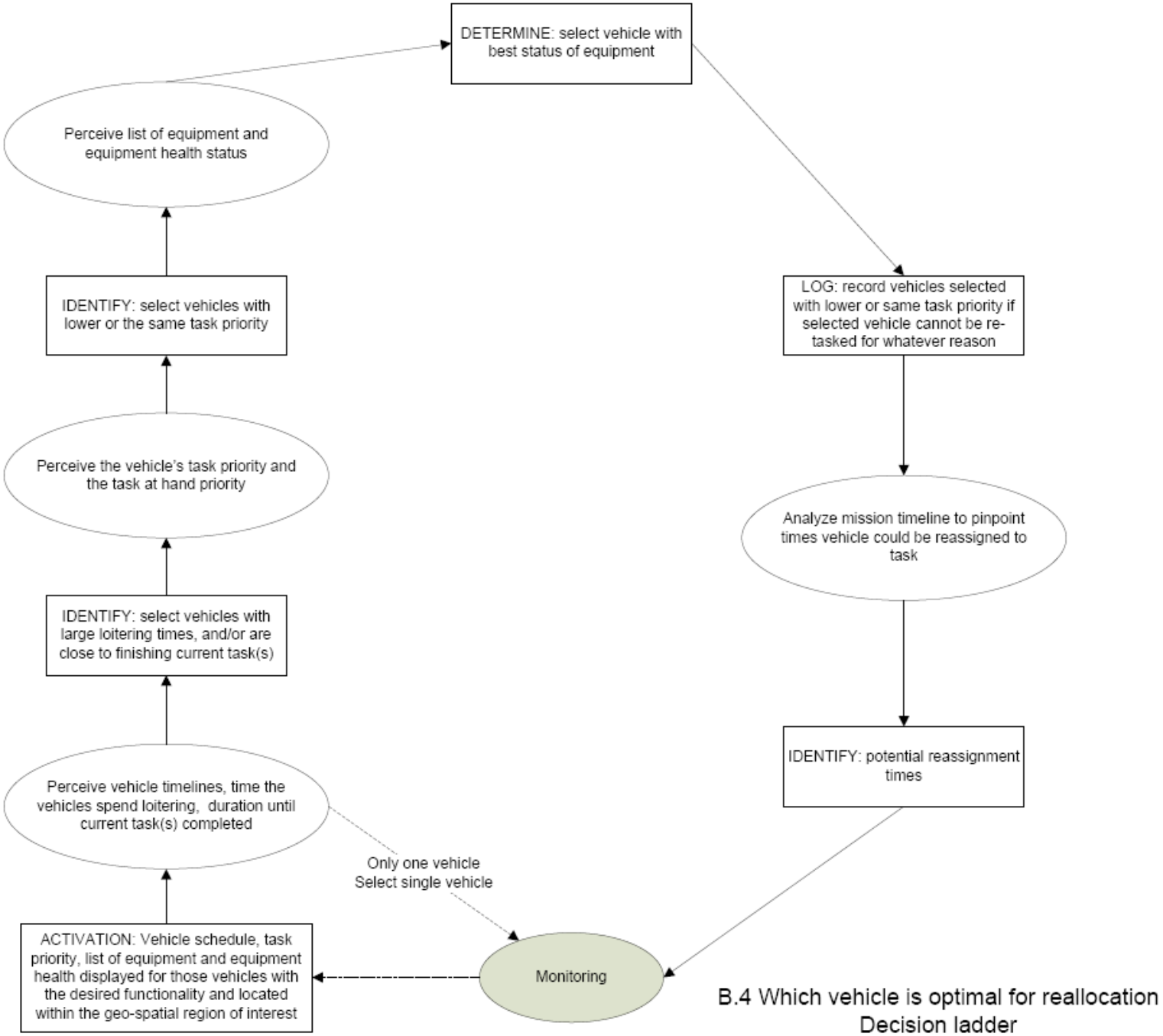
B.1 Is Target a Threat Decision Ladder



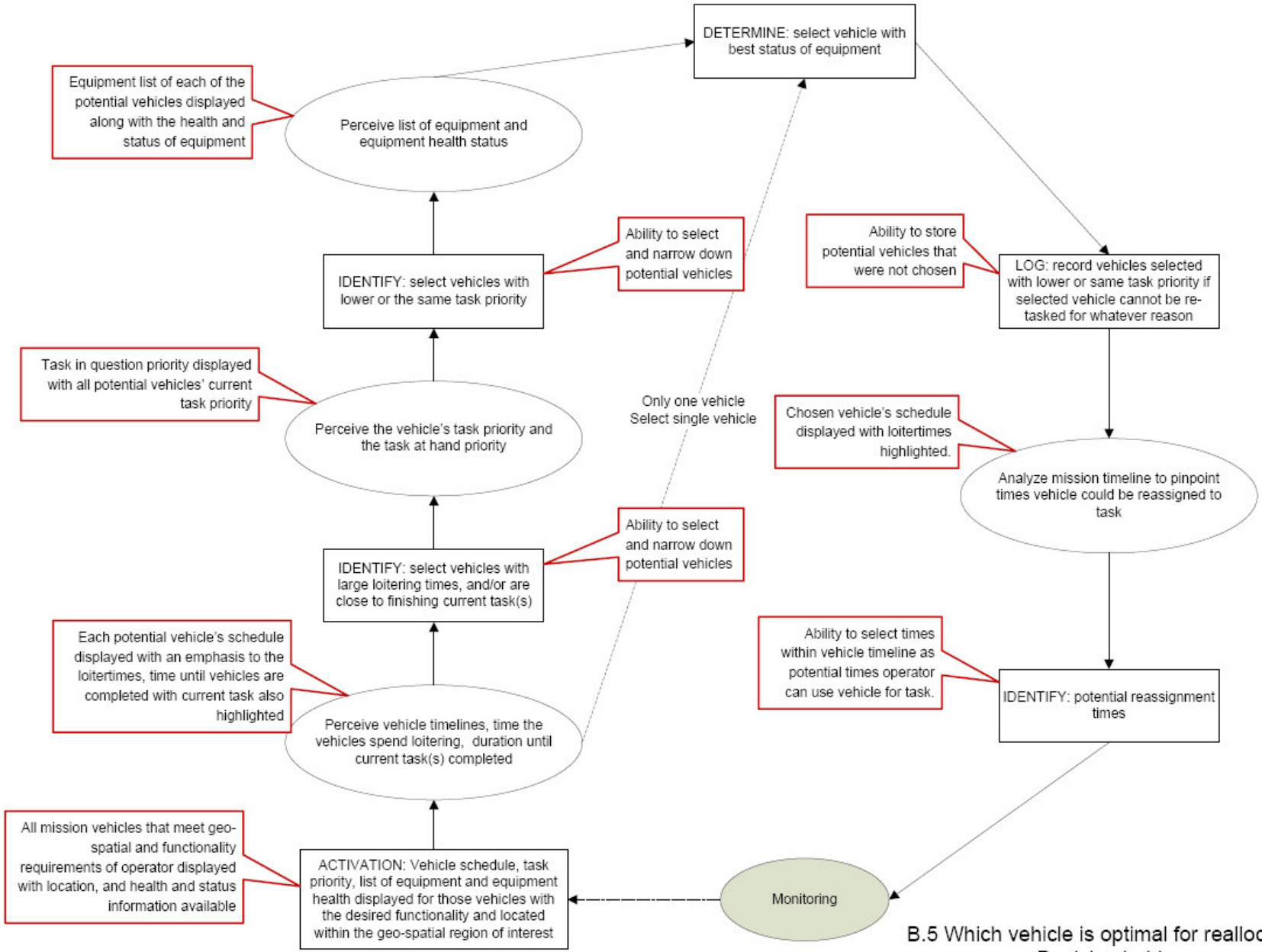
B.2 Is Target a Threat
Decision Ladder
With Display Requirements
*ISR Oriented Tasks



B.3 Is Target a Threat
Decision Ladder
With Display Requirements
*MCM Oriented Tasks



B.4 Which vehicle is optimal for reallocation
Decision ladder



B.5 Which vehicle is optimal for reallocation
Decision ladder
With Display Requirements
*For ISR or MCM

Appendix C: Situational Awareness Requirements

	Level I (Perception)	Level II (Comprehension)	Level III (Projection)
Preemptive alarms	– Aural or visual alerts that a health and status issue has occurred, and that a potential target has occurred (D2, D10) – Indicate which vehicle has alert (P1, P2) – Critical health and status information displayed (P1, P2) – List of potential problems with the vehicle (P1, D4, D5, D6, D8) – Vehicle checklists (P1, D4, D5, P3, D6, P5, D8) – Indication that operator delayed an alarm (D13, P7) – Indication of time alarm first initiated (D13, P7) – Overview of the predetermined termination action (P4) – Health and status of vehicle (P1, P2, D4, D5, D6, D8)	– List of all global tasking orders have been completed, which need to be done and which are new (L1, D11) – Separate and distinctive alerts for health and status and target alarms (D2, D10) – Vehicle component gauges (fuel, battery, speed) that are vehicle specific (D4, D5, P1) – Solutions to potential vehicle problems should be readily available when requested (D6, P5) – Conversation history with stakeholders while gaining further information or instructions (P1, P2, D5, P4, D6, P5, D10)	– Potential consequences of delaying a response to a health and status alarm (D4, D13, P7) – Uncertainty of alert validity (D2, D10) – Comparison of optimal system performance and current state (D4, D5, P1) – Vehicle limitations (when predicted to exceed some safe region) (D4, D5, P1) – Probability that target is a mine (D10) – Potential consequences of the predetermined termination action and how that affects other vehicles (P4)
Imaging and Monitoring Loop	– Visual or aural indication that new data/images have been uploaded (P1, D12) – Time history of data/images for given location/vehicle (D2) – Mission schedule (D5, D6, P4, D16, D18) – Vehicle schedule (D5, D6, P4, D16, D18) – Geo-spatial boundaries of land masses, hazardous areas and areas of interest (D5, D7, D15, D16, D17) – Audio/visual feedback for confirmation of target acquisition (D3, D13, D14) – Operator's vehicle sensor coverage (P1, D2, D3, D4, D6, P3, D13, D16) – Communications link coverage and strength	– Vehicle limitations (D5, D6, D7, D8, D10, D11, P4, D15, D16, D18) – Vehicle sensor limitations (D2, D3, D4, P3, D13, D14) – Conversation history with stakeholders (P2) – Link between vehicle and mission schedule (D5, D6, P4, D16, D18) – Mission vehicle sensor coverage (past, present) by vehicle type (D5, D6, D7, D11,D15, D16, D17) – Checklist of all local activities (completed, are being completed, need to be completed) (L2, D1, D5, D6, P4, D18) – Schedule latencies (D5, D6, D15, D16, D17, D18)	– Potential changes in time series of data/images (P1, D2, D3, D4) – Quality of the data/images compared to the standard quality (P1, D2, D3, D4, D12, P3, D13, D14) – Probability that a potential target is a mine (D14) – Projected vehicle coverage by vehicle type (D5, D6, D7, D11,D15, D16, D17) – Potentially missed checkpoints or loiterpoints (D5, D6, D7, D11, D15, D16) – Potentially missed communication points (D1, P1, D12, D5, D6, D15, D10, D11) – Potential areas of interest for more/new data/imagery (D5, P4, D6, D16, D17)

	(D1, P1, D12, D5, D6, D15, D10, D11) – Health and status of vehicles (D1, D5, D6, P4, D15, D18)		– Uncertainty of predicted vehicle and geo-spatial boundary location (P1, D2, D3, D4, P2, D5, D7, D12, P3, D13, D14, P4, D15, D16, D17, D18)
Mine Neutralization loop	– Data and imagery of mine (P1, P2, D1, D6) – Geo-spatial location of all vehicles (neutral or threats) (D5, P6, P7, P8) – Geo-spatial location of probable mines (D5, P6, P7, P8) – Visual/aural indication that vehicle has new images/data regarding mine (P9, D6, P11, D10) – Communication link coverage, strength, range and schedule (D8, P8, P9, P10, P11) – Visible and/or audible alert if there is a comm link latency or a link is dropped mid transmission (D8, P8, P10) – Visible and/or audible confirmation of a communications link (P8, P10) – Health and status of vehicle (D4, D8)	– Record and indication of current mine type and threat level (D3, P3, D6, D9, P10) – Conversation history with stakeholders (P4, D4, P12, P13) – Pinpoint vehicles that can destroy mine on the global map when the type of mine has been determined (D3, D4, D8) – Decision help to determine classification of mine (D3, P4, D4) – Vehicle limitations (D4, D8, P8, D9, P10)	– Uncertainty of the data/images given by the vehicle (P1, P2, D1, D3, D6) – Uncertainty of predicted vehicle (neutral and threats) and geo-spatial boundary location (D5, P6, P7, P8) – Likelihood that vehicle will be able to complete given orders (D4, P8, D9, P10) – Potential consequences of orders to mission, and region (D4, P8, D9, P10) – Potential flexibility in the communications link (D8, P8, P10) – Uncertainty of location of mine (P1, P2, D1, D3, D9) – Probability that marker will stay at desired location (P11, D10)
Target Monitoring Loop	– Data and imagery (P1) – Target coordinates (P2) – Geo-spatial boundaries of land masses, hazardous areas, areas of interest , vehicle, target and other mission vehicles(P2, P4, D3, P8, D4, D5, D7) – Visible and/or audible alert when target is disengaged (D5, D6, P9) – Communication link coverage, strength, range and schedule (P6, P7, D3, D4, D6, P9, D7, P10, P11) – Visible and/or audible alert if comm link is dropped (P6, P7, D3, D4, D6, P9, D7, P10, P11) – Sensor coverage of vehicle (P6, D3, P8) – Indication of target threat	– Vehicle sensor limitations (P1, P2, D1) – Target handoff constraints (D2, D6, P9, D7) – Conversation history with stakeholders when determining what action to take with the potential threat (P4) – Indication that vehicle is tracking a target (P6) – Moving target indicator of target (P8, D4) – Decision help when determining what action to take with the potential threat (P4)	– Uncertainty of predicted target location and vehicle location(s) (P2, D1, P7, D2, D3, P8, D4, D5, D7, P10) – Uncertainty of geo-spatial boundaries (P2, P4, D3, P8, D4, D5, D11) – Predicted target track (P2, D2, P7, D3, P8, D4) – Potential missed communications points (P3, P4, P6, D2, D7, D8, P10) – Uncertainty in communication link coverage, strength, range and schedule (P6, P7, D3, D4, D6, P9, D7, P10, P11) – Vehicle sensor limitations (D2, D11, D3, P8, D4, D5) – Likelihood that vehicle could be threatened by the

	and status (P4, D3, D4, D8, P10, D10, D9) – Health and status of vehicle (D3, D11, D14)		target (P4, D2, D7)
Reallocation of vehicles loop	– Checklist of desired vehicle functionality (D1, P1, D2, D3, P3, D5, P7, P8) – Geo-spatial boundaries of land masses, hazardous areas, areas of interest, and mission vehicles (P2, D3, D4, P7, P8, D7, P11) – Geo-spatial position of operator's task at hand (P2, D2, P3, D3, D4, P5) – Mission timeline (D3, D4, P5, P7, P8, P11) – Vehicle timelines with timeline latency (D3, D4, P5, P7, P8, P11) – List of vehicles that meet functionality and geo-spatial requirements (D2, D3, D5, P3) – Relative task priorities in mission (D3, P7) – Communication link coverage, strength, range and schedule (P4, D4, P5, P7, D7, P10) – Health and status of vehicle (D3, D4, D5)	– Vehicle (all vehicles in selected geo-spatial area) task area, and operator in control of vehicle (D2, D3, P4, D4) – Vehicle sensor limitations (P1, D2, D3, D4, D5, P7, P11) – Connection of vehicle timelines with the mission timeline (D3, D4, P5, P7, P8, P11) – Conversation history with stakeholders (P4, P8, P10) – Decision support for not fully capable vehicles (D5, P6) – Indication that vehicle transferred to operator or away from operator (D4, P5, D7, P10)	– Uncertainty of predicted geo-spatial boundaries and location of mission vehicles (P2, D3, D4, P7, P8, D7, P11) – Uncertainty of geo-spatial position of operator's task at hand (P2, D2, P3, D3, D4, P5) – Uncertainty of mission timeline and mission deadlines (D3, D4, P5, P7, P8, P11) – Uncertainty of vehicle schedule and schedule latency (D3, D4, P5, P7, P8, P11) – Probability that vehicle will be able to complete task (D5, P6, P9) – Uncertainty in communication link coverage, strength, range and schedule (P4, D4, P5, P7, D7, P10)
Path Planning Supervision Loop	– Vehicle schedule (D1, D3, D5, D6, D7) – Vehicle path (D1, D3, D5, D6, D7) – Waypoints and loiterpoints of vehicle(s) (D4, P4, D6, D7, P5, D8) – Geo-spatial boundaries of land masses, hazardous areas, and mission areas of interest (D1, D3, D5, D6, D7, D8) – Communication link coverage, strength, range and schedule (P1, P6, D11, P7) – Visual/aural indication if data uplink too large for system (D10, P7) – Visual/aural confirmation that data link to vehicle successful (L6, D12)	– Connection between vehicle schedule and path (D1, D3, D5, D6, D7) – Track and schedule of all mission vehicles when requested (D4, P4, D6, D7, P5, D8) – Location of vehicles with similar functionality (D8, D9) – Solution possibility(s) for partially incapacitated vehicles (D2, P2) – Conversation history with stakeholders when determining to go through no-travel zone, or to miss a waypoint (P9, P10, P11) – Decision support when determining to go through no-travel zone,	– Uncertainty of vehicle location, geo-spatial boundaries and no-travel zones (D1, D3, D5, D6, D7) – Uncertainty and flexibility of communications link schedule and location (D10, P6, D11) – Decision support to determine what to do with a slightly hurt vehicle (D2, P2) – Uncertainty in communication link coverage, strength, range and schedule (P1, P6, D11, P7) – Probability of a communications lag (D10, P6, D11, P7)

		or to miss a waypoint (P9, P10, P11)	
What is the next task? Loop	– Indication of any preemptive alerts and time alert first was initiated (D1) – Checklist of local tasking orders (P1, D2, P4, D4, P6) – Mission timeline (P2, P3, P4, D4, P6) – Vehicle, and task actions of previous task (P3, D3) – Data/Images collected with time and vehicle specification since last viewing the data/images (P4, D4, P5, P6) – Geo-spatial track of operator vehicles during previous task, and interruption activity (P4, D4, P5, P6) – Missed waypoints or loiterpoints during previous task and interruption activity (P4, D4, P5, P6)	– Indication for tasking orders that were added/modified while in previous task (P1, D2) – Duration spent in previous task linked with mission timeline (P2, P3, P4, D4, P6) – Time-lapse view of actions taken in previous task when requested (P3, D3) – Mission events that occurred when previous task and interruption activity was being performed if requested (P3, D3, P4, D4, D5, P6)	– Uncertainty of alert validity (D1) – Probability that tasking orders no longer relevant to mission (P1, D2) – Probable next action the operator would have taken in their previous task (P3, D3) – Potential waypoints and loiterpoints in near future (P4, D4, P5, P6)

Appendix D: Information Requirements

Vehicle Location Information

- Geo-spatial location of all vehicles (friendly, neutral, and targets)
- Uncertainty of vehicle location
- Indication of vehicles of the same type (i.e. all vehicles capable of MCM similarly marked)

Geo-spatial Boundary Information

- Geo-spatial boundaries of land masses, hazardous areas, areas of interest and no travel zones
- Uncertainty of geo-spatial boundaries

Vehicle Coverage

- Past and future vehicle tracks by vehicle type
    a. Vehicles operator is in charge of emphasized over other vehicles
- Sensor/imagery coverage visualized
- Waypoints and loiter points of each vehicle marked on the vehicle track
- Waypoints and loiter points that might be missed in future highlighted

Communications Aspects

- Communications link coverage range
- Uncertainty/flexibility of communications link range
- Communications link schedule
- Conversation history with stakeholders and/or other operators
- Probability that a communications link lag could occur

Pre-condition: Communications link activated

- Duration of communications link
- Probability of communication link success
- Indication that a communications link was dropped
- Confirmation that a data link to a vehicle was successful
- Indication if a data uplink is too large for the communications link

Pre-condition: Lag in communications link

- Scheduled probable duration of lag
- Potential ways that operator can modify communications link to keep on schedule

Global and Local Tasking Orders

- List of global tasking orders that have been completed, are currently being attended to, and which need to be completed
- Indication for new global tasking orders
- Link of tasking orders to the mission schedule where applicable

Pre-condition: Operator enters into local tasking orders

- List of local tasking orders that have been completed, are currently being completed, and those that need to be completed
- Indication for new local tasking orders

- Link of tasking orders to the mission schedule where applicable

Schedule Information
- Full mission timeline
- Range of time operator and mission specific task areas should be completed in
- Operator's vehicle schedules

Vehicle Specific Information (only display information regarding operator's vehicles)
- Vehicle functionality
- General health and status of vehicle
- Vehicle limitations (only shown when predicted to exceed some safe region)
- List of vehicle equipment and health and status of that equipment

Pre-condition: vehicle has uploaded data/images
- Indication that new data/images have been uploaded
- Data/images linked to vehicle and geo-spatial location they were acquired
- imitations and uncertainty regarding the data/images

In the Case of a Preemptive Alert (requirements necessary if preemptive alert occurs)
- Indication if there is a health and status issue, or if a potential target has been located
- Indication of which vehicle has an alert
- Uncertainty with regards to the validity of the alert
- Vehicle checklists
- Critical health and status information highlighted

Pre-condition: Operator attends to preemptive alert (H&S alarm)
- Geo-spatial location of vehicle in question highlighted from other vehicles
- Vehicle specific equipment information including optimal and critical system performance ranges and current state
- Potential problems with vehicles and their solutions should be listed in all possible cases (with a decision help tool)
- Probability that vehicle will be able to complete designated action (return to base, continue with current task, termination action…)
- Predetermined termination action and the potential consequences of that action for other vehicles and the mission outlined

Pre-condition: Operator attends to preemptive alert (Target alarm)
- Geo-spatial location of vehicle in question highlighted from other vehicles
- Geo-spatial location of target in question highlighted
- Probability that target is a mine

Pre-condition: Operator delays alarm
- Indication that alert has been delayed and duration of alarm delay displayed on all work surfaces

During Imaging and Monitoring Activities (requirements necessary when operator has begun to follow a global tasking order)

- Indication if vehicle is loitering (static) or dynamic

Pre-condition: Operator identifies a potential target

- Visual/aural confirmation of target acquisition
- Likelihood that target is a mine/target

Pre-condition: Vehicle is loitering (static image gathering)

- Time history of data/images taken for that geo-spatial location
- Potential differences between the data/images taken over a segment of time
- Possible explanations of the differences in the data/images when requested

Pre-condition: Loitering vehicle scheduled to change loiter points or transition to dynamic searching

- Highlight vehicle schedule latencies
- Flexibility in mission task milestones and/or deadlines

Pre-condition: Operator searching an area that needs more data/images

- Potential aspects of the current data/images that need further information listed out when requested
- Geo-spatial location of areas that need more imagery/data by a specific (or any) vehicle type
- Schedule latencies
- Flexibility in mission task milestones and/or deadlines

Potential Mine Identification (requirements necessary when an operator has discovered a potential mine, or preemptive alert has been indicated with regards to a potential mine)

- Data/images and coordinates of mine
- Target threat and status
- Geo-spatial location of all pre-determined potential mines
- Repository of images taken of target, and of area around target
- Limitations and uncertainties regarding data/imagery of threat
- Parameters for imagery change or clarification from vehicles
- Currently known mine database including potential types of mines, their images, data signatures and behavior description
- Decision support (such as a Dynamic Contextual Decision Tree (DCDT)[3]) to identify target
- Accessible record of the key characteristics of mine inputted in by operator if desired
- Ability to change status of target

Pre-condition: potential target/mine marked as a threat

- Decision support (known mine database query tool such as DCDT in Nehme (2006)) to determine which target/mine type
- Indication of type of target included with target status (from vehicle location info)

Pre-condition: mine type has been determined

[3] Nehme, C. E., "Supporting Dynamic Contextual Decisions in Supervisory Control of Heterogeneous Unmanned Vehicles", Proceedings of Unmanned Vehicle Systems Canada 2006, Montebello, QC, Canada, November 8-10, 2006.

- Decision help in cases of uncertainty concerning mine neutralization
- Likelihood that vehicle will be able to neutralize mine as desired
- Visual/aural indication that vehicle has new images/data regarding mine and/or location of mine

Pre-condition: vehicle marking location of mine
- Probability that marker will stay where placed

Potential Target (non mine) Identification (requirements necessary when operator has discovered a potential target, or preemptive alert has been indicated with regards to a potential target)
- Target threat and status
- Repository of images taken of target, and of area around target
- Limitations and uncertainty of images
- Parameters for imagery change or clarification from vehicles
- Currently known potential target database including their images, target behavior and other key descriptions to help operator identify target at hand
- Decision support (such as DCDT in Nehme (2006)) to identify target
- Accessible record of the key characteristics from vehicle information and operator input
- Ability to change status of target

Pre-condition: potential target marked as a threat, and stakeholder not available/not responsible with determining action to complete
- Decision support (known target database query tool such as DCDT in Nehme (2006)) to determine what action to take with a potential threat

Pre-condition: stakeholder or operator elects to disengage
- Visible/aural alert is target is disengaged
- Target handoff constraints

Pre-condition: stakeholder or operator elects to monitor and track
- Likelihood that operator's vehicle could be targeted
- Indication that a vehicle is tracking a target
- Indication and record history that target threat has changed
- Predicted target track(s) in the case of a moving target (MTI)

Pre-condition: stakeholder or operator elects to engage target
- Likelihood that operator's vehicle could be targeted
- Indication that target has been designated to be eliminated
- Visible/aural alert if vehicle has updated data/images of target
- Predicted target track(s) in the case of a moving target (MTI)

Vehicle Reallocation (requirements necessary when an operator is assigning vehicle a vehicle that has fulfilled all its tasking orders and there is still time in the mission)
- Vehicle functionality and location
- Vehicle list and health & status of equipment

Pre-condition: vehicle found to be not fully capable

- Decision support (cost-benefit optimization) to determine what to do with incapacitated vehicle

Pre-condition: operator assigns vehicle to new task or recalls it
- Visual/aural indication that the vehicle has been transferred to its new task
- Visual/aural indication that vehicle has safely arrived back to where it was launched

When Reallocating a Vehicle (requirements necessary when an operator is attempting to obtain an additional vehicle for assistance on a specific task)
- Description of operator's task
- Necessary equipment list for a vehicle to perform task
- Selection of geo-spatial location of operator's task
- Uncertainty of task location
- Computer-generated list of vehicles that meet task requirements and within a certain distance from task's geo-spatial location

Pre-condition: One or more vehicles meet task requirements within the geo-spatial region of the task
- Potential vehicle's schedule with schedule loiter times and/or time latencies emphasized
- Ability for operator to narrow down computer generated list
- Task priority and/or relative task priority of potential vehicles in the list
- List health and status of equipment for each potential vehicle in the list
- Ability to select optimal vehicle
- Ability to store other potential vehicles in case chosen vehicle cannot be transferred

Pre-condition: No vehicles meet task requirements within given distance to task location
- Ability to modify functionality requirement
- Ability to modify distance from task's geo-spatial location

Pre-condition: Optimal vehicle for task determined
- Selection of periods of time within vehicle's timeline that operator could use for specific task

When Performing Path Planning Supervision Functions (requirements necessary when operator is rescheduling, or rerouting a vehicle's path)
- Automatically highlight waypoints and loiter points that may/will be missed in the future
- Vehicle path and schedule as well as their link highlighted
- Track and schedule of all mission vehicles when requested

Pre-condition: operator has uncertainty regarding the vehicle track
- Decision support (cost-benefit optimization) to determine what to do with an incapacitated vehicle
- Critiquing decision support to aid in determining proposed routes through no-travel zones or possible missing of a waypoint/loiter point

When the operator has finished an "interruption" task (path planning, mine neutralization, etc or a preemptive alert) (requirements necessary when operator has completed "interruption" task)
- Delayed preemptive alert(s) description and time stamp become more prominent
- Amount of time spent in "interruption" task

- Changes or additions to global tasking orders and when changes occurred

Pre-condition: operator has no new global orders or other preemptive alerts
- Recap of the last tasks the operator completed
- Ability for the operator to ask for further information regarding previous actions and the mission state
- Events applicable to the previous task within the mission shown chronologically and geo-spatially
- Probable next action the operator would have completed in the previous task
- Changes in health and status of vehicles in previous task

Pre-condition: operator determines previous task completed or no longer necessary
- All new data/images for the operator's vehicles displayed with the time and geo-spatial location of acquisition
- Missed waypoints, loiter points, or communication links that occurred for vehicles under operator's control
- Changes to health and status of operator's vehicles
- Checklist of all local tasking orders, which orders completed, new/updated orders with an emphasis on when orders changed, and any orders that are late or will soon become late due to "interruption" task
- Ability for the operator to request further information regarding mission events that occurred during task, and/or events specific to the operator's local tasking orders