

COGNITIVE TASK ANALYSIS FOR THE LCS OPERATOR

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Executive Summary

The following Tables and Figures detail the cognitive task analysis (CTA) performed to determine the information requirements needed to support a single operator located aboard the futuristic Littoral Combat Ship (LCS). This operator is responsible for controlling four underwater unmanned vehicles in conjunction with a UAV operating on a shared network.

- Table 1 is a scenario task overview that breaks the overall mission into 3 phases (planning, execution, and recovery) and then details the subtasks for each of the 3 mission phases.
- Figure 1 is an event flow diagram that demonstrates what events must occur in a temporal order for each of the 3 phases. There are three basic event types in Figure 1: 1) a loop (L) that represents a process that occurs in a looping fashion until some predetermined event occurs, 2) a decision (D) that represents some decision that is required from the LCS operator, and 3) a process (P) which requires some human-computer interaction to support the required tasks. In each event block, an alphanumeric code is included which labels that particular event type (L#, D#, P#). This label is important because later information requirements will be mapped to one of these events.
- Table 2, which details the situation awareness (SA) requirements for the LCS Operator for each of the 3 mission phases and associated subtasks. Each of these SA requirements is mapped directly to one or more events in Figure 1.

Because the decisions in Figure 1 represent critical events that require detailed understanding of what information and knowledge is needed to support the operator's decision-making process, decision ladders were constructed for the diamonds and loops in Figure 1 that correspond to an involved decision process to resolve the question being posed at that stage in the event flow (Figures 2-4). Decision ladders are modeling tools that capture the states of knowledge and information-processing activities necessary to reach a decision. Decision ladders can help identify the information that either the automation and/or the human will need to perform or monitor a task. Decision Ladders, illustrate the need not only for the same information identified by the cognitive task analysis, but the need for several other pieces of information such as the need for visual or aural alerts in contingency situations. In Figures 2-4, three versions are included that detail (a) the basic decision ladder, (b) the decision ladder with corresponding display requirements, and (c) the decision ladder with possible levels of automation.

- Figure 2 represents the automated target recognition (ATR) decision ladder (D3 from Event Flow): (a) decision ladder, (b) decision ladder with corresponding display requirements, and (c) decision ladder with possible levels of automation.
- Figure 3 shows the decision ladder information and knowledge requirements for the sentry handoff (L3 from Event Flow).
- Figure 4, the UUV Recovery Decision Ladder (D7 from Event Flow), illustrates what information is nominally needed. Since this phase was not a major focus, the decision ladder is not as detailed as it could be. This should be a point of focus in Phase II.

Lastly Figure 5 demonstrates the coordination loop that must occur in the case where a handoff failure occurs (for a number of reasons to include equipment failure, communication delays, etc.) Again, because the multi-player coordination issues are not a primary focus in Phase I but are a significant consideration for any follow-on phases.

Table 1. Scenario Task Flow Overview

<p>Mission Planning</p>	<p>It is assumed that the following issues will be resolved in this phase:</p> <ul style="list-style-type: none"> • Search area for Search UUVs will be determined. • Sentry positions for Sentry UUVs will be determined. • Mission route for each UUV will be determined. • Communication / location checkpoints will be scheduled for UUVs. 	<p>Helpful information for resolving these issues may include:</p> <ul style="list-style-type: none"> • known harbor traffic schedule / peak times • mission clock • estimated time to harbor entry • time average target acquisition will take, based on speed of UUVs (transit time), communication time (ATR-flagged EO imagery sent / LCS confirm/reject, new EO imagery acquired, etc.) • known traffic lanes • ideal range of UUVs for accurate target ATR • ideal range of UUVs for accurate target monitoring • limitations of camera angle view? • UAV schedule (to include windows of availability for this mission)
	<p>Mission Execution</p>	<p>Phase Goals</p>
<p>Launch UUVs Phase</p>		<ul style="list-style-type: none"> - Launch Search UUVs - Launch Sentry UUVs
<p>Acquire Target Phase</p>		<ul style="list-style-type: none"> - LCS tracks progress of UUVs, making sure UUVs are at expected positions at scheduled checkpoints (geo-fix should update actual location) - LCS tracks status & availability of UAV (ongoing) - Search UUVs surface to scan shoreline at planned location / time (updated geo-fix position data sent via UAV, if UAV is in range) - If ATR flags an image during a Search UUV scan, EO imagery is sent to LCS via UAV. If UAV unavailable, UUV loiters, resurfacing & resending at next scheduled checkpoint. Continue until UAV is available. Once EO imagery is sent, UUV loiters until Acknowledgement (Ack) is received from LCS – surfacing at each scheduled checkpoint. - LCS examines EO-imagery, then sends Ack back to all UUVs. If Ack is ‘positive’, UUV continues to loiter in current position, monitoring confirmed target. If Ack is ‘negative’, UUV resumes search task. - Acquire phase is complete once one of the UUVs has received a ‘positive’ Ack from the LCS. Second Search UUV should be retasked to confirmed target location for redundant monitoring (or retasked to another potential target or returned to LCS)

Table 1. Scenario Task Flow Overview (cont'd)

	Phase Goals	Phase Breakdown
Mission Execution (cont'd)	Monitor Target Phase	<ul style="list-style-type: none"> - Search UUV should continue to surface at scheduled checkpoints to continue monitoring target – ATR should continue to flag target as contact of interest and update imagery. - When onboard ATR no longer has target in camera range, target tracking should be handed off to UAV...last known location should be available to Sentry UUVs, to UAV's MTI program, and to LCS. - When target is lost by Search UUV(s), Sentry UUVs, UAV (if available) & LCS should be given last known location by UUV as well as historical and predicted track of target. - Monitor Target phase is complete once UAV is tracking the target, or Search UUVs handoff to Sentry UUVs. - LCS should retask or recall Search UUVs
	Tracking Target Phase	<ul style="list-style-type: none"> - UAV should use last known location from UUV + MTI software to track target. UAV should send LCS MTI feed. - LCS should monitor LCS MTI feed - LCS should determine estimated time of arrive of target at harbor entrance based on MTI feed from UAV and schedule Sentry UUVs to surface and capture EO-imagery of expected target location at that time via UAV communication link (this should be automated to the highest degree possible). - Tracking Target phase is complete once target reaches Sentry UUVs, UAV tracking could be discontinued at this time.
	Exit Harbor Phase	<ul style="list-style-type: none"> - Within a predetermined window of time, Sentry UUVs should surface and wait for target arrival, - UUV should capture and send collected EO-imagery to LCS via UAV. If UAV is unavailable, surface at scheduled time intervals to retry EO-imagery transmission. Continue cycle until Ack is received from LCS. Regardless of Ack status, at least 1 UUV will track the target out of the harbor based on a set of predetermined criteria. - LCS should determine tracking profile of Sentry UUVs and determine when they will be retasked or recalled.
Mission Recovery	Once the Mission Execution Phase is completed - or is aborted - UUVs should be recalled to LCS or retasked to another mission.	

Figure 1. Event Flow Diagram

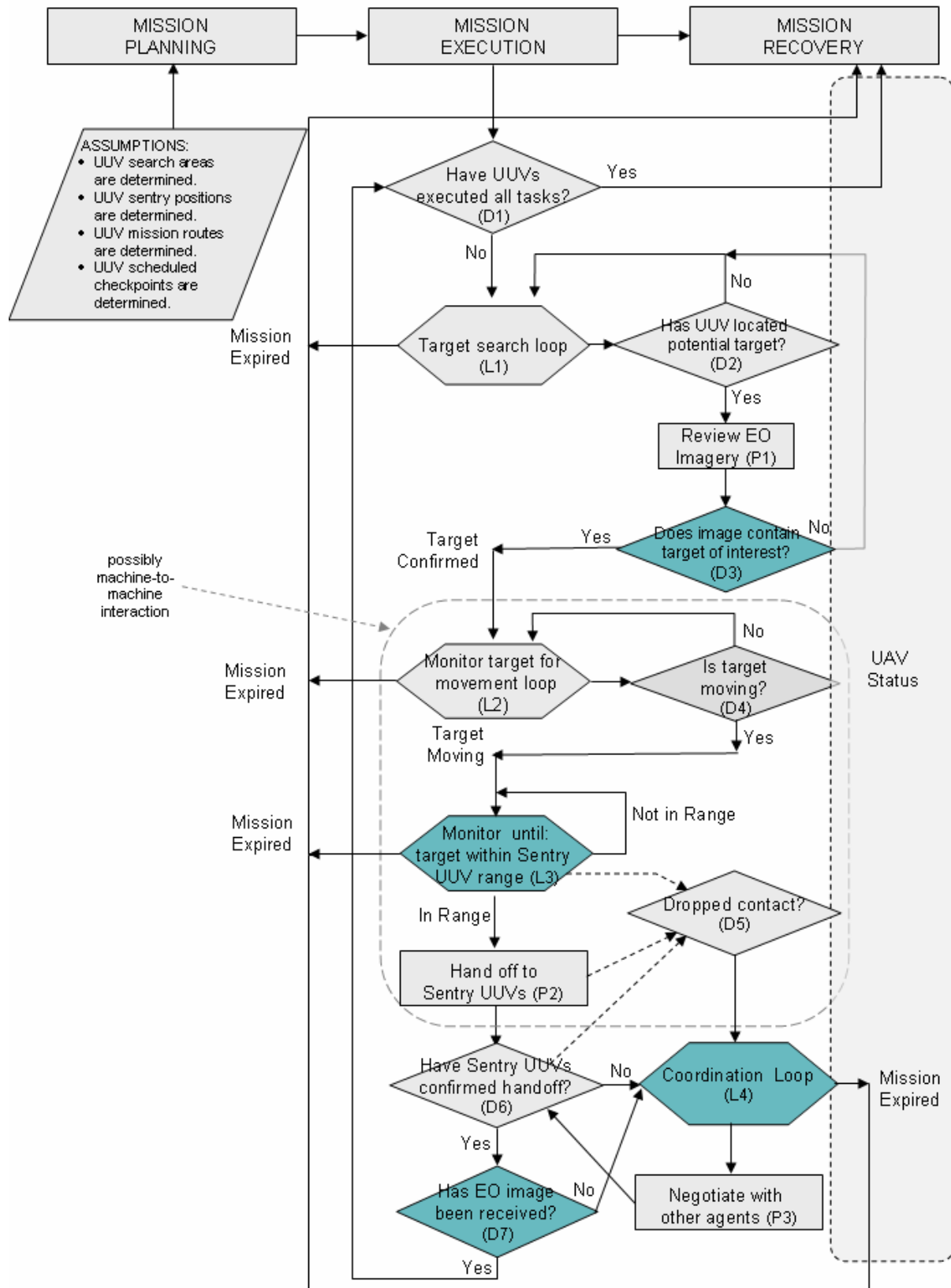


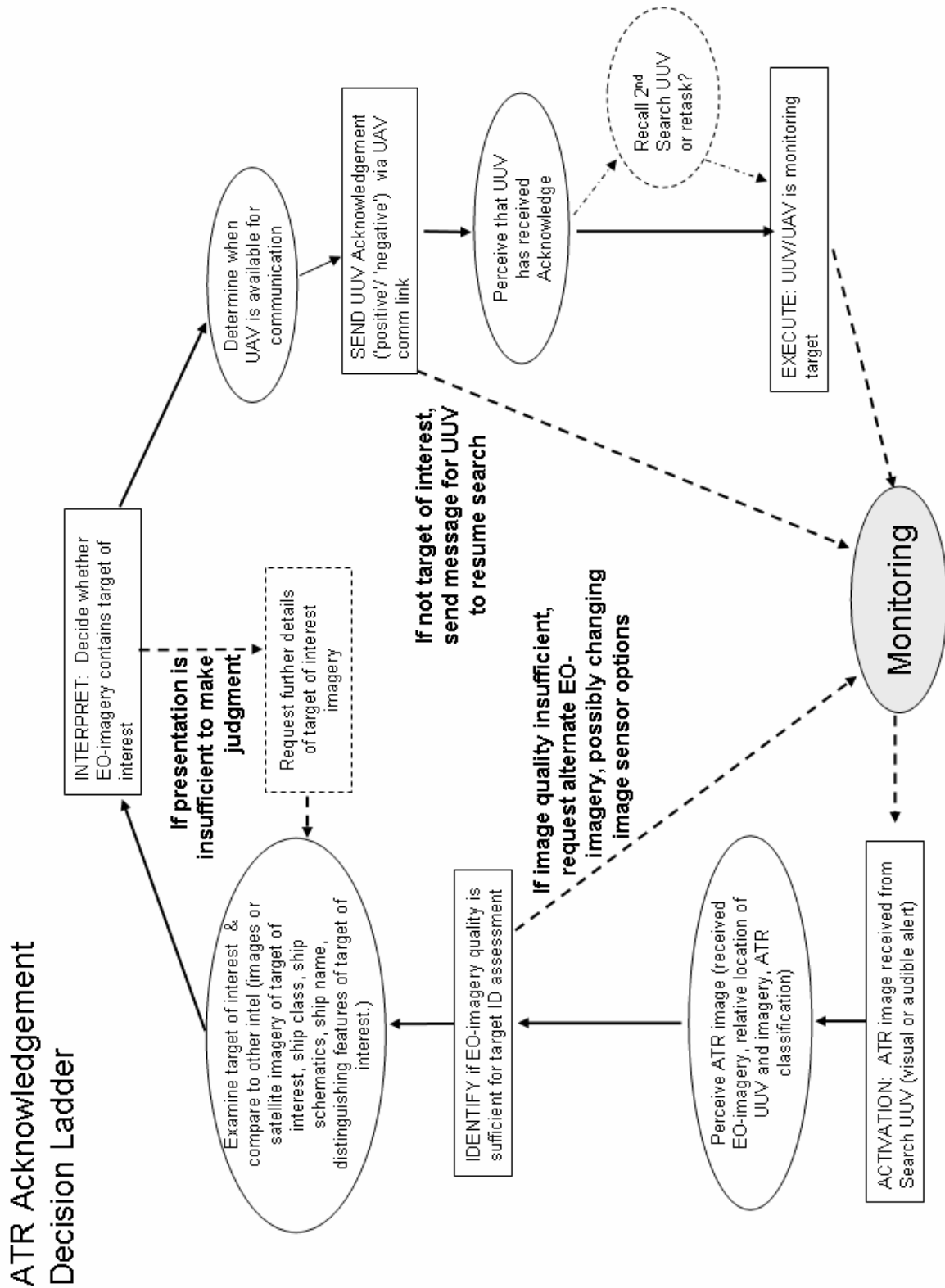
Table 2. Situation Awareness Requirements for the LCS Operator

	Level I (Perception)	Level II (Comprehension)	Level III (Projection)
Acquire Target Phase	<ul style="list-style-type: none"> - Visual & audible alert when UAV leaves or returns on-station duty (D2) - All agents' position information (D3) - Hazardous areas (L1, D2) - Geo-spatial boundaries (L1, D2) - Indicate communications link coverage range when on-station (D2, D3) - Sensor coverage should be visualized on tactical map (D2, D3) - Visual/audio feedback for confirmation of target acquisition (D2, L1, D3) 	<ul style="list-style-type: none"> - Error/alert message clarification (L1, D2, P1, D3) - Vehicle limitations (on demand) (P1, D3) - UUV schedules (D2, D3) - Health & status of UUVs (L1, D2) - Strength of comms link to UUV scheduled to check in should be indicated on tactical map (based on current position of UAV and comms range) (D2, L1, D3) - Expected connection should be indicated at UUV scheduled checkpoint time – if UAV out of range / unavailable, missed connection should be indicated (L1, D2) - Temporal constraints (P1) 	<ul style="list-style-type: none"> - Schedule of estimated UAV on-station availability should be provided on a visual timeline (D2, D3) - Uncertainty of estimated timeframes should be indicated on availability timeline (D2, D3) - Potential missed communications points (D2, D3) - Future likely UUV tracks (D2, D3) - Vehicle limitations (when predicted to exceed some safe region) (D3) - UUV schedules (D2, D3) - Prediction of system health/status (D2)
Tracking Target Phase	<ul style="list-style-type: none"> - UAV MTI imagery (D4, P2) - UUV target imagery/sensor data (D4, L3, P2) - Visual & audible alert when UAV leaves or returns on-station duty (D4, L3, P2) - All agent position information including target (D4, L3, P2) - Indicate communications link coverage range when on-station (D4, L3, P2) - Sensor coverage should be visualized on tactical map (L3) - Visual & audible alert when target is dropped (L3, D5) - Potential environmental hazards for tracking (L3, P2) 	<ul style="list-style-type: none"> - MTI exploration capabilities (playback, zooming) (D4, L3, P2) - UAV handoff constraints (P2) - Health & status of UUVs (D4, P2) - Comms link coverage should be visualized on tactical map (D4, L3, P2) - Strength of comms link to UUV scheduled to check in should be indicated on tactical map (based on current position of UAV and comms range) (D4, P2) - Feedback if target is dropped (L3, D5) - Expected connection should be indicated at UUV scheduled checkpoint time – if UAV out of range / unavailable, missed connection should be indicated (D4, L3, P2) 	<ul style="list-style-type: none"> - Uncertainty of predicted target location should be displayed on tactical map (D4, L3, P2) - Predicted target track (L3, P2) - Schedule of estimated UAV on-station availability should be provided on a visual timeline (D4, L3, P2) - Uncertainty of estimated timeframes and position for handoff should be indicated on availability timeline (P2) - Availability schedule should also indicate the UUVs' scheduled checkpoint times (D4, L3, P2) - Vehicle limitations (when predicted to exceed some safe region) (P2) - Prediction of dropped contact (L3, D5)

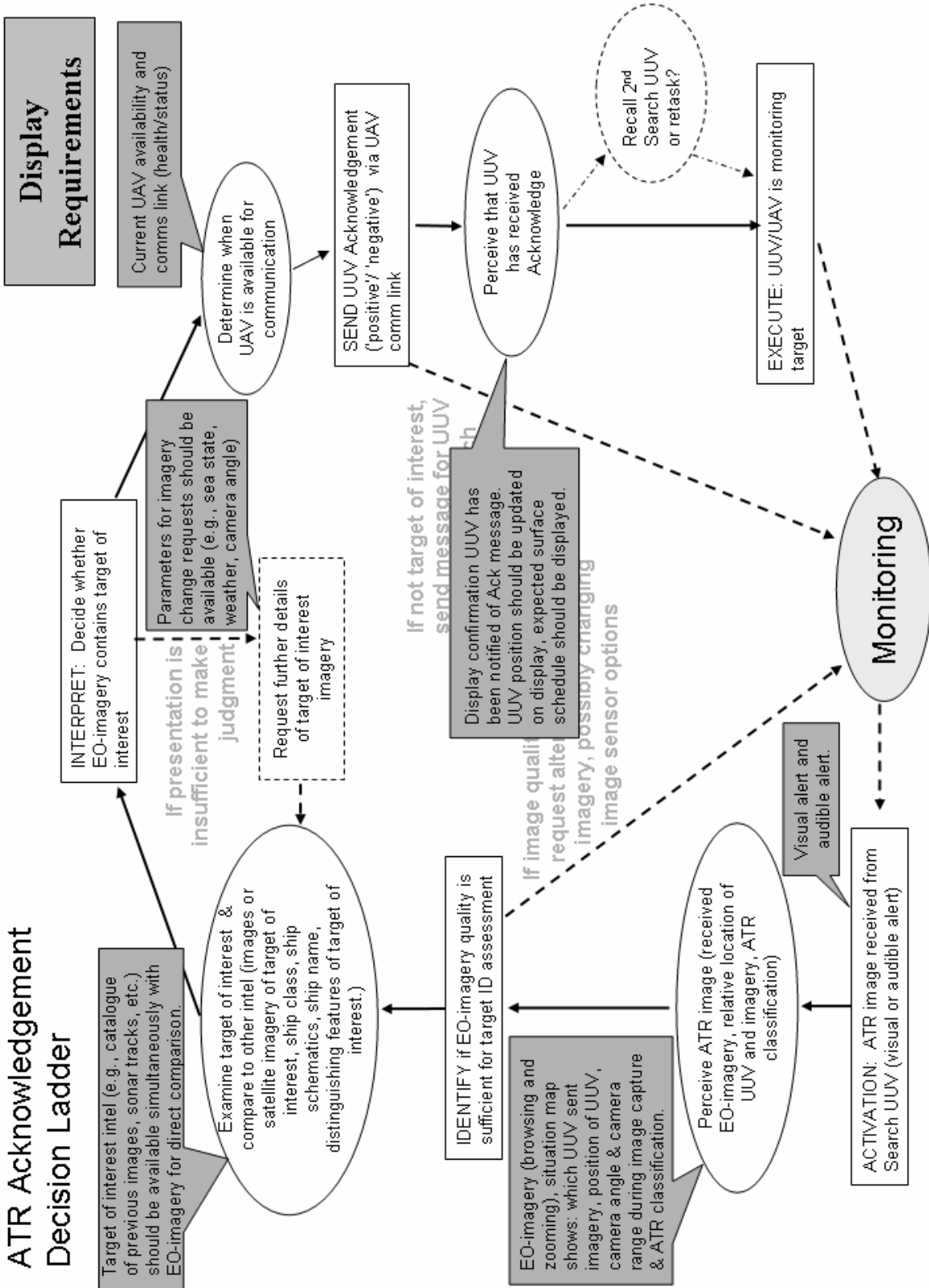
Table 2. Situation Awareness Requirements for the LCS Operator (cont'd)

	Level I (Perception)	Level II (Comprehension)	Level III (Projection)
Exit Harbor Phase	<ul style="list-style-type: none"> - Visual & audible alert when UAV leaves or returns on-station duty (D6, L4, P3, D7) - Indicate communications link coverage range when on-station (D6, L4, P3, D7) - All agent position information (D6, L4, D7) - Visual & audible alert when target is dropped (D6, L4, D7) 	<ul style="list-style-type: none"> - Sentry acquisition confirmation (D6) - Comms link coverage should be visualized on tactical map (D6, L4, D7) - Strength of comms link to UUV scheduled to check in should be indicated on tactical map (based on current position of UAV and comms range) (D6, L4, D7) - Health & status of UUVs (D6, L4, D7) - Expected connection should be indicated at UUV scheduled checkpoint time – if UAV out of range / unavailable, missed connection should be indicated (D6, L4, D7) 	<ul style="list-style-type: none"> - Schedule of estimated UAV on-station availability should be provided on a visual timeline (D6, L4, D7) - Uncertainty of estimated timeframes should be indicated on availability timeline (D6, L4, D7) - Availability schedule should also indicate the UUVs' scheduled checkpoint times (D6, L4, D7) - Vehicle limitations (when predicted to exceed some safe region) (D6, L4, P3)

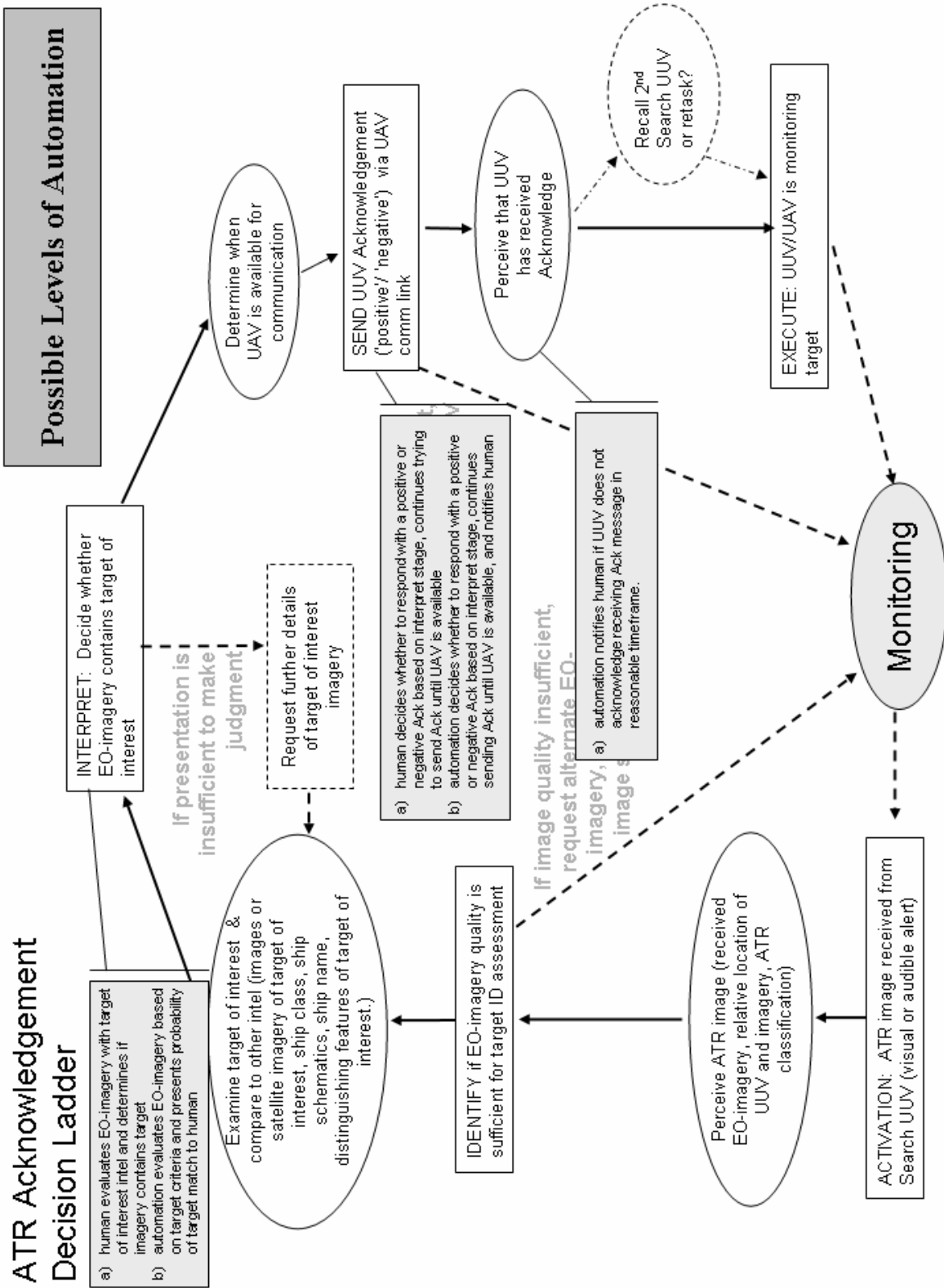
Figure 2. ATR Decision Ladder (D3 from Event Flow): (a) decision ladder, (b) decision ladder with corresponding display requirements, and (c) decision ladder with possible levels of automation.



2(a)



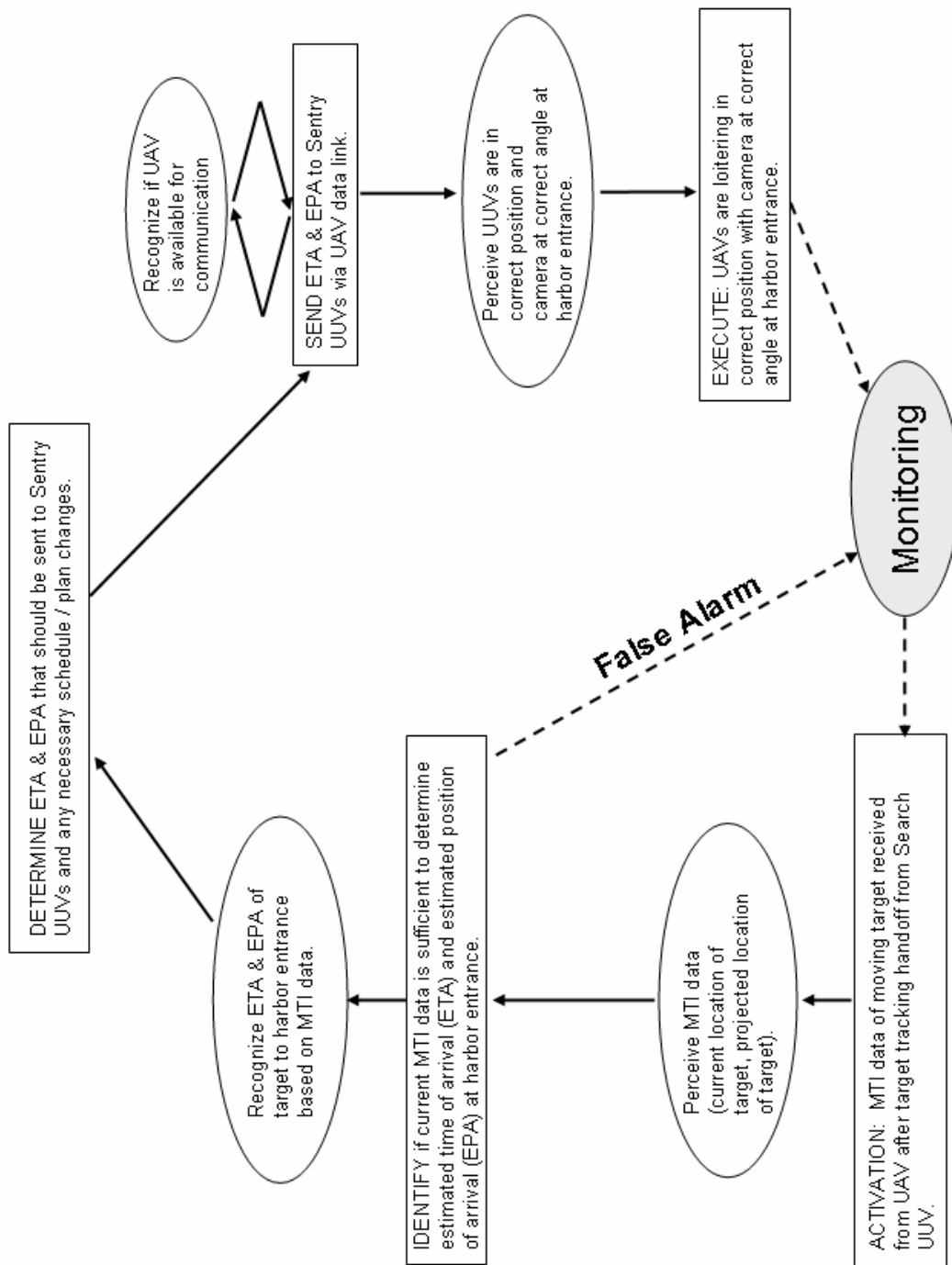
2(b)



2(c)

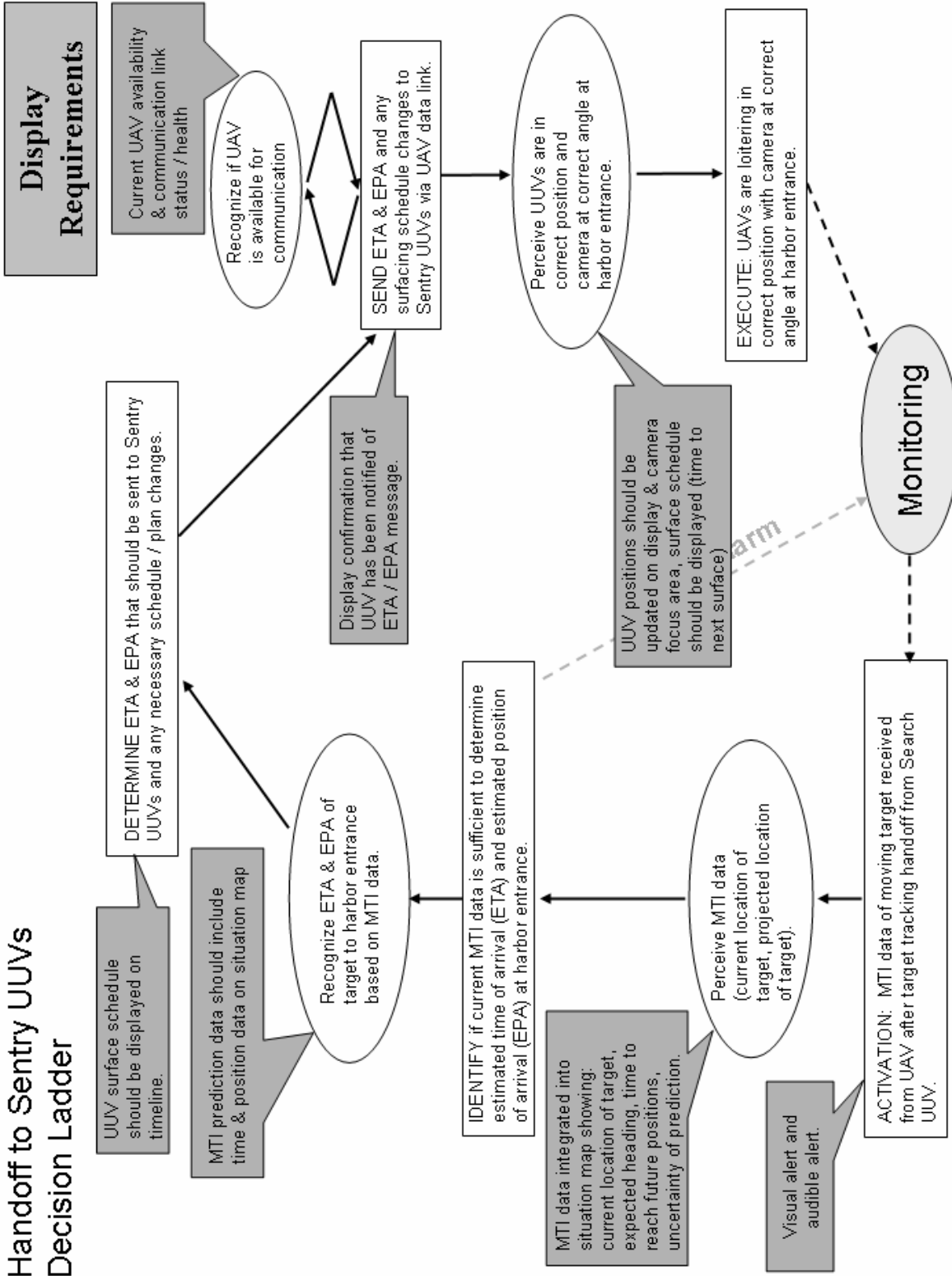
Figure 3. Sentry Handoff Decision Ladder (L3 from Event Flow): (a) decision ladder, (b) decision ladder with display requirements, and (c) decision ladder with possible levels of automation.

Handoff to Sentry UUVs Decision Ladder



3(a)

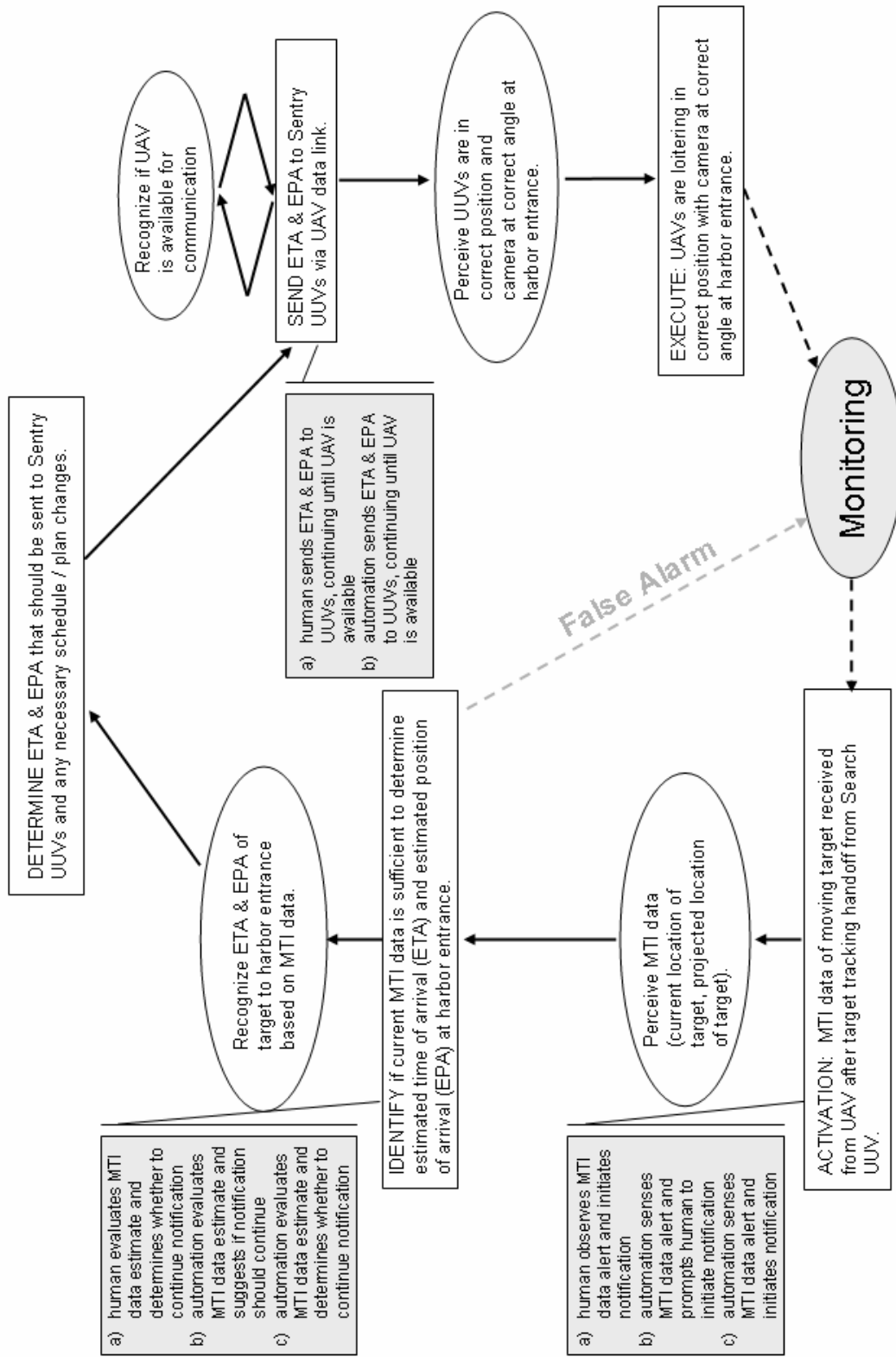
Handoff to Sentry UUVs Decision Ladder



3(b)

Handoff to Sentry UUVs Decision Ladder

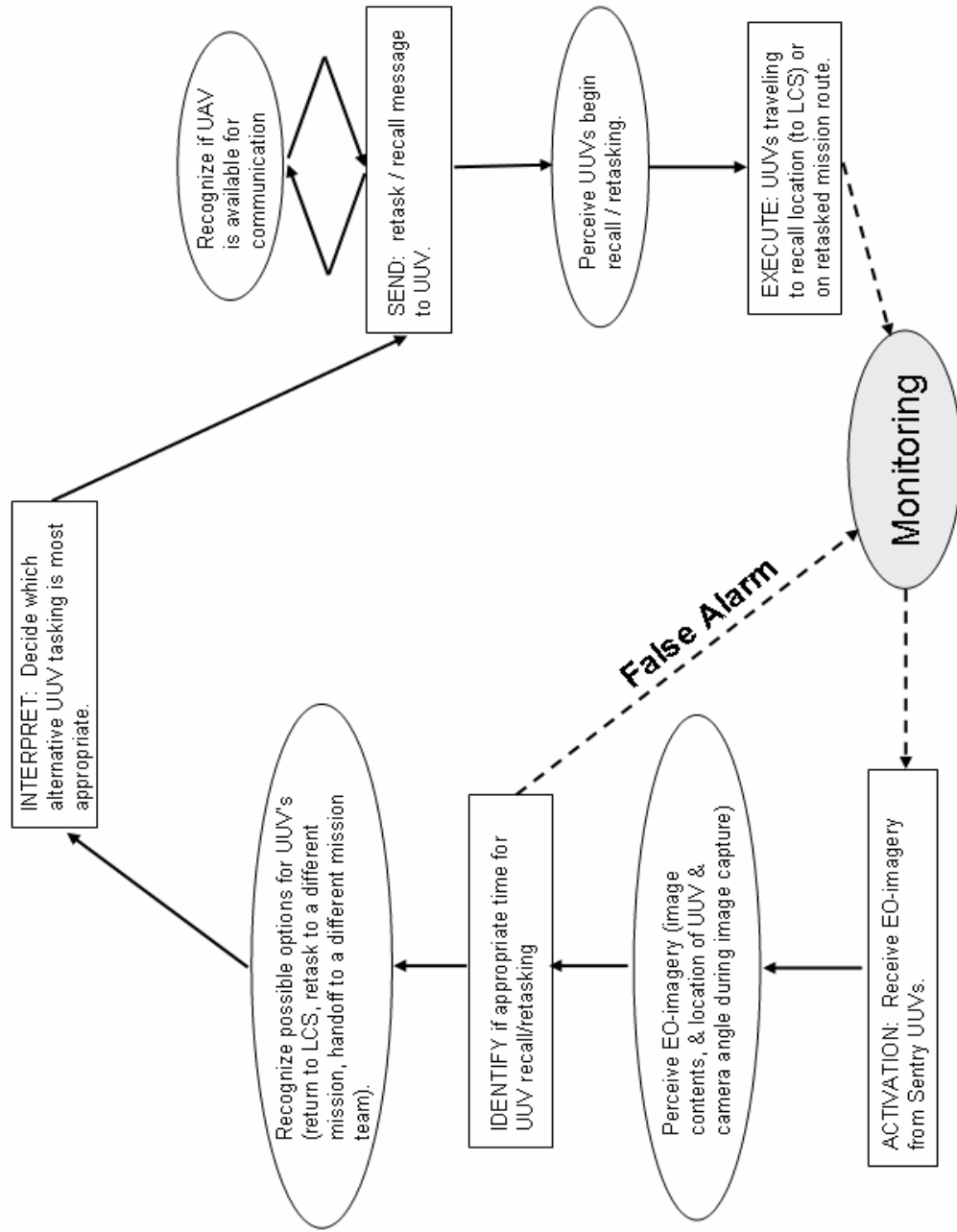
Levels of Automation



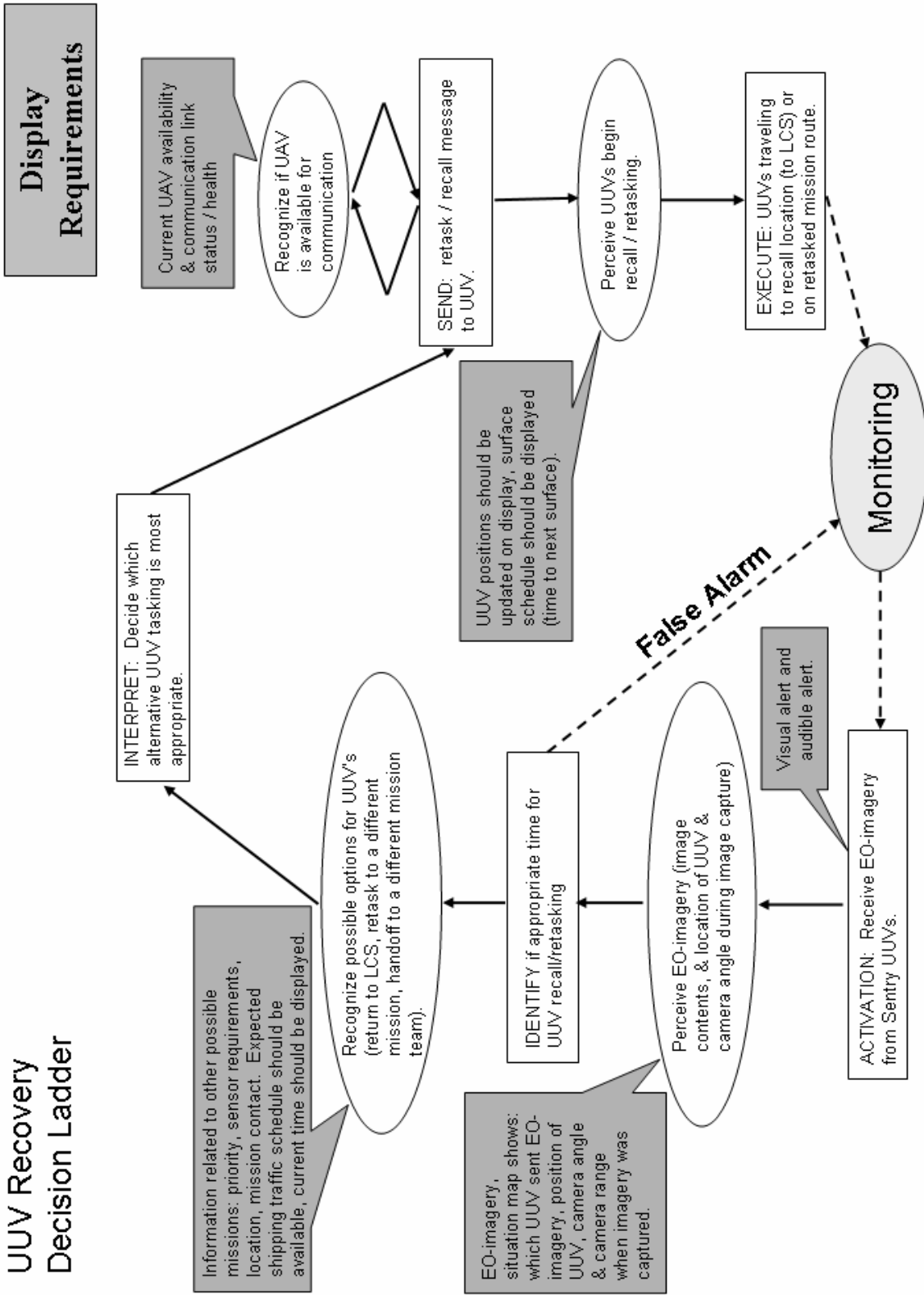
3(c)

Figure 4. UUV Recovery Decision Ladder (D7 from Event Flow): (a) decision ladder, (b) decision ladder with display requirements, and (c) decision ladder with possible levels of automation.

**UUV Recovery
Decision Ladder**



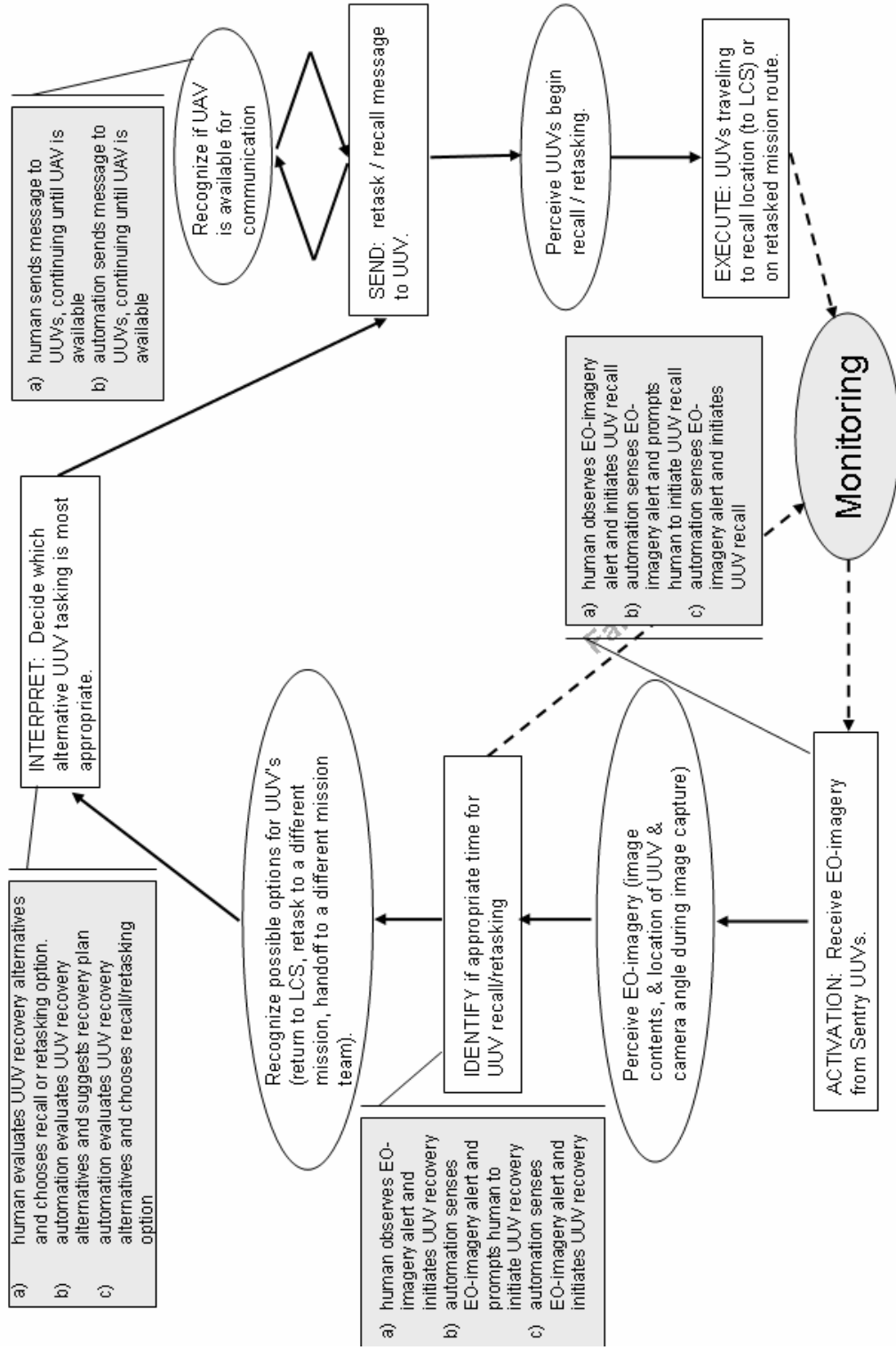
4(a)



4(b)

UUV Recovery Decision Ladder

Levels of Automation



4(c)

Figure 5. Coordination Loop (L4 from Event Flow).

