Shadow TUAV
Single Operator Consolidation: Display Assessment

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1 Introduction

Currently, Shadow UAV operations require two people: the Air Vehicle Operator (AVO) and the Mission Payload Operator (MPO). A previous workload study demonstrated that it is possible to combine these two positions such that one person can assume both roles (Appendix A). However, to achieve this consolidation, improved displays in terms of usability and increased automated functionality will be necessary to keep the workload of the single operator to acceptable levels. To demonstrate the types of changes that will need to occur for successful AVO and MPO consolidation, this report focuses on display and automation improvements in the following three areas: systems management, vehicle situation awareness, and payload operations. For each of these areas, a previous display has either been designed or improved upon, always applying human factors design principles. Each of these display redesigns exemplifies how operator workload can be decreased, as well as improve overall mission capability.

For the system management example, the Identification Friend-or-Foe (IFF) display was chosen for re-design as a representative system display. For the vehicle situation awareness representative design, a new display was proposed: the situation awareness display. Additionally, improvements were suggested for the horizontal map display. Finally, within the payload operations category, an automatic target recognition system was proposed for small weapons fire.

2 Systems Management

For the system management display, the IFF display was chosen because it was representative of the type of re-design that should be implemented in order to decrease operator workload. The IFF is a system that does not require continuous monitoring or interaction and is "managed" in the sense that it must be attended to occasionally as a mission dictates. Thus it is a display that will seldom be accessed in flight, and thus is a display not considered critical for routine operations. (Even in an emergency, it only needs to be accessed briefly to change a setting.)

The original IFF display can be seen in Figure 1 (left). A usability analysis revealed problematic issues: large screen space, separation of command modes, unnecessary buttons, inconsistent use of color, and critical information scattered across the display. Furthermore, in interview conducted at Ft. Huachuca, operators commented that they would forget to load IFF codes and that it required too much effort to implement a simple change. If interaction times could be reduced, this would contribute to overall lower workload on the part of the proposed dual-use operator..

The specific problems identified within the IFF display were:

- Repeated use of two separate buttons for activating and deactivating functions (e.g., for "squawking", enabling emergency mode, and "zeroize" Mode 4).
- Buttons for infrequently used functions (e.g., changing duration of the "squawk").
- Visual separation between UAV reported IFF codes and command codes, forcing a repeated scanning between the two sections of the display.
- Inconsistent use of color (e.g., using green to indicate "emergency" mode is activated).

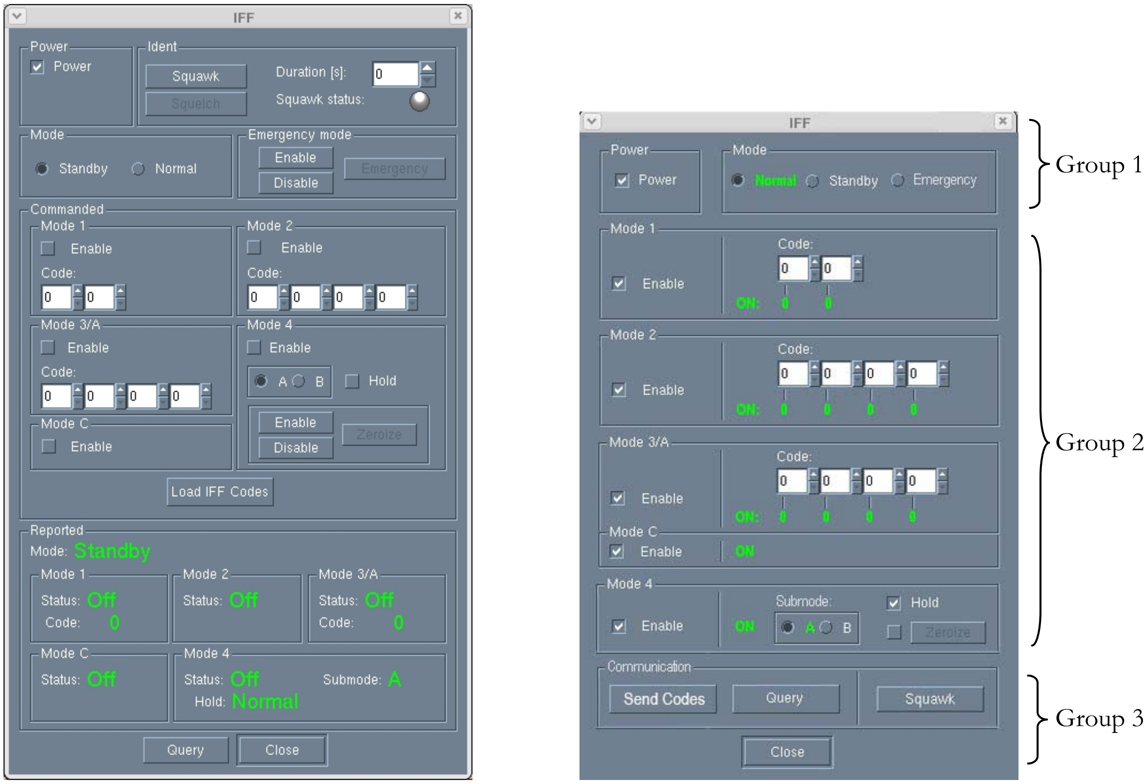

Figure 1 IFF display, original (left) and revised (right)

2.1 *Proposed revised IFF display*

The proposed revised IFF display (Figure 1, right) was improved based on the following design principles:

- Alignment or functional grouping [1]
- Salience of elements [2]
- Proximity compatibility principle [3]
- Direct perception interaction [4].

By applying these principles, the size of the display was reduced by 25% and ease-of-use was facilitated.

Three functional groupings were used to re-arrange the IFF display: main modes, mode inputs/outputs, and communication. On the top of the display (Figure 1, right), the main modes (normal, standby, and emergency) are grouped. Potentially, pre-set conditions could be also included (e.g., in-flight refueling), incorporated as a drop-down menu selection.

The second grouping (in the middle of the display) contains the input/output IFF modes. These modes are listed sequentially. As in the original display, the same enabling buttons and code inputs are used. Most importantly, the corresponding reported modes (from the UAV) are listed alongside the inputs. Instead of having to scan two areas in the original display to assess if the reported codes match the inputs, the operator only has to look in one place to directly ascertain this information. Furthermore, color was used to indicate if the reported codes and the inputs match (green for matching). Yellow was selected to indicate that the codes are being changed and they have yet to be sent the UAV (Figure 2, left) while red means there is a disparity (Figure 2, right). By leveraging color, the display makes mismatches salient and reminds the operator to load any code changes.

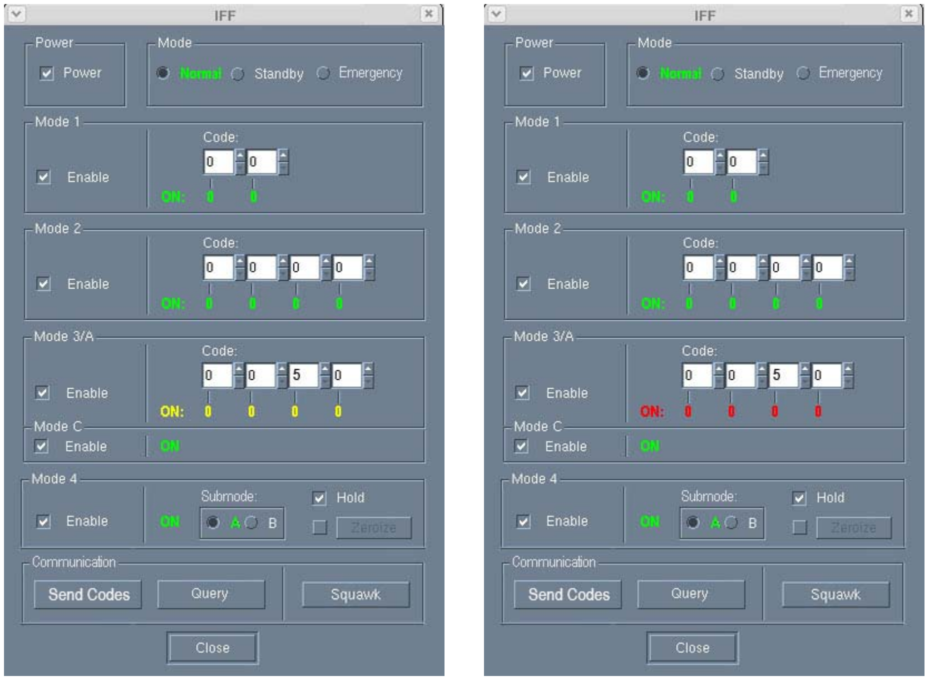

Figure 2 Example of color use to indicate codes have not been sent (left) and when reported codes do not match entered codes (right)

All the functions related to communication are grouped at the bottom of the IFF display. These functions include: sending codes, querying the UAV (for uploaded codes), and squawking codes. Originally, the “send codes” buttons was named “load IFF codes”. The “Send” was used since it is unambiguous as the phrase “loading” codes could imply input of the codes into the display. The “squelch” and squawking durations were removed as these are not used.

This redesign of the IFF display promotes workload reduction. To illustrate this, Figure 3 depicts the actions involved in entering and sending IFF codes. Each yellow circle is contiguous to information that the operator needs to complete the task; each arrow denotes the next piece of information that is assessed. For the original IFF display (Figure 3, left), the UAV operator has to assess information all over the display. On the other hand, in order to complete the task with the revised display (Figure 3, right), the operator follows a set of sequential steps from top to bottom, concluding in sending the codes up to the UAV and then “squawking” this information. The revised display essentially leads the operator directly and efficiently through the task of entering and sending IFF codes, simplifying the task and hence, reducing workload.

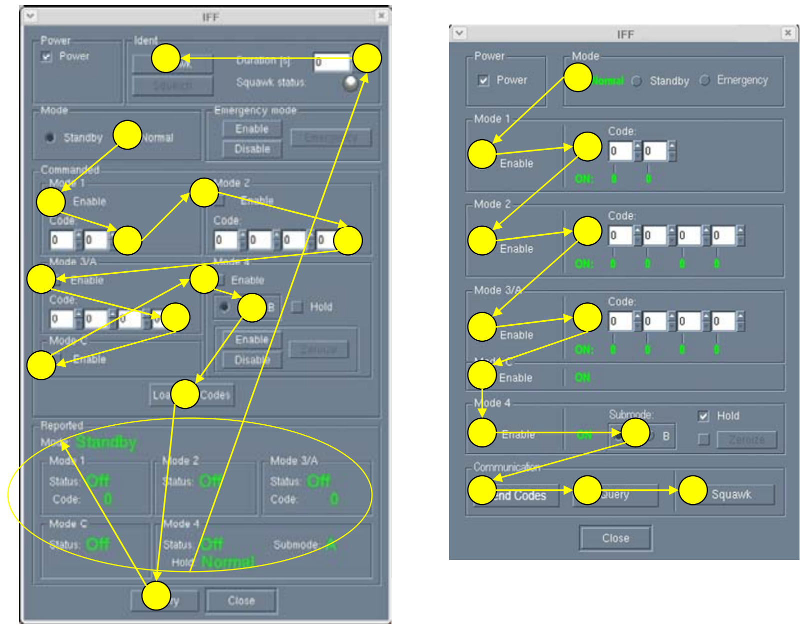

Figure 3 Comparison of actions when inputting and sending IFF codes

Future implementations of the IFF display could leverage automation to further facilitate the use of this display. For instance, it is unclear if a specific "query" button is necessary as this function could be automatically done at particular time intervals or after a change in codes or command occurs. This would alleviate the operator from doing this action and keep the reported IFF codes up-to-date. Additionally, a pop-up reminder may be used to alert the operator that he/she has not uploaded the newly changed IFF codes after a fixed amount of time (e.g., 20 seconds).

In summary, the redesign of the IFF display resulted in a decrease in display size (about 25%). Furthermore, this approach should reduce the operator's workload as inputs and reported codes are closely aligned, promoting direct perception interaction, which reduces operator cognitive workload. We have also increased the reliability by utilizing color to remind operators to send modified codes and to quickly inform operators of discrepancies between IFF codes and reported codes. It should be noted that the proposed revised IFF display is similar to the new CDL IFF display (independently designed, Figure 4). The primary difference between this display and the proposed IFF display is that the reported and current codes are not co-aligned.

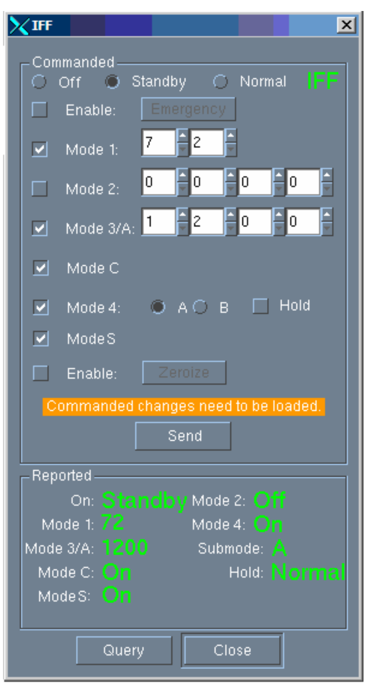

Figure 4 CDL Revised IFF display

3 Vehicle Situation Awareness

Currently, there is one operator (AVO) dedicated to monitoring the health and status of the UAV. The AVO must maintain situation awareness through the perception, comprehension and projection of important elements that pertain to the health and status of the vehicle [5]. A display that facilitates vehicle situation awareness is one that highlights important variables about current UAV operation and assists in projecting future states of these variables. The use of these displays can potentially dramatically reduce workload. Thus, in order to improve situation awareness of the TUAV in general (either for a dual or single operator configuration), a new vertical situation display is proposed in conjunction with a few revisions to the current horizontal, geo-spatial display. A vertical situation display would assist the operator in integrating terrain elevation information with the UAV's flight profile, which is currently accomplished purely through cognitively costly mental computations, causing high workload and possible errors.

Furthermore, if automated agents (such as automated path planners) were incorporated to assist in the task of UAV path planning and route management, this would permit the AVO to allocate his/her attention to other functions, such as operating the payload (which supports the single operator configuration).

3.1 *Information Requirements*

With respect to the horizontal and vertical displays, the important variables for UAV operation were identified through a cognitive task analysis consisting of subject matter expert interviews and training document review. These variables allow the AVO (or single operator) the ability to maintain situation awareness during operations. These variables are summarized in Table 1 as information requirements, and are grouped into three major categories:

- Status of UAV: 4D spatial relationships, including position and time,
- Environment: weather, terrain, infrastructure, other agents (e.g., other UAVs), forces on the ground,
- Operational constraints: mission constraints, type of constraint.

Currently, there is no single Shadow display that captures all this information. Many of the important variables are either not shown or found among other, smaller displays. For instance, many of the UAV state variables (e.g., true airspeed, heading, and fuel indicator) are visible in the AV control panel, but not on the horizontal display. Furthermore, this information is not integrated to predict future states, a task left solely to the operator. For example, the operator would have to mentally calculate, based on the total remaining fuel and current airspeed, how far the UAV can travel. This estimation can be easily computed by the computer and displayed to the operator. There are also key variables that may affect UAV operations which are not present in the horizontal display (or in any display), such as weather and airspace restrictions. This is due primarily to current operational information-sharing constraints (which theoretically will become possible through the network-centric concept of operations.) Finally, Table 1 also shows how the vertical and horizontal displays have complimentary information that would further assist operators in integrating these important variables.

Table 1 Summary of information requirements for UAV operation

	Information requirement	Display-specific
State of UAV	• Barometer, true airspeed (TAS), pitch, roll, heading • Identification (Name/callsign) • Range (position) • Fuel range	• *Vertical display*: projected time indication
	• Flight path o Current path (manual) o Projected path (automatic control) o Loiter pattern o Flight path history • Waypoints (range, time/arrival) • GPS coordinates	• *Vertical display*: altitude of waypoints
Environment	• Terrain o Hostile • Weather o Clouds, rain/thunder • Other aerial vehicles • Targets o Range, time (arrival), identification	• *Vertical display*: o Terrain elevations and obstacles o Aerial vehicles within heading envelope only • *Horizontal display*: o Map, landing, take-off, hand-off o Ground control station
Operational Constraints	• Airspace o Hostile, closed, borders	• *Vertical display*: altitude range of airspace

3.2 *Proposed vertical situation and revised horizontal displays*

The revised horizontal and proposed vertical situation displays (annotated in Figure 6 and Figure 5, respectively) includes the important variables summarized in Table 1. The suggested layout is to have the horizontal display (HD) above the vertical situation display (VSD). The main differences between the current and revised horizontal display are the overlay of restricted airspace, weather (e.g., clouds), targets, and range circles (centered about current UAV position). For further screen capture images of display, see Appendix B.

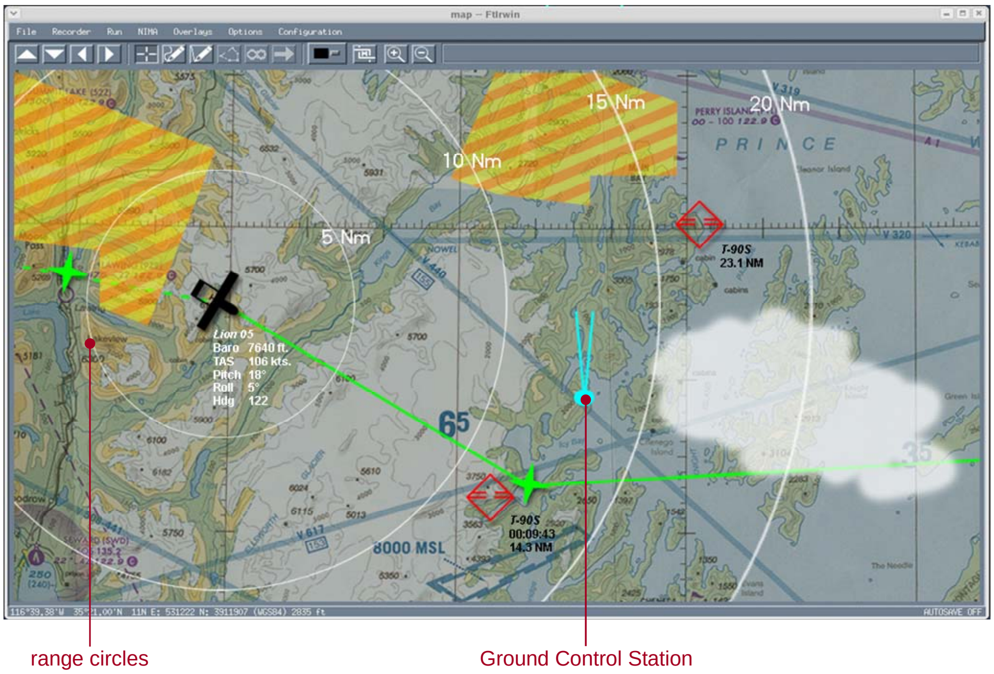

Figure 5 Revised horizontal display (annotated)

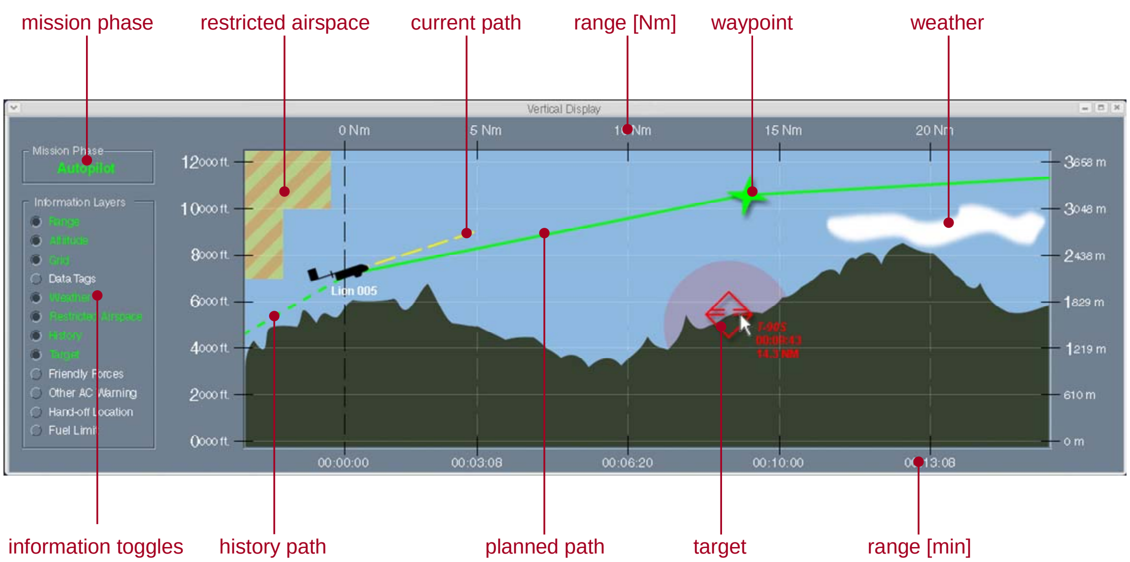

Figure 6 Proposed vertical situation display (annotated)

The design principles applied for both vertical and horizontal displays are:

- Saliency of important elements
- Functional grouping and simplicity
- Consistency between horizontal and vertical displays
- Direct perception interaction.

The terrain profile in the VSD is determined by the planned flight trajectory. A VSD is desirable because it provides geospatial awareness of the vertical space, which is poorly represented in a horizontal display, and in certain operations such as those in mountainous terrain, this information is critical for operator understanding of safe operating envelopes. In the current display, a mouse-over over the horizontal map display indicates the elevations (which is based on an underlying digital elevation map). This type of interface does not facilitate ease of use and may hinder situation awareness. For instance, if the operator wants to assess if a current or planned path will encounter a vertical obstacle, he/she must first find and recall the terrain elevation along the entire path and the expected altitude of the path. With the vertical situation display, the operator can directly perceive if the UAV will fly through any vertical obstacle, be it prohibited airspace or terrain (Figure 6). With the VSD, the mental effort required to determine a safe path is eliminated through direct perception which is nearly effortless on the part of the operator.

Information layers have been added to both the horizontal and vertical displays in order to facilitate assessment of potential future conflicts (in addition to possible terrain collisions). These layers are operator-selectable in order to prevent display clutter. The following elements have been added specifically to assist the operator at the task of conflict detection:

- *Fuel range*: The grayed region in Figure 7 and Figure 8 are areas that cannot be reached due to the amount of fuel remaining. In the given example, the planned flight trajectory enters the out-of-fuel zone, indicating to the operator that he/she must re-plan or return to base.
- *Airspace*: Prohibited airspace is prominently displayed in both displays (orange/red zones in Figure 7 and Figure 8), permitting the operator to quickly assess if planned flight trajectories will violate operational constraints. The given example highlights the importance of including both a horizontal and vertical display. If only the horizontal display was present, the operator would conclude that the UAV path crossed prohibited airspace. However, by assessing the vertical situation display, the UAV actually did not violate airspace restrictions, as it flew below the prohibited zone.
- *Targets*: Targets are depicted with a red diamond in Figure 7 and Figure 8. These may pose a threat to the UAV, and hence, their location and firing range (red airspace about target in Figure 7) are depicted in the vertical situation display, so the operator can avoid flying into or near the target's threat range.
- *Weather*: Various weather phenomena such as thunderstorms and dust storms can significantly affect the operation of a UAV. Additionally, different clouds may affect sensor performance (e.g., preventing image capture). Figure 7 and Figure 8 show clouds, which can be avoided if the UAV's trajectory is altered (see Appendix B for more examples).

Figure 7 Vertical situation display with fuel limit layer

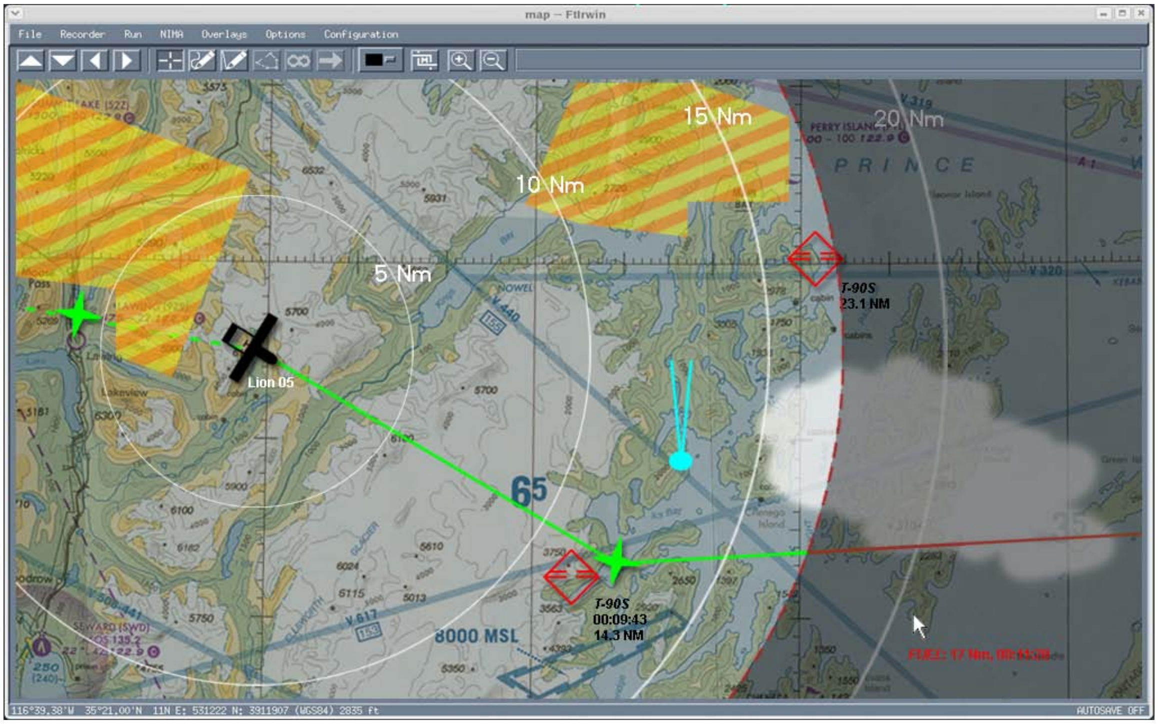

Figure 8 Horizontal display with fuel limit layer

Since the vertical situation display shows the terrain that matches the UAV's flight trajectory, depicting a loiter pattern is not trivial. When the UAV is in a loiter pattern, the VSD terrain (and all ground elements) will repeat in a loop. Thus, while detecting a loiter pattern is relatively simple on the horizontal display, it is not in the vertical. Careful design and implementation of the VSD during loiter path display is crucial to avoid operator confusion.

The chosen implementation of a loiter pattern is shown in Figure 9 and Figure 10. There are several cues to indicate that the UAV is in a loiter pattern, in order to make it clear that a special (i.e., repeated) path will be executed. First, the mission phase (top left corner of Figure 9) says "Loiter". Second, the planned path line pattern changes from a solid line to a dashed-dotted line in both the HD and VSD. The loiter pattern repeats at the loiter symbol ("L" in green diamond in the VD), also denoted by a vertical, dashed line. Aside from these changes in visualization, the VSD still provides the same vertical awareness (terrain elevation, cloud coverage, threat zones, etc.).

Figure 9 Vertical situation display, UAV in loiter pattern

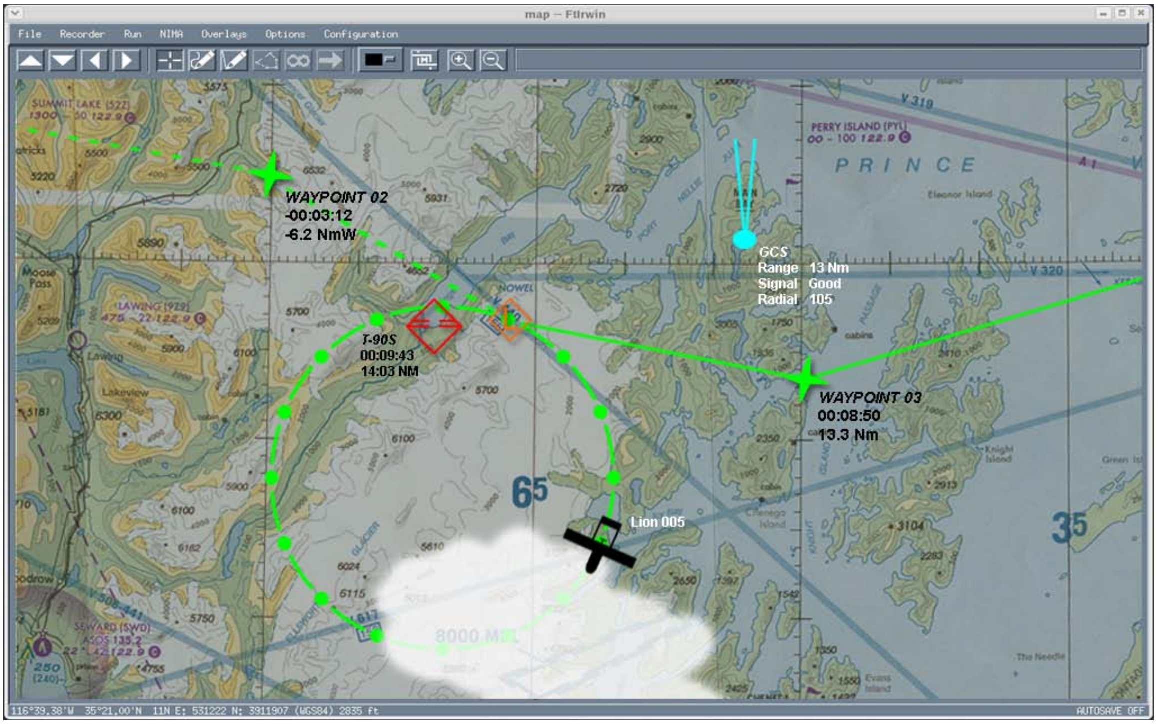

Figure 10 Horizontal display, UAV in loiter pattern

3.2.1 Optimal Loiter Positioning

While the revised horizontal and proposed vertical situation displays are aimed at improving overall vehicle situation awareness, if the Shadow operator has high workload, he/she will be unable to maintain awareness. The operator may become too busy to attend or monitor key variables [6, 7]. Thus reducing the operator's workload, particularly by assigning particular tasks to automation, would be beneficial for the operator's vehicle situation awareness. One such task that is proposed for automation is optimal UAV loiter path planning.

A common mission is to place the UAV in a loiter pattern around or near a target of interest. In order for the automation to calculate an ideal loiter pattern and location, the operator must first highlight the area of interest (in Figure 11, the box around a target on the northeast quadrant of the map). The operator must also specify the resolution range at which the target needs to be surveyed[1]. With this information, the automation can predict the optimal area in which the UAV should loiter for best coverage (green/orange ring donut shape in Figure 12). This area is determined based on multiple criteria, such as target characteristics, physical constraints of UAV and payload, sunlight direction, and fuel consumption. While loitering within the area, there are locations that are more and less ideal than others, which is differentiated using a color gradient (green is more ideal, orange is less ideal). Since the operator specifies a resolution range, a range of loiter altitudes are possible. This is shown in the vertical display (Figure 13). Finally, the automation would suggest a possible loiter pattern within the loiter area. Showing both a loiter pattern solution and the possible range of all solutions is appropriate because a dynamic constraint might force the operator to decide on a

[1] This is payload specific. The current assumption is that that target needs to be observed with an on-board camera.

different loiter pattern within the loiter area, but may not be the ideal one due to operational constraints.

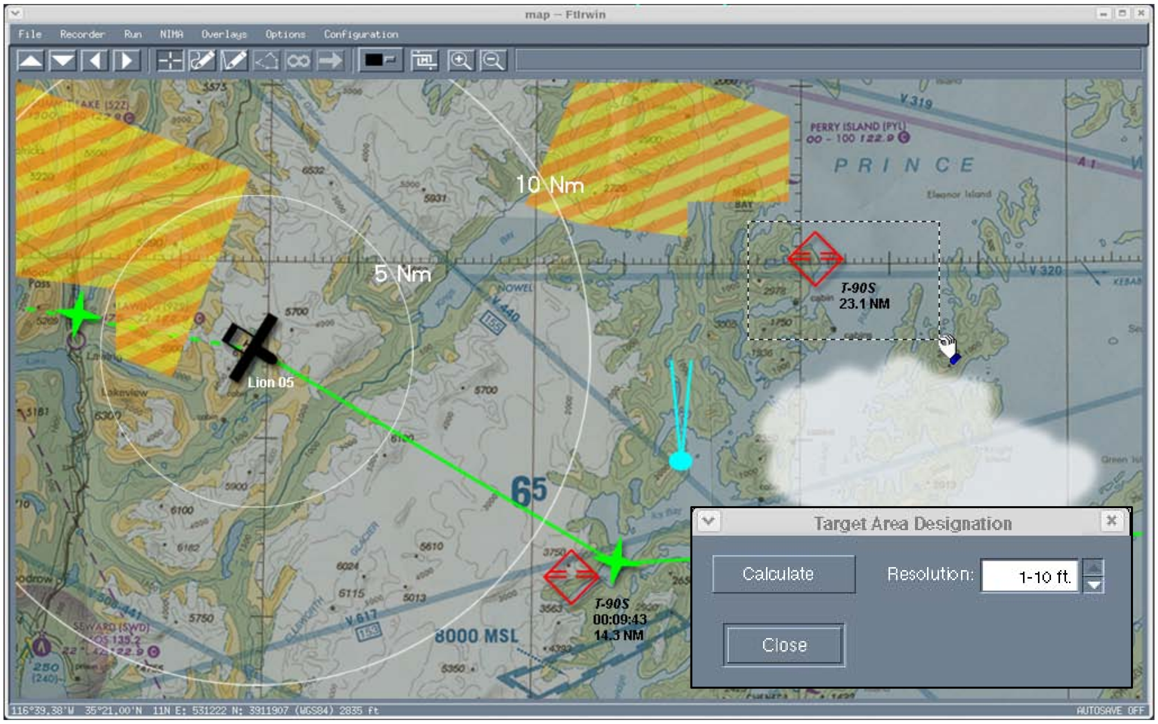

Figure 11 Selecting area of loiter interest and specifying resolution range

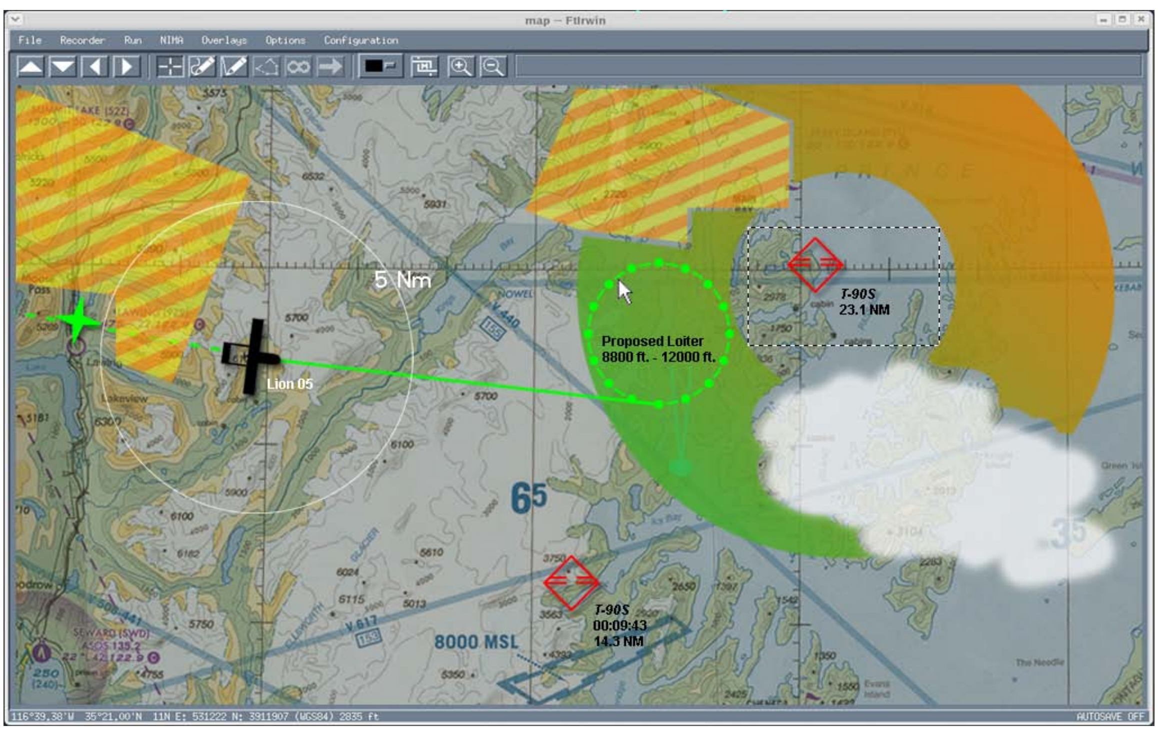

Figure 12 Horizontal display with possible loiter area and suggested loiter pattern

Figure 13 Vertical display with proposed loiter pattern and permissible altitude range

In summary, maintaining situation awareness (SA) is critical for successful mission execution, particularly if a single operator is to control the UAV. In order to promote operator SA, displays should highlight and integrate key variables, as well as project future states. Through such variable integration and projection tools, the proposed vertical situation display and revised horizontal display provide better geospatial awareness of the vertical space, which is lacking in the current interface, and improved lateral SA. The implementation of both of these displays will be essential to reduce the number of Shadow UAV operators from two to one.

4 Payload Displays

Consolidating from two operators to one requires combining tasks from the operators and allocating some to automation, in order to reduce overall workload. Through the cognitive task analysis, target recognition was recognized as a task that required the MPO's constant attention. This is a workload saturation point and one that could be improved by automation. Thus, an interface is proposed that conducts automatic target detection and recognition which will aid operators in situation awareness recovery, specifically in the small arms fire regime. While there are many types of targets that could be identified and engaged by the Shadow, we focus on the small arms fire scenario because of the general operational envelope of the Shadow TUAV and the difficulty associated with visually acquiring such a target in real time with a moving platform.

4.1 *System characteristics and requirements*

The following section describes the characteristics and requirements for an automatic target recognition system in support of small arms fire detection. Previous research in automatic target detection has been significant, and the characteristics listed below are based on the technology that is currently commercially available.

The most basic requirement for automatic target recognition is an IR (infrared) camera. Many UAVs have a payload that includes an IR camera which can be used at day and nighttime to provide a clear picture of the outside world. The IR camera captures the radiation signal of an object. Every object emits radiation in both the visible and near infrared range of the electromagnetic spectrum (typical wavelength infrared: 750 nm – 1 mm). The hotter the object or the more reflective it is, the more radiation it emits, resulting in a brighter IR image. During gunfire, the muzzle flow involves hot air (explosion that drives the bullet), and is visible as an IR signal rise (or flash). The IR signal characteristics of a particular gunfire can change due to use of flash suppressant and/or the number of rounds emitted. An infrared spectrum analysis of the IR signal can differentiate among these conditions [8]. Thus, an IR signal must be processed with the addition of a spectrum analyzer for an automatic target recognition system that can identify the IR flash as different target types.

Studies have shown that of the three possible infrared spectrums (long-wave, mid-wave, and short-wave), mid-wave infrared sensors give the best result in detecting targets [9]. The POP300-LRF payload used in the Shadow UAV is equipped with an InSb 3-5m IR sensor, which covers this mid-wave infrared. In order to reduce the number of false alarms, an automatic target recognition system should also be equipped with an additional long-wave infrared detector.

IR signal detection and processing requires automation computation, detection algorithms, and an extensive IR database. Once an IR flash is detected, the signal has to be analyzed to filter out reflections or other IR sources that are not potential gunfire. If the source belongs to gunfire, this IR signal characteristics are compared to those from an extensive target recognition database. The target database and algorithms are the key parts of the automatic target recognition system. Ideally, the database should be complete enough to detect the use of dampers, flash suppressants, and the number of rounds emitted by the target. The algorithms should also take into account changes in atmosphere and altitude of UAV. Aside from identifying the target through the IR signal, the algorithm should determine the degree of certainty of the identification. Finally, the target's range could be determined by the system through the integration of the following information: time and location of IR flash, current position of the UAV, orientation of payload camera, and a laser rangefinder. This IR signal processing requires additional computation power and memory, which does not have to be located on the UAV itself, as all this processing could be done on the control station.

In summary, the following hardware and software are required to develop an automatic target recognition system:

- Hardware
    - Wide field of view IR camera (MWIR)
    - An IR spectrum analyzer
    - Gimbals with angle measurement to determine direction of view
    - Rangefinder
    - Data processors
- Software
    - Signal fusers
    - Filters and algorithms
    - Target databases

Based on the system requirements and characteristics described, the proposed automatic IR based target recognition system assumes the following:

- Detection of IR rise/flash, during both day and night
- Recording and replaying both EO (electro-optical) and IR signal (to be discussed in a subsequent section)
- The existence of advanced detection algorithms

- An extensive target database for target recognition
- The algorithms can assess their degree of certainty of the target recognition.

4.1.1 Existing systems

Among different systems that are tested and under development [10-12], one commercially available system is the WeaponWatch™ system from Radiance Technologies. While we were unable to obtain system specifications, this system appears to fulfill the requirements for the proposed automatic target recognition system.

Radiance Technologies [13] asserts they have a system that detects weapon fire, be it stationary or mobile, in real-time day or night across a wide 120° field of view. WeaponWatch can discern between different weapons, even if simultaneously fired. This system classifies detected gunfire using a vast database of weapon fire signatures for small arms, sniper rifles, machine guns, RPGs, MANPADs, tanks, mortars, artillery and others. Finally, the system does not have to be within the target's effective range in order to detect the target.

4.2 *Functional and Display Requirements*

A decision ladder [14] was created in order to map the decision processes involved during the task of target recognition. This analytical tool helps organize the relevant information requirements and knowledge states that are needed during a task. Based on this ladder, the display requirements were determined and the different functional allocations of decision processes (i.e., possible levels of automation) were identified. The developed decision ladder and the corresponding display requirements and functional allocations can be found in Appendix C.

The display requirements for the automatic target recognition system can be grouped into two categories:

- *Automation transparency*: Among the display requirements embedded alongside the decision ladder, several specify the need to clearly indicate the processes being conducted by the automation. For instance, the target recognition interface should display when the automation is attempting to recognize the IR flare, matching it to known signals, and certainty of the match between the target identification and the IR flare. Requirements also delineate the need to allow human intervention in the target identification process, permitting the operator to confirm, reject, or even specify target identification. Manual identification is based on the operators own investigation or information available from external intelligence sources. In addition, operators should have access to changing particular threshold settings of the algorithm (e.g., sensitivity of IR flare capture).
- *Situation awareness recovery*: Display requirements were identified that address situation awareness recovery. Situation awareness recovery occurs when an operator is engaged in one task, but is interrupted by another task, and then needs to reengage in the initial task. The recovery process effectively determines what was missed, including high priority events. Interruption recovery is on ongoing process in Shadow control as operators constantly respond to new events (both internally and externally generated), and because the target recognition task is visually intensive, any slight distraction can cause an operator to look away from the display at a critical moment. To enable situation awareness recovery in the small arms fire detection task, the operator needs a video replay of the EO or IR imagery, a timeline of IR events, and a summary of events. By including a timeline and video imagery,

operators can integrate both time and spatial information, which should increase their awareness of the possible on-ground targets, especially in the case of divided attention.

4.3 *Proposed Payload Displays*

Based on the display requirements, an automatic target recognition system interface was designed. Furthermore, current sensor payload displays were consolidated into one interface in order to facilitate the operation of the payload. The design principles applied to both of these interfaces are:

- Feedback and mode awareness
- Simplicity
- Proximity compatibility principle
- Salience of elements and colors
- Geospatial and temporal situation awareness

4.3.1 Main payload interface

The current sensor payload is operated through the use of multiple displays (see Figure 14). The most commonly used functions, and hence, displays, were consolidated into one (Figure 15). This provides a top-level control of the sensor payload. The selected display windows were the "live video", "sensor control", "payload steering", and "step and stare". All the other functions are still accessible on the top bar of the combined, revised display.

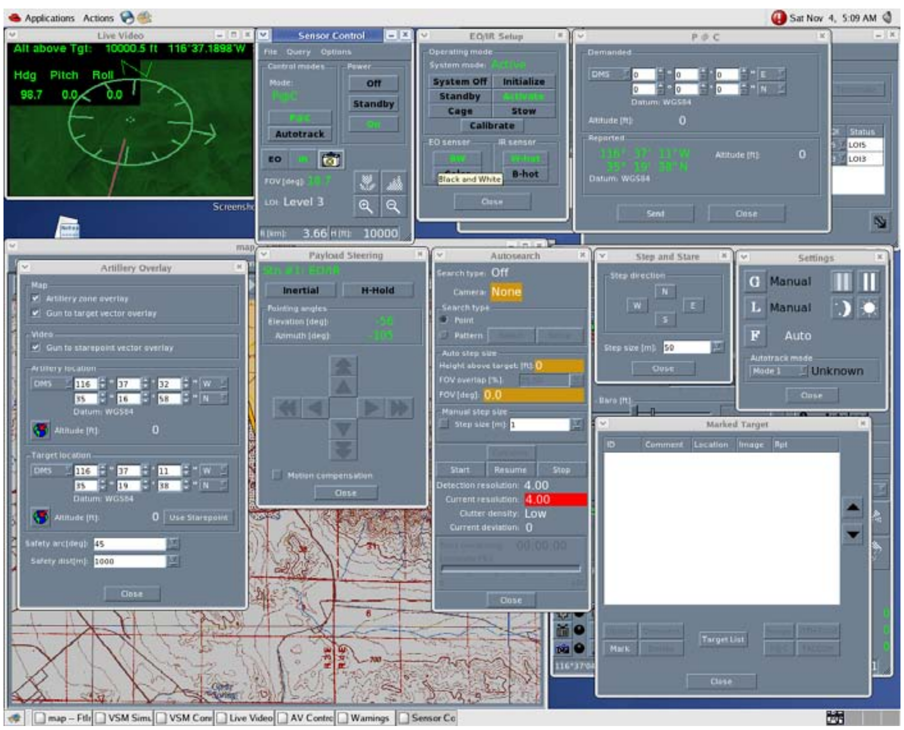

Figure 14 Current sensor payload displays

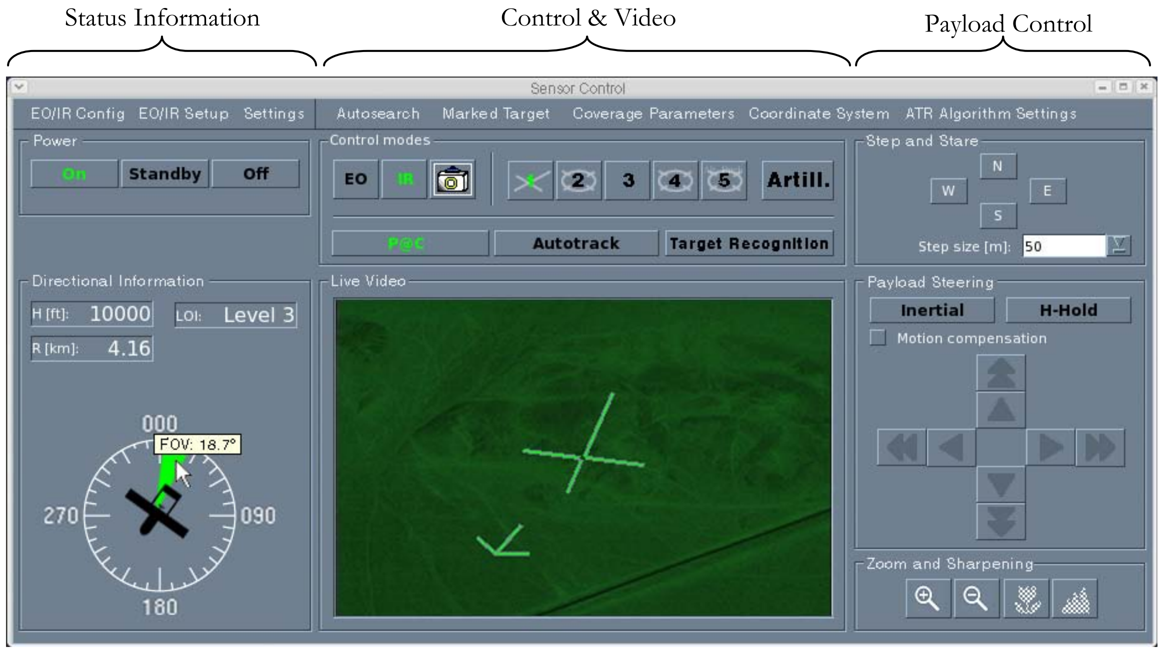

Figure 15 Revised sensor control display

By simplifying the sensor control displays, the key variables for sensor operation are accessible in one location, which aids the operator in reducing navigation and function searches. This display is organized into three functional groupings: status information, control & video, and payload control.

The UAV *status information* in Figure 15 includes the orientation of the UAV and the relative orientation of the sensor beam. The mouse-over functionality is used only for detailed information that is not frequently used. For instance, the exact field of view (shown in Figure 15) of the sensor beam is only accessible through a mouse-over. In the *control & video* section (center, Figure 15), the juxtaposition of the UAV and sensor beam orientation with the live video promotes situation awareness between the UAV and the payload. The video overlay buttons include a small image of the type of overlay[2]. A new button for "target recognition" is added that would call up the new automatic target recognition system display (discussed subsequently). The right portion of the display, the *payload control* section, contains the buttons for controlling and steering the sensor's beam.

4.3.2 Target recognition display

When an IR flare is detected by the automation, the target recognition display "pops up" (Figure 16). IR flares are quick and may be small, and if the operator is distracted or occupied with another task, he/she may miss the signal. The target recognition display alerts the operator that an IR flare was detected. The interface also logs all incidents, providing the operator with a situation awareness recovery tool (similar to the aid described in Scott et. al, 2006 [15]), as well as an archival history of other possible IR events. Once the target recognition display appears, the operator does not have to necessarily attend to the display until he/she is able to focus on this task. Once the operator's workload permits him/her to review the detected IR flares, the incidents can be reviewed by playing

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[2] Overlay 3 is an operator defined overlay, hence no image is assigned to it. The simpler, more streamlined design would include only the optimal overlay design, which could be determined through another workload study.

back the EO and IR imagery, scrolling through the events listing (lower left of Figure 16), or examining the timeline (another log of IR flare incidents).

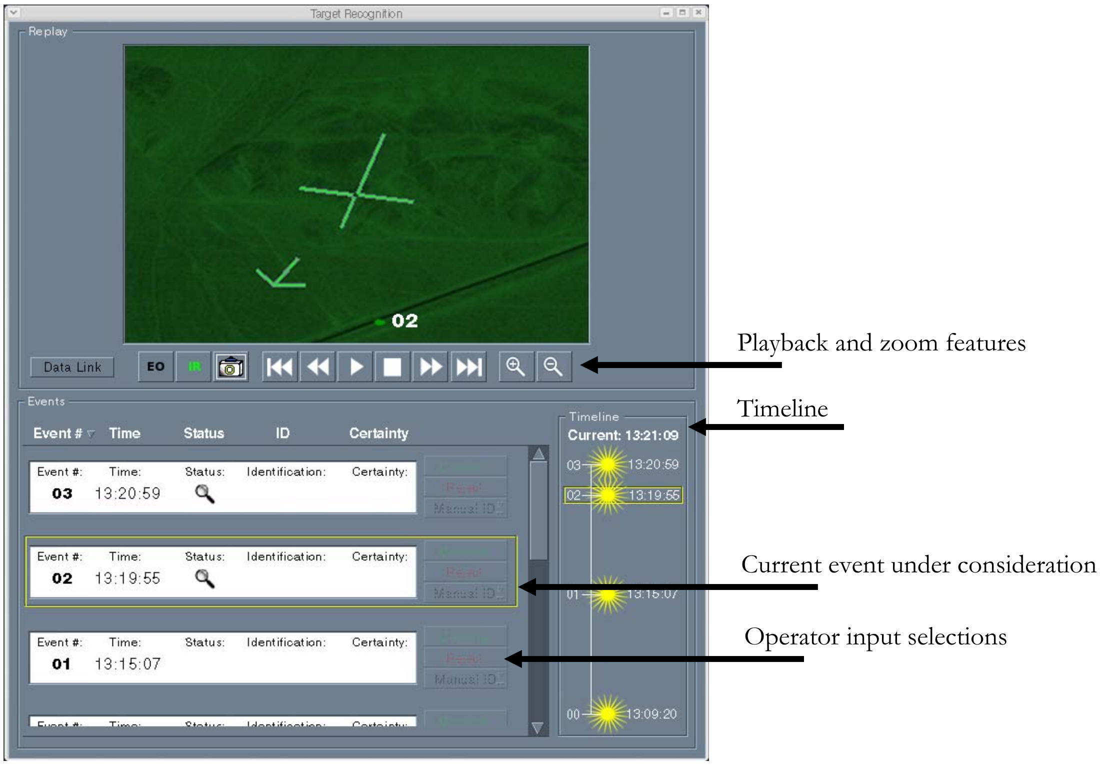


Figure 16 Target recognition display

On the top half of the target recognition display, the recording of the EO/IR imagery can be accessed with appropriate play-back controls (play, pause, rewind, etc). The label (e.g., #2 in Figure 16) is the event number, and provides a cross-referenced identification with the timeline and events log. The event listing is on the lower left section of the display. Each event is associated with a number, time stamp, status, identification, and the certainty of the identification (as computed by the algorithm). There are three buttons to the right of the events that allow the operator to confirm, reject, and manually designate the identification of the IR event. In Figure 16, these buttons are grayed-out since the automation is not yet ready for the operator's input. The yellow box frames the current IR flare incident that is being viewed. The timeline (on the bottom right of the display) summarizes all the events that have been recorded.

As IR flares are detected, they are logged sequentially and the processing of the IR signal begins. The first step is determining if the IR flare is a reflection or a true target. As the automation processes this signal, a "spyglass" icon flashes in the event's status (left, Figure 17). Once the automation determines if the IR signal is a possible target or not (as opposed to an environmental anomaly), it communicates to the operator this initial identification and waits for the confirmation or rejection of this classification (right, Figure 17). If the event is a reflection, no further processing takes place. If the event is identified as a possible target, the automation will continue and through the database, compare the IR signal to a specific target IR signal (unless the operator manually labels the IR flare).

Figure 17 First step in automatic processing of IR signal. Processing (left) and identification (right)

After the operator confirms the initial possible target identification, the automation system searches its database in order to specify the target further. The current automation mode is communicated to the operator through a flashing "file" icon in the event status (Figure 18). Once a match is made, the display shows a target (diamond icon) in the event status, as well as the identification and the associated certainty. In the example (Figure 18, insert), the IR flare is identified as a target with only a medium level of certainty. The operator could confirm or reject this classification, or seek more information in order to manually identify the target. This information may come from data provided through the "data link" button (bottom left of the replay video) or voice communications. Additional examples are provided in Appendix D.

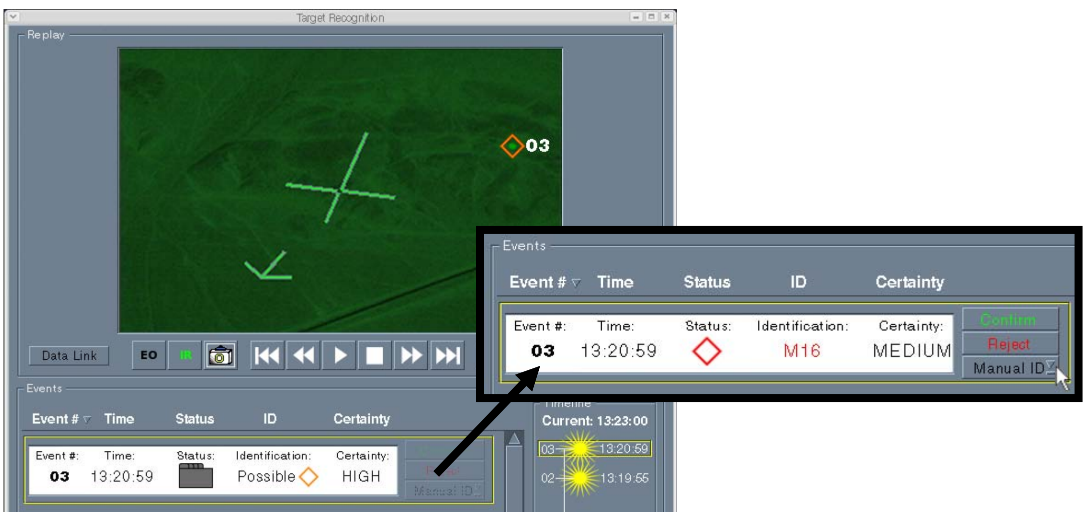


Figure 18 Next step in automatic processing of IR signal. Processing (left) and identification (insert)

Other possible future features include:

- *Real-time adjustment of identification algorithms*: In the main sensor control interface, there is a top-level option named "ATR Algorithm Settings" (top-right in Figure 15). This permits the operator to adjust the automatic target recognition settings based on his/her knowledge. For instance, if it is known that the UAV is monitoring an area of heavy small arms fire, the operator may want to reduce the sensitivity (or threshold) of detecting targets as he/she knows there are multiple targets being observed. Additionally, the operator should be able to *filter* particular events (e.g., alerting operators of only certain types of fire).
- *External intelligence availability*: Improving an operator's knowledge of ground activities can be accomplished by providing external intelligence through a "data link" (button in Figure 16). By pressing the data link button, the automation could advice the operator about friendly ground soldiers or near-by UAVs that might help further confirm or identify the source of

the detected IR signals. This functionality again assumes some kind of network-centric enabled information grid.

- *Overlay symbols*: The overlay buttons and symbols should be improved in order to make it easier for the operator to remember which overlays are available, (i.e., ideally they should not have to remember any extra information and the icons should be intuitive). With this relatively simple improvement, the operator will no longer have to recall which button number is associated with what overlay type, allowing him/her to further focus attention on more important tasks.
- *Future prediction of target location*: The automatic target recognition system could potentially predict the future locations of targets if it can track a sequence of IR flares being emitted by the same source. Once the UAV operator can identify the target, he/she can also follow the target, assessing direction and velocity of the target and updating the automated predictions.
- *Debriefing tool*: The proposed automation target recognition display logs every event detected (in time, type, and with video). With this capability, it is possible to use this system as a debriefing tool. Supervisors and operators could review the archived IR events and learn from mistakes or improve upon future IR flare identification. In addition, this information would be valuable to intelligence analysts.

In summary, an automatic target recognition system, specifically for small arms fire, has been proposed. The goal of introducing such a system in Shadow UAV operations is to reduce workload so that some of the tasks could be shared between a single operator and automation. For this proposed automated target detection tool, the automation's task would be to monitor and identify targets as detected by IR signals. Humans have difficulty maintaining vigilance while monitoring for long periods of time and can easily miss small targets, particularly in high workload environments with many interruptions. Thus, this automated capability provides assistance for the visually intense perception of critical events, as well as the cognitively intense task of analyzing them, both which require significant operator attention.

This technology (IR-based target recognition) is not only feasible but commercially available. However, unless implemented with decision aiding that supports the perceptual and cognitive needs of operators, the technology will not reach its full capacity and likely add to operator workload instead of reduce it. To this end, both functional and display requirements have been identified. The display requirements were implemented into a revised sensor control display and a new target recognition display, which demonstrate how such a technology should be implemented from the operator's viewpoint. The revised sensor control display is a simpler, more compact version of the current interface, and should improve ease of use. The target recognition interface provides a way of archiving and reviewing IR events and their classification, and also supports situation awareness recovery.

5 Summary

In order to reduce the number of Shadow UAV operators from two to one, the total number of tasks the operator needs to accomplish and the workload (including difficulty) of these tasks needs to be reduced. This can be achieved by allocating some tasks to automation and also simplifying the UAV displays in order to ease in use and emphasize the important operation variables. In turn, these proposed changes will reduce workload and potentially increase the operator's overall situation awareness. We have exemplified automation task allocation and revisions of current displays within three areas: system management, vehicle situation awareness, and payload operations. Within system management, the IFF display was revised in order to be more streamlined and to have improved accessibility. Within vehicle situation awareness, the horizontal display was modified and a new vertical situation awareness display is proposed. Finally, within the payload operations, a consolidated sensor control display is proposed alongside an automatic target recognition system. These designs/re-designs are representative of the kinds of changes and implementations that will be needed to streamline and reduce operator workload such that performance improves, errors are reduced, and even training time (both initial and in the field) are minimized. Future work should include actual implementation and assessment of these displays, as well as a more comprehensive analysis of other areas that need improvement, such that workload reduction can be quantified.

6 Acknowledgements

Support (pro-bono) provided by CDL Systems was critical in the completion of this research, as was the assistance provided by the Shadow school house at Fort Huachuca. In addition, Patrick Laney (MIT Sloan and former USN F/A-18 pilot) and 2nd LT Jeremy Conrad (USAF), an undergraduate research assistant, were critical members of the research team. All displays were created by Mark Visser, a visiting student from Delft University, in Adobe Illustrator®.

Appendix A: Shadow TUAV Workload Study

Humans and Automation Laboratory

January 24, 20076

Modeling Shadow Operator Workload

Patrick Laney
M.L. Cummings

Executive Summary

Human supervisory control research suggests that for tasks similar to what Shadow operators experience, operator workload should not exceed 70% utilization [16-18]. This means that operators should not be tasked more than 70% of any working period. Analysis of a task utilization model conducted to examine Shadow operator workload suggests that consolidation of the roles of AVO and MPO is feasible, with a few modifications to the current ground station software. Under current manning policies, the utilization levels for an AVO never exceed 70% for any portion of a typical mission. In fact, it appears as if the AVO is significantly underutilized except for cases of extreme emergencies. However, currently the MPO is saturated during the operational phases of target search and target track. With minimal automation, the utilization levels could be decreased significantly for the MPO, creating more availability to perform previous AVO roles and take on additional tasking. This report will show that with some automated decision support and minimal changes to the current software, consolidation of the AVO and MPO is highly feasible.

I. The Model

The utilization model for the Shadow AVO and MPO is based on the work flow detailed in the flow charts as depicted in Appendix A1. The model breaks down the actual AVO and MPO tasks performed to a level of detail closely representative of actual operations. The model was based on data gathered in interviews, checklists, observations and was vetted twice by operators and instructors, including a recent Iraqi veteran with several hundred hours experience.[3] This model enabled us to get a clearer view of areas of operator tasking and interactions that could be improved whether through automation or by existing "off the shelf" technology.

[3] MSGT Konarik, SGT Petersen, Ft. Huachucha

As depicted in Appendix A, there are 4 basic phases in a Shadow mission:

1. Preflight consisted of ground operations up to launch.
2. Enroute time consisted of post-launch, recovery, or any transits between separate targets of interest.
3. Mission phases consisted of target search and if found, target track.
4. Postflight consisted of the time after landing (mission complete).

This report focuses primarily on the most critical phase, #3 Mission Phase, but includes some data on the enroute phases. Workload modeling for pre and post flight revealed no saturations and these phases would not present any obstacles to operator consolidation.

For the mission phase portion, three basic scenarios were examined that represent increasing complexity (and thus higher workload): Operational baseline, operational worst case, and emergency.

1. Operational Baseline Case - The baseline scenario models a typical 8-hour mission with two Shadows each flying four hours of the mission (thus the vehicles are operated sequentially). Each vehicle mission consisted of 30 minutes of transit to and from the marshaling point, along with 30 minutes of transit between each target. We assumed five targets and approximately 20 minutes of target search (high confidence coordinates) and 30 minutes of target track before proceeding to the next target. While we recognize that a Shadow may investigate many more than five targets in a single mission, this was deemed average for an 8-hour Shadow mission. It is worth noting that operators were very hesitant to define a "typical" mission but were comfortable with the task flow modeling presented here.
2. Operational Worst Case - In this case, we tried to model the most difficult, high-intensity workload task that a team of operators would experience. Thus a counter mortar response was chosen as the representative operational worst case. In this scenario, the team has little time and medium confidence coordinates to find a mortar team (which represents a typical insurgent tactic in Iraq). In this case, most of the tasking is focused on target search and ultimately, target track. Our model assumes that the target is discovered and confirmed after approximately 40 minutes.
3. Emergency - Many of the operators stressed how difficult emergencies can be in the case of a futuristic single operator configuration. However, interviews revealed that there has never been a case where the Shadow team continued with a mission after an emergency was experienced. In other words, the task load with an emergency is essentially irrelevant (particularly for the MPO) since the mission is over (a current policy). No attempts are made to fix problems and continue a mission with any level of a degraded system. Thus the only task to perform is the emergency procedure checklist, and an attempt to get the vehicle to a safe landing. The engine failure emergency was used as the representative scenario to obtain an understanding of how saturated an AVO and MPO become based on the failure severity. The severity was estimated by proximity to the ground, i.e., the lower the altitude, the less time to respond for an engine failure, thus the more difficult the emergency.

   Other Assumptions:

   1. Assumed that once emplaced, the unit would not move to a new location.
   2. There was no operator shift change.
   3. Handoffs are between PGCS and GCS crews.

II. Current AVO & MPO Utilizations

Table 1 summarizes our findings from the workload model previously described. The Overall Utilization (UT) is, given an 8 hour mission, the percentage of time operators are actually utilized. The column marked either indicated that there is some task that can be accomplished by either the AVO or MPO. As can be seen, even if the MPO does all tasks in the Either Category, the overall utilization for either operator never goes above 42%.

However, this overall UT incorporates en-route time which is typically low in workload so to obtain a more realistic picture of workload, we examined the mission phase, which was split into two main categories, Target Search (TS) and Target Track (TT), as seen in the middle of Table 1. This analysis indicated that under current manning and operating conditions, the MPO is over-utilized, ranging from 70%[4] – 90%, with an average of 86% during these critical mission phases.

Table 2: AVO & MPO Utilizations in Percentages

	Current AVO	Current MPO	Either AVO or MPO
Overall UT including Enroute phases	13	29	23
UT Mission phase			
Baseline TS	8.9	84.8	0
Baseline TT	16.4	83.6	0
Operational Worst TS	7.1	90.2	0
Operational Worst TT	29.7	70.3[2]	0
Emergency (Engine Failure)			
Worst Case @ 1500ft	89	22	0
Moderate Case @ 2000 ft	67	44	0
Easy Case @ 3000 ft	33	22	0

In contrast to the MPO, the AVO is significantly under-utilized during the target search and track phases (9% and 16%). Most of the AVO's tasks are dedicated to adjusting AV parameters, but as will be discussed in the next section, with appropriate automation, these task times can be significantly reduced and the position integrated into a single vehicle-mission operator (VMPO) position.

AVO saturation generally occurs only during emergencies less than 2000 ft, and this is due to limited response time due to ground proximity. During these emergencies, the MPO's workload is significantly reduced as he/she typically performs one task, stowing the payload. In addition, the MPO may help with picking a site to deploy the chute at altitudes > 2000 ft. It is important to note

[4] The UT drops to 70% in the worst case since so much time is spent in target search, not as much time is left for target track.

that when an emergency occurs, the mission is over and one operator can perform the short list of tasks.

One question that could be asked is, "If the AVO is under-utilized and the MPO over-utilized during the mission phase, then why not offload some of the MPO's tasks onto the AVO?" As will be discussed more in detail in a subsequent section, a large part of the MPO's high workload is camera management and searching, two tasks that must be done in concert by a single operator so that he/she can maintain high situation awareness. Moreover, the communication overhead of a MPO trying to tell an AVO where to move the camera would cause an even higher workload because of the cognitive dissonance and need to verbally express every action. In short, none of the MPO's tasks can be offloaded to another person, but as will be illustrated, significant help could come from automation.

III. The Case for Consolidation

The results clearly show that if the AVO and MPO positions are to be consolidated, the current workload of the MPO will need to be drastically reduced such that he/she can pick up the AVO tasks as well, with the overall goal of not-to-exceed 70% UT. To do this, we identified several areas as candidates for higher levels of automation that could significantly reduced the workload of the AVO and MPO, and thus allow for consolidation. These design change recommendations are listed below and our estimations for what kind of workload reduction are included in parentheses at the end. These estimates are based on our observations and further research is needed to quantify this more objectively.

1. Target Lock Feature – The Target Lock feature is currently not used because it is unreliable and when its drop lock, the payload slews well away from tracked target, causing a spike in workload. This should be fixed with a scene tracking algorithm, coast mode (memory for temporary obscurations), and snow plow backup (if target lock drops, camera continues to look in last known direction) (Hypothesized MPO reduction in workload - 50%).
2. AV/Payload Coordination – The payload should drive AV restrictions on turns; in other words, the payload shouldn't "fly" off a target due to an AV turn. The vehicle flight controls (including obstacle avoidance) should be automated such that it flies the best profile for the camera view commanded, and in the case where the MPO is attempting an illegal maneuver, the display should convey both the vehicle restrictions as well as what to do to alleviate the problem. (Hypothesized MPO reduction in workload - 5%)
3. Best Resolution Altitude and Angle - The MPO would benefit from optimization information based on atmospherics to yield best picture or best direction of arrival to spot a given target. In effect this would be a camera situation awareness display that depicted constraints, best areas, best altitudes, some way to know when vehicle dynamics conflict with desired search areas/patterns, and a critiquing tool that gives the user recommendation for the most optimal position for both vehicle and camera for a desired view. (Hypothesized MPO reduction in workload - 10%)
4. Navigation Toolbar - Instead of going into the Mission Planner to plan a route, a toolbar with some click and drop function that could drop points right on the map would significantly reduce the workload of the AVO. These points could be "grabbed" to fine adjust or right-clicked to adjust specific coordinates and flight profile information which should default to what the AV is currently flying. The mission planner is currently not used

due to trouble in access and loading the data. (Hypothesized AVO reduction in workload - 25%)

5. History Toolbar - Another icon for the NAV toolbar could be history on/off so the MPO can easily see where he/she has searched (Hypothesized MPO reduction in workload - 5%)
6. Overlays - There are many uses from FalconView that could be incorporated directly into operating software. FalconView is used by mission commanders to obtain coordinates based on payload camera pictures. It also has the ability to parse the ATO (Air Tasking Order) so operators can see what the current restrictions are via drawing files that they would normally have to create. In addition, FLIR prediction in FalconView is a great training tool to produce estimates of what targets should look like based on atmospherics and target library. (Hypothesized MPO reduction in workload - 5%, possibly much more if all the features listed here were included).
7. Health & Status Monitoring - Impending failures could be highlighted by noting rising temperatures, pressures, and other system operating conditions so that the operator could avoid catastrophic failures and make decisions on whether to continue with an AV or RTB (return-to-base). This health & status monitoring should also look for potential collisions and other operational violations (such as possible flight into no-fly zones) to keep the operator alert of potential hazards. (Hypothesized AVO reduction in workload - 10%)
8. IR burst locator - One of the many missions is location of enemy fire, whether it is small arms or mortar. IR from weapons fire is generally many times stronger than surrounding IR emissions and can be highlighted on the display. This would aid in both target search and target track but the thresholds would need to be measured to find a medium between false returns and missed true returns. Operators could be provided with the ability to set contextual alerts to maintain flexibility with intelligence, the environment, and rules of engagement (Hypothesized MPO reduction in workload - 25%)

While not considered in this model in terms of workload, there are additional design interventions that could reduce both AVO and MPO workload:

1. Automatic search profiles – The MPO should be given access through either top level or a second level feature that allows for selection of automatic search profiles given different target types, hostile threats, atmospherics, etc.
2. Vertical situation awareness displays that indicate potential conflicts, trajectories, optimal operating areas, no fly zones, etc.

With these recommendations, the model was run again to see what benefit would be achieved given our assumptions on utilization improvement, which were generally very conservative. During the target search phase, the MPO utilization decreased from 84% to 55%. Utilization decreased from 83% to 33% for the target track phase. This percent decrease is calculated relative to previous total phase times. In other words, the MPO has at least 50% more time available to do other things in the target track phase. The MPO could look for a 6th target in this scenario or simply focus more intently on the task at hand.

One area not explicitly modeled due to its informal nature is that of communications (COMMs). In combat operations, COMMs can be rather intensive and degrade operator performance. In the review of playbacks of Shadow combat missions, it was interesting to note that COMMs were short, but numerous. In fact, most of the COMMs were unnecessary chatter between the MPO and AVO.

By consolidating the AVO and MPO positions, this communication overhead will be eliminating, freeing cognitive resources for other tasks.

In the case of emergencies, we propose that with the addition of intelligent health and status monitoring that aids in more quickly determining the cause of a failure, as well as a predictive overlay that would indicate safe landing sites, significant reductions could be achieved in workload.

Table 3: Proposed Operator Utilizations with Advanced Automation

	AVO Before/After	MPO Before/After	Proposed VMPO
Target Search	8.9/5.8	84.8/54.6	60.4
Target Track	16.4/10.6	83.6/33.4	44.0
Emergency			
@1500 ft	89/67	22/22	89
@ 2000 ft	67/55	44/28	83
@3000 ft	33/28	22/14	42

Table 2 highlights three important points:

1. Possibly more than 30% reduction in MPO workload could be achieved with a range of automated decision support tools
2. In the mission phase, currently the AVO's responsibilities account for on average 13% of the total mission time and with more automated tools, is predicted to only peak at 10.6% of total mission time.
3. With the recommended improvements, a single operator would only be tasked at most ~60% of the time in normal operations, which is well below the recommended threshold of 70% and thus leaves more room for more mission objectives or more complex missions.
4. In the most critical emergency phases (at and below 2000 ft), the proposed VMPO would be tasked somewhere between 83-89%. This occurs because of the extreme time criticality at these low altitudes. It should be noted that the proposed VMPO's workload would not exceed that already experienced by current AVOs under the <2000' scenario and this high workload period, which is driven by mandatory checklists, would not exceed ~90 seconds).

These proposed reductions are estimates, and more work needs to be done with rapid prototypes to determine if the estimates for the additional decision support tools are accurate. However, even if these were considered optimistic (but we propose they are conservative), they demonstrate that significant progress can be made towards both reducing the workload of both operators, as well as consolidating the positions.

IV. Challenges to Consolidation

There are two areas beyond the technical considerations that will present challenges to our findings that consolidation is viable in the Army's Shadow unit. These are more socio-technical than technical but it is important to recognize that they could present significant hurdles.

1. Aviation Legacy - While aviation's traditions and learned methods will benefit the UAV community, there is a danger in looking at UAVs as remotely piloted-vehicles in need of a dedicated pilot. The UAV has the potential to do much more than manned vehicles ever could, but placing a pilot requirement on them will only impede this progress. Moreover, control of unmanned vehicles will become less like flying and more like air traffic control in the future, but progress towards this higher-level goal-based control could be slow due to traditions and entrenched standards.
2. Trust - With an established means for performing operations, the existing crews will have a difficult time adopting any new system. This is characteristic in implementing any new system. With automation involved in the new system, there is human tendency to mistrust automation and resist utilization of the automation [19].

V. References

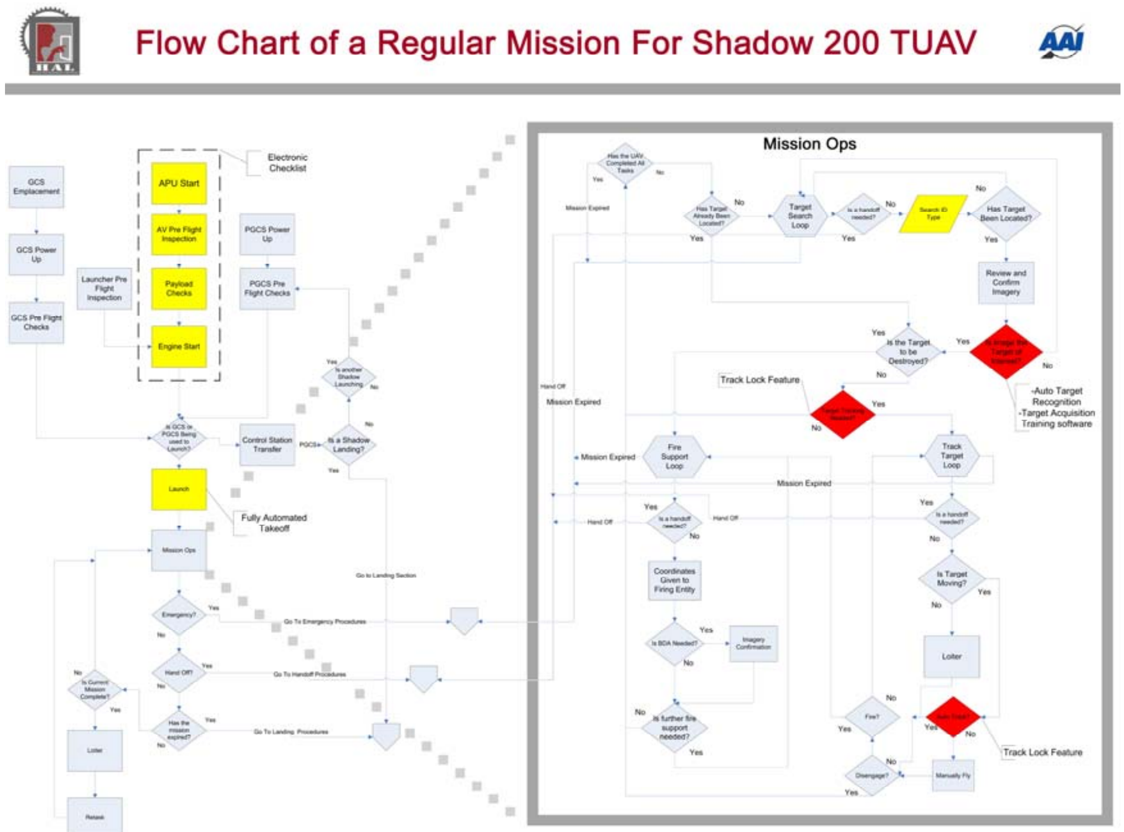
[1] W. B. Rouse, *Systems Engineering Models of Human-Machine Interaction*. New York: North Holland, 1983.

[2] D. K. Schmidt, "A Queuing Analysis of the Air Traffic Controller's Workload," *IEEE Transactions on Systems, Man, and Cybernetics*, vol. 8, pp. 492-498, 1978.

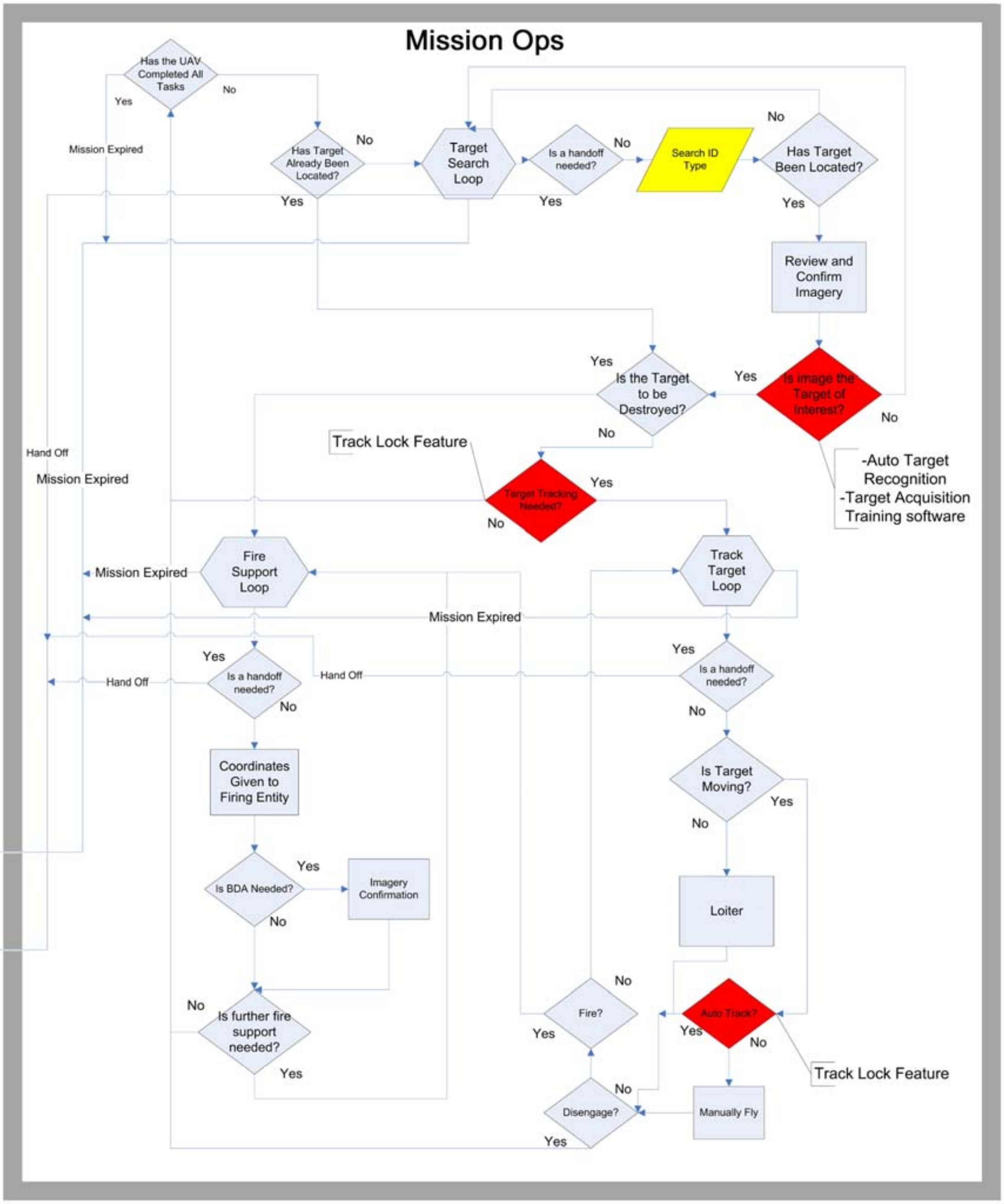
[3] M. L. Cummings and S. Guerlain, "Developing Operator Capacity Estimates for Supervisory Control of Autonomous Vehicles," *Human Factors*, in press.

[4] R. Parasuraman and V. Riley, "Humans and Automation: Use, Misuse, Disuse, Abuse," *Human Factors*, vol. 39, pp. 230-253, 1997.

Appendix A1



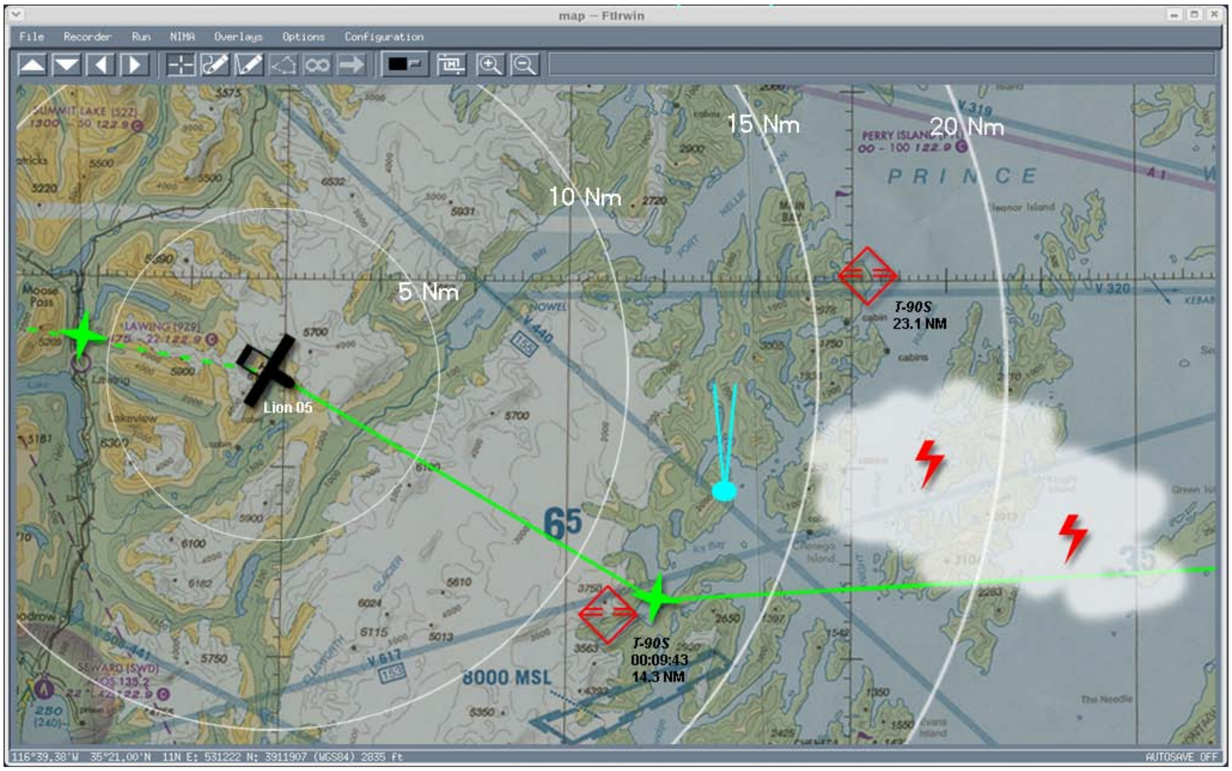
A larger representation of the mission operations workflow chart can be found on the next page.


Mission Ops
Has the UAV Completed All Tasks
Yes
No
Mission Expired
Has Target Already Been Located?
No
Yes
Target Search Loop
Is a handoff needed?
No
Yes
Search ID Type
Has Target Been Located?
No
Yes
Review and Confirm Imagery
Is image the Target of interest?
Yes
No
-Auto Target Recognition
-Target Acquisition Training software
Is the Target to be Destroyed?
Yes
No
Track Lock Feature
Target Tracking Needed?
Yes
No
Hand Off
Mission Expired
Fire Support Loop
Mission Expired
Track Target Loop
Mission Expired
Is a handoff needed?
Yes
No
Hand Off
Hand Off
Is a handoff needed?
Yes
No
Coordinates Given to Firing Entity
Is Target Moving?
Yes
No
Is BDA Needed?
Yes
No
Imagery Confirmation
Loiter
Is further fire support needed?
No
Yes
Fire?
No
Yes
Auto Track?
Yes
No
Track Lock Feature
Disengage?
No
Yes
Manually Fly

Appendix B: Supplementary images of vertical and horizontal displays

Example of different weather patterns:

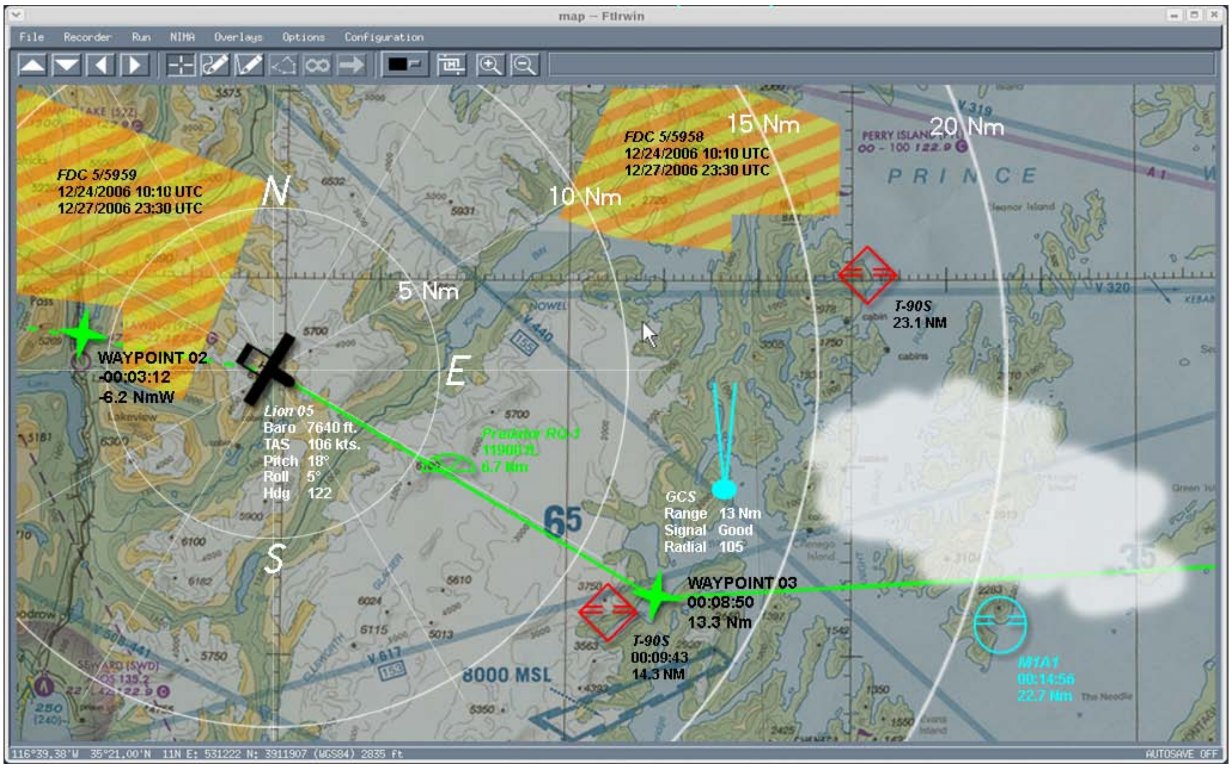
- Thunder clouds are depicted in the horizontal and vertical situation displays.

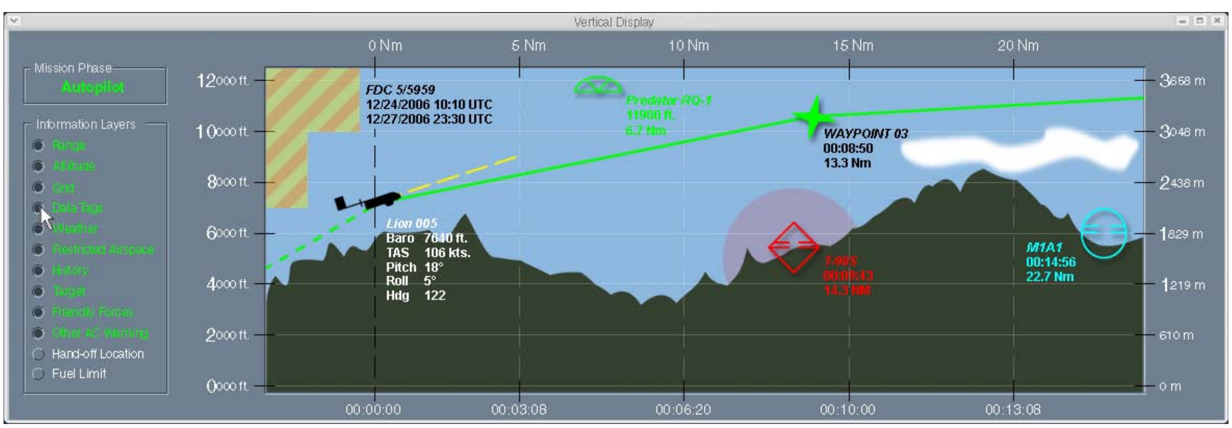


Example of identification labels, friendly forces and other air vehicles:

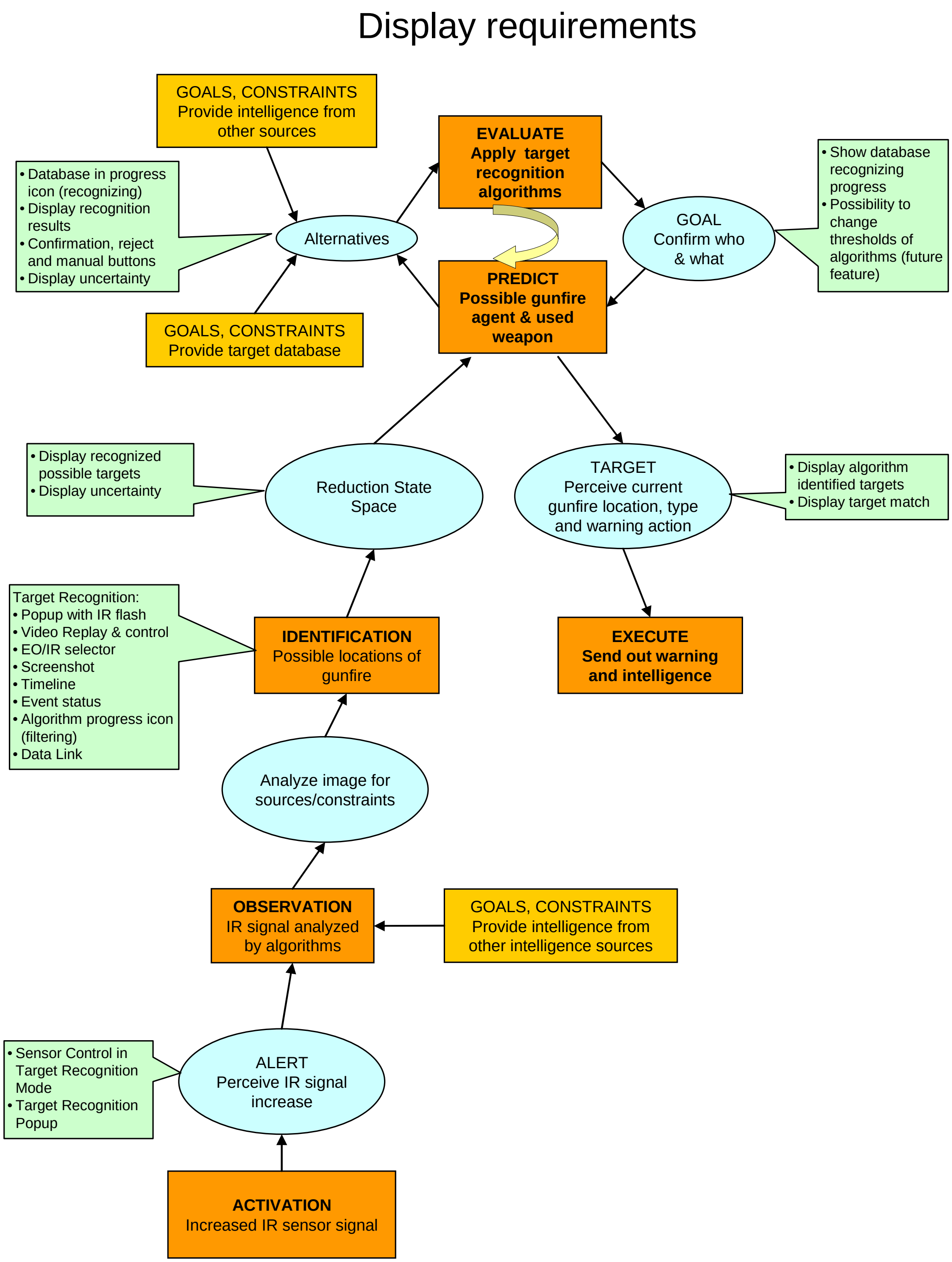
- The identification labels for all elements on the display can be toggled on/off. Labels are specific to the elements. For instance, the label for waypoints includes the range (i.e., how far out from the UAV is this waypoint) and the estimated time of arrival. The identification label for the UAV includes state variables, such as barometer (altitude), true airspeed, pitch, roll, and heading.

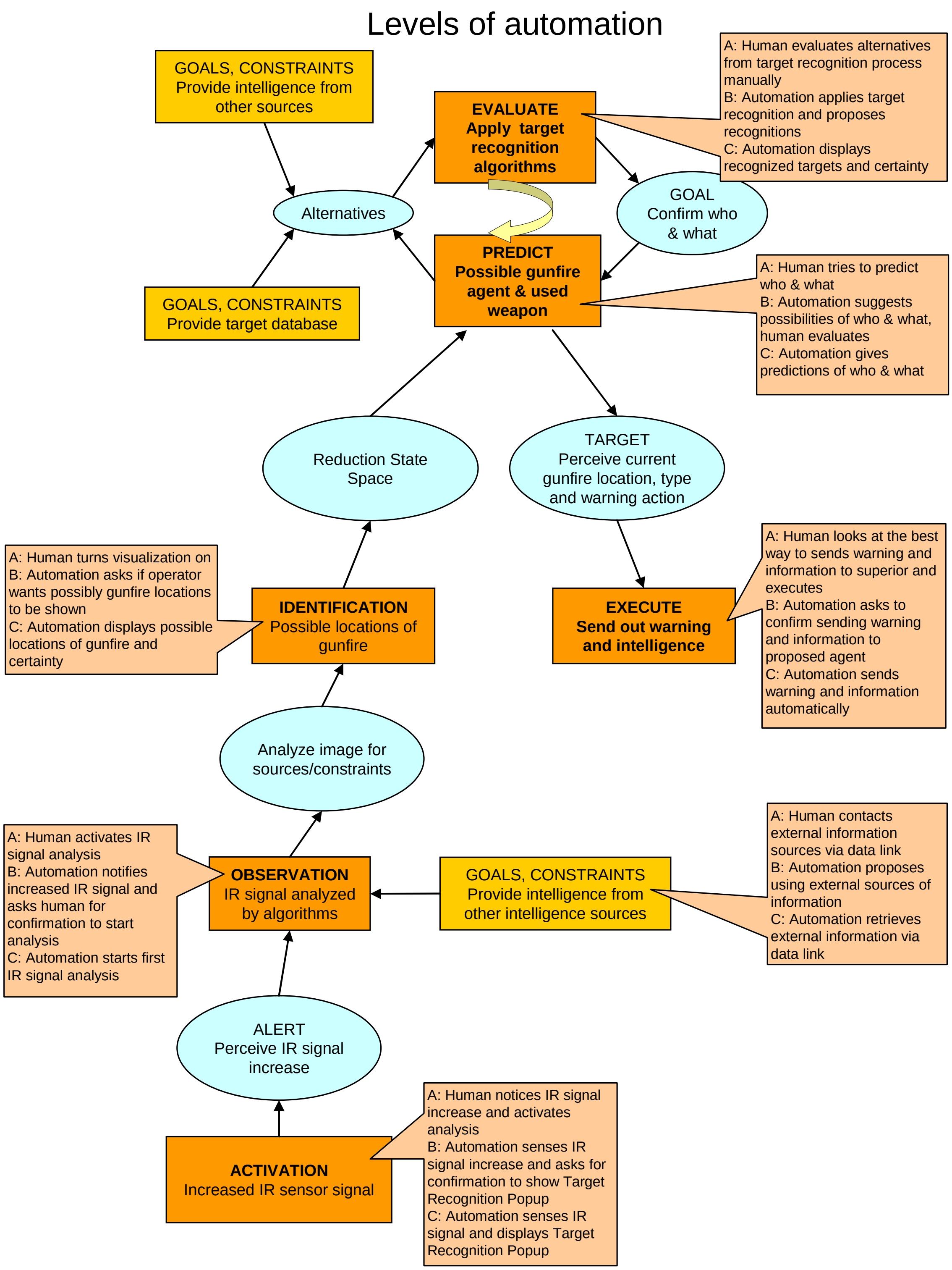
- Friendly forces are identified through a round, blue symbol in keeping with MIL-STD-2525A.
- Other air vehicles in the area are identified through a semi-circle, green symbol. In the vertical display, an air vehicle is shown if it is within a (pre-set) heading range and/or on the same path as the current UAV.





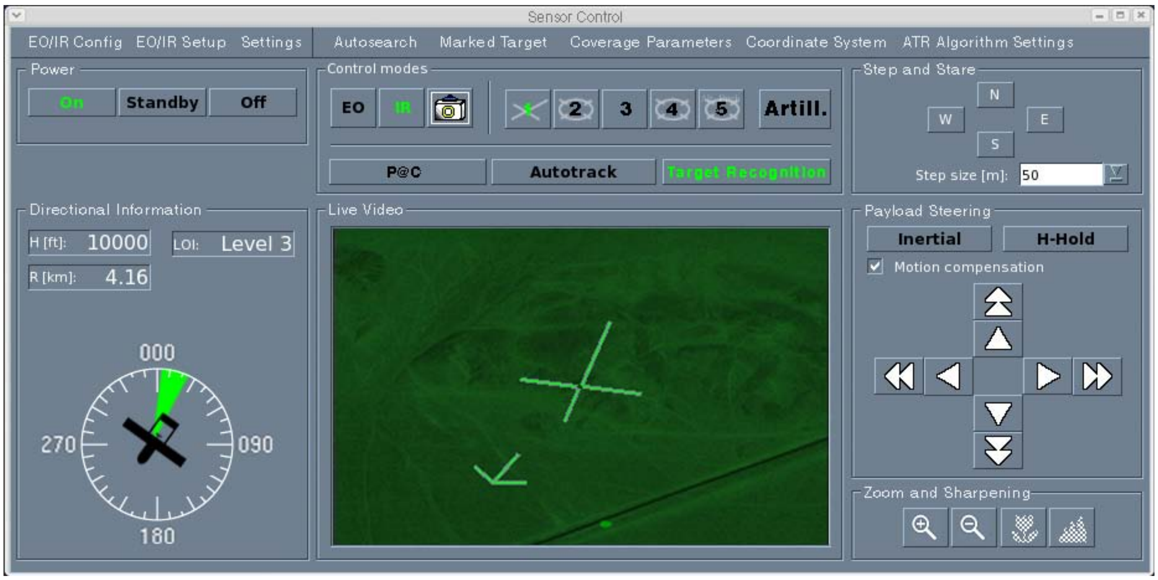
Appendix C: Decision Ladders for Automatic Target Recognition Interface




Levels of automation
GOALS, CONSTRAINTS
Provide intelligence from other sources
EVALUATE
Apply target recognition algorithms
A: Human evaluates alternatives from target recognition process manually
B: Automation applies target recognition and proposes recognitions
C: Automation displays recognized targets and certainty
Alternatives
GOAL
Confirm who & what
GOALS, CONSTRAINTS
Provide target database
PREDICT
Possible gunfire agent & used weapon
A: Human tries to predict who & what
B: Automation suggests possibilities of who & what, human evaluates
C: Automation gives predictions of who & what
Reduction State Space
TARGET
Perceive current gunfire location, type and warning action
A: Human turns visualization on
B: Automation asks if operator wants possibly gunfire locations to be shown
C: Automation displays possible locations of gunfire and certainty
IDENTIFICATION
Possible locations of gunfire
EXECUTE
Send out warning and intelligence
A: Human looks at the best way to sends warning and information to superior and executes
B: Automation asks to confirm sending warning and information to proposed agent
C: Automation sends warning and information automatically
Analyze image for sources/constraints
A: Human activates IR signal analysis
B: Automation notifies increased IR signal and asks human for confirmation to start analysis
C: Automation starts first IR signal analysis
OBSERVATION
IR signal analyzed by algorithms
GOALS, CONSTRAINTS
Provide intelligence from other intelligence sources
A: Human contacts external information sources via data link
B: Automation proposes using external sources of information
C: Automation retrieves external information via data link
ALERT
Perceive IR signal increase
ACTIVATION
Increased IR sensor signal
A: Human notices IR signal increase and activates analysis
B: Automation senses IR signal increase and asks for confirmation to show Target Recognition Popup
C: Automation senses IR signal and displays Target Recognition Popup

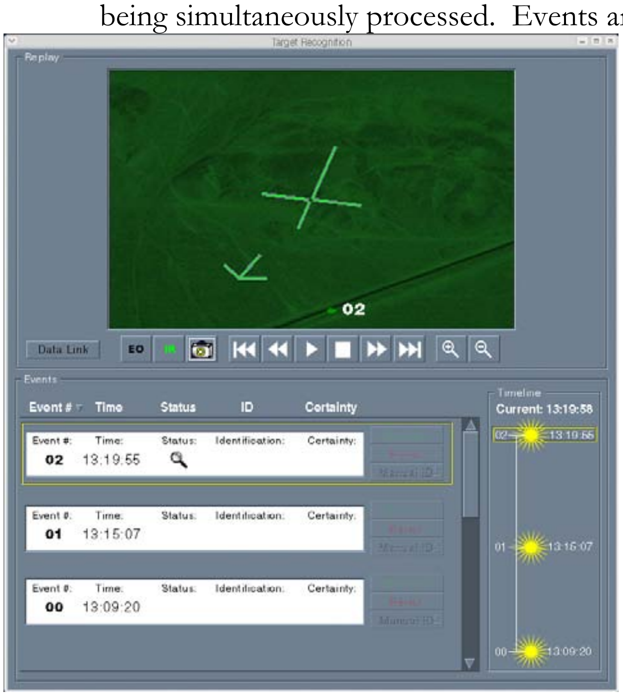
Appendix D: Sequence of displays for automatic target detection interface

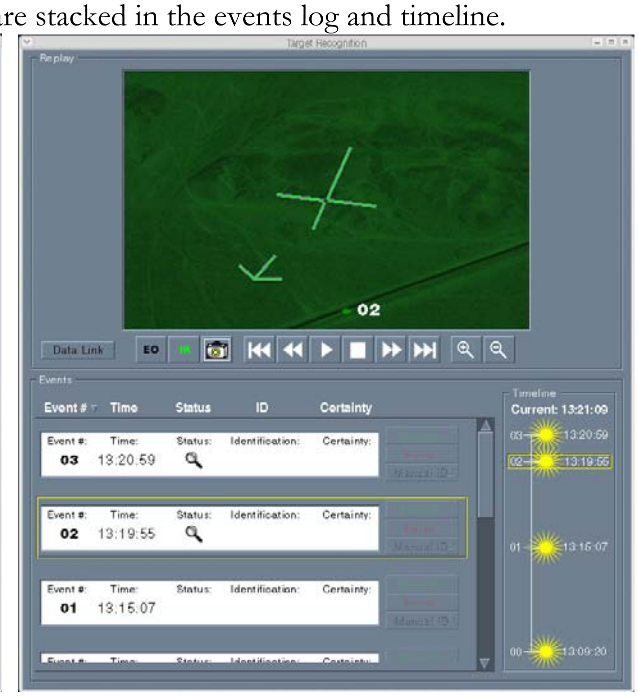
An IR event occurs in main sensor control display:



The next set of pictures illustrates the proposed target recognition display after IR flare detection

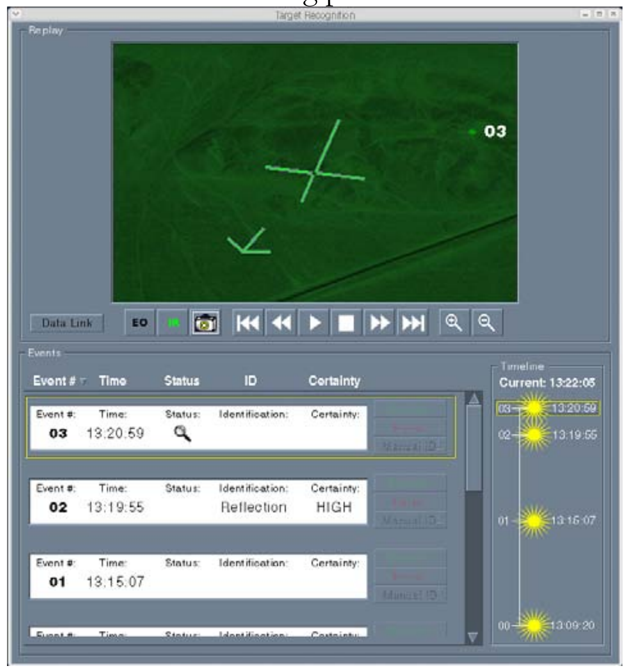
- Left: Event # 2 being processed
- Right: Event #2 still being processed but another IR event (#3) has been detected and is being simultaneously processed. Events are stacked in the events log and timeline.





The next set of pictures illustrates an initial IR event identification:

- Left: Event #2 identified as a reflection and waiting for confirmation from the operator
- Right: Event #2 confirmed as reflection, and Event #3 is still being processed



The next set of pictures demonstrates additional IR event identification processing.

- Left: Event #3 identified as a possible target and waiting for operator confirmation
- Right: Event #3 confirmed, and automation searches database for target identification

The next set of pictures illustrated both an automatically identified IR event as well as a manual identification event.

- Left: Event #3 automatically identified as a target (M16) and awaits confirmation. The automation's certainty of this identification is "medium".
- Right: Event #3 is manually identified by the operator as another type of target (AK47).

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