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Get-in-the-Zone (GITZ) Transition Display Format for Changing Camera Views in Multi-UAV Operations

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TECHNICAL REVIEW AND APPROVAL

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14. ABSTRACT
Control applications involving multiple Unmanned Aerial Vehicles (UAVs) will require the operator to switch attention between UAVs, each potentially involving very different scenario environments and task requirements. A transition display format that employs synthetic vision technology designed to enhance an operator's situation awareness when switching between missions is under evaluation. Instead of discretely switching from the camera view for one UAV to the camera view for another, a transition format is presented such that the camera imagery seamlessly fades into a synthetic imagery correlate of the real video image and uses a "fly-out, fly-in" metaphor over several seconds, finishing with the transition back from synthetic to real video imagery at the new camera viewpoint. This report documents two pilot studies conducted to help design the transition format, as well as a full multi-UAV simulation evaluation. Results were promising: subjective data were favorable and some objective measures improved (none showed a decrement). Several potential enhancements to the transition format were identified, ranging from the speed of various segments of the transition to whether or not the operator has direct control over transition parameters.

15. SUBJECT TERMS
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EXECUTIVE SUMMARY

Control applications involving multiple Unmanned Aerial Vehicles (UAVs) will require the operator to switch attention between UAVs, each potentially involving very different scenario environments (terrain, threat environment, mission objectives, weather, etc.) and task requirements. Not only is a potential for negative effects associated with task interruptions and the mental effort required in "context acquisition" after the switch, there also is a potential for negative transfer of context to occur. Such that, the specific information and tasking involved in the previous mission might delay or degrade the operator's ability to effectively perform tasks in a new mission. A transition aid that employs synthetic vision technology designed to enhance an operator's situation awareness when switching between missions in a multi-UAV control environment is now under evaluation. Instead of discretely switching from the camera view on one UAV to the camera view of another, a transition format is presented such that the camera imagery seamlessly fades into a synthetic imagery correlate of the real video image. It then uses a "fly-out, fly-in" metaphor over several seconds and finishing with the transition back from synthetic to real video imagery at the new camera viewpoint. During transition, points of interest (threats, landmarks, runways, etc.) are continuously highlighted with overlaid, geo-registered computer-generated symbology.

The objective of recent evaluations was to examine whether this transition aid would enhance a multi-UAV operator's overall situation awareness and improve performance on a target designation task after switching UAV/camera views. First, two pilot studies were conducted to help design the transition format for multi-UAV applications. Then, a full simulation evaluation was conducted that manipulated the nature of the source mission and assessed whether the transition had any negative effects on participants' completion of tasks in the new mission, as well as secondary mission-related tasks (e.g., a communications task). The experiment utilized the Vigilant Spirit multi-UAV operator control station testbed developed by the US Air Force Research Laboratory. The station included a (simulated) camera view from the selected UAV, thumbnail camera views from the other UAVs, Tactical Situation Displays showing the location of four UAVs as well as a close in view of the selected UAV, and windows used for secondary mission-related tasks.

Results were mixed, but very informative. Participants' subjective ratings on questionnaires indicated that they had more situation awareness in trials with the transition aid, compared to trials without it. However, they failed to perform better on a probe administered during the mission that was designed to measure context-specific situation awareness. While the transition was not found to hinder performance on secondary tasks, it also did not impact performance on the key task – the average time to locate/designate targets was only slightly faster when the transition was utilized. The transition however, did improve the target designation task in terms of camera movement efficiency (accuracy of initial camera movement and camera path length). Several potential enhancements to the transition aid were identified, ranging from the speed of various segments of the transition to whether or not the operator has direct control over transition parameters. Follow-on research will examine the nature of the specific missions involved when switching UAV/camera views as well as operator strategy.

INTRODUCTION

Unmanned Aerial Vehicle (UAV) operators must rely on video imagery transmitted from one or more cameras mounted on the air platform for maintaining situation awareness [1]. In many cases, this video camera is mounted on a gimbaled turret and thus can be rotated by a remotely situated sensor operator in order to view various points of interest in the UAV's surrounding environment. UAV pilots use this imagery to verify clear path for taxi/runway operations, scan for other air traffic in the area, and identify landmarks and potential obstructions. Sensor operators use the imagery to conduct a wide variety of intelligence, surveillance, and reconnaissance activities as well as to directly support combat operations. However, video imagery quality (and by extension, operator situation awareness) is often compromised by narrow camera field-of-view, datalink degradations, poor environmental conditions (e.g., dawn/dusk/night, adverse weather, variable clouds), bandwidth limitations, and highly cluttered visual scenes (e.g., in urban area or mountainous terrain).

A system that superimposes computer-generated graphics over real world imagery can potentially enhance the video interpretation and situation awareness of the UAV operator, consequently improving decision making [2]. With this technology, non-stereoscopic imagery from the UAV camera(s) (the substratum defining the principal scene being presented from the real world) is presented on a monitor along with computer graphic images that are overlaid to create an enhanced view [3]. Specifically, the spatially-relevant information, created from databases (e.g., terrain, maps, photo-imagery, pre-mission plan, etc.) and updates from other sources (via networked communications), can be represented as computer symbology and simulated imagery and overlaid conformal onto the dynamic camera video imagery that is presented to operators. Figure 1 shows an example of colored synthetic symbology added to simulated UAV gimbal video imagery, with symbology marking threats, landmarks, areas of interest, and a runway.

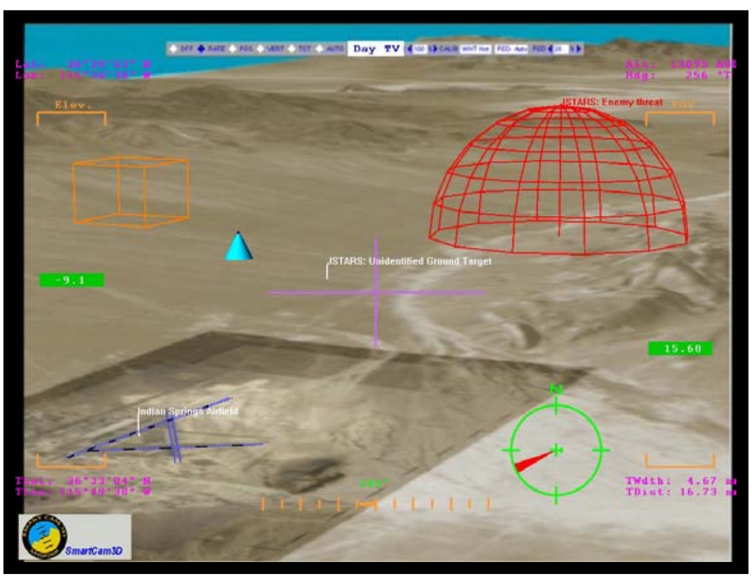


Figure 1. Illustration of Synthetic Symbology Added to UAV Video Imagery

Use of synthetic vision and augmented technology is expected to improve UAV operator situation awareness by highlighting, in real time, key information elements of interest directly on the camera video. Also, the system can include information that does not have a correlate in the actual sensor imagery, such as lethality envelopes of ground-based threats. The system can convey self-motion cues and depth cues without occluding the sensor image. It may also help an operator maintain situation awareness during periods of video datalink degradation and poor visibility, through a combination of real and synthetic imagery. At a maximum setting, the synthetic vision imagery would totally replace the real sensor image, while other settings would specify a blending of the two information sources by changing the transparency of the synthetic vision imagery. Additionally, an augmented display system can serve a key role in supporting distributive collaborative communication in a net-centric battlespace environment. In this case, the system is applied both as a display and as a control, enabling a net-centric member to mark a specific spatially referenced point of interest on the camera display, causing matching informative synthetic symbology to appear on the displays of other geographically separated stations in the warfare network [4].

All of the aforementioned expected benefits will be of increasing importance in future envisioned scenarios that will require multiple semi-autonomous UAVs to be controlled by a single supervisor. Compared to current UAV systems that require one or more operators to control a single UAV, single operator supervisory control of multiple UAVs is anticipated to be a particularly time-critical, cognitively demanding task [5]. Even with highly autonomous UAVs, operators will need to respond to changes in mission requirements, constantly monitor for unscheduled changes in information sources, supervise autonomous services, and intermittently collaborate and communicate with others in the distributed control network. Tasking will also require switching attention from one UAV/camera view to another. For scenarios in which multiple UAVs are monitoring the same object/scene, camera view transition aids that help the operator make sense of how the different camera images are related to one another spatially would be useful to help maintain operator situation awareness. Transition aids that help the operator when the UAVs are monitoring different objects/scenes would also be useful. In this case each UAV could entail drastically different scenario conditions (terrain, threat environment, mission objectives, weather, aircraft emergencies/malfunctions, etc.). Plus, the type of mission can vary [6]. In interviews with UAV controllers, Intelligence/Surveillance/Reconnaissance (ISR) missions can be placed into two general categories: 1) *dynamic missions* which are less frequent and include a rapidly evolving situation, time-critical tasks, and coordination between multiple assets (e.g., use of ordinance, tracking a moving target, and handling emergencies) and 2) *static missions* that are more common and generally involve surveillance on a static position for an extended period of time.

Dynamic missions are likely to require the operator's full attention. Thus, any static missions would be "on hold" until the dynamic mission is completed. It is probable that the multi-UAV operator will witch between dynamic and static missions, each potentially involving very different scenario environments and task requirements. Not only is there a potential for the negative effects associated with task interruptions and the mental effort required in "context acquisition" after the switch [7], there also is the potential for negative transfer of context to occur, such that the specific information and tasking involved in the previous mission might delay or degrade the operator's ability to effectively perform tasks in the new mission. For instance, if the operator has a mental model of friendly forces being south of the target in the first mission, will the operator inappropriately apply this mental model to the new mission? If the camera is oriented north, with the UAV moving in the same direction before the switch, will it be hard for the operator to quickly acquire the new camera orientation and direction of UAV movement for the new mission? For these scenarios where the UAVs are monitoring different objects/scenes, the objective of the transition aid would be to help the operator dissociate from the context/spatial relationships for the first UAV/camera view and rapidly acquire needed situation awareness of the new UAV/camera view.

Regardless of the application employing multiple cameras, an operator, when abruptly switched from one camera viewpoint to another, needs time to acquire situation awareness – an understanding of the elements of the new environment. "Visual momentum" is one construct that has been used to aid the transition from one view to another. Inspired by cinematography techniques to help audiences maintain spatial understanding of a scene across discrete film cuts, use of a continuous transformation between views to create visual momentum "supports the rapid comprehension of data following the transition to a new display" [8, p. 231].

Previous research has demonstrated the utility of visual momentum, showing an improvement in task switching when operators are provided with a transition between two-dimensional and three-dimensional views of the same scene [9] and improvements in spatial judgments with transitions between different perspective-rendered views of the same scene [10]. The use of smooth transitions between two and three-dimensional views for air traffic control displays has also been explored [11]. A "RealityFlythrough" tele-reality/telepresence system is introduced [12] to provide dynamic transitions between cameras viewing the same scene in order to help the user generate an internal model of the view. When the user is not viewing real images generated by live cameras, a dynamic fly-through transition is presented as the user moves from one camera view to another, providing useful cues on the spatial relationships between the cameras. Morphing techniques that combine interpolations of shape and color have been used to successfully produce compelling transitions between two-dimensional images, as well as between three-dimensional views of either the same scene or different scenes [13]. An example of how view morphing can be applied to Predator UAV camera images, as well as scenes that contain moving objects, is available at [14].

An Augmented Virtual Reality system designed to display abstract information constructed from multiple sensors, as well as allowing access to raw sensor information such as video streams, has been tested in three scenarios, each requiring a different mixture of both capabilities [15]. For each camera switching event, the scene seamlessly fades into a virtual world scene that is in-sync with the real-life scene. The user completes a virtual fly-though before the scene transitions back to the real-life video stream of the new camera view. The smooth transitions using virtual fly-though are designed to move the user between camera views while maintaining the user's relationship with the objects and events in the real world. The test results showed that users were able to maintain a good spatial sense of the environment due to the smooth transitions, and were able to operate a ground robot without any delay after each camera change.

To date, efforts have primarily focused on transitioning between ground-based camera views of the same object/scene. Using augmented reality technology, the user is provided computer-generated views not served by the physical cameras to help the user retain context and spatial relationships with respect to the scene when transitioning between the old and new viewpoints. The results from these efforts inform the design of a transition display for multi-UAV applications that involve more than one UAV viewing the *same object/scene*. The present report describes efforts performed by the Air Force Research Laboratory, 711th Human Performance Wing, Human Effectiveness Directorate, Warfighter Interface Division's, Supervisory Control Interfaces Branch (711 HPW/RHCI) to develop a transition display format designed to help a UAV operator transition between camera views for applications requiring two or more airborne vehicles monitoring *different objects/scenes*. The goal for this application is to help the operator dissociate from the context/spatial relationships associated with the first UAV/camera view and rapidly acquire needed situation awareness of the new camera view, reducing the potential for negative transfer of context to occur. This acquisition of situation awareness can be described as "Getting Into The Zone," and hence the 711 HPW/RHCI format under development is referred to as the "GITZ transition."

711 HPW/RHCI 'GITZ' TRANSITION DISPLAY FORMAT FOR CHANGING CAMERA VIEWS

The 711 HPW/RHCI "Get In The Zone" (GITZ) transition display concept is designed to enhance an operator's situation awareness when switching between missions in a multi-UAV control environment where each associated camera is viewing a different object/scene. Instead of discretely switching from the camera view of one UAV to the camera view of another, the algorithms driving the transition automatically interpolate to provide a display format that dynamically changes between the source and new camera views in a semi-continuous manner. This dynamic transition takes several seconds and uses a "fly-out, fly-in" metaphor utilizing synthetic vision technology. More specifically, the transition provides a three-dimensional perspective of synthetic ground imagery from varying altitudes as the operator switches from an egocentric view (determined by the camera's orientation/viewpoint on the current UAV), to an exocentric view (a global view not tied to any one UAV; "bird's eye view"), and then back to an egocentric view (determined by the camera's orientation on the newly selected UAV). During this transition, points of interest are highlighted with overlaid, geo-registered computer-generated symbology.

Figure 2 illustrates the key segments of the transition display format (fly-out, traverse, and fly-in). Additionally, it shows the numerous design issues to consider in implementing a transition format. For the fly-out and fly-in segments, what path should the virtual camera take, moving at what rate, and for how long? Regarding the traverse segment, if the operator was transitioning between two camera views of the same target, then this segment would be important to help retain context and spatial relationships. However, for the targeted application where the camera views are changing from one geographical area to another, showing the scene between the two environments is not of interest. Manipulation of the parameters listed in each oval shown in Figure 2, can change how the transition is perceived by the operator and potentially its utility. Another research question is the degree to which the operator should have control over the transition parameters in each segment.

To help determine optimal GITZ transition parameter settings, we conducted two pilot studies focusing on one segment of the transition. Later, we evaluated a GITZ transition in a high fidelity multi-UAV simulation. For this evaluation, both objective and subjective data were recorded from thirteen participants performing multiple tasks while periodically switching UAV missions and associated camera views. This report presents the procedures and results from both informal pilot studies and the formal, larger scale simulation evaluation. Recommendations for follow-on evaluations are also made.

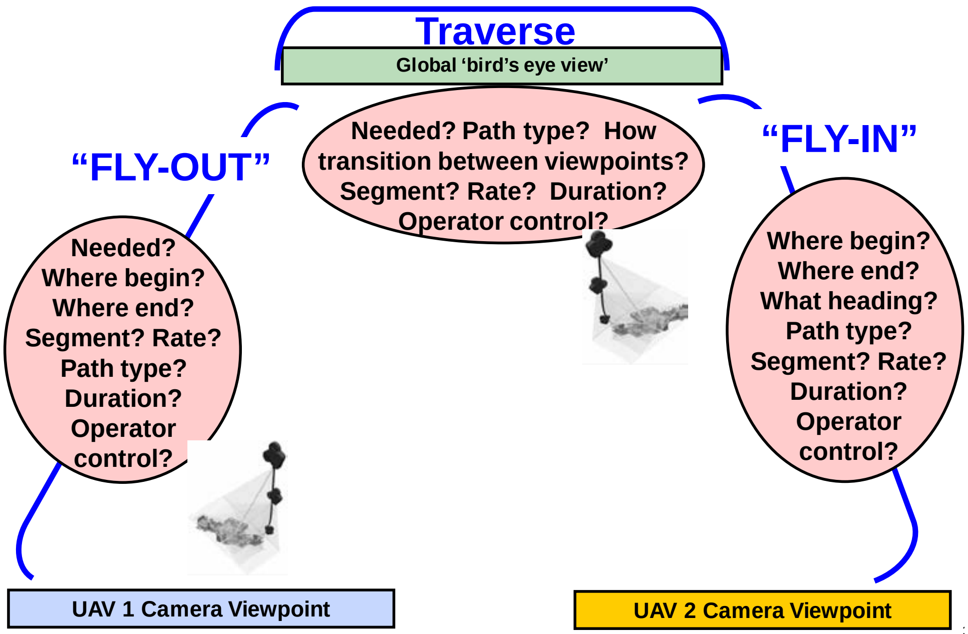


Figure 2. Illustration of Design Issues for each Segment of the Transition Format

PILOT STUDY 1

Purpose

The purpose of Pilot Study 1 was to perform a subjective assessment of the fly-in portion of the GITZ transition, evaluating several different fly-in concepts, and durations. The fly-in portion of the transition must be able to provide operators with the visual cues needed to rapidly develop a cognitive map of spatial points of interest relative to the environment in the sensor view. By providing operators with a fly-in that incorporates a bird's eye view of the environment, we hoped to be able to improve situation awareness beyond the sensor's Field-Of-View (FOV). This type of situation awareness could result in faster, more efficient responses to mission requirements with fewer errors. Another objective for the fly-in is to have the transition be visually appealing such that the movement and flow of information is not distracting and does not cause negative physical effects.

Fly-in Development

In order to create such a fly-in, three questions had be answered: 1) where should the fly-in begin, 2) what type of path should the fly-in take, and 3) what is an appropriate duration for a fly-in? We determined that operators should be able to see the UAV's entire area of influence at the beginning of the fly-in phase so they would have a perspective of the total environment and gain a context for the sensor's FOV. After trying several different pitches for the fly-in start point, we found that -85 degrees from horizontal was the best initial pitch for providing a view of the area surrounding the UAV. This pitch was optimal because it gave a slight bias towards the sensor's FOV which kept it in the picture better during the fly-in and the slight tilt created a smoother transition. In our simulated scenario, the UAV had an area of influence of 12 Nautical Miles (NM) as the maximum optimal viewing range for the sensor was four NM and the UAV's loiter pattern was a circle, four NM in diameter. In order to fit this area into the Virtual Camera (VC) view at the beginning of the fly-in, the fly-in had to start at an altitude of 33,000 ft AGL (Above Ground Level) as the maximum FOV was 48 degrees. An issue that arose while configuring the fly-in start point was the initial heading. When transitioning from one UAV to another, the heading of the sensors could be different. The heading would need to change at some point in order to create a continuous transition. We had several ideas for how to do this, which would potentially yield different headings at the fly-in start-point. We determined through informal testing that we did not want the heading to change during the fly-in portion of the transition as it would be too disorienting. Thus, the initial heading was set to match the sensor's heading. Any changes in heading will occur during the traverse or possibly the fly-out segment of the transition.

The end point for the fly-in was controlled by the position of the UAV's sensor. For the purposes of this study, the UAV was always fixed at 10,000 ft AGL with its sensor at a negative 49.2 degrees pitch and 2.6 degrees FOV to simulate real-world settings for a tactical UAV performing surveillance/reconnaissance.

With the start and end points in place, the fly-in path had to be determined. The fly-in path had to provide the operator with a smooth, intuitive descent from the beginning of the fly-in to the end at the sensor's viewpoint. Numerous path types were proposed, of which four were chosen based on informal testing and technological limitations: Short Vertical Drop (SVD), Long Vertical Drop (LVD), Exponential Sweep (ES), and Linear Sweep (LS). These fly-ins were divided into two phases, drop and zoom-in. During the drop phase, the VC would start with the UAV's entire area of influence in sight at 33,000 ft AGL and descend at a linear rate to 10,000 ft AGL while reducing the FOV from 48 degrees to 16 degrees, decreasing the area in the camera view. For SVD and LVD, the pitch did not change during this phase. Whereas for LS, the pitch increased to 49.2 degrees at a linear rate and for ES, the pitch increased to 49.2 degrees at an exponential rate of negative 0.5. The duration of the first phase of the fly-in was varied between two, four, and six seconds to determine the best time. For the zoom-in phase of the fly-in, the altitude remained at 10,000 ft AGL and the FOV decreased at an exponential rate of negative 0.07 to 2.6 degrees for all four fly-ins. The zoom-in phase lasted one second for all of the fly-ins except LVD which lasted three seconds. For SVD and LVD, the pitch increased linearly to 49.2 degrees during zoom-in. The pitch for ES and LS did not change during the zoom-in phase of the fly-in because it already matched that of the sensor. During the second zoom-in portion of the fly-in, the negative exponential rate of narrowing the FOV effectively enhanced the perception of the Virtual Camera slowing its velocity as it came to a stop. This all occurred in a fairly smooth and continuous manner with no pauses or excessively sharp changes in perspective. By varying the duration of the fly-in, we were able to create twelve different fly-ins for evaluation.

The duration of the fly-in was of particular importance as it had long enough to provide operators with the necessary visual cues, but not so long that it kept operators from being able to perform their missions in a timely manner. One of the main goals of the GITZ transition is to provide operators with a tool that can aid them in rapidly acquiring situation awareness, with an emphasis on *rapidly*. In order for the GITZ transition to be recommended, it must be able to improve situation awareness after switching without degrading performance on mission required tasks. One of the key performance criteria by which the GITZ transition will be measured is the time required for task completion. The GITZ transition will take time that would otherwise be used by the operator to complete the task. For this reason, the duration of the transition cannot exceed the possible performance benefits that could be realized by its implementation. As the GITZ transition was still untested at this point in time, the performance benefits were unknown. Therefore, in this pilot study, we used subjective measures of situation awareness and preference to establish a baseline from which to work.

Fly-out Development

The fly-out segment of the GITZ transition would precede the fly-in segment. Its purpose would give operators visual cues, letting them know that they were leaving one UAV and going to another. It was thought that this would allow them to mentally dissociate themselves from the first UAV's environment and prepare themselves for the second. This distinction between environments might lead to fewer errors caused by negative transfer of context. The fly-out portion of the transition was not the focus of this study, but one was included. A fly-out was created that was nearly identical to the fly-in, but reversed. The fly-out started at 10,000 ft AGL with a 2.6 degree FOV and negative 65 degree pitch and opened its FOV to 16 degrees at an exponential rate of negative 0.5 over the course of 0.5 seconds. Then, while decreasing its pitch to negative 90 degrees at a linear rate, was ascended to 33,000 ft AGL in 1.5 seconds. The main difference between the fly-out and the fly-in was time. Initially, both took the same amount of time, but we found that we needed more time for the fly-in phase. The transition time constraints required us to reduce the duration of the fly-out in order to increase the duration of the fly-in. The fly-out duration was changed to 0.5 seconds, but the overwhelming consensus was that this was too fast and created confusion. The presumed reason for this was the brain still trying to process the new information that appeared during the fly-out while the fly-in started, diverting attentional resources from the main focus. The duration was incrementally increased to two seconds, at which point the developers concluded that it was no longer a distraction. This was deemed an appropriate action as the objectives of the two segments were different. The objective of the fly-out was to separate the operator from the old environment. In contrast, the objective of the fly-in was to provide operators with visual cues which would allow them to develop a cognitive map of spatial points of interest relative to the new sensor view in the new environment. More time is required to accomplish the objective of the fly-in. An informal checkout showed a preference for a four second fly-in, which, given our five to seven second duration constraint, left one to three seconds for the fly-out.

Method

Experimental Design

In order to evaluate the perceptual impact of the four fly-in concepts (Short Vertical Drop: SVD, Long Vertical Drop: LVD, Exponential Sweep: ES, and Linear Sweep: LS) and three durations of drop time (two, four, and six seconds), subjective data were collected from six participants (mean age = 26.2 years) using a within-subjects design. The participants were asked to evaluate a series of paired fly-ins, with each pair comprised of two different fly-in concepts with the same drop duration. After viewing each pair of fly-ins, participants were asked to compare the two on a short questionnaire. Preceding every fly-in, a fly-out was presented from the first camera view. Parameters for the fly-out were not manipulated in this study.

A balanced paired comparison design was used in which all possible comparison pairs were tested within each of the three blocks of the drop duration time variable (two, four, or six seconds). To control for order bias, each fly-in concept was compared to every other fly-in concept for a given drop duration time twice, with each concept presented first in one comparison and presented second in the second comparison. For example, in one comparison participants were presented with SVD fly-in first, followed by the LVD fly-in, and then asked to compare the two in the Post-Trial Questionnaire. Later in the experimental session, participants were presented with the same two fly-ins in the opposite order, first the LVD fly-in and then the SVD fly-in, followed by the questionnaire. Within each drop time block, 12 comparisons were made, the order of which was randomly determined with the following constraints: a) the two orders of any pair of fly-ins could not occur consecutively (e.g., SVD – LVD and then LVD – SVD) and b) no more than two consecutive comparisons could have the same fly-in concept occur first in the two pairs.

The order of the three drop time blocks was counterbalanced across participants such that each drop time block (two, four, or six seconds) followed each other drop time block an equal number of times across participants. Participants were randomly assigned to one of the six orders of the three drop time blocks. A total of 36 trials (12 paired comparisons x three drop time blocks) were conducted for each participant and each trial lasted approximately two minutes (including questionnaire time). Total session time, per participant, was approximately two hours (including 15 minutes for training).

Simulation Environment

The study was performed using 711 HPW/RHCI's Open Scene Environment (OSE) version 0.4.67 visualization software to present participants with a manipulated synthetic camera view that moved along a preset path in an urban environment. The computer used for this experiment was a Dell Precision Workstation 670, Pentium Xeon with dual 3.6GHz processors, 1GB RAM, and a 512MB PCIe nVidia Quadro FX video card. Two 17" flat screen LCD monitors were used: participants viewed the left monitor, while the experimenter controlled experimental conditions with a keyboard and mouse at the right monitor (Figure 3). Pairs of fly-in concepts were shown back to back using command-line arguments in the Fedora Core five operating system.

Figure 3. Experimental Set-up for Pilot Study 1

Procedures

Participants were first provided an overview of the study and shown the Post-Trial Questionnaire in order to set a frame of reference for evaluating the display concepts. After signing the Informed Consent Document, participants filled-out a Background Questionnaire (Appendix A) and an initial Simulator Sickness Questionnaire [16; Appendix B]. Although sickness symptoms were not anticipated because the participants were experienced with video games that had moving backgrounds, this questionnaire was administered before and after each trial block to document health. Training consisted of demonstrating the four fly-in concepts for the 12 paired comparisons for the first drop duration time trial block. Demonstrations were repeated upon request. Next, experimental trials were completed. Note that there was no interaction required from the participant except to reply affirmatively when asked if he/she was ready to begin. Each trial consisted of showing one fly-in concept and then the second. (All fly-ins were preceded by a fly-out, as described above). Immediately after viewing each pair of fly-in concepts, participants were asked to compare them in terms of situation awareness, visual appeal, and preference in a Post-Trial Questionnaire (Appendix C). A sample question is shown in Figure 4 with each "fly-in" referred to as a "transition." The scoring method used was as follows: a score of "one" was given if the concepts were equal. If the first fly-in (transition) viewed was better than the second, a positive rating was given with two being "slightly more," and three or four being "substantially more." If the second viewed fly-in was better, a rating of negative two, negative three, or negative four was given. This type of question (using judgment matrices to assess relative comparisons of pairs of experimental conditions) was used frequently in the studies documented in this report and is based on the Subjective Workload Dominance (SWORD) technique developed by [17]. The ratings used in the statistical analyses were calculated using a geometric means approach.

3. In terms of *preference*, compare the two transitions.

Mark 1 of the 3 boxes below:

***Equal p*reference for Transition 1 and Transition 2**	☐		**If you preferred one transition more than the other, how much more did you prefer it?**		
			Mark 1 of the 3 columns below.		
Prefer Transition 1	☐	**then :**	**Slightly more** > ☐	>> ☐	**Substantially more** >>> ☐
Prefer Transition 2	☐				

Comments (If you preferred one transition over the other, please discuss why):

Figure 4. Sample Question after Participants Viewed a Pair of Fly-ins (transitions)

After each drop duration time block of 12 trials, a Post-Block Questionnaire (Appendix C) was administered asking participants to make a series of relative judgments, comparing each fly-in concept to the others on a nine-point scale. Participants' ratings on the drop duration time used in that particular trial block were also collected with a seven-point Likert Scale ("Too Slow" … "Too Fast"). The Post-Session Questionnaire was administered after all trials were completed (Appendix C) and consisted of a series of paired comparisons to evaluate drop duration time and fly-in concepts. This was followed by various questions on preferences and strategies and a section for general comments.

Results

Analyses were conducted on the subjective data collected via the questionnaires. These results are presented below, grouped by when the questionnaires were administered: post-trial, post-block (after all trials with one drop duration time), and post-session. It should be noted that the data from the Simulator Sickness Questionnaire was also analyzed and indicated that the participants did not experience any significant symptoms as a result of viewing any of the fly-in concepts.

Post-Trial Questionnaire

Situation Awareness Rating. Figure 5 presents the geometric means of the four fly-in concepts (Short Vertical Drop (SVD), Long Vertical Drop (LVD), Exponential Sweep (ES), and Linear Sweep (LS)) for each block of drop duration time (two, four, and six seconds). Since the experimental trials were blocked by drop duration time, Friedman Two-Way Analyses of Variance were first performed separately on paired comparisons data from each time block. Results for each drop duration block are as follows:

2 second block: participant ratings did not significantly differ across fly-in concepts ($\chi^2(3) = 1.850$, $p = 0.604$).

4 second block: significant difference found across geometric means ($\chi^2(3) = 11.00$, $p = 0.012$). Post-hoc Wilcoxon Signed Ranks Test results showed that ratings for the SVD concept were lower than two concepts ($Z = 2.201$, $p = 0.028$; $Z = 1.992$, $p = 0.046$ for LS and ES, respectively). Also, LVD was rated lower than LS ($Z = 2.201$, $p = 0.028$).

6 second block: significant difference found across geometric means ($\chi^2(3) = 11.300$, $p = 0.010$). Post-hoc Wilcoxon Signed Ranks Test results showed that comparison ratings for SVD were significantly lower than LVD, LS, and ES ($Z = 2.023$, $p = 0.043$; $Z = 2.201$, $p = 0.028$; $Z = 2.201$, $p = 0.028$; respectively).

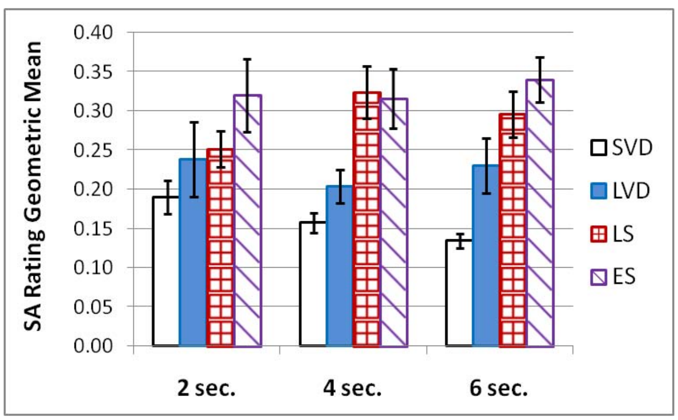


Figure 5. Geometric Mean for Situation Awareness Rating for each Fly-in Concept and Drop Duration Time
(error bars are SEM: standard error of the mean)

Analysis of situation awareness paired comparison ratings for drop duration time was conducted using the Friedman Two-Way Analysis of Variance and no significant differences in the geometric means were found ($\chi^2(2) = 2.583$, $p = 0.275$). The ratings were then collapsed across drop duration times and reanalyzed using the Friedman Two-Way Analysis of Variance and a significant difference was found ($\chi^2(3) = 11.00$, $p = 0.012$; see Figure 6). The post-hoc Wilcoxon Signed Ranks Test results showed that geometric means for SVD were less than for LS and ES (Z = 2.201, $p = 0.028$ for both comparisons).

Visually Appealing Rating. Figure 7 presents the geometric means of the four fly-in concepts for each block of drop duration time. Since the experimental trials were blocked by drop duration time, Friedman Two-Way Analyses of Variance were first performed separately on paired comparisons data from each time block. Results for each drop duration block are as follows:

2 second block: participant ratings did not significantly differ across fly-in concepts ($\chi^2(3) = 3.400$, $p = 0.334$).

4 second block: significant difference found across geometric means ($\chi^2(3) = 8.300$, $p = 0.040$). Post-hoc Wilcoxon Signed Ranks Test results showed that ratings of the SVD concept were lower than the LS and ES concepts ($Z = 2.023$, $p = 0.043$ for both comparisons). Also, LVD was rated lower than LS ($Z = 2.023$, $p = 0.043$).

6 second block: participant ratings did not significantly differ across fly-in concepts ($\chi^2(3) = 5.100$, $p = 0.165$).

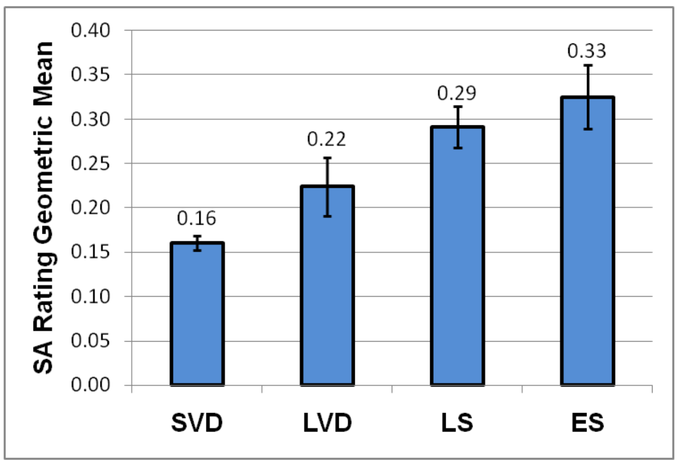


Figure 6. Situation Awareness Geometric Mean for each Fly-in Concept

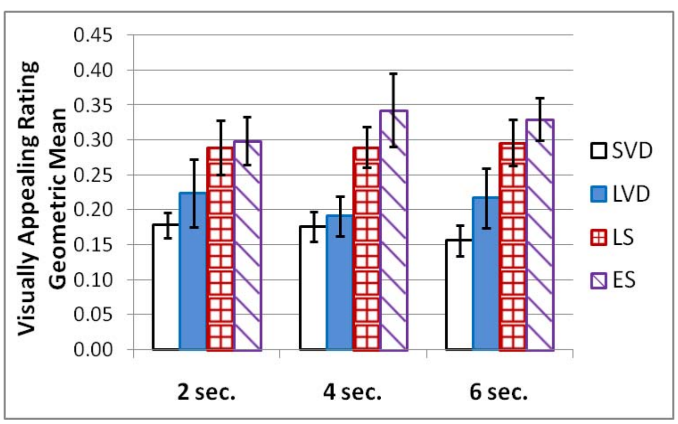


Figure 7. Geometric Mean for Visually Appealing Rating for each Fly-in Concept and Drop Duration Time

Similar to results pertaining to the situation awareness ratings, no significant differences were found using the Friedman Two-Way Analysis of Variance on the drop duration time factor ($\chi^2(2) = 4.33$, $p = 0.115$). The ratings were then collapsed across drop duration times and reanalyzed using the Friedman Two-Way Analysis of Variance. The difference across geometric means just missed being statistically significant at the 0.05 level ($\chi^2(3) = 7.450$, $p = 0.059$). A post-hoc Wilcoxon Signed Ranks Test was performed and the results showed that SVD geometric means were less than the LS and ES fly-in concepts ($Z = 2.023$, $p = 0.043$; $Z = 2.201$, $p = 0.028$; for LS and ES, respectively). Figure 8 shows the geometric means for the visually appealing ratings for each fly-in concept.

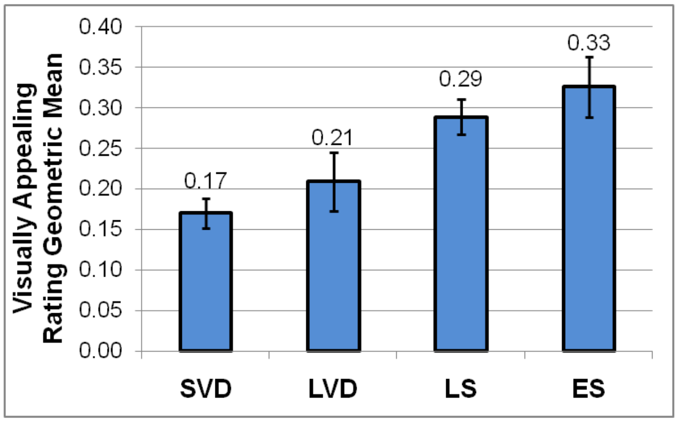


Figure 8. Visually Appealing Rating Geometric Mean for each Fly-in Concept

Preference Rating. Figure 9 presents the geometric means of the four fly-in concepts for each block of drop duration time. Friedman Two-Way Analyses of Variances were first performed separately on paired comparisons data from each time block. Results for each drop duration block are as follows:

2 second block: participant ratings did not significantly differ across fly-in concepts ($\chi^2(3) = 3.000$, $p = 0.392$).

4 second block: significant difference found across geometric means ($\chi^2(3) = 13.400$, $p = 0.004$). Post-hoc Wilcoxon Signed Ranks Test results showed that ratings of the SVD concept were lower than the LS and ES concepts ($Z = 2.201$, $p = 0.028$ for both comparisons). Also, LVD was rated lower than LS ($Z = 2.201$, $p = 0.028$).

6 second block: significant difference found across geometric means ($\chi^2(3) = 9.400$, $p = 0.024$). Post-hoc Wilcoxon Signed Ranks Test Results showed that ratings of the SVD concept were lower than the LS and ES concepts ($Z = 2.201$, $p = 0.028$; $Z = 2.201$, $p = 0.028$ for LS and ES, respectively).

Similar to results pertaining to the situation awareness and visual appeal ratings, no significant differences were found using the Friedman Two-Way Analysis of Variance on the drop duration time factor ($\chi^2(2) = 3.583$, $p = 0.167$). The ratings were then collapsed across drop duration times and reanalyzed using the Friedman Two-Way Analysis of Variance and a significant difference was found ($\chi^2(3) = 11.000$, $p = 0.012$). A post-hoc Wilcoxon Signed Ranks Test was performed and the results showed that the geometric means for SVD were less than that of the

LS and ES fly-in concepts ($Z = 2.201$, $p = 0.028$ for both comparisons). Figure 10 shows the geometric means of the preference ratings for each fly-in concept.

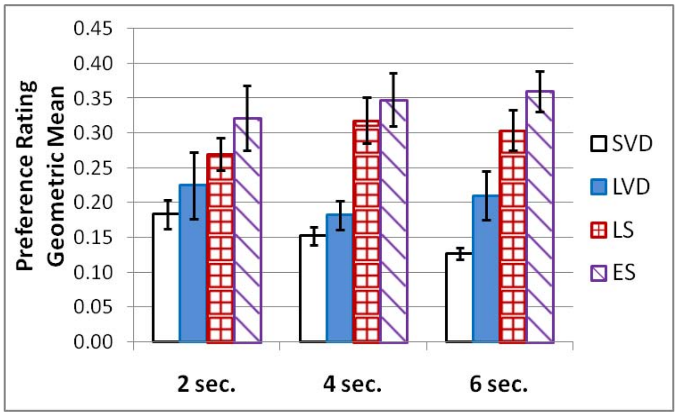


Figure 9. Geometric Mean for Preference Rating for each Fly-in and Drop Duration Time

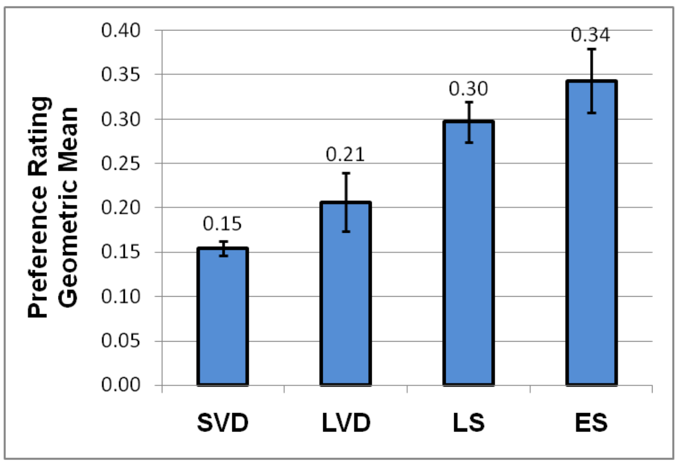


Figure 10. Preference Rating Geometric Mean for each Fly-in Concept

Post-Block Questionnaire

After all trials with one drop duration time were conducted, participants completed a post-block questionnaire which asked which of the fly-in concepts they preferred, as well as their assessment of the drop duration time. The following reports the results of these analyses.

Preference Rating. Figure 11 presents the geometric means of the four fly-in concepts for each block of drop duration time. Friedman Two-Way Analyses of Variances were first performed separately on paired comparisons data from each time block. Results for each drop duration block are as follows:

2 second block: the difference across geometric means just missed being statistically significant at the .05 level ($\chi^2(3) = 7.620$, $p = 0.055$). Post-hoc Wilcoxon Signed Ranks Test results did not show any statistically significant differences.

4 second block: significant difference found across geometric means ($\chi^2(3) = 10.920$, $p = 0.012$). Post-hoc Wilcoxon Signed Ranks Test Results showed that ratings of the SVD concept were lower than that for the LS and ES concepts ($Z = 2.023$, p = 0.043; $Z = 2.023$, $p = 0.043$).

6 second block: significant difference found across geometric means ($\chi^2(3) = 10.680$, $p = 0.014$). Post-hoc Wilcoxon Signed Ranks Test Results showed that the SVD concept was preferred less than the LS and ES concepts ($Z = 2.023$, $p = 0.043$ for both comparisons). Also, ES was preferred over LVD ($Z = 2.201$, $p = 0.028$).

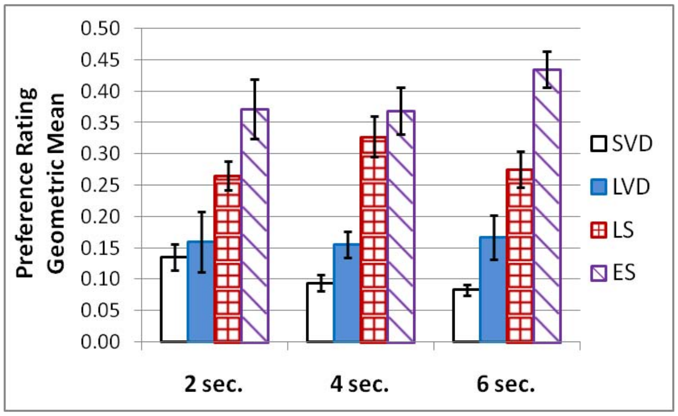


Figure 11. Geometric Mean for Post-Block Preference Rating for each Fly-in Concept and Drop Duration Time

No significant differences were found using the Friedman Two-Way Analysis of Variance on the drop duration time factor ($\chi^2(2) = 1.583$, $p = 0.453$). The ratings were then collapsed across drop duration times and reanalyzed using the Friedman Two-Way Analysis of Variance and a significant difference was found ($\chi^2(3) = 9.000$, $p = 0.029$). A post-hoc Wilcoxon Signed Ranks Test showed that the geometric means for the SVD concept were less than the LS and ES fly-in concepts ($Z = 2.201$, $p = 0.028$ and $Z = 1.992$, $p = 0.046$, respectively). Also, ES was preferred over LVD ($Z = 2.201$, p=0.028). Figure 12 shows the geometric means for the post-block preference ratings by fly-in concept.

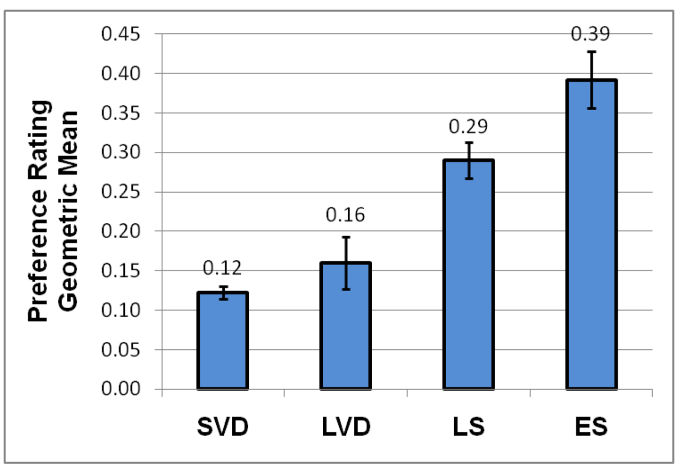


Figure 12. Post-Block Preference Rating Geometric Mean for each Fly-in Concept

Drop Duration Time Rating. The Post-Block Questionnaire included a seven-point Likert Scale for participants to rate their judgment of the duration of the drop time for the fly-in (Rating One equals "Too Slow" and Rating Seven equals "Too Fast"). A Friedman Two-Way Analysis of Variance did not show any significant differences as a function of drop duration time ($\chi^2(3) = 2.333$, $p = 0.311$). Data from this question are shown in Figure 13. The horizontal line indicates the value if the participants rated the duration "just right" (i.e., the middle of the scale, a rating of "four"). A comparison of the mean ratings with this benchmark suggests that participants rated the two and four second drop duration time as too fast and the six second drop duration time as slightly too slow.

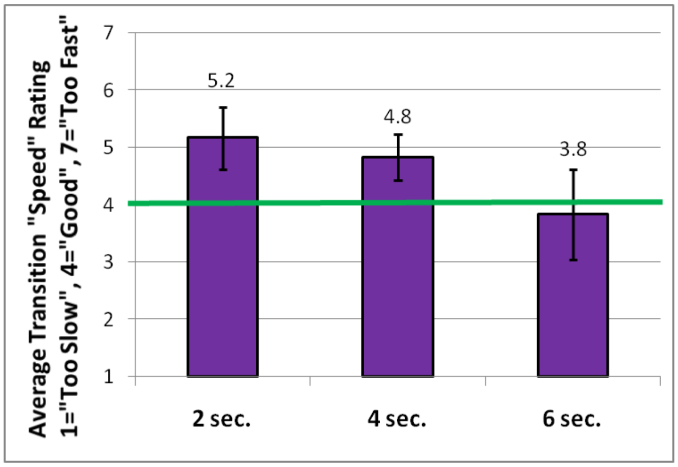


Figure 13. Ratings on the Drop Duration Time

Post-Session Questionnaire

There were two key items in the Post-Session Questionnaire, a series of paired comparisons asking participants to compare their preferences in terms of fly-in concept and drop duration time. Results for each of these questions will be addressed, in turn.

Fly-in Concept Preference: Results from a Friedman Two-Way Analyses of Variance test indicated a significant difference across ratings ($\chi^2(3) = 11.640$, $p = 0.009$). The preference ratings were lower for the SVD fly-in compared to the other three fly-in concepts (Figure 14). Post-hoc Wilcoxon Signed Ranks Tests indicated that this difference was significant for the LS and ES fly-in concepts ($Z = 2.023$, $p = 0.043$ for both comparisons).

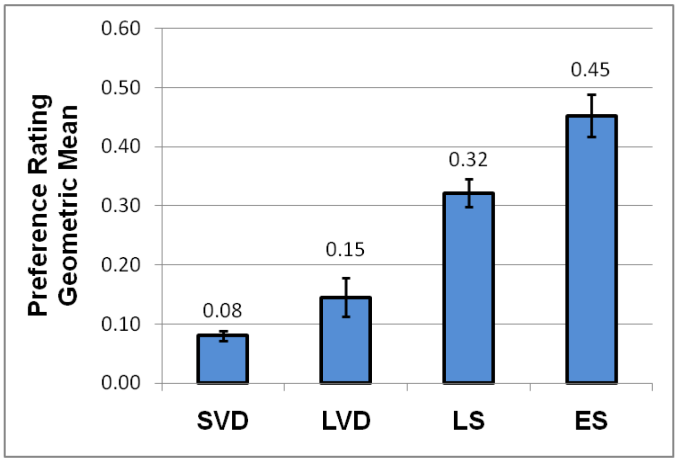


Figure 14. Post-Session Preference Rating Geometric Mean for each Fly-in Concept

Fly-in Drop Duration Time Preference. A Friedman Two-Way Analysis of Variance was performed on paired comparisons data from relative judgments of drop time preference, and the results showed that the differences across geometric means just missed being statistically significant at the 0.05 level ($\chi^2(2) = 4.750$, $p = 0.093$). Results from a post-hoc Wilcoxon Signed Ranks Test indicated that preference ratings for four seconds were more favorable than ratings for two seconds ($Z = 2.201$, $p = 0.028$; Figure 15).

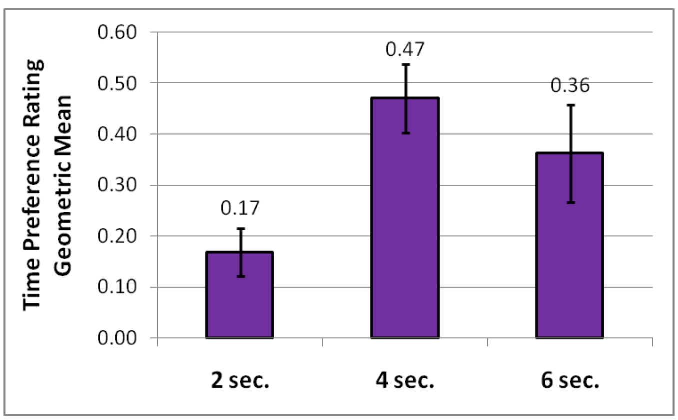


Figure 15. Post-Session Preference Rating Geometric Mean for each Drop Duration Time

Conclusions

The results were consistent across questionnaires administered after each individual trial, block of trials, and at the end of the experimental session. First, there were no significant differences in rating between the two vertical drop conditions, indicating that the extra time devoted to the second phase of the long vertical drop (LVD) was not beneficial. More importantly, participants preferred the exponential sweep (ES) and the linear sweep (LS) over both the short and long vertical drop concepts (SVD, LVD). In both vertical drop fly-in concepts, the pitch of the virtual camera did not change during the drop phase. In contrast, the pitch increased for the other two fly-in concepts, one linearly (LS) and one exponentially (ES). Increasing the pitch during the drop phase lengthened the time in which the target remained in the camera FOV. Review of participants' comments indicated that this was the basis of their preference and situation awareness ratings. Participants did not want to lose sight of the target during the fly-in.

The preference ratings suggest that the drop duration time should be four seconds. This duration, together with one second for the zoom in phase, would mean allowing five seconds for the total fly-in segment of the transition.

Implications for Future Research

Based on the results of Pilot Study 1, we decided that the fly-in segments to be tested in follow-on studies should be approximately five to six seconds in duration. Furthermore, the virtual camera's view should increase in pitch during the fly-in (similar to what was employed in the linear and exponential sweep conditions). It is also recommended that the camera needs to spend as much time as possible at a location that provides maximum view of the area. These design criteria are supported by the participants' comments to keep the target in view as much as possible, but not lengthen the total fly-in duration any more. Some participants suggested providing more time (even a pause) at the top of the fly-in.

For follow-on pilot studies of the fly-in, we also decided not to present the fly-out segment as well. In the present study, fly-out transition segments preceded each fly-in. It was originally hypothesized that the presence of a fly-out might help the participants divorce themselves from the environment in the previous camera view. However, pilot study participants commented that the presence of the fly-out was distracting in the evaluation process.

This Pilot Study, besides providing data to drive fly-in design for transitioning between camera views, was informative in regards to evaluation methodology. First, the hardware utilized in this study imposed several limitations. The database was slow in rendering the transition segments. This meant there was a short break between the viewing of each fly-in concept for the paired presentations, making it more difficult for participants to compare the pairs of fly-ins back to back. Although the experimental variables were presented in all possible orders across trials, to control for order effect, the breaks imposed by the hardware may have introduced fatigue and/or frustration in the completion of the experimental sessions. It is desirable for follow-on research to employ different hardware, such that the delay between viewing transition segments is minimized.

This study also showed the shortcomings of the data we measured. With the approach used in Pilot Study 1, we were limited to subjective ratings of the various transition parameter manipulations. It is more desirable to have an approach that is a better representation of the envisioned operational task after changing camera views. Moreover, objective measures of situation awareness and the degree to which negative transfer of context occurs would be desirable.

PILOT STUDY 2

Purpose

In Pilot Study 1 we examined several different fly-in concepts and durations to determine what parameters were best for implementing this segment of a transition format designed to aid changing camera views. With these parameters, we designed three improved fly-in concepts using new software tools. One objective of Pilot Study 2 was to evaluate these three fly-in concepts. Another objective was to obtain an objective measure of situation awareness afforded by the transition segment, in addition to subjective assessments. In particular, we were interested in whether situation awareness of points of interest beyond the sensor view would be enhanced with these fly-in concepts.

Fly-in Development

Several major changes were made during the development of the second generation of fly-ins. The first was a change in the focus of the fly-ins. The first iteration of fly-in segments focused on the area surrounding the UAV with the idea that this would give the operator a better idea of the environment as it relates to the UAV, and that it would allow the operator to see the sensor's entire area of influence. After reviewing the fly-ins from the first study and consultation with UAV operators, we determined that this was not the best use of the GITZ transition for several reasons. First, the purpose of the fly-in was to provide operators with the visual cues needed to rapidly develop a cognitive map of spatial points of interest relative to the environment in the sensor view, not the environment surrounding the UAV. Information about the environment surrounding the UAV is already represented in the Tactical Situation Display. Also, the UAVs that are being simulated do not fly directly above their target, as this would give away their position and intentions. Instead they fly 2-4 NM away from the area-of-interest (AOI), at a range that is best for the sensors and that puts the AOI off to the side of the UAV's loiter. With this in mind, we changed the center point at the beginning of the fly-in from the area around the UAV to the area around the target. By incorporating this with a new stare point lock-on tool, we were able to keep the target in the center of the camera view at all times regardless of the fly-in path. This approach allowed for much more flexibility in the path design.

Changing the focus of the fly-in from the area surrounding the UAV to the area surrounding the target required us to reexamine the Virtual Camera's (VC) start-point at the beginning of the fly-in. The three main ideas were: 1) start the VC over the target, 2) keep the VC over the UAV, or 3) start the VC above the UAV away from the target. Figure 16 illustrates these three alternatives. Dropping the camera straight down into the UAV (Number 2 in Figure 16) did not make sense as it was designed with the idea that the GITZ transition would focus on the area surrounding the UAV. Starting the VC above the target (Number 1 in Figure 16) would tailor the fly-in to the new focal point, the target. This approach would give the operator a bird's-eye-view of the target area before flying into the sensor view. However, an expert in the role of perspective in observation and navigation pointed out that this was an unnatural flight path for a human to see. The combination of the straight downward fall and drastic change in perspective would give the sensation of falling backwards and make processing information in the camera view very difficult. He proposed the concept illustrated in Number 3 of Figure 16: starting the VC behind and above the actual sensor. This would allow the VC to fly towards the target throughout the fly-in instead of falling on it. This fly-in would be visually similar to flying a plane towards the target.

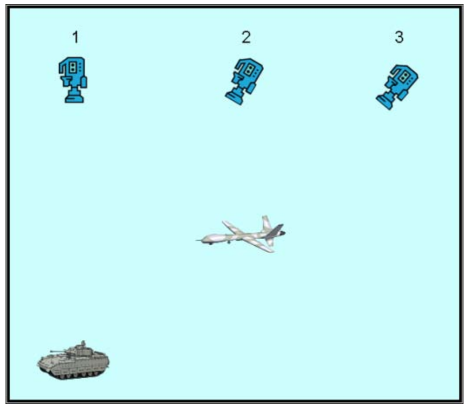
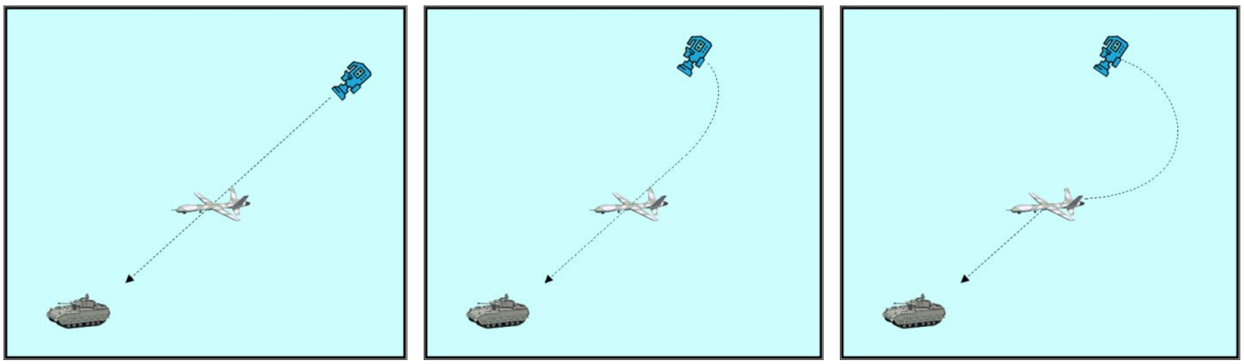


Figure 16. Illustration of Three Possible Virtual Camera Start Points

Using this approach (starting the VC above and behind the target), we developed three new fly-in concepts: linear, shallow curve, and deep curve (Figure 17). For the linear fly-in, we simply took the vector from the target through the UAV and had the VC start 12,000 ft away from the UAV on the opposite side of the vector from the target. We had the UAVs start at an altitude of 4500 ft AGL (standoff distances from the ground targets were adjusted to maintain camera pitch of ~45 degrees). This meant that the VC started at an altitude of only 13,500 ft AGL. We were able to get the entire area we wanted to observe in the VC's view at the start point by increasing the FOV to 72 degrees. This fly-in was broken up into two stages: the VC's descent from the start point to the UAV, and the zoom-in to the sensor's viewpoint. The first portion lasted 5.15 seconds and used an exponential function of 0.6 so the fly in started slowly and sped up in the middle. The second portion of the fly-in lasted 0.85 seconds and used an exponential function of negative 0.9 to slow down the zoom-in as it approached the end.

The two curved fly-ins (see Figure 17) started 12,000 ft away from the UAV as well and had 72 degree FOVs. These two fly-ins always started at an angle of 77.5 degrees above horizontal with respect to the UAV, whereas the first fly-in started at the same angle that the UAV was at with respect to the target (in this study it was ~46 degrees in all trials). The curved fly-ins flew towards the target along paths created using cubic Bezier curves. This was done with the thought that providing the operator with multiple perspectives of the area would give them information about its layout. One fly-in followed a shallow curve that approached the vector from the target through the UAV as it flew. The first stage of this fly-in took 5.2 seconds with an exponential function of 0.2. The second stage of the shallow curve took 0.8 seconds and used an exponential function of negative 2.0. The other fly-in followed a deeper curve that went well beyond the vector and approached horizontal flight as it flew in towards the camera. The first stage of this fly-in took 4.8 seconds with an exponential function of 0.1. The second stage of the deep curve took 1.2 seconds and used an exponential function of negative 3.0.

The exponential functions that we used were chosen for several reasons. The first was to give more time at the beginning of the fly-in to view the whole area. The second was to slow down the camera before the end of the fly-in so the conclusion would not be abrupt. The third reason was to give the impression that the cameras moved at similar speeds during the different fly-in concepts. In examining the different combinations of stage durations and exponential functions, we found that the parameters specified above were the best. All three fly-in concepts had a total duration of six seconds, meeting the recommendation derived from Pilot Study 1.



Linear Fly-in | Shallow Curve Fly-in | Deep Curve Fly-in

Figure 17. Illustrations of Three Fly-in Concept Camera Paths

Method

Experimental Design

Twelve volunteers (mean age = 25.75) participated in this two-part study. Part I of Pilot Study 2 was designed to collect an objective measure of the effect of the fly-in concept on situation awareness of the AOI, in addition to a subjective assessment. Part 2 used procedures similar to those used in Pilot Study 1 and was designed to collect additional subjective assessments of the improved fly-ins.

In Part I, we used a 3 x 2 within-subjects design: two trials with each of the three fly-in concepts: linear, shallow curve, and deep curve. Trials were blocked by the three fly-in concepts and the trial orders in which the fly-in concepts were presented to the participants was counterbalanced across participants. The UAV’s 2.55 NM x 2.55 NM target area was divided up into nine sections. The area, across the sections, was populated with overlaid computer-generated symbology consisting of 4-5 red (enemy) flags, 4-5 blue (friendly) flags, and one flag of each of the following colors; light green, light blue, magenta, yellow, and orange. The blue and red flags acted as clutter with the rest being possible targets. The flags were distributed such that each column and row of sections in the area contained 3-5 flags with at least one flag in each section and no more than two flags of the same color in any section. The UAV was positioned approximately 5000 feet above and away from the center of the area with its sensor focused on a target at the center point. See Figure 18 for an illustration of the placement of the colored flags. Note: the yellow grid lines were not visible during trials.

In Part II of the study, conducted after completion of Part I, the fly-ins were tested using a balanced paired comparison design. To control for order bias, each fly-in concept was compared to every other fly-in concept, with each concept being presented first in one comparison and presented second in the second comparison. After each pair of fly-ins were shown back-to-back, participants were asked to complete a questionnaire to collect subjective assessment on the degree to which one was better than the other in terms of situation awareness and visual appeal. In contrast to the procedure used in Pilot Study 1, the presentations of the fly-in transition segments were not preceded with a fly-out transition segment. The order of the comparisons was randomly determined with the constraint that there were no more than two consecutive trials with the same first fly-in concept.

Figure 18. Illustrations of Method used to Distribute the Presentation of Colored Flags

Simulation Environment

The study was performed using AFRL's Open Scene Environment (OSE) version 0.4.67 visualization software to present the participant with a manipulated synthetic camera view that moved along a preset path in an urban environment. The computer used for this experiment was a Dell Precision Workstation 670, Pentium Xeon with dual 3.6GHz processors, 1GB RAM, and a 512MB PCIe nVidia Quadro FX video card. A single 17" flat screen LCD monitor was used. The participant viewed the monitor while the experimenter controlled experimental conditions with a keyboard and mouse. Fly-in concepts were shown using the Open Scene Environment and command-line arguments in the Fedora Core 5 operating system. Back-to-back comparison videos were shown using Windows Media Player, which helped reduce the delay between viewing pairs of transition segments.

Procedures

Participants were first provided an overview of the study and shown the Post-Trial Questionnaire (Appendix D) in order to set a frame of reference for evaluating the display concepts. After signing the Informed Consent Document, participants filled out Background Questionnaire (Appendix A) and an initial Simulator Sickness Questionnaire [16; Appendix B]. Even though sickness symptoms were not anticipated because the participants were experienced with video games that had moving backgrounds, this questionnaire was administered before and after each trial block to document health. Training consisted of demonstrating each of the fly-ins individually and explaining the characteristics of the fly-in paths. Practice trials were conducted until participants felt comfortable with the procedures. Then experimental trials were completed.

In Part I of the study, participants were instructed to create a mental map of the area and its flags during the fly-in. Following the presentation of the fly-in, they were asked to draw a line from the center of the area to the location of a flag that was then specified (light green, light blue, magenta, yellow, or orange) on a form (Figure 19; Appendix D). The participants were not told which flag to indicate until after the fly-in was presented. The angle formed by the intersection of the recalled vector of the target and the actual vector from the center of the area was used to measure accuracy from 0 to 180 degrees.

1) For **this trial**, draw a line from the center flag to the direction of the (light green, light blue, magenta, yellow, and orange) flag:

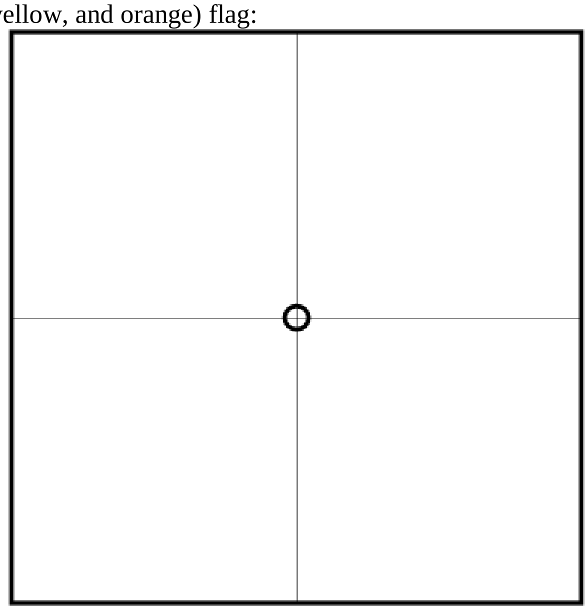


Figure 19. Post-Trial Form for Participants to Indicate the Direction of the Requested Flag

Next, participants rated the fly-in for situation awareness and visual appeal using Likert Scales (Figure 20; Appendix D). The first trial with each type of fly-in was treated as a training trial. Only data from the second trial with each fly-in were analyzed.

Mark the box (☐) which best reflects your ratings for each of the following:

2) <u>Situation Awareness</u>: For **<u>this trial</u>**, rate your **<u>overall situation awareness</u>** -- the degree to which you: were aware of important elements in your environment (i.e., landmarks, targets, major features), comprehended your current location, and were able to project future status.

Low			***Situation Awareness Rating***			**High**
Never Aware						**Always Aware**
1 ☐	**2** ☐	**3** ☐	**4** ☐	**5** ☐	**6** ☐	**7** ☐

3) <u>Visually Appealing</u>: For **<u>this trial</u>**, rate ***<u>how visually appealing</u>*** the fly-in was.

			Visually Appealing Rating			
Lowest Appeal						**Highest Appeal**
1 ☐	**2** ☐	**3** ☐	**4** ☐	**5** ☐	**6** ☐	**7** ☐

Figure 20. Post-Trial Question - Part 1 for Rating Fly-in Situation Awareness and Visual Appeal

After the six trials of Part I were completed (two with each fly-in), participants were asked to fill-out a Post-Part 1 Questionnaire (Appendix D) to indicate which fly-in approach they preferred. The survey consisted of a series of relative judgments. Each judgment required the participant to indicate which of the two concepts being compared was preferred in terms of situation awareness gained or visual appeal. A nine-point scale was used for comparing the preference of each of the pairs of fly-in concepts.

After each trial in Part II of Pilot Study 2, participants were asked to compare the two fly-in concepts just presented back-to-back to indicate which one provided more situation awareness (Figure 21) and was more visually appealing (Figure 22) on a Post-Trial-Part 2 Questionnaire. After completing all six trials in Part II, participants were asked to complete a Post-Part 2 Questionnaire, indicating which fly-in concept they preferred. These questionnaires can be viewed in Appendix D. All subjective data were analyzed using the procedures employed in Pilot Study 1.

After both Part I and II were completed, study participants were given a Post-Session Questionnaire (Appendix B) in which they were asked about their strategies in making the comparison judgments. The questionnaire also solicited other ideas for fly-in concepts and general comments.

1. In terms of your *ability to gain situation awareness (SA)* of the entire area, compare the first and second fly-in observed.
SA = the degree to which you: were aware of important elements in your environment (i.e., landmarks, targets, major features), comprehended your current location, and were able to project future status.

Mark 1 of the 3 boxes below:

SA *equal* with Fly-in 1 and 2	☐
More SA with Fly-in 1	☐
More SA with Fly-in 2	☐

If you had more SA with one fly-in compared to the other, how much more?

then:

Mark 1 of the 3 columns below.		
Slightly more > ☐	>> ☐	**Substantially more** >>> ☐

Figure 21. Post-Trial Question Comparing Situation Awareness across Fly-in Concepts

2. In terms of being *visually appealing*, compare the first and second fly-in observed.

Mark 1 of the 3 boxes below:

Fly-in 1 and 2 were *equally* visually appealing	☐
Fly-in 1 more visually appealing	☐
Fly-in 2 more visually appealing	☐

If you found one fly-in more visually appealing, how much more appealing was it compared to the other fly-in?

then:

Mark 1 of the 3 columns below.		
Slightly more > ☐	>> ☐	**Substantially more** >>> ☐

Figure 22. Post-Trial Question Comparing Visual Appeal across Fly-in Concepts

Results – Part I

The average difference in the angle between the marked location of the requested flag and the real location of the flag (for the second trial with each fly-in concept) was analyzed in a one-way Analysis of Variance (ANOVA). Results indicated that the mean accuracy in marking the requested flag location on the map, across fly-in concepts, just missed being statistically significantly different at the 0.05 level ($F(2,22) = 3.485$, $p = 0.055$). Post hoc Hypothesis Tests on the ANOVA were completed to compare mean accuracy for each possible pair of fly-in concepts at a time. The mean accuracy for the shallow curve and deep curve were contrasted against that for the linear fly-in. Hypothesis Test results showed that participants more accurately indicated the location of the requested flag with the linear fly-in concept as it was significantly less compared to performance with the Shallow and Deep Curve ($F(1,11) = 12.634$, $p = 0.005$). See Figure 23.

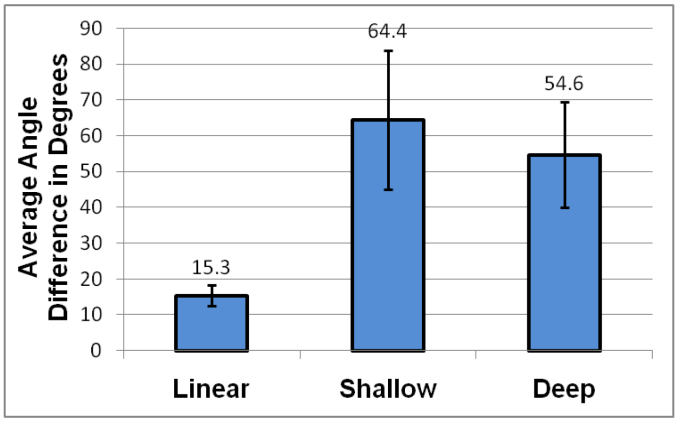


Figure 23. Accuracy in Indicating Target Flag Location with Each Fly-in Concept

Analyses were also conducted on the subjective questionnaire data collected after the second trial with each fly-in concept (Figure 20). Friedman Two-Way Analysis of Variance tests were conducted on participants' two post-trial rating scales. The results failed to find any significant differences in the ratings pertaining to situation awareness ($\chi^2(2) = 1.167$, $p = 0.558$; Figure 24) and visual appeal ($\chi^2(2) = 2.042$, $p = 0.360$; Figure 25). Using the same statistical test, the results also did not show a significant difference in participants' rating of their fly-in concept preference in the questionnaire administered after all trials were completed in Part I ($\chi^2(2) = 0.042$, $p = 0.979$; Figure 26). Finally, participants' ratings on the Simulator Sickness Questionnaire indicated that there were not any significant symptoms as a result of viewing the fly-in concepts.

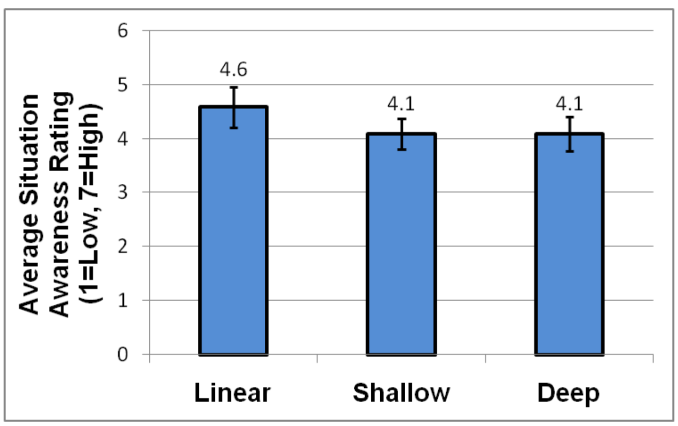


Figure 24. Post-Trial Situation Awareness Rating for Each Fly-in Concept

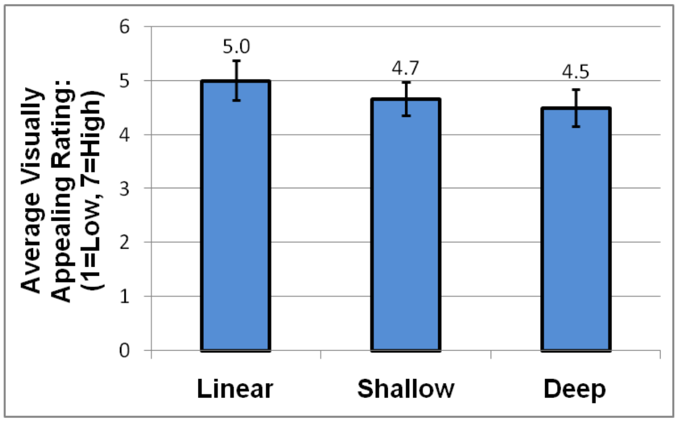


Figure 25. Post-Trial Visual Appeal Rating for Each Fly-in Concept

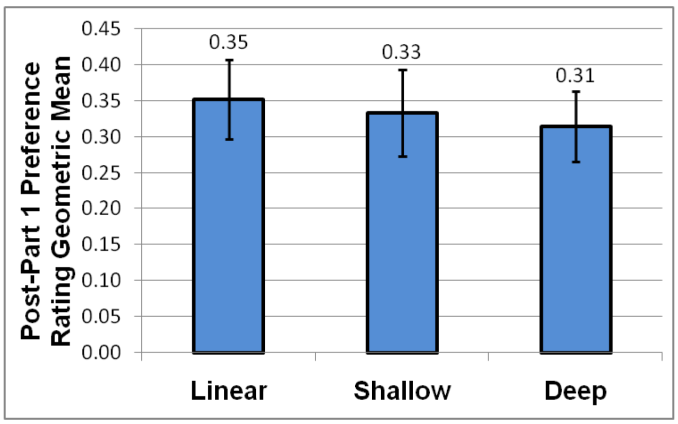


Figure 26. Post-Study Part I Geometric Mean Rating for Fly-in Preference

Results – Part II

Only subjective data were collected in Part II that involved the paired comparison design. Analyses using the Friedman Two-Way Analysis of Variance failed to find statistical significant differences in participants' post-trial ratings on the three fly-in concepts in terms of situation awareness ($\chi^2(2) = 0.875$, $p = 0.646$) and visual appeal ($\chi^2(2) = 2.042$, $p = 0.360$). Nor were there significant differences found in the preference ratings collected after all trials were completed in Part II ($\chi^2(2) = 0.042$, $p = 0.979$) and in a Final Questionnaire ($\chi^2(2) = 0.375$, $p = 0.829$).

Conclusions

Many participants commented that they felt the linear fly-in provided better situation awareness of the area, but that both curved fly-ins were more visually appealing. However, analysis of the questionnaire data did not show a significant difference across fly-in concepts in terms of perceived situation awareness, visual appeal, or fly-in preference. In light of these contradictory results, we will base the conclusions for Pilot Study 2 on the objective performance data.

For the task in which participants had to recall where the requested flag was located and indicate it on a form (Figure 19), performance was best when the linear fly-in was utilized, in comparison to the two curved fly-ins. Performance with the linear fly-in was both more accurate (lower angle difference) and consistent (less variance) than those for the shallow curve and deep curve fly-in concepts. These data indicate that participants were able to more consistently and accurately create and recall mental maps of the areas when using the linear fly-in. We surmise that participants were able to create better cognitive renditions of the areas with the linear fly-in due to the fixed perspective it utilized. With the linear fly-in, as the camera flew in, the flags' orientations relative to the fly-in path vector remained fixed, whereas with the curved fly-ins, their orientations changed constantly. It should be noted that in this experiment we only measured directional accuracy across a plane. It is not known which fly-in concept provided better cues with respect to elevation and distance differences.

Implications for Future Research

Based on the results of Pilot Study 2, we decided that a linear fly-in, as opposed to a curved approach, should be tested in follow-on studies. Furthermore, consideration should be given to the numerous participant comments in determining other parameters of the fly-in. Many mentioned that they would like the virtual camera to spend more time at the beginning or top of the fly-in. This would provide more time to survey the entire area and create a mental map. In regards to the middle segment, several participants said that it should be speeded up, because they did not pick-up any meaningful information during this portion. At the end of the fly-in, participants indicated that there should be a less abrupt stop by slowing the transition. The information presented at the end of the fly-in is of great importance as well, as it provides the operator with information about the target's immediate surroundings. In sum, these comments suggest that the very beginning and end of the fly-in are the two most important segments for acquiring information.

Most participants also expressed disappointment or frustration at the fact that they were unable to control the fly-in. It was suggested to have a function which allowed the operator to choose whether or not they wanted to use the GITZ transition, as well as tools for controlling parameters of the fly-in (e.g., speed). They also wanted to be able to go back and forth and pause during the fly-in (similar to the functions on many digital video recorders).

FULL MULTI-UAV SIMULATION EVALUATION

Purpose

Pilot Studies 1 and 2 focused on the fly-in segment of a transition format. The participants' only mission-related task was to view the GITZ transition and the data collected primarily consisted of subjective assessments. Only one objective measure was recorded (Pilot Study 2), the average difference in the angle between the marked location of the requested flag and the real location of the flag. However, these part-task simulations were valuable in that a series of fly-in segments could be presented rapidly, allowing multiple fly-in parameters to be systematically manipulated and evaluated. This provided data to inform the design of the fly-in segment for testing in a full simulation evaluation.

One purpose of the present evaluation was to determine if participants' subjective assessments of a fly-in approach determined from the results of the pilot studies are also favorable when the transition is employed in a full multi-UAV simulation that involves the completion of multiple tasks while periodically switching missions/camera views. Besides recording the participants' impressions, another objective was to obtain multiple performance measures to determine if the GITZ transition helped the participants' overall situation awareness and improved their performance on a target designation task after switching to a new UAV/camera view. This evaluation also manipulated the mission scenario to determine if the utility of the GITZ transition depends on whether the previous mission was a static, surveillance type mission or a dynamic, close air support mission. Finally, this study was designed to determine if the presence of the GITZ transition had any negative effects on participants' completion of secondary mission-related tasks. This is important because if the GITZ transition degrades performance on any task, then its candidacy for multi-UAV control applications is questionable, even if it improves situation awareness after switching to a different UAV/camera view.

Transition Development

The full multi-UAV control simulation environment used in this evaluation allowed scenarios that included multiple UAVs flying in loiterers patterns. Because the UAVs did not have to be stationary, adjustments were required to make the fly-in more flexible. The camera pitch was no longer fixed at 46.2 degrees but was determined by the angle from horizontal between the UAV and the stare point on the ground. Each UAV's altitude and distance from the targets changed from Pilot Study 2 as well because we were no longer constrained by the virtual environment. The UAVs flew between 8,000 and 12,000 ft MSL at 2 to 4 NM from their targets. This allowed us to return to the more realistic 48 degree max FOV that we used in Pilot Study 1. The minimum FOV was reduced to 0.41 degrees (spotter mode) to allow the participants to identify and designate targets on the ground. Other changes were made in the linear fly-in, based on comments from Pilot Study 2. For instance, we took the vector from the target through the UAV and had the VC start 18,000 ft away from the UAV on the opposite side of the vector from the target. This distance was increased from the original to allow the entire area of observation to fit in the reduced max FOV. Also, a fly-out segment preceded the fly-in for this study to determine if it would help reduce negative transfer of context that could occur when switching from one camera view to another. Figure 27 illustrates how the GITZ transition was implemented for this evaluation. In this figure, the operator's initial view of a house is from the camera mounted on UAV 1. Next, the operator views a semi-continuous transition implemented with synthetic vision/augmented reality technologies. The transition consists of a fly-out portion (triangle shapes numbered Points 1 and 2), a "bird's eye view" of UAV 2 (Point 4), and a fly-in portion (Points 4 and 5). The "fly-out" phase of the transition was similar in structure to the "fly-in" phase, but operated in reverse. The operator's final view of the tank was from the camera mounted on UAV 2. The entire transition lasted 6.5 seconds. Further detail on each segment of the transition is provided below and in Figure 27. The timeline in Figure 27 shows the duration and rate of change (exponential factor) for each segment, as well as the timing of experimental script prompts to change the mission (Circle A) and locate a specific tank target (Circle B).

- Point 1: The camera view switched from a (simulated) live video feed to a purely synthetic environment from a VC. The imagery from the VC started at the same position with which the live video ended: 12,000 to 24,000 ft away from the house (varied because the UAV is loitering), and 7,000 ft AGL giving a pitch of 60 to 74 degrees from horizontal. From this start-point, the VC's FOV opened from 0.41 degrees (horizontal) to 48 degrees over the course of 1.25 seconds, gradually increasing the rate at which it opened by an exponential factor of 0.5. This gave the visual impression of flying away from the house along a vector from the house to the first UAV at an increasing speed.
- Point 1 to Point 2: The VC began to physically (in the virtual environment) move away from the house along the same vector for 6,000 ft over the course of 0.25 seconds with an exponential change in speed of -1.2 to Point 2. This gave the impression of slowing down slightly at the end of the fly-out. Overall, the participants had the impression of a smooth continuous fly-out that started slowly, sped up in the middle, and ended slowly.
- Point 3: The view switched immediately from the environment surrounding the first UAV (Point 2) to the environment surrounding the second UAV (Point 4). In this respect, the transition was semi-continuous.
- Point 4: The VC started 18,000 ft away from the second UAV along the vector from the sensor view's stare point through the UAV with a FOV of 48 degrees and a pitch of 60 to 74 degrees from horizontal.
- Point 4 to Point 5: The VC moved towards the second UAV along the same vector over 3.0 seconds with the speed increasing at an exponential rate of 1.3. This gave the impression of almost standing still at the top of the fly-in and then accelerating towards the tank.
- Point 5: Once the VC reached the second UAV the FOV narrowed to 0.41 degrees in 2.0 seconds at an exponential change in rate of -2.5. This gave the impression that the VC was still moving towards the target, slowing down as it approached the truck.

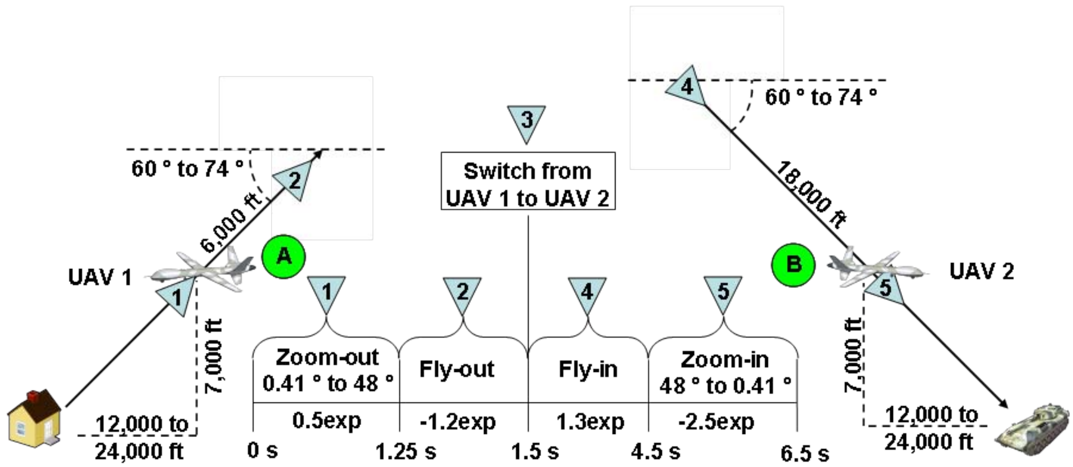


Figure 27. Illustration of Transition for Changing Camera Views in Multi-UAV Operations

Method

Experimental Design

Performance was examined while participants completed trials both with and without the GITZ transition in a multi-UAV control environment. Mission type was also manipulated (see Table 1). Each scenario involved multiple static and dynamic missions, and participants were told that performance would be recorded during all missions. However, the data analyses focused on the second static-to-dynamic mission transition in Scenario Type 1 and the dynamic-to-dynamic mission transition in Scenario Type 2. This factor was included to determine if the utility of the GITZ tool was a function of the mission types involved in the transition. (Note: for trials with the GITZ tool, the format was only presented when transitioning to a dynamic mission, from either a static or dynamic mission.)

Table 1. Scenario Types Completed by Participants: Data Analysis Focused on Shaded Cells

Scenario	Order of Four Mission Types Presented			
1	Static	Dynamic	**Static**	**Dynamic**
2	Static	**Dynamic**	**Dynamic**	Static

A within-subjects 2 x 2 x 2 design was utilized with 13 participants (average age = 26.69 years) to examine the GITZ transition, scenario/mission transition type, and replication variables. There were a total of eight experimental trials. Trials with each GITZ transition (off or on) were blocked with participants receiving both scenarios (static-to-dynamic or dynamic-to-dynamic, two replications each) with one GITZ level prior to receiving the other GITZ level. Orders of the GITZ on/off level and mission transition type were counterbalanced for 12 participants and randomly assigned for the thirteenth. Each trial lasted approximately 12 minutes. Total session time, per participant, was approximately 4.5 hours (including 2 hours for training).

Multi-UAV Control Simulation Environment

This experiment utilized the Vigilant Spirit multi-UAV operator control station testbed (Figure 28). The testbed consisted of two 24 inch monitors (resolution 1920 x 1200 pixels), a keyboard, and a right hand joystick and mouse.

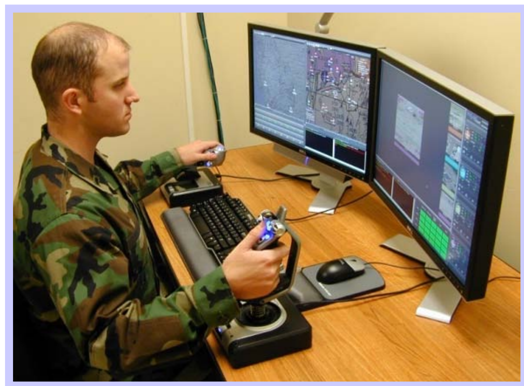


Figure 28. Vigilant Spirit Multi-UAV Testbed

The left monitor (Figure 29) presented both a Global Tactical Situation Display (TSD) (showing the path of four UAVs performing missions over different urban areas; 1290 x 1057 NM) and a local TSD (fixed on the center of the loiter pattern of the UAV currently

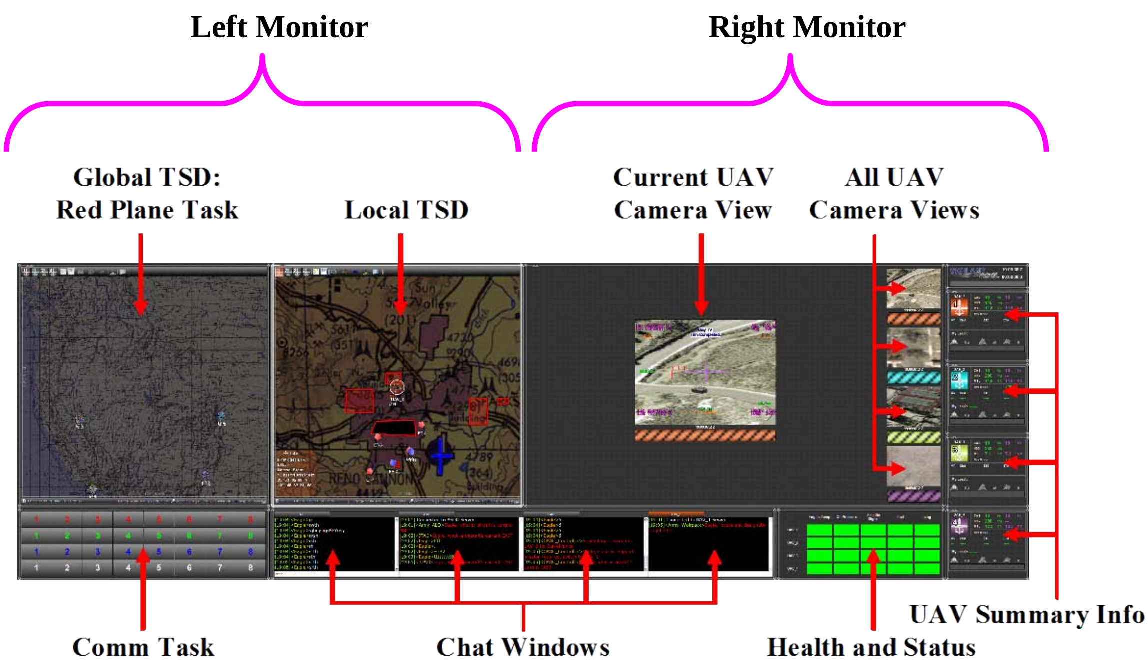


Figure 29. Illustration of each Multi-UAV Testbed Window Used for Experimental Tasks

selected (12.0 x 10.6 NM). Figure 30 shows a sample view of the local TSD with computer-generated symbology depicting the currently selected UAV, mission forces information, sensor footprint (blue), and no-fly zones (red).

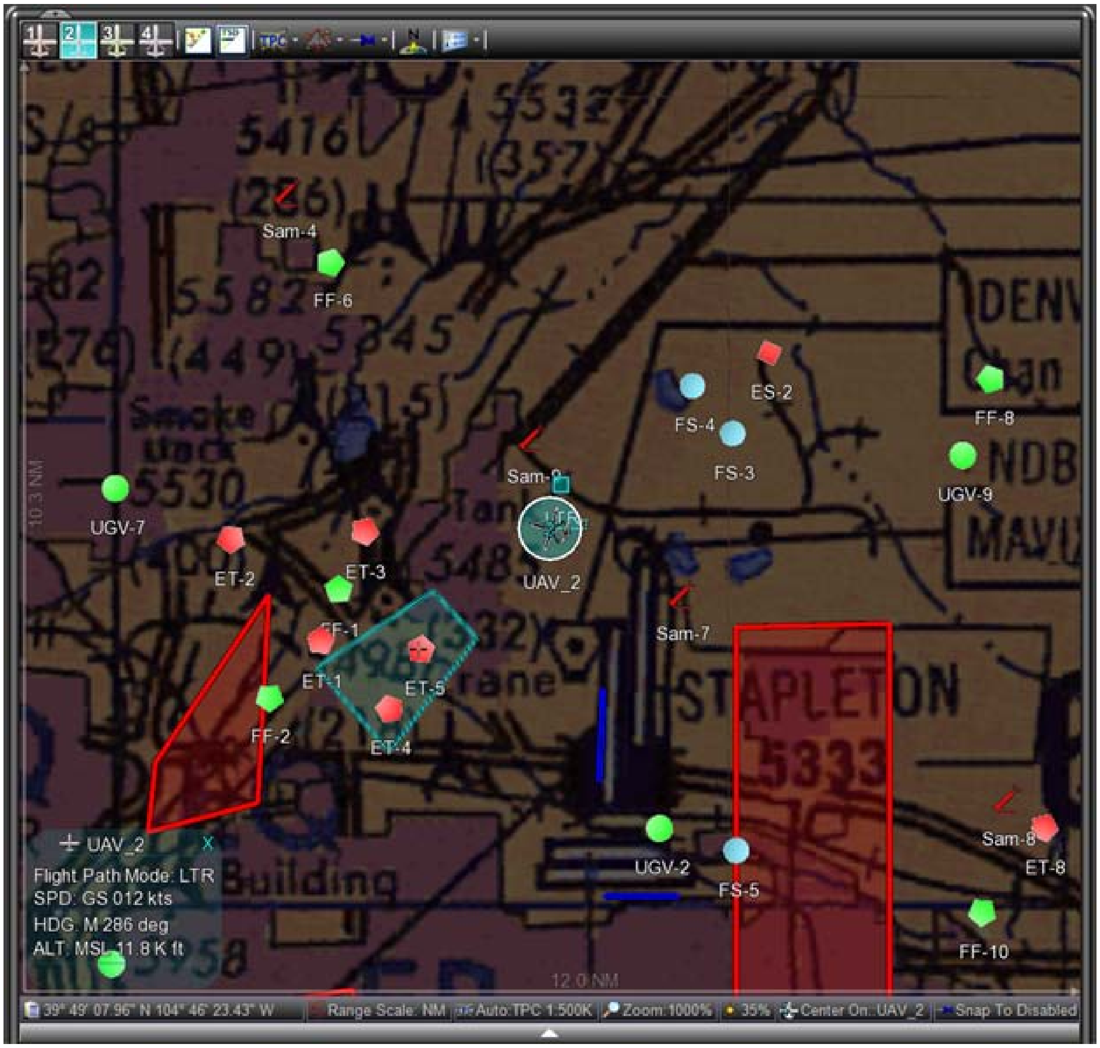


Figure 30. Sample View of Local (Selected UAV) Tactical Situation Display

The right monitor presented the view from the gimbaled camera of the specific UAV selected with an overlay of Head-Up-Display (HUD) symbology and overlaid synthetic symbology, showing enemy (red) and friendly (blue) forces and the Forward Air Control (FAC) center. Figure 31 shows a sample (simulated) camera view with overlaid symbology depicting red and blue mission forces information and the FAC (pink cone). During each GITZ transition (between Points 1 and 5, Figure 27), the video turned monochrome, the crosshairs became white, and the HUD symbology overlay was blanked. This was done because previous research [18] showed the importance of clearly distinguishing between the synthetic and real world view. The video imagery was depicted with the MetaVR sensor visualization software package (VRSG™) Version 5.3. The video and symbology overlay were updated at 10 Hz.

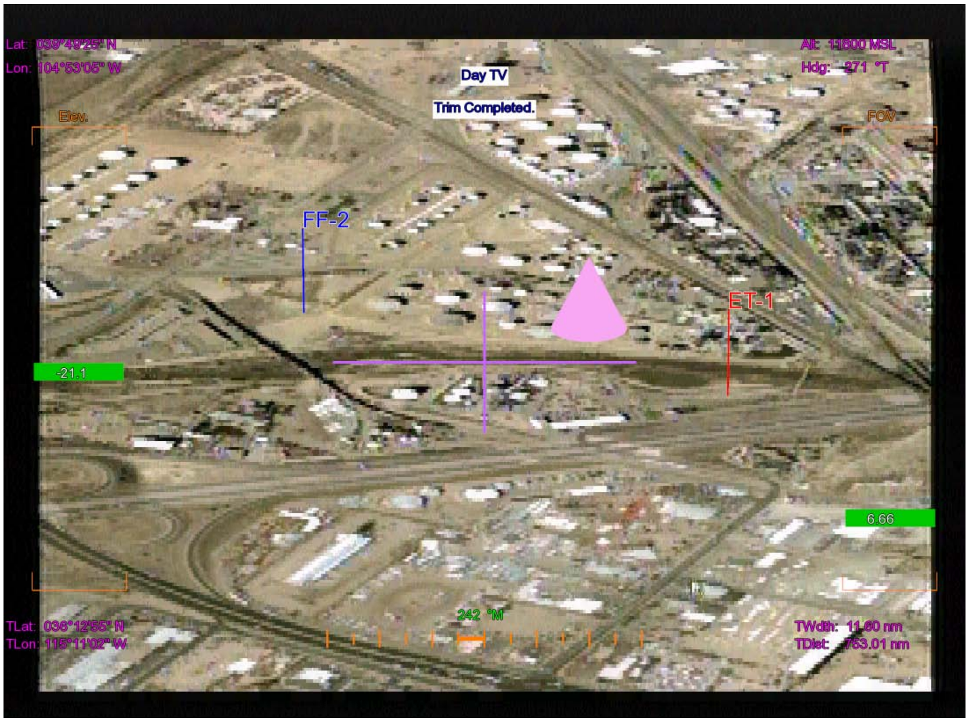


Figure 31. Sample of (Simulated) Camera View

To the right of the camera window were four UAV thumbnails, the selection of which changed other windows (local TSD, camera view, and local UAV chat window) to formats specific to that UAV. The other windows on the two monitors (summary panels for each UAV, communications task matrix, health/status matrix, and other chat windows) were used for secondary mission-related tasks. Verbal prompts for several task types were issued over the computer's speaker system and participants heard an audio alert whenever the designation button on the joystick was pressed over the correct selection area defined for a target. Besides the keyboard, there was a right handed mouse and joystick. The mouse was used during static missions for cursor control to select windows and complete secondary-tasks. The joystick was used in dynamic missions, and allowed manipulation in two degrees-of-freedom for control of camera orientation in azimuth and elevation. The larger center "hat switch" controlled camera zoom and the center upper button was used to designate locations indicated by the crosshairs.

Primary Experimental Tasks

Each trial/scenario consisted of multiple dynamic (close air support) and static (surveillance) missions (Table 1). Participants received multi-modal commands (verbal prompt and chat message) when mission transitions should occur; this information identified the next UAV and mission type.

- Dynamic Missions: participants were tasked with locating and designating two enemy tanks, according to prompts received verbally and in a chat window. Participants were also tasked with remembering the tank types (no barrel/short barrel/long barrel, the tank shape (dome/box/cone), and color (green/magenta/yellow) of the symbol denoting the FAC. At the end of each dynamic mission, a situation awareness probe regarding the tank types or FAC symbol appeared in the local UAV chat window, and participants entered their response in the same window via the keyboard. Two examples include: "What was the color and shape of the FAC?" and "What type of tank did you designate first in this mission?" The intent of the probe was to detect negative transfer of context, as accuracy would depend on knowledge of the current camera view, as opposed to the previous camera view. Participants had two minutes to complete each dynamic mission. Response time and accuracy for the tank designation and probe tasks were recorded, as well as the efficiency with which the camera was moved.

- Static Missions: participants were tasked with monitoring the video feed for the selected UAV and typing "truck" in the UAV chat window when a truck appeared in the video. Each time a truck was displayed, it remained in the camera view for only 10-15 seconds. The percent of trucks detected was recorded, as well as response time. Static missions lasted between 2-5 minutes. During static missions, participants monitored the camera view from one UAV at a time, although in some missions, there was a command to switch to a different UAV and monitor its camera view for the appearance of a truck. During static missions, the camera view was automatically zoomed in all the way and the joystick was inactive to prevent participants from gaining awareness of the surrounding area that might influence performance on subsequent missions. When the camera controls were inactive, the crosshairs changed from magenta to green, as an additional cue of camera state.

Secondary Experimental Tasks

During the static missions of each scenario, participants were required to complete several types of secondary tasks (see below). During the dynamic missions, the prompts for the secondary tasks were still presented. However, participants were trained to not complete the secondary tasks during these short dynamic missions and instead focus their attention on the critical tasks involving the tanks and FAC. This procedure was used as it is anticipated that in operational multi-UAV dynamic missions, such housekeeping tasks would be tabled until after the critical tasks are completed.

There were five types of secondary tasks. These tasks are described below and the corresponding interfaces are illustrated in Figure 29. These tasks were designed to represent the type and range of activities anticipated for multi-UAV supervisory control. Each of these secondary tasks occurred frequently during the scenarios such that the participants received a tasking approximately seven times each minute.

- Switch UAV/Camera Feed: Participants received prompts (verbal and chat window) indicating which UAV to employ for the next mission. In response, participants positioned the cursor on the corresponding UAV thumbnail and selected it with the mouse. Selection of the thumbnail changed the Local TSD, camera view, and chat window under the camera view to formats/views appropriate to that UAV. During static missions, this task was used repeatedly so that the participants sequentially monitored the camera views for 2-4 UAVs. During dynamic missions, participants were only requested to switch to a different UAV at the completion of the mission. The time from the prompt until correct thumbnail selection was recorded.

- Provide Requested Information: Participants responded to requests for information (prompted via one of the chat windows) by typing information (UAV altitude, airspeed or heading) into the appropriate chat window. Data from this task were not analyzed.
- Monitor for Unexpected Airplane Symbol: Occasionally, a red plane symbol (representing an unexpected new hostile threat) appeared on the Global TSD and remained for up to 10 seconds. To respond, participants centered the cursor on the aircraft and selected it with the mouse. The symbol disappeared once it had been designated or when the time period expired. Measures included number of symbols detected and time from the symbol appearance until its designation.
- Monitor Health and Status of Vehicles: A matrix at the bottom of the right monitor showed the health/status of five subsystems (columns) for each of the four UAVs (rows). The cells were green when the health/status was nominal. When a subsystem exceeded a pre-established threshold (script driven), the corresponding cell turned yellow on the matrix. The participants' task was to select and designate the yellow cell with the mouse. If the participant failed to select the yellow cell, it turned red after 10 seconds. If still not selected by the participant, the cell returned to green after 5 seconds and a time-out was recorded. Performance measures included completion time (time from color change until cell was selected) and percent detected.
- Monitor and Respond to Audio Communications: A version of the Coordinate Response Measure (CRM), a communication performance task was employed [19]. Participants continually heard a string of call signs and color-number combinations, all embedded within a carrier phrase. For example, in "ready Eagle, go to blue five now," "Eagle" is the call sign, and "blue five" is the color-number combination, meaning the button labeled with a "blue 5" should be selected from the communications matrix window at the bottom of the left monitor. The participant was assigned a call sign and instructed to make the appropriate button choice with the mouse every time that call sign was issued. Audio commands were issued for 4 call signs, one approximately every 15 seconds. The participants' call sign was issued approximately once every 2 minutes. Performance measures included completion time (the time from when the call sign was issued until the coordinate button was selected) and percent detected.

Procedures

Participants first received a general overview of the experiment (Appendix E). This was followed by detailed training and practice trials were completed until performance stabilized. Next, experimental trials were completed. Note that there was no flight control task in these trials; each UAV automatically loitered in a circular pattern. The participants' control inputs involved moving the cursor and making inputs via the keyboard for the static missions and the various secondary tasks. They also manually controlled the camera viewpoint in the dynamic missions, via the joystick, to locate, zoom in on, and designate specific targets.

After each experimental trial, rating scales were administered to obtain the participants' impression of that particular trial in terms of situation awareness, task difficulty, and workload. Participants also completed a final questionnaire after the study asking them to compare the GITZ and no-GITZ conditions and provide comments on the strategy they used for task completion. (See Appendix F for all questionnaires used in this evaluation.)

Results

Results are presented for each experimental objective raised earlier: in a multi-UAV control environment, does the GITZ transition improve participants' overall situation awareness and performance on target designation tasks, without hurting performance on other secondary mission-related tasks?

GITZ Transition Impact on Overall Situation Awareness

Participants' ratings on the Post-Trial Questionnaire indicated they had more situation awareness in trials with the GITZ transition, compared to trials without the GITZ transition ($F(1,12) = 5.493$, $p = 0.037$). (Ratings did not significantly differ (all $p > 0.2$) for the other rating scales pertaining to task difficult, and workload.) On the post-experiment questionnaire Final Questionnaire, nine of the thirteen participants indicated that they had more situation awareness with the GITZ transition. The other four participants rated their situation awareness as equal with and without the GITZ transition.

Another measure of situation awareness was the participants' performance on the situation awareness probe administered in the dynamic mission. Response time to the probe did not differ significantly as a function of whether the GITZ transition was present or not ($F(1,12) = 1.522$, $p = 0.241$). Accuracy was also similar across the conditions; five and four errors were made with and without the transition, respectively. However, collapsing across transition condition, response time to the probe was faster for the dynamic-to-dynamic scenarios compared with static-to-dynamic scenarios ($F(1,12) = 8.798$, $p = 0.012$).

GITZ Transition Impact on Target Locate/Designate Task

To address this objective, the metric used was the participants' performance in locating and designating the first tank after transitioning to the new UAV/camera view (in the second dynamic mission of each scenario). First, the time it took to designate the tank was analyzed.

For these data, the results showed a significant difference. Participants took about six seconds longer to locate/designate the tank target when the GITZ transition was present compared to when it was absent (means=28.7 and 22.6 seconds, respectively; $F(1,12) = 6.709$, $p = 0.024$). Since the response time period analyzed was from the issue of the prompt identifying the target until the target was designated, the time spent presenting the transition format was not a factor in this result.

Further examination of the raw data indicated that this time difference between transition conditions can be attributed to the variability in initial camera zoom state. In trials without the GITZ transition, participants used the 6.5 seconds after the 'switch mission' prompts to zoom the camera out. With the camera zoomed out, more of the synthetic symbology denoting tanks, FAC, etc. was visible. There was a similar response in the trials with the GITZ transition. As soon as participants regained control of the joystick after the 6.5 second transition, they zoomed the camera out in order to quickly move the camera's viewpoint to the tank's location (this strategy was learned from reviewing post-experiment comments). Thus, a completely zoomed out camera state, a prerequisite for rapid camera viewpoint translation, was achieved in the trials without the GITZ transition prior to the official task start time. This was not the case for the trials with the GITZ transition. During these trials, part of the recorded task completion time (over 5 seconds) was spent zooming out the camera.

To account for the effect of the asymmetric camera state on task completion time, the data were reanalyzed using a modified definition of task time. Task time was measured from when maximum camera zoom was achieved, in both conditions, to the time the designation button was pressed. This time period more accurately reflects the time each participant spent moving the camera to the tank, zooming in on it, and designating it. Analyses of these data indicated that the average time to locate/designate the tank target was slightly faster (2.3 seconds) with the GITZ transition compared to when the transition was not presented. However, this difference was not significant ($F(1,12) = 2.054$, $p = 0.177$).

The above analyses are for the first tank designation task in the dynamic missions, as it was hypothesized that any beneficial effect of the GITZ transition would be transitory in nature, diminishing as the operator's interactions with the new environment accumulated. As expected, data analyses for the task to locate and designate the second tank revealed no significant effects as a function of transition condition.

Next, the efficiency of the participants' movement of the camera toward the tank target was examined. One measure was based on the participants' initial movement of the camera. The angle formed between the vector describing the camera's instantaneous movement direction after the command prompt and the vector defined by the direction of the target from the initial camera position was computed (after filtering for random movements associated with grasping the joystick). Results showed that participants' initial camera movement was more accurate (by approximately 12 degrees) when the GITZ transition was present ($F(1,12) = 5.969$, $p = 0.031$) compared to when it was not presented.

Another camera efficiency measure was camera path length (length of optimal path between camera initial position and target location divided by length of the camera's actual path). The results showed a significant interaction of GITZ transition and the type of scenario ($F(1,12) = 5.024$, $p = 0.045$; see Figure 32). Bonferroni pair-wise comparisons of the data showed that with the GITZ transition, the camera was moved more efficiently during static-to-dynamic scenarios, compared to dynamic-to-dynamic scenarios ($t(12) = 3.424$, $p = 0.030$). Without the GITZ transition, there was little difference in average path length ($t(12) = 1.018$, $p = 1.00$).

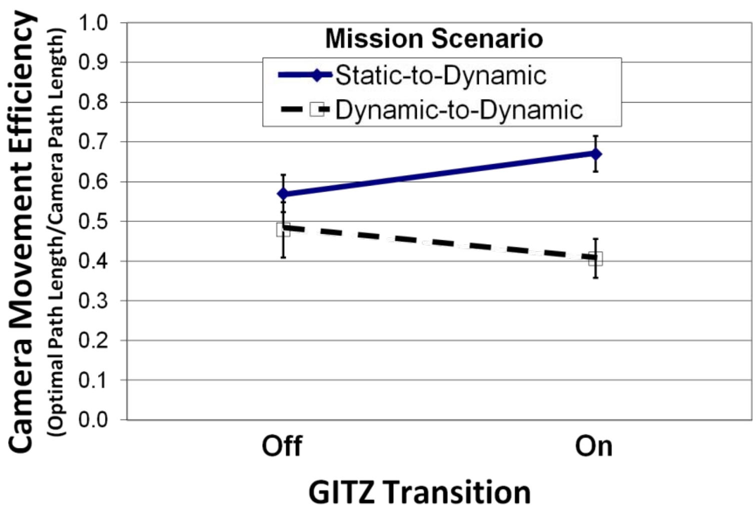


Figure 32. Average Path Length Traversed by the Camera as a function of GITZ Transition

Participants were asked in the Final Questionnaire to rate the extent to which the GITZ transition impacted performance on the target locate/designation task. Eleven of 13 participants responded that GITZ aided performance (the other 2 participants said it had no impact).

GITZ Impact on Secondary Tasks

None of the performance measures related to the various mission-related secondary tasks showed significant differences as a function of transition condition. For all task measures (response time to switch UAV and both response time and percent detected for tasks to monitor and respond to unexpected aircraft, health/status alerts, and audio communications), p was > 0.1.

The subjective data supported the performance data. Ten of the 13 participants responded on the Final Questionnaire that the GITZ transition had no impact on other tasks. (The other three thought the GITZ transition actually aided these tasks.)

Discussion

The rationale for this research was that tailoring a transition feature (similar to what can be downloaded from web-based mapping tools) to a multi-UAV control application may help operators more rapidly dissociate themselves from the mission environment of one UAV and quickly acquire a mental map of the new mission area. Additionally, having an expanded view of the new area before acquiring the new camera's viewpoint may provide the operator with an awareness of threats and terrain features outside of the camera's current FOV. In sum, it was thought that the GITZ transition would reduce negative transfer effects and enhance situation awareness, resulting in improved performance on the tasks required in the new mission (without hindering performance on other mission-related tasks).

In the present experiment, the subjective data indicated increased situation awareness when the GITZ transition was presented. However, the objective situation awareness probe performance data did not show a benefit for the GITZ transition. Moreover, a significant reduction in time to locate and designate the target after switching missions was not realized with the transition. The GITZ transition did slightly aid the tank target designation task in terms of the efficiency of camera movement (for static-to-dynamic scenarios only) and the accuracy of the initial camera movement. Additionally, the GITZ transition did not hinder secondary task performance.

This was the first evaluation of a transition aid for multi-UAV control applications. Based on the fact that participants rated the transition format favorably in the questionnaires and some performance measures showed a benefit, further evaluation of this transition aid for multi-UAV control is recommended. However, the results of the present study, combined with comments provided by participants, indicate that several issues should first be considered in the design of a refined transition aid. We discuss these below.

Transition Design Changes

Participants commented that the transition format should be modified in three aspects. First, many suggested that the fly-out portion take less time as there was no requirement to glean information about the old environment when switching to an entirely new UAV/mission. With this change, the goal of the shortened fly-out would simply be to cue that there will be a new view and that it is time to dissociate attention from the current UAV. A second recommendation was to lengthen the time spent in a global view over the new UAV location. This change would provide more time to retrieve key spatial information before video movement begins. Third, comments suggested that the speed at the start and end of the fly-in was too fast for effective information retrieval.

Information Retrieval/Control Across Displays

In this experiment, both the TSD and the camera view included overlay symbology indicating the location of tanks, etc. However, the symbol indicating FAC location was intentionally only included in the synthetic symbology on the camera view. During dynamic missions, the participants were tasked with remembering tank and FAC description information in order to answer the situation awareness probe. During trials without the GITZ transition, participants focused their attention on the camera view, looking for the FAC symbol in addition to the tank they were to designate. In contrast, many participants in the trials with the GITZ transition focused their attention on the TSD to locate the commanded tank. This approach was likely used because participants were able to learn about the FAC and general spatial relationships from the synthetic symbology presented on the camera view during the transition. Once the tank target was in the sensor footprint on the TSD, they switched attention to the camera view for the final designation steps. However, precise control of the camera, using the TSD, was difficult as the sensor footprint's movements were dependent on its orientation relative to the circular orbiting UAV. Thus, the TSD-centric technique employed in trials with the GITZ transition may have lengthened response times for tank designations. This change in information retrieval/control strategy between the trials with and without the transition was unexpected and follow-on research is needed to determine what specific factors play a role. One possibility is that participants had insufficient training with the transition format. Focused demonstrations may have been needed on the ease of camera control using the camera display in comparison to the TSD. Experimental manipulation of where task-related information is displayed (camera view versus the TSD) would also be informative. Indeed, there are numerous cognitive factors that influence information retrieval, task switching strategy, and performance, such as sensory modalities, response modalities, and stimulus-response mappings [20].

Mission Before and After Transition

Follow-on research should further examine the type of mission scenarios involved in the transition. It has been shown that task switching time is influenced by the stimulus-response mapping characteristics of the two tasks [19]. This finding, together with the results from the present study showing performance differences as a function of mission scenario type, suggest that the design of any transition aid should also consider the specific cognitive processes involved.

Operator Control of Transition

Given that many factors may influence the method of task switching desired for a particular situation (e.g., mission type, relative knowledge of the area, information needs, time available, etc.), there may not be a 'one size fits all' method of implementing a transition for multi-UAV applications. It may be preferable for the operator to have flexible control over the transition method employed. However, the advantages of this flexibility need to be weighed against any concomitant task loading.

Influence of Video Imagery Generator Fidelity

The scene generator employed for this study did not have the resolution required to permit the use of easily recognizable landmarks in the imagery without also labeling these locations on the TSD (and/or via overlaid symbology on the camera image). Having a system that enables display of high-resolution ground environments, depicting detailed features, would be more representative of what the operator views in operational scenarios (i.e., not everything that's important has a label) and may enhance the utility of a transition format.

SUMMARY

This first instantiation and evaluation of a transition aid for multi-UAV supervisory control was very informative and the concept shows promise for benefiting UAV operator performance [21]. With the transition format, participants rated their situation awareness as higher and there were improvements in camera movement efficiency measures. However, this transition did not preclude participants from needing to zoom out the camera view after switching, and for several dynamic mission performance metrics, it failed to provide a significant benefit.

The results from this full mission simulation evaluation indicated several potential enhancements which may increase the utility of the GITZ transition for switching between UAV camera views. First, the transition format needs refinement, ranging from the speed of various transition segments to whether or not the operator has direct control over transition parameters. The findings also indicate that research is needed to determine which station display(s) should present each information element for a multi-UAV control application. Additionally, this experiment showed that there are numerous factors that may influence the utility of a transition aid, including the nature of the missions involved and the users' strategy. Finally, this experiment illustrated the limitations of the scene generator employed.

Follow-on research is underway to address potential enhancements and other issues identified as a result of this evaluation. It is also planned to examine how best to implement a transition for scenarios that involve more than one UAV viewing the *same* object/scene for collaborative operations. The use of transitions for improving multi-UAV operator situation awareness when switching to a different UAV and its associated camera view is just one of many potential benefits of applying augmented reality technology to UAV operations.

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APPENDIX A

BACKGROUND QUESTIONNAIRE

Please PRINT:

Name: ______________________________

Organization (school or employment): ______________________________

Address: ______________________________

Phone: ______________________________

Email: ______________________________

Age (yrs): ______________ **Gender: Male** ☐ **Female** ☐

Vision/Hearing **Normal** ☐ **Corrected to Normal** ☐ **Deficient** ☐

If deficient, please describe: ______________________________

Do you consider yourself especially sensitive to motion sickness or simulator sickness?
No ☐ **Yes** ☐

Experienced with 3D video games (games with a "moving" background)?

No ☐ **Yes** ☐

If yes, estimate how much: **Seldom** ☐ **Occasional** ☐ **Frequent** ☐

Please list a few of your favorite games, or games you have the most experience with:

1. ______________________________
2. ______________________________
3. ______________________________

Have you had any experience with sensor imagery? **No** ☐ **Yes** ☐
If yes, please briefly explain the extent of your sensor imagery experience:

Experienced with piloting an aircraft? **No** ☐ **Yes** ☐ **If yes:**

	Yes	No	Status?	Active Duty	Guard	Reserve	Retired	Civilian
IFR Rated?	☐	☐		☐	☐	☐	☐	☐

Total Flying Time: __________ **Total Jet Time:** __________

Current Aircraft and Hours:	Other Aircraft and Hours:

APPENDIX B

SIMULATOR SICKNESS QUESTIONNAIRE

(at start and end of each experimental section & if symptoms present)

Please circle one severity rating for each of the 16 symptoms listed below. Circle the word that best matches your current feeling "right now."

		(0)	(1)	(2)	(3)
1.	**General Discomfort**	None	Slight	Moderate	Severe
2.	**Fatigue**	None	Slight	Moderate	Severe
3.	**Headache**	None	Slight	Moderate	Severe
4.	**Eye Strain**	None	Slight	Moderate	Severe
5.	**Difficulty Focusing**	None	Slight	Moderate	Severe
6.	**Increased Salivation**	None	Slight	Moderate	Severe
7.	**Sweating**	None	Slight	Moderate	Severe
8.	**Nausea**	None	Slight	Moderate	Severe
9.	**Difficulty Concentrating**	None	Slight	Moderate	Severe
10.	**Fullness of Head**	None	Slight	Moderate	Severe
11.	**Blurred Vision**	None	Slight	Moderate	Severe
12.	**Dizzy (Eyes Open)**	None	Slight	Moderate	Severe
13.	**Dizzy (Eyes Closed)**	None	Slight	Moderate	Severe
14.	**Vertigo** (loss of orientation with respect to upright (i.e., confusion "which way is up"))	None	Slight	Moderate	Severe
15.	**Stomach Awareness** (discomfort just short of nausea)	None	Slight	Moderate	Severe
16.	**Burping**	None	Slight	Moderate	Severe

If you have additional comments on the above symptoms, please include them below.

Are there any <u>other symptoms</u> that you are experiencing <u>right now</u>? If so, please describe the symptom(s) and rate their severity.

Time________ ☐ Pre-Session ☐ Post-Session ☐ Other:

APPENDIX C

PILOT STUDY 1 QUESTIONNAIRES

POST-TRIAL QUESTIONNAIRE

1. In terms of your *ability to gain situation awareness (SA)* of the entire area, compare the first and second transitions observed. SA = the degree to which you: were aware of important elements in your environment (i.e., landmarks, targets, major features), comprehended your current location, and were able to project future status.

Mark 1 of the 3 boxes below:

SA *equal* with Transition 1 and 2	☐
More SA with Transition 1	☐
More SA with Transition 2	☐

If you had more SA with one of the transitions, how much more?

then:

Mark 1 of the 3 columns below.		
Slightly more > ☐	>> ☐	**Substantially more** >>> ☐

Comments:

2. In terms of being *visually appealing*, compare the first and second transitions observed.

Mark 1 of the 3 boxes below:

Transition 1 and 2 were *equally* visually appealing	☐
Transition 1 more visually appealing	☐
Transition 2 more visually appealing	☐
	☐

If you found one transition more visually appealing, how much more appealing was it compared to the other transition?

then:

Mark 1 of the 3 columns below.		
Slightly more > ☐	>> ☐	**Substantially more** >>> ☐

Comments:

3. In terms of *preference*, compare the two transitions.

Mark 1 of the 3 boxes below:

***Equal* preference for Transition 1 and Transition 2**	☐
Prefer Transition 1	☐
Prefer Transition 2	☐

If you preferred one transition more than the other, how much more did you prefer it?

then:

Mark 1 of the 3 columns below.		
Slightly more > ☐	>> ☐	**Substantially more** >>> ☐

Comments (If you preferred one transition over the other, please discuss why):

POST-BLOCK QUESTIONNAIRE

RELATIVE JUDGMENTS INSTRUCTIONS

We would like you to compare the different concepts in terms of ***personal preference***. The form for doing this is on the next page and here are the instructions for filling out the form:

- This survey consists of a series of relative judgments comparing two concepts. For example, Concept A might be compared to Concept B in terms of how much you preferred one to the other. A nine-point scale will be used for comparing the preference of each of the transition types or transition times. Examples on how to use the scale are given next:

If you prefer neither concept "A" nor concept "B", then you mark the form in the center:

	>>>>	>>>	>>	>	Equal	<	<<	<<<	<<<<	
"A"	____	____	____	____	X .	____	____	____	____	"B"

<u>If you prefer "A" a little more than "B"</u>, then you would move your mark a little closer to "A":

	>>>>	>>>	>>	>	Equal	<	<<	<<<	<<<<	
"A"	____	____	____	X .	____	____	____	____	____	"B"

<u>If you prefer" A" a lot more than "B"</u>, you would move your mark very close to "A":

	>>>>	>>>	>>	>	Equal	<	<<	<<<	<<<<	
"A"	X .	____	____	____	____	____	____	____	____	"B"

On the other hand, <u>if you prefer "B" moderately more than "A"</u>, then you would move your mark in that direction:

	>>>>	>>>	>>	>	Equal	<	<<	<<<	<<<<	
"A"	____	____	____	____	____	____	X .	____	____	"B"

Questions?

1. Preference: Please compare each style of Fly-in Concept in terms of which you prefer.

Fly-in Concept	>>>	>>>	>>	>	*Equal*	<	<<	<<<	<<<	**Fly-in Concept**
Long Vertical Drop	___	___	___	___	___	___	___	___	___	***Short Vertical Drop***
Short Vertical Drop	___	___	___	___	___	___	___	___	___	***Exponential Sweep***
Exponential Sweep	___	___	___	___	___	___	___	___	___	***Long Vertical Drop***
Linear Sweep	___	___	___	___	___	___	___	___	___	***Exponential Sweep***
Linear Sweep	___	___	___	___	___	___	___	___	___	***Long Vertical Drop***
Short Vertical Drop	___	___	___	___	___	___	___	___	___	***Linear Sweep***

Please try to explain your above ratings:

What one fly-in concept do you prefer the most and why?

2. Transition time: For **<u>this block of trials</u>**, rate ***<u>how you felt</u>*** about the duration of time during the transition.

Transition "Speed" Rating						
Too Slow			**Good**			**Too Fast**
1 ☐	**2** ☐	**3** ☐	**4** ☐	**5** ☐	**6** ☐	**7** ☐

POST-SESSION QUESTIONNAIRE

1. **During the course of the study the time duration of the different fly-in transitions you viewed was varied. Please compare your preference for the fly-in duration times (2 seconds, 4 seconds, or 6 seconds).**

Preference: Please compare each "Fly-in" time in terms of which you prefer.

Fly-in Time	>>>	>>>	>>	>	*Equal*	<	<<	<<<	<<<	Fly-in Time
6 seconds	___	___	___	___	___	___	___	___	___	*2 seconds*
2 seconds	___	___	___	___	___	___	___	___	___	*4 seconds*
4 seconds	___	___	___	___	___	___	___	___	___	*6 seconds*

Please try to explain your above ratings:

What one fly-in time do you prefer the most (2 seconds, 4 seconds, or 6 seconds) and why?

2. Preference: Please compare each style of Fly-in Concept in terms of which you prefer.

Fly-in Concept	>>>	>>>	>>	>	*Equal*	<	<<	<<<	<<<	Fly-in Concept
Long Vertical Drop	___	___	___	___	___	___	___	___	___	*Short Vertical Drop*
Short Vertical Drop	___	___	___	___	___	___	___	___	___	*Exponential Sweep*
Exponential Sweep	___	___	___	___	___	___	___	___	___	*Long Vertical Drop*
Linear Sweep	___	___	___	___	___	___	___	___	___	*Exponential Sweep*
Linear Sweep	___	___	___	___	___	___	___	___	___	*Long Vertical Drop*
Short Vertical Drop	___	___	___	___	___	___	___	___	___	*Linear Sweep*

Please try to explain your above ratings:

What one fly-in concept do you prefer the most and why?

3. Was there a strategy you employed to judge if one transition was better than another?

4. **Beyond the transition concepts you saw today (transitioning from one camera viewpoint to another camera viewpoint), do you have any transition ideas that you feel may afford more awareness of an environment?**

5. **Do you have any comments you would like to make concerning this experiment (e.g., briefing, training, tasks, etc.)?**

Thanks for your participation.

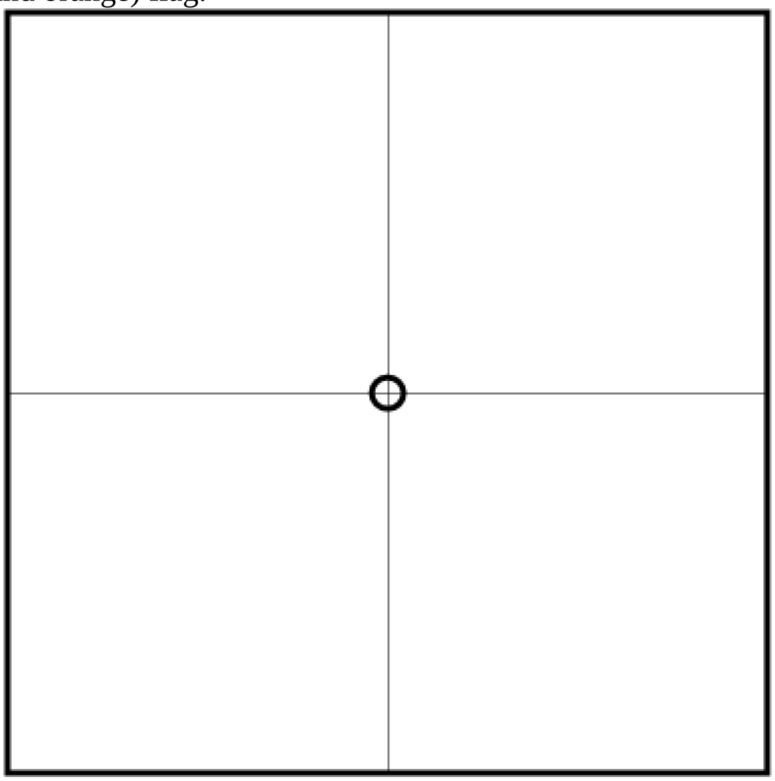
~The SIRUS Team.

APPENDIX D

PILOT STUDY 2 QUESTIONNAIRES

POST-TRIAL QUESTIONNAIRE – PART 1

1) For **<u>this trial</u>**, draw a line from the center flag to the direction of the (light green, light blue, magenta, yellow, and orange) flag:



Mark the box (☐) which best reflects your ratings for each of the following:

2) <u>Situation Awareness</u>: For **<u>this trial</u>**, rate your **<u>overall situation awareness</u>** -- the degree to which you: were aware of important elements in your environment (i.e., landmarks, targets, major features), comprehended your current location, and were able to project future status.

Low			***Situation Awareness Rating***			**High**
Never Aware						**Always Aware**
1 ☐	**2** ☐	**3** ☐	**4** ☐	**5** ☐	**6** ☐	**7** ☐

3) <u>Visually Appealing</u>: For **<u>this trial</u>**, rate ***<u>how visually appealing</u>*** the fly-in was.

Visually Appealing Rating						
Lowest Appeal						**Highest Appeal**
1 ☐	**2** ☐	**3** ☐	**4** ☐	**5** ☐	**6** ☐	**7** ☐

POST-PART 1 QUESTIONNAIRE

For Question 1 below, we would like you to compare the different fly-in concepts in terms of ***personal preference***. First, here are the instructions for filling out the question:

This survey consists of a series of relative judgments comparing two concepts. For example, Concept A might be compared to Concept B in terms of how much you preferred one to the other. A nine-point scale will be used for comparing the preference of each of the fly-in concepts. Examples on how to use the scale are given next:

If you prefer neither concept "A" nor concept "B", then you mark the form in the center:

	>>>>	>>>	>>	>	Equal	<	<<	<<<	<<<<	
"A"	____	____	____	____	_X_.	____	____	____	____	"B"

<u>If you prefer "A" a little more than "B"</u>, then you would move your mark a little closer to "A":

	>>>>	>>>	>>	>	Equal	<	<<	<<<	<<<<	
"A"	____	____	____	_X_.	____	____	____	____	____	"B"

<u>If you prefer "A" a lot more than "B"</u>, you would move your mark very close to "A":

	>>>>	>>>	>>	>	Equal	<	<<	<<<	<<<<	
"A"	_X_.	____	____	____	____	____	____	____	____	"B"

On the other hand, <u>if you prefer "B" moderately more than "A"</u>, then move your mark in that direction:

	>>>>	>>>	>>	>	Equal	<	<<	<<<	<<<<	
"A"	____	____	____	____	____	____	_X_.	____	____	"B"

1. Preference: Please compare each Fly-in Concept in terms of which you prefer.

Fly-in Concept	>>>	>>>	>>	>	***Equal***	<	<<	<<<	<<<	**Fly-in Concept**
Linear	___	___	___	___	___	___	___	___	___	***Shallow Curve***
Shallow Curve	___	___	___	___	___	___	___	___	___	***Deep Curve***
Deep Curve	___	___	___	___	___	___	___	___	___	***Linear***

Please try to explain your above ratings. Also identify what one fly-in concept you prefer the most and explain why. (If you need more room, use the back of this sheet.)

POST-TRIAL QUESTIONNAIRE – PART 2

1. In terms of your *ability to gain situation awareness (SA)* of the entire area, compare the first and second fly-in observed.

SA = the degree to which you: were aware of important elements in your environment (i.e., landmarks, targets, major features), comprehended your current location, and were able to project future status.

Mark 1 of the 3 boxes below:

SA *equal* with Fly-in 1 and 2	☐
More SA with Fly-in 1	☐
More SA with Fly-in 2	☐

then:

If you had more SA with one fly-in compared to the other, how much more?

Mark 1 of the 3 columns below.

Slightly more >	>>	Substantially more >>>
☐	☐	☐

Comments:

2. In terms of being *visually appealing*, compare the first and second fly-in observed.

Mark 1 of the 3 boxes below:

Fly-in 1 and 2 were *equally* visually appealing	☐
Fly-in 1 more visually appealing	☐
Fly-in 2 more visually appealing	☐

then:

If you found one fly-in more visually appealing, how much more appealing was it compared to the other fly-in?

Mark 1 of the 3 columns below.

Slightly more >	>>	Substantially more >>>
☐	☐	☐

Comments:

POST-PART 2 QUESTIONNAIRE

For Question 1 below, we would like you to compare the different fly-in concepts in terms of ***personal preference***. First, here are the instructions for filling out the question:

This survey consists of a series of relative judgments comparing two concepts. For example, Concept A might be compared to Concept B in terms of how much you preferred one to the other. A nine-point scale will be used for comparing the preference of each of the fly-in concepts. Examples on how to use the scale are given next:

If you prefer neither concept "A" nor concept "B", then you mark the form in the center:

	>>>>	>>>	>>	>	Equal	<	<<	<<<	<<<<	
"A"	____	____	____	____	_X_.	____	____	____	____	"B"

<u>If you prefer "A" a little more than "B"</u>, then you would move your mark a little closer to "A":

	>>>>	>>>	>>	>	Equal	<	<<	<<<	<<<<	
"A"	____	____	____	_X_.	____	____	____	____	____	"B"

<u>If you prefer "A" a lot more than "B"</u>, you would move your mark very close to "A":

	>>>>	>>>	>>	>	Equal	<	<<	<<<	<<<<	
"A"	_X_.	____	____	____	____	____	____	____	____	"B"

On the other hand, <u>if you prefer "B" moderately more than "A"</u>, then move your mark in that direction:

	>>>>	>>>	>>	>	Equal	<	<<	<<<	<<<<	
"A"	____	____	____	____	____	____	_X_.	____	____	"B"

1. Preference: Please compare each Fly-in Concept in terms of which you prefer.

Fly-in Concept	>>>	>>>	>>	>	***Equal***	<	<<	<<<	<<<	**Fly-in Concept**
Linear	___	___	___	___	___	___	___	___	___	***Shallow Curve***
Shallow Curve	___	___	___	___	___	___	___	___	___	***Deep Curve***
Deep Curve	___	___	___	___	___	___	___	___	___	***Linear***

Please try to explain your above ratings. Also identify what one fly-in concept you prefer the most and explain why. (If you need more room, use the back of this sheet.)

FINAL QUESTIONNAIRE

For Question 1 below, we would like you to compare the different fly-in concepts in terms of ***personal preference***. First, here again are the instructions for filling out the question:

This survey consists of a series of relative judgments comparing two concepts. For example, Concept A might be compared to Concept B in terms of how much you preferred one to the other. A nine-point scale will be used for comparing the preference of each of the fly-in concepts. Examples on how to use the scale are given next:

If you prefer neither concept "A" nor concept "B", then you mark the form in the center:

	>>>>	>>>	>>	>	Equal	<	<<	<<<	<<<<	
"A"	____	____	____	____	_X_.	____	____	____	____	"B"

<u>If you prefer "A" a little more than "B"</u>, then you would move your mark a little closer to "A":

	>>>>	>>>	>>	>	Equal	<	<<	<<<	<<<<	
"A"	____	____	____	_X_.	____	____	____	____	____	"B"

<u>If you prefer "A" a lot more than "B"</u>, you would move your mark very close to "A":

	>>>>	>>>	>>	>	Equal	<	<<	<<<	<<<<	
"A"	_X_.	____	____	____	____	____	____	____	____	"B"

On the other hand, <u>if you prefer "B" moderately more than "A"</u>, then move your mark in that direction:

	>>>>	>>>	>>	>	Equal	<	<<	<<<	<<<<	
"A"	____	____	____	____	____	____	_X_.	____	____	"B"

1. Preference: Please compare each Fly-in Concept in terms of which you prefer.

Fly-in Concept	>>>	>>>	>>	>	***Equal***	<	<<	<<<	<<<	Fly-in Concept
Linear	___	___	___	___	___	___	___	___	___	***Shallow Curve***
Shallow Curve	___	___	___	___	___	___	___	___	___	***Deep Curve***
Deep Curve	___	___	___	___	___	___	___	___	___	***Linear***

Please try to explain your above ratings. Also identify what one fly-in concept you prefer the most and explain why. (If you need more room, use the space on the next page.)

2. Was there a strategy you employed to judge if one fly-in concept was better than another?

3. Beyond the fly-in concepts you saw today, do you have any fly-in ideas that you feel may afford more awareness of an environment?

4. Do you have any comments you would like to make concerning this experiment (e.g., briefing, training, tasks, etc.)?

Thanks for your participation. ~The SIRUS Team.

APPENDIX E

FULL MULTI-UAV SIMULATION EVALUATION: SUBJECT OVERVIEW

Thank you for participating in this Synthetic Interface Research for UAV (Unmanned Aerial Vehicle) Systems (SIRUS) Lab experiment. The SIRUS Lab conducts research on candidate UAV operator interfaces. The simulator being used in this experiment is designed to give a single operator control of multiple UAVs. This experiment will test a new UAV to UAV transition display called Get In The Zone (GITZ). GITZ is being developed as a tool to help operators rapidly gain situation awareness of a new area when switching camera views from one UAV to another and to mitigate the carry-over effects commonly associated with these switches.

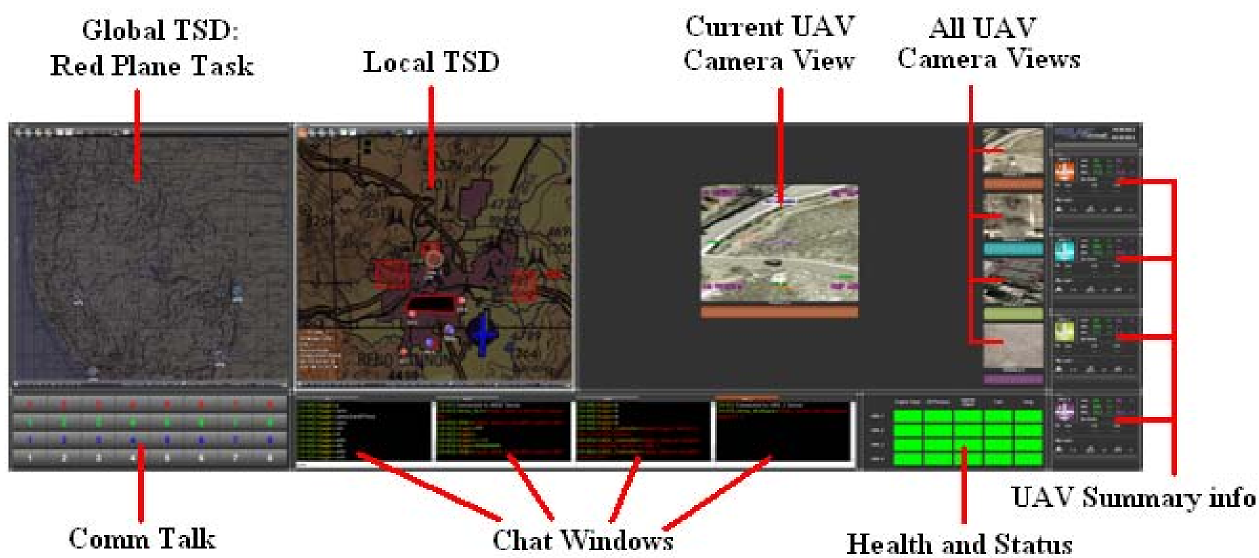
Experimental Scenario

You will need to switch from one UAV to another to perform surveillance and Close Air Support (CAS) missions while communicating with different customers and monitoring UAV health and status, air traffic, and radio chatter. Specifically, we will test a new type of transition display called GITZ to determine if it helps you perform this mission better.

In this experiment, 4 UAVs are flying in fixed loiter patterns over 4 different cities under your supervision. You will be tasked with switching among these UAVs to perform surveillance and CAS missions while you perform other, more secondary mission tasks. You will not have control over the UAVs' flight; you will only be able to switch between the camera view of one UAV to the camera view of a different UAV.

Experiment Simulator

Vigilant Spirit Control Station



Experimental Tasks

Upon completion of training, you will be given 8 experimental trials. Each trial will require you to perform surveillance and Close Air Support (CAS) missions while responding to inquiries and monitoring several displays. You may find that you do not always have enough time to perform all tasks so it is essential that you prioritize your tasks. Some tasks are more important than others. For the purposes of this experiment, the missions are the primary task and have priority over the numerous secondary tasks.

PRIMARY TASK:

Mission During the trials you will be asked via both radio and chat to switch UAVs to perform different missions. There are 2 types of missions; CAS and Surveillance. In each trial you will be asked to switch back and forth between a number of CAS and Surveillance missions.

1) CAS Missions During CAS missions, you will be asked to locate and designate two enemy tanks in an area. It is important that you identify and remember what types of tanks you designate. There are three different types of tanks (NB, SB, and LB):


Tank 1: No Barrel (NB)


Tank 2: Short Barrel (SB)


Tank 3: Long Barrel (LB)

During CAS missions you must also identify and remember the shape and color of the Forward Air Control center (FAC). There are three different shapes; dome, box, and cone also three different colors; green, magenta, and yellow.

At the end of each CAS mission a message will appear in the UAV chat window asking you a question related to the mission (for example: what was the shape and color of the FAC, what type of tank did you designate first in this mission, or what type of tank did you designate second in this mission). You must respond to this inquiry as quickly and accurately as possible by typing the answer in the chat window like so:

Q: What was the color and shape of the FAC?
A: magenta box (magenta/green/yellow | box/dome/cone)

Q: What type of tank did you designate first in this mission?
A: NB (NB, SB, LB)

CAS missions require your full attention and take priority over everything. Do not attempt to perform any other tasks until after you have designated the second enemy tank and answered the question in the UAV chat window.

2) Surveillance Mission During Surveillance missions you will be asked to monitor the video feed for a pickup truck. It only appears for 10-15 seconds and then disappears so you must be vigilant. The truck does not appear in every surveillance mission and may appear more than once. When the truck appears, report it by typing "truck" in the UAV chat window.

Workload is less in Surveillance missions compared to the CAS missions. You can try to continue to respond to inquiries and monitor the other displays while performing these missions but keep in mind that the Surveillance missions are a primary task and take priority over other secondary tasks.

SECONDARY TASKS

1) Chat Throughout the trials, questions will appear in the 4 chat windows at the bottom of the screen. In addition to the CAS Mission questions, there will be questions asking you for your current MSL (altitude relative to the Mean Sea Level), CAS (Current Airspeed), and HDG (Heading). Locate this information in the UAV summary info panels on the right side of the station and answer these questions as quickly as you can by typing the correct number in the corresponding chat window. The monitoring and responding to the chat is more important than the other secondary tasks because CAS Mission questions appear in chat. Do not attempt to answer any chat questions while performing CAS Missions with the exception of the CAS Mission questions.

The three tasks described below (Red Plane, Health and Status and Communications Monitoring) are all of equal importance. The purpose of these tasks is to ensure you are scanning both screens and to represent the workload envisioned for operational applications.

2) Red Plane A red plane symbol will periodically appear and disappear on the global Tactical Situation Display (TSD). When this happens, use the mouse to click on the red plane before it disappears. This simulates monitoring air traffic for airborne hostiles.

3) Health and Status You will receive warnings throughout the trials regarding each UAV's systems status. Boxes will go from green (normal) to yellow (caution) when a problem occurs. Simply click on any yellow box to return the health and status to normal. If you fail to click on a yellow box quickly enough it will turn red (emergency) indicating that the problem is getting worse. Click on any red box to return the system to normal.

4) Communications Throughout the trials you will hear radio chatter that will consist of phases, each beginning with a call sign (e.g. "Ready Bravo go to green three now," "Ready Eagle go to blue seven now"). You will be assigned the call sign Eagle. Whenever you hear your call sign, click on the color/number button the radio operator asks for using the mouse. Ignore radio calls that are not addressed to you.

Again, for the purposes of this experiment, prioritize the tasks in the following order from highest priority to lowest priority:

Highest Priority
|
|
|
|
V
Lowest Priority

Primary Tasks	**CAS Missions**: Locate/Designate Targets, Post Mission Question
	Surveillance Missions: Find/Report Targets
Secondary Tasks	**Chat Questions**: Report UAV Summary Info
	Health and Status: Detect Warnings/Emergencies
	Communications Tasks: Detect/Follow Radio Instructions
	Red Planes: Detect/Select Red Planes

Experiment Requirements

One 4-5 hour session
- Training: ~2 hours
- Experiment/Trials: ~2 hours
- Questionnaires: ~30 min

Approximately 12-16 subjects

20/20 vision, normal color vision, normal hearing

APPENDIX F

FULL MULTI-UAV SIMULATION EVALUATION QUESTIONNAIRES

POST-TRIAL QUESTIONNAIRE

Mark the box (☐) which best reflects your ratings for each of the following:

1) Situational Awareness: For **this trial**, rate your **overall situation awareness** -- the degree to which you: were aware of important elements in your environment (i.e., landmarks, targets, major features), comprehended your current location, and were able to project future status.

Low	*Situation Awareness Rating*					**High**
Never Aware						**Always Aware**
1 ☐	**2** ☐	**3** ☐	**4** ☐	**5** ☐	**6** ☐	**7** ☐

2) Perceived Task Difficulty: For **this trial**, rate ***how difficult*** it was to complete your tasks.

Easy	*Task Difficulty Rating*					**Hard**
Lowest Difficulty						**Highest Difficulty**
1 ☐	**2** ☐	**3** ☐	**4** ☐	**5** ☐	**6** ☐	**7** ☐

3) Perceived Task Performance: For **this trial**, rate your impression of ***how well you performed*** your tasks.

Poor	*Performance Rating*					**Excellent**
Lowest Performance						**Highest Performance**
1 ☐	**2** ☐	**3** ☐	**4** ☐	**5** ☐	**6** ☐	**7** ☐

4) Workload Estimate: Provide a **workload rating** that represents your workload for **this trial**. For ratings greater than 3 (Moderate activity), comment on key contributors to your workload for that trial.

Workload Rating						
Nothing to do: No system demands	**Light Activity:** Minimum demands	**Moderate Activity:** Easily managed; Considerable spare time	**Busy:** Challenging but manageable; Adequate time available	**Very Busy:** Demanding to manage; Barely enough time	**Extremely Busy:** Very difficult; Non-essential tasks postponed	**Overloaded:** System unmanageable; Essential tasks undone; Unsafe
1 ☐	**2** ☐	**3** ☐	**4** ☐	**5** ☐	**6** ☐	**7** ☐

FINAL QUESTIONNAIRE

Experimental Conditions: In each trial, the "Get-in-the-Zone" (GITZ) display was either 'on' or 'off' during transitions between camera views for dynamic missions:

Without a Get-in-the-Zone (GITZ) display, your selection of a different UAV for a dynamic mission (target search/designate) abruptly switched the tactical map of interest and camera view from one UAV to another. The displays immediately depicted the different terrain, threat environment, and camera view pertaining to the newly selected UAV.

1) Rate below the extent to which transitioning between camera viewpoints without a GITZ display was *distracting* to you:

Degree Distracting				
Very Distracting		**Slightly Distracting**		**Not at All**
-4 ☐	**-3** ☐	**-2** ☐	**-1** ☐	**0** ☐

Comments:

With a GITZ display, the camera's view transitioned, retreating upward from the starting location in the first mission, traveling across the terrain towards the new location at an altitude of approximately 80,000 feet, and then descending to the view of the camera located on the newly selected UAV.

2) Rate below the extent to which transitioning between camera viewpoints with a GITZ display was *distracting* to you:

Degree Distracting				
Very Distracting		**Slightly Distracting**		**Not at All**
-4 ☐	**-3** ☐	**-2** ☐	**-1** ☐	**0** ☐

Comments:

3) To what extent did the GITZ display *impact performance* on the *target search/designation task* in the experimental trials?

Impact (if any) on Performance				
Hurt Performance		**No Impact**		**Aided Performance**
-2 ☐	**-1** ☐	**0** ☐	**1** ☐	**2** ☐

Comments:

4) To what extent did the GITZ display *impact performance* on the other mission related tasks in the experimental trials? (UAV switching, responding to info requests and SA probes, detecting health/status changes and unexpected aircraft, and making inputs in response to aural commands)

Impact (if any) on Performance				
Hurt Performance		**No Impact**		**Aided Performance**
-2 ☐	**-1** ☐	**0** ☐	**1** ☐	**2** ☐

Comments:

5) Did you *change your strategy* (for any of the tasks), depending on whether the GITZ display was 'on' or 'off'?

☐ yes ☐ no If yes, please explain how and identify for which task(s) this occurred.

For trials in which the GITZ display was on, GITZ was shown in two types of mission transitions: a) Static Mission to Dynamic Mission and b) Dynamic Mission to Dynamic Mission. Static Missions involved monitoring video thumbnails for four UAVs and Dynamic Missions involved locating/designating targets with a single UAV/camera).

6) Did the *usefulness of the GITZ display* depend on whether you were transitioning from a static mission versus transitioning from another dynamic mission?

☐ yes ☐ no If yes, please explain.

7) In terms of your *ability to maintain situation awareness* *(SA)* of the entire area, compare 'GITZ-On' versus "GITZ-Off":

First, mark one box below:

SA *equal* with GITZ-On & -Off	☐
More SA with GITZ-On	☐
More SA with GITZ-Off	☐

then:

If you had more SA with one of the GITZ display conditions, how much more? Mark 1 of the 3 columns below.

Slightly more	>>	**Substantially more**
> ☐	☐	>>> ☐

Comments:

8) In terms of your *ability to locate and designate targets in the dynamic missions*, compare GITZ-On with GITZ-Off

First, mark one box below:

Ability *equal* with GITZ-On & -Off	☐
Ability better with GITZ-On	☐
Ability better with GITZ-Off	☐

then:

If you had better task completion with one of the GITZ display levels, how much more? Mark 1 of the 3 columns below.

Slightly more	>>	**Substantially more**
>☐	☐	>>> ☐

Comments:

9) In terms of your *ability to accomplish other mission tasks* (UAV switching, responding to info requests and SA probes, detecting health/status changes and unexpected aircraft, and making inputs in response to aural commands), compare GITZ-On with GITZ-Off

First, mark one box below:

Ability *equal* with GITZ-On & -Off	☐
Ability better with GITZ-On	☐
Ability better with GITZ-Off	☐

then:

If you had better task completion with one of the GITZ display levels, how much more? Mark 1 of the 3 columns below.

Slightly more	>>	**Substantially more**
> ☐	☐	>>> ☐

Comments:

10) The GITZ transition display involved three segments:

a) retreating upward from the starting location in the original (old) mission
b) traveling across the terrain towards the new UAV location
c) descending to the view of the camera located on the UAV of the new mission

Rate below the acceptability of the transition speed for each of the three segments:

a) Speed of Retreating Upward from Camera View on First Mission				
Too Slow		**Just Right**		**Too Fast**
-2 ☐	**-1** ☐	**0** ☐	**1** ☐	**2** ☐

b) Speed of Traveling Across Terrain				
Too Slow		**Just Right**		**Too Fast**
-2 ☐	**-1** ☐	**0** ☐	**1** ☐	**2** ☐

c) Speed of Descending to Camera View for New Mission				
Too Slow		**Just Right**		**Too Fast**
-2 ☐	**-1** ☐	**0** ☐	**1** ☐	**2** ☐

Comments:

11) Do you have any suggestions on how the implementation of the GITZ transition display might be improved? Or other aids to help transition from one camera view to another? ☐ yes ☐ no If yes, please explain.

12) Please provide any additional comments concerning the experiment, training, tasks, and/or simulator you might have (include things you liked, things that were confusing, etc.):

Thanks for your participation!! The SIRUS Team

LIST OF ABBREVIATIONS

AFRL	**Air Force Research Laboratory**
AGL	**above ground level**
ES	**exponential sweep (type of fly-in)**
FAC	**forward air controller**
ft	**feet**
FOV	**field-of-view**
GITZ	**Get in the Zone (Transition Format)**
ISR	**intelligence, surveillance, and reconnaissance**
LS	**linear sweep (type of fly-in)**
LVD	**long vertical drop (type of fly-in)**
SA	**situation awareness**
MSL	**mean sea level**
NM	**nautical miles**
SVD	**short vertical drop (type of fly-in)**
UAV	**unmanned aerial vehicle**
VC	**virtual camera**