

Technical Report 1273

**Input Device Characteristics Contribute to
Performance during Training to Operate a Simulated
Micro-Unmanned Aerial Vehicle**

Deborah R. Billings

University of Central Florida

Consortium Research Fellows Program

Paula J. Durlach

U. S. Army Research Institute

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Research Program Manager
Training and Leader Development
Division**



**MICHELLE SAMS, Ph.D.
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Technical review by

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Deborah R. Billings
University of Central Florida
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Paula J. Durlach
U. S. Army Research Institute

Orlando Research Unit
Stephen L. Goldberg, Chief

U.S. Army Research Institute for the Behavioral and Social Sciences
2511 Jefferson Davis Highway, Arlington, Virginia 22202-3926

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INPUT DEVICE CHARACTERISTICS CONTRIBUTE TO PERFORMANCE DURING TRAINING TO OPERATE A SIMULATED MICRO-UNMANNED AERIAL VEHICLE

EXECUTIVE SUMMARY

Research Requirement:

Unmanned aerial vehicles (UAVs) have demonstrated usefulness in a variety of military environments, and the U.S. Army has embraced this technology (Cambone, Krieg, Pace, & Wells, 2005; Military.com, 2008). Micro-unmanned aerial vehicles (MAVs) are small, man-portable, UAVs intended for use at the small unit level. As this technology is increasingly utilized, systematic training requirements and performance metrics for vehicle operators need to be addressed.

Previously, researchers at the United States Army Research Institute for the Behavioral and Social Sciences (ARI) developed a research environment to examine training issues related to manual operator control of MAVs (Durlach, Neumann, & Billings, 2008; Billings & Durlach, 2008). This research platform consisted of a simulated operator control unit (OCU), which provided sensory imagery from the onboard cameras of a simulated MAV, altimeter information, a digital map, and other components critical to the successful operation of the MAV. Operator training missions were created, and various performance metrics were assessed for usefulness. In the previous experiments, performance for flight skill missions was measured via completion times, and performance for reconnaissance missions was measured via the number of targets identified. It was found that the mission completion measures for flight skill missions were sensitive to human-interface manipulations, whereas the number of targets identified for reconnaissance missions was not. The interface manipulation involved whether manual flight was controlled by a game controller or a point and click method using a mouse. Thus, the specific finding was that flight skill missions were completed more quickly with the game controller than with the mouse. The current research followed up these findings in two ways. First, it explored the sensitivity of temporal measures of performance for simulated reconnaissance missions. Second, it explored the characteristics of the game controller vs. the mouse configurations that may contributed to performance advantages in the control of the simulated MAV. More specifically, this research investigated three characteristics of the game controller that may have led to a performance advantage: attention (focused vs. divided), control of vehicle speed (user-controlled vs. system-controlled), and movement ability (one direction vs. multiple directions simultaneously).

Procedure:

Data were collected from 50 participants recruited from the local university. Participants were randomly assigned to one of five input device configurations, through which we were able to isolate attention, directional movement, and control of speed to see if any of these game controller characteristics contributed to performance advantages. Participants sat in front of the OCU to complete the experiment. The layout of the OCU was the same as it was for our prior experiment, but the methods of input were different. In addition, the general procedure was the

same as in our prior research (Billings & Durlach, 2008), with minor changes to the reconnaissance missions to allow for measurement of mission completion times.

Before beginning training, participants completed several pre-task measures. Then participants underwent operator training using the OCU, where they learned how to control the MAV and navigate through the simulated environment. As part of their initial training, participants reviewed a manual and completed six practice exercises. After successful completion of these practice exercises, participants completed five missions. Three missions were flight skill missions, where participants were required to navigate the simulated MAV following landmarks and avoiding obstacles. Two were reconnaissance missions, where participants had to locate and photograph targets using the simulated MAV. The first three missions occurred in the same environment where initial practice occurred, while the last two occurred in a novel environment. After each training mission, participants were given the NASA Task Load Index (NASA TLX) to measure subjective workload. Additional performance measures included mission completion times and number of collisions.

Findings:

Generally, the findings replicated the pattern of results from the previous research. The game controller configuration that was used in Billings and Durlach (2008) led to significantly better performance than the mouse on training missions. Findings also suggested that completion time for reconnaissance missions is a more discriminating performance metric than number of targets detected or number of collisions (which were used in our prior research). Finally, there were several findings of interest related to game controller characteristics. Results indicated that the ability to control movement in multiple directions simultaneously yielded significantly better performance than single direction movement for flight skill missions, but user control over speed failed to have an effect. In contrast, during reconnaissance missions, user control over speed contributed to significantly better performance than no control; however, control in only a single vs. multiple directions failed to have an effect. The attentional manipulation failed to influence performance in either type of mission. Thus, different features of the game controller contribute to different aspects of operator performance. Speed control was a significant factor for reconnaissance-related tracking tasks, while degrees of freedom in movement direction was a significant factor for navigation tasks.

Utilization and Dissemination of Findings:

Temporal measures of performance proved sensitive to interface manipulations for both flight skill and reconnaissance missions. Different aspects of input device control affected performance of the different missions in different ways. The results demonstrate the importance of matching input device characteristics to task characteristics. Several implications for the design of teleoperation training systems and the design of input controls are as follows.

Implications for Instructional Design for Teleoperation

- To achieve effective standards-based training for teleoperation, simulation-based training should include a series of progressively more challenging missions. Each step should

have an associated performance criterion which must be met before advancing to the next more challenging level. Missions should cover the entire range of tasks the operator would be expected to perform. Rationale: In prior research (Billings & Durlach, 2008), as well as in this current effort following this guidelines, students learned to perform complex simulated missions relatively quickly.

- In designing standards-based simulation training for teleoperation, temporal measures are very discriminating performance metrics and could be combined with required, but less sensitive performance metrics to assess mastery. Rationale: During the course of our experiments we found that discrete performance measures such as number of targets detected or number of collisions were relatively insensitive to manipulation of the input device. They may represent a minimum requirement for standards-based training (e.g., a mission must be completed without any collisions); however, to discriminate different degrees of mastery above and beyond these essential requirements, mission completion criterion times are appropriate.
- The possibility that experienced video-game players may perform better in teleoperation should be further investigated. Rationale: We have consistently found that experienced video-game players perform teleoperation in simulation better than nonplayers; however, it is unknown whether this generalizes to live environments.

Implications for the Design of Teloperation Input Controls

- Matching user input device characteristics to required task characteristics improves teleoperation performance. The entire gamut of tasks to be performed must be considered to maximize the benefits. Rationale: We found that different aspects of input device control affected different tasks differently. The ability to maneuver in multiple directions at one time affected route following, but not target photography. Conversely, the ability to control speed affected target photography but not route following.
- The specific way in which an input device capability is implemented and not just the capability itself is important, because the implementation may affect performance on other tasks. Rationale: We found (across experiments) that the ability to maneuver in multiple directions at a time facilitated route following. Depending on this ability was implemented in the user interface, however, it affected performance on other tasks such as photographing targets.

INPUT DEVICE CHARACTERISTICS CONTRIBUTE TO PERFORMANCE DURING TRAINING TO OPERATE A SIMULATED MICRO-UNMANNED AERIAL VEHICLE

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INPUT DEVICE CHARACTERISTICS CONTRIBUTE TO PERFORMANCE DURING TRAINING TO OPERATE A SIMULATED MICRO-UNMANNED AERIAL VEHICLE

Introduction

Unmanned aerial systems (UASs) have proven their ability to assist in a wide range of military missions, especially reconnaissance. One type of UAS currently under development is the Class I micro-unmanned aerial vehicle (MAV; Coffrey & Montgomery, 2002; Carey, 2007). MAVs are man-portable and have the potential to assist small military units in local reconnaissance, surveillance, and target acquisition. In fact, U.S. Army infantry brigade combat teams are scheduled to be equipped with MAVs by 2011. As this type of UAS is deployed at the small unit level, new training requirements will need to be developed, for training of operators, maintainers, and leaders. MAV operators will need to be trained on system operability and maintenance, while commanders will need training on system utilization (Durlach, 2007). From an operator standpoint, human-system interaction should take into account human capabilities and limitations and will require efficient and systematic training procedures. Unfortunately, the military has focused more on developing the technology than on designing effective human-robot interaction components and training protocols (Billings & Durlach, 2008). Therefore, research efforts need to address the optimization of human-machine interfaces for these UAS operators, as well as the proper design of training procedures, performance metrics, and standards.

Background

Due to the rapidly approaching training demand, we previously developed simulation-based operator training exercises to evaluate the usefulness of various performance measures for their ability to contribute to a standards-based simulation training curriculum (Durlach, Neumann, & Billings, 2008; Billings & Durlach, 2008). During the course of this prior research, we examined the impact of operator interface features on performance and found that for flight skill missions, temporal measures (e.g., time to complete a mission) were most sensitive to the manipulated interface features (i.e., different mouse and game controller input device configurations). In contrast, the number of targets detected in a fixed-time simulated reconnaissance mission failed to be affected by the manipulated features. One purpose of the current research project was therefore to examine whether a temporal measure for reconnaissance missions would prove more sensitive for training purposes. Another goal was to determine why certain factors of our previous interface manipulations affected performance.

Prior Research Findings

Two prior investigations were conducted with the simulation-based MAV training platform. In our first experiment (Durlach, Neumann, & Billings, 2008), one finding was that trainees using a dual-thumb stick game controller (GC) as an input device completed skill missions more quickly than those who used a mouse (M) to select on-screen icons representing different directions of MAV movement. There were several ways in which the GC configuration

differed from the M configuration, and any one of these could have contributed to the performance difference, one of which is spatial learning.

In our first experiment (Durlach, Neumann, & Billings, 2008), the user interface, or simulated operator control unit (OCU), was equipped with streaming video of the virtual environment in which the simulated MAV flew (as captured by the MAV's forward-looking or downward-looking fixed cameras). Visual attention to this sensor window was necessary to see the environment, find buildings, avoid obstacles, detect targets, and so on. Trainees using the GC could focus all their visual attention on this window, because they could control all the MAV functions by feel with the GC. In contrast, trainees using the M had to continuously shift their visual attention between the sensor window and the on-screen icons they needed to select to control the MAV functions. Because participants conducted initial training (practice) in the same environment in which mission performance measures were taken, it is possible that trainees in the GC condition may have learned the spatial layout of the simulated village better during this practice period than the trainees in the M condition. Better spatial learning may have allowed them better ability to anticipate obstacles and use landmarks to maneuver.

In our second experiment (Billings & Durlach, 2008), we examined the possibility that the performance difference between GC and M could be attributed to differences in spatial learning, resulting from the different demands the two input devices made on visual attention. Two missions were completed in a virtual environment different from that used in the other missions. In this way, we could determine if the performance differences between the GC and M transferred to a new environment, or if performance was contingent on spatial learning of the practice environment. Results indicated that spatial learning was not a likely explanation, however (Billings & Durlach, 2008). The GC vs. M performance difference was evident both during initial training and during the transfer test in a novel environment. Because neither the GC or M conditions had any opportunity to learn the spatial relations of the novel transfer environment, differences in spatial learning during training could not underlie the performance differences.

Differences in the deployment of visual attention might still account for the performance differences observed with the GC and M, although not through its impact on spatial learning. It is possible that the requirement to continuously shift visual attention in the M condition affects performance through an on-line mechanism, such as increased demand on visual working memory. In the present research, we attempted to assess this possibility, by isolating the visual attention factor across input devices. In our initial experiments, the GC provided the ability to maneuver the MAV in multiple directions simultaneously (i.e., parallel input of directional commands) and to control the speed of the MAV anywhere between zero and six knots. These capabilities were enabled via the thumb sticks such that the direction of displacement of each stick from its center determined two axes of movement, and the extent of the displacement determined speed. In contrast, the M supported the ability to input maneuver commands only in one axis at a time (e.g., up or forward, but not both), and speed was controlled by the system, not the operator. The M condition required serial input of all movement commands. To test whether different demands on visual attention accounted for the performance effects observed, we re-engineered GC functioning so that only one axis of movement could be controlled at a time and the system controlled the speed (see GC2 in Table 1). In this way, the only difference in

functioning between the GC2 condition and the M condition (other than the physical device) was that attention was divided between the sensory imagery and the navigation controls in the M condition, and attention was focused on the sensory imagery in the GC2 condition.

Table 1. Conditions and the Comparisons Required to Test the Effects of Divided Attention, Axis Control, and Speed Control

Condition	Input Device Characteristics			
	Attention	Axis of Control	Speed Control	Physical Input Device
M	Divided	One at a time.	System	Mouse (same as Billings & Durlach, 2008)
GC1	Focused	Multiple axes simultaneously.	User	Game Controller (same as Billings & Durlach, 2008).
GC2	Focused	One at a time.	System	Game Controller
GC3	Focused	Multiple axes simultaneously.	System	Game Controller
GC4	Focused	One at a time.	User	Game Controller
Group Comparison	Factors that were isolated by the comparison			
M vs. GC1	Comparison made in previous experiments, factors confounded			
M vs. GC2	Isolates effect of visual attention			
GC1 + GC4 vs. GC3 + GC2	Isolates effect of speed control, collapsing over axis control			
GC1 + GC3 vs. GC4 + GC2	Isolates effect of axis control, collapsing over speed control			

GC functioning was also manipulated across three additional conditions to allow determination of the separate effects of axis control and speed control. To change the GC to one-direction at a time mode, the dominant direction of displacement on a thumb stick was translated into movement in the dominant direction only. To change the GC to system speed control, the extent of thumb stick displacement was made irrelevant. The MAV started and stopped with some inertia. Once given the command to move, it gradually sped up to six knots and then stayed at that speed until a new command was issued, regardless of how far the thumb stick was displaced from center. The various resulting conditions of the present experiment are listed in Table 1, along with the comparisons required to determine the effects of visual attention, axis movement control, and speed control on performance. For GC2, the MAV could only move in one direction at a time, and speed was controlled by the system. For GC3, movement in multiple axes was enabled, and speed was controlled by the system. For GC4, movement was in only one direction at a time, and the flight speed was controlled by the user.

Method

Participants

Twenty-five male and 25 female participants from the University of Central Florida completed this experiment in exchange for college course credit or monetary compensation. The mean age was 19.5 years (range 18 to 35). Four other participants (all female) failed to pass the initial performance criteria and were excused from the experiment. All participants signed an informed consent before beginning the experiment. Each experimental condition consisted of 10 participants and had an equal number of males and females to account for possible gender differences related to video game experience and spatial ability.

Materials

A combination of subjective measures and questionnaires were used, including a demographics survey (see Appendix B), a training evaluation worksheet (See Appendix C), the Hidden Patterns Test (ETS, 1976), and an electronic form of the NASA Task Load Index (TLX; Hart & Staveland, 1988). The demographics survey was a paper-based questionnaire requesting information about gender, remote control experience, video game skills, and computer experience. The training evaluation worksheet presented participants with a screenshot of the OCU and required participants to match the components in the interface with their functions. This worksheet verified comprehension of the MAV interface and operating procedures. The Hidden Patterns Test was a paper-based measure of spatial ability and required participants to find simple patterns within more complex, distracting patterns (ETS, 1976). This particular measure of spatial ability was used because Durlach, Neumann, and Billings (2008) found that results on this test correlated with several dependent measures of performance that were used in the current research. The NASA TLX was administered on a desktop computer, where workload scores were automatically calculated. Participants were required to rate their perceived workload on six different dimensions, including mental demand, physical demand, temporal demand, performance, effort, and frustration.

The experimenter followed a script carefully to ensure that all experimental procedures were administered correctly and that all participants received the same instructions (See Appendix D). A training manual provided detailed information about the simulation and instructed participants how to operate the simulated MAV. Participants read through the training manual, which led them through training exercises. A full copy of the participant training manual can be found in Billings and Durlach (2008).

Apparatus

The simulation required the use of three computers. The OCU, the synthetic terrain database, and the MAV simulator were run on one computer. A computer ran One-SAF Testbed (OTB) version 2.5, which allowed insertion of entities (people and vehicles) into the synthetic environment via a network. Finally, a third computer was used to administer the NASA TLX.

The configuration of the OCU screen is illustrated in Figure 1, and was identical to that used by Billings & Durlach (2008). It had a window with streaming camera imagery, an altimeter, a mission timer, task bar icons, a heading tape, an overhead map view, and a control pad that provided visual feedback to the operator. The simulated MAV was based on Honeywell's Class I t-MAV prototype, which incorporated a ducted fan design that allowed for vertical take-off and landing, hovering in mid-air, and rotating in place (Carey, 2007). The flight model included some basic inertial properties, and like the t-MAV prototype limited speed to six knots in manual mode, and tilted forward in forward flight 1° for every knot of forward speed. The simulated MAV was equipped with two fixed cameras, one pointed down, and the other pointed forward. Only one camera view appeared on-screen at a time, and participants switched views using their respective input device (pressing a button on the GC, and clicking an on-screen icon with the M).

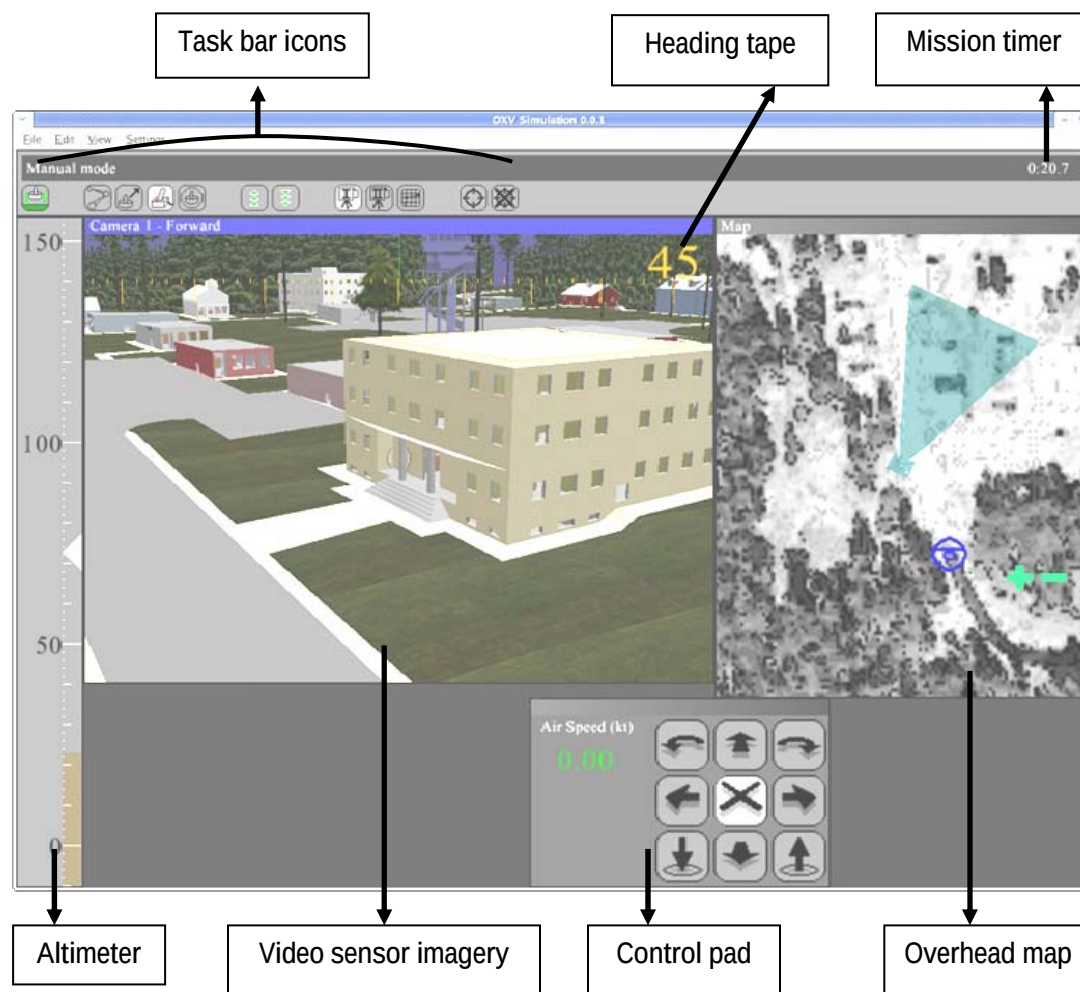


Figure 1. Layout of the Operator Control Unit (OCU).

Participants sat at a desk and piloted the simulated MAV using either a Logitech dual thumb-stick GC (See Figure 2) or a standard two-button M with a scroll wheel. Participants using the M clicked on the desired icon on the OCU to give commands to the MAV. Participants using the GC manipulated the controller to issue commands to the MAV. There were four different GC conditions, as outlined in Table 1. Input device set-up was manipulated as a between-group variable, i.e., each participant had the same configuration throughout the experiment. Regardless of the input configuration used, the same visual feedback appeared on the control pad (e.g., when directed to move forward, the OCU forward-arrow icon lit up).

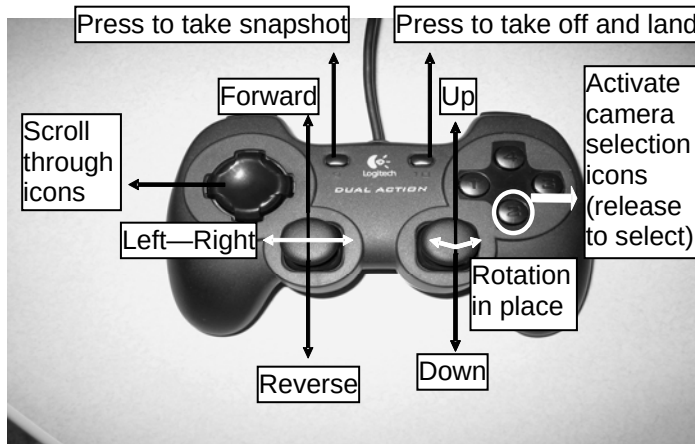


Figure 2. Logitech GC mapping of commands for the GC conditions.

Procedure

Participants were assigned to one of the five input device configurations outlined in Table 1. They each signed an informed consent form and then completed a demographics survey and the Hidden Patterns Test. Participants were then trained to operate the simulated MAV, with the aid of a manual which guided them through six hands-on practice exercises. For the first four practice exercises, participants followed simple consecutive movement directions such as take-off, fly forward, rotate, and land. These exercises allowed the participant to practice manipulating the controls of the input device. Practice Exercises 5 and 6 were flight skill exercises and required participants to pilot the MAV along predetermined paths, avoiding poles and other obstacles. Each of the practice exercises required completion within a specific criterion time and without any collisions before moving on to the next practice exercise. If they collided with anything, participants were restarted from the beginning of the exercise. Participants were given five attempts to successfully complete each of the practice exercises without collisions. Four female participants who were unable to do this were dismissed from the experiment.

The practice exercises were completed in a training environment that simulated a military operations in urban terrain (MOUT) training area at Fort Polk, LA, which included trees, buildings, and other potential obstacles. For Practice Exercises 1, 2, 3, and 4, participants were required to perform various actions with the MAV, such as taking off, landing, capturing a

photograph, and following a series of oral commands. These exercises ensured that participants had learned the mappings of the input device. For Practice Exercise 5, participants manually piloted the MAV around a gray pathway while remaining to the left of four red poles, and then they landed in a designated landing zone. This exercise had to be completed within three minutes and 50 seconds. For Practice Exercise 6, participants manually piloted the MAV through an obstacle course similar to a slalom course, where participants had to weave between red and green poles. At the end of the course, they were also required to photograph a target before landing in the designated landing zone. Participants had five minutes to complete this exercise. The time criteria were set in order to make sure that participants were able to demonstrate competency in the tasks in a timely fashion. Full details of the practice exercises can be found in the Experimenter's Script (Appendix D) as well as in Billings and Durlach (2008). Performance data was recorded for each of these practice exercises.

After successful completion of the practice exercises, the training evaluation worksheet and NASA TLX were administered to participants. Next, participants completed five missions during which their performance data were recorded. Three missions were flight skill tasks. For these, participants had to navigate around obstacles while following a predetermined path. The other two missions were reconnaissance tasks. For these, participants had to photograph a given number of targets. The first three missions (two skill missions, one reconnaissance mission) were conducted in the Fort Polk, LA, MOUT area, whereas the last two missions (one skill mission, one reconnaissance mission) were conducted in a new simulated environment, a MOUT site from Fort Benning, GA. For all missions, the primary dependent variable was completion time. Participants who committed a collision during the course of a mission were instructed to restart, and all mission times used were for collision-less missions.

Missions 1 and 2 required participants to navigate courses designated by poles throughout the training environment of Fort Polk, LA. In Mission 1, participants followed a road around the outskirts of the MOUT site (resembling a racetrack). In Mission 2, participants navigated a slalom course in which they weaved through poles. These skill missions were similar to the last two practice exercises (Practice Exercise 5 and Practice Exercise 6). The only difference was that during the practice exercises, participants were able to track the location of the MAV along a visible route on the satellite map. During the missions, this path was not visible.

For Mission 3, participants were given pictures of various targets and were instructed to fly around the environment to find and photograph six (stationary) targets, and then to land the MAV back at the launch point. Participants were allowed a maximum of 15 minutes. Mission 4 was a skill mission that involved navigation around poles and obstacle avoidance in a new location, which was the Fort Benning, GA-MOUT environment. Mission 5 was a reconnaissance mission also performed in the new location of the Fort Benning, GA-MOUT environment. Similar to Mission 3, participants were required to locate and photograph six targets with a maximum allowed time of 15 minutes; the targets were new and five were stationary whereas the sixth was moving.

Participants completed the NASA TLX following each of the missions. After completing Mission 5, participants were debriefed and compensated for their time. Computerized logs were kept of each participant's mission times and workload scores.

Results

Data Analysis Plan

Because our previous research showed some relation between video game experience (VGE) and performance, as well as between spatial ability and performance, these measures were used as covariates. A single value was used for (VGE) by standardizing and summing three highly correlated demographic questions relating to video game usage and skill into a single score. The score from the Hidden Patterns Test was used for spatial ability. The dependent variables of interest were mission completion times and NASA TLX scores. When covariates are not mentioned, they failed to have a significant effect.

For each dependent measure, three separate analyses were conducted. First, GC1 and M were compared to check whether the performance differences found in our previous research had been replicated, as these input device configurations were the same as those used in our prior research. Next, GC2 and M were compared. These conditions differed only in the aspect of visual attention. Better performance in GC2 than M would indicate that having to divide attention between the sensor window and the control pad is detrimental to performance. Finally, a 2 x 2 analysis of covariance (ANCOVA) was conducted using the data from GC1 – GC4, with factors: movement control (one vs. multiple) and speed control (system vs. user).

For the temporal data for each of the three comparisons described above, we conducted two separate analyses, one for flight skill missions, and one for reconnaissance missions. Thus, for the flight skill mission analysis there were five repeated measures (Practice 5, Practice 6, Mission 1, Mission 2, and Mission 4). The practice exercises were included in the analyses because they were identical and employed the same skills and characteristics of Missions 1, 2, and 4. In this way, performance across these similar missions could be analyzed. For the reconnaissance mission analysis there were two repeated measures (Missions 3 and 5).

Mission Completion Times—Flight Skill Missions

The temporal performance data for the flight skills missions were examined first. Table 2 shows the mean completion times and standard deviations for Practice 5, Practice 6, Mission 1, Mission 2, and Mission 4 for the different input device configurations. In addition, mean completion times for collapsed conditions are shown. GC1 and GC4 isolated user control of speed. GC3 and GC2 isolated system control of speed. By collapsing these groups, comparisons between user-controlled speed and system-controlled speed can be made. In addition, GC1 and GC3 isolated participants who could navigate in multiple directions simultaneously. GC4 and GC2 isolated participants who could control movement in only one direction at a time. In this way, multiple versus single directional control could be analyzed.

Table 2. Mean Completion Times in Seconds (Standard Deviations) for Flight Skill Missions

Input Device Configuration	Flight Skill Missions				
	Practice 5	Practice 6	Mission 1	Mission 2	Mission 4
M	212.57 (9.13)	263.14 (19.48)	211.20 (19.40)	254.76 (32.51)	282.79 (61.17)
GC1	190.79 (15.11)	218.89 (26.79)	187.51 (16.61)	227.60 (47.68)	220.58 (29.08)
GC2	212.71 (7.54)	261.79 (27.87)	209.07 (22.72)	246.96 (33.41)	259.29 (37.39)
GC3	208.64 (16.39)	245.88 (34.71)	189.58 (18.11)	240.79 (32.66)	233.60 (50.79)
GC4	210.17 (10.72)	259.42 (29.49)	202.08 (15.83)	238.92 (34.88)	256.00 (34.27)
Speed control isolation					
GC1 + GC4	200.48 (16.17)	239.16 (34.41)	194.80 (17.47)	233.26 (41.07)	238.29 (35.87)
GC3 + GC2	210.67 (12.59)	253.84 (31.71)	199.33 (22.35)	243.87 (32.31)	246.44 (45.37)
Directional control isolation					
GC1 + GC3	199.72 (17.87)	232.39 (33.20)	188.55 (16.94)	234.19 (40.35)	227.09 (40.83)
GC4 + GC2	211.44 (9.11)	260.61 (27.96)	205.58 (19.39)	242.94 (33.50)	257.64 (34.95)

Mouse vs. GC1. Figure 3 illustrates the mission completion times across flight skill missions for participants in the M and GC1 configurations. These configurations were identical to the configurations used in our prior research (Billings & Durlach, 2008). A 2 x 5 mixed design ANCOVA was used to analyze data from M and GC1, with the repeated measure representing skill mission. Mauchly's test indicated that the assumption of sphericity had been violated ($\chi^2 = 32.20$, $p < .005$), and therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\epsilon = .54$). There were significant differences in average times to complete the different missions, $F(2.17, 34.73) = 20.84$, $p < .005$, $\eta^p = .57$, with both groups showing shorter completion times for Practice 5 and Mission 1 than for the others. Of more interest, the main effect of condition was significant, $F(1, 16) = 14.60$, $p < .005$, $\eta^p = .48$, replicating our prior results that mission times were shorter in GC1 than M.

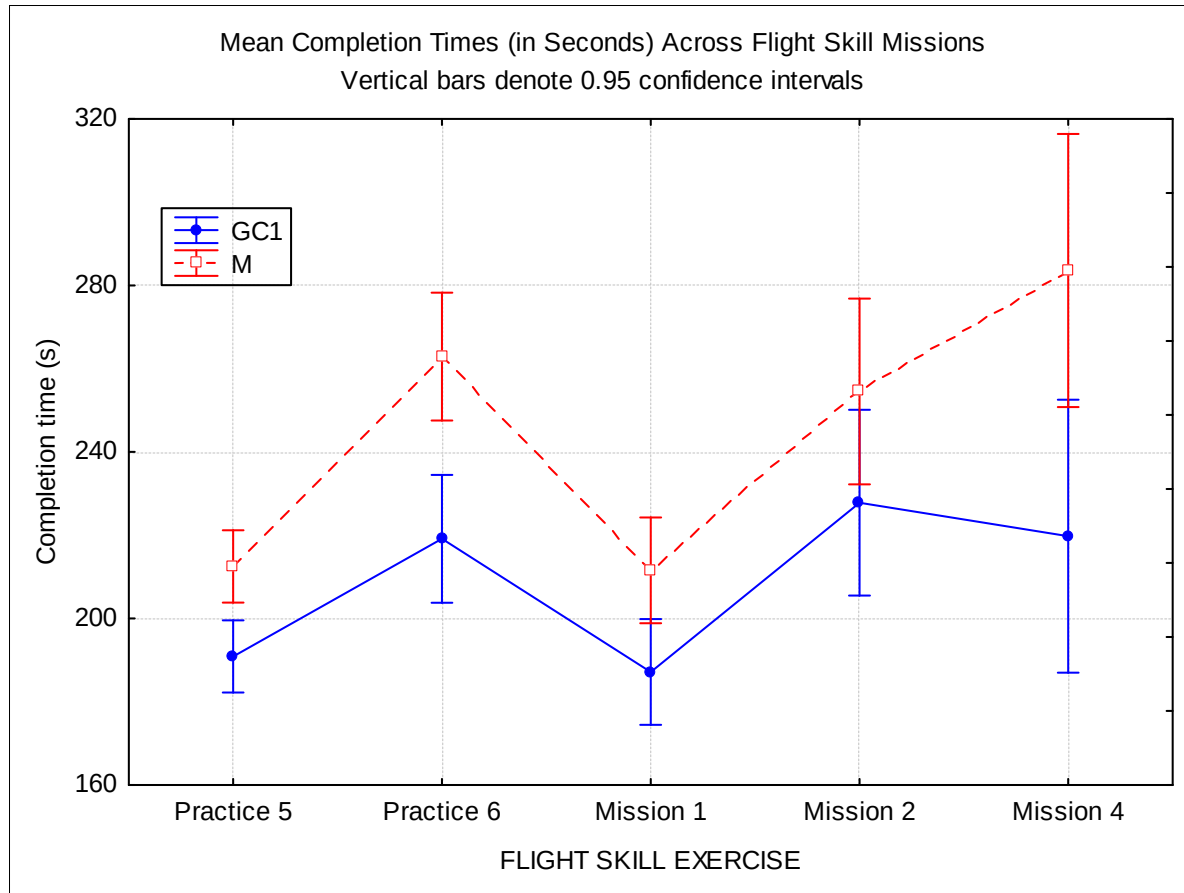


Figure 3. Mean completion times (in seconds) across flight skill missions, for GC1 and M configurations.

Attention. A 2 x 5 mixed design ANCOVA was used to analyze the data from M and GC2. These configurations were identical except that M required participants to divide visual attention, whereas GC2 allowed participants to focus their visual attention. In this way, any existing performance differences between these two configurations could be attributed to an attentional factor. Figure 4 illustrates the mission completion times across flight skill missions for participants in the M and GC2 configurations. Mauchly's test indicated that the assumption of sphericity had been violated ($\chi^2 = 26.84, p < .005$), so degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\epsilon = .54$). Mission was significant, $F(2.15, 34.40) = 26.22, p < .005, \eta^p = .62$, with both groups showing shorter completion times for the "racetrack" missions (Practice 5 and Mission 1). There failed to be a significant effect of attention, $F(1, 16) = 0.60, p = .45, \eta^p = .04$. These results suggest that the difference in flight skill completion time between GC1 and M (as was found in our prior research) was not due to different demands on visual attention.

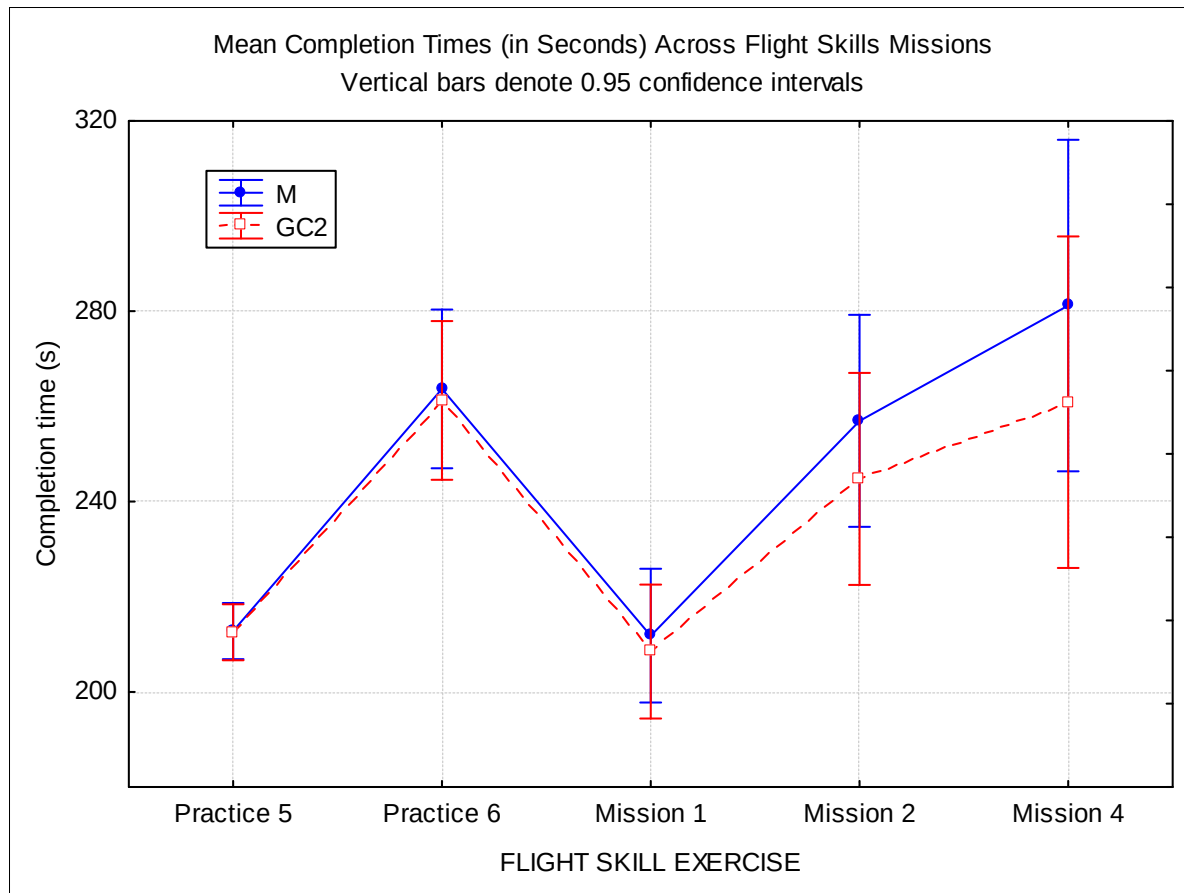


Figure 4. Mean completion times (in seconds) across flight skill missions, for GC2 and M configurations.

Directions and speed control. A 2 x 2 x 5 (movement ability x speed control x skill mission) mixed design ANCOVA was used to assess the effects of movement control and speed control. Mauchly's test indicated that the assumption of sphericity had been violated (chi-square = 59.00, $p < .005$), and degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (epsilon = .64). Mission was significant, $F(2.56, 87.01) = 47.00$, $p < .005$, $\eta^p = .58$, with all groups showing shorter completion times for the "racetrack" missions. The effect of movement control was also significant, $F(1, 34) = 7.01$, $p = .01$, $\eta^p = .17$ (See Figure 5). Conditions GC1 and GC3, which could move in multiple directions simultaneously, had shorter mission times overall ($M = 217.0$ s) than conditions GC2 and GC4 ($M = 235.03$ s), which could move in only one direction at a time. Speed control failed to have a significant impact, $F(1, 34) = 1.18$, $p = .29$, $\eta^p = .03$ (See Figure 6). Mean completion time was 222.2 s for GC1 and GC4 combined, and was 229.8 s for GC2 and GC3 combined. The interaction between movement ability and speed control failed to be significant, $F(1, 34) = 1.06$, $p = .31$, $\eta^p = .03$.

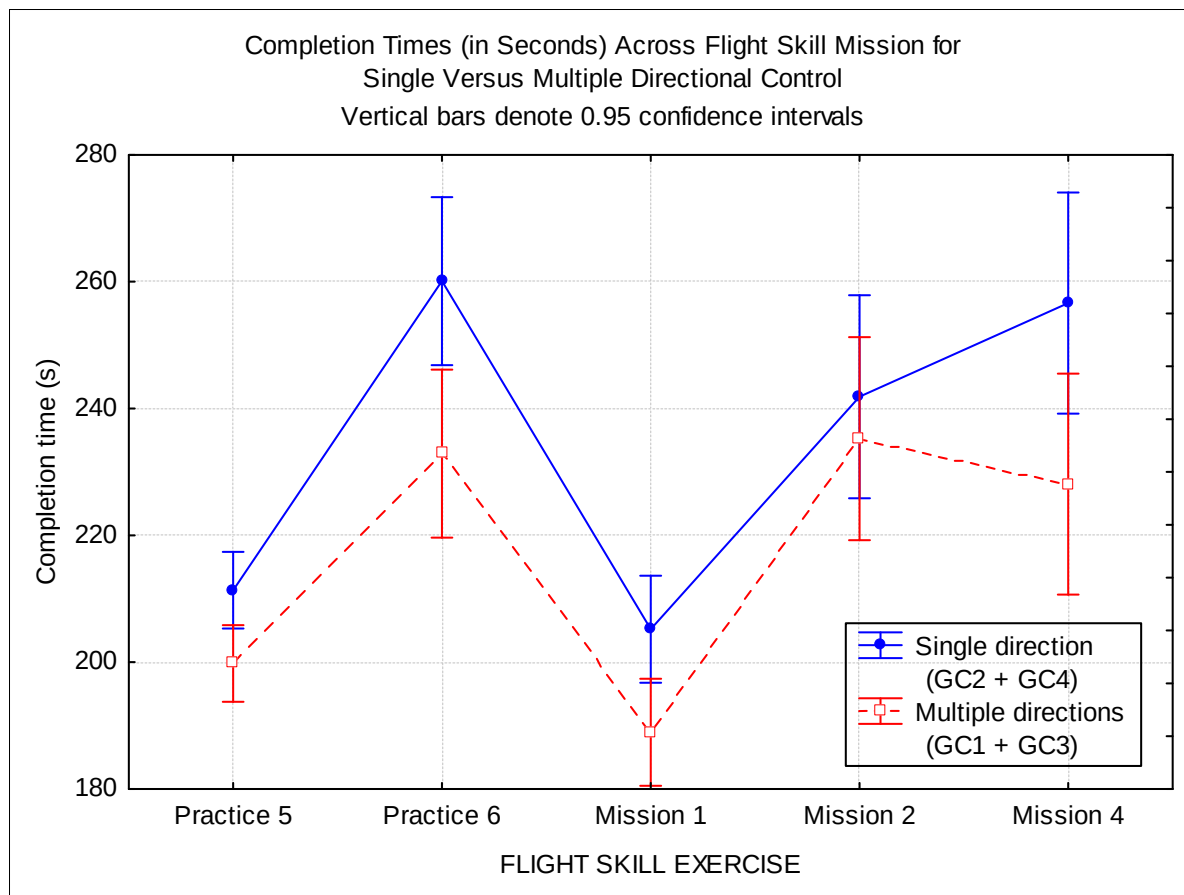


Figure 5. Mean completion time (in seconds) across flight skill missions for GC configurations with single versus multiple directional control.

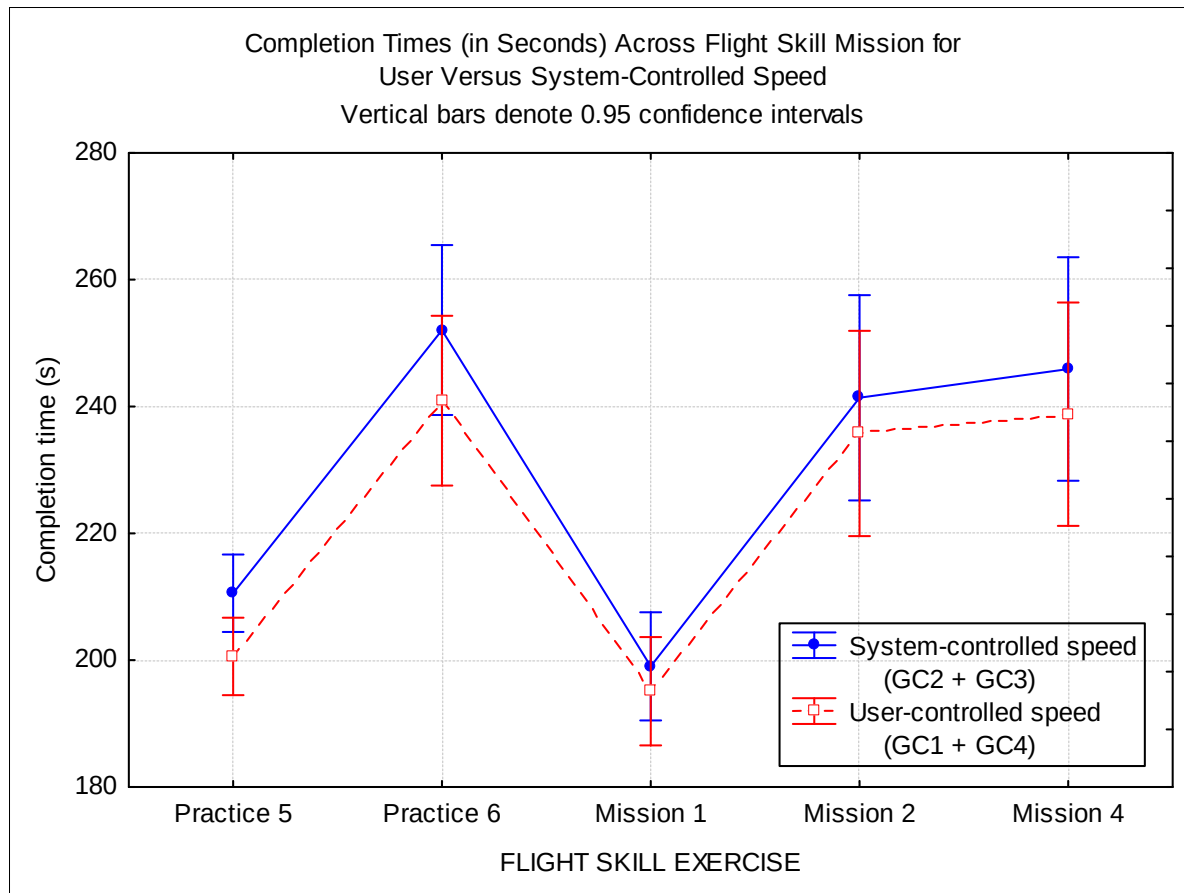


Figure 6. Mean completion time (in seconds) across flight skill missions for GC configurations with user versus system-controlled speed.

Mission Completion Times—Reconnaissance Missions

The temporal performance data for the reconnaissance missions were examined next. Table 3 shows the mean completion times and standard deviations for Mission 3 and Mission 5 for the different input device configurations, as well as the collapsed conditions. Again, GC1 and GC4 isolated user control of speed, while GC3 and GC2 isolated system control of speed. Furthermore, GC1 and GC3 isolated movement in multiple directions simultaneously, while GC4 and GC2 isolated movement in one direction at a time.

Table 3. Mean Completion Times in Seconds (Standard Deviations) for Reconnaissance Missions

Input Device Configuration	Reconnaissance Missions	
	Mission 3	Mission 5
M	700.15 (153.35)	740.59 (128.77)
GC1	483.48 (175.49)	432.04 (192.19)
GC2	683.26 (183.67)	608.12 (219.74)
GC3	632.87 (195.63)	529.26 (243.22)
GC4	494.84 (150.06)	491.26 (198.15)
Speed control isolation		
GC1 + GC4	489.16 (159.02)	461.65 (192.40)
GC3 + GC2	658.06 (186.48)	568.69 (229.19)
Directional control isolation		
GC1 + GC3	558.17 (196.44)	480.65 (219.10)
GC4 + GC2	589.05 (189.71)	549.69 (212.28)

Mouse vs. GC1. Figure 7 illustrates mission completion times for the reconnaissance missions graphically. A 2 x 2 (input device x mission) mixed design ANCOVA indicated lack of difference in completion times for Missions 3 and 5, $F(1, 16) = .08, p = .78, \eta^p = .01$. More importantly, there was a significant effect due to input device, $F(1, 16) = 16.15, p < .005, \eta^p = .50$. As can be seen in Figure 7, GC1 completed reconnaissance missions more quickly than M. In our prior experiments, there were no significant performance effects detected for our reconnaissance missions (Billings & Durlach, 2008); however, we had used a different performance measure, number of targets detected. The present results therefore suggest that the temporal measure used here is more sensitive to performance differences.

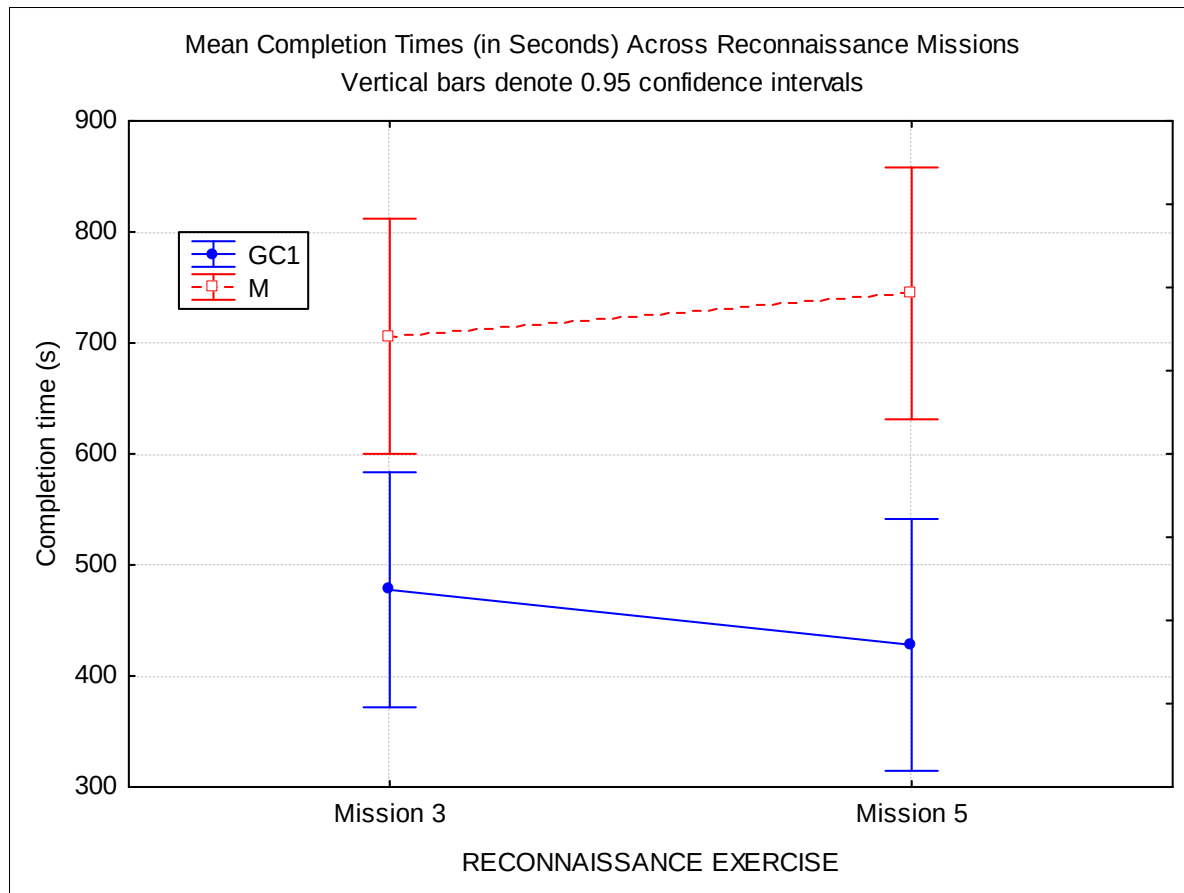


Figure 7. Mean completion times (in seconds) across reconnaissance missions, for GC1 and M configurations.

Attention. A 2 x 2 (attention x mission) mixed design ANCOVA examined data from M and GC2. Mission failed to have a significant impact $F(1, 16) = 0.35$, $p = .56$, $\eta^p = .02$, as did attention, $F(1, 16) = 1.08$, $p = .31$, $\eta^p = .06$. These results suggest that the difference in reconnaissance mission completion time between GC1 and M (as found in the current research, as well as our prior research) was not due to different demands on visual attention.

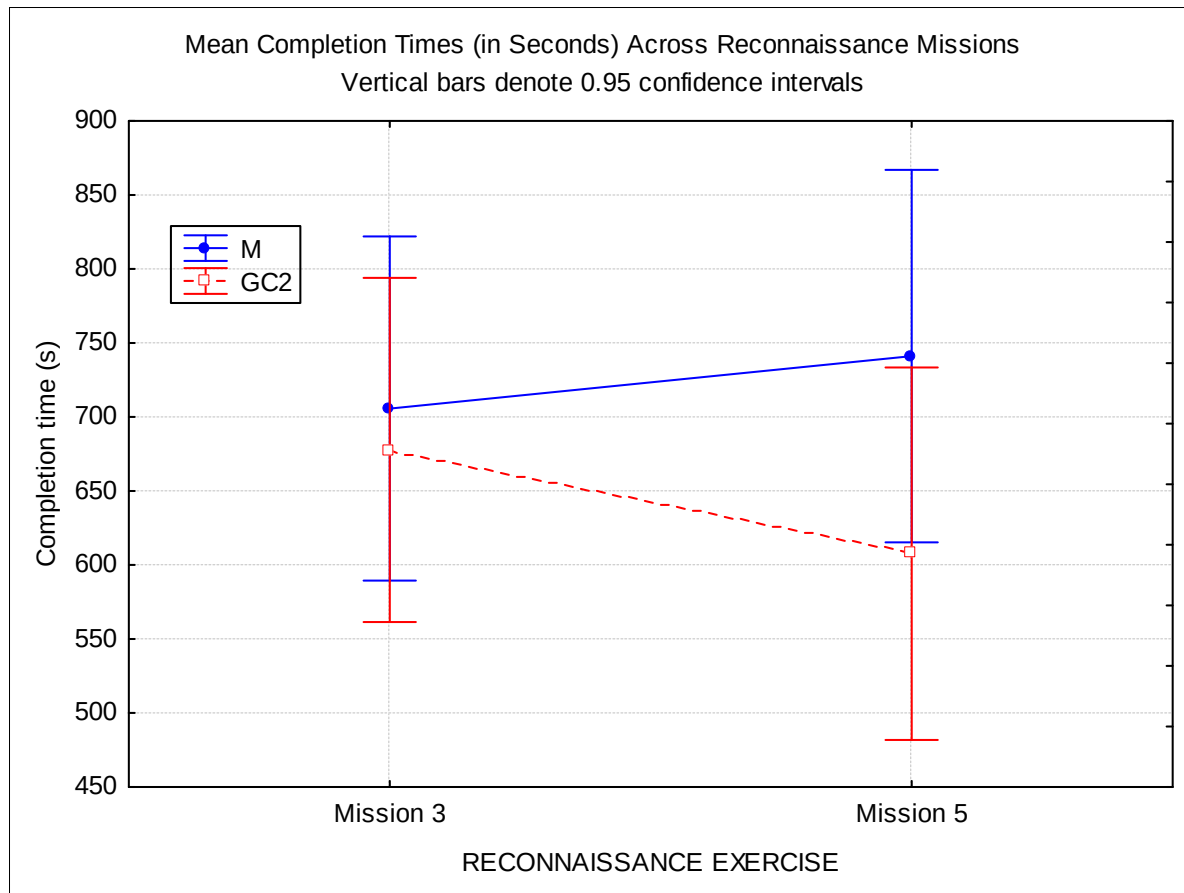


Figure 8. Mean completion times (in seconds) across reconnaissance missions, for GC2 and M configurations.

Direction and speed control. A 2 x 2 x 2 (movement control x speed control x reconnaissance mission) mixed design ANCOVA detected a significant effect of mission, $F(1, 34) = 5.82, p = .02, \eta^p = .15$. When averaged across the four conditions (GC1 – GC4), Mission 3 was completed more quickly than Mission 5. The effect of movement control failed to be significant, $F(1, 34) = 0.52, p = .48, \eta^p = .02$; See Figure 9 for graphical illustration. However, the effect of speed control was significant, $F(1, 34) = 4.45, p = .04, \eta^p = .12$. (See Figure 10). User control of speed in GC1 and GC4 allowed faster reconnaissance mission completion time ($M = 486.82s$) than did system control for GC2 and GC3 ($M = 601.96s$). There was no evidence for an interaction between movement control and speed control, $F(1, 34) = .01, p = .92, \eta^p = .00$. VGE was found to be a significant covariate, $F(1, 34) = 6.56, p = .02, \eta^p = .16$.

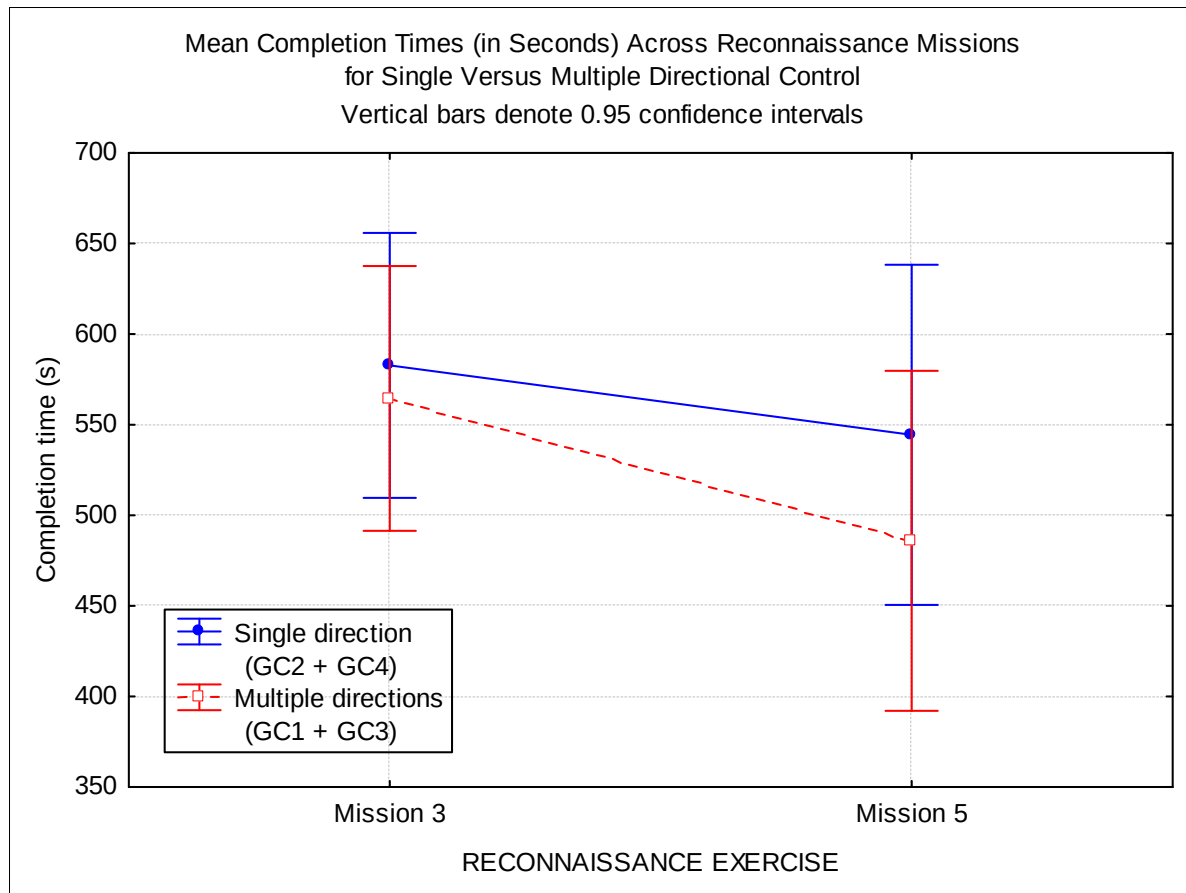


Figure 9. Mean completion time (in seconds) across reconnaissance missions for GC configurations with single versus multiple directional control.

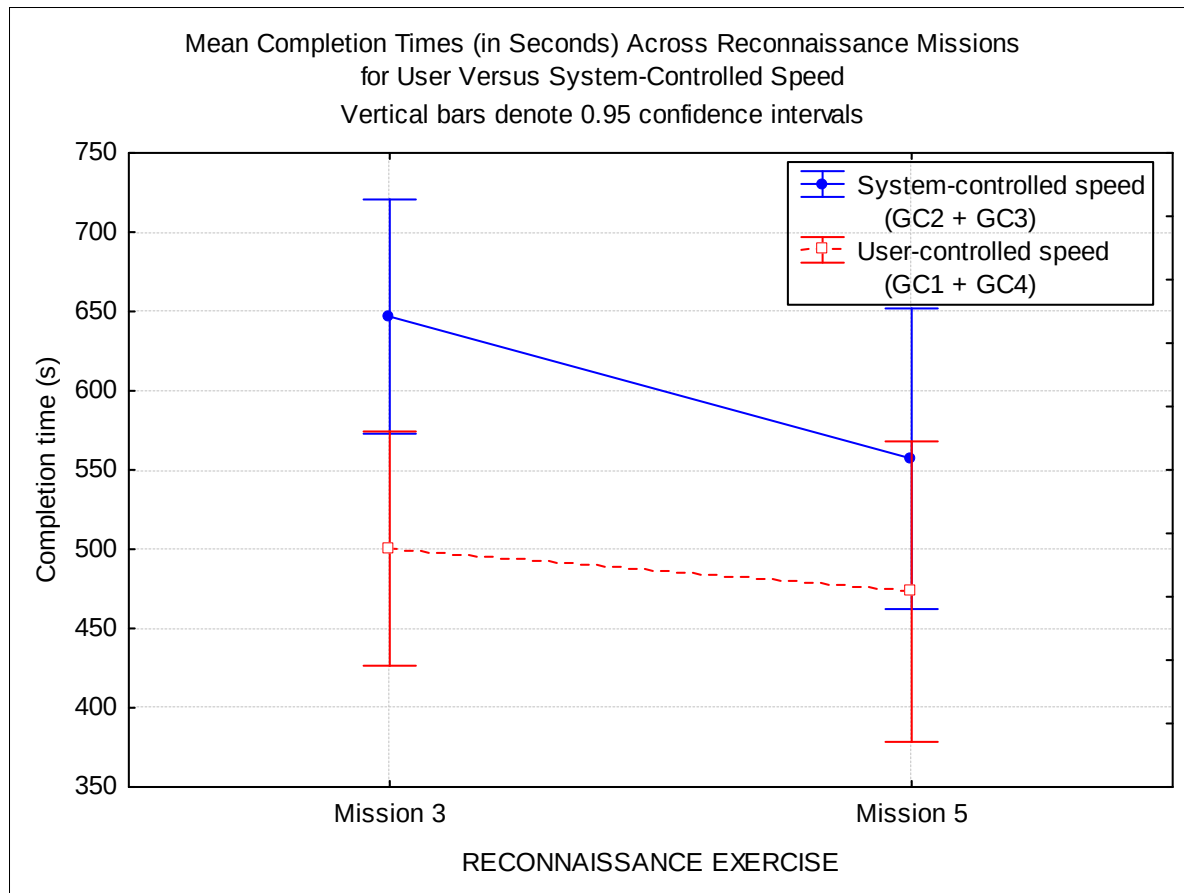


Figure 10. Mean completion time (in seconds) across reconnaissance missions for GC configurations with user versus system-controlled speed.

NASA TLX Workload Analyses

Data analysis of workload measures followed the same strategy as above, except each mission was analyzed separately because of nonparallelism in the covariates across the missions. Table 4 gives the means for each condition and comparison for the flight skill missions. Table 5 gives the analogous data for reconnaissance missions.

Flight skill missions. Table 4 lists the means for the flight skill missions. In general, workload was rated lower in GC1 than M, and the difference was significant for ratings given after Practice, $F(1, 16) = 5.97, p = .03, \eta^p = .27$, Mission 2, $F(1, 16) = 5.06, p = .04, \eta^p = .24$, and Mission 4, $F(1, 16) = 9.36, p = .01, \eta^p = .37$. Higher VGE was associated with lower workload scores, and this covariation was significant for Missions 2 and 4. Pearson r 's = $-.57, F(1, 16) = 12.77, p < .005$ and $-.44, F(1, 16) = 6.10, p = .03$, for Missions 2 and 4, respectively.

Table 4. Mean Rated Workload (Standard Deviation) for Flight Skill Missions

Input Device Configuration	Flight Skill Missions			
	Practice	Mission 1	Mission 2	Mission 4
M	61.3 (18.8)	41.5 (16.7)	49.9 (20.8)	62.2 (18.2)
GC1	40.9 (25.7)	27.6 (16.6)	31.7 (17.4)	34.6 (20.6)
GC2	59.9 (12.9)	47.4 (16.7)	50.6 (19.5)	48.3 (19.7)
GC3	49.2 (17.0)	38.3 (17.9)	39.2 (17.5)	46.2 (23.7)
GC4	46.5 (19.6)	36.4 (17.1)	43.3 (16.2)	50.3 (20.9)
GC1 + GC4	43.7 (22.4)	32.0 (17.0)	37.5 (17.4)	42.5 (21.7)
GC3 + GC2	54.6 (15.7)	42.9 (17.5)	44.9 (18.9)	47.3 (21.2)
GC1 + GC3	45.1 (21.6)	32.9 (17.6)	35.5 (17.4)	40.4 (22.4)
GC4 + GC2	53.2 (17.5)	41.9 (17.4)	47.0 (17.8)	49.3 (19.8)

With respect to the comparison of GC2 and M, there failed to be any significant differences, indicating that the different attentional demands of these two conditions had no detectable effects. To assess whether movement control or speed control affected workload, the 2 x 2 analysis was conducted for each mission. Movement control failed to have a significant effect for any mission. Likewise, movement control failed to have a significant impact during Practice, Mission 1 or Mission 4. For Mission 2, however, participants with greater movement control reported significantly lower workload, $F(1, 34) = 4.45$, $p = .04$, $\eta^p = .12$. For this 2 x 2 analysis, higher VGE tended to be associated with lower workload ratings, and was a significant covariate for each mission except Mission 1. For Practice, Pearson $r = -.38$, $F(1, 34) = 5.08$, $p = .03$, $\eta^p = .13$. For Mission 2, Pearson $r = -.33$, $F(1, 34) = 4.54$, $p = .04$, $\eta^p = .12$. For Mission 4, Pearson $r = -.41$, $F(1, 34) = 11.63$, $p < .005$, $\eta^p = .26$. Higher Spatial ability also tended to be associated with lower workload ratings; but this relation was significant only for Mission 4, Pearson $r = .21$, $F(1, 34) = 5.17$, $p = .03$, $\eta^p = .13$.

Reconnaissance missions. Table 5 shows the mean workload scores for the reconnaissance missions. Workload was rated as lower in GC1 than M, for both Mission 3, $F(1, 16) = 5.06$, $p = .04$, $\eta^p = .24$, and Mission 5, $F(1, 16) = 5.74$, $p = .03$, $\eta^p = .26$. Higher VGE was associated with lower workload scores and was significant for Mission 3, Pearson $r = -.41$, $F(1, 16) = 4.60$, $p = .05$.

Table 5. Mean Rated Workload (Standard Deviation) for Reconnaissance Missions

Input Device Configuration	Reconnaissance Missions	
	Mission 3	Mission 5
M	57.4 (18.1)	63.3 (20.7)
GC1	38.9 (20.2)	38.3 (23.0)
GC2	64.6 (17.3)	57.9 (16.3)
GC3	51.7 (22.7)	50.1 (24.8)
GC4	52.9 (18.9)	51.9 (23.0)
GC1 + GC4	45.9 (20.4)	45.3 (23.4)
GC3 + GC2	58.2 (20.8)	54.0 (20.8)
GC1 + GC3	45.3 (21.9)	44.4 (24.0)
GC4 + GC2	58.8 (18.7)	54.9 (19.7)

With respect to the comparison of GC2 and M, there failed to be any significant differences, indicating that the different attentional demands of these two conditions had no detectable effects on workload during reconnaissance missions. To assess whether movement control or speed control affected workload, the 2 x 2 analysis was conducted for each reconnaissance mission. The only significant effect detected was of movement control in Mission 3, $F(1, 34) = 5.09$, $p = .03$, $\eta^p = .13$, with lower workload reported by participants with the ability to move in multiple directions at one time compared with participants who could only move in a single direction at a time. For this 2 x 2 analysis, higher VGE was a significantly associated with lower workload for both Mission 3, Pearson $r = -.46$, $F(1, 34) = 9.70$, $p < .005$ and Mission 5, Pearson $r = -.40$, $F(1, 34) = 9.27$, $p < .005$. Spatial ability was a significant covariate for Mission 5, $F(1, 34) = 4.35$, $p = .05$, $\eta^p = .11$, but in an unexpected direction. Higher spatial ability was associated with higher workload scores, Pearson $r = .19$.

Discussion

Wide deployment of MAVs at the platoon level will mean a growing need to train many operators, and likely involve some simulation-based training. The current research explored training measures for such a purpose. In particular, the present findings indicated that temporal measures of performance are relatively sensitive and could provide a measure for training to a criterion for both flight skill missions and reconnaissance missions. Completing simulated training missions within set temporal parameters could be added to other prerequisite performance criteria (such as lack of collisions and number of targets detected) gating hands-on training with an actual vehicle.

Besides investigating the temporal performance measure, we also examined the factors which affected why some input device configurations support faster mission completion than others. In our previous research, participants completed missions more quickly with a GC than with a mouse (GC1 vs. M in the present experiment). In the current experiment we attempted to un-confound the factors distinguishing these devices to determine which factors contributed to that effect. One difference between a GC device and a point and click device such as a M (or a

touch screen), is that the point and click device requires the user to switch visual attention between the sensor imagery and the icons, which must be selected to control vehicle movement and functions. In contrast, the GC allows focused attention on the sensory image, because all controls can be operated by feel (without the need for visual attention on the controls themselves). We therefore reconfigured our GC in condition GC2 to make it operate identically to our M condition, except for the factor of visual attention. Because performance failed to differ across GC2 and M, our results indicated that visual attention was not the source of the difference between GC1 and M.

In our original research, the GC and M differed in the control they afforded the user of both maneuver directions and speed. The GC allowed simultaneous control of all axes of maneuver and user-control of speed. In contrast, the M allowed only one axis of maneuver at a time and speed was controlled by the system. To tease apart the contribution of these factors, in this experiment we engineered three new GC conditions, and examined the effects of each factor in a 2 x 2 (movement control x speed control) analysis. The results indicated that movement control significantly affected mission completion time on flight skill missions, although not on reconnaissance missions. Conversely, speed control affected mission completion time on reconnaissance missions, but not flight skill missions. The interpretation of this pattern is fairly straight-forward with some reflection on the mission requirements. Flight skill missions required route following and maneuver around obstacles. The ability to move with a curved trajectory or off at an angle while still moving forward would be particularly useful and much easier to accomplish with multi-directional control. The reconnaissance missions required not only the finding of targets, but also their photographing. The ability to creep ahead at a very slow speed would be particularly useful when trying to line up the camera focal point with the target (which was required). Under system-speed control, moving faster than desired was likely an impediment to getting the target lined up, and operators may have had to stop and hover to get the picture. In contrast, with user-controlled speed, operators could move very slowly and take a photo without having to come to a stop. This could have enabled them to complete reconnaissance missions more quickly.

Interestingly, the results of this experiment are completely compatible with some results of our original experiment, not heretofore mentioned. In that experiment (Durlach, Neumann, & Billings, 2008) we included a condition in which participants used a M, but had different on-screen control iconology from that used here. That control scheme allowed both user-control of speed and multiple directions of maneuver simultaneously. Mission completion times for flight skill missions for that condition were as good as in the GC condition on some missions. Thus, in that experiment, we improved performance with the M by adding the ability to maneuver in multiple directions simultaneously and control speed. In the present experiment, we undermined performance with the GC by removing the ability to maneuver in multiple directions simultaneously or control speed.

With regard to workload scores for this experiment, like for our previous experiments, participants with higher VGE generally found the tasks less demanding, regardless of condition. In addition, here, participants in GC1 (the original GC condition) often reported significantly lower subjective workload than participants in M. Sporadically, significantly lower workload was also reported by participants with multi-directional control (GC1 and GC3), compared with

those with only uni-directional control (GC2 and GC4). It is not clear why workload reports were more sensitive to input device characteristics in this experiment than in our prior research. Previously, this difference was detected only once (Durlach, Neumann, & Billings, 2008, Church Mission). Systems designers may sometimes impose constraints on operators' freedom of control in order to lessen workload or the training requirements. For example, the t-MAV prototype (Durlach, 2007) limited the velocity of the MAV to six knots in manual mode, despite the capability of the system to fly at speeds over 25 knots. This limitation was intended to prevent aerodynamic instabilities, which could occur if particular patterns of maneuver commands were issued when the MAV was traveling at faster speeds. By limiting velocity in manual mode, the need to train operators on the types of maneuvers they should avoid at higher speeds was eliminated. The present results indicate that multi-directional control and options to move at slower speeds aid performance without adding a workload or training burden.

The results of this investigation are concordant with others which have suggested that matching input device characteristics to task characteristics can lead to performance benefits (Jacob, Sibert, McFarlane, & Mullen, 1994; Rogers, Fisk, McLaughlin, & Pak, 2005; McLaughlin, Rogers, & Fisk, 2009). Optimizing this matching may be challenging, however, when the same input device is required for accomplishing various tasks. For example, in the Durlach, Neumann, & Billings (2008) condition where the iconology afforded user-speed control and multi-directional control with the M, flight skill performance was superior to the standard M condition (the same as that used in the present research); however, target detection and photography was impaired. We inferred this was due to that configuration's lack of a single discrete command to hover. With hindsight, it seems obvious that a discrete command would be best for this; however, in practice, it may be difficult to anticipate how input device characteristics and on-screen display characteristics will interact. Although matching task to input device is critical, research is still needed to address the challenge arising from using one input device for many different tasks, which is a more realistic situation in most human-computer interfaces.

Finally, in the present experiment we failed to find an effect of focused vs. divided attention on performance. This should not be taken to imply that attentional factors are not important, however. Use of input devices does require attention, and the match between device and task may be more important as the task becomes more attentionally demanding for the user. McLaughlin, Rogers, and Fisk (2009) found not only that task performance was influenced by the match between input device and task requirements, but also that older participants benefited more than younger. This benefit increased as less attentional resources were available. Hence, even though our current investigation did not suggest any impact of attention on task performance, other research implies that attentional demands do actually contribute to performance differences among input devices.

Implications for Instructional Design for Teleoperation

- To achieve effective standards-based training for teleoperation, simulation-based training should include a series of progressively more challenging missions. Each step should have an associated performance criterion which must be met before advancing to the next more challenging level. Missions should cover the entire range of tasks the operator

would be expected to perform. Rationale: Unstructured training simulations merely familiarize students, but do not enforce mastery criteria for a specific set of skills. We have shown that by structuring training and providing performance-based feedback, students can learn to perform complex simulated missions relatively quickly.

- In designing standards-based simulation training for teleoperation, temporal measures are the very discriminating performance metrics and should be combined with required, but less sensitive performance metrics to assess mastery. Rationale: During the course of our experiments we found that discrete performance measures such as number of targets detected or number of collisions were relatively insensitive to manipulation of the input device. They may represent a minimum requirement for standards-based training (e.g., a mission must be completed without any collisions); however, to discriminate different degrees of mastery above and beyond these essential requirements, mission completion criterion times are appropriate.
- The possibility that experienced video-game players may perform better in teleoperation should be further investigated. Rationale: We have consistently found that experienced video-game players master teleoperation in simulation more quickly than nonplayers; however, it is unknown whether this generalizes to live environments.

Implications for the Design of Teloperation Input Controls

- Matching user input device characteristics to required task characteristics improves teleoperation performance. The entire gamut of tasks to be performed must be considered to maximize the benefits. Rationale: We found that different aspects of input device control affected different tasks differently. The ability to maneuver in multiple directions at one time affected route following, but not target photography. Conversely, the ability to control speed affected target photography but not route following.
- The specific way in which an input device capability is implemented and not just the capability itself, is important, because the implementation may affect performance on other tasks. Rationale: We found (across experiments) that the ability to maneuver in multiple directions at a time facilitated route following. Depending on how it was implemented, however, it differently affected performance on other tasks.

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Appendix A

List of Acronyms

ANCOVA	Analysis of Covariance
ARI	Army Research Institute for the Behavioral and Social Sciences
GC	Game controller
GC1	Game controller, 1 st configuration
GC2	Game controller, 2 nd configuration
GC3	Game controller, 3 rd configuration
GC4	Game controller, 4 th configuration
M	Mouse
MAV	Micro-unmanned aerial vehicle
MOUT	Military operations on urban terrain
NASA TLX	NASA Task Load Index
OCU	Operator control unit
OTB	One-SAF Testbed
SUAS	Small Unmanned aerial system(s)
UAS(s)	Unmanned aerial system(s)
UAV	Unmanned aerial vehicle
VGE	Video game experience

Appendix B

Demographics Questionnaire

1. Year of birth: _____

2. Gender:

☐ Male ☐ Female

3. Have you graduated from high school?

☐ Yes ☐ No

4. Which hand do you write with?

☐ Left ☐ Right

5. Is your vision in each eye correctable to 20/20?

☐ Yes ☐ No

6. To your knowledge, are you color blind?

☐ Yes ☐ No

7. Do you own or have access to a computer?

☐ Yes ☐ No

8. If yes, how often do you use a computer?

☐ Daily ☐ Several times a week ☐ Occasionally ☐ Never

9. Estimate how many hours per week you use a computer.

☐ Never ☐ 1-5 hrs ☐ 5-10 hrs ☐ 10-20 hrs ☐ 20-30 hrs
☐ 30-40 hrs ☐ 40 + hrs

10. How do you rate your computer skills?

☐ Novice/Beginner ☐ Intermediate ☐ Expert

11. Do you use the Internet?

☐ Yes ☐ No

12. Do you have any previous remote control (R/C) experience (including cars, boats, etc.)?

☐ Yes ☐ No

13. Do you own or use a video game system?

☐ Yes ☐ No

14. How would you rate your video game skills?

☐ Novice/Beginner ☐ Intermediate ☐ Expert

15. How often do you play video games?

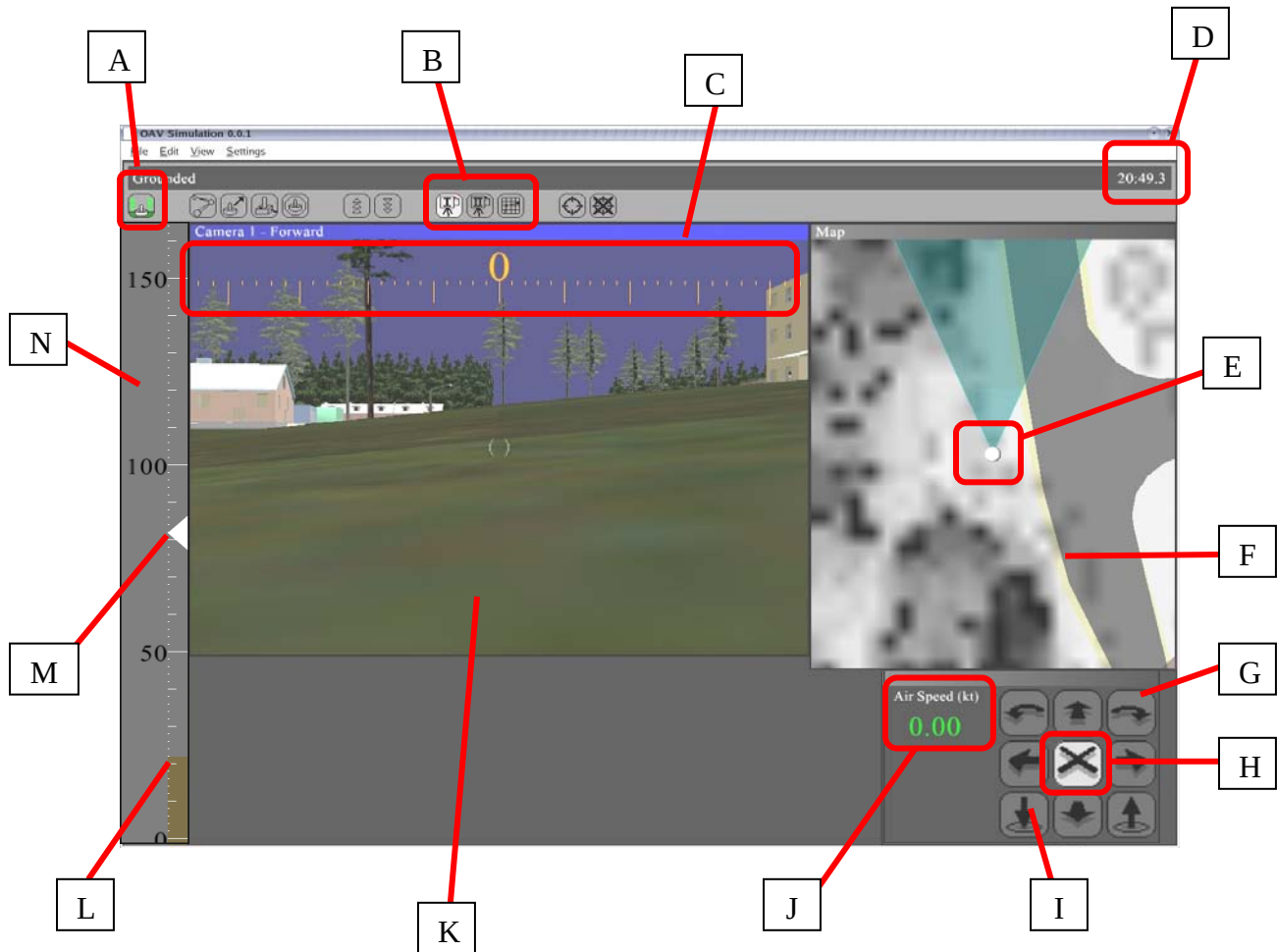
☐ Daily ☐ Several times a week ☐ Occasionally ☐ Never

16. Estimate how many hours per week you play video games.

☐ Never ☐ 1-5 hrs ☐ 5-10 hrs ☐ 10-20 hrs ☐ 20-30 hrs
☐ 30-40 hrs ☐ 40 + hrs

Appendix C

Training Evaluation Worksheet



To ensure that you have a basic grasp of the MAV pilot interface and the available flight commands, please complete the following exercise.

Each of the critical features of the user interface is labeled above with letters A – N. Every letter must be used, so choose the best answer. Enter the corresponding letter in the blank following each of the item descriptions below:

Altimeter _____
 Mission Timer _____
 MAV Rotational Icons _____
 Heading Tape _____
 Satellite Map View _____
 Current MAV Altitude _____
 Forward Camera Image _____

Camera Selection Icons _____
 Altitude Control _____
 Take-off and Land Icon _____
 Halt Movement Icon _____
 MAV Location on Map _____
 Ground Level Indicator _____
 Air Speed Indicator _____

Appendix D

Experimenter's Script



Army Research Institute
Intuitive Means of Robotic Control
Testbed

Experimenter's Guide



Exp 3 Follow-up MAV Study – IST

Summer/Fall 2008

(Read with participant)

Introduction to the Micro-Unmanned Aerial Vehicle Study

The U.S. Army is undergoing a major transformation. One element of the transformation is the introduction of a new class of military platforms known as unmanned air and ground vehicles (*called UAVs and UGVs*). A major benefit of these unmanned vehicles is that they can perform reconnaissance missions and survey areas contaminated with radiological, chemical, or biological agents without risk to human life. They can also survey the battlefield and provide real-time video feedback.

We are investigating the design of operator control systems for micro-unmanned aerial vehicles that can perform these kinds of reconnaissance missions. In addition, we are investigating operator training requirements. In this experiment, you will be trained on how to fly a simulated micro-UAV (MAV), and then you will complete a set of missions that will test your ability to maneuver the MAV and locate various targets. After each mission, you will be given a short questionnaire that asks you to rate certain aspects of the task you performed.

We have allotted approximately 3 hours for this experiment, although most people finish in less time. No previous flight experience is necessary to participate in this study.

Confidentiality

Your identity will be kept confidential to the extent provided by law. Your information will be assigned a code number. The list connecting your name to this number will be kept in an electronic file. When the study is completed and the data have been analyzed, the list will be destroyed. Your name will not be used in any report.

If you are prepared to participate in this experiment, please read and sign the **Consent Form and Voluntary Agreement**. Please also indicate on that form your preferred method of compensation. We offer cash payment or course credit. You will receive compensation per half hour you participate in this experiment.

- 1) Give each participant the informed consent form to read and sign before disclosing any details about the study.**
- 2) Once the informed consent is signed, the participant should complete the demographics questionnaire.**
- 3) After this is finished, the experimenter should administer the written ETS paper-based Hidden Patterns spatial test.**

All forms such as the informed consent should remain on file.

After participants complete the Hidden Patterns spatial test, tell them to begin by reading page 3 in their Participant Manuals.

(Participant will read the following by himself/herself):

Overall Description of the MAV Simulation

You will be working with a simulation for flying a micro-unmanned aerial vehicle. The micro-UAV itself will be referred to from now on as “the MAV.” This is not a fixed-wing aircraft like most airplanes are; rather, it is a small rotary craft with an internal fan and duct design (see prototype photos below). An operator controls the MAV using a laptop computer equipped with an input device such as a mouse or game controller. This interface is referred to as the OCU – Operator Control Unit. This is a dismounted control unit, as it is envisioned that a dismounted soldier (on foot rather than in a vehicle) will be controlling the MAV.



Prototype Micro UAVs from Honeywell and Allied Aerospace

Introduction to the OCU and MAV Camera System

The MAV is equipped with a dual camera system. When the vehicle flies through the simulated environment you will be able to view video images sent back to the OCU. You will be instructed on how to operate the cameras as well as how to use the OCU interface and controllers to pilot the MAV. You will also have an opportunity to practice some manual flight/piloting techniques before beginning the actual experiment. After basic instruction, a training session will take place; then you will move on to the assigned pilot mission tasks where performance data will be recorded. Be sure that you understand the objective of each mission before starting a trial. The experimenter is available to answer your questions before you begin each task, so please ask for help if you are unsure of any requirements. Unless instructed otherwise, it is important that you complete each task as **quickly and efficiently as possible**.

At the end of the training session and at the end of each mission you will complete a short computer-based questionnaire. In the first section you will rate different aspects of the task you performed; then you will be asked to choose between a pair of items that relate to your performance. You must choose one and only one item for each pair. Then you will proceed to the next mission. Please let the experimenter know when you are done reading this section.

Training Session and Exercises

Experimenter: When the participant reaches this point in the handout, explain that a short training session will be administered. You should have a good understanding of the MAV flight characteristics to run this study.

(Begin this and every exercise by reviewing the mission objectives with the participant.)

At this time load the correct condition properties file (.opf). To do this click FILE – Properties, then FILE – Open, and select the property (.opf) file from the list. Then click “apply” to begin the simulation.

Condition		File name
1	Focused, multiple, user-defined speed (GC)	exp3_cond1.opf
2	Divided, single, system-defined speed (MOUSE)	exp3_cond2.opf
3	Focused, single, system-defined speed (GC)	exp3_cond3.opf
4	Focused, multiple, system-defined speed (GC)	exp3_cond4.opf
5	Focused, single, user-defined speed (GC)	exp3_cond5.opf

(Read the following with participant):

Training Session

The goal of training is to familiarize you with the flight characteristics of the MAV and to give you an opportunity to practice piloting the MAV. We will begin by reviewing the features of the OCU and then proceed to a series of practice exercises. I will facilitate this training session and provide instruction on how to complete the assigned tasks.

OCU Layout and On-Screen Controls

Below you will see a sample layout of the OCU. On the left side of the screen is the video sensor imagery (camera views), and in the upper-right side you will find an overhead map view of the terrain database. Just below the map view there is a control pad that is used in issuing flight commands to the MAV. The control pad will be examined in greater detail throughout training. There is an altimeter along the left border area of the OCU display as well as a task bar along the top that contains various icons. We will go over how to use all relevant gauges and icons during training.

Please review the game controller buttons:

(If mouse condition, then continue with training)



The **upper task bar** (shown below) includes the **take-off (and landing) and camera control buttons**. There is also a mission timer located on the far right of this task bar. For this study, you will need to know how to use the take-off icon and the camera control icons.



[FOR MOUSE] clicking on the task bar icon for take-off and landing, or by

[FOR GAME CONTROLLER] pressing button (10) to activate the task bar icon for take-off and landing.

Once the take-off button is pressed the MAV will automatically climb to an altitude of approximately **60 feet above the ground level**. You will not be able to enter any flight commands to the MAV until you see a red stop sign icon illuminate (meaning that you have reached take-off altitude).

You may now execute the take-off command.

Pressing the take-off button again will execute the land command. You may land the MAV now.

These mode buttons switch between control modes.

- **Mission Mode** – (1st icon) causes the MAV to automatically navigate through pre-programmed waypoints. (experimenter only does this)
- **Go-To Mode** – (2nd icon) allows the operator to select a location on the map for the MAV to travel to by clicking on a point in the map frame. We will not use Go-To in this study.
- **Manual Mode** – (3rd icon) allows the participant to manually pilot the MAV by using the mouse or joystick controller. (As per the experiment)
- **Idle Mode** – (4th icon) stops the MAV.

Activating Camera Views and taking Snapshot photos



These camera buttons allow the operator to switch between the two available camera images. On the OCU, camera image #1 is the view from the MAV's forward camera, and camera image #2 displays the view from the downward camera. In this experiment, one camera view will be displayed at a time so the operator will need to switch views in order to **activate** a camera for taking snapshots.

The active camera image will always have a blue border on the top of the view frame as well as an () overlay in the center of the image. The corresponding icon on the task bar will also illuminate. To change the active camera view, you must use the [MOUSE/GAME CONTROLLER] to activate the group of icons on the task bar and select the camera you want.

To activate a camera view:

FOR MOUSE: This is done by using the mouse to click on the desired camera view in the task bar. I will demonstrate this feature now.

FOR GAME CONTROLLER: This is done by pressing and holding button (2) while you scroll through the available camera views with the directional pad. I will demonstrate this feature now.

If not already airborne, try taking off and switching the camera view.

FOR MOUSE: Snapshots of targets can now be taken by using the mouse to right-click on the frame of the active camera view.

FOR GAME CONTROLLER: Snapshots of targets can now be taken using button (9) on the game controller.

(Continue going over the manual with the participant):

Main Window Components



Altimeter - (See vertical bar on the left side of this page)

The ruler-like markings on the altimeter display the altitude of the MAV in feet above sea level. If the experimenter has activated the altitude alarm system, flying above or below the specified altitudes will result in a visual alarm on the altimeter. The experimenter will notify you **if** an alarm has been set.

< The white triangle cut-out points to the current altitude of the MAV. In this case, the MAV is approximately 82 feet above sea level.

The light brown column at the lower end of the bar marks the altitude of the nearest surface below the MAV (this is the current ground level).

Note!~ In the current example, the MAV is approximately 82 feet above sea level, but the ground level is approximately 22 feet. This means the MAV is only 60 feet above ground!

Input Control Pad Game Controller:



You will issue commands to the MAV by using the game controller, and you will receive feedback from the on-screen input control pad.

The four arrow icons will illuminate when forward, backward, (strafe) left, and (strafe) right commands are issued to the MAV. The curved arrow icons in the upper corners will illuminate when rotate commands are given. The lower-corner icons will illuminate when you issue the ascend or descend command to the MAV. The middle X icon lights up if you give a stop/hover command to the MAV.

The control pad provides feedback in this way to the operator that a command has been issued and is being executed. As discussed, arrow icons on the control pad will illuminate when that command has been entered (e.g., when you push forward on the game controller, the forward arrow will illuminate). The brighter the icon gets, the faster you are traveling. Your airspeed is also shown here in knots. The max speed is 6 knots.

We will now go over how to use the game controller for all of the tasks required during this experiment.

Input Control Pad Mouse:



You will issue commands to the MAV by using the mouse, and you will receive feedback from the on-screen input control pad. This input control pad lets you control the position of the MAV manually. For this display, nine buttons are used as the interface to the MAV.

The four arrow icons move the MAV forwards, backwards, (strafe) left, and (strafe) right. The curved arrow icons in the upper corners rotate the MAV left and right. The lower corner icons move the MAV up and down. The middle X icon stops the MAV.

You must use the mouse to click on the control display in order to activate the MAV. Arrow icons on the discrete control pad will illuminate when a command has been entered (e.g., when you click on the forward arrow on the control pad, the forward arrow will illuminate). The brighter the icon gets, the faster you are traveling. Your airspeed is also shown here in knots. The max speed is 6 knots.

We will now go over how to use the mouse for all of the tasks required during this experiment.

Controlling MAV movement with the Mouse (condition 2):

The **left mouse button** is responsible for clicking and activating icons on the task bar as well as the directional arrows on the control pad to direct MAV movement, actions, and camera views.

The **right mouse button** is responsible for taking snapshots. The **scroll wheel** will not be used during this simulation. At this time, you may take off and practice piloting the MAV for 1-2 minutes.

Controlling MAV movement with the Game Controller (condition 1):

The **left thumb stick** controls movement forward, backward, and sideways (or at angles), but the MAV heading never changes when the left thumb stick is used. Pushing up on this thumb stick moves the MAV forward. Pulling down on the stick moves the MAV backwards. Moving the stick from side to side moves the MAV right or left without altering heading (moving laterally).

The **right thumb stick** controls altitude and heading/rotation. Pushing up on the stick increases the MAV's altitude, and pulling down decreases altitude. Moving the right thumb stick from side to side rotates the MAV in place.

It is possible (and expected) to use both sticks simultaneously to rotate, change altitude, and move at the same time. Vehicle speed is graded, meaning that barely pressing the thumb stick will cause the MAV to move more slowly than pressing it all the way down. Releasing the thumb sticks will slow and stop the MAV, causing it to hover in mid-air.

At this time, you may take off and practice manipulating the thumb sticks for 1-2 minutes.

Controlling MAV movement with the Game Controller (condition 3):

The **left thumb stick** controls movement forward, backward, and sideways (or at angles), but the MAV heading never changes when the left thumb stick is used. Tapping up with this thumb stick moves the MAV forward. Tapping down with the stick moves the MAV backwards. Tapping the stick from side to side moves the MAV right or left without altering heading (moving laterally). You should **not** hold the thumb stick down when sending a command—always press and release to issue a command.

The **right thumb stick** controls altitude and heading/rotation. Tapping up with the stick increases the MAV's altitude, and tapping down decreases altitude. Moving the right thumb stick from side to side and releasing rotates the MAV in place. You should **not** hold the thumb stick down when sending a command—always press and release to issue a command.

The **stop/hover command** is given by pressing in and releasing either thumb stick. I will demonstrate this now.

You are only able to move in **ONE** direction at a time. A new command will cancel the previous command.

At this time, you may take off and practice manipulating the thumb sticks for 1-2 minutes.

Controlling MAV movement with the Game Controller (condition 4):

The **left thumb stick** controls movement forward, backward, and sideways (or at angles), but the MAV heading never changes when the left thumb stick is used. Tapping up with this thumb stick moves the MAV forward. Tapping down with the stick moves the MAV backwards. Tapping the stick from side to side moves the MAV right or left without altering heading (moving laterally). You should **not** hold the thumb stick down when sending a command—always press and release to issue a command.

The **right thumb stick** controls altitude and heading/rotation. Tapping up with the stick increases the MAV's altitude, and tapping down decreases altitude. Tapping the right thumb stick from side to side rotates the MAV in place. You should **not** hold the thumb stick down when sending a command—always press and release to issue a command.

The **stop/hover command** is given by pressing in and releasing either thumb stick. I will demonstrate this now.

It is possible (and expected) to use both sticks simultaneously to rotate, change altitude, and move at the same time. To do this, you must **press and release** the controls **at the same time**.

Now, you may take off and practice manipulating the thumb sticks for 1-2 minutes.

Controlling MAV movement with the Game Controller (condition 5):

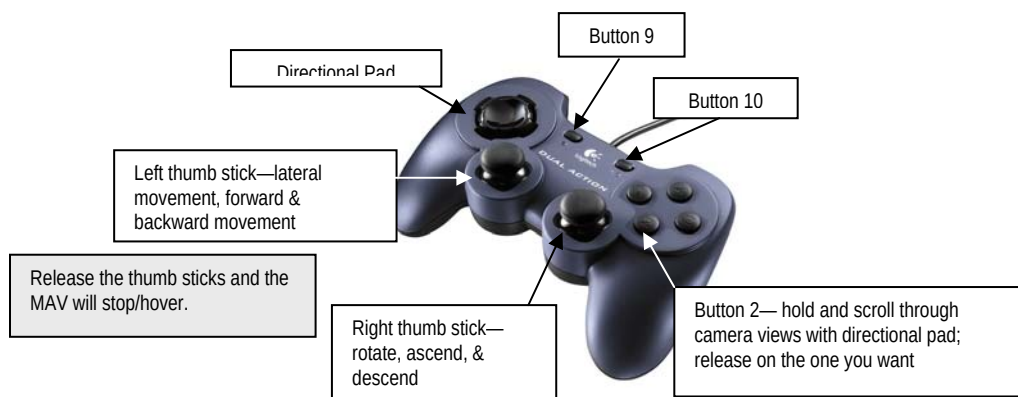
The **left thumb stick** controls movement forward, backward, and sideways (or at angles), but the MAV heading never changes when the left thumb stick is used. Pushing up on this thumb stick moves the MAV forward. Pulling down on the stick moves the MAV backwards. Moving the stick from side to side moves the MAV right or left without altering heading (moving laterally).

The **right thumb stick** controls altitude and heading/rotation. Pushing up on the stick increases the MAV's altitude, and pulling down decreases altitude. Moving the right thumb stick from side to side rotates the MAV in place.

You are only able to move in **ONE** direction at a time. A new command will cancel the previous command. Vehicle speed is graded, meaning that barely pressing the thumb stick will cause the MAV to move more slowly than pressing it all the way. Releasing the thumb sticks will slow and stop the MAV, causing it to hover in mid-air.

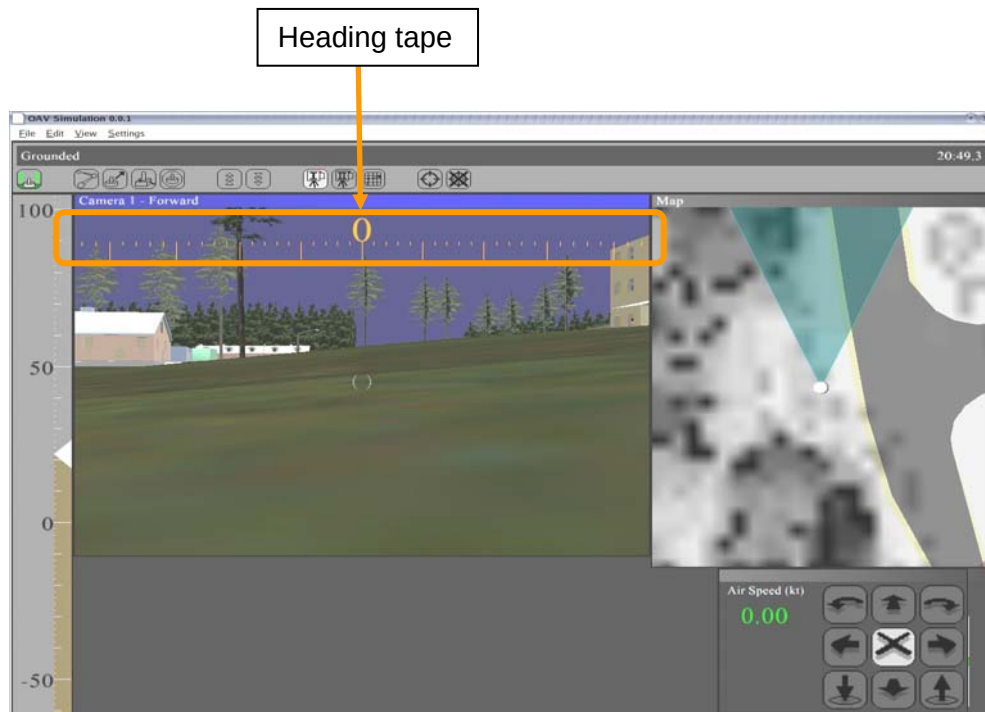
At this time, you may take off and practice manipulating the thumb sticks for 1-2 minutes.

Game Controller Configuration:

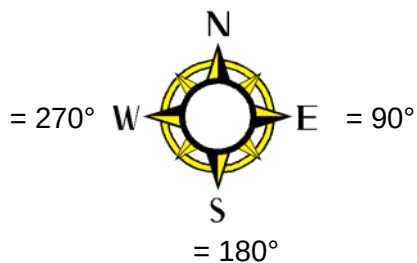


Heading Tape

Note that each camera view window has a **heading tape** located along the top edge of the frame. This number indicates the current heading of the vehicle (based on 360 degrees) with regard to that camera image. Because the cameras have been locked in place for this experiment, you can assume that the forward camera view heading is the same as the MAV heading.



If the heading tape = 0°



Important Note!! The downward camera view is locked at 90 degrees from horizontal, which is essentially straight down. However, when the MAV is in motion the vehicle tilts in a similar manner to a moving helicopter. This tilting will cause the downward camera to point slightly backwards when moving.

Practice Time: Now that you have learned all the functions of the operator control unit (OCU) and the flight controls, we will complete a series of practice exercises beginning on the next page.

Practice Exercises

These exercises will give you a chance to practice the various tasks required to complete the missions in this study.

For each of these simulated exercises, you will be controlling the MAV from a C2 (command-control) vehicle (which looks like a Hummer). Your C2 vehicle is marked on the satellite map with a blue icon.



= C2 vehicle

(Continue going over the manual with the participant):

FOR MOUSE: Warm Up: Load the correct properties file—exp3_cond2.opf. No mission file or OneSAF scenario is required for this exercise.

The experimenter will call out movement commands one by one, and you need to move the MAV accordingly. You will notice that inertia comes into play when trying to stop the MAV, so you will need to learn to estimate things like stopping distances and rotational velocity carry-over.

- 1) Use the mouse to click on the up and down arrows located on the bottom left and right of the control pad to make the MAV ascend and descend.
- 2) Click the curved arrows to rotate the MAV left and right.
- 3) Click the up and down arrows to make the MAV fly forward and backwards.
- 4) Click the left and right arrows to move the MAV laterally. These arrows allow you to strafe left and right. Note that the heading only changes when you rotate the MAV with the curved arrows.
- 5) Click the X to halt movement of the MAV. Note that the MAV will not stop immediately; instead, it will decelerate and then come to a halt.
- 6) Activate camera 2 (by clicking the camera icons on the task bar), and then activate camera 1. Now switch back to camera 2 and take a snapshot (**by right-clicking on the camera frame**).
- 7) Land the MAV.

Next you will complete a series of timed practice exercises. The experimenter will observe these exercises and determine if you have met the time requirement before allowing you to proceed to the next exercise. You have 5 attempts to successfully complete each of the practice exercises. Failure to complete within 5 attempts will result in a dismissal from the experiment. If this happens, you will be compensated for the time you participated.

FOR GAME CONTROLLER: Warm Up: Load the correct properties file— No mission file or OneSAF scenario is required for this exercise.

The experimenter will call out movement commands one by one, and you need to move the MAV accordingly. You will notice that inertia comes into play when trying to stop the MAV, so you will need to learn to estimate things like stopping distances and rotational velocity carry-over.

- 1) Move the right thumb stick up and down to make the MAV ascend and descend.
- 2) Move the right thumb stick side to side to rotate the MAV.
- 3) Move the left thumb stick up and down to make the MAV fly forward and backwards.
- 4) Move the left thumb stick side to side to move the MAV laterally. Note that the heading only changes when you rotate the MAV with the right thumb stick.
- 5) Activate camera 2, and then activate camera 1. Now switch back to camera 2 and take a snapshot.
- 6) Land the MAV.

Next you will complete a series of timed practice exercises. The experimenter will observe these exercises and determine if you have met the time requirement before allowing you to proceed to the next exercise. You have 5 attempts to successfully complete each of the practice exercises. Failure to complete within 5 attempts will result in a dismissal from the experiment. If this happens, you will be compensated for the time you participated.

FOR MOUSE & GAME CONTROLLER: Practice Exercises

Practice Exercise 1: Load the correct properties file for the condition— No mission file or OneSAF OTB scenario is required for this exercise.

We will go over the practice exercise requirements before you begin:

- 1) Click OK (*button 10 on game controller*) to start the simulation and timer.
- 2) Execute the **Take-off** command.
- 3) When the Red Stop icon illuminates, execute the **Land** command.
- 4) This must be completed in 30 seconds (:30) or less.

Do you have any questions about the practice exercise?

Practice Exercise 2: Load the correct properties file for the condition— No mission file or OneSAF OTB scenario is required for this exercise.

We will go over the practice exercise requirements before you begin:

- 1) Click OK (*button 10 on game controller*) to start the simulation and timer.
- 2) Execute the **Take-off** command.
- 3) At or before the completion of take-off, activate the view window for camera 1 (forward view).
- 4) Take a snapshot with camera 1.
- 5) Activate the view window for camera 2 (down view).
- 6) Take a snapshot with camera 2.
- 7) Execute the **Land** command.
- 8) This must be completed in 40 seconds (:40) or less.

Do you have any questions about the practice exercise?

Practice Exercise 3: Load the correct properties file for the condition— No mission file or OneSAF OTB scenario is required for this exercise. **Set the upper altitude alarm at 150 feet and activate it.**

We will go over the practice exercise requirements before you begin:

- 1) The upper altitude alarm will be set at 150 feet and activated.
- 2) Click OK (*button 10 on game controller*) to start the simulation and timer.
- 3) Execute the **Take-off** command.
- 4) Ascend to a little above 150 feet, and you will trigger the alarm automatically.
- 5) Immediately descend to 50 feet or below without hitting the ground.
- 6) Ascend back up to 100 feet but less than 150 feet.
- 7) Rotate the MAV 360-degrees without dropping below 100 feet. It is required that the heading tape shows the number “0” after completing 1 rotation with the MAV. The “0” must remain in the forward camera view window before landing (it does not need to be centered, just viewable on the screen).
- 8) Execute the **Land** command.
- 9) This exercise must be completed in 1 minute 35 seconds (1:35) or less.

Do you have any questions about the practice exercise?

Practice Exercise 4: rapid command execution: Load the correct properties file for the condition— No mission file or OneSAF scenario is required for this exercise.

After take-off and as soon as the Red Stop icon illuminates, you will immediately begin to hear a series of flight commands. Commands will be given as fast as you can correctly comply. Once the correct feedback is observed from the OCU, [the experimenter] will give you a new command.

Note: It is not important that the MAV travels any considerable distance. The purpose of this exercise is to allow you to learn the mapping of all buttons and icons and their corresponding functions. The experimenter is looking mainly for the correct feedback from the OCU control pad located in the lower right of the display.

We will go over the practice exercise requirements before you begin:

Rapid command execution - Part A Participant

- 1) Click OK (*button 10*) to start the simulation and timer.
- 2) Execute Take-off.
- 3) The first series of commands after take-off will be: **9 commands**
- 4) This exercise must be completed in 1 minute 5 seconds (1:05) or less.

Do you have any questions about the practice exercise?

Rapid command execution - **Part A Experimenter**

- 1) The first series of commands after take-off should be: ***Ascend, descend, fly forward, fly (strafe) right, fly (strafe) left, fly backwards, rotate right, rotate left, land.***
- 2) This exercise must be completed in 1 minute 5 seconds (1:05) or less.
- 3) Note the time to complete and reload the properties file (this resets timer).

The experimenter will now reload the scenario.

Rapid command execution - **Part B Participant**

- 1) Click OK (*button 10*) to start the simulation and timer.
- 2) Execute Take-off.
- 3) The first series of commands after take-off will be: **14 commands**
- 4) This exercise must be completed in 1 minute 25 seconds (1:25) or less.

Do you have any questions about the practice exercise?

Rapid command execution - **Part B Experimenter**

- 1) The second series of commands after take-off should be: ***fly forward, fly backwards, rotate right, fly (strafe) right, fly (strafe) left, activate camera 2, take snapshot with camera 2, ascend, descend, hover, activate camera 1, take snapshot with camera 1, fly forward, land.***
- 2) This exercise must be completed in 1 minute 25 seconds (1:25) or less.
- 3) Note the time to complete.

The next two exercises involve flying the MAV over longer distances and following pre-determined mission parameters. These will be similar to the missions you will complete during the remainder of the experiment.

Practice Exercise 5: Load the correct properties file for the condition (with racetrack poles, see below)— Then load the mission file: **Racetrack.ovm**. No OneSAF scenario is required for this exercise. Run the mission autonomously with waypoints visible and point out the Landing Zone (LZ) on the (H) building.

In this exercise you will pilot the MAV around the main roadway. Waypoints will be visible in the overhead map view window so that you can refer to them if you need to look at the route.

We will go over the practice exercise requirements before you begin:

- 1) The experimenter will load and run this mission autonomously and will point out the Landing Zone (LZ) on the (H) building.
- 2) After the autonomous mission finishes, the simulation will be reset.
- 3) You must now pilot the MAV around the gray pathway while remaining to the left of the four red poles and then land in the correct LZ.
- 4) When ready, click OK (*button 10*) to start the timer.
- 5) Execute the **Take-off** command.
- 6) Complete one lap around the four red poles and stay over the gray path.
- 7) Land on the (H) building.
- 8) This exercise must be completed in 3 minutes 50 seconds (3:50) or less.

Do you have any questions about the practice exercise?

Experimenter:

- 1) Run the mission autonomously with waypoints visible and point out the Landing Zone (LZ) on the (H) building.
- 2) Reload the properties file with waypoints visible.
- 3) Reload the mission file.
- 4) Explain that the operator must now manually pilot the MAV around the gray pathway while remaining to the left of the 4 red poles and landing in the correct LZ.
- 5) User now executes the **Take-off** command.
- 6) User completes one lap around the red poles and lands on the (H) building.
- 7) This exercise must be completed in 3 minutes 50 seconds (3:50) or less.
- 8) **If the participant crashes, reload the properties file and the mission file and have them restart the exercise.**

Practice Exercise 6: Load the correct properties file for each condition with obstacle course poles (see below)— Then load the mission file: **obstaclecourse.ovm**. No OneSAF OTB scenario is required for this mission.

In this exercise you have obstacles to navigate. Complete the mission by flying through the series of red and green poles, and then return to your start point to take two snapshots of your C2 vehicle.

We will go over the practice exercise requirements before you begin:

- 1) The experimenter will load and run this mission autonomously. Observe how the MAV passes to the **right** of all green poles and to the **left** of all red poles.
- 2) At the end of the run you will see the C2 vehicle parked on the road.
- 3) The experimenter will now reload the mission.
- 4) You must now complete the course with a few additional instructions: **After you finish navigating around the poles, you will need to take snapshots of the C2 vehicle with both cameras before landing the MAV.**
- 5) When ready, click OK (*button 10*) and then execute **Take-off**.
- 6) Complete the obstacle course.
- 7) Take snapshot of C2 vehicle from camera 1.
- 8) Take snapshot of C2 vehicle from camera 2.
- 9) Land near the C2 vehicle – but do NOT land on the C2 vehicle.
- 10) This exercise must be completed in 5 minutes (5:00) or less.

Do you have any questions about the practice exercise?

Experimenter:

- 1) Have the participant complete the **NASA TLX** on the laptop at the conclusion of practice exercise 6.
- 2) Then give the paper-based training **quiz** to verify that the operator can identify all of the icons and control buttons used in the study.
- 3) When this is completed you may proceed to the mission trials on the next page. There will be five total missions that will be run in the following order:

Mission 1 – Racetrack without visible waypoints (Ft. Polk).

Mission 2 – The obstacle course with snapshots of the C2 vehicle without visible waypoints (Ft. Polk).

Mission 3 – The multiple target ID/reconnaissance mission with “unlimited” time (Ft. Polk).

Mission 4 – Transfer skills mission without visible waypoints (Ft. McKenna).

Mission 5 –Moving target reconnaissance mission with “unlimited” time (Ft. McKenna)

Note: Each mission will have a corresponding section on the “observer data collection” form where the experimenter should note all pertinent information. This can then be cross-referenced with the time stamps and other recorded actions contained in the OCU data file.

Mission Protocol

There will be 5 missions for you to complete during this portion of the study. The experimenter will instruct you on mission requirements and provide any documentation necessary. Once you begin a mission, the experimenter will not be able to answer questions on mission requirements, so please ask beforehand.

Mission 1: Racetrack without visible waypoints (Ft. Polk).

Stress to person that they need to try to complete this mission as quickly as possible but **also** without any collisions –if they have a collision, restart the mission immediately and make them redo until they complete without a collision.

Experimenter:

- 1) Load the correct properties file for each condition (with racetrack poles)--
- 2) No OneSAF OTB scenario is required for this exercise.
- 3) Read over the mission with the participant (see below).
- 4) User now executes the **Take-off** command and completes mission.
- 5) User completes one lap around the red poles and lands on the (H) building.

Mission 1:

This mission is a repeat of practice exercise #5, where you piloted the MAV around the gray pathway while remaining to the left of the four red poles. The only difference is that there will be no waypoints on the satellite map.

You need to try to complete this mission as quickly as possible but **also** without any collisions – if you have a collision, you will be required to redo the mission from the beginning until you complete it without a collision.

We will go over the mission requirements before you begin:

- 1) You will pilot the MAV around the gray pathway while remaining to the left of the four red poles, and then land on the (H) building.
- 2) When ready, press OK to start the timer.
- 3) Execute the **Take-off** command.
- 4) Complete one lap around the four red poles and stay over the gray path.
- 5) Land on the (H) building.

Do you have any questions about the mission?

Experimenter: After Mission 1, have the participant take the NASA TLX before Mission 2.

Mission 2: The obstacle course with snapshots of the C2 vehicle (Ft. Polk).

Stress to person that they need to try to complete this mission as quickly as possible but **also** without any collisions –if they have a collision, restart the mission immediately and make them redo until they complete without a collision.

Experimenter:

- 1) Load the correct properties file with obstacle course poles—
- 2) No OneSAF OTB scenario is required for this mission.
- 3) Read over the mission with the participant (see below).
- 4) Operator should now take-off and complete the mission.

Mission 2:

This mission repeats practice exercise #6, where you navigated a series of red and green poles. You will also take two snapshots of the C2 vehicle at the end of the run. The only difference is that there will be no waypoints on the satellite map.

You need to try to complete this mission as quickly as possible but **also** without any collisions – if you have a collision, you will be required to redo the mission from the beginning until you complete it without a collision.

We will go over the mission requirements before you begin:

- 1) You must complete the obstacle course.
- 2) After you finish navigating around the poles (right of the green poles and left of the red poles), you will need to take snapshots of the C2 vehicle with both cameras.
- 3) When ready, press OK and then execute Take-off.
- 4) Complete the obstacle course.
- 5) Take snapshot of the C2 vehicle with camera 1.
- 6) Take snapshot of the C2 vehicle with camera 2.
- 7) Land, but do NOT land on the C2 vehicle.

Do you have any questions about the mission?

Experimenter: After Mission 2, have the participant take the NASA TLX before Mission 3.

Mission 3: The multiple target ID/reconnaissance mission (Ft. Polk).

Experimenter:

- 1) Load the OneSAF scenario **Exp3Polk6targets.2.gz**
- 2) Load the correct properties file:
- 3) No mission file is required for this mission.
- 4) Advise the participant to click OK to begin the mission and start looking for entities to identify via the camera snapshots.
- 5) Make notes on the data collection form as to any entities that are identified more than once, as well asking any mission related questions as outlined on the same form.
- 6) The user should land when all targets have been identified or when the 15 minute mark is reached.

Mission 3:

This mission involves using the MAV to do reconnaissance work. This is primarily a target identification mission. You need to complete this mission as quickly as possible.

We will go over the mission requirements before you begin:

- 1) You need to find and identify (take snapshots) all 6 targets on the map (see Intel sheet on the next page), with a maximum search time of 15 minutes.
- 2) Positive ID can only be achieved by taking snapshots of each entity with both the forward and downward cameras, and each entity must be centered in the frame so that the center () overlay is touching part of the entity. The entity doesn't need to be perfectly centered in the overlay.
- 3) When ready press OK to begin the mission and start the timer.
- 4) Begin looking for entities to identify via the cameras.
- 5) Land the MAV immediately after finding and photographing all targets.

Do you have any questions about the mission?

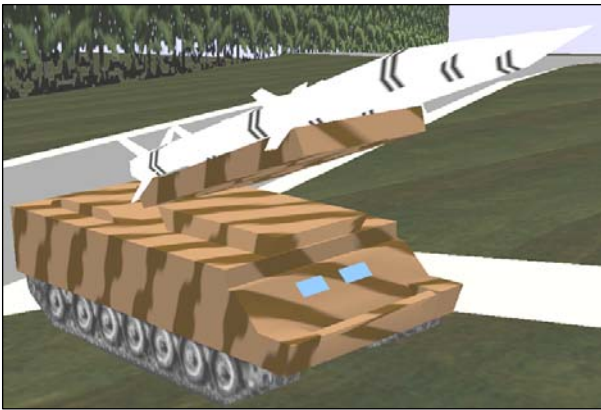
Experimenter: After completing Mission 3, have the participant take the NASA TLX before Mission 4. ***Inform the participant that the next two missions will be in new simulated environments.***

Mission 3: Intel Sheet

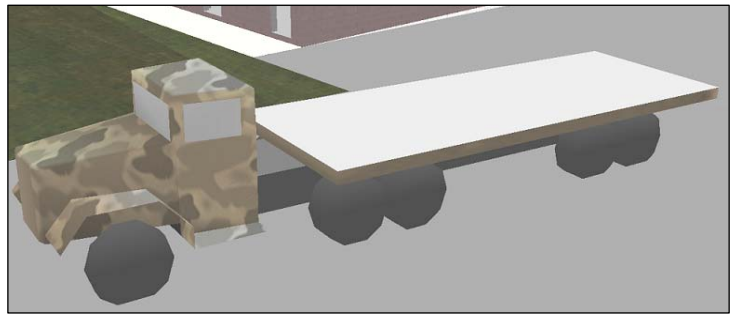
The entities shown below have been identified as having terrorist involvement within the military base. Your mission will be to scout the base area and identify all 6 of these enemy targets.

Positive identification can only be achieved by taking snapshots of each entity with BOTH the forward and downward cameras, and each entity must be centered in the frame so that the center framing () overlay is touching the entity in the picture. The entity doesn't need to be perfectly centered in the overlay. Find and photograph all entities as quickly as you can. The mission will end if targets have not been found within 15 minutes.

DO NOT crash the MAV vehicle! Land the MAV immediately after finding and photographing all targets.



(A) 2 Tanks with Armed Missiles



(B) 2 Flatbed Supply Trucks



(C) 1 Oil Truck



(D) 1 Armed Soldier

Mission 4: The transfer skills obstacle course (Ft. McKenna).

Stress to person that they need to try to complete this mission as quickly as possible but **also** without any collisions –if they have a collision, restart the mission immediately and make them redo until they complete without a collision.

Experimenter:

- 1) Load the correct properties file with new environment and obstacle poles
- 2) Load the mission file: **McKenna Obstacle Course.ovm**
- 3) No OneSAF OTB scenario is required for this exercise.
- 4) Read the mission with the participant (see below).
- 5) Run the mission autonomously with waypoints visible.
- 6) Inform the participants that they must complete the course (without crashing) in as many tries as necessary before moving on the Mission 5—there is no time limit for this particular mission.
- 7) Reload the properties file.
- 8) User now executes the **Take-off** command and completes mission.

Mission 4:

The final two missions will be in a new simulated environment. Mission 4 involves using the MAV to navigate around obstacles. Complete the mission by piloting the MAV around the roadway, flying through the series of red and green poles, and then landing in the designated area. **You must fly to the left of the red poles and to the right of the green poles.**

You need to try to complete this mission as quickly as possible but **also** without any collisions – if you have a collision, you will be required to redo the mission from the beginning until you complete it without a collision. We will go over the mission requirements before you begin:

- 1) The experimenter will load and run this mission autonomously with waypoints visible. Observe how the MAV passes to the **right** of all green poles and to the **left** of all red poles.
- 2) You must now complete the course. You must navigate the obstacle course without crashing before you can move on to the final mission.
- 3) When ready, press OK and then execute **Take-off**.
- 4) Complete the obstacle course.
- 5) Land in the designated area beside the church.
- 6) This exercise must be completed without crashing in as many tries as necessary. There is no time limit.

Do you have any questions about the mission?

Experimenter: After completing Mission 4, have the participant take the NASA TLX before Mission 5.

Mission 5: The multiple target ID/reconnaissance mission (Ft. McKenna).

Experimenter:

- 1) Load the OneSAF OTB scenario ***Exp3McKenna6targets.1.gz***
- 2) Load the correct properties file—
- 3) No mission file is required for this mission.
- 4) Make notes on the data collection form as to any entities that are identified more than once, as well asking any mission related questions as outlined on the same form.
- 5) The user does not need to land unless all targets have been identified. When the timer reaches **15 minutes** and the operator hasn't found all targets, ask him or her to land.

Mission 5

This mission involves using the MAV to do more reconnaissance work. This is primarily a target identification mission. You need to complete this mission as quickly as possible.

We will go over the mission requirements before you begin:

- 1) The experimenter will load the mission files and scenario.
- 2) You need to find and identify (take snapshots) all 6 targets on the map (see Intel sheet on next page), with a maximum search time of 15 minutes.
- 3) Positive ID can only be achieved by taking snapshots of each entity with both the forward and downward cameras, and each entity must be centered in the frame so that the center () overlay is touching part of the entity. The entity doesn't need to be perfectly centered in the overlay.
- 4) When ready press OK to begin the mission and start the timer.
- 5) Begin looking for entities to identify via the cameras.
- 6) Land the MAV immediately after finding and photographing all targets.

Do you have any questions about the mission?

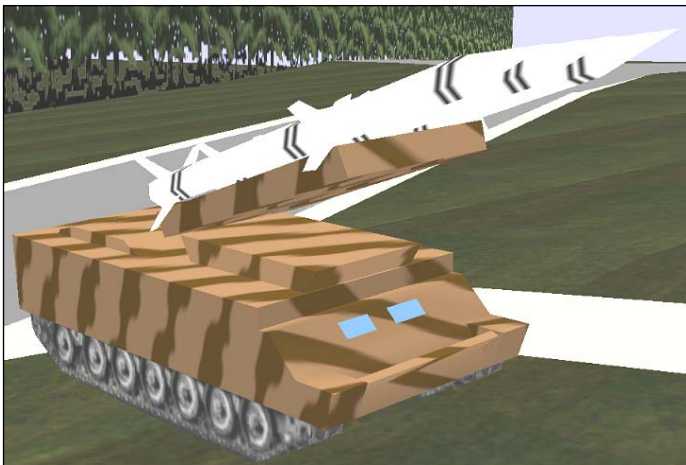
After Mission 5, complete the computer-based questionnaire; then proceed to the final debriefing session.

Mission 5: Intel Sheet

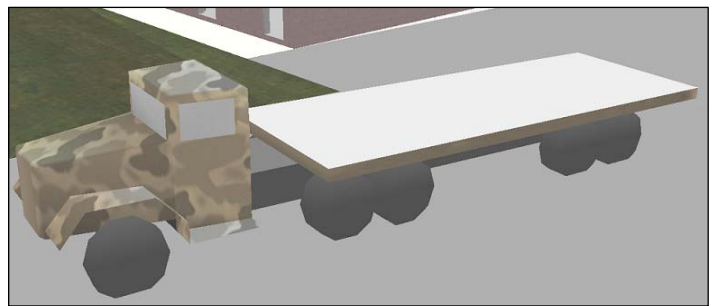
The entities shown below have been identified as having terrorist involvement within the military base. Your mission will be to scout the base area and identify all 6 of these enemy targets.

Positive identification can only be achieved by taking snapshots of each entity with BOTH the forward and downward cameras, and each entity must be centered in the frame so that the center framing () overlay is touching the entity in the picture. The entity doesn't need to be perfectly centered in the overlay. Find and photograph all entities as quickly as you can. The mission will end if targets have not been found within 15 minutes.

DO NOT crash the MAV vehicle! Land the MAV immediately after finding and photographing all targets.



(A) **2** Tanks with Armed Missiles



(B) **2** Flatbed Supply Trucks



(C) **1** Oil Truck



(D) **1** Armed Soldier

Experimenter: After Mission 5 is completed...

- 1) Have the participant take the NASA TLX
- 2) Give participant the Debrief sheet, and field any questions he/she may have
- 3) If no questions, proceed to either give participants monetary compensation or point compensation.
- 4) Before they leave, give them the Psychology Participant Research Experience Form.