

2007

Operating an Unmanned Aerial System from a Moving Platform

Cadet Guennadi S. Antonov

Cadet Mark C. Domogala

Lt Col Wesley A. Olson

Follow this and additional works at: https://corescholar.libraries.wright.edu/isap_2007



Part of the [Other Psychiatry and Psychology Commons](#)

Repository Citation

Antonov, C. S., Domogala, C. C., & Olson, L. A. (2007). Operating an Unmanned Aerial System from a Moving Platform. 2007 *International Symposium on Aviation Psychology*, 13-18.
https://corescholar.libraries.wright.edu/isap_2007/133

This Article is brought to you for free and open access by the International Symposium on Aviation Psychology at CORE Scholar. It has been accepted for inclusion in International Symposium on Aviation Psychology - 2007 by an authorized administrator of CORE Scholar. For more information, please contact corescholar@www.libraries.wright.edu, library-corescholar@wright.edu.

OPERATING AN UNMANNED AERIAL SYSTEM FROM A MOVING PLATFORM

Cadet Guennadi S. Antonov
Cadet Mark C. Domogala
Lt Col Wesley A. Olson
United States Air Force Academy
USAF Academy, CO

While the Spatial Disorientation (SD) has long been recognized as an important causal factor in aviation incidents and accidents, it is only beginning to be recognized as a factor in Uninhabited Aerial Systems (UASs). Self, Ercoline, Olson and Tvaryanas (2006) predicted SD to be most likely for a manually controlled UAV when operated from a mobile platform. As a first step towards better understanding the effects of control platform motion on manual UAV control Olson, DeLauer and Fale (2006) had 10 rated Air Force pilots fly a simulated UAV task (MS Flight Simulator) from a motion capable control platform (aircraft simulator). Participants performed two basic flight tasks – a vertical task (climb/descent) and a horizontal (turning task). The control platform motion was varied to provide either congruent, neutral, or conflicting motion cues. Congruent and incongruent motion cues were defined as motion in the same axis and either same/different direction as the primary task (i.e., simulator turned left/right and task was a constant left hand turn). Neutral motion was defined as motion in a different axis of motion relative to the primary task (i.e., simulator motion was climb/descent and task was a constant bank turn). There were three levels of visual and vestibular control platform motion cues (no motion/visual cues, motion with no outside visual display, motion with outside visual). The results indicate that there was little effect of control platform motion on roll axis performance, i.e., bank and heading error. However, pitch axis deviations (altitude and vertical velocity) showed an effect of both control platform motion and motion type. Presence of both visual and motion cues resulted in greater pitch deviations than motion only or baseline (no motion/no visual cue) conditions and the presence of motion in the off-axis of motion resulted in the greatest error. These results suggest that platform motion may interfere with an operator's ability to manually control a UAV from a moving platform (a possible precursor to SD). The current study replicates the simulator study using an aircraft (C-172) as the control platform. This will allow for a more complete examination of platform motion cues since simulators cannot adequately simulate sustained motion. This study also adds a landing task to examine glide path and azimuth error. Data collection is not yet complete, however initial results indicate that, as in the previous simulator study, control platform motion resulted in greatest interference in the vertical axis and the presence of both motion and visual cues resulted in the greatest control interference. These results have implications for planned UAV operations from both fighter and transport aircraft.

Background

Operational needs are driving both military and civilian operators to consider operating UASs from moving platforms (ground, sea, and air vehicles) (DeLauer & Fale, 2006). Controlling a UAS from a moving platform introduces challenges that are different from a ground-based control station; namely Spatial Disorientation (SD) and conflicting visual cues and vestibular/proprioceptive inputs. It seems likely that motion cues (visual as well as vestibular/proprioceptive) resulting from control platform motion may interfere with UAS control.

A wealth of experience from manned aviation indicates that conflicting motion cues can lead to SD. In the case of UAS control from a moving platform these conflicting cues may be manifested by degraded UAS control. While little formal research has been conducted in UAS SD or control interference, work by Self, Ercoline, Olson and Tvaryanas (2006) suggests that these phenomena would be most likely to occur when UAS's are manually controlled from a moving platform. While

the concept of spatial disorientation in a UAS may seem unlikely to those unfamiliar with UAS operations, Tvaryanas, Thompson and Constable (2005) report a number of UAS accidents in which SD was a causal factor. In order to better understand the linkage between conflicting visual and vestibular cues and UAS control performance, controlled studies must examine the impact of visual cues and control platform motion.

One of the few laboratory studies on the effects of control platform motion and UAS controllability was conducted by Reed (1977) at the Advanced Systems Division, Wright-Patterson Air Force Base, Ohio. This study concentrated on visual-proprioceptive cue conflicts in the control of remotely piloted vehicles (RPVs). In this study, a simulated RPV was controlled from a motion-based simulator. Control platform motion was limited to simulated turbulence. The results indicate that simulated turbulence did have a negative effect on RPV control (control errors and response time), particularly when control platform motion conflicted with control inputs

necessary for RPV control and in the presence of visual motion cues.

In order to better understand the impact of control platform motion cues and direction of platform motion, Olson, DeLauer and Fale (2005) conducted a preliminary study on UAS control from a moving platform. In this study, 10 rated military pilots flew a simulated UAS (Microsoft Flight Simulator) from a motion based simulator. The two UAS control tasks included a vertical task (constant rate climb and descent) and a horizontal task (constant bank turns) Independent variables included type of control platform motion cues (none, motion only, visual + motion) and direction of control platform motion relative to the UAS control task (same direction, opposite direction, motion in a different axis). The results indicated that control platform motion did interfere with UAS control, primarily in the vertical axis (climb/descent rate & altitude control). Performance was particularly degraded in the presence of both visual and motion cues and when control platform motion was in different axis than the UAS control task, e.g., control platform climbing or descending when UAS task was to maintain a constant bank turn.

These simulator studies provide important evidence that control platform motion may interfere with UAS control, however, generalizability to an actual aircraft is somewhat limited since simulators can only simulate the onset of control platform motion and cannot simulate sustained motion. Additionally, the Olson, DeLauer and Fale (2005) did not simulate the presence of turbulence.

The purpose of this study is to replicate Olson, DeLauer and Fale (2005) using a Cessna C-172 as the control platform. In addition to the vertical and horizontal tasks, participants in this study will also complete a simulated landing task. Based on previous research we expect that the presence of both motion and visual cues will create a larger error in vertical performance measures (altitude and vertical velocity), especially when the control platform motion is incompatible or in a different plane of motion. Additionally, it seems likely that UAS glide path error will be most affected in the landing task.

Method

Participants

A total of 15 military fixed-wing pilots will serve as participants in this study. Only data from the first 9 participants is reported in this paper. These

participants ranged in military rank from Captain to Brigadier General.

Apparatus

Control Platform. A USAF T-41 (Cessna 172) served as the control platform. This aircraft seats 3 people (pilot, participant and facilitator) and was capable of making the 30 degree banks and 500 fpm climbs and descents with all personnel on board. The participants sat in the back seat of the T-41. In order to ensure adequate out-of-window views, all flights were conducted in visual meteorological conditions (VMC).

Simulated UAS controls and displays. Participants flew a simulated Mooney Bravo in Microsoft Flight Simulator 2004 in the full screen mode (See Figure 1). The simulated weather was clear with unrestricted visibility for all UAS tasks. Both wind and turbulence were set to zero. The simulation was run on a Dell Latitude computer with 17" display and was controlled using a Logitech Attack 3 Joystick. The laptop and joystick were mounted on a kneeboard situated on the participant's lap.



Figure 1. Simulated UAS display for horizontal and vertical tasks.

UAS Control Tasks

Participants flew three different UAS control tasks - a horizontal task, a vertical task and a landing task. In the horizontal task, participants were instructed to maintain a 30 degree bank turn to the right or left while holding a constant altitude. This turn was held for approximately 90 degrees. In the vertical task, participants were instructed to perform a constant rate climb or descent (500 feet per minute) while maintaining a constant heading. The altitude gained or lost during this maneuver was approximately 500 feet. In the landing tasks, the simulated UAS was positioned approximately 3 miles from the landing

runway on the desired glide path and aligned with the landing runway. The simulated landing environment included a standard four light Visual Approach Slope Indicator (VASI) system which was visible to the left of the touchdown zone (See figure 2). Participants were instructed to perform an approach to landing while maintaining a normal glide path and alignment with the runway centerline.



Figure 2. Simulated UAS display for landing task.

Independent Variables

This study employed two independent variables – type of control platform motion cues and direction of control platform motion. *Control platform motion cues*. There were three types of control platform motion cues – no-motion cues, motion-only cues and visual + motion cues. The baseline no-motion cue data was collected on the ground. Motion-only cues were created by having the participants wear a vision restriction device (foggles) so they could only see the UAS display and had no ability to see motion cues out of the aircraft windows. In this case, vestibular and proprioceptive cues served as the only source of information regarding control platform motion. Motion + visual cues were present when the participant was in the air and not wearing vision restricting devices. In this case the participant received both visual (out the window) and vestibular/proprioceptive information regarding control platform motion.

Direction of control platform motion. There were three levels of control platform motion – compatible, incompatible, and different plane of motion. For each type of motion, the control platform (T-41 aircraft) executed 30 degree bank turns or 500 fpm climbs and descents as appropriate. Compatible motion was defined as aircraft motion in the same magnitude and direction as the simulated UAS task,

e.g., aircraft in a 30 degree left turn during a UAS horizontal task requiring a 30 degree left turn. Incompatible motion was defined as aircraft motion in the same magnitude but in the opposite direction of the simulated UAS task, e.g., aircraft climbing at 500 fpm during a UAS task requiring a 500 fpm descent. Different plane of motion was defined as aircraft motion in a different axis from that required by the UAS task, e.g., aircraft climbing at 500 fpm during a UAS task requiring a 30 degree bank turn.

Dependent Variables

Horizontal and vertical measures of UAS control error were collected for each flight task. Error measures were collected using the FSUIPC flight recorder module and were sampled at approximately 2 Hz. For the horizontal (turning) task error measures were altitude error and bank angle error. For the vertical (climb/descent) task error measures were vertical velocity error and heading error. For the landing task error measures were angular deviation from optimum glide path and runway alignment as indicated by Horizontal Situation Indicator (HSI) deviation.

Procedure

Upon arrival, participants were given a brief introduction to the study describing the UAS simulated flight tasks, equipment and procedures. After this introduction, the participants were given 10 minutes of practice time on the flight simulator using the same simulated aircraft and view as required during actual trials. The first five minutes of practice was composed of 90 degree left and right turns at 30 degrees bank as well as wings level 500 feet per minute climbs and descents. After 5 minutes, participants were shown the landing task and allowed to land once. This familiarized them with the runway and VASI lights used to assist in glide path control.

Following this introduction and practice session, participants were pseudo-randomly assigned to complete the baseline (no motion) condition either prior to or after the flight. Roughly half of the participants completed the tasks in the baseline condition prior to the in-flight conditions and roughly half afterwards. Furthermore, within each motion cue condition, half the participants completed the horizontal and vertical tasks prior to the landing task and vice versa.

The baseline (no-motion) condition was completed on the ground. Both the motion-only and the motion+visual condition were completed in the

aircraft. The participant was seated in the aft seat of the T-41 while the facilitator and the pilot sat in the front two seats (see Figure 3). Although sitting in the front seat would have given the participant a better view of the visual platform motion cues, safety considerations prevented the participant from sitting in the front seat.



Figure 3. Seating arrangement for participants.

For the baseline (no-motion) condition, each participant completed each of the three flight tasks one time. For the two in-flight conditions (motion-only and motion+visual cues), the horizontal and vertical tasks were repeated three times – once with each type of platform motion. The landing task was repeated twice – once while the control platform was turning from side to side using 30 degree bank turns, once while the control platform was climbing and descending at 500 fpm. The presentation of each task within each motion cue condition and type of platform motion was blocked to minimize order effects. The facilitator in the front seat coordinated maneuvers with the pilot and instructed the participant which task to complete and when to start and stop each maneuver.

Participants were debriefed after the experiment was finished. The length of the entire experiment was approximately 60 minutes.

Results

Data collection in this study is not yet complete; the data presented in this paper are for only 9 of the planned 15 participants. Please note that only descriptive statistics are presented (means for each condition) since statistical significance using inferential statistics is unlikely due to the small sample size. The following set of figures depicts the mean square horizontal and vertical error measures collected for two of the three flight tasks (the landing data is not included). Recall that bank angle error and altitude error were collected during the horizontal

(turning) task. Vertical velocity and heading error were collected during the vertical (climb/descent) task. Finally, glide path and runway alignment error were collected during the landing task. The figures that follow depict mean square error broken out by motion cue condition and type of platform motion. On each chart, the MSE of the baseline (no-motion) condition error is presented first followed by the motion-only cue condition for each type of platform motion (compatible, incompatible, different plane), and finally the motion + visual cue condition for each type of platform motion.

Figures 4 and 5 present the horizontal (heading) and vertical (VVI) error measures for the vertical (climb/descent) task.

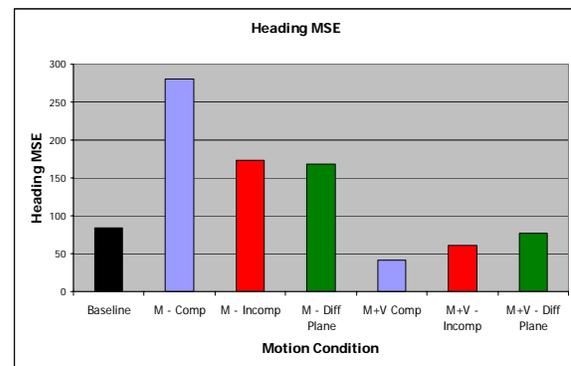


Figure 4. Mean Square Heading error for the climb/descent task.

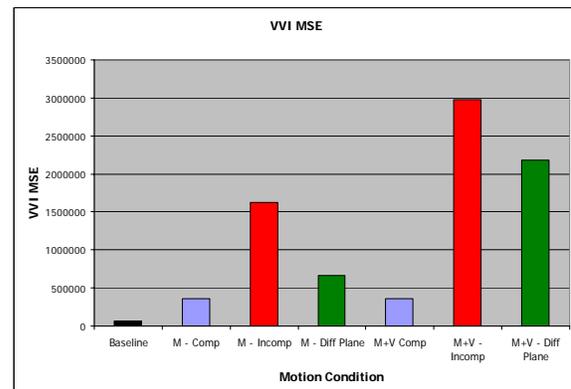


Figure 5. Mean Square VVI error for the climb/descent task.

Although inferential statistics have not been accomplished due to the relatively small sample size, there is a definite trend towards larger error when the control platform was moving. Furthermore, there is a trend towards greater heading error in the motion-only cue condition while vertical velocity error tends to be larger for the motion+visual cue condition. Vertical velocity error also tends to be higher when

the aircraft motion was not in the same direction as required by the UAS flight task.

Figures 6 and 7 present the horizontal (bank angle) and vertical (altitude) error for the horizontal task (30 degree bank turns). It appears that although there is a general increase in bank angle error when UAS control was accomplished in the aircraft, there is no apparent effect of either motion cue type or direction of motion. As was the case with VVI error, the presence of motion and visual cues tended to produce greater altitude error, but the relationship between direction of motion and error is not clear.

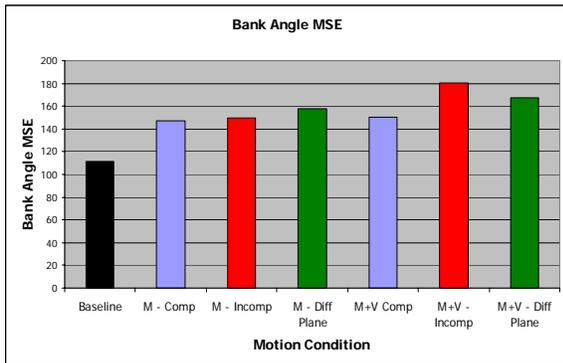


Figure 6. Mean Square bank angle error for the climb/descent task.

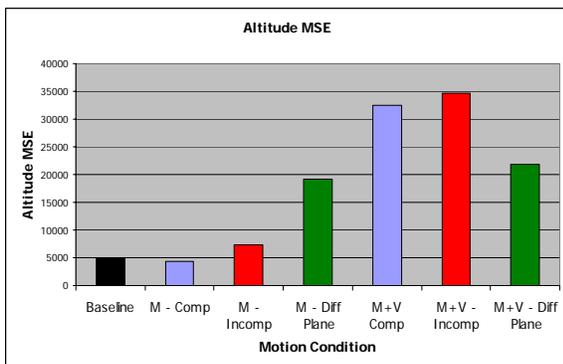


Figure 7. Mean Square altitude error for the climb/descent task.

Data reduction for the landing task is not yet complete, but will be presented at the conference.

Discussion

Caution must be exercised when interpreting the results from this study due to the low sample size, however, some general observations may be made. First, our data are in general agreement with the previous simulator study by Olson, DeLauer and Fale (2005) as well as Reed (1977), i.e., UAS control in

flight tended to result in greater error than when performed in a non-moving platform (the baseline condition). Furthermore, vertical error measures seemed most affected by type of motion cues as well as direction of motion. These data show a trend towards greater vertical error in the presence of both visual and vestibular/proprioceptive cues. Finally, it appears that compatible motion produced the lowest vertical error, although strong statements cannot be made about the relative difference between incompatible motion and motion in a different plane. These findings support the theory that conflicts between the platform motion cues and the UAS control task do result in interference. The relatively greater error when both visual and vestibular/proprioceptive cues are present may be a result of the relative importance of visual information in spatial orientation (Previc, 2004).

The results associated with horizontal error (i.e., bank angle error and heading error) also support the finding that UAS control from a moving platform may be problematic. Both bank angle error and heading error tended to be larger when the UAS task was accomplished in the aircraft. In contrast to the vertical error measures, however, the presence of visual motion cues did not appear to lead to larger horizontal error. On the contrary, it appears that only heading error was affected by motion cue type; it appears that heading error was larger when only motion cues were present. We do not have a strong explanation for this finding, although relative differences in control sensitivity in the horizontal and vertical axes of the simulated UAS task may have accounted for some of these differences.

In addition to these error measures, participants also provided their subjective opinions during the post-experiment debrief. Participants reported the most difficulty in the presence of visual and motion cues when the control platform motion incompatible maneuvers with the UAS control task. Many of the subjects also mentioned that the outside visual cues created considerable difficulty in their performance whether it was a turning or a landing task. These verbal reports do not necessarily match the error data.

These findings have two major implications for UAS control from a moving platform. First, planned UAS operations from moving aircraft must take the likelihood of greater vehicle control error into account. In order to counter these errors UAS systems may need to consider provisions for supervisory control (autopilot, etc.) as opposed to manual vehicle control. Second, it appears that the presence of visual cues may exacerbate control error,

especially in the vertical axis. This finding suggests that operators may be able to better manually control a UAS if they do not have a view of the outside world.

A full data analysis will be presented at the conference. For more information, please contact the authors of this report.

Acknowledgements

This research was supported by a grant from the Institute for Information Technology Applications (IITA) at the United States Air Force Academy. We would also like to thank the project sponsor, Maj Dan Branan, for his support.

References

- Olson, W.A., DeLauer, E.H., and Fale, C. (2006). UAS Control from a Moving Platform – A Preliminary Study. *3rd Human Factors of UAVs Workshop, Mesa AZ, 25 May 2006.*
- Previc, F. (2004) *Visual orientation mechanisms, in Spatial disorientation in aviation.* Edited by F. Previc and W. Ercoline. Progress in Astronautics and Aeronautics, Vol 203. AIAA.
- Reed LE. *Visual-proprioceptive cue conflicts in the control of remotely piloted vehicles.* Brooks AFB, TX: Air Force Human Resources Laboratory; 1977 Sep. Report No.: AFHRL-TR-77-57.
- Self, B.P, Ecronline, W.R., Olson, W.A., and Tvaryana, A.P. (2006). Spatial Disorientation in Uninhabited Aerial Vehicles. In *Human Factors of Remotely Piloted Vehicles.* Amsterdam: Elsevier Science.
- Tvaryanas, A.P., Thompson, B.T. and Constable, S.H. (2005). *U.S. military unmanned aerial vehicle mishaps: Assessment of the role of human factors using Human Factor Analysis and Classification System.* HSW-PE-BR-TR-2005-0001.