Design of a Common UAS Operator Interface: An Exploratory Analysis

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ABSTRACT

There are many inherent challenges in the design and development of Unmanned Autonomous System (UAS) control interfaces. Despite the fact that advances in technologies are beginning to address some of these issues, the growing employment of UASs increases the complexity of the problem space. Multiple UAS platforms have led to a wide disparity among operator interfaces. Rather than continue to increase the number of interfaces as the number of platforms increase, one option is the adoption of a common UAS operator interface. The goal of such an approach is to reduce manufacturing, maintenance, and supply costs, streamline training, and ultimately, improve human performance.

In order to develop design guidelines for the common interface, a set of common tasks were developed based on task analytical data from the Global Hawk and Predator UAS communities. After segmenting the common tasks by phase of flight, each task was evaluated with regard to the implications for interface requirements. Evaluation results and recommendations are provided for a common UAS operator interface.

ABOUT THE AUTHORS

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INTRODUCTION

Many inherent challenges exist in the design and development of Unmanned Autonomous System (UAS) control interfaces. Despite the fact that advances in technologies are beginning to address some of these issues, the growing employment of UASs increases the complexity of the problem space. Multiple UAS platforms have led to a wide disparity among operator interfaces. As the defense services, the Department of Homeland Security, and private industry continue to develop additional unmanned systems, there is a huge potential cost savings associated with the identification of common interface needs and interface design guidelines. Interface design guidelines lead to an effective system which does not encumber the user, and allows the user to predict what happens with each of their actions (Shneiderman, 1998).

Rather than continue to increase the number of interfaces as the number of platforms increase, one option is the adoption of a common UAS operator interface. The goal of such an approach is to reduce manufacturing, maintenance, and supply costs, streamline training, and, ultimately, improve human performance. Cost savings could be achieved through reduced development (producing additional software modules only to address platform specific functions) and maximized common training for all UAS operators.

In this paper we describe a task analytical approach developed to determine basic requirements for a common user interface for UAS Ground Control Station operators. This paper discusses findings based on Subject Matter Expert (SME) interviews and offers potential solutions and recommendations based on human factors principles and necessary UAS functionality for a common operator interface.

METHOD

Front-end analyses were obtained for the Predator and Global Hawk UAS platforms (Nagy, Kalita, & Eaton, 2006; Nagy, Muse, Eaton, & Phillips, 2006). The U.S. Air Force performed these analyses in order to improve existing and future unmanned aircraft systems by applying human performance technology principles to determine optimal performance support solutions (Nagy et al., 2006). These were the only two front-end analyses for UASs that provided the richness of information necessary for this research effort. For the current task, the focus was limited to the operator interface and the team did not address the interface needs of sensor operators. The term operator was chosen to refer to the personnel primarily responsible for maneuvering the vehicle from points A to B, as used in Cooke, Pringle, Pedersen, & Connor (2006).

In examining these front-end analyses, we identified tasks performed by personnel in the GCSs for the Global Hawk and Predator UAS platforms. These tasks were put into a spreadsheet for each platform separated by phases of flight (i.e., mission planning, handover, changeover, en-route, recovery, emergency procedures). Mission relevant tasks were intentionally not included due to limited commonality between platform missions. Once these spreadsheets were assembled, the authors examined the tasking of the two platforms in each phase of flight and identified tasks common to both platforms. These tasks were then combined into a new spreadsheet, again separated by phases of flight. Tasks that were not the responsibility of the operator were subsequently deleted. Finally, initial design implications were linked to each task. Thus, the document became an initial repository for common UAS operator tasks.

The design implications were based on basic human factors principles and literature in the field of UAS

interface design. For example, during the Recover phase, operators must "*Maintain proper airspace*." A potential interface design implication of this task is to show the aircraft as a transparent avatar in "chase plane" view, as this has been shown to increase operator situation awareness (Drury, Richer, Rackliffe, & Goodrich, 2006).

In order to validate the design implications specified, SMEs were consulted from the Human Performance Wing of Brooks City-Base, Texas. Our experts were a Royal Air Force exchange officer and recognized authority on the Predator system, and a medical doctor with a specialty in Aerospace Medicine. Both SMEs are very familiar with the UAS domain and had extensive Ground Control Station experience.

SMEs examined line by line the tasks and design implications put forth by the authors. Additionally, the authors held a question and answer session with the SMEs followed by a period of open discussion. The SMEs provided valuable input used to revise the document iteratively until it contained all information requested by the team and SMEs for the design of a common Ground Control Station interface for UAS operators (Table 1).

In Table 1, a portion of the En-route phase of flight is shown composed of 26 common tasks from larger individual lists of 27 Predator tasks and 30 Global Hawk tasks. The first seven of these tasks, which fall under the sub-phase of flight *Navigate to Mission Start Point*, are shown. The reader can see at a glance the individual tasks, whether the operator performed the task, the design implications listed by the initial research team panel, and the implications for future display provided by SMEs.

RESULTS

While differences in commonality varied by phase of flight, in comparing the two front-end analyses, a larger number of task commonalities than task differences were found. For example, during Handover, the Predator front-end analysis identified 43 tasks performed by the operator. The Global Hawk front-end analysis listed 40 tasks as the responsibility of the operator. Together, the Global Hawk and Predator had 29 tasks in common during the Handover task. This phase of flight, with 29 common tasks out of 43, had the lowest commonality of any phase of flight examined.

At the other end of the spectrum, the Emergency Procedures phase of flight had 28 operator tasks listed in each front-end analysis – all of which were identical between the Predator and Global Hawk. Based upon this information, the authors suggest a modular architecture to support tasks and functions unique to individual platforms, while providing a common interface for a majority of UAS operator tasks. The individual phases of flight (and the implications for future displays) are discussed below.

En-route				
Navigate to Mission Start Point				
Predator 27; Global Hawk 30; Common 26				
Task #	Task	Internal Pilot	Design Implications	Implications for Future Display
1	React to and monitor hazardous/adverse meteorological conditions during flight[1]	Yes	Pilots need to be alerted during these conditions	Utilize spatial audio to draw attention to proper area
2	Correct for wind[1]	Yes	Heading indicator needed	Actual hard switches preferred
3	Maintain selected course correcting for wind[1]	Yes	Heading indicator needed	Actual hard switches preferred
4	Operate navigation systems[1]	Yes	Need to display this information	
5	Perform GPS position check[1]	Yes		Quality of signal indicator; warning for low signal
6	Perform IFR navigation[1]	Yes	Altimeter, airspeed indicator, heading indicator, GPS or FMS need to be in pilot's view	Need different modes (e.g., navigation mode, planning mode, weapons employment, enroute) with colorized borders to differentiate
7	Perform in-flight navigation planning[1]	Yes	GPS, FMS, calculator, E6-B and other tools need to be available to the pilot for this task	Need different modes (e.g., navigation mode, planning mode, weapons employment, enroute) with colorized borders to differentiate

Table 1: Sample Portion of Common Task List

Mission Planning

There are major differences between the Global Hawk and the Predator with regard to Mission Planning. For Global Hawk, much of the mission planning is already done for the operator and it is the operator's task to validate the plan. For Predator, mission planning is the operator's responsibility. However, the front-end analyses identified fewer tasks for the Predator operator (eight) than for the

Global Hawk operator (13), and seven tasks common to both.

For the two platforms, there are common design implications for visualizing the mission and route planning. SMEs specifically identified the need for one display that contains all the information needed for mission planning as, currently, the information is presented on separate screens. Additionally, SMEs pointed to the need to display necessary information to plan an Instrument Flight Rules (IFR) flight. Integrated electronic flight planning for both pre-flight and dynamic filing is one potential solution. Further, route planning to possible alternate destinations and safe passage assessments could be facilitated through 3D displays for both terrain and weather avoidance.

For many of the mission segments, operator communication is critical. The Global Hawk front-end analysis specifically points this out with regard to mission planning, and, in particular, highlights the need for secure communications (Nagy et al., 2006). During interviews with our SMEs, multiple communication channels were discussed. A Ground Control Station may simultaneously utilize radios, intercommunications systems, telephones, communication lines, whiteboards, and chat software. Given this huge information onslaught, further analysis is warranted to examine the information requirements and method by which this information should be transmitted and received.

Handover

The Handover phase of flight (split into Losing and Gaining Handover Checklists) occurs when a Ground Control Station operator accepts or relinquishes control of the aircraft. This can occur during a series of tasks associated with getting the aircraft airborne and handing control to the Ground Control Station (referred to as the Mission Control Element or MCE for the Predator). It is essential during this transition that all critical information is salient to the incoming operator. The Predator operator is responsible for 43 total tasks during handover, the Global Hawk operator is responsible for 40 tasks, and the two platforms have 29 tasks in common.

Much of the feedback obtained from our SMEs for the Losing Handover Checklist phase centered on the fact that operators prefer actual hard switches as opposed to virtual/computer generated switches for controlling altitude, airspeed, and heading. The corollary to this is the suggestion that operators would be comfortable with a radio in the form of a Graphic User Interface (GUI) rather than tangible hardware.

Aside from obvious design implications evident in the losing handover tasks (e.g., in order to establish and maintain constant altitude an operator must have an available altimeter) our SMEs provided valuable information regarding potential future design implications for the task of calculating new Estimated Times of Arrival (ETAs). Specifically, our SMEs suggested a function enabling the operator to place a cursor over a waypoint and click to display an ETA. This would result in less cognitive workload, as the operator's task would then be to validate ETA, not to make the initial calculation.

There are similar common tasks for the operator with regard to Gaining Handover (e.g., establishing and maintaining altitude, airspeed, heading, and clear communications). Other tasks, such as analyzing wind conditions and identifying and avoiding weather hazards, prompted two similar design suggestions. First, sensors employed on the vehicle to detect wind shear and ice would aid in providing operator alerts during this phase. In addition, the incorporation of a weather overlay into the display would also benefit the operator, although it is noted that a server outside of the Ground Control Station would be needed. Finally, an indication of whether or not a specific communication channel is secure would aid the operator in the task of maintaining classified communications.

Changeover

Changeover represents the substitution from one operator to another, which, in the Global Hawk platform, occurs approximately every four hours. The Global Hawk and Predator operators both have 13 identified tasks, and 11 of these tasks are common across both platforms. Changeover requires a comprehensive brief to the incoming operator, with particular focus upon situational elements that have changed since the pre-flight brief (e.g., weather, intelligence). Typically, this information becomes more relevant once the operator is immersed within the mission for a period of time. For this reason, the SMEs recommended one consolidated mission transfer display for all crew brief data which can be referred to when needed once the outgoing crew has departed.

During discussions with the SMEs, the two tasks "*Verify operational missions"* and "*Verify emergency missions"* drove the recommendation for an ability to return to a default screen. The information presented

in the Primary Flight Display (PFD) is critical to obtaining and maintaining situational awareness during the mission. SMEs identified the presence of too many hierarchical menus as one of the biggest issues in current control interfaces. Often, a large number of menus and submenus propel the operator into the equivalent of being lost in hypertext (Landauer, 1995). Our SMEs suggested making the menus no more than one layer deep when possible and practical, and providing a default button to return to the original PFD.

En-route

During the time in which a UAS is en-route to a mission start point, front-end analyses identified 27 tasks for Predator operators and 30 tasks for the Global Hawk operator. A majority (26) of these tasks are common between the two platforms. This presents a number of opportunities to support the operator through a common optimized interface design.

One important task for operators en-route is to *"React to and monitor hazardous/adverse meteorological conditions during flight."* The resulting design implication is to alert the operator during these conditions. Discussions with SMEs resulted in the suggestion to utilize spatial audio to draw attention to the proper geographic area. Access to a weather map and forecast data could alert the operator to future weather and wind conditions.

While en-route, airspace deconfliction is an important operator responsibility. For the task "*Perform GPS position check,"* operators expect the GPS signal to be of sufficient quality and accurate within 23 feet (S. A. Chapple, personal communication, January 22, 2009). While providing a signal indicator when the GPS signal is of sufficient quality may be considered clutter, not knowing whether or not the signal is good or assuming it is good can certainly lead to poor situation assessment. Thus, our SMEs suggested providing a "low-signal quality" indicator on the GPS display that appears only when the GPS has insufficient strength to provide accurate information.

To remain within cleared airspace, there are several design implications which affect the interface. First, not all operators and aircraft utilize the Traffic alert and Collision Avoidance System (TCAS), yet there must be an established two-way communication between operators and Air Traffic Control to avoid potential airspace conflicts. Thus, in order to respond to traffic conflicts as appropriate, the UAS should be equipped with a combination of TCAS, Link-16, or ground-based radar to ensure all affected parties are aware of the UASs position in the airspace. Further, the two-way communication can be supplemented with a visual representation of the airspace. A drawing tool (such as the one currently in Predator GCSs) can be utilized to create a no-fly zone on the operator's map.

Finally, in order to eliminate possible confusion between display functions, the SMEs suggested utilizing different interface modes (e.g., navigation mode, planning mode, weapons employment mode) differentiated by outlining the display with colorized borders for each mode.

Recover

Perhaps the most adamant recommendation made by our SMEs was to automate, to the fullest extent possible, take-off and landing functions. The nature of the task (human separated from the system) coupled with the slight delay in visual information (approximately .225 seconds for the entire control loop) make take-off and landing the most accident prone segments of a UAS mission. Furthermore, Predators must fly a very steep glide slope during landings due to the forward-mounted flight camera (Pedersen, Cooke, Pringle, & Connor, 2006). For the Predator platform, 67% of mishaps occur during landing, with 75% of those due to human error. Eighty-one percent of those due to human error involved nose-wheel first landings. (Tvaryanas, Thompson, & Constable, 2005) Subsequent calculation shows that over 40% of all Predator mishaps are due to nose-wheel first landings. Butler's study (as cited in Tvaryanas et al., 2005) quotes General John Jumper, the Air Force Chief of Staff, as saying "We've…got to have some respect for the fact that because these are UAVs, they are neither expendable or disposable. They cost a lot of money."

Currently, the Global Hawk platform utilizes automation during recovery while the Predator does not. Thus, the front-end analyses for these two systems vary widely with regard to the level of difficulty. Nonetheless, the Predator analysis identified 25 operator tasks during recovery and the Global Hawk analysis distinguished 24 tasks. Of these, 18 tasks were common to both platforms, resulting in several common interface design implications indicated on the common task list.

While performing the approach to landing, during landing, and during roll-out, the operator needs visual references (outside view) along with an altimeter,

attitude indicator, airspeed indicator, and landing checklist; however, the design implications should be driven by the level of automation. For the task *"Perform go-around/missed approach check,"* a future interface capability could be the ability to click a "go around" button, supporting the operator on an aborted landing. For extreme weather recovery, our SMEs suggested the interface should be capable of automatically calculating and displaying performance tables for cold and hot weather as well as high altitude, humidity, and other environmental factors that could affect the vehicle. For example, braking distance and sensitivity increase in cold weather, and the interface should reflect these changes.

While the operator is not responsible for performing all safety procedures for securing the aircraft, they are responsible for ensuring the tasks are complete. Thus, an indication that informs the operator that the procedures have been completed would be useful. Finally, once the aircraft is safely secured, common post-flight tasks include the completion of required paperwork. For these tasks, our SMEs suggested that the information needed for the forms could be automated and perhaps even CAC-enabled such that data items like number of flight hours could be automatically updated to the operator's records.

Emergency Procedures

Many of the design implications previously addressed are applicable to tasks performed after emergencies (e.g., instrument and navigation displays, etc.). Due to the nature of the task, the need to support communication requirements is stressed. This is particularly evident in the task "*Assess impact to personnel on ground in event of emergency recovery."* While radio communications must be available, an overlay on the map display may aid the operator in identifying potential landing areas. A button to display potential nearby emergency landing fields (e.g., areas clear of buildings and people) would help prevent injuries and damage to buildings.

Similarly, additional design considerations for this task are driven by the need to "*Maintain the aircraft within cleared airspace*" and "*Respond to traffic conflicts."* Thus, displaying shaded regions of the map to indicate cleared space and displaying other air traffic would support the operator under any condition, but would be of particular importance under emergency conditions.

CONCLUSIONS

The SMEs interviewed during this research process stated a common interface for UAS operators is feasible, needed, and desired. Additionally, issues similar to those discussed here have been identified for sensor operators, though the entire role of a sensor operator has not been clearly defined. Throughout the duration of this research, it has become clear that there is much work to be done toward the improvement of UAS Ground Control Station interfaces. The exploratory analysis described here is only an initial step – future efforts should be based on a larger number of front-end analyses. Additionally, it remains to be seen if the recommendations described here are generalizable to other unmanned air, surface, or subsurface platforms. It is our hope to coordinate this effort with other ongoing and future efforts resulting in improvements in UAS operator training effectiveness, an increased number of skilled UAS operators, an increased number of UASs controlled per operator, substantial cost savings, speedier Ground Control Station development, and an improved interface which can withstand future changes in UAS missions.

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AUTHORS' NOTE

The views expressed herein are those of the authors and do not necessarily reflect the official position of the organizations with which the authors are affiliated.

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