HUMAN FACTOR IN UNMANNED AIRCRAFT SYSTEM FLIGHT TEST

Feng Wang, Shengjun Qi and Xinlong Wu Chinese Flight Test Establishment

Keywords: *Human Factor, Human Error, Flight Test, Unmanned Aircraft System, Suggestions*

Abstract

The flight test is a critical step in process of development in Unmanned Aircraft System (UAS) to demonstrate performance and verify innovative technologies and methods applied to the system. According to experience and statistic data, human error is becoming one of primary causes of incidents/accidents in UAS operations, but there is less comments about human factor in UAS flight test. However, one significant objective for test is to ensure success of test and safety of testing vehicle, ground people and ground asset within testing range. For this reason, analyzing human factor is an effective way to avoid human errors leading to accidents or catastrophes in testing. In this paper, the characteristics of UAS flight testing, which includes special testing environment, high level of automation, less human intervention, high risk and difficulties of testing due to new integrated system and complex data processing and so on, were presented at first in order to identify human factor issues involved in testing. Then, reviews of UAS incident and accident caused by operator error were described. Moreover, in order to analyze effects of human factor in testing, typical UAS mission were designed and conducted in both experimental unmanned vehicle and ground simulator. Through experimental and results analysis, several key human factor issues affecting flight testing were discussed, such as workload, confusion, situation awareness, teaming, human-machine relationship, etc. while all of these factors may lead to unsafe operation during testing. Although the main roles of UAS test operator/pilot are supervising the status of systems and handling emergency situations, human crew still have a significant effect on testing. Operator and automatic system is forming a partnership during operation. To enhance the safety of testing and improve crew performance, especially to minimize possibility of incorrect operation, suggestions are proposed on the above analysis, which can be used in UAS flight testing, operator selection and improvement of control station design. On the other hand, studying of human factor in flight testing can provide an effective guidance and mitigation to avoid human errors both in civil and military UAS operation.

1 Introduction

As development of Unmanned Aircraft System (UAS) has rapidly expanding in last 20 years, more than 76 countries have deployed or developed UAS [1], which is suitable for dull, dirty, and dangerous missions than their counterpart, manned aircraft. However, accident reports of Unmanned Aircraft System show human factor issues are becoming one primary cause. From US statistics data, failure rate range from 33% in Global Hawk to 67% in Shadow [2], which was led by human error or mishap. But there is less comment about human errors in UAS flight test. It is known that the purpose of flight testing is to demonstrate performance of system and to find out problems in design or operation so that the system could be improved. Human is crucial to successful UAS testing. Although UAS operate with varying degrees of autonomy, they all require human interface throughout the task/mission. Hence, the study of human factor issues in UAS flight test could improve the safety of operation, improve operator performance and decrease accident rate both in flight testing and in-service. In this paper, in the view of testing, the characteristics of UAS flight testing were analyzed at first. Then according to incidents caused by human factor, the experiments were designed to identify human factor issues involved in testing. Through experimental and results analysis, several key human factor issues affecting flight testing were discussed. Finally, suggestions are proposed on the above analysis.

2 Characteristics of UAS Flight Test

As the UAS is an extremely complex integrated air-ground system, the contents and requirements of flight test are also complex and different from manned aircraft. In this section, the distinct and unique aspects of UAS flight test will be described as follows.

2.1 Special Testing Environment

The UAS performance has been improved significantly as the development of technology. The airspeed covers low speed, high speed and Supersonic speed, while the flight altitude is reaching from near ground to 60,000 feet to near space. Due to these developments, traditional test site cannot meet the testing requirements of UAS. At first, meteorological condition should be taken into special account, since compared with manned aircraft, the current structure of UAS is fragile, size is small and airspeed is relative low for most types of UAS. Even Global Hawk cruise airspeed is 345 knots, which will be affected heavily by wind. Moreover, as range of radio is limited, and frequency range is also narrow due to limitation, radio signal could be interrupted and blocked easily by surroundings, severe weather and complex electromagnetic environment. Hence, test site should be located in spacious area like desert or seashore. Furthermore, due to immature of new systems and uncertainty of testing, testing site should be unpopulated areas, controlled airspace, avoiding civil airspace, which ensures not only the safety of ground people and asset, but also other manned planes documents.

2.2 Complexity of Test

The UAS is an integrated air-ground system so that the flight test is also complex. First and foremost, UAS consists of not only air segment, the unmanned aerial vehicle and satellite for beyond line of sight flight communication, but also ground elements such as ground control station, human crew, data link system, and other support systems. Therefore, flight test should demonstrate the basic performance of system as well as the integration between system and operator. Moreover, the control mode is different from traditional manned plane, and all of operations and decisions are based upon the data via up and down linking during testing such as radar image, status information, attitude, live video, etc. A large amount of data should be processed to ensure the safety of test. From statistics, over 800 parameters are displayed in screen from the status of the whole system to alerts. Furthermore, as the application of UAS expanding to different areas, the UAS execute various types of mission, such as attacking, surveillance and data collecting. Hence, test crew should not only consider content of related mission and environment, but also testing method and measurement, which raises higher requirements on the remote pilot and test method [3].

2.3 Autonomy

UAS is a smart system. The modes of control are divided into three categories according to degree of human interaction: fully autonomous (without human intervention), semi-autonomous and remote control [4]. Remote control provides a directly link between ground control station and aircraft and requires highest level of remote pilot skill and training. Remote control allows operator to control UAS via video or looking at vehicle directly. Although this mode is similar to manned aircraft control, there is no feedback to pilot like smoke, vibration and noise. While the semi-autonomous refers to a kind of autopilot, a higher level of autonomy, in this mode flight management system manipulates vehicle and fulfills assigned mission with limited human intervention, for example changing the waypoints, requesting aircraft back to base etc. Finally, fully autonomy refers to no human intervention and all actions are performed by UAS itself, which is hard to evaluate. As the definition of autonomy shown, fully autonomy is that a UAS has ability of integrated sensing, perceiving, analyzing, communicating, planning, decision-making, and acting. To achieve these goals, the UAS is based on a set of software and instructions uploaded before flight. Accordingly, how to measure and evaluate the level of autonomy is a challenge to Flight Test Engineer.

Additionally, like manned aircraft, UAS heavily relies on complex software or even more. Every sub-system of UAS involves a series of software containing millions of lines of code that oversee its activities, undertake almost all functions and allow it to interact with the environment [5]. Besides, the architecture of software is distributed and contains a series of sub-modules. Each computation module supports multiple applications by providing services to the network, and the services could be discovered and consumed in a dynamic way [6]. Once there is a failure in software, the consequence will be catastrophic. So verifying high-security and reliable of software is another objective of flight testing.

2.4 Complicate Information Processing

Evaluating test results are mainly depending on the data coming from sensors fixed on the vehicle, external instrumentation and acquisition data system onboard like Air Data Systems (ADS). During test, operator controls aircraft and payloads in a remote ground control station, and all of operations and decisions are based upon the data such as radar image, status information, attitude, live video, etc. via down linking. Therefore, a large amount of data should be processed, which is another challenge for FTI and remote pilot. What's more, in view of the level of mission, the amount of the information is different, e.g. in the performance test of radar, radar imagery has high resolution and it is complicate to process it in real time to get useful intelligence. During supervision, the FTE and remote pilot not only process data of aircraft on primary flight display such as status of sub-system, attitude, but also intelligence and data from payloads like video, SAR image. If the operator find something wrong from these information reflecting failure to be happening, he can change the mission immediately and control aircraft back to test base, which could prevent accident happening. Especially, these activities are happened in the Ground Control Station (GCS) not in the cockpit, which increase the level of operational difficulty [3].

2.5 Safety and risk consideration

Obviously, without aircrew on board to worry about, however, UAS still puts real threats to other aircraft from air collisions and to people on the ground from ground collisions. Once failure appears, the only thing remote pilot can do is sending orders to tackle, and then waiting the pre-program plan to handle. As an integrated air-ground system, safety assessment must consider every facet of the whole system. Taking data link delay as an illustration, how to compensating it by operator is a key factor for safe operation, as the delay may add nearly several seconds between operator and aircraft via satellite, which will worsen the system performance. Indeed the data shown on the GCS could not be guaranteed as the real-time display due to time delay, and the operator may not realize the real-time control on unmanned aircraft and may not predict latency. Once an unexpected malfunction appears, the operator may not realize it and react immediately, which will lead to failure of the experimentation. Therefore, to ensure the test going well, safety procedure and risk assessment should be established prior to flight test, especially what will happen because of time delay [7].However, a series of factors will define safety requirements such as data link, weather, mission complexity, and so forth. Therefore, risk analysis is really important before test. One of tasks for FTE is to assess the possible risk to ensure the safety of aircraft and people on the ground.

To sum up, flight test of UAS is different from manned vehicle testing, which needs additional considerations. Since the UAS is an integrated air-ground system and without aircrew onboard, during flight test the test team must consider not only testing environment, complexity and other factors affecting test, but also every element of the whole system, including GCS, payloads, data link, and other related sub-systems.

3 Human factor involved in testing

At present, human crew are viewed as one of key elements in UAS and play a significant role in testing operation, but it was not acknowledged at the beginning of test. One opinion was so popular previously that UAS test is like pilot do in manned aircraft, UAV can control itself automatically and crew is not important as they do in manned aircraft. However, accidents/incidents led by human crew mishap change the situation and opinions. As mentioned before, the complexity and automation of UAS increase the rate of incidents/accidents. In this section, two accidents caused by human errors were described. In order to verify effects of human factor in testing, two typical experiments were executed for assessment of human factor. Finally, the results were analyzed to conclude the human issue involving in UAS flight test.

3.1 Incident/accident review

Two accidents are described as follows. Case one was due to careless attention, case two was accounted to human intervention. All of that were caused by human errors.

Case 1

In one payload test, a low fuel warning indicator was not observed until returning to base, so the emergency landing was attempted. Fortunately, UAV landed safely. This indicator repeated over 8 times but the operator did not notice that alarm. The operator started sensor, took image, analyzed data and shut sensor down repeatedly when cruising over the target area. During test, there was one fault in sensor. All crew members were handling payload problem and decided to fly one more circle to verify performance of payload. So that no one notice the warning. The investigation showed the mission assignment operator was not reasonable and the responsibility was not fulfilled. On the other hand, the sound of alarm was closed by operator before take-off, which is another reason.

Case 2

In another test, due to ground dust, the UAV descended with left sideslip, and only left landing gear touched the runway during landing phase. The operator found that phenomenon and wanted to revise the attitude. But unfortunately, pilot wrongly push right pedal/joystick and gave the opposite order. Consequently, the landing gear collapsed and the wingtip damaged. After investigation, the evidence showed that the operator did not get enough emergency training and the manual said during landing the flight management system would revise UAV’s attitude and airspeed autonomously according to condition, but the operator controlled vehicle as he did in manned aircraft, which led to this accident.

3.2 Experimental design and analysis

In order to confirm the influence of human factor in operation of UAS, the experiments were designed and implemented in ground simulator and small UAV. Hence, the goals of tests are to assess which kind of status information or mission operation has significant influence on operator’s operation, to evaluate if operator could make appropriately and quickly response to unexpected situation, both in normal and emergency condition. Due to space constraints, here is the brief introduction of tests and results.

3.2.1 Test Objectives

To investigate the human factor issues in flight test and to provide guidance to the operation in application and improvement of human-machine interface.

3.2.2 Testing crew

6 teams, each team consists sophisticated retired manned-aircraft test pilot and engineers with aeronautical background and experienced flight with aerobatic aircraft.

3.2.3 Testing conditions

GCS, small UAV, support equipment, data link, power unit, appropriate maps, controlled airspace and so on.

3.2.4 Testing missions

Mission one: ground closed-loop surveillance testing, connecting GCS with UAV, to verify sensor's performance and capability, to testify system integration.
Mission two: with purpose of demonstration of sensor using small UAV.
Mission three: ground simulator, simulation of emergency such as in-flight engine shutdown.

3.2.5 Testing Methods

Test methods include: Modified Cooper-Harper Rating Scale, Situation Awareness Global Assessment Technique (SAGAT), questionnaire and video recording [8].

3.2.6 Testing Recording and Results

During testing, four teams completed these three experiments separately. Every mishap or incident was recorded carefully and comments and suggestions were fulfilled in questionnaires. All test crew said they felt dull and tired during 4 or 6 hours task, especially staring on the screen for so long time. When one hour passed, 60% of crew could not concentrate on screen, sometimes operator did not hear what other said about status of system. In the GCS, they had less communication, just supervising the main status of the whole system, when 3 hours passed. According to Modified Cooper-Harper rating scale, for long endurance testing, the operators evaluated the workload as high.
Through video recording analysis, when engine shutdown in simulation, operator had slow reaction to this situation and did not realize failure in quite few seconds. Several seconds later, they start to handle emergency. From statistics, 40% of test crew could not react to emergency quickly.
Comparing with operator having less piloting experience, test pilot who has well experience in manned aircraft performs well, they could determine the status of UAV from information display in GCS and handle emergency confidently. During test operation, all human errors were recorded. Table 1 shows human factors related to UAV incidents/accidents during experiments execution.

Tab. 1 Human Factors Related to UAV Incidents/Accidents in Experiments

Human Factors	Number of errors	Percent
Pilot-in-command	15	37.5%
Alerts and alarms	6	15%
Situation awareness	5	12.5%
Procedural error	6	15%
Display Design	8	20%

Although the UAS is an autonomous system, human crew also play a significant role in all operations and mission execution. Therefore, evaluation of human factor is an important part of flight test program, which can improve the performance and capability of crew. Through analysis and statistics, human factor issues were concluded in next section, which usually includes four aspects: operator qualification, workload, situation awareness and teaming.

3.3 Human Factor involved in testing

According to experiments' results, human factors involved in testing operation are analyzed and concluded as follows.

3.3.1 More demanding on operator qualification

During flight testing, the interaction between remote pilot and other operators, operators and aerial vehicle is more complex than manned aircraft, which demands strict requirements on operation and communication. If one of them appears abnormal behavior, the consequence may be disastrous. The operators are not only supervising the status of aircraft, sending orders in limited condition, completing assigned mission, adjusting task or waypoints, but also tackling emergency and failure accurately to ensure safety of test, system and crew on the ground. Before flight testing, the UAS operators should be well trained in theories, skills and abilities. They should learn how to navigate and control the vehicle, how to interact with the whole system, how to respond to unexpected events without direct feedback. Furthermore, the operator must be capable of avoiding, detecting and reacting to the accidents. In particular, the cue from environment could not felt and observed by remote pilot before realizing the risk. So it is dangerous to permit an inexperienced operator to manipulate such a complex and demanding unmanned system [9].

Thus, there are more demanding on operators, and they need sophisticated experience.

3.3.2 Workload and fatigue

The complexity of UAS and mission requirements has more demanding on operator both mentally and physically. The workload refers to the amount of work conducted by operator in a specified time [10]. As the definition of workload said, combinations of task demands and operator's response have significant influence on workload. As the research shown, the more complex the task is, the more mental workload increases [10]. Also, the level of autonomy is changing requirements for operator, increasing workload and affecting operator's performance [11]. Unlike pilot in cockpit of manned aircraft doing almost fully manual control, the role of operator in automated GCS is just supervising and cooperating with autonomous system to complete mission in considerably limited period, including scheduling, controlling movement of the vehicle, monitoring status, navigating to target zone, communicating with other crew, avoiding risk and managing emergency. In this situation, workload would rise due to time pressure. Other than this phase, the operator enjoys free time. In normal flight, the workload is acceptable, but in emergency the operator has higher workload, and feels tired and exhausted after accomplishment.

Another source of workload is long time work demanding [10], which is also a cause of fatigue to operator. Usually, the endurance for UAS could reach up to more than 36 hours, so it is a challenge for remote pilot and payload operators. In order to optimize flight schedule and utilize every flight efficiently, flight test engineer will arrange maneuvers as much as possible to demonstrate performance of UAS. Especially, for long endurance flight, the aerial vehicle will fly so many hours for calculating estimation of endurance and range. In this test, monitoring system parameters and keeping attentiveness for unexpected situations over a long period of time are the tasks required extensive attentions from crew. In this situation, focusing on the changes of information leads to visual and mental fatigue. As a consequence, the attention of operator decreases. Supervising during the whole mission can become repetitious and dull over time and lead to worsened performance and operational errors especially in persistent surveillance and reconnaissance mission [12]. Thus, how to mitigate fatigue and workload is one major problem for FTE, which also require more attention in test plan.

3.3.3 Situation awareness

Situation awareness describes the operator's awareness of status and changes in operation [7], which permits the crew to react appropriately and quickly to unpredicted cases. In UAS flight test, a high level of awareness could enhance success of test, especially in the context of complex automated system, complicate tasks, the separation of crew from the UAV and invisible environment. Remote pilots supervise the aircraft through on-board sensors and cameras down linking information displayed on the screen of computer, while the operator could not get the same quality of feedback as a manned aircraft pilot feels such as visual weather, smell of smoke, and vibration of fuselage. All the conditions of subsystems and status of UAV could only be felt by remote pilot via radio telemetry or overhead satellite communication and all maneuvers that remote pilot does are through up link to transmit order to the UAV. On this count, the situation awareness must be evaluated comprehensively. Besides, because awareness has a direct or indirect impact on the workload, the mental model should be established to evaluate the relation between them [3].

3.3.4 Teaming

UAS testing operation is the result of cooperation and communication between multi-crew. That means it is a team activity. The team includes the remote pilot, command officer, payload operator, Air Traffic Control (ATC) controller and other engineers. They must share the valuable information in order to accomplish flight test. The success of one flight test is depending on the operators collaborating and less confusion [10]. The size of operating team is determined by the size of UAS and complexity of task. For instance, military UAV crews for reconnaissance missions include an air vehicle operator, a mission commander and a payload operator [11]. The payload operator captured mission area image by sensor, then reading intelligence from image and delivering it to commander. If the commander misunderstood the meaning of operator, the message delivered to pilot from commander would lead to wrong operation. Therefore, crew team should simulate and deduce mission to guarantee as less confusion as possible between members before test. Additionally, the operation team should be well trained to handling trouble or malfunctions to ensure the safety of vehicle and minimize risk once failure happens.

3.4.5 Human-machine relationship

Study shows that dynamic allocation of human-machine function is the key aspect to increase system performance [7]. As the autonomous and intelligent technology was introduced widely into GCS, the workload was alleviated. Meanwhile, situation awareness was decreased, which needs higher requirement in decision making within short term. However, human-machine relationship was designed regularly before test according to task requirements in different phases, which decrease flexibility of operation and increase difficulty of decision-making. Hence, for the purpose of improving performance efficiency and effectiveness, dynamic distribution of human-machine function should be considered in task planning phase, so that to max extent the human errors could be reduced and the safety of system could be achieved for the purpose of high reliability and effectiveness.

As development of control mode, one operator will control more than one vehicle simultaneously, or operator could control UAV to cooperate with manned aircraft to accomplish task. So operator could have a global view of the battlefield, not just as a UAS operator, but as a commander if needed. Therefore, the operator could not manipulate the vehicle frequently for lower level of task, which could be completed by intelligent assistant system. All of these could be achieved on condition that human-machine performance could be distributed dynamically by task, for this reason evaluation of ergonomics in GCS should be designed and accomplished aiming at different levels of mission.

4 Suggestions

According to the statistics and analysis, certain recommendations based on analysis are made to prevent accidents in future to improve safety operation and enhance mission effectiveness as follows.

3.1 Scheduling before test

For long endurance test, shift work would be an effective way for improve performance and health of operator. If the test endurance is more than 6 hours, the operator should be arranged to have a rest after 4 hours work. For short endurance mission, reasonable task distribution should be considered and rational planning will increase the efficiency.

3.2 Training

Prior to testing, operator should be well-trained both theoretically and practically. And training program should be divided into three parts: theory study, simulator practice, Small UAV operation. Theory study includes general principle, system introduction, risk assessment, operating procedure and limitations. Simulator practice contains mission deduction, task planning, testing simulation, and emergency simulation. Small UAV practice consists of controlling the vehicle to landing and take-off, monitoring mission, to name a few. Moreover, the operator should be experienced and trained in normal and emergency procedures. Finally, a training platform should have sound price and high quality.

3.3 Operator selection

For testing pilot, they should be acquainted with aeronautical knowledge, well experienced in flight, especially good consciousness about emergency handling. Test sensor operator should know well about not only payload but also vehicle and flight. Another rule for selection is collaboration, since the test is a team work. All members should bear in mind that testing relies on cooperation, and any minor confusion may lead to mishap, or even accidents.

3.4 Human-system interface evaluation

The purpose of human-system interface (HSI) evaluation is to identify if there is undesirable design and if the error-proof design is helpful to prevent human error and to provide suggestions for remedial measures. First of all, define which types of task operator should complete, which tasks are left to automatic system. Before test, engineer should discuss test maneuvers with operators comprehensively, and make sure which aspects need operators' extremely attention, which parts engineer cares about in GCS for the purpose of decreasing workload. Secondly, the HSI design should reconsider the mitigating workload and fatigue. HSI should be user-configurable and provide multiple of feedback. In light of difficulty of test, test procedure should be well designed. Better designed HSI could improve crew performance and enhance connection between machine and human. Now the GCS is designed to use HSI displays and controls not only containing computer synthetic interface but also including button, mouse, control box and joystick [13]. In order to optimize HSI, evaluation is an effective way. Usually, HSI evaluation includes design uniformity, information readability, information visibility, information formatting, information interpretability, information integrity, error-proofing design. That means interface functionalities meet the requirements of operation, switchover among interfaces should be easy and smooth, interface should not cause fatigue on vision of operator or increase workload, interface display must provide all and only necessary data to user. The objective of this evaluation is to verify that overall functionalities meet the related regulations and design requirements, and then to optimize. After all, optimization is aiding to increase mission effectiveness.

3.5 Assessment of human error in operation

Testing engineer should design specialized experimental to evaluate human factor issues. The primary purpose is to demonstrate if human and machine can be cooperated efficiently. Another objective is to verify if the GCS could provide sufficient functionalities for crew to implement associated mission. The third one is to conclude human factor issues involved in testing operation. Therefore, modification can be made according to results of assessment and advice given by operators.

Through these measures, the performance of operator could be improved and the safety of UAS will be enhanced significantly.

5 Conclusions

Human crew is one of key elements comprising the whole integrated air-ground system and the assessment of human factor is a major element of flight test project. Now engineers are paying more attentions to human factor in testing. Not only because human issues are critical in GCS design and accidents investigation, but also important in operator training and missing planning. This study has discussed human factors involved in testing. In light of analysis, suggestions are given in order to improve flight safety and performance efficiency. This investigation may improve crew performance and also increase safety of testing. Additionally, this study might provide additional useful information to be used in operation in-service in future.

References

[1] Richard K. Barnhart, Stephen B. Hottman, Douglas M. Marshall, Eric Shappee. *Introduction to Unmanned Aircraft Systems*. 1st edition, CRC Press, 2012.

[2] Kevin W. Williams. A summary of Unmanned Aircraft accident/incident data: human factors implications. DOT/FAA/AM-04/24, Office of Aerospace Medicine Washington, DC 20591, pp11-12, 2004.

[3] John J. Spravka, Deborah A. Moisio, Mary G. Payton. Unmanned air vehicles: a new age is human factors evaluations. AFFTC-PA-05069, Air Force Flight Test Center, Edwards AFB CA, USA, pp6-8, 2005.

[4] Huang H.M, Pavek K, et al. Autonomy levels for Unmanned Systems (ALFUS) framework: an update. *Unmanned Ground Vehicle Technology* VII.Vol.5804, pp439-449, 2005.

[5] Reg Austin. *Unmanned Aircraft Systems:UAVs design development and deployment*. 2nd edition, WILEY, 2011.

[6] Mettler B, Schouwenaar s T, How J, Paunicka J and Feron E. Autonomous UAV guidance build-up: flight-test demonstration and evaluation Plan. *AIAA Guidance, Navigation and Control Conference and Exhibit*. Austin Texas, USA, pp5744, 2003.

[7] Warren Williams. UAV handling qualities: you must be joking. Available online at: http://www.aerosciences.com.au/hidden/UAV%20Handling%20Qualities%20Paper%20v1.pdf. Pp1-6, 2003.

[8] Christopher D Wickens. *An introduction to human factor engineering*. 2nd edition, Pearson, 2003.

[9] Beth Blickensderfer, Timothy J. Buker, Stephen P. Luxion, Beth Lyall, Kelly Neville and Kevin W. Williams. The design of the UAS Ground Control Station: challenges and solutions for ensuring safe flight in civilian skies. *The Human Factors and Ergonomics Society 56th Annual Meeting*, Boston Massachusetts USA, pp51-55, 2012.

[10] Mustapha Mouloua, Richard Gilson, Jason Kring, and Peter Hancock. Workload, situation awareness, and teaming issues for UAV/UCAV operations. *Proceedings of the human factors and ergonomics society annual meeting*. Los Angeles CA, USA, Vol.45.No.2,pp162-165, 2001.

[11] McCarley J. S, Wickens C. D. Human factors implications of UAVs in the national airspace. AHFD-05-05/FAA-05-01. Aviation Human Factors Division, Savoy, Illinois. USA.2005.

[12] Hancock P.A, Warm J. S. A dynamic model of stress and sustained attention. *Human Factors* 31(5), pp519-537, 1989.

[13] D.C. Nagel, *Human Factors in Aviation*. San Diego,CA: Academic Press. pp433-461, 2010.

Copyright Statement

mailto:saintknight372@hotmail.com