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Research Workshop

8-9 November 2011
Dayton, OH

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Introduction

This document is a summary of the proceedings of the Unmanned Aircraft System / Remotely Piloted Aircraft (UAS/RPA) Human Factors and Human Systems Integration Research Workshop, hosted by the Naval Medical Research Unit – Dayton. The workshop was held 8-9 November 2011 in Dayton, OH. The goal of the workshop was to identify, discuss, and eventually address science and technology (S&T) research gaps related to a range of UAS/RPA Human Factors and Human Systems Integration Research topics. To accomplish this, the workshop brought together UAS researchers and other subject matter experts from across the Navy, Air Force, and Army. Ten speakers presented overviews of past, present, and future UAS/RPA research efforts and introduced a broad spectrum of issues currently facing the UAS/RPA discipline. Major discussion topics included: UAS operator selection, training, control station design, manpower and scheduling, manned-unmanned aircraft teaming, motion sickness, and medical standards.

The goal of the workshop, and this report, is to provide a mechanism for information exchange, to enhance government agency coordination, and to provide guidance for UAS topic areas that require future research. Section 1 lists the organizing committee members and the workshop agenda. Section 2 provides a summary of each brief, capturing the essence of the various presentations. Each summary was written by the authors of this report and approved and/or edited by the original presenter. Section 3 lists the top UAS/RPA S&T research gaps identified by workshop attendees, and Section 4 provides recommendations for future research directions.

Section 1: Organizing Committee and Agenda

NAMRU-Dayton Organizing Committee

Dr. Richard Arnold	Director, Aeromedical Research
Dr. Henry Williams	Deputy Director, Aeromedical Research
Dr. Beth Hartzler	Research Psychologist
LCDR Wilfred Wells	Department Head, Acceleration and Sensory Sciences
LT Stephen Eggan	Aerospace Experimental Psychologist
LT Rick Varino	Research Psychologist
Ms. Ashley Turnmire	Research Assistant III

UAS/RPA HSI Research Workshop Agenda

**Hosted by NAMRU - Dayton
Hilton Garden Inn, Beavercreek, OH**

Tuesday, 8 November, 2011

1200 – 1215: Welcome & Opening Remarks - Rick Arnold

1215 – 1345: General UAS/RPA Status Reports

- Henry Williams – General UAS HF Issues
- Lt Col Anthony Tvaryanas – Human Performance Issues in USAF RPA Operations - Past Experience and Future Vision
- CDR Joseph Cohn – Naval UAS S&T Initiatives

1345 – 1400: Break

1400 – 1430: Naval UAS Training

- Lcdr Brent Olde

1430 – 1500: Control Station Design Issues

- Melissa Walwanis

1500 – 1600: Tour of NAMRU-D research facilities

Wednesday, 9 November, 2011

0800 – 0930: Personnel Selection

- Phil Mangos – Naval UAS Cross-Platform Task Analysis
- Thomas Carretta – USAF RPA Personnel Selection and SAOC Review
- Rick Arnold – Naval UAS Personnel Selection

0930 – 1000: Manpower & Scheduling

- Lt Col Anthony Tvaryanas – Manning & Scheduling in UAS/RPA Ops

• 1000 – 1015: Break

1015 – 1115: Miscellaneous

- Jeremy Athy – UAS Manned/Unmanned Teaming and Motion Sickness
- Other (medical standards, optionally-manned aircraft, multi-UAS control, UAS CASEVAC, maintenance, airspace integration HF issues, etc.)

1115 – 1145: General Discussion & Gap Identification

1145 – 1300: No-host lunch

1300 – 1430: Lab tour, and USAF RPA and Integrated Combat Operations Team Training

- Wink Bennett

Section 2: Summaries of Briefings

Some General UAS Human Factors Issues

Dr. Henry P. Williams
Deputy Director - Aeromedical Research
Naval Medical Research Unit – Dayton

Dr. Lisa W. Billman
Lead Human Factors Engineer
MITRE

Twelve UAS Human Factors issues were introduced and briefly discussed. This list of issues was at least partially informed by reviews by Nisser and Westin (2006) and McCarley and Wickens (2005).

Workload – UAS's are becoming increasingly automated and autonomous. When systems are operating normally, operators can become under-loaded and bored, yet when malfunctions occur, workload can spike. The goal is to maintain an optimal workload between these two extremes. Automating the right tasks can help optimize workload levels while maintaining operator situation awareness.

Situation Awareness (SA) – UAS operators must deal with impoverished perceptual cues. UAS's often have small visual displays and their sensors have small fields of view. UAS air vehicle operators are not afforded the vestibular, auditory and tactile cues that pilots of manned aircraft experience. UAS sensor operators must often reconcile the typical misalignment between sensor heading and unmanned aerial vehicle (UAV) heading. UAS interfaces therefore have special design challenges to promote and maintain good SA. Tools like Mission Task Analysis can help determine what information is required to perform tasks and to build good SA.

Vigilance - With virtually all routine monitoring tasks, operators experience a “vigilance decrement”, as soon as 15 – 30 minutes into the task. The vigilance decrement can cause operators to miss critical events, but proper control station design can help reduce the consequences of the vigilance decrement.

Fatigue - UAS's are typically designed for long endurance missions, and their crews are subjected to rotating shiftwork. However, research has indicated that long-term UAS shiftwork assignments are associated with increased fatigue (Tvaryanas, Platte, Swigart, Colebank, & Miller, 2008). The impact of fatigue on human performance in UAS operations needs to be better understood and managed.

Decision Making - Several factors that can impose decision-making challenges in UAS operations include uncertain dynamic environments, uncertain feedback loops, time stress, multiple team players, and high stakes environments (Orasanu & Connolly, 1993). Naturalistic Decision Making techniques (Kline, 2008) and specialized training can help address these issues.

Teamwork - UAS operations require tight coordination among physically separated teams. If we compare the transfer of control between the pilot/co-pilot of a manned aircraft to

the handoff of a UAV from one operator to another, non-colocated operator, we quickly see teamwork and communication challenges. Special attention must be paid to communication and feedback among UAS teams.

Trust in Automation – Operator trust in automation is a complicated issue. One automation failure, or *perceived* failure, can destroy an operator's trust in the system. If the operators revert to manual control or start second-guessing the automated processes, the system will probably perform in a sub-optimal fashion. It should be apparent to the operator what the automated system is doing; that is, the algorithms should be transparent. Trust will likely become an even bigger issue if remotely piloted vehicles eventually carry humans.

Information Technology (IT) - Computers and their networks are the backbone of most UAS's and are used for tasks such as mission planning/re-planning, vehicle control, navigation/airspace management, communications, sensor control, and imagery/electronic intelligence (ELINT) management. Since UAS's rely so heavily on IT systems, at least certain crewmembers should have IT trouble shooting and problem solving skills.

Field Interface - Some UAS's will likely have a "Field Interface" for the minimally-trained operator in the field. This interface could be used to request imagery of a particular area, or provide last minute landing guidance for vertical UAV cargo/re-supply operations. For example, an operator may need to quickly convey information such as "Land 10 meters to the south of your originally intended landing spot." These interfaces will probably be the size of a personal digital assistant (PDA) or laptop, with constraints on the level of control that the field user has and on the amount of information that can be displayed. Additionally, since the field user may not be fully trained in UAS operation, the interfaces should be especially simple and intuitive to use.

Onboard Control Interface for Optionally Manned Vehicles - Future UAS's may eventually have some ability for human onboard control. Like the Field Interface, this interface should be especially simple and intuitive, and will likely provide limited control capability. It would probably be used to provide fly-to-waypoint control, and to fine-tune landing spots.

Crew/Operator Selection and Training – There are questions as to whether operators should be winged aviators, enlisted specialists, or other specially designated personnel. Certain medical and/or anthropometry standards can be relaxed as compared to manned aircraft standards. While some required Knowledge, Skills, and Abilities (KSAs) mirror those of manned aircraft, others do not; therefore new UAS selection tests are in order. With respect to training for different UAS platforms, there is the question as to whether there could be some common UAS training modules, applicable to most or all platforms. Given the wide range of capability and complexity across the various UAS platforms, guidance on which KSAs overlap would be useful.

Manpower/Manning – There is a push within the DoD to reduce the number of personnel required to operate UAS's. There is also interest in having an operator-to-vehicle ratio of less than one. For example, a team of 3 operators might be managing 9 UAVs. There are questions about what that ratio should be, and for which crew positions (e.g., Air Vehicle Operator,

Mission Payload Operator, Mission Commander, Tactical Coordinator, UAV Watch Officer, Field Operator, etc.).

Many of the issues presented here will interact with others. For example, manpower levels will affect fatigue. Fatigue, in turn, will affect SA, vigilance, and decision making. It is also recognized that this is not a complete list, and that new UAS human factors issues will emerge.

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Human Performance Issues in USAF RPA Operations – Past Experience and Future Vision

*Lt Col Anthony P. Tvaryanas
Technical Advisor*

*711th Human Performance Integration Directorate
Air Force Research Laboratory*

This brief consisted of three main sections: 1) Summarizing the Human Performance Problem Space, 2) Macroergonomic (Sociotechnical) Issues, and 3) Microergonomic Issues.

RPA Human Performance Problem Space - Warfare is becoming less about kinetic force and more and more about information, and RPAs are critical tools in gaining information. We are moving from brute force to a cognitive/information battlespace. Lt Col Tvaryanas presented a top down view of the information battlespace involving a three step process of a) building situation awareness (SA), b) making decisions in the battlespace, and c) executing those decisions. Human information processing feeds into building SA. Factors affecting information processing include complexity, stress and workload, automation, and interface design. Engineers have designed machine-to-machine communication networks, but we have to consider the human, or “carbon-node”, within those networks. Human Systems Integration (HSI) is a tool that can be used to optimally combine the personnel and technological sub-systems of Unmanned Aerial Systems (UAS). When these two sub-systems are properly combined, the resulting UAS should have emergent properties that are valued by the stakeholders (i.e., UAS operators, intelligence customers, etc.). The properly designed UAS (i.e., one possessing a balanced integration of hardware, software, and humans) should help address a major UAS/RPA challenge of relating the performance of an RPA crew, which is part of a bigger network, to overall mission effects in a theater that can be halfway around the world.

Macroergonomic (Sociotechnical) Issues – There has been a Revolution in Military Affairs leading to Network Centric Warfare (NCW), wherein we are taking networks to war. This revolution includes the themes of Enhanced Information Sharing leading to shared SA and bottom up self-synchronization to meet the commander’s intent. In theory these elements can lead to dramatic increases in mission effectiveness, but NCW has met with mixed success. Regardless, our weapon systems are moving from platforms to networks, and this is a fundamental change.

The evolution of Technology, Information, and Culture has enabled a much improved integration of Operations and Intelligence. This evolution has led to a dramatic decrease in the Find-Fix-Track-Target-Engage-Assess (F2T2EA) cycle. This cycle could take 75 days during WWII, while it may take only 10 minutes today. At the same time there has been a vast reduction in the number of aircraft and aircrew needed to prosecute a target, to the point where today we are attacking multiple targets with one aircraft and pilot. In WWII, multiple specialized personnel and aircraft were involved with each step of the F2T2EA cycle. Today the commander of an RPA network may perform many of the tasks, and could be viewed as a generalist making strategic and tactical decisions. Also, with RPAs, there is a DoD push from leadership for operator-to-vehicle ratios of less than one. For example, three people might be managing nine aircraft, with each aircraft capable of prosecuting multiple targets. Operators are not necessarily in favor of this given current platforms and their limited level of autonomy (the

latter being larger than the issue of automation). Eventually we may be using swarms of highly autonomous UAS to simultaneously pursue a very large number of targets based on emergent, goal-directed system behaviors.

USAF communities or “tribes” align and identify themselves according to the weapon system or technology system that they use. The current senior leadership is from the era when aviation was dominated by manned aircraft, many of which were single seat platforms. The growing use of UAS’s is “birthing a new tribe”. Applying manned aviation experience and doctrine to the UAS world may hinder progress.

There has been a huge increase in the demand for RPA combat air patrols, and this increase has put significant pressures on RPA crews. For example, Predator units operate 24/7 with no holidays, and crews must try to adapt to rotating shifts. Operators also face the challenge of performing lethal combat operations and then returning to their family life just hours later. RPA researchers (Thompson et al., 2006; Tvaryanas & MacPherson, 2009) have found that RPA crews suffer from Acute Fatigue, Chronic Fatigue, Burnout, and Quality of Life Issues to a greater extent than manned aviation crews. Interestingly, these issues are more problematic with Nevada-based Mission Control Element crews who return home everyday than with their Landing and Recovery Element counterparts who are deployed in Iraq.

Microergonomic Issues – In a classic human factors sense, there are issues with RPA control station design. These issues include: poor ergonomics; varying data input methods; multiple inputs required to implement a single command; lack of system feedback; non-intuitive multilayered menus; multiple screens creating a high visual workload and requiring significant mental integration; narrow sensor field of view; poorly designed advisory, caution, and warning systems; poorly integrated add-on systems; no decision aiding/support technology. Aggregate analyses of RPA mishaps using DoD HFACS (Human Factors Analysis and Classification System) have demonstrated recurrent skill based and perception error pathways consistent with Level 1 Situation Awareness (SA) failures. The frequency of these Level 1 SA failures in UAS is comparable to historical data for manned aviation. The human factors design issues listed above contribute to the errors. These are not new design issues, but rather it seems that the builders of RPA control stations have not applied what is already known. The human factors community needs to take what we know about good control station design to the designers, engineers, and acquisition community for them to employ that knowledge.

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Proposed Future Naval Capability Unmanned Aerial Systems Interface, Selection, & Training Technologies (U-ASISTT)

*CDR Joseph Cohn
Military Deputy, Human and Bioengineered Systems Division
Office of Naval Research*

Aviation is transitioning from an occupation that requires pilots to frequently physically interact with aircraft to one that requires more cognitive capabilities and significantly less hands-on interaction. This transition has created many challenges for selecting and training future Unmanned Aircraft Systems (UAS) operators and for providing them with an intuitive and well-designed user interface. This need for further research is evident from the growing number of human-factors related UAS mishaps, most frequently during take-off and landing. CDR Joseph Cohn from the Office of Naval Research presented initiatives for future research that focus on developing new methods for personnel selection, training, and user interface design with the goal of reducing mishaps and improving mission performance.

CDR Cohn established three challenges to safe and effective unmanned systems. First, the cognitive capabilities that a UAS operator should possess need to be defined. Second, methods for developing and presenting realistic and authentic training scenarios need to be developed. Third, we need to design and provide the right control station equipment for UAS operators to effectively and safely operate multiple UAS.

Though these three domains are distinct, there is a great deal of synergy and overlap between them. CDR Cohn proposed three products that should be developed in parallel, and with information shared across the three domains. The first planned project focuses on personnel selection and accurately forecasting operator performance across UAS platforms and missions. The second proposed product would focus on providing advanced training system capabilities, such as generating realistic scenarios and adaptive synthetic entities from data collected during UAS flight. This type of training program would be adaptive to the student's performance, continually comparing actual performance with how the student ought to be performing, and allowing instructors to monitor the student's progress. The third research area focuses on information display concepts for single operator, multi-mission/multi-platform UAS operations, improving the user interface by controlling the amount of information that is presented concurrently and making sensor information more understandable.

In addition to potentially decreasing the number of human-factors related mishaps, the implementation of these proposed products for UAS operation could also help to decrease manpower costs by reducing the number of operators required. Specifically, improved personnel selection standards would make it possible to identify enlisted sailors who have the appropriate skills for UAS operators, and improved training tools would help to hone these skills. Further, improved user interfaces could make UAS operation more intuitive and thus less cognitively demanding and stressful, especially when implemented in a common control station environment.

Navy UAS Training

*LCDR Brent Olde
Air Warfare Training Development IPT Lead
Naval Air Systems Command, PMA-205*

LCDR Olde discussed the current status of personnel training for unmanned aircraft systems (UAS) in the Navy. The outline covered 1) how the Navy acquires/manages UASs with regard to specific program offices, 2) the Basic UAS Qualification (BUQ) Levels – the current training qualifications for UASs, and 3) how personnel are currently trained to operate specific UAS platforms. Discussions centered on the current training paradigms and future training issues, such as the implementation of a common control station (operations and training) and operator selection for unmanned systems (i.e., enlisted or officers).

The discussion first outlined the different UASs (current and planned) in the Navy inventory and explained that UASs are acquired and managed by different Program Management Activities (PMAs) according to mission. These include the Unmanned Combat Air System (UCAS) and Unmanned Carrier-Launched Airborne Surveillance and Strike (UCLASS; managed by PMA-268 – penetrating mission), Broad Area Maritime Surveillance (BAMS) UAS (PMA-262 – persistent maritime), Fire Scout (PMA-266 – multi-mission tactical), and Scan Eagle, Shadow, and Small Tactical UAS (STUAS; PMA-263 – small tactical).

Similarly, the skill level requirements to operate each type of UAS (BUQ level) are determined by mission and size; the amount and type of training are determined by the altitude ceiling and capabilities of the UAS. These training requirements range from the minimum BUQ-I level to a maximum BUQ-IV level, which equates to a training level equivalent to an FAA private pilot license with instrument rating. These UAS training qualifications are detailed in OPNAVINST 3710.7U, Chapter 14, APPENDIX P.

Although there are defined training qualifications for operating UASs, LCDR Olde stated there is currently very little formal UAS operator training in the Navy; this is because 1) most UAS platforms (e.g. BAMS and Fire Scout) are still in development and have not been officially fielded, 2) UAS operators are currently either contractors or Navy pilots from similar platforms who receive UAS training (e.g. P3/P8 pilots operate BAMS or MH-60 pilots operate Fire Scout), and 3) current fielded small UAS operators (Raven, Shadow, etc.) are trained at Army or Air Force facilities. However, as the number and variety UASs utilized by the Navy increase, the need for a selection process and UAS training pipeline becomes essential.

The discussion also outlined several unique UAS training issues. For example, the continuous operation capability (persistence maritime) of BAMS requires training “hand-off” of control between UAS operators (both on-site and between distant locations) and procedures for maintaining situational awareness of the aircraft status as it is passed from operator to operator.

The Navy is working towards a common control system and achieving UAS combat readiness without any live flights (through simulated training). For simulated training, the Mission System Trainer (MST) currently planned for BAMS was presented as an example. The

BAMS MST is a redundant control station as well as an embedded training system. Simulated training is uniquely applicable to UASs because the “cockpit” never leaves the ground and all the mission/sensor data is sent to the control station. As long as the data can be accurately replicated, the operator can train and conduct operations on the same crew station (ideal instance of train as you fight). This provides beneficial cost reductions in that the operator will not burn fuel or incur wear and tear on the platform during training. Also there are cost savings from using the same equipment for training and missions. The common control station (CCS; see summary of CDR Cohn’s presentation for details) was also suggested as a cost saving option as one CCS, with “plug-and-play” components for specific UASs, could be used to train personnel for many different types of UASs.

Finally, the topic of who should be trained to operate unmanned systems (i.e., enlisted or officers) was introduced. Time restrictions prevented a thorough discuss but it was agreed that DOD decisions on these issues need to be made and will impact selection, training, and system design.

Toward a Common Control Station

*Ms. Melissa Walwanis
ONR Program Officer
Senior Research Psychologist
Naval Air Warfare Center – Training Systems Division*

There are many challenges in the development of a common control station interface for Unmanned Aircraft Systems (UAS). Due to budget constraints, there has been a growing need to reduce manning and training costs, yet increase the number of platforms controlled by a single operator, consequently increasing the complexity of the user interface design. Additionally, the wide variety of UAS platforms has led to different user interface designs. The Naval Air Warfare Center Training Systems Division (NAWC-TSD) is pursuing the development of a Common Control Environment for UAS, as well as for Unmanned Surface, Sub-surface, and Ground Systems (UxS). A common control station user interface which accommodates all of these platforms may reduce costs associated with procurement, manpower, and training.

Ms. Melissa Walwanis, a Senior Research Psychologist from NAWC-TSD, presented lessons learned from previous common control station design efforts. In one study described, a set of common tasks was documented for the Global Hawk and Predator UAS platforms. These tasks were sorted by the six phases of flight in which they occurred: mission planning, en-route, vehicle handover, crew changeover, recovery, and emergency procedures. Each task was then evaluated for common design implications and, including input gathered from subject matter experts, used to develop guidelines for a common control station user interface. Analyses revealed that between the Global Hawk and the Predator, there was a great deal of overlap regarding common task. Design recommendations resulting from this study include:

- To support tasks such as mission planning, display information needed for the task in a common location, and on one screen if possible.
- For vehicle handover, provide a function that allows the operator to validate Estimated Time of Arrival (ETA) simply by placing the cursor over a waypoint.
- To support crew changeover, provide consolidated mission transfer display which can serve as a log and be referred to once the outgoing crew has departed.
- Provide a “Low Signal Quality” Indicator on Global Positioning Satellite (GPS) Display to inform crew of potential navigation/position issues.
- In designing a common control station, a modular approach can be used to avoid burdening crews with functions that are not common to their platform.

Another UAS project conducted at NAWC-TSD was a heuristic-based usability analysis of Open Unmanned Mission Interface (UMI). Open UMI is a prototype interface that supports operation of multiple UAV systems. The testing approach consisted of a free-play analysis and a feature-based walkthrough analysis. Those evaluating the interface identified design strengths, as well as software bugs usability concerns. Some of the areas of concern included the need for improved alerts and feedback for the user, graphical user interface design, and prevention, identification, and diagnosis of user errors.

This brief also detailed several research initiatives which will aid in the development of a common control environment focused on the needs of the operator. This research would include further analyses to recognize a wider variety of common operator tasks across the different platforms, and include those tasks most important for sensor operators of different platforms as well. It is also important to determine whether the recommendations generated for UAV control stations would also be appropriate for other types of vehicles such as surface and subsurface platforms.

Naval UAS Cross-Platform Task Analysis

*Dr. Phillip Mangos
Senior Quantitative Research Scientist
Kronos, Inc.*

A variety of UAS human factors applications, such as personnel selection, training development, and operator interface design draw upon data from job or task analyses. As unmanned systems expand across the DoD at an accelerating rate, it will be important to identify the most critical mission-related tasks performed, and skills required, by UAS operators and crew members. Recently several Navy laboratories collaborated to conduct a large-scale cross-UAS job-task analysis to provide an empirical foundation for near-term applied UAS human factors efforts, such as selection test or training system development.

An important concern in personnel selection is the recognition of which skills and abilities are most important to ensuring the successful completion of any mission. In his presentation, Dr. Phillip Mangos explained the importance of identifying the differences and commonalities in necessary skills and abilities between the different UAS platforms used by the Navy and Marine Corps. Specifically, a detailed analysis of operator requirements would aid in the development of UAS-focused knowledge, skills, abilities and other characteristics (KSAOs) and by extension help to ensure that those personnel who are recruited to serve as UAS operators possess the necessary skills.

Dr. Mangos presented findings from a recent study which examined whether there were any particular KSAO requirements which were common across different Naval platforms. An extensive survey was administered to UAS crew members of different positions (e.g., mission commander, pilot, sensor operator, etc) asking them to rate on several dimensions the tasks associated with their particular position. The four dimensions on which tasks were rated were the task's importance, how difficult it was to learn, how often it was used, and the level of mastery required for a qualified operator. Data on KSAO importance were collected as well.

Subject responses to the survey revealed that key cross-platform tasks included: performing takeoffs and landings; performing intelligence, surveillance and reconnaissance tasks, including collecting, reporting, and disseminating intelligence information; maintaining awareness of air traffic and air space; and reading, understanding, and analyzing warning or emergency messages. Important KSAOs included oral comprehension, dependability, adaptability, critical thinking, deliberation/concentration, accountability, task prioritization, assertiveness, and teamwork skills. Responses indicated high inter-rater agreement for several of the skill clusters, including airspace and operating area management, ship board tasks, and flight maneuvers. These resulting clusters of skills may be beneficial in the development of common personnel selection criteria as well as establishing training programs applicable to the different service areas and improving job family development.

USAF RPA Personnel Selection and SAOC Review

*Dr. Thomas R. Carretta
Senior Research Engineering Psychologist
Air Force Research Laboratory*

As the United States' involvement in different conflicts has increased over the last decade, so too has interest in and demand for remotely piloted aircraft (RPAs) and skilled operators. To address this increase in demand, the US Air Force shifted many pilots from manned aircraft to operate RPAs, resulting in a dearth of skilled pilots for manned aircraft. Further, there also was an insufficient number of trained sensor operators for these RPAs. Owing to these circumstances, and because selection criteria for manned aircraft also were being used as the selection criteria for unmanned aircraft operators, it was necessary to develop a recognized set of RPA-specific selection criteria in order to recruit capable operators from non-pilot populations.

In conjunction with the Human Resources Research Organization (HumRRO), the Air Force determined that several existing entry-level selection tests, such as the Air Force Officer Qualifying Test (AFOQT), Armed Services Vocational Aptitude Battery (ASVAB), and Test of Basic Aviation Skills (TBAS), are effective for assessing the most important RPA skills and abilities. These could be supplemented by experimental measures of personality such as the Naval Computer Adaptive Personality Scale (NCAPS), Self-Description Inventory (SDI+), or Tailored Adaptive Personality Assessment System (TAPAS). However, there are several skills and abilities, thought to be critical to the safe operation of an RPA, which are not adequately assessed by existing DoD tests. These are skills such as judgment and decision making, critical thinking, and teamwork, and abilities such as oral comprehension and expression, working memory, task prioritization, and situational awareness.

Several recommendations were made regarding methods to address shortcomings in personnel measurement and selection. Variations of the TBAS Dichotic Listening and the Enhanced Computer Administered Test (ECAT) Mental Counters tests were thought to adequately assess oral comprehension and working memory, respectively. It was also suggested that portions of the synthetic work program SynWin® and the FAA's Air Traffic Selection and Training battery could be used to measure task prioritization, selective attention, and time sharing abilities. Further, there were several important skills and abilities for which no suitable test was currently available, such as situational awareness, critical thinking, judgment and decision making, and teamwork. It was speculated that these might better be addressed during training rather than personnel measurement selection. Also thought to be important for safe RPA operation is the potential operator's ability to adapt to the RPA work environment. To address this, HumRRO developed a person-environment (P-E) fit measure focused on factors unique to the RPA environment.

Crew Selection Testing for Naval Unmanned Aircraft Systems

*Dr. Richard D. Arnold,
Director - Aeromedical Research
Naval Medical Research Unit - Dayton*

This presentation summarized crew selection testing for Naval Unmanned Aircraft Systems (UAS). Navy selection-related projects that were discussed included a Pioneer operator test battery developed by Naval Aerospace Medical Research Laboratory (NAMRL) in the late 1990s, a follow-up analysis of the Pioneer platform test by Naval Aerospace Medicine Institute (NAMI) in 2002, and a 2010 cross-platform UAS job-task analysis conducted jointly by NAMRL (now NAMRU-Dayton), NAWC-AD, and NAWC-TSD.

In the late 1990s, a project was launched to develop and validate a computer-administered performance-based test battery to select Pioneer External Pilots (EP). A job analysis was performed which identified essential Knowledge, Skills, Abilities, and Other characteristics (KSAO). These included mental reversals/rotations, time estimation, hand-eye coordination, selective auditory attention, and multitasking (psychomotor and visual components). Test battery elements included specific sub-tests that were used because they tapped essential KSOAs. These included horizontal and vertical tracking, two-dimensional tracking, dichotic listening, digit cancellation, the Manikin test, and a time estimation task. The project ended prematurely, and the UAV selection tests that were developed were not transitioned to operational use.

In 2002, investigators at NAMI made contact with the Pioneer training unit, which had continued to administer the NAMRL test battery after the original project concluded in 1998. Test and training criteria data were obtained from the period 1998-2002, and additional validity analyses were performed. The sample included 5 Internal Pilot (IP) and 34 Ground Control Station Operator (GCSO) students. The main analyses included: 1) prediction of final training grade, and 2) prediction of qualification status at post-training operational units. Psychomotor, multitasking-calculation, multitasking-psychomotor, and visuospatial composite scores were generated and combined into an equally-weighted composite score. It was found that composite test scores correlated highly with the training grades, and that the final training average predicted completion of operator qualification at post-training operational units.

In 2010 a cross-platform UAS job-task analysis was conducted to determine if the operator KSAO requirements from the Pioneer project were similar, or generalizable, to current UAS missions. Results from 79 Subject Matter Experts (SME) revealed that many of the most important KSOA requirements from the Pioneer project were rated among the least important requirements for current UAS operators. The most important requirements for current UAS operators across platforms included communication skills, conscientiousness, coping with stress and emergencies, learning and memory skills, multitasking and attentional skills, planning and organizing skills, problem solving/reasoning skills, and social/interpersonal skills. It was suggested that such differences from the older Pioneer system largely reflect changes in control interfaces and concepts of operations (CONOPS), with current systems relying much more on automated processes, particularly with respect to flight controls. In addition, newer systems are becoming much more highly interconnected with higher echelon leadership, ground elements, and other unmanned systems.

Manning and Scheduling in UAS/RPA Operations

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Manning and scheduling is not a novel challenge in military operations; however, manning and scheduling in UAS/RPA operations does present some unique issues compared to manned operations. Some of these issues were assessed by Lt Col Tvaryanas whose presentation sought to “understand the manning and scheduling problem space and the human performance implications in life cycle planning for UAS operations.”

One of the most significant issues regarding manning and scheduling in general is the health impact that fatigue and shiftwork has on individuals, which can create a large economic cost. The current standard governing manning and scheduling is the standard work week, which assumes that there is X number of work hours and each individual can work eight to ten hours depending on the operation. However, the standard work week does not take into consideration work load or time of day issues, which can significantly affect fatigue. This is a concern because shiftwork related fatigue is one of the biggest health impacts and medical drivers in Intelligence, Surveillance, and Reconnaissance (ISR) communities and presents a significant performance challenge. The difficulty in dealing with shiftwork is that there is no optimal answer – research can suggest more preferable options, but union rules limit what can be done and individuals vary in ability and adaptability to do shiftwork (~20% cannot adopt/tolerate shiftwork).

Regarding UASs/RPAs specifically, Lt Col Tvaryanas presented data demonstrating that operators rate fatigue and shiftwork as significant performance issues. For instance, studies report that UAS operators rated fatigue and shiftwork as a major capability challenge, about 1/3 of shift workers (across multiple work environments) were found to be significantly fatigued, and mishaps were more likely when UAS crewmembers are fatigued. Data were presented that suggested fatigue may be a greater performance issue in UAS/RPA crews than manned crews causing significant reductions in reaction time, target recognition, cognitive throughput, vigilance, and mood. Additionally, UAS operators were found to have increased irritability, jitteriness, and sleepiness, which lead to decrements in crew resource management and team interaction.

Interestingly, performance decrements were not found to correlate with the number of flying hours as might be predicted. Lt Col Tvaryanas suggested that this might be because the number of hours worked and the time of worked hours is not the same – eight hours worked at night are harder than eight hours during the day. Furthermore, the work environment may have effects on fatigue – eight hours in a UAS operations “box” may be more difficult than working eight hours outside the box.

The brief by Lt Col Tvaryanas continued by discussing current UAS shiftwork heuristics and compared the effects of rapid vs. slow vs. fixed (compliant and noncompliant) shift rotation schedules on fatigue based on M&S experiments using actigraphy data collected from UAS

crewmembers. He reported that slow schedules are better than rapid and that a fixed compliant schedule is the best; however the worst for fatigue is a fixed non-compliant schedule, which is reality. Unfortunately, regardless of the recovery model employed, the current “pervasive manning/operational demand imbalances limit opportunities to schedule sufficient opportunities for personnel recovery to mitigate fatigue” – we currently just do not have the manpower to build in sufficient recovery time.

In summary, there is no current answer, but the lack of manpower and suboptimal shiftwork scheduling for UAS crews may cause immediate human performance decrements and possible long-term medical issues – both of which will increase cost.

Aerial Command and Control of Unmanned Aircraft Systems

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This presentation summarized a study that was conducted to investigate the ability of Unmanned Aerial System (UAS) operators to control a simulated Unmanned Aerial Vehicle (UAV) while those operators actually flew in the passenger area of an Army helicopter. This Manned-Unmanned teaming concept provides tactical advantages such as the ability to use UAVs as forward-deployed sensors for manned aircraft. This study took place aboard a United States Army Aeromedical Research Laboratory (USAARL) research JUH-60A Black Hawk helicopter. The objective was to measure simulated UAS flight performance and motion sickness symptoms of UAS controllers. The participants were 47 active-duty male Soldiers who were no more than moderately susceptible to motion sickness and who had less than 30 hours of flight time as crew members.

There were three independent variables:

1. JUH-60A flight condition (four levels):

- a) Classroom setting, b) JUH-60A with rotors turning on helipad, c) JUH-60A airborne with participant's out-the-window (OTW) view obstructed, d) JUH-60A airborne with OTW unobstructed

2. UAS controller seating direction (three levels)

- a) Forward, b) Sideways, c) Aft

3. Amount of JUH-60A maneuvering (two levels):

- a) Smooth: angle of bank (AOB) less than 10 degrees, airspeed less than 12 knots, altitude between 50 and 100 feet above ground level (AGL)
- b) Vigorous: AOB up to 45 degrees, airspeed between 80 and 100 knots, altitude between 100 and 300 feet AGL

Dependent variables were flight parameter errors (climb rate, heading, altitude, and bank angle) during 15 minute simulated UAV flights, and self-reported scores on the Motion Sickness Questionnaire (MSQ). All UAV tasks were simulated using MS Flight Simulator.

The results showed that participants aboard the JUH-60A could perform nearly all of the UAV tasks as well as they could when they were in a classroom training session. The one exception was that during UAV take-off, heading maintenance was better in the classroom than aboard the helicopter. The difference was small but still statistically significant. Even with that difference, participants were able to maintain UAV performance within Army flight standards.

For the MSQ, several significant effects were observed. When participants performed the UAV task in the classroom or in the JUH-60A on the helipad (with rotors turning), their MSQ scores were low and did not indicate motion sickness. When the JUH-60A was airborne, MSQ scores increased significantly. Seating position (facing forward, sideways, or aft) did not significantly affect MSQ scores. During smooth/limited maneuvering flight, MSQ scores were elevated as compared to ground scores, but not to the point where individuals would be considered motion sick. However, when the JUH-60A was engaged in vigorous maneuvering, MSQ scores increased significantly and to levels indicating motion sickness. This effect was amplified when the participant's view of the OTW scene was obstructed.

Discussion of the results highlighted that participants were able to effectively perform a simulated UAV flight task from a control station aboard an airborne helicopter. When helicopter maneuvering was mild and operators could see out of the aircraft windows, increases in motion sickness scores were limited. It was also noted that the simulated UAV task lasted only 15 minutes, and that operations of longer durations could possibly result in increased frequency and severity of motion sickness symptoms. Additionally, it is not known if the symptoms of motion sickness would decrease following a period of adjustment or time to build up tolerance to the flight conditions. Although manned-unmanned aircraft teaming looks promising, some human performance research questions remain.

Section 3: S&T Research Gaps

Workshop attendees were provided with worksheets and were asked to record their top S&T research gaps in the various topic areas. The authors of this report conferred and sorted the input from these worksheets into the following five categories of gaps: Interface Design, Manpower, Personnel, Training, and Fatigue and Scheduling. Similar worksheet responses within each category were grouped and tallied, and the results are listed below, rank ordered within each category. The numbers in parentheses represent the number of times the gap was listed by respondents.

Interface Design

1. Study the human factors issues involved in the development of a common control station (CCS) (5)
 - a. Listed factors to consider included: degree of commonality possible, multi-vehicle control, heterogeneous (air, sea, land) vehicle control, and effects of automation
2. Evaluate novel vs. traditional interface design (e.g. UAV control station vs. cockpit) (5)
3. Quantify the cost, training, and performance benefits of a CCS (3)
4. Improve interface design to allow operators to gain and maintain situation awareness (3)
 - a. Listed factors to consider included: Implications of sensory impoverishment (i.e. reduced field of view, vestibular, auditory cues) and high visual-cognitive demands
5. Design interface to support time-coupled tasking required for collaborative missions (1)

Manpower

1. Determine safe manning levels and operator to vehicle ratio (9)
2. Develop methods to optimize crew workload/workload distribution (4)
3. Explore the effects of the location of common control station in relation to the unmanned vehicle and its impact on system and human performance (e.g. control station and operators INCONUS, controlling a weaponized UAV in an OCONUS theatre halfway around the world) (1)

Personnel

1. Identify appropriate UAS/RPA personnel selection criteria (i.e., Knowledge, Skills, Abilities and Other characteristics (KSAOs)) (10)
 - a. Consider KSAOs that may not be used in manned aviation selection tests, such as computer/info technology KSAs
2. Perform platform specific task analyses (3)
3. Identify standards/selection criteria for different crew positions (3)
4. Determine if operators should be trained pilots (2)
5. Define vision standards (1)

Training

1. Establish UAV-specific training requirements (2)
2. Determine level of simulation fidelity required to provide transparent training environments (2)
3. Explore training options of how to improve situational awareness (1)
4. Quantify the benefits of tri-service training (1)

Fatigue & Scheduling

1. Conduct research on optimal shiftwork schedules for 24/7 UAS operations (5)
2. Measure and monitor UAS operator vigilance and fatigue (2)
3. Assess impact of visual fatigue (including its contribution to overall fatigue) over a period time on performance (2)
4. Study the effects of shiftwork on operators' performance and health (1)
5. Study the effects of environment (e.g. night vs. day, A/C vs. no A/C) on operator fatigue (1)
6. Improve standards for better monitoring of UAS crew health and safety (1)
7. Determine if 24hrs/day operations are required, versus an alternative such as 20 hrs/day (1)

Section 4: Future Research Directions

Based on the presentations and input from the attendees of this workshop, recommendations can be made for research activity in each of the five following topic areas.

Interface Design – There is certainly interest across the services in the development of a common control station. Before such a control station can be designed, however, research needs to be conducted so that we can better understand issues such as how “common” control stations can be, especially if multiple and heterogeneous vehicles are to be controlled by those interfaces. Another topic to be considered is whether a UAS/RPA control station should be designed like a traditional manned aircraft cockpit, or whether it should follow completely new design paths. The respondents also called for more research on designing control stations that provide and maintain good operator SA and appropriate workloads, taking into account the highly networked, collaborative and time-coupled nature of UAS/RPA operations.

Manpower – Determining safe manning levels and operator-to-vehicle ratios was high on the list of manpower issues noted by workshop participants. It was noted that these should not be rigid ratios such as a fixed number like three vehicles to one operator, but rather something like nine vehicles per three operators. This way, if an operator experienced a problem with an assigned vehicle, he/she could shed his/her other vehicles to the other operators and focus on troubleshooting the malfunctioning craft. Closely related to this idea was the need to develop methods to optimize crew workload, and to distribute workload properly among UAS/RPA crew members. This is a challenge since when operations and automation are working smoothly, workload tends to be quite low. When a malfunction occurs, however, workload can spike.

A third and somewhat unique research/S&T gap mentioned under manpower was the need to study the effects of manning control stations INCONUS with operators who are conducting lethal warfare operations with vehicles half a world away. These operators are subject to very demanding schedules and life and death decisions at work, and then return to their families on a daily basis. The effects of this “commuting to war” work life need to be better understood.

Personnel Selection – Respondents identified the research need to determine the appropriate KSAO’s required in successful UAS/RPA personnel, and noted that new KSAO’s may be required as compared to the manned aviation world. For example, computer skills and knowledge of information technology may be more important for the UAS/RPA domain, while there may be room for more flexibility in some physical standards (e.g., vision standards). Respondents also identified the need to conduct platform specific task analyses. These analyses would help fill the need to identify selection criteria for the various crew positions, and would also help inform decisions on common control station designs. The need to determine whether or not UAS/RPA operators should be trained pilots of manned aircraft was also raised.

Training – The need to establish UAV-specific training requirements, and the need to determine the level of simulation fidelity required to conduct that training were gaps listed in this

area. Exploring training options to improve SA was mentioned, as was the need to quantify the benefits of tri-service training.

Fatigue and Scheduling – By design, unmanned aircraft engage in long endurance flights, and the demand to maintain 24/7 UAS/RPA presence in certain locations is very high. Not surprisingly, shiftwork was listed as a concern in UAS/RPA operations. Specifically, there is a need to determine optimal schedules to support around-the-clock operations, and to study shiftwork effects on operator performance and health. Respondents also identified the need to measure and monitor operator vigilance and fatigue, and given that the operator's task is visually intense, the effects of visual fatigue on overall fatigue need to be studied. Since UAS/RPV operators are often deployed in harsh settings, environmental effects on fatigue need to be investigated. Finally, respondents called for improved standards for better monitoring of crew member health and safety.

SUMMARY

The purpose of the workshop was to gather researchers and other SMEs to identify and discuss S&T gaps in the UAS/RPA domain. This proceedings report summarized the content of the formal presentations from the U.S. Army, Air Force, and Navy. Prioritized lists of S&T research gaps were also created. These gaps span most of the “life-cycle” of UAS/RPA operators and operations. Initially, we see the need for better selection and classification methods. Once candidates are selected, there is still much uncertainty surrounding the training methods and tools that should be used to create the best UAS/RPA crews. After training and transition to the field/fleet, crews are using sub-optimal interfaces to control their vehicles, and operators may soon be tasked with managing multiple vehicles with a common control station. Operators are often deployed in difficult environments, and they face challenging shiftwork schedules and long endurance missions. There is a clear need to better understand fatigue and scheduling issues associated with shiftwork operations, as well as potential long term impacts on operator health and quality of life.

UAS/RPA systems continue to be employed at a rapidly accelerating pace, and their roles are expanding and evolving as well. As these systems are used in new ways, new human factors and HSI issues are emerging. This workshop and report are examples of how we are beginning to identify and define these issues and S&T research gaps. It is hoped that by identifying current and future gaps and issues, resources will be directed toward research and development activities designed to address them. The end result will be improved UAS/RPA warfighter performance, mission effectiveness, and safety.

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14. ABSTRACT This document is a summary of the proceedings of the Unmanned Aircraft System / Remotely Piloted Aircraft (UAS/RPA) Human Factors and Human Systems Integration Research Workshop, hosted by the Naval Medical Research Unit – Dayton. The workshop was held 8-9 November 2011 in Dayton, OH. The goal of the workshop was to identify, discuss, and eventually address science and technology (S&T) research gaps related to a range of UAS/RPA Human Factors and Human Systems Integration Research topics. To accomplish this, the workshop brought together UAS researchers and other subject matter experts from across the Navy, Air Force, and Army. Ten speakers presented overviews of past, present, and future UAS/RPA research efforts and introduced a broad spectrum of issues currently facing the UAS/RPA discipline. Major discussion topics included: UAS operator selection, training, control station design, manpower and scheduling, manned-unmanned aircraft teaming, motion sickness, and medical standards.					
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