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Knowledge, Skills, Abilities, and Other Characteristics for Remotely Piloted Aircraft Pilots and Operators

William R. Howse
Damos Aviation Services, Inc.

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HQ AFPC/DSYX & HQ AF/A1PF
Kenneth L. Schwartz
Strategic Research and Assessment Branch

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Air Force Personnel Center
Strategic Research and Assessment
HQ AFPC/DSYX
550 C Street West, Ste 45
Randolph AFB TX 78150-4747

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This report presents the results from a review of a literature base of more than 200 publications in which eight were found to contain lists of Knowledge, Skills, Abilities, and Other Characteristics (KSAOs) for remotely piloted aircraft (RPA) crew positions, either for the purpose of system design specification or for personnel selection. The report compares KSAO lists across these studies and presents a cross reference table for them. The report also surveys past efforts to establish KSAOs in anticipation of related developments and discusses the major likely sources and nature of future changes in KSAO demand for RPA operators.

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CONTENTS

TABLES

ABSTRACT

This report presents the results from a review of a literature base of more than 200 publications in which eight were found to contain lists of Knowledge, Skills, Abilities, and Other Characteristics (KSAOs) for remotely piloted aircraft (RPA) crew positions, either for the purpose of system design specification or for personnel selection. The report compares KSAO lists across these studies and presents a cross reference table for them. The report also surveys past efforts to establish KSAOs in anticipation of related developments and discusses the major likely sources and nature of future changes in KSAO demand for RPA operators.

KNOWLEDGE, SKILLS, ABILITIES, AND OTHER CHARACTERISTICS

FOR REMOTELY PILOTED AIRCRAFT PILOTS AND OPERATORS

Introduction

In August 2009 Damos Aviation Services (DAS) accepted Subcontract TCN 09216 from Battelle Columbus Operations under the U.S. Army Research Office Scientific Services Program, Contract W911NF-07-D-0001 / Delivery Order 0906. This report responds to the requirement to compare and contrast current and future Knowledge, Skills, Abilities, and Other Characteristics (KSAOs) for Remotely Piloted Aircraft operators. In pursuit of this requirement relevant works were extracted from more than 40 sources beginning with the bibliographic database previously produced under this Delivery Order (Howse & Damos, 2011) and expanding with search criteria tailored to remotely piloted systems. More than 200 works were reviewed and only eight were found that are relevant to identification and evaluation of KSAOs for remotely piloted aircraft personnel and that at least elicited information from practitioners and/or subject matter experts that contributed to the identification of KSAOs.

Terminology varies considerably across services and over time within services. Even the phrases used to refer to the systems of interest are different. The phrases found in common use are: Unmanned Aerial Vehicle (UAV), Unmanned Aerial System (UAS), Unmanned Combat Air Vehicle or Uninhabited Combat Aerial Vehicle (UCAV), Remotely Piloted Vehicle (RPV), Tactical Unmanned Aerial Vehicle (TUAV), Unmanned Combat Armed Rotorcraft (UCAR), Vertical Take-off UAV (VTUAV), Ground Control System (GCS), and Common Ground Station (CGS). Because the U.S. Air Force has transitioned to universally adopting the term, Remotely Piloted Aircraft, the default term for air vehicles for this report is RPA.

There are a number of crew positions that are part of RPA systems. Not all of these have been targets of research efforts to identify or develop KSAOs. Again, there are differences in terminology across services. The crew positions that are the subject of one or more efforts cited in this paper are listed with their relevant Military Occupational Specialties (MOS), Ratings, and Air Force Specialty Codes (AFSC) are listed in Table 1.

Table 1. Duty positions and their associated MOS, Rating, AFSC.

Personnel Duty Positions	Service	MOS, Rating, AFSC	Basic Position Description
Air Vehicle Operator (AVO)	USA	96U	The tactical unmanned aerial vehicle (TUAV) operator supervises or operates the TUAV, to include mission planning, mission sensor/payload operations, launching, remotely piloting, and recovering the aerial vehicle.
	USA	15W	RPA operators are integral to providing Army personnel with information about enemy forces and potential battle areas. RPA operators are remote pilots of unmanned observation aircraft, who gather and study information that's required to design operational plans and tactics. The RPA operator supervises or operates the RPA, such as the Army's Shadow RPA, to include mission planning, mission sensor/payload operations, launching, remotely piloting, and recovering the aerial vehicle.
	USN	NEC 8363	Operates and navigates RPA during the enroute, mission, and return phase of flight.
	USMC	7413	External RPA operators execute the initial takeoff and final landing phases of RPA operations. They are also an integral part of all mission planning, takeoff and landing sequences, and crew coordination aspects of RPA flight.
	USAF	18X	Air Force RPA Pilots plan and prepare for missions. They review mission taskings, intelligence, and weather information, supervise mission planning, equipment configuration, and crew briefings. Also, they ensure ground station and aircraft are preflighted, inspected, loaded, and equipped for mission. RPA pilots operate aircraft and command crew, operate aircraft controls and equipment, perform, supervise, or direct navigation, surveillance, reconnaissance, and weapons employment operations. Further, they conduct or supervise training of crewmembers, ensure operational readiness of crew by conducting or supervising mission specific training. RPA Pilots also develop plans and policies, monitor operations, advise commanders, assist commanders and perform staff functions related to this specialty.
Internal Pilot (IP) - See AVO above			
External Pilot (EP)	USN	NEC 8362	Performs organizational level maintenance on aircraft systems. RPA External Pilot directly controls the flight of the RPA during launch and recovery operations by visual reference to the RPA.
	USMC	7413	
Mission Package Operator (MPO)	USA	96U	
	USA	15W	
	USN	NEC 8364	Operates the EO/IR RPA sensor during all phases of flight.

	USAF	1UOX1	RPA Sensor Operators perform duties as a mission crew member on unmanned aerospace systems. They employ airborne sensors in manual or computer-assisted modes to actively and/or passively acquire, track, and monitor airborne, maritime and ground objects. Qualified personnel conduct operations and procedures in accordance with Special Instructions (SPINS), Air Tasking Orders (ATO) and Rules of Engagement (ROE). Crewmembers assist UAS pilots (who are commissioned officers) through all phases of employment to include mission planning, flight operations, and debriefings. Sensor Operators continually monitor aircraft and weapons systems status to ensure lethal and non-lethal application of airpower. At present, Air Force 1UOX1 specialists perform their duties on the MQ-1 Predator and the MQ-9 Reaper remotely piloted aircraft (RPA).
Sensor Operator (SO) - See MPO above			
Mission Commander (MC)	USN	NEC 8364	
Common Ground Station Operator (GSO)	USA	96H	The common ground station (CGS) operator supervises or participates in detecting, locating and tracking ground targets and rotary wing and slow moving fixed wing aircraft. The GSO receives Joint Surveillance Target Attack Radar System (JSTARS) near-real time radar imagery data, RPA imagery, Commander's Tactical Terminal/Joint Tactical Terminal (CTT/JTT) Signals Intelligence (SIGINT) data, and Secondary Imagery Dissemination (SIDS) products which are transmitted to the Common Ground Station (CGS) to provide situational development, battle management, and targeting information and imagery intelligence of value to the commander.
Intelligence Analyst	USA	96B	The intelligence analyst supervises, performs, or coordinates, collection management, analysis, processing, and dissemination of strategic and tactical intelligence.
Imagery Analyst (Enlisted)	USA	96D	The imagery analyst supervises or analyzes aerial and ground permanent record imagery developed by photographic and electronic means. Plans and recommends the use of imaging sensors for reconnaissance and surveillance missions.

Imagery Analyst (Warrant Officer)	USA	350D	Provides technical expertise and manages activities engaged in imagery interpretation activities. Acts as the chief of a platoon, section, detachment, or team performing imagery interpretation. Identifies changes of terrain, equipment locations, troop movements, or other information that contributes to intelligence. Identifies equipment by nomenclature and location to develop assessments of possible threat to U.S. forces. Develops summaries and prepares reports on imagery interpretation findings. Establishes and maintains files on imagery interpretation data, findings, records, and reports. Develops map overlays which reflect changed tactical information. Conducts intelligence briefings based on information obtained.

Historical Background

The following is an extremely brief timeline of the development and acquisition of remotely piloted systems by the U.S. military. It is included to give the reader a sense of the time-span of RPA development and the rapidity, in recent years, with which system capabilities have expanded. It will also give the reader a sense of position in the timeline for the RPA systems that were evaluated in studies cited below. A far more complete history of RPAs has been written by L.R. Newcome (Newcome, 2004). Descriptions of current and emerging RPA systems can be found in the Department of Defense's Unmanned Systems Integrated Roadmap for the years 2009 to 2034 (Department of Defense, 2009).

The first documented application of remote piloting in aviation was contained in an operating model dirigible balloon exhibited by A.J. Roberts of Australia in 1912. This balloon was radio controlled (based on designs of Nikola Tesla). The model was about 15 feet long and could be controlled at a maximum range of about 500 feet.

At the beginning of World War I Professor A.M. Low of England, whose prior efforts were related to radio range finding, developed a remotely piloted airplane for the Royal Flying Corps. He successfully developed a radio control system. However, the engine of the prototype aircraft created too much radio interference for it to function properly. The first successful flight of a practical remotely piloted dirigible balloon took place in 1924 when the Royal Aircraft Establishment's *Target* flew for 12 minutes after launch from the deck of the HMS Stronghold. This project led to the design of the *Larynx*, a monoplane designed as an unmanned aerial bomb. It first flew in 1927 but there is no record of application in combat. The DeHavilland Tiger Moth, a biplane, served as a trainer from 1932 to 1947 in England. Several hundred of these aircraft were modified as remotely piloted target aircraft (designated *Queen Bee*). A few of these were employed in coastal reconnaissance missions during World War II.

In the early 1950s the Northrop/Radioplane Company developed the YQ-1B high altitude target drone into an unmanned reconnaissance vehicle, the B-67 *Crossbow*. The YQ-1B was equipped with a warhead and a radiation seeker for attacking air defense systems. The acquisition program was cancelled in 1957 before it became operational. Another early remotely piloted air vehicle was the AQM-34A *Firebee I*. This system was a modified target drone developed by Teledyne Ryan for the U.S. Air Force. It first flew in 1960. It could autonomously fly pre-programmed reconnaissance routes and employ a variety of mission equipment modules including photographic and infrared imaging and electronic countermeasures. Firebee I was used during the Vietnam war. No records have been located regarding selection practices for system operators.

In the 1970s the Army developed the MQM-105 *Aquila*, with Lockheed Missile and Space Company as the major contractor. It was designed for multiple battlefield roles concentrating on target acquisition, designation and aerial reconnaissance. The prototype first flew in 1975 and the first full scale development air vehicle flew in 1982. It had an endurance of 3.5 hrs and carried a daylight television camera and a laser rangefinder/designator with autotracking capability. Its flight path could be preprogrammed by altering waypoints stored in the flight control system. *Aquila* was never considered a successful system and was cancelled in 1987.

The RQ-2 *Pioneer* was procured first by the Navy in 1985 from Israeli Aircraft Industries (IAI) as a naval gunnery spotting system. It has been used by the Army, Navy and Marine Corps. It has an approximate 5 hour endurance carrying electro-optical and infrared sensors.

Another system originally developed by IAI is the RQ-5 *Hunter*, originally procured from TRW in 1993 and, starting in 2003, from Northrop Grumman as the MQ-5B. *Hunter* system acquisition ended in 1996 but existing units continue to be employed and retrofitted. These systems have an endurance of 12-18 hours. In 1999 some were equipped with a laser designator and in 2003 some were modified to carry a variant of the Brilliant Anti-Tank (BAT) guided munition. They can carry a variety of munitions as wing stores and a variety of sensor packages with electro-optical and infrared capabilities. It also can carry a radio relay package to provide extended communications ranges.

The Army began procurement of the RQ-7 *Shadow* in 1999. It has an on-station endurance of approximately 6 hours and carries a variety of electro-optical and infrared sensor packages and can be equipped with a laser designator.

The MQ-1 *Predator* was developed by General Atomics for the Air Force, though Army and Navy also use them, and has been in service since 1995. This is a long-range system capable of covering very long distances to an area of operations and loitering there for as much as 14 hours before returning. Whereas the preceding systems are controlled by line-of-sight radio link, Predator uses satellite links, allowing operators to be located nearly anywhere on the globe. It can carry a variety of sensor packages in daylight and infrared modes plus a laser designator and synthetic aperture radar. It can carry various wing-mounted stores including weapons, especially modified Hellfire missiles. Variants include the MQ-1C Extended Range/ Multipurpose (ER/MP) UAS with greater range and payload, and the MQ-9 Grey Eagle.

Identifying RPA Operator KSAOs

In 1979 an effort was made by the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) to extract from the small existing cadre of remotely piloted air vehicle operators and sensor operators a set of attributes that could be used to inform the development of selection and training systems (Crumley & Bailey, 1979). The approach was to administer two survey instruments, one to air vehicle operators and the other to sensor operators, and use their responses to guide structured group interviews. The surveys were made up of 27 multiple choice items, mostly having a Likert-type format, and one open-ended item soliciting written comments. Participants in the interviews were six airframe and sensor operators and nine support personnel and supervisors. These people were serving in the development group for the *Aquila* system. The survey items were derived from system manuals and contractor job descriptions. The group interview was guided toward consensus. The responses to the survey instruments were neither tabulated nor reported.

The authors suggested there were two personality types within their subject sample. This is based on the existence of two comparatively distinct attitudes toward continued work as system operators. Personnel who preferred the air vehicle operator role were described as having an affinity for planning and logic, those who preferred the sensor operator role were described as having an affinity for uncertainty. All operators disliked having close supervision during missions but agreed that a third (artillery trained) person was needed in the Ground Control Station (GCS).

The authors inferred from their data that eye/hand coordination was an important component of job performance but that physical strength, endurance, hearing acuity and color vision were not required at greater than average levels. Other attributes included patience and logic. Skill in verbal communication was also indicated as important. Two specific knowledge components were identified: map reading and photo interpretation.

After a 19 year absence of any apparent attempts to identify KSAOs for unmanned aerial system operators, Biggerstaff et al. (Biggerstaff, Blower, Portman, & Chapman, 1998) conducted a more formal project to predict training performance albeit their scope was limited to the role of the RPA external pilot (EP). This study had the expressed purpose of establishing selection criteria for entrance into training for *Pioneer* RPA operators. The attributes identified were also used to assist in making recommendations for medical screening of applicants for EP and internal pilots (IP); however, this study did not establish any training or job performance predictors for any crew position other than that of EP. The EP for the Navy version of *Pioneer* has a more extensive role in system operation than in larger RPAs. For *Pioneer* the EP is in direct interactive control of the airframe for takeoffs, landings, and while the airframe is in visual range of the crew. That is, the EP operates the airframe by manipulation of a set of flight controls similar to those of a recreational radio controlled aircraft. Takeoff and landing may be accomplished on a short airstrip or by jet-assisted launch from a pedestal and landing by capture net (shipboard operations).

The authors approached the operator tasks through task analyses, field observations, interviews (structured and unstructured), and test battery trials. An initial set of critical tasks was derived from observations and interviews of EPs, IPs, mission payload operators (MPO) and other related personnel. These tasks provided the source for personal attributes posited to affect performance. A single test battery, the Computer-Based Performance Test (CBPT) was selected to measure predictor variables (Delaney, 1992). A criterion measure was formed from an unspecified composite of instructor evaluations and flight grades, on a 0-100 scale.

The derived list of attributes, according to the authors, consisted of skills only; no specific knowledge, abilities, or other attributes were included. The derived skills were likely referred to as such because their source was a sample of fully trained, successful practitioners, rather than candidates. Therefore, personal attributes imparted by prior selection and training processes are assumed to be present. These skills were: Mental reversals/rotation, estimation of time to contact, eye-hand coordination, selective auditory attention, and multitasking (psychomotor + visual). It was determined that six subtests of the CBPT would adequately measure these skills: Psychomotor (PMT), Dichotic Listening (DLT), Horizontal Tracking (HT), Digit Cancellation (DC), Manikin, and Time Estimation (TET).

It appears to be the case that performance on the test battery components operationally defined the skill set. These test battery components are neither simple nor independent. They are designed to be administered in combinations and in specific orders progressing in complexity. PMT is combined with DLT, HT with DC, and Manikin with TET. The test components were associated with specific abilities: PMT with multilimb coordination, DLT with divided attention, HT with perceptual motor tracking, DC with reaction time and short-term memory, Manikin with mental rotation and short-term memory, and TET with perceptual tracking. Note that the abilities associated with DC do not directly correspond to any of the identified skills but may contribute indirectly to their measurement. The authors state that DC was used as a distracter, although no rationale for this is given. It may be that without an interfering secondary task HT was insufficiently difficult to produce measurement variance. The prototype battery was administered to eight students in EP training and six practicing EPs. It is not specified whether data from all 14 subjects were used to factor analyze eight performance scores derived from the battery. A single factor, consisting of a linear combination of the eight derived performance scores, was determined and used to predict the criterion measure using linear regression. The authors recognized that eight subjects (for whom the criterion measure was available) made for a rather small sample. Their solution was to insert 3 fictitious data points, one at the extreme low end of both predictor and criterion score, one at the extreme high end of both scores, and one at the approximate midpoints of both scores. The fictitious data points placed at the extremes were placed not at the extremes of observed scores on the predictor but rather, near the extremes of possible scores on the predictor. It is not unreasonable to expect that such manipulation would have a strong effect on the outcome of the regression. A review of the plot of factor scores versus criterion scores for 11 data points indicates that if the fictitious points were removed the slope of the regression would be similar but the dispersion far greater. The actual utility of the reported adjusted R^2 of .86 is questionable.

A job analysis intended for RPA future requirements was conducted by the Army Research Laboratory Human Research and Engineering Directorate (Barnes, Knapp, Tillman, Walters, & Velicki, 2000) that used the Job Assessment Software System (JASS) to explore manpower alternatives. The primary issues considered were the need for rated aviators and for imagery and intelligence specialists in RPA crews. This study was not intended to produce any information regarding selection of personnel for training. JASS was used to elicit relative importance ratings of two reduced sets of skills and abilities for RPA operators. The reduced skill and ability sets were extracted, presumably by the authors, from the 50 that comprise the full set in the JASS application. The 50 attributes in JASS are based on 52 abilities in Fleishman's Manual for Ability Requirements Scales (Fleishman & Quaintance, 1984). The reduced attribute sets were cognitive skills and abilities judged to be related to flight and navigation tasks for air vehicle operators (AVO) and to takeoff and landing tasks for EPs. The ratings were taken from a mix of 30 soldiers and contractors who were practicing as *Hunter* AVOs, MPOs and EPs. In addition, ratings on the EP list were taken from 16 Army aviators. (These will not be further discussed here.) Reduced attribute sets for JASS were also established for intelligence analysts and imagery analysts based on task structures for each. Rating data were collected in JASS on these attribute sets from nine intelligence analysts and eight imagery analysts. The ratings for each specialty were correlated with ratings taken from the original sample of AVOs, MPOs and EPs.

The JASS structure groups the 50 abilities taken from Fleishman into 8 categories: Communication, Conceptual, Reasoning, Speed Loaded, Vision, Audition, Psychomotor, and Gross Motor. The ratings indicate that the AVOs considered the Communications group (including oral and written comprehension and oral and written expression) to be most important, followed by the Conceptual group (including memorization, problem sensitivity, spatial orientation, and selective attention), and the Reasoning group (deductive reasoning, information ordering and inductive reasoning). The Vision, Audition and Gross Motor groups received comparatively low importance ratings. The ratings indicate that the EPs considered the Conceptual, Vision and Psychomotor groups most important.

The authors did not attempt any evaluation of psychomotor skills in their own work for this report but did review and report the results of previous unpublished work (Hopson, 1995) in which psychomotor ability was assessed for use in selecting RPA EPs. (We have not obtained a copy of that manuscript and so must rely on the reporting of the authors.) The instrument used in that study was the Enhanced Computer Administered Test (ECAT) battery. The ECAT battery was developed by ARI and the U.S. Navy Personnel Research and Development Center (NPRDC) to evaluate candidates for augmentation of the Armed Services Vocational Aptitude Battery (ASVAB), under ARI's Project A (Oppler et al., 1992). The authors report that the unpublished study used two of nine subtests in the battery (Oppler et al. list 10 subtests in ECAT), One-Hand Tracking (also known as Target Tracking Test 1) and Two-Hand Tracking (also known as Target Tacking Test 2). The subtests were administered to 28 EP candidates in training in both Hunter and Pioneer systems, from the Army, Navy, and Marine Corps. The authors report that the unpublished work indicated a strong relationship between the One- and Two-Handed Tracking scores and failure to complete training. No statistical analysis of the data is reported.

In another application of the JASS tool, Warner and Knapp (2000) compared the current skill requirements for Army Common Ground Station Operators with projected skill requirements for an enhanced Common Ground Station in development. They also considered whether skills and abilities possessed by Intelligence Analysts and Image Analysts should be integrated into CGS personnel. JASS was administered to 41 CGS Operators (GSO) to acquire importance ratings on seven high level functions specific to their duty position in the enhanced CGS. These were:

1. Establish Comm Links
2. Display moving target indicator (MTI) track targets
3. Respond to All Source Analysis System (ASAS) tasking
4. Respond to fire support tasking
5. Correlate sensor data from RPA, Commander's Tactical Terminal (CTT), and MTI
6. Perform target analysis
7. Use intel-ops knowledge

Of the 41 operators participating, 13 had experience in the developmental enhanced CGS. Only four of the eight JASS skill categories were considered likely to be impacted in the enhanced CGS: Communication, Conceptual, Speed Loaded, and Reasoning. These four groups contain 23 of the 52 abilities listed in Fleishman's Manual for Ability Requirements Scales (Fleishman & Qaintance, 1984). The data indicate that in the Communication group skill demands were expected to decrease for all seven functions in the enhanced CGS. Skill demands for Functions 2, 3, and 4 were also expected to decrease in all four skill groups. These decreases were attributed to expected efficiencies stemming from improved user interfaces and increased automation. For Functions 1, 5, and 7 the expectation was for an increase in skill demand for the Conceptual, Speed Loaded, and Reasoning skill groups.

The authors also compared their rating data with ratings obtained earlier from Image Analysts and Intelligence Analysts. Their data indicated that for several of the abilities rated in JASS the Image Analysts and Intelligence Analysts tended to rate the requirement as high (an arbitrary rating of 3 or greater) on a greater proportion of the functions involved. This comparison is unclear at best because the function sets rated by the Imagery and Intelligence Analysts were different from the GSO function set and presumably different from each other. The authors concluded that fielding of the enhanced CGS would be expected to produce a shift in ability requirements toward cognitive and perceptual categories. It should be noted that the enhanced CGS that was in development during this study is not yet fully implemented.

In a 2003 presentation at the Military Testing Association Conference, Phillips et al., (Phillips, Arnold, & Fatolitis, 2003) described their effort to validate a selection battery for RPA operator training. This was a follow-on to Biggerstaff et al., described above. However, whereas Biggerstaff et al. developed their battery for EP selection, Phillips et al. conducted a validation of a similar battery for prediction of success in IP training. It is assumed that the validation is based on analysis of data that had been in existence for several years. The battery was administered to 39 individuals who were in IP training between 1995 and 1997. It is not clear at what point in training the battery was administered. The test battery was the same as that used in Biggerstaff et al. except the Time Estimation Test (TET) was not used. Scoring, however, was accomplished rather differently. Predictor variables were four Component Scores and an Index Score. The four Component Scores, each consisting of the mean of a set of standardized battery performance scores, were taken from the PMT, DL, HT, DC, and Manikin tests. The four Component Scores were named: Psychomotor, Multitasking-calculation, Multitasking-psychomotor, and Visuospatial. These score components were not independent. For example, from the simultaneous presentation of DL and the one-hand tracking portion of PMT (stick), the DL score was used in the Multitasking-calculation score component and the one-hand tracking (stick) portion was used in the Multitasking-psychomotor component. The mean of the four Component Scores comprised the Index Score.

Two criterion variables were used. The first, Training Performance, was the average of all test scores and flight evaluation grades in training. The second was dichotomous, attrition from training, presumably without regard to cause. Of the 39 students in the sample, six failed to complete training. These as a group had significantly lower performance on the predictor variables, all four Component Scores, and on the Index Score, as indicated by t-tests calculated using an alpha value of .05. The Index Score is a linear combination of the Component Scores. Considering only the Component Scores, the sum of the Type I error probability is .25. Attriting students did not exhibit significantly different training performance scores from non-attriting students. All four Component scores and, not surprisingly, the Index Score, significantly correlated with training performance. This is based on a univariate correlation matrix. No multivariate analysis was reported. The correlation between the Index Score and Training Performance was .59.

A selection test battery was developed for Army UAS operators in 2007 (Bruskiewicz, Houston, Hezlett, & Ferstl, 2007). The Army uses a single Military Occupational Specialty (MOS) for both AVO and MPO positions. Because they are completely cross-trained and interchangeable, a single battery can be used for training selection. This battery was not designed for any other

UAS-related position. Development of the battery was in anticipation of the effects on UAS operator tasks and missions and, therefore, on relevant personal attributes that would result from the transfer of all Army UAS assets (except for Raven, which remains with the Infantry) from the Military Intelligence Branch to the Aviation Branch. Under the Military Intelligence branch the relevant MOS was 96U. Under the Aviation branch it is 15W.

Development of the battery began with a job analysis using the job inventory approach implemented through a Job Analysis Questionnaire (JAQ). Prior job analyses and training materials were reviewed to produce a preliminary task list with related KSAOs. These provided the base content of a draft JAQ. The draft JAQ was reviewed by subject matter experts who provided feedback on both content and structure, and was revised to produce an instrument with 135 task statements and 77 KSAO statements. The resulting JAQ was administered at five locations and generated valid responses from 75 individuals. Ten of these were subject matter experts (SME) who had particular knowledge of emerging UAS airframe and mission capabilities and who were asked to complete the JAQ with future KSAO requirements in mind. All of the remaining 65 respondents were current Army UAS operators. For the SME respondents the inter-rater agreement on importance of KSAO statements was .64, which is considered high. For the rest of the respondents the inter-rater agreement on importance of KSAO statements was .58, which is considered moderate.

Using a conservative Type I error rate of .10 the authors found nine KSAOs on which the SME subgroup differed from the rest of the respondents as indicated by the means of importance ratings. Using a more customary Type I error rate of .05, there are only four: Operation of Weapon Systems and Equipment, Operation of Sensor/Tracking Systems and Equipment, Risk Tolerance, and Deliberation. In the first two cases the SMEs produced higher mean importance ratings than the rest of the respondents. In the last two cases the SMEs produced lower mean importance ratings. The first two were Knowledge attributes that directly relate to weapon system operation. Only the SMEs had experience with weaponized UAS. The other two were both Other attributes. The lower mean SME rating of the importance of risk tolerance could be anchored in the increased level of responsibility, magnitude of consequences and emphasis on rules of engagement that attend weaponization of UAS. These differences did not impact decisions regarding assessment of the attributes, but they do provide indication of shifting demands relating to required personal attributes.

System specific knowledge is presumed to be imparted during the training process. It was therefore deemed unnecessary (and probably unproductive) to assess the Knowledge attributes in the prototype selection battery. The Skills, Abilities, and Other Characteristics were considered to be critical if they received a mean importance rating (from the whole sample) of 3.0 or higher. Of the 65 non-Knowledge KSAOs, 49 were considered critical. Responding to guidance to maximize the use of existing instruments rather than develop new ones, the authors selected four instruments that had been developed for or used in a preceding project to develop an aviator selection battery for the Army, the Selection Instrument for Flight Training (SIFT). These were: Army Aviation Biodata, Assessment for Individual Motivation, Perceptual Speed and Accuracy-Hidden Figures, and Perceptual Speed and Accuracy-Simple Drawings. Two subtests were selected from the Navy's Aviation Selection Test Battery (ASTB): Reading Comprehension and Spatial Apperception. Finally, a subtest was selected from the Navy's Performance Based

Measures (PBM) battery, the Directional Orientation Test. The combination of these into a selection battery for UAS operator training selection is believed to assess 35 of the 49 critical KSAOs, while retaining an acceptable cost of administration, particularly in terms of administration time (typically less than 2 hours).

Pilot testing was conducted on the prototype battery using 20 students in Army UAS operator training. There were no indications of psychometric deficiencies among the subtests. Intercorrelations of scores appeared to be logical and consistent with expectation. None of the correlations were high enough to preclude expectation of unique contribution to predictive validity. Review of the courses of training at that time lead to a recommended set of Criterion Measures for UAS operator training selection. These include five derived from scores on written tests in specific phases of the common core training and a Behavioral Summary Scale (BSS) to be completed by instructors on a daily basis. Three additional measures would be derived from the advanced phases of training that are system specific. These would include the score on one written exam, the number of retests required to pass the Simulator-based flight portion of training, and the number of retests required to pass the flight portion of training. In addition BSS scores would also be used.

Recently the Air Force Research Laboratory 711th Human Performance Wing (Chappelle, McDonald, & King, 2010) conducted a study to identify critical personal attributes relevant to training success and career performance for RPA sensor operators. The authors approached their work through structured interviews conducted in five venues. In the Command Interviews senior commanders were interviewed individually and in a group discussion to elicit their perceptions on RPA operational roles and on personal attributes relating to success. The authors also conducted RPA Pilot interviews and Sensor Operator interviews, and Multidisciplinary Group interviews. Finally, Instructor Interviews were conducted in concert with observation of simulator-based training scenarios. A total of 69 RPA operators participated. These represented four subgroups: Commanders, instructors, pilots, and sensor operators.

Notes from the structured interviews were consolidated and a list of 130 attributes was extracted. After elimination of redundancies and elimination of knowledge and skill attributes that resulted from system training, the remaining attributes were reviewed to determine the number of subgroups that identified them as critical. Those so identified by three of the four subgroups of participants were retained. The remaining 21 critical attributes were placed into one of four groups: physical health, cognitive aptitude, personality traits, and motivation.

A related study (Chappelle, McDonald, & McMillan, 2011) was conducted to identify critical personal attributes relevant to training success and career performance for RPA pilots. This approach was based on structured interviews starting with SMEs, then senior commanders. The authors conducted individual and group interviews with RPA pilots, received 4 hrs of pilot training and conducted group interviews with pilots and sensor operators. They also interviewed a group of flight surgeons. A total of 82 individuals participated. Notes were consolidated and a preliminary list of 130 attributes was extracted (interestingly, the same number as in the previous study). Redundancies, and the knowledge- and skill-based attributes were removed. The resulting list of 21 attributes was nearly identical to that of the previous study. At this point there occurred a novel change in the process. The 21 attributes were sorted into four "domains":

cognitive aptitudes, intrapersonal traits, interpersonal traits, and motivational traits. Three of the four correspond to the groups used in the previous study. Physical health was eliminated and apparently the personality traits group was split into intra- and inter-personal traits. The 21 attributes from the final list were sorted into the four "domains" at which point they are referred to as "facets." Each facet was given a set of "distinct attributes." These correspond closely with the descriptions used in the previous study. What had been attributes became facets. What had been descriptions became attributes. In order to make sense of any comparison of KSAOs across studies, this shift in terminology will be ignored and the "facets" will be treated as attributes.

Comparison of RPA Operator KSAOs

Eight publications that in some form produced KSAOs for RPA crew positions were reviewed in the previous section. The KSAO lists from each of these are presented in Tables 3 through 10. As a baseline reference, and because of commonality with several of the attribute lists, Table 2 presents a list of the Abilities attributes contained in Fleishman's Manual for the Ability Requirements Scales. In Table 2 there are Abilities only, no Knowledge, Skills or Other Characteristics. Fleishman constructed this list with the goal of eventually developing a global taxonomy that could describe any task in terms of personal attributes required to complete it. This was to be a tool for comparing tasks and sorting them into categories. The list presented here contains the names of 52 human abilities with definitions for each. They can be seen still in the far larger and more complex lists of the Occupational Information Network (O*NET). The numbering of these is the same as used by Fleishman. For Job Analysis, the use of an attribute taxonomy allows greater ability to generalize across studies and behavioral situations than if attributes are named and operationally defined uniquely in every instance. That can lead to overly complex attribute labels and wide variance among job evaluators in redundancy and specificity. Additionally, it can create conditions in which attributes with the same or very similar names may refer to very different capabilities. The attribute set in Table 2, however, is far from global, covering only a portion of one major domain, abilities, that are the concern of job and task analysts.

Table 3 lists the Skills, Abilities and Other Characteristics that appeared to be contained in the report by Crumley and Bailey (1979). This report predates Fleishman's taxonomy and the work reported by them was not intended to provide a complete job analysis for RPA operators. It is the earliest example of any attempt to identify personal attributes that was found. This list contains only eight entries: Two Skills, four Abilities and two Other Characteristics. The authors did not offer any operational definitions of these attributes. They are numbered approximately in the order in which they are mentioned in the text.

Table 4 lists the attribute list derived from Biggerstaff et al. (1998). It is even shorter, with only 5 entries, all considered Skills. The operational definitions appear to be the test tasks themselves rather than qualities intrinsic to job related tasks. It appears that in this case the development of predictor measures for training performance may have been the reverse of the usual process: The personal attributes were derived from the available assessment instruments and assigned to the job of RPA External Pilot.

The list in Table 5, from Barnes at al. (2000), is longer, with 50 attributes listed and numbered in the order in which the authors listed them. The correspondence with Fleishman's taxonomy is nearly perfect, not surprisingly since the survey tool used (JASS) is directly derived from Fleishman. The developers of JASS re-ordered the abilities and grouped them logically. They also changed a few of the definitions to make them more readable and intuitive. For example, their ability # 23, Choice Reaction Time, corresponds with Fleishman's #22, Response Orientation. This correspondence becomes clear only when the definitions are compared.

Table 6 lists 50 attributes that were identified by Warnes and Knapp (2000). These are identical to those in Table 5 because the same tool, JASS, was employed. Where Barnes et al. concentrated on AVO and EP jobs, Warnes and Knapp concentrated on the job of GSO.

The attribute list from Phillips et al. (2003) is the shortest with only four entries. As with Biggerstaff et al. (1998), it appears that the assessment instruments were more the source of attribute definition than either the job or tasks. Table 7 lists these and shows that they are identical to those in Biggerstaff et al. except for the absence of time estimation.

Things are very different in Table 8, which lists the attributes identified by Bruskiewicz et al. (2007) from a job analysis performed on both AVO and MPO positions. This list contains 77 attributes: 12 Knowledge, 6 Skills, 25 Abilities, and 38 Other Characteristics. They are numbered in the order in which the authors listed them. This large set, covering all four attribute domains exists largely because they were produced by the only study on KSAOs for RPA operators that performed a complete process for KSAO identification. The danger attendant to their approach is that there is not a strong connection to any particular taxonomy, and so many of the attributes and their definitions may be ad-hoc. Therefore, it becomes difficult to compare these with attributes listed in other works.

Table 9 presents 21 attributes identified by Chappelle at al. (2010) for MPO positions, including seven Abilities and 14 Other characteristics. Although the authors reported that Knowledge and Skill attributes had been identified, their screening process eliminated them. The attributes are numbered in the order in which the authors listed them. These attributes, derived entirely from interviews with practitioners, are largely ad hoc with little correspondence to KSAOs identified in other works. They also tend to be vague and poorly defined.

Table 10 presents the 21 attributes identified for AVOs by Chappelle at al. (2011). There is a fair amount of correspondence between this and the previous list in the attribute names. The definitions, however are in some cases identical and in others radically altered. In addition, they have been reordered. This makes comparison even between these two related studies problematic.

Table 2. Attribute list from Fleishman's Manual for the Ability Requirements Scales (Fleishman & Quaintance, 1984).

	Attribute Name	Description
	Abilities	
1	Oral Comprehension	Ability to understand spoken English words and sentences.
2	Written Comprehension	Ability to understand written sentences and paragraphs.
3	Oral Expression	Ability to use English words or sentences in speaking so others will understand.
4	Written Expression	Ability to use English words or sentences in writing so others will understand.
5	Fluency of Ideas	Ability to produce a number of ideas about a given topic.
6	Originality	Ability to produce unusual or clever ideas about a given topic or situation. It is the ability to invent creative solutions to problems or to develop new procedures to situations in which standard operating procedures do not apply.
7	Memorization	Ability to remember information, such as words, numbers, pictures, and procedures. Pieces of information can be remembered by themselves or with other pieces of information.
8	Problem Sensitivity	Ability to tell when something is wrong or is likely to go wrong. It includes being able to identify the whole problem as well as the elements of the problem.
9	Mathematical Reasoning	Ability to understand and organize a problem and then to select a mathematical method or formula to solve the problem. It encompasses reasoning through mathematical problems to determine appropriate operations that can be performed to solve problems. It also includes the understanding or structuring of mathematical problems. The actual manipulation of numbers is not included in this ability.
10	Number Facility	Involves the degree to which adding, subtracting, multiplying, and dividing can be done quickly and correctly. These can be steps in other operations, such as finding percentages and taking square roots.
11	Deductive Reasoning	Ability to apply general rules to specific problems to come up with logical answers. It involves deciding if an answer make sense.
12	Inductive Reasoning	Ability to combine separate pieces of information, or specific answers to problems, to form general rules or conclusions.
13	Information Ordering	Ability to follow correctly a rule or set of rules to arrange things or actions in a certain order. The rule or sets of rules used must be given. The things or actions to be put in order can include numbers, letters, words, pictures, procedures, sentences, and mathematical or logical operations.
14	Category Flexibility	Ability to produce many rules so that each rule tells how to group a set of things in a different way. Each different group must contain at least two things from the original set of things.
15	Speed of Closure	Involves the degree to which different pieces of information can be combined and organized into one meaningful pattern quickly. It is not known beforehand what the pattern will be. The material may be visual or auditory.
16	Flexibility of Closure	Ability to identify or detect a known pattern (such as a figure, word, or object) that is hidden in other material. The task is to pick out the disguised pattern.

17	Spatial Orientation	Ability to tell where you are in relation to the location of some object or to tell where the object is in relation to you.
18	Visualization	Ability to imagine how something will look when it is moved around or when its parts are moved or rearranged. It requires the forming of mental images of how patterns or objects would look after certain changes, such as unfolding or rotation. One has to predict how an object, set of objects or pattern will appear after the changes are carried out.
19	Perceptual Speed	Involves the degree to which one can compare letters, numbers, objects, pictures or patterns, quickly and accurately. The things to be compared may be pictures or patterns, quickly and accurately. The things to be compared may be presented at the same time or one after the other. This ability also includes comparing a presented object with a remembered object.
20	Control Precision	Ability to move controls of a machine or vehicle. This involves the degree to which these controls can be moved quickly and repeatedly to exact positions.
21	Multilimb Coordination	Ability to coordinate movements of two or more limbs (for example, two arms, two legs or one leg and one arm), such as in moving equipment controls. Two or more limbs are in motion while the individual is sitting, standing or lying down.
22	Response Orientation	Ability to choose between two or more movements quickly and accurately when two or more different signals (lights, sounds, pictures) are given. The ability is concerned with the speed with which the right response can be started with the hand, foot or other parts of the body.
23	Rate Control	Ability to adjust an equipment control in response to changes in the speed and/or directions of a continuously moving object or scene. The ability involves timing these adjustments in anticipating these changes. This ability does not extend to situations in which both the speed and direction of the object are perfectly predictable.
24	Reaction Time	Ability to give one fast response to one signal (sound, light, picture) when it appears. This ability is concerned with the speed with which the movement can be started with the hand, foot or other parts of the body.
25	Arm-Hand Steadiness	Ability to keep the hand or arm steady. It includes steadiness while making an arm movement as well as while holding the arm and hand in one position. This ability does not involve strength or speed.
26	Manual Dexterity	Ability to make skillful coordinated movements of one hand, a hand together with its arm, or two hands to grasp, place, move or assemble objects, such as hand tools or blocks. This ability involves the degree to which these arm-hand movements can be carried out quickly. It does not involve moving machine or equipment controls, such as levers.
27	Finger Dexterity	Ability to make skillful coordinated movements of the fingers of one or both hands and to grasp, place or move small objects. This ability involves the degree to which these finger movements can be carried out quickly.
28	Wrist-Finger Speed	Ability to make fast, simple repeated movements of the fingers, hands and wrists. It involves little, if any, accuracy or eye-hand coordination.
29	Speed of Limb Movement	Involves the speed with which a single movement of the arms or legs can be made. This ability does not include accuracy, careful control or coordination of movement.

30	Selective Attention	Ability to concentrate on a task one is doing. This ability involves concentrating while performing a boring task and not being distracted.
31	Time Sharing	Ability to shift back and forth between two or more sources of information.
32	Static Strength	Ability to use muscle force in order to lift, push, pull or carry objects. It is the maximum force that one can exert for a brief period of time.
33	Explosive Strength	Ability to use short bursts of muscle force to propel oneself or an object. It requires gathering energy for bursts of muscle effort over a very short time period.
34	Dynamic Strength	Ability of the muscles to exert force repeatedly or continuously over a long time period. This is the ability to support, hold up or move the body's own weight and/or objects repeatedly over time. It represents muscular endurance and emphasizes the resistance of the muscles to fatigue.
35	Trunk Strength	Involves the degree to which one's stomach and lower back muscles can support part of the body repeatedly or continuously over time. The ability involves the degree to which these trunk muscles do not fatigue when they are put under such repeated or continuous strain.
36	Extent Flexibility	Ability to bend, stretch, twist, or reach out with the body, arms or legs.
37	Dynamic Flexibility	Ability to bend, stretch, twist, or reach out with the body, arms and/or legs, both quickly and repeatedly.
38	Gross Body Coordination	Ability to coordinate the movement of the arms, legs and torso together in activities in which the whole body is in motion.
39	Gross Body Equilibrium	Ability to keep or regain one's body balance or stay upright when in an unstable position. This ability includes maintaining one's balance when changing direction while moving or standing motionlessly.
40	Stamina	Ability of the lungs and circulatory systems of the body to perform efficiently over long time periods. This is the ability to exert oneself physically without getting out of breath.
41	Near Vision	Capacity to see close environmental surroundings.
42	Far Vision	Capacity to see distant environmental surroundings.
43	Visual Color Discrimination	Capacity to match or discriminate between colors. This capacity also includes detecting differences in color purity (saturation) and brightness (brilliance).
44	Night Vision	Ability to see under low light conditions.
45	Peripheral Vision	Ability to perceive objects or movements towards the edges of the visual field.
46	Depth Perception	Ability to distinguish which of several objects is more distant from or nearer to the observer or to judge the distance of an object from the observer.
47	Glare Sensitivity	Ability to see objects in the presence of glare or bright ambient lighting.
48	General Hearing	Ability to detect and to discriminate among sounds that vary over broad ranges of pitch and/or loudness.
49	Auditory Attention	Ability to focus on a single source of auditory information in the presence of other distracting and irrelevant auditory stimuli.
50	Sound Localization	Ability to identify the direction from which an auditory stimulus originated relative to the observer.
51	Speech Hearing	Ability to learn and understand the speech of another person.
52	Speech Clarity	Ability to communicate orally in a clear fashion understandable to the listener.

Table 3. Attribute list from Crumley & Bailey, 1979.

	Attribute Name	Description
	Skills	
1	Map Reading	
2	Photo Interpretation	
	Abilities	
3	Oral Comprehension	
4	Situational Awareness	
5	Oral Expression	
6	Multilimb Coordination	
	Other Characteristics	
7	Affinity for Planning and Logic	
8	Affinity for Uncertainty	

Table 4. Attribute list from Biggerstaff et al., 1998.

	Attribute Name	Description
	Skills	
1	Mental reversals/rotation	Manikin test performance
2	Estimation of time to contact	Time Estimation Test (TET) performance
3	Eye-hand coordination	Horizontal Tracking (HT) Test performance
4	Selective auditory attention	Dichotic Listening Test (DLT) performance
5	Multitasking (psychomotor + visual)	Psychomotor Test (PMT) performance

Table 5. Attribute list from Barnes et al., 2000.

	Attribute Name	Description
	Abilities	
1	Oral Comprehension	Ability to understand spoken English words and sentences.
2	Written Comprehension	Ability to understand written sentences and paragraphs.
3	Oral Expression	Ability to use English words or sentences in speaking so others will understand.
4	Written Expression	Ability to use English words or sentences in writing so others will understand.
5	Memorization	Ability to remember information, such as words, numbers, pictures, and procedures. Pieces of information can be remembered by themselves or with other pieces of information.
6	Problem Sensitivity	Ability to tell when something is wrong or is likely to go wrong. It includes being able to identify the whole problem as well as the elements of the problem.
7	Originality	Ability to produce unusual or clever ideas about a given topic or situation. It is the ability to invent creative solutions to problems or to develop new procedures to situations in which standard operating procedures do not apply.
8	Fluency of Ideas	Ability to produce a number of ideas about a given topic.
9	Flexibility of Closure	Ability to identify or detect a known pattern (such as a figure, word, or object) that is hidden in other material. The task is to pick out the disguised pattern.
10	Selective Attention	Ability to concentrate on a task one is doing. This ability involves concentrating while performing a boring task and not being distracted.
11	Spatial Orientation	Ability to tell where you are in relation to the location of some object or to tell where the object is in relation to you.
12	Visualization	Ability to imagine how something will look when it is moved around or when its parts are moved or rearranged. It requires the forming of mental images of how patterns or objects would look after certain changes, such as unfolding or rotation. One has to predict how an object, set of objects or pattern will appear after the changes are carried out.
13	Inductive Reasoning	Ability to combine separate pieces of information, or specific answers to problems, to form general rules or conclusions.
14	Category Flexibility	Ability to produce many rules so that each rule tells how to group a set of things in a different way. Each different group must contain at least two things from the original set of things.
15	Deductive Reasoning	Ability to apply general rules to specific problems to come up with logical answers. It involves deciding if an answer make sense.

16	Information Ordering	Ability to follow correctly a rule or set of rules to arrange things or actions in a certain order. The rule or sets of rules used must be given. The things or actions to be put in order can include numbers, letters, words, pictures, procedures, sentences, and mathematical or logical operations.
17	Mathematical Reasoning	Ability to understand and organize a problem and then to select a mathematical method or formula to solve the problem. It encompasses reasoning through mathematical problems to determine appropriate operations that can be performed to solve problems. It also includes the understanding or structuring of mathematical problems. The actual manipulation of numbers is not included in this ability.
18	Number Facility	Involves the degree to which adding, subtracting, multiplying, and dividing can be done quickly and correctly. These can be steps in other operations, such as finding percentages and taking square roots.
19	Time-Sharing	Ability to shift back and forth between two or more sources of information.
20	Speed of Closure	Involves the degree to which different pieces of information can be combined and organized into one meaningful pattern quickly. It is not known beforehand what the pattern will be. The material may be visual or auditory.
21	Perceptual Speed	Involves the degree to which one can compare letters, numbers, objects, pictures or patterns, quickly and accurately. The things to be compared may be pictures or patterns, quickly and accurately. The things to be compared may be presented at the same time or one after the other. This ability also includes comparing a presented object with a remembered object.
22	Reaction Time	Ability to give one fast response to one signal (sound, light, picture) when it appears. This ability is concerned with the speed with which the movement can be started with the hand, foot or other parts of the body.
23	Choice Reaction Time	Ability to choose between two or more movements quickly and accurately when two or more different signals (lights, sounds, pictures) are given. The ability is concerned with the speed with which the right response can be started with the hand, foot or other parts of the body.
24	Near Vision	Capacity to see close environmental surroundings.
25	Far Vision	Capacity to see distant environmental surroundings.
26	Night Vision	Ability to see under low light conditions.
27	Visual Color Discrimination	Capacity to match or discriminate between colors. This capacity also includes detecting differences in color purity (saturation) and brightness (brilliance).
28	Peripheral Vision	Ability to perceive objects or movements towards the edges of the visual field.
29	Depth Perception	Ability to distinguish which of several objects is more distant from or nearer to the observer or to judge the distance of an object from the observer.
30	Glare Sensitivity	Ability to see objects in the presence of glare or bright ambient lighting.
31	General Hearing	Ability to detect and to discriminate among sounds that vary over broad ranges of pitch and/or loudness.
32	Auditory Attention	Ability to focus on a single source of auditory information in the presence of other distracting and irrelevant auditory stimuli.
33	Sound Localization	Ability to identify the direction from which an auditory stimulus originated relative to the observer.

34	Control Precision	Ability to move controls of a machine or vehicle. This involves the degree to which these controls can be moved quickly and repeatedly to exact positions.
35	Rate Control	Ability to adjust an equipment control in response to changes in the speed and/or directions of a continuously moving object or scene. The ability involves timing these adjustments in anticipating these changes. This ability does not extend to situations in which both the speed and direction of the object are perfectly predictable.
36	Wrist-Finger Speed	Ability to make fast, simple repeated movements of the fingers, hands and wrists. It involves little, if any, accuracy or eye-hand coordination.
37	Finger Dexterity	Ability to make skillful coordinated movements of the fingers of one or both hands and to grasp, place or move small objects. This ability involves the degree to which these finger movements can be carried out quickly.
38	Manual Dexterity	Ability to make skillful coordinated movements of one hand, a hand together with its arm, or two hands to grasp, place, move or assemble objects, such as hand tools or blocks. This ability involves the degree to which these arm-hand movements can be carried out quickly. It does not involve moving machine or equipment controls, such as levers.
39	Arm-Hand Steadiness	Ability to keep the hand or arm steady. It includes steadiness while making an arm movement as well as while holding the arm and hand in one position. This ability does not involve strength or speed.
40	Multi-Limb Coordination	Ability to coordinate movements of two or more limbs (for example, two arms, two legs or one leg and one arm), such as in moving equipment controls. Two or more limbs are in motion while the individual is sitting, standing or lying down.
41	Extent Flexibility	Ability to bend, stretch, twist, or reach out with the body, arms or legs.
42	Dynamic Flexibility	Ability to bend, stretch, twist, or reach out with the body, arms and/or legs, both quickly and repeatedly.
43	Speed of Limb Movement	Involves the speed with which a single movement of the arms or legs can be made. This ability does not include accuracy, careful control or coordination of movement.
44	Gross Body Equilibrium	Ability to keep or regain one's body balance or stay upright when in an unstable position. This ability includes maintaining one's balance when changing direction while moving or standing motionlessly.
45	Gross Body Coordination	Ability to coordinate the movement of the arms, legs and torso together in activities in which the whole body is in motion.
46	Static Strength	Ability to use muscle force in order to lift, push, pull or carry objects. It is the maximum force that one can exert for a brief period of time.
47	Explosive Strength	Ability to use short bursts of muscle force to propel oneself or an object. It requires gathering energy for bursts of muscle effort over a very short time period.
48	Dynamic Strength	Ability of the muscles to exert force repeatedly or continuously over a long time period. This is the ability to support, hold up or move the body's own weight and/or objects repeatedly over time. It represents muscular endurance and emphasizes the resistance of the muscles to fatigue.

49	Trunk Strength	Involves the degree to which one's stomach and lower back muscles can support part of the body repeatedly or continuously over time. The ability involves the degree to which these trunk muscles do not fatigue when they are put under such repeated or continuous strain.
50	Stamina	Ability of the lungs and circulatory systems of the body to perform efficiently over long time periods. This is the ability to exert oneself physically without getting out of breath.

Table 6. Attribute list from Warner & Knapp, 2000.

	Attribute Name	Description
	Abilities	
1	Oral Comprehension	Ability to understand spoken English words and sentences.
2	Written Comprehension	Ability to understand written sentences and paragraphs.
3	Oral Expression	Ability to use English words or sentences in speaking so others will understand.
4	Written Expression	Ability to use English words or sentences in writing so others will understand.
5	Memorization	Ability to remember information, such as words, numbers, pictures, and procedures. Pieces of information can be remembered by themselves or with other pieces of information.
6	Problem Sensitivity	Ability to tell when something is wrong or is likely to go wrong. It includes being able to identify the whole problem as well as the elements of the problem.
7	Originality	Ability to produce unusual or clever ideas about a given topic or situation. It is the ability to invent creative solutions to problems or to develop new procedures to situations in which standard operating procedures do not apply.
8	Fluency of Ideas	Ability to produce a number of ideas about a given topic.
9	Flexibility of Closure	Ability to identify or detect a known pattern (such as a figure, word, or object) that is hidden in other material. The task is to pick out the disguised pattern.
10	Selective Attention	Ability to concentrate on a task one is doing. This ability involves concentrating while performing a boring task and not being distracted.
11	Spatial Orientation	Ability to tell where you are in relation to the location of some object or to tell where the object is in relation to you.
12	Visualization	Ability to imagine how something will look when it is moved around or when its parts are moved or rearranged. It requires the forming of mental images of how patterns or objects would look after certain changes, such as unfolding or rotation. One has to predict how an object, set of objects or pattern will appear after the changes are carried out.
13	Inductive Reasoning	Ability to combine separate pieces of information, or specific answers to problems, to form general rules or conclusions.

14	Category Flexibility	Ability to produce many rules so that each rule tells how to group a set of things in a different way. Each different group must contain at least two things from the original set of things.
15	Deductive Reasoning	Ability to apply general rules to specific problems to come up with logical answers. It involves deciding if an answer make sense.
16	Information Ordering	Ability to follow correctly a rule or set of rules to arrange things or actions in a certain order. The rule or sets of rules used must be given. The things or actions to be put in order can include numbers, letters, words, pictures, procedures, sentences, and mathematical or logical operations.
17	Mathematical Reasoning	Ability to understand and organize a problem and then to select a mathematical method or formula to solve the problem. It encompasses reasoning through mathematical problems to determine appropriate operations that can be performed to solve problems. It also includes the understanding or structuring of mathematical problems. The actual manipulation of numbers is not included in this ability.
18	Number Facility	Involves the degree to which adding, subtracting, multiplying, and dividing can be done quickly and correctly. These can be steps in other operations, such as finding percentages and taking square roots.
19	Time-Sharing	Ability to shift back and forth between two or more sources of information.
20	Speed of Closure	Involves the degree to which different pieces of information can be combined and organized into one meaningful pattern quickly. It is not known beforehand what the pattern will be. The material may be visual or auditory.
21	Perceptual Speed	Involves the degree to which one can compare letters, numbers, objects, pictures or patterns, quickly and accurately. The things to be compared may be pictures or patterns, quickly and accurately. The things to be compared may be presented at the same time or one after the other. This ability also includes comparing a presented object with a remembered object.
22	Reaction Time	Ability to give one fast response to one signal (sound, light, picture) when it appears. This ability is concerned with the speed with which the movement can be started with the hand, foot or other parts of the body.
23	Choice Reaction Time	Ability to choose between two or more movements quickly and accurately when two or more different signals (lights, sounds, pictures) are given. The ability is concerned with the speed with which the right response can be started with the hand, foot or other parts of the body.
24	Near Vision	Capacity to see close environmental surroundings.
25	Far Vision	Capacity to see distant environmental surroundings.
26	Night Vision	Ability to see under low light conditions.
27	Visual Color Discrimination	Capacity to match or discriminate between colors. This capacity also includes detecting differences in color purity (saturation) and brightness (brilliance).
28	Peripheral Vision	Ability to perceive objects or movements towards the edges of the visual field.
29	Depth Perception	Ability to distinguish which of several objects is more distant from or nearer to the observer or to judge the distance of an object from the observer.
30	Glare Sensitivity	Ability to see objects in the presence of glare or bright ambient lighting.

31	General Hearing	Ability to detect and to discriminate among sounds that vary over broad ranges of pitch and/or loudness.
32	Auditory Attention	Ability to focus on a single source of auditory information in the presence of other distracting and irrelevant auditory stimuli.
33	Sound Localization	Ability to identify the direction from which an auditory stimulus originated relative to the observer.
34	Control Precision	Ability to move controls of a machine or vehicle. This involves the degree to which these controls can be moved quickly and repeatedly to exact positions.
35	Rate Control	Ability to adjust an equipment control in response to changes in the speed and/or directions of a continuously moving object or scene. The ability involves timing these adjustments in anticipating these changes. This ability does not extend to situations in which both the speed and direction of the object are perfectly predictable.
36	Wrist-Finger Speed	Ability to make fast, simple repeated movements of the fingers, hands and wrists. It involves little, if any, accuracy or eye-hand coordination.
37	Finger Dexterity	Ability to make skillful coordinated movements of the fingers of one or both hands and to grasp, place or move small objects. This ability involves the degree to which these finger movements can be carried out quickly.
38	Manual Dexterity	Ability to make skillful coordinated movements of one hand, a hand together with its arm, or two hands to grasp, place, move or assemble objects, such as hand tools or blocks. This ability involves the degree to which these arm-hand movements can be carried out quickly. It does not involve moving machine or equipment controls, such as levers.
39	Arm-Hand Steadiness	Ability to keep the hand or arm steady. It includes steadiness while making an arm movement as well as while holding the arm and hand in one position. This ability does not involve strength or speed.
40	Multi-Limb Coordination	Ability to coordinate movements of two or more limbs (for example, two arms, two legs or one leg and one arm), such as in moving equipment controls. Two or more limbs are in motion while the individual is sitting, standing or lying down.
41	Extent Flexibility	Ability to bend, stretch, twist, or reach out with the body, arms or legs.
42	Dynamic Flexibility	Ability to bend, stretch, twist, or reach out with the body, arms and/or legs, both quickly and repeatedly.
43	Speed of Limb Movement	Involves the speed with which a single movement of the arms or legs can be made. This ability does not include accuracy, careful control or coordination of movement.
44	Gross Body Equilibrium	Ability to keep or regain one's body balance or stay upright when in an unstable position. This ability includes maintaining one's balance when changing direction while moving or standing motionlessly.
45	Gross Body Coordination	Ability to coordinate the movement of the arms, legs and torso together in activities in which the whole body is in motion.
46	Static Strength	Ability to use muscle force in order to lift, push, pull or carry objects. It is the maximum force that one can exert for a brief period of time.
47	Explosive Strength	Ability to use short bursts of muscle force to propel oneself or an object. It requires gathering energy for bursts of muscle effort over a very short time period.

48	Dynamic Strength	Ability of the muscles to exert force repeatedly or continuously over a long time period. This is the ability to support, hold up or move the body's own weight and/or objects repeatedly over time. It represents muscular endurance and emphasizes the resistance of the muscles to fatigue.
49	Trunk Strength	Involves the degree to which one's stomach and lower back muscles can support part of the body repeatedly or continuously over time. The ability involves the degree to which these trunk muscles do not fatigue when they are put under such repeated or continuous strain.
50	Stamina	Ability of the lungs and circulatory systems of the body to perform efficiently over long time periods. This is the ability to exert oneself physically without getting out of breath.

Table 7. Attribute list from Phillips et al., 2003.

	Attribute Name	Description
	Skills	
1	Mental reversals/rotation	Manikin test performance
2	Eye-hand coordination	Horizontal Tracking (HT) Test performance
3	Selective auditory attention	Dichotic Listening Test (DLT) performance
4	Multitasking (psychomotor + visual)	Psychomotor Test (PMT) performance

Table 8. Attribute list from Bruskiewicz et al., 2007.

	Attribute Name	Description
	Knowledge	
1	Unit/Command Objectives	Unit's function and operations; METL, mission briefs and commander's intent
2	Aviation Principals	Fundamentals of flight; force; gravity; speed; velocity; distance; motion; altitude, direction; object rotation; geography/terrain
3	Basic Operation Procedures	Loading/unloading procedures for internal and external load operation; emergency procedures; safety procedures; post-flight checks
4	Unmanned Aerial System Operations	Navigation; sensors; weapons
5	Communication Procedures	Radio, data, intercom operation; system display indicator operation; tactical report transmission; crew coordination
6	Threat Categories and Indicators	Types of enemy systems; warning and detection systems; identification
7	Reconnaissance Procedures	Scanning assigned sectors; aerial observation; route, zone, and area reconnaissance
8	Engagement Procedures	Weapons control measures; firing position operations; weapons initialization; weapon system operation; masking and unmasking; target handover procedures
9	Meteorology	Ambient light; clouds and precipitation; forces and winds; air masses and fronts; weather forecasting; storms; effects of weather on aircraft operations
10	Aeronautical Terminology	Principles and practices of navigation; aviation phraseology; standard crew terminology

11	Operational Terms and Graphics	Chart and map reading, topography, symbology
12	Flight Rules and Regulations	Civil, military, and unit specific regulations (SOP)
	Skills	
13	Operation and Maneuvering of Unmanned Aircraft Systems	Adjusting altitude; maintaining airspeed; changing flight direction; flight control precision; recognition of flight parameters
14	Operation of Communication Systems and Equipment	Radio/aircraft systems; intercom communication systems; digital communications systems
15	Operation of Navigation Systems and Equipment	Electronic systems; navigation radio; homing; etc.
16	Operation of Sensor/Tracking Systems and Equipment	Lasers, illuminators
17	Operation of Weapon Systems and Equipment	Hellfire missile system; stinger system
18	Performance of Unmanned Aircraft Systems Operational Checks	Security checks; engine checks; run-up and taxi checks; preflight checks; after-takeoff checks; inflight checks; post-launch checks
	Abilities	
19	Management of Stressors	Recognize and cope with stress in self and others
20	Situational Awareness	Accurately perceive self, others, and aircraft in relation to the environment
21	Psychomotor Ability: Control Precision	Make highly controlled and precise adjustments in moving controls of an aircraft precisely and repeatedly
22	Psychomotor Ability: Multi-limb Coordination	Coordinate movements of two or more limbs at once (e.g., two arms, one leg and one arm)
23	Psychomotor Ability: Simple Reaction Time	Give a fast response to a signal when it appears
24	Psychomotor Ability: Choice Reaction Time	Choose between two or more movements quickly and correctly when there is more than one choice
25	Psychomotor Ability: Rate Control	Adjust an equipment control in response to changes in the speed or direction of a continuously moving object or scene, (e.g., keeping aircraft at a given altitude in turbulent weather or tracking a moving target)

26	Perceptual Speed and Accuracy	Perceive and process visual information quickly and accurately; to notice subtle visual details
27	Oral Communication	Speak in a clear, concise and persuasive manner; to give clear directions and information; to ask questions to clarify and ensure understanding
28	Oral Comprehension	Listen to and understand information and ideas that are presented orally
29	Written Communication	Write in a logical, well-organized manner; to use correct punctuation and grammar
30	Reading Comprehension	Perceive and understand principles governing the use of verbal concepts and symbols; to interpret meaning from written information
31	Mathematical Ability	Understand and apply basic (e.g., addition, rounding) and advanced (e.g., algebra) math principles; arithmetic reasoning
32	Mechanical Comprehension	Perceive physical relationships and practical problems in mechanics; to understand the operation of mechanical equipment
33	Analytical Ability	Reason logically and critically to draw correct, well-supported, and consistent conclusions
34	Planning	Develop courses of action to accomplish objectives and avoid potential problems; to manage activities effectively; to actively prepare for high workload/problem situations
35	Organization/Time Management	Prioritize activities and determine which ones require immediate attention; to manage and allocate time effectively
36	Judgment/Decision-Making/Problem Solving	Make high quality and timely decisions; to assess the level of risk associated with a given course of action; to recognize when additional information is required to make a decision or solve a problem; to identify potential and/or novel solutions to problems; to anticipate the consequences of decisions
37	Spatial Visualization and Orientation	Recognize and distinguish shapes and patterns; to identify an object at different angles; to anticipate a moving object's spatial orientation over time; to recognize one's own physical orientation in an unfamiliar environment; to estimate location after traveling for a period of time; to read a map and understand it's content
38	Information Processing Ability: Divided Attention	Pay attention to multiple tasks occurring at the same time
39	Information Processing Ability: Selective/Focused Attention	Focus on and process information related to a single task amid the presence of competing information or background noise
40	Information Processing Ability: Working Memory	Temporarily hold information in memory, use it while performing ongoing tasks, and update it continually to reflect the current situation
41	Information Processing Ability: Long-Term Memory	Remember information for long periods of time; to recall information that was learned some time ago
42	Vigilance	Stay alert and be attentive to one's surroundings over long periods of time, including small details; to recognize hazards and threats within one's environment; to perform repetitive tasks effectively

43	Cognitive Task Prioritization	Properly pay attention to tasks in order to achieve subgoals which support the overall mission goal; that is, ensure the Operator is "doing what he or she should be doing at all times"
	Other Characteristics	
44	Assertiveness	Tendency to act in an appropriately bold and energetic fashion in order to accomplish objectives; willingness to communicate appropriate urgency when delivering information
45	Followership	Tendency to follow requests or orders; to accept suggestions and guidance from other crewmembers without being defensive
46	Self-Regulation	Tendency to keep oneself focused on a task/work even when external factors make it difficult to do so.
47	Excitement-Seeking	Tendency to crave excitement and stimulation, but not to the point of being reckless
48	Risk-Tolerance	Willingness to accept risk and engage in activities that involve a lack of certainty or fear of failure, but without being reckless
49	Work Ethic	Tendency to strive for competence in one's work; willingness to work long hours when appropriate; tendency to reliably complete one's work in a timely fashion and complete the mission
50	Initiative	Tendency to take personal initiative in accomplishing tasks and to see tasks through until their completion
51	Self-Confidence	Being sure of one's abilities without being over-confident or arrogant
52	Straightforwardness	Tendency to be frank, sincere, and genuine
53	Helpfulness	Tendency to have an active concern for others' welfare; expressed through generosity, consideration of others, and a willingness to assist others in need of help
54	Teamwork	Tendency to function effectively as part of a team; to cooperate with other crewmembers to accomplish goals and solve problems
55	Interpersonal Skills	Tendency to understand and deal effectively with a variety of people; to treat others with courtesy and respect; to be considerate of others' needs
56	Dutifulness	Tendency to adhere to one's set of ethical principals and to strictly follow rules and regulations
57	Achievement Striving	Tendency to set ambitious goals for oneself and to work hard to attain a high level of work proficiency
58	Self Discipline	Tendency to control one's conduct and impulses
59	Deliberation	Tendency to think carefully before acting, time permitting
60	Dependability	Tendency to be reliable, planful, well-organized, disciplined, and determined
61	Responsibility	Tendency to assume responsibility and accept consequences of own decisions and actions
62	Perseverance	Tendency to stick with a task until completion in spite of obstacles
63	Integrity	Tendency to behave in a moral or ethical manner
64	Loyalty	Tendency to remain loyal to one's country, unit, superiors, peers, and subordinates
65	Stress Tolerance	Tendency to maintain composure in challenging and threatening situations
66	Adaptability/Flexibility	Tendency to adjust easily to changing situations or conditions; to quickly adapt and change priorities when needed

67	Learning Orientation	Tendency to seek out and acquire new knowledge; natural curiosity about how things function in one's environment
68	Control	Belief that one has high levels of control over what happens in one's life and the rewards and punishments one receives
69	Resourcefulness	Tendency to use one's resources both creatively and effectively to accomplish tasks
70	Leadership: Delegation	Preference for assigning tasks and giving orders to others
71	Leadership: Performance Management	Monitor crewmember performance and take action when performance is substandard
72	Leadership: Provide Feedback	Provide performance feedback and coaching to crewmembers as necessary; able to effectively inform crewmembers of mistakes or potential problems
73	Leadership: Motivation	Motivate crewmembers to perform effectively under difficult circumstances
74	Leadership: Resolving Conflicts	Resolve conflict among crewmembers; to foster an environment of teamwork and camaraderie
75	Attention to Detail	Tendency to keep track of details; to notice even subtle changes or inconsistencies in a person or situation
76	Work in Confined Spaces	Tolerate small/confined spaces for long periods of time
77	Physical Conditioning	Tendency to be active and participate in sports, exercise and physical activity.

Table 9. Attribute list from Chappelle et al., 2010.

	Attribute Name	Description
	Abilities	
2	Stamina (2)	Physical stamina for sitting and sustaining vigilance for extended periods. Postural strength & endurance. Resilience to physical and cognitive fatigue.
3	Cognitive Proficiency	General cognitive ability. Speed and accuracy of information processing.
4	Visual Perception	Visual acuity, scanning and discrimination. Visual recognition, tracking and analysis.
5	Attention	Vigilance to multiple sources of visual & auditory information (situational awareness). Sustained and divided attention to visual and auditory information.
6	Spatial Processing	Spatial analysis and orientation. Spatial reasoning and construction (manipulation of 2-diminesional information into 4-dimensional mental imagery).
7	Memory	Visual and auditory memory (working, immediate, and delayed). Spatial memory (working, short-term, and delayed).
8	Reasoning	Real time general and deductive reasoning (problem solving). Carefully and quickly assess risk, likely outcomes, and potential repercussions (forward thinking). Quickly perceives the next steps and multi·tasks high level of information and procedures (task prioritization and management).
	Other Characteristics	
1	General Health	No significant or chronic injuries, illnesses, or defects affecting performance (e.g., manual dexterity, vision, posture) or reliability. Resilience to shift work adjustments.
9	Composure	Remains composed and in control of behavior and emotions under stress. Effectively compartmentalizes emotions.
10	Resilience	Emotional stamina and hardiness in response to monotony, confined workspace, and high pressure situations.
11	Self-Certainty	Clear sense of self-confidence. Clear sense of role as war-fighter. Maintains confidence during performance feedback.
12	Conscientiousness	Deliberate, methodical, and organized. Self disciplined.
13	Success Oriented	Self-motivated and driven to succeed. Committed to self-improvement.
14	Perseverance	Sustains a high level of effort over long periods of time despite hardships.
15	Decisiveness	"Real time" decision making during monotony and high pressure situations.
16	Humility	Effectively recognizes the need and asks for help. Seeks and accepts performance feedback from others.
17	Cohesiveness	Values the role and supportive of other personnel. Participates in morale building exchanges.
18	Assertiveness	Speaks up and effectively voices concerns in "real time." Provides appropriate and decisive feedback.
19	Adaptability	Generally flexible, realistic, and effectively responds to change and unpredictable stressors.

20	Moral Interest	Motivated to save lives and protect U.S. and coalition forces. Personal beliefs and world views (spiritual, religious) support combat operations.
21	Occupational interest	Possess a sense of duty as a war fighter. Realistically understands and intrinsically appreciates RPA platform. Critical to retention: Enjoys duties of the position and contribution to daily operations in theater, strong intrinsic interest in advanced and emerging avionic RPA technology. Strong interest in advancing national interests and mission objectives.

Table 10. Attribute list from Chappelle et al., 2011.

	Attribute Name	Description
	Abilities	
1	Cognitive Proficiency	General cognitive ability. Speed & accuracy of information processing.
2	Visual Perception	Visual acuity, scanning and discrimination. Visual recognition, tracking and analysis.
3	Attention	Vigilance to multiple sources of visual and auditory information (situational awareness). Sustained and divided attention to visual and auditory information.
4	Spatial Processing	Spatial analysis and orientation. Spatial reasoning and construction (manipulation of 2-diminesional information into 4-dimensional mental imagery).
5	Memory	Visual and auditory memory (working, immediate, and delayed). Spatial memory (working, short-term, and delayed).
6	Reasoning	Real time general and deductive reasoning (problem solving). Task prioritization. Carefully and quickly assess risk, likely outcomes, and potential repercussions (forward thinking). Cognitive flexibility (thinking outside the box).
7	Psychomotor Processing	Fine motor dexterity and reaction time. Psychomotor-spatial coordination and accuracy.
	Other Characteristics	
8	Emotional Composure	Remains calm, composed, and in control of behavior and emotions under stress (e.g., does not readily show or experience fear, sadness, or irritability).
9	Resilience	Emotional stamina and hardiness in response to monotony, confined workspace, and high pressure situations.
10	Self-Certainty	Clear sense of self-confidence across routine and high pressure tasks and situations. Clear sense of role as an officer and war-fighter.
11	Conscientiousness	Deliberate, methodical, and highly organized. Highly dependable, reliable and self disciplined.
12	Perseverance	Completes tasks despite boredom, hardship, and potential distractions. Sustains a high level of effort over long periods of time despite hardships.
13	Success Oriented	Self-motivated and driven to succeed and achieve . Seeks new and innovative ways to improve performance. Strong interest in mastering challenging tasks and in emerging computer-based technology.
14	Decisiveness	Makes decisions in real time, under pressure, and within operational deadlines. Operationally patient in making the right decision and committing to a course of action.
15	Adaptability	Effectively sizes up and deals with problematic situations and environmental demands. Generally flexible, realistic, and effectively understands problematic stressors in occupational and personal settings. Finds good ways of managing and resolving stressors and conflicts. Effective compartmentalization of personal stress from occupational duties.
16	Humility	Ability to recognize the need and willingness to seek help from leadership and others.

17	Extraversion	Open and accepting of critical feedback from peers, subordinates and others. Shares credit for success, accepts responsibility for mistakes. Receptive and approachable. Socially engaging and outgoing; fosters positive relations. Understands and effectively responds to emotional states of others.
18	Judgment	Comfortable with different personality styles and working under constrained and varied conditions. Situationally aware; responsive; effectively resolves/diffuses interpersonal conflict. Social behavior at work and off-base settings demonstrates prudence for national security and the integrity of military operations.
19	Team Oriented	Comfortable leading, working with enlisted personnel as a team. Competitive disposition but does not jeopardize group and mission goals for individual goals. Interest in teaching others and promoting morale. Trusting of other aircrew and military personnel.
20	Moral	Motivated to save lives and protect U.S. and coalition forces. Personal beliefs and world views (spiritual, religious) support combat operations.
21	Occupational	Possesses a sense of duty as an officer and warfighter. Realistically understands and appreciates RPA platform. Strong interest in advanced and emerging avionic RPA technology. Enjoys duties of the position and contributes to daily operations in theater. Strong interest in advancing national interests and mission objectives.

A simple means of comparing attributes across studies is presented in Table 11. This table lists all of the identified KSAOs that were used in one way or another, for example in the construction of a selection battery. As a result, for example, the Knowledge and Skills identified in Bruskiewicz et al. are not listed here because they were excluded from construction of the selection battery on the grounds that the Knowledge and Skills identified would be imparted in the training process. The left most column in Table 11 lists the unique attribute names from all of the studies reviewed here. In the columns to the right are the attribute numbers of the study named in their headers. With the exception of the second column, which lists the attribute numbers from Fleishman and Qaintance (1984), the attribute lists are not in numeric order. The numbers have been placed in the row that best corresponds, according to compared definitions, to the attribute name in the left column. Attribute numbers may appear in more than one row because of overlapping definitions or lack of specificity, in more than one row. Therefore Table 11 is a cross reference of KSAOs identified and used among the studies reviewed in this report.

Table 11. Cross reference of KSAOs for RPA operators.

Attribute Name	Fleishman & Quaintance, 1984	Crumley & Bailey, 1979: AVO, MPO	Biggerstaff et al., 1998: EP	Barnes et al., 2000: AVO, EP	Warner & Knapp, 2000: GSO	Phillips et al., 2003: IP	Bruskiewicz et al., 2007: AVO, MPO	Chappelle et al., 2010: MPO	Chappelle et al., 2011: AVO
KNOWLEDGE									
SKILLS									
Map reading		1							
Photo interpretation		2							
Communication procedures							5		
ABILITIES									
Oral comprehension	1	4		1	1				
Written comprehension	2			2	2		30		
Oral expression	3	5		3	3				
Written expression	4			4	4				
Fluency of ideas	5			8	8				
Originality	6			7	7				
Memorization	7			5	5			7	
Problem sensitivity	8			6	6				
Mathematical reasoning	9			17	17				
Number facility	10			18	18				
Deductive reasoning	11			15	15		33	8	
Inductive reasoning	12			13	13		33	8	
Information ordering	13			16	16			8	
Category flexibility	14			14	14				
Speed of closure	15			20	20			3	
Flexibility of closure	16			9	9				
Spatial orientation	17		1	11	11	1	37	6	
Visualization	18			12	12			6	
Perceptual speed	19			21	21		26	5	
Control precision	20		3	34	34	2			7
Multlimb coordination	21	3	3	40	40	2			7
Response orientation	22			23	23		24		
Rate control	23			35	35			6	7
Reaction time	24			22	22		23		7
Arm-hand steadiness	25			39	39				
Manual dexterity	26			38	38				

Finger dexterity	27			37	37				7
Wrist-finger speed	28			36	36				
Speed of limb movement	29			43	43				
Selective attention	30		5	10	10	4	39		
Time sharing	31		5	19	19	4			
Static strength	32			46	46				
Explosive strength	33			47	47				
Dynamic strength	34			48	48				
Trunk strength	35			49	49			2	
Extent flexibility	36			41	41				
Dynamic flexibility	37			42	42				
Gross body coordination	38			45	45				
Gross body equilibrium	39			44	44				
Stamina	40			50	50				
Near vision	41			24	24				
Far vision	42			25	25			4	
Visual color discrimination	43			27	27				
Night vision	44			26	26				
Peripheral vision	45			28	28				
Depth perception	46			29	29				
Glare sensitivity	47			30	30				
General hearing	48			31	31				
Auditory attention	49		4	32	32	3			
Sound localization	50			33	33				
Speech hearing	51								
Speech clarity	52								
Estimation of time to contact			2						
Situational awareness							20	5	
Organization/Time management							35		
Judgment/Decision-making/Problem solving							36		
Vigilance							42		
Cognitive task prioritization							43	8	
Adaptability/Flexibility							66	19	
Cognitive proficiency								3	1
Stamina (2)								2	
Visual perception								4	2
Attention								5	3
Spatial processing			1			1		6	4
Memory								7	5
Reasoning								8	6
OTHER ATTRIBUTES									
Affinity for planning and logic		6						12	
Affinity for uncertainty		7							
Management of stressors							19	19	
Assertiveness							44	18	
Followership							45		
Self regulation							46		
Work ethic							49	13	
Initiative							50		
Self confidence							51	11	
Straightforwardness							52		

Helpfulness							53		
Teamwork							54		
Interpersonal skills							55	16	
Achievement striving							57	13	
Self discipline							58	12	
Dependability							60		
Responsibility							61		
Stress tolerance							65		
Leadership: Performance management							71		
Leadership: Provide feedback							72		
Leadership: Motivation							73		
Leadership: Resolving conflicts							74		
Attention to detail							75		
General health								1	
Composure								9	8
Resilience								10	9
Self-certainty								11	10
Conscientiousness								12	11
Success oriented								13	13
Perseverance								14	12
Decisiveness								15	14
Humility								16	16
Cohesiveness								17	
Adaptability								19	15
Moral interest								20	20
Occupational interest								21	21
Extraversion									17
Judgment									18
Team-oriented									19

Future KSAOs

Of the reports reviewed above there are three that identified KSAOs with an intent to anticipate future requirements. The first two, Barnes et al. (2000) and Warner et al. (2000), were not aimed at development of personnel selection instruments, but rather design considerations for future systems and their impact on manpower requirements. The first issue for consideration in Barnes et al. concerned the need for rated aviators as operators rather than enlisted personnel. The authors did not find evidence to support the replacement of enlisted personnel in either the AVO or EP positions with rated aviators. They instead pointed to training solutions as the best alternative for addressing the demands of expected design changes. Additionally, the authors found no evidence to compel the introduction of image or intelligence analysts into the RPA crew complement. They did conclude that some of the skills possessed by image and intelligence analysts could have application within the RPA crew for certain missions. Again, their recommended solution was to approach this through training.

Warner and Knapp (2000) were concerned with the impact of an enhanced CGS, then in development, on manpower and personnel requirements. Most, but not all, of the features of that developmental system have been implemented. The authors predicted a skill shift toward increased demand for analytical skills (and presumably the abilities that enable those skills) in the enhanced CGS. Much of that shift was expected to stem from increased reliance on and intelligence and imagery analysis by the RPA crew. As in the previous study, the authors concluded that the introduction of imagery and intelligence analysts into the RPA crew would not be cost effective and that it would be more practical to augment training for Army RPA operators to impart the needed skills. The recommendations of both of these studies regarding training solutions have been partly implemented and are continuing. However, there is a long road ahead, at least for the Army, in implementing sufficient training enhancements to cover the needs of future systems.

Government guidance at the outset of the project that produced the Bruskiewicz et al. (2007) report was specific in the need to consider the likely impact of near future changes on personal attribute demands that could affect personnel selection criteria. To address this, the authors included a sample of SMEs who had special knowledge of developments in the RPA arena in their administration of the JAQ. These SMEs were requested to apply their knowledge of coming changes to their ratings. This approach appears to have had an effect because the SME subgroup produced somewhat different ratings, as illustrated in the review above.

The emphasis in these three examples of anticipation of shifts in operator KSAO demand is on design changes to the RPA systems. These changes were expected both in the user interface (CGS) and in expanded system capabilities (e.g. weaponization). System design changes constitute only one of several sources that can drive shifts in KSAO demand. Other drivers include changes in organization, manpower and missions.

Addition of new system capabilities or expansion of existing system capabilities most often increase total demand while differentially affecting demand across attribute domains. Even “improved” designs can be a double edged sword. The control interface and display systems for RPA operation are getting improvements that are intended to reduce total workload and reduce demand on perceptual-motor abilities, but as workload decreases it is common to see an increase in expectations that translate into expanded mission requirements or addition of still more new capabilities. Likewise, increases in automation are often viewed as opportunities to add new requirements. Another area within system capabilities is the continued weaponization of RPA systems. Introduction of an onboard munition adds far more than the requirement for knowledge and skills relevant to operation of that subsystem. It also adds intellectual and decision making requirements related to knowledge and interpretation of the current rules of engagement, commander’s intent for the current mission, and understanding of the performance envelope and constraints of the weapon and its terminal effects (e.g., burst radius). Attitudinal and personality attributes that previously were not particularly prominent may take on much greater importance when the system that a person is operating becomes deadly. The addition of weapons also changes the system’s area and timeline of influence in a mission. Even if the decision to employ a weapon is made outside the CGS, the crew inside are faced with another set of decision points that have a characteristic of immediacy. Therefore the personal attributes that mediate decision speed will be in greater demand.

There also has been, over the past decade, increasing effort expended toward development of the capability for a RPA crew to control multiple RPAs simultaneously. Beyond the obvious impact on total workload, this capability places increased demand for KSAOs that mediate situation awareness. With multiple airframes under their control, AVOs and MPOs need greater application of selective and divided attention, spatial orientation, and time sharing.

Changes in organization can have both direct and indirect effects on KSAO demand. The recent transfer of Army UAS assets and responsibility from the Military Intelligence (MI) Branch to the Aviation Branch (AVN) is having a large effect on attribute demands for UAS operators. Under MI, UAS missions, and therefore training (especially on-the-job training), concentrated on intelligence, surveillance, and reconnaissance (ISR). Under AVN there is a transition to a much broader scope that parallels manned aviation assets. This includes not only reconnaissance, surveillance, and target acquisition (RSTA), but also command, control, communications and intelligence (C3I) as well as other roles and functions. This transition has been shown (Stewart, Bink, Barker, Tremlett, & Price, 2011) to have resulted in gaps in training that are slowly being addressed. Rectification, through augmented training content, in itself will increase demand for cognitive abilities. In addition, the transition involves increased requirements for RPA operators to interact with personnel outside their immediate (RPA) community.

The Air Force is beginning to confront a major change in manpower relevant to RPA systems. The transition from requiring RPA pilots first be qualified manned aircraft pilots to personnel who have only completed the Undergraduate Remotely Piloted Aircraft Training (URT) course with much less hands-on flying training is a step that may produce shifts in the experiential background and attitudes of the RPA pilot population. Changes in the general population from which all RPA operators are ultimately obtained can also alter the complement of abilities and other attributes of people available for entry into RPA crew positions.

Changes in RPA missions can result from changes in organization and/or system capabilities, as well as other causes. In recent years the scope of RPA missions has greatly increased to include a far broader range of reconnaissance and targeting, and is now moving into the attack realm. This increase in mission scope has consequences in communications, cognitive abilities, and other attributes such as time-sharing and teamwork. A major increase in mission scope is the expanding use of manned-unmanned arial teaming (MUM). In MUM missions a RPA is teamed with one or more manned aircraft (e.g. OH-58D Kiowa Warrior) to carry out reconnaissance/ attack operations. This requires close interaction between the system crews, as well as with supporting and commanding ground units. As a result, RPA crews and manned aircraft crews must acquire knowledge of each others system capabilities and limitations and develop a common lexicon for efficient communications. In addition, demand for time-sharing and situational awareness are increased because of the need to maintain awareness of the status of every system in the team. Recently, Pavlas et al. (2009) analyzed the features of MUM teaming to identify knowledge, skills, and attitudes that are demanded by these missions and will require augmented training. They identified a combined 60 areas that acquire increased demand in MUM operations. While their focus is on training solutions, their findings should be reviewed to determine where the training burden could be mitigated by shifts in KSAOs used for selection.

Table 12 presents the KSAO list from Table 11 and expresseses expected shifts in demand based on consideration of the factors outlined above. A "+" indicates an expected increase in demand, a "–" indicates an expected decrease. A "0" indicates no expected change and an "X" indicates the attribute is not well enough defined to be evaluated, and should be dropped.

Table 12. Expected shift in KSAO demand.

Attribute Name	
KNOWLEDGE	
SKILLS	
Map reading	X
Photo interpretation	X
Communication procedures	+
ABILITIES	
Oral comprehension	+
Written comprehension	+
Oral expression	0
Written expression	0
Fluency of ideas	0
Originality	0
Memorization	+
Problem sensitivity	0
Mathematical reasoning	+
Number facility	+
Deductive reasoning	+
Inductive reasoning	+
Information ordering	+
Category flexibility	+
Speed of closure	+
Flexibility of closure	+
Spatial orientation	+
Visualization	+
Perceptual speed	+
Control precision	-
Multlimb coordination	-
Response orientation	-
Rate control	-
Reaction time	-
Arm-hand steadiness	-
Manual dexterity	-
Finger dexterity	-
Wrist-finger speed	-
Speed of limb movement	-
Selective attention	+
Time sharing	+
Static strength	0
Explosive strength	0
Dynamic strength	0
Trunk strength	0
Extent flexibility	0
Dynamic flexibility	0
Gross body coordination	0
Gross body equilibrium	0
Stamina	0

Near vision	0
Far vision	0
Visual color discrimination	0
Night vision	0
Peripheral vision	0
Depth perception	0
Glare sensitivity	0
General hearing	0
Auditory attention	+
Sound localization	0
Speech hearing	0
Speech clarity	0
Estimation of time to contact	+
Situational awareness	+
Organization/Time management	+
Judgement/Decision-making/Problem solving	+
Vigilance	+
Cognitive task prioritization	+
Adaptability/Flexibility	+
Cognitive proficiency	+
Stamina (2)	X
Visual perception	+
Attention	+
Spatial processing	+
Memory	+
Reasoning	+
OTHER ATTRIBUTES	
Affinity for planning and logic	X
Affinity for uncertainty	X
Management of stressors	X
Assertiveness	0
Followership	0
Self regulation	0
Work ethic	0
Initiative	+
Self confidence	0
Straightforwardness	X
Helpfulness	X
Teamwork	+
Interpersonal skills	+
Achievement striving	X
Self discipline	0
Dependability	0
Responsibility	0
Stress tolerance	0
Leadership: Performance management	0
Leadership: Provide feedback	0
Leadership: Motivation	0
Leadership: Resolving conflicts	0
Attention to detail	+
General health	X

Composure	X
Resilience	X
Self-certainty	X
Conscientiousness	+
Success oriented	X
Perseverance	X
Decisiveness	X
Humility	X
Cohesiveness	X
Adaptability	X
Moral interest	X
Occupational interest	X
Extraversion	X
Judgment	X
Team-oriented	X

Conclusion

There are very few published treatments of KSAOs for RPA operators and most of those have severe methodological deficiencies. Of those reviewed here only three (Barnes et al., 2000; Bruskiewicz et al., 2007; Warner & Knapp, 2000) could be considered rigorous and systematic in their approach. There appear to be no instances of RPA operator selection instruments that have been validated. The closest to that would be the battery developed by Bruskiewicz, et al, which could be implemented for validation in a short time. Services should, however, conduct studies of training failure rates to determine if the costs of development and fielding selection instruments are justifiable.

The demand for specific abilities and other attributes in persons entering training as RPA operators is driven by changes occurring in system capabilities, organization, manpower, and missions. Overall, the positions within RPA crew are acquiring an increased demand although some attributes are likely to see decreases. These changes are likely to have an even greater impact on training requirements.

The area of RPA KSAOs is prone to confusion stemming from differences in terminology regarding operational systems and their names, and names and definitions of crew positions. Greater confusion stems from conflicting definitions of personal attributes, loosely defined attributes and a proliferation of ad hoc attributes with little or no theoretical basis. There is a critical need for a KSAO taxonomy that minimizes overlap between attributes and covers the range of behaviors critical to system operation.

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