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CFEC Project Report on the Alternative Crew Selection Method

Philip S. E. Farrell, Paul Hubbard and Iain Culligan

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Abstract

The Canadian Forces Experimentation Centre (CFEC) investigated a novel crew selection method that could be used to staff new defence systems. The method involved matching existing job elements (task and knowledge statements) to predicted job elements generated from an Uninhabited Aerial Vehicle (UAV) scenario. A Job Similarity Index (JSI) was developed that provided a number to represent the degree to which existing job elements matched predicted job elements for any given CF position or member. Theoretically, the JSI value could be used as a 'first cut' at selecting crewmembers for new equipment and procedures operated by the CF.

The postulate is that a person in a CF position that has more existing job elements in common with the predicted job elements will perform better in the scenario than a person in a CF position with fewer Job elements in common. An experiment was designed and conducted to determine the relationship between JSI and performance. If performance is directly related to JSI then JSI can be used to discriminate between jobs, positions, or people.

The main conclusion was that the null hypothesis – there is no relationship between JSI and performance – was not falsified. However, there are indications from the analysis that performance varies directly with JSI to some degree. The data seem to suggest that the participants had enough general skill and knowledge to perform the straightforward scenario tasks and successfully complete the mission. Further testing is required to determine if the crew selection method is a viable alternative for selecting crews particularly when job incumbents do not exist. As additional subjects are tested, the results should eventually reach levels of statistical significance.

It is recommended that a second set of experiments be conducted with careful consideration to the design of the composite scenario. The scenario should include baseline activities that are known to discriminate amongst the population.

Résumé

Le Centre d’expérimentation des Forces canadiennes (CEFC) a étudié une nouvelle méthode de sélection des équipages qui pourrait être appliquée à de nouveaux systèmes de défense. La méthode consistait à apparier des éléments de travail (énoncés de tâches et de connaissances) actuels à des éléments de travail prévus qui ont été tirés d’un scénario relatif à un véhicule aérien sans pilote (UAV). On a ensuite établi un indice de similitude de travail (IST) qui indique dans quelle mesure des éléments de travail actuels correspondent aux éléments de travail prévus d’un poste ou d’un membre des FC. Théoriquement, la valeur de l’IST pourrait servir à faire une « première élimination » dans la sélection des membres d’équipage qui doivent être affectés à de nouvelles procédures et à de nouveaux équipements des FC.

Le postulat est qu’un membre des FC qui a plus d’éléments de travail actuels en commun avec les éléments de travail prévus donnera un meilleur rendement dans le scénario qu’un membre des FC qui en a moins. Une expérience a été conçue et menée pour déterminer la relation entre l’IST et le rendement. Si le rendement est fonction de l’IST, celui-ci pourra servir à distinguer des emplois, des postes ou des personnes.

La principale conclusion est qu’il n’a pas été possible d’affirmer que l’hypothèse nulle – c’est-à-dire l’absence de relation entre l’IST et le rendement – était fausse. L’analyse donne cependant à penser que le rendement varie dans une certaine mesure en fonction de l’IST. Les données semblent également indiquer que les participants avaient assez de compétences et de connaissances générales pour exécuter les tâches simples du scénario et remplir la mission. Il faudra faire d’autres essais pour voir si la méthode de sélection des équipages offre une solution viable, particulièrement dans les cas où il n’y a pas de titulaire de poste. Il faudra soumettre d’autres sujets aux essais pour en arriver à obtenir des résultats statistiquement significatifs.

Il est recommandé qu’une deuxième série d’expériences soit menée, une attention particulière étant portée à la conception du scénario mixte. Le scénario devrait comprendre des activités de référence dont on sait maintenant qu’elles permettent de distinguer des éléments de la population.

Executive summary

A question was raised from the Pacific Littoral ISR Experiment (PLIX, July 2003) about crew selection: that is, “which CF personnel should ‘man’ the ‘unmanned’ system?” Upon request by the then Intelligence and Information (I2) Team at CFEC, the S&T Team initiated a research project investigating new ways for selecting UAV crewmembers. It was quickly realised that the new method is not limited to UAVs but can be generalized for any new technology or procedure where job incumbents do not exist.

This report represents a compilation of all project activities and experimental results. The report begins with a description of the alternative method for crew selection and comparison to current practice. The section on the experimental protocol and design shows how the scientific method is employed to generate an answer to the question. The data reduction section records the procedures used to prepare the data for analysis. The results and discussion section provides the interpretation of experimental results. The final section provides conclusions and recommendations for the way ahead.

Current practice for selecting crews begins with interviewing job incumbents and generating job descriptions from the information. However, this new method has shown the ability to predict tasks and knowledge statements when no job incumbents exist. The new method has four steps:

1. Decompose a composite scenario involving new technologies into a hierarchy of goals.

2. Propose and link the new job elements to the goals.

3. Compare existing job elements to predicted job elements.

4. Select positions based on the best match.

Steps one and two provide the predictive power of the method. The Atlantic Littoral Intelligence Reconnaissance Surveillance eXperiment (ALIX) results show that 82% of predicted tasks were actually performed in the event. Step three involves calculating a Job Similarity Index (JSI) that is a ratio of existing job elements (i.e., tasks and knowledge statements) from a CF position or member and the predicted job elements from steps one and two. Step four seems to be the simplest step, but other selection issues must be considered including safety, training, career progression and policy.

One can postulate that if an existing job were to produce a JSI value close to one, then the person who performs that job would perform well during the new mission. If the JSI were close to zero, then the person would perform poorly. An experiment was designed to explore this postulate that involved CF members who are in certain positions conducting various jobs. The experiment was conducted in a UAV synthetic environment, and participants repeated the composite scenario three times as the vehicle operator, payload operator, and mission commander. The JSI was calculated and performance, cognitive ability, training proficiency, and situational awareness were measured for participants.

In conclusion, the results indicate that there is some relationship between the JSI and performance (for most performance measurements). All participants performed the UAV mission fairly well despite having different JSI values. The analysis shows that the scenario seemed to be simple enough that the tasks required only a general level of skill and knowledge.

It is recommended that Directorate of Human Resources Research and Evaluation take the lead in conducting a second series of experiments to provide more data over the complete range of the JSI so that statistical significance levels can be obtained and reported. The experimental design should carefully consider a test scenario that requires a wider range of skills and knowledge in order to accomplish the tasks and complete the mission.

Farrell, P.S.E., Hubbard, P. and Culligan, I. (2006) CFEC Project Report: Alternative Crew Selection Method CFEC Project Report. DRDC Ottawa TM 2006-154 Defence R&D Canada – Ottawa.

Sommaire

L'expérience RSR sur le littoral du Pacifique (PLIX, juillet 2003) sur la sélection des équipages a débouché notamment sur la question suivante : À quels membres des FC devrait-on confier le « pilotage » d'un système « sans pilote »? À la demande de l'équipe du renseignement et de l'information du CEFC, l'équipe S & T a lancé un projet de recherche pour étudier de nouveaux modes de sélection des membres d'équipage des UAV. L'équipe a rapidement compris que la nouvelle méthode ne s'appliquait pas uniquement aux UAV, mais qu'elle pouvait être étendue à n'importe quelle technologie ou procédure sans titulaire de poste.

Ce document présente les activités liées au projet et les résultats des expériences. Il s'ouvre par une description de la nouvelle méthode de sélection des équipages et une comparaison avec les pratiques actuelles. La section sur le protocole et le plan d'expérimentation montre comment une méthode scientifique a été utilisée pour répondre à la question. La section sur la réduction des données expose les procédures qui ont été utilisées pour préparer les données à l'analyse. La section des résultats et de l'analyse contient une interprétation des résultats de l'expérience. La dernière section présente des conclusions et des recommandations.

Dans la pratique actuelle, les services responsables de la sélection des équipages interrogent d'abord des titulaires de poste; ils établissent ensuite des descriptions de travail à partir des renseignements ainsi recueillis. La nouvelle méthode a toutefois montré qu'il est possible de prévoir des énoncés de tâches et de connaissances sans qu'il y ait de titulaire de poste. La nouvelle méthode comprend quatre étapes.

1. Décomposer un scénario mixte faisant intervenir des technologies nouvelles en une série de buts hiérarchisés.

2. Proposer les nouveaux éléments de travail et les rattacher aux buts.

3. Comparer les éléments de travail actuels aux éléments de travail prévus.

4. Choisir les postes en fonction de la meilleure correspondance

Les deux premières étapes déterminent l'efficacité prévisionnelle de la méthode. Les résultats de l'expérience de renseignement, de surveillance et de reconnaissance sur le littoral de l'Atlantique (ALIX) montrent que 82 pour 100 des tâches prévues ont effectivement été remplies dans le cadre de cette expérience. La troisième étape comporte l'établissement d'un indice de similitude de travail (IST) qui correspond à un ratio des éléments de travail actuels (énoncés de tâches et de connaissances) d'un poste ou d'un membre des FC et des éléments de travail prévus dans les deux premières étapes. La quatrième étape semble être la plus simple, mais elle fait intervenir d'autres questions de sélection comme la sécurité, l'instruction, l'avancement professionnel et les politiques.

Il est possible de postuler que, si la valeur de l'IST pour un emploi actuel est voisine de 1, la personne qui occupe cet emploi donnera un bon rendement dans la nouvelle mission. Si la

valeur de l’IST est voisine de 0, la personne ne donnera pas un bon rendement. Pour vérifier ce postulat, on a conçu une expérience dans laquelle des membres des FC qui occupaient certains postes ont été invités à remplir diverses tâches. L’expérience a été menée dans un environnement UAV synthétique, les participants étant invités à reprendre trois fois le même scénario comme opérateur de véhicule, responsable de la charge utile et commandant de mission. On a ensuite calculé l’IST et mesuré le rendement, la capacité cognitive, la capacité d’apprentissage et la connaissance de la situation des participants.

En conclusion, les résultats révèlent qu’il y a (pour la majorité des mesures du rendement) une certaine relation entre l’IST et le rendement. Les participants ont tous assez bien rempli la mission UAV, même s’ils avaient des valeurs d’IST différentes. L’analyse montre que le scénario était assez simple pour que les tâches n’exigent que des compétences et des connaissances générales.

Il est recommandé que la Direction de la recherche et de l’évaluation en ressources humaines pilote une seconde série d’expériences qui permettra de recueillir plus de données sur toute la gamme des valeurs de l’IST, afin que des résultats statistiquement significatifs puissent être obtenus et communiqués. Il faudrait concevoir pour l’expérience un scénario nécessitant un plus large éventail de compétences et de connaissances pour remplir les tâches et la mission.

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Introduction

The Canadian Forces Experimentation Centre (CFEC) conducted an experimentation campaign that investigated the use of Uninhabited Aerial Vehicles (UAVs) as the focal point for a new Integrated Intelligence Surveillance Reconnaissance (ISR) Architecture (IISRA) concept for Network Enabled Operations (NEOps). IISRA and NEOps represent a paradigm shift for the CF where information should flow seamlessly amongst CF operational members at home or abroad who are connected to the architecture – similar to a secure world wide web for military personnel. Conceptually, UAVs and other sensor assets would be able to connect to this secure network and transfer information. A key operational advantage of UAVs is their potential as a Joint asset for truly Joint littoral operations.

In July 2003, the Pacific Littoral ISR Experiment (PLIX) investigated a UAV's capability to augment the recognized maritime picture by identifying all surface contacts off the west coast of Canada. In August 2004, the Atlantic Littoral ISR Experiment (ALIX) examined information flows from multiple assets, including UAVs, and evaluated the proposed IISRA (Newton, Regush, Comeau, Van Bavel, Bowes, and Shurson, 2005). The military Human Resources Group, now known as the Military Personnel Group (Mil Pers Gp), tasked selection officers to interview UAV crews and document the tasks, skills, and knowledge (i.e., job elements) that they performed during both experiments. The UAV crews consisted of contractors and CF members, but none were job incumbents since no UAV jobs exist in the CF.

Given the experimental limitations, the job elements collected during PLIX and ALIX were bound to be different from those that would be collected on an exercise or during actual operations. The experimental designers were constrained by contractual agreements as well as Transport Canada regulations on who could be part of the UAV crew, and so those positions of the people who participated in the experiment would not necessarily be those that would be selected to operate UAVs in a CF unit.

A question was raised during PLIX about crew selection: that is, "which CF personnel should 'man' the 'unmanned' system?" This question had strategic and political impact since the deployment of the French SPERWER UAV and its CF crew to Afghanistan with operations starting on Oct 31, 2003 (http://www.forces.gc.ca/site/feature_story/2003/sept03/10_f_e.asp). The interim solution was to select crews in conformance with CF policies related to the safety of aircraft occupants in manned aircraft and airspace coordination and de-confliction, even though these vehicles are uninhabited. Thus, the crew selection focus was on policy and to a lesser degree on the required competencies to operate UAVs. The answer to this question will have strategic ramifications about how the CF will engage adverse systems in the 21st Century.

In response, CFEC initiated a research project investigating new ways for selecting crewmembers with UAVs as the initial application. In conjunction with this project, Captain Glen Smith of the Directorate of Human Resources Research and Evaluation (DHRRE) began a Master's degree in the Department of Psychology and the Faculty of Social Science at the University of Western Ontario with his supervisors Dr. Mitch Rothstein of the Ivey School of

Business and Dr. Philip S. E. Farrell of CFEC S&T Team. The thesis focused on the development of a Job Similarity Index (JSI) as a predictor of performance.

A key resource for this project was a synthetic environment for conducting an experiment. This project used the ALIX UAV Research Test Bed, primarily funded by the Future Forces Synthetic Environment (FFSE) Section at Defence R&D Canada (DRDC) Ottawa, and the work on Intelligent Adaptive Interfaces (IAI) from DRDC Toronto. Under contract, CMC Electronics evolved the UAV research test bed into the synthetic environment used for this project.

As the IISRA and UAV work was coming to an end at CFEC, CF sponsors were identified in June 2005: the Military Occupational Structure, Analysis, Redesign, and Tailoring (MOSART) project; DHRRE; and UAV Joint Project Office (JPO). They will review the results of this project and determine the future direction of this work.

This report represents a compilation of all project activities and experimental results, and is organized as follows. It begins with a description of the alternative method for crew selection and comparison to current practice. The section on the experimental protocol and design shows how the scientific method is employed to explore the efficacy of the new crew selection method. The data reduction section records the procedures used to prepare the data for analysis. The results and discussion section provides the interpretation of experimental results. The final section provides conclusions and recommendations for the way ahead for this area of research.

Alternative Crew Selection Method*

Uninhabited Military Vehicles (UMVs) are new technologies for most militaries around the world, and these militaries may require new jobs, positions, occupations, and units to command and control these assets. On the other hand, militaries have similar inhabited vehicles with similar payloads, and perhaps the skill sets and knowledge that already exist can be transferred to the uninhabited systems.

Moreover, if UMVs exhibit high levels of intelligence and autonomy then only general skill and knowledge levels are required to operate the vehicles and their payload. The transfer of skills and knowledge, and the requirement for general skill and knowledge levels, would allow recruiters to draw from an existing and broader pool of people for future UMV crews.

For example, a pilot, a tank driver, and an Officer of the Watch might be well suited to fly Uninhabited Aerial Vehicles (UAVs), drive Uninhabited Ground Vehicles, and sail Uninhabited Surface Vehicles, respectively. However, a navigator, a gunner, and a sailor may have enough general skill and knowledge to quickly become expert UMV operators, particularly if the systems have sophisticated navigational capabilities (e.g., waypoint navigation) that simplify the operator's tasks.

Current methods for selecting crews begin with interviewing job incumbents (people that are in the job for more than 6 months) and distilling from the interviews the task, skill, and knowledge statements for that position. Job descriptions, selection criteria, and training packages can be developed from the statements. In the case where no job incumbents exist, the selection officer might need to rely on another country's job description for the same or similar job, and/or conduct the interviews with experimental/exercise "role players" as in the case with PLIX and ALIX.

In contrast, the alternative method for selecting crews does not require job incumbents. The method involves matching tasks and knowledge statements (i.e., job elements) derived from existing jobs to predicted job elements derived from a composite scenario involving the new technology – multiple UAVs in this case. In effect, the predicted job elements take the place of interviewing job incumbents. This raises a question about the ability of the method to reliably predict job elements. Preliminary results from ALIX showed that 82% of the predicted tasks were performed, and the thirty respondents identified no additional tasks beyond the predicted tasks. This result provided a high level of confidence that the goal decomposition methodology used to predict job elements is a systematic way of generating provisional task and knowledge lists that are fairly complete. Also, the alternative crew selection method can be used in addition to current job selection methods based on cognitive ability, career progression, legal considerations, availability, and ownership of the new asset.

The idea of using a Mission Function Task Analysis (MFTA) to predict tasks for a new composite scenario is not a new idea (Canadian Marconi Company, 1995). Task analyses are often used to generate requirements for equipment. However, few studies can be cited that

* This section was edited from the original version (Farrell, 2005) for insertion into this report.

use MFTA to generate requirements for humans (i.e., task and knowledge statements). Perceptual control theory Analysis Technique (PAT: Farrell and Chéry, 1998) is a variant of MFTA that was employed for this project instead of a traditional MFTA. Some risk was taken in employing this relatively new technique for this new application, although PAT has been used previously for the interface design of a Control Display Unit for Griffon Helicopters (Chéry, Vincente, and Farrell, 1999).

The new method has four steps:

1. Decompose a composite scenario involving new technologies into a goal hierarchy.

   A Hierarchical Goal Analysis (HGA) of a composite scenario was performed as part of the PAT technique, where the scenario is described in terms of desired system goals. The goals are assigned to humans and machines at some level of the hierarchy. There are some design principles to determine the appropriate level, however, further research is required to optimise this allocation based on workload predictions.

2. Propose and link the new job elements to the goals.

   According to PAT, task and knowledge statements can be associated with the completion of each goal within the hierarchy. The job elements are not limited to task and knowledge statements but include other elements, such as cognitive ability and training. Further investigation is required to determine the relationships amongst job elements and how they influence job performance.

3. Compare the existing job elements to the predicted job elements.

   The mathematical equation for the comparison between existing and predicted job elements has been named a Job Similarity Index (JSI). The simplest matching algorithm (or JSI) is as follows:

   $$\text{JSI} = \frac{\text{number of existing statements that match predicted statements}}{\text{number of predicted statements}} \qquad [1]$$

   As the existing statements match the predicted statements for a given job then the JSI approaches one. Thus, one would hypothesise that a person who has a high JSI will perform well in the new job with minimal training, since they already perform most of the tasks and have most of the knowledge required for the new job.

   Job elements are the basic building blocks associated with a job, a position, or a person. A person may have several positions over the course of their career, and each position may be required to perform several jobs (a job is defined as a group of tasks required to accomplish a high level goal). When listing job elements with respect to an existing job, position, or person, the lists would be different sizes and many statements would be repeated on each of the lists. Therefore the JSI value will depend on which list of existing statements is chosen.

Two methods are employed in this report to calculate the JSI. The first method is based on an existing position (position-based JSI). Mil Pers Gp is the custodian for a CF inventory of tasks and knowledge statements being developed under the Military Occupational Structure, Analysis, Redesign, and Tailoring (MOSART) project. The inventory contains job elements from a survey conducted in 2000 for 252 operational positions. In this relational database, the statements are associated with an existing position* via a Military Occupation Structure Identification (MOS ID) number. A list of existing statements is generated for each MOS ID (or each position) and then the JSI can be calculated from equation [1] for that position.

The most difficult challenge to overcome was to relate the MOSART statements to the predicted statements from the goal analysis when the statements carried the same meaning but the actual wording was different. A simple word or phrase search engine would not suffice. A contractor compared over 6000 task statements and close to 5000 knowledge statements from MOSART to approximately 600 predicted task and knowledge statements and manually linked similar existing and predicted statements from the two separate databases (Kobierski, Coates, and Torenvliet, 2005).

The contractor had a good understanding of military operations and the UAV scenario but was not privy to all the experimental protocol details and the experimental objectives. He took about 20 hours to complete this task. This is a potential source of error for the experiment in that if this task were given to another individual, they may have produced slightly different matches. There was some discussion about developing an intelligent search algorithm that would provide a confidence level that two phrases are the same or similar. This idea was not pursued since the focus is to see whether the JSI could be used to discriminate rather than to develop an intelligent search engine that matches phrases. If this line of research were to continue, it would be highly recommended to investigate the feasibility of such a search engine and apply it to this issue.

The advantage of the position-based JSI is that it can be calculated using the information within the relational database only. The disadvantage of this method is that the database must be continually updated to reflect the current statements for that position – and even then, it would only be an estimate of a person's JSI since the individual might have a variety of job experiences (e.g., secondary duties, staff positions, and multiple career paths) within the CF.

The second method is based on a person's existing tasks and knowledge that they have gained over their career (person-based JSI). That is, a CF member is likely to have done many jobs within the MOSART database – not all associated with their MOS ID number. JSI varies with a person's experiences over time. For example, a CF member might have started a task in 1988, became fully proficient in 1989, continued doing the task until 1998, experienced some psychomotor memory loss, and lost some proficiency by 2005. For this report, it is assumed that it took one year to become fully proficient (a value of 1) on a task or to gain full knowledge for the task, and psychomotor and/or cognitive memory loss decayed exponentially by ¼ per

* Also, the job elements are associated with a given job in the MOSART database.

year. These numbers are gross estimates and should be considered a starting point. Further investigation is required to refine the estimates for each statement. Once the time varying curves are calculated for each statement, then equation [1] can be applied at any moment in time.

The advantage of the person-based JSI is primarily for experimental purposes. That is, this JSI calculation represents an accurate and “up-to-date” JSI for the participant that is then compared to their performance results. The disadvantage of this method is that it is specific to individuals.

4. Select crew positions based on the best match.

   Realistically, selecting positions or people with a high JSI would be a ‘first cut’ at determining the right crew for the new job. Other considerations would be career path, secondary duties, regulations and policies, for instance.

Experiment Setup

Given existing job elements derived from either a position or a person, and given the predicted job elements derived from a hierarchical goal decomposition of the scenario, it is postulated that:

The higher the number of matches between existing and predicted job elements (i.e., the higher the JSI), the better the person's performance as they conduct the new scenario.

This postulate is not intuitively obvious because UMV operations may be simple enough that only general skills and knowledge are required to perform and complete the new job, or too hard that it requires many hours of education and training. Also, factors such as simulator fidelity and general computer familiarity acquired outside of their current occupation may also influence the JSI and performance relationship. Thus, an experiment was designed to test the postulate. DRDC Toronto's Ethics Committee approved the experimental protocol (ANNEX A) in March 2005. The protocol was the official guiding document for the experiment.

The study's purpose was to investigate a crew selection method based on matching existing job elements to predicted job elements generated from a goal analysis. A scenario involving multiple UAVs was chosen as the application for the method since the CF anticipates Tiers 1, 2, and 3 categories of systems (see glossary) will form a "family of UAVs" by 2010.

Thus, the experimental aim is to evaluate the alternative crew selection method by determining whether JSI is a predictor of performance.

Hypothesis

The hypothesis is that job performance is directly related to the JSI. That is, people with low, medium, and high JSI values would produce low, medium, and high performance scores, respectively. The null hypothesis is that there is no difference in performance over a range of JSI values. The challenge is to measure performance for a number of people with different JSI values, and see if performance varies with the JSI value.

Selection of Human Subjects

The subject pool was limited to CF personnel* who have existing jobs described in the portion of the MOSART inventory that was made available for this study. These job elements were about five years old at the time of the experiment. The inventory contains job elements from 252 operational positions and from all three services (navy, army, and air force). For this initial round of testing, CF personnel from the National Capital Region (where the synthetic environment was located) were invited to participate as long as their current or former position was in the MOSART inventory. In the past, human-in-the-loop experiments of this kind have been supported by very small subject pool (10 – 15 subjects). Thus, it was anticipated that the results would be reported as trends rather than statistical significance.

* A civilian computer technician was the first "test" subject for the experimental setup and runs.

The analysis of the multiple UAV scenario determined that a three-person crew is appropriate. The positions are Mission Commander (MC), Vehicle Operator (VO), and Payload Operator (PO). Participants performed the mission three times and rotated through all three positions while two *white cell*[*] personnel played in the remaining positions. The experimental control staff filled all other scenario positions including the Regional Command Centre where the crew received their tasking orders and all information about their mission.

Methodology

Participants filled out general demographic information including their MOS ID number for the position-based JSI calculation. They also completed the Wonderlic General Cognitive Ability (GCA: more commonly known as I.Q.) test at the beginning of the experiment. Each participant performed a one-hour UAV mission in DRDC Ottawa's UAV Research Test Bed (RTB): 20 minutes as VO, 20 minutes as PO, and 20 minutes as MC. All participants received training in the form of a question and answer period, followed by a simple proficiency test. The participants then performed a second run as VO, PO, and MC. Thus, GCA, "first run" performance, proficiency test results, and "second run" performance were the measured values. The experimental schedule is given in ANNEX A.

Unfortunately, the experimental protocol was modified midway through the experiment. A decision was made to forego the second run in favour of having more subjects. The training was provided after the first run in 10 cases (nine participants had 2 runs, and one participant had 3 runs), and before the first run in 22 cases. This was a costly decision since the learning effect could not be analyzed although there were strong indications that learning had reached its maximum after 2 runs. It is recommended to include a second run in future experiments in order to confirm the learning effect.

An additional survey was developed that listed the predicted task and knowledge statements associated with the UAV jobs within the experimental scenario, and the participants were asked to indicate the duration (in years) and end date (year only) for each of the statements. The survey was administered on a volunteer basis ten months after the simulation runs. From these data, a time varying, person-based JSI was calculated. Of the 13 participants who returned the survey, eight participants performed 1 run only, and five participants from 2 runs. The comparison between their assessed performance and the person-based JSI calculation appears in the main body of the report since it best represents the participant's current JSI; the position-based JSI comparisons are archived in ANNEX B.

Equipment

The experiment employed an upgraded version of the UAV Research Test Bed (UAV RTB) developed by DRDC Ottawa in collaboration with CFEC. The UAV RTB was used in a synthetic mission rehearsal prior to the live ALIX experiment (Hubbard, 2004).

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[*] A white cell player is part of the experimental team who acts on behalf of the experimental director. The supplemental crewmembers became experts within 6 times through the scenario.

The simulator is composed of a control station and a synthetic environment (SE). The SE includes terrain models, platform models, behaviours and their interactions and employs Commercial Off the Shelf (COTS) SE software (CAE, 2005). The synthetic scenario was designed based on a composite mission scenario (Kobierski and Lamarre, 2005), which provides tracks for fifteen sea vessels, the initial positions of two Vertical Takeoff UAVs and one mini-UAV, a path for the Maritime Patrol Aircraft (CP-140) overhead of the search area, and release times for three mini-UAVs that are dropped from the CP-140.

All sea vessels were computer-generated, while a live crew controlled the synthetic UAVs in real-time. The vessel models include motion dynamics, a set of waypoints to be repeatedly followed, and a 3-D visual representation from which a 2-D synthetic image can be generated depending on the viewing angle. This synthetic image can be adjusted to mimic a given electro-optical and infra-red (EO/IR) sensor, but a generic camera model was used in this experiment. The locations of the vessels are also posted to a run-time infrastructure used with the High Level Architecture (Fujimoto, 2000; HLA Website, 2005), and so the experimental apparatus could be linked to other simulators or synthetic environments in the future. In the simulated environment, a “perfect” operating picture, based on a CP-140 pulsed-Doppler radar in Surveillance Mode 2, was available and displayed on the UAV control station. The simulated CP-140 flew 155 knots at a 70 degree heading and released (manually “unfreeze” the simulated entities) three mini-UAVs 1, 2, and 3 minutes after the start of the run.

The control station employed in the experiment, shown in Figure 1, was developed under contract (Zhang, 2005). This control station allows the crew to operate multiple UAVs at the same time. This is an extension to the original UAV RTB that employed an operational control station for a single UAV (CDL, 2005). As shown in Figure 1, the multi-UAV interface consists of three displays and two touch screens (left picture) for the vehicle and payload operators (the radar display in the middle is shared and the top two displays were not used for this study), and a radar display and touch screen for the MC position (right picture). The primary PO display shows the EO/IR camera view from all UAVs as “thumbnails” at the bottom of Figure 2. The PO may assign thumbnail views to the main window and the smaller inset window. The VO display also provides sensor views, but the control of the platform is done through the touch screen below the display. The control station is linked to a UAV model in the SE through a NATO Interface Standard (Bandzul, 2003; NATO, 2004) for UAV communications, meaning that, in principle, the control station could be transitioned to control live UAVs.

Figure 1. VO and PO workstations on the left and the MC workstation on the right

The simulator also has an experimenter's control station where the scenario was controlled and monitored and from which the data were collected. This station gives real-time control of all platforms with the COTS SE tool through an interface that overlays vessel icons on a map of the region of operation. An inset window also provides a map view to monitor the progress of the scenario.

A Validation and Verification (V&V) activity was conducted for the simulator (Moore, Kobierski, and McKay, 2005). This resulted in lessons learned for the Synthetic Environment Coordination Office co-located at CFEC. For example, there is a clear distinction made between V&V for experimental purposes, versus V&V for operations. "Fit for purpose" is a fundamental concept for verification, and in this case, the SE was designed specifically for this crew selection experiment and not as a crew selection tool or a training simulator.

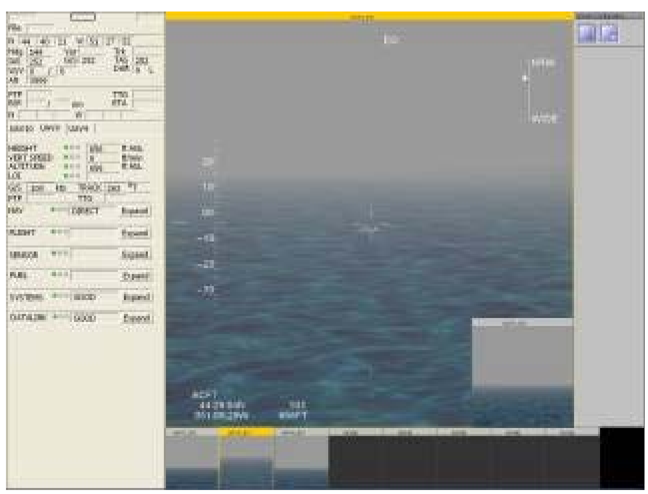

Figure 2. PO's Graphical User's Interface that can show up to 8 sensor images

Analysis

The data collection and analysis will be used to determine whether a relationship between the JSI and performance exists. Figure 3 shows fictitious data where a point represents the performance measurement for a given participant with a particular JSI value. That is, performance is plotted against the JSI. The data are likely to be dispersed as shown; a line of best fit, or a trend line, can be generated. The closer the data are to the trend line, the higher the confidence we have that any conclusions derived for the trend line apply to the data as well. In this case, the trend line indicates that the performance is directly related to the JSI. Thus, the analysis has three parts: 1) correlation between JSI and performance, 2) the Mean Distance between the data and the trend line (see ANNEX C for Mean Distance derivation), and 3) interpretation of the trend line's slope and intercept.

The JSI is calculated under four circumstances:

- JSI (calculated for all predicted tasks);
- VO JSI (calculated for VO tasks only);
- PO JSI (calculated for PO tasks only); and
- MC JSI (calculated for MC tasks only).

There are four predictors of performance and three performance measurements:

- Years of Service;
- Service (Army, Navy, Air Force);
- GCA;
- Proficiency Test;
- VO, PO, and MC Performance Assessments (maximum and average);
- VO, PO, and MC Situational Awareness (SA); and
- VO, PO, and MC Path Metric (maximum and average).

A pair wise comparison is proposed where the four predictors of performance are plotted against the overall JSI, and the three performance measures are plotted against their respective position JSI values. A multiple regression analysis would be appropriate in this case, however there are not enough data points to determine statistical significance.

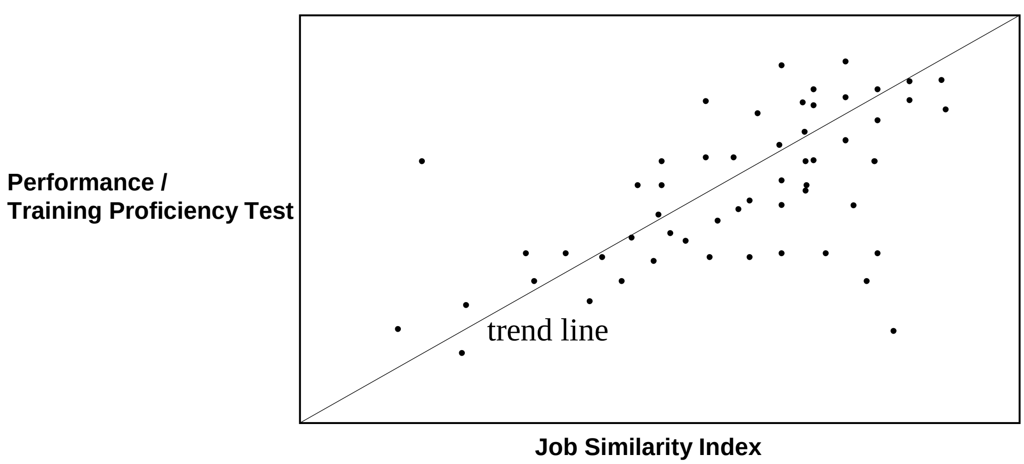

Figure 3. Anticipated results showing that performance is directly related to the JSI

Results and Discussion

The crew selection experiment consisted of 32 participants: 31 CF personnel and 1 civilian test subject. Each participant had a unique 5-character alphanumeric ID for this experiment and each data component is associated with the participant's unique ID. There were seven data components for each participant: 1) demographic survey, 2) an additional survey used to calculate an accurate Job Similarity Index, 3) GCA test score, 4) proficiency test score, 5) observer assessment, 6) situational awareness (SA) tactical plot, and 7) system log file that captures all vehicles' longitude and latitude every 5 seconds. The data sets were incomplete and this analysis included only:

- 28 demographic surveys (26 with MOS ID numbers);
- 13 additional surveys;
- 29 GCA tests;
- 27 proficiency tests;
- 28 sets of assessment forms;
- 32 sets of SA tactical plots; and
- 30 sets of log files.

There were 8 participants with no missing data components.

Pair wise comparisons of the maximum person-based JSI and other performance measures are presented in this section. In addition to a correlation (R) calculation between the dependent and independent variables, a trend line analysis is conducted and conclusions are drawn about the relationship between JSI and performance. If the trend line slope is diagonal or close to one, then we would conclude that the two variables are directly related to each other and if the slope is horizontal or close to zero then there is no relationship between the two variables.

The Mean Distance (MD) between the trend line and the actual paired data points indicates a degree of confidence that the trend line conclusions apply to the actual data. The MD metric is calculated by summing the perpendicular distance between data points and the trend line, dividing by the total number of data points, and normalising with respect to a specific function of the slope and the maximum y value (see ANNEX C). As MD approaches zero, the actual data points lie on the trend line and so there is high confidence that any conclusions made for the trend line would apply to the actual data. As MD increases, the confidence decreases. It is expected that the MD calculation would be inversely related to the R calculation.

Demographics

Basic information about the participants was collected from the demographic survey including rank, MOS ID, job title, years of service, Force status (i.e., regular Forces or Reserves), and education level. Rank, Force status and education level were not used in this analysis, but are available for future analyses. Table 1 lists the Job Name, MOS ID, ten unique Job Codes, the position-based JSI from the 2000 MOSART database, the person-based JSI at the year 2000, and the maximum person-based JSI over their career (i.e., job elements are retained with no memory loss). Note that the person-based JSI has 13 JSI numbers that represent the 13 respondents.

TABLE 1: JSI FOR EXPERIMENT PARTICIPANTS

Job Name	MOS ID	Job Code	No. of participants	position-based JSI (%) (2000)	person-based JSI (%) (2000)	person-based JSI (%) (max)
Air Navigator	310	001	2	54.2	11.6, 20.9	43.5, 49.3
Armoured Engineer	41, 42	126	1	29.8	-	-
Artillery Technician	21	060	2	48.3	6.8	7.9
Clearance Diver Officer	71	011	1	42.5	16.9	23.3
Civilian	-	-	1	-	-	-
Communications Signaller	31	084	1	37.5	-	-
Electrical/Mechanical Engineer	-	-	2	-	7.8	8.0
Naval Electronic Sensor Operator	276	033	3	46.8	10.9, 15.9	14.1, 16.9
Line Pilot	32	021	6	54.3	1.1, 32.6	18.2, 36.2
Officer of the Watch, Air Traffic Controller	71, 390	062	2	40.9	48.7,11.9	75.1, 28.1
Senior Naval Combat Information Operator	275, 390	081	3	45.7	31.5	52.6
Squadron Air Traffic Control Officer	390	039	5	45.2	41.9	62.9

The position-based and person-based JSI calculations yield different values. For example, one of the Line Pilots had a JSI value of 1.1% in 2000 (18.2% maximum) while his position-based JSI is the highest at 54.3%. The highest maximum person-based JSI at 75.1% surpasses the highest position-based JSI by over 20%. Thus, the person-based JSI would predict that the Officer of the Watch would perform better than the Line Pilot, while the opposite prediction would be made for the position-based JSI.

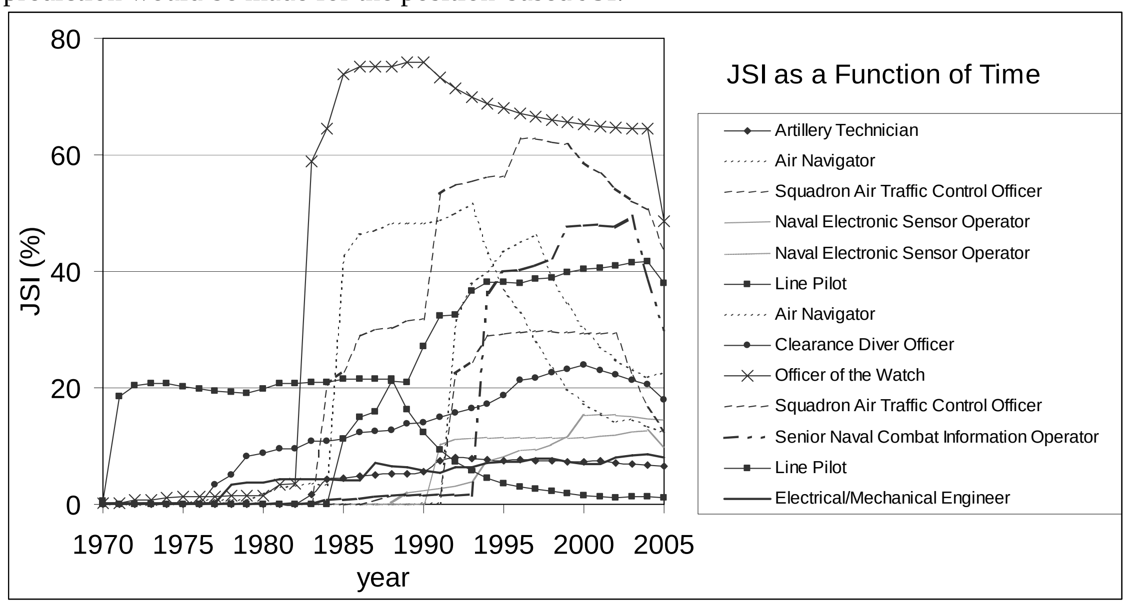

Figure 4. Person-based JSI as a Function of Time

Figure 4 shows the person-based JSI as a function of time from 1970 to 2005 for the 13 participants (assuming full proficiency after 1 year, and exponential memory loss of ¼ per year after end date). However, the maximum person-based JSI value is arguably the most realistic index since most statements involve procedural and declarative knowledge that do not decay significantly with time or require a specialized skill. The maximum person-based JSI values are used in the following comparisons.

The years of service ranges from 15 to 42 (possible outlier at the 99th percentile) with an average value of 23.5 years, a standard deviation of 7.8 years, and a skew value of 1.1. There is no apparent relationship between JSI and years of service as shown by the shallow slope in Figure 5 (slope = -0.03; R = -0.09, and MD = 5.8%).

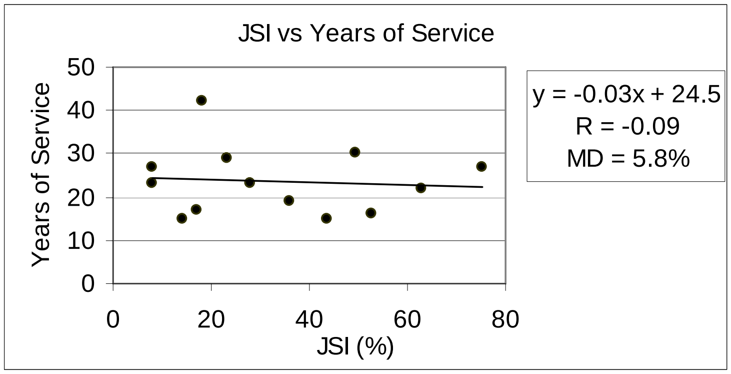

Figure 5. JSI versus Years of Service

Also, all three services participated in the event (of the 26 that had MOS ID numbers, 15 Air Force, 4 Army, and 7 Navy). On average the Air Force positions had more task and knowledge statements that are in common with the littoral UAV scenario (average position-based JSI = 45%), followed by the Navy (average position-based JSI = 32%), then the Army (average position-based JSI = 8%).

General Cognitive Ability

Each participant was given the General Cognitive Ability (GCA) test (Appendix B in ANNEX A). The participants had 12 minutes to complete as many of the 50 test questions as possible. These test scores were collected, converted to a percentage value, and plotted against the person-based JSI in Figure 6.

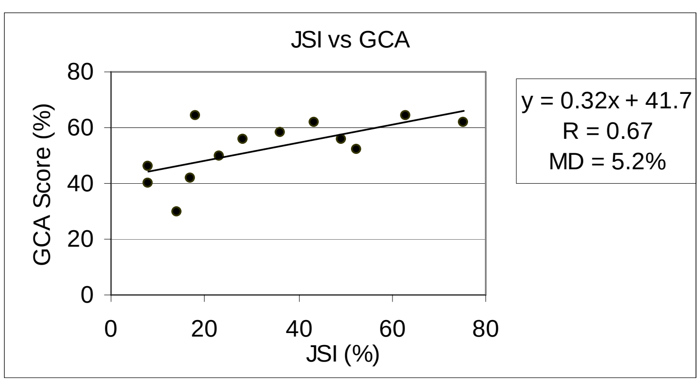

Figure 6. JSI versus General Cognitive Ability

The trend line for JSI versus GCA slope is equal to 0.32, the correlation is 0.67, and MD is equal to 5.2%. There seems to be a positive relationship between JSI and GCA. This would imply that both JSI and GCA would predict the same task performance. However, more data from a wider set of operational positions is required to confirm this implication.

Proficiency Test

Each participant was given a proficiency test following the completion of the training. The proficiency test consisted of 10 multiple-choice questions and was designed to measure the participant's comprehension of the tasks and knowledge they need for the mission. The proficiency test scores were converted to a percentage value and plotted in Figure 7 with the corresponding JSI value.

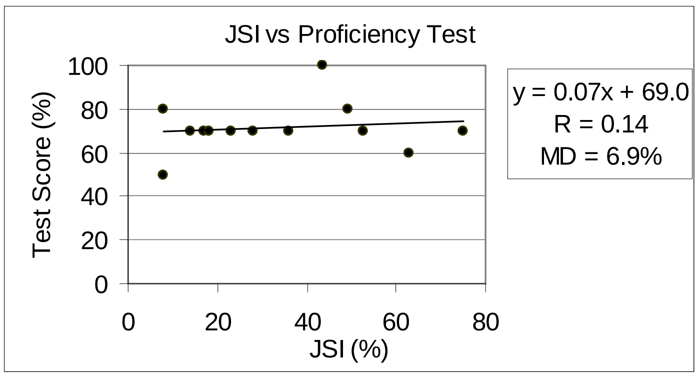

Figure 7. JSI versus Proficiency Test

JSI versus Proficiency Test shows no relationship between these two variables (slope = 0.07). In other words, everyone did well on the test (intercept =69%). Perhaps the test was easy or perhaps the UAV tasks were easy. Experimental observations indicate the latter.

Performance Assessment

An experimental run consisted of three 20-minute segments in the VO, PO and MC positions respectively. During each segment, at least two out of five assessors rated the participant's performance in the role of VO, PO, and MC on a scale from zero to five using the assessment forms in Appendix A of ANNEX A. A score of 0 indicated that the participant did not do the task, while all other scores infer that the task was completed. The remaining numbers on the scale provide a subjective assessment of how well the task was performed, where a score of 1 meant that the task was performed poorly and 5 meant that the task was performed very well. An inter-reliability test between assessors was not performed.

Three performance measures were extracted from the data: 1) Yes/No performance (either the task was done or not done), 2) Maximum performance (the maximum value from the observers' ratings), and 3) Average performance (the average value of the observers' ratings). Figure 8 is a representative plot of VO JSI versus the Assessed Average Performance.

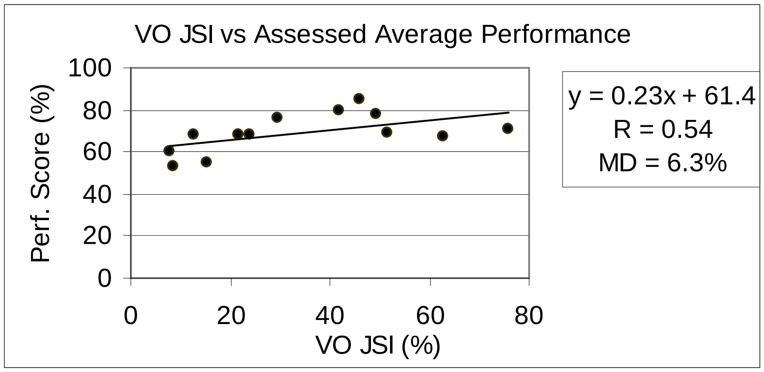

Figure 8. VO JSI versus the average performance ratings

Table 2 lists the results for pair wise comparisons between the appropriate JSI and the three assessment performance measures. Clearly, this is a multivariate problem that requires multivariate statistics. However, it was clear from the beginning of the project that there would not be enough participants from the already limited CF population to achieve statistical significance. Therefore it was decided to do simple pair wise comparisons to find any indications of a relationship between the JSI and performance.

TABLE 2: JSI VERSUS ASSESSED PERFORMANCE RESULTS

JSI (%)	**Performance (%)**	**Slope**	**Intercept**	**R**	**MD (%)**
JSI	Reference (null hypothesis)	**0**	**100**	**1**	**0**
VO JSI	Yes/No	**0.09**	**94.7**	**0.49**	**2.2**
	Maximum	0.20	69.7	0.49	5.8
	Average	0.23	61.4	0.54	6.3
PO JSI	Yes/No	**0.05**	**97.6**	**0.50**	**1.3**
	Maximum	-0.00	77.3	-0.00	10.3
	Average	0.10	68.7	0.17	10.3
MC JSI	Yes/No	**0.05**	**97.6**	**0.45**	**1.2**
	Maximum	0.14	70.5	0.30	7.2
	Average	0.17	65.8	0.43	6.5
JSI	Reference (hypothesis)	**1**	**0**	**1**	**0**

The “Reference” slope and intercept at the top of Table 2 reflects the null hypothesis that there is no relationship between JSI and performance even though the performance is the best possible at 100%, the correlation is perfect, MD is equal to zero. The bottom Reference represents the hypothesis that JSI and performance are directly related to each other.

The first observation is that the slopes are positive (except for PO JSI versus Maximum performance where the slope is -0.0002 or practically flat) but small. This means that JSI might explain some, but not all of the performance variance. Nevertheless, a positive slope indicates that there is a positive linear relationship between JSI and performance.

Second, the intercept values range from 61.4 to 97.6. Generally, the participants performed well regardless of their JSI number.

Third, the correlation ranges from 0 to 0.54. There are indications that JSI and performance are correlated for cases where R > 0.4 (anecdotally, R > 0.4 is encouraging for psychological testing). Also, R is inversely related to MD as expected (correlation = -0.8).

Fourth, there is high confidence in reporting the Yes/No performance results (MD: VO = 2.16%, PO = 1.29%, MC = 1.20%). The results show that there is little to no relationship between the JSI and the number of tasks that were performed (slope: VO = 0.09, PO = 0.05, MC = 0.05). All participants performed a high percentage of tasks (intercepts: VO = 94.7%, PO = 97.6%, and MC = 97.6%) regardless of their JSI value. This result supports the ALIX finding that a high percentage of predicted tasks were performed. The conclusion is that all the participants had enough general skill and knowledge to accomplish these tasks.

Finally, the average performance results seem to indicate a slight relationship between the JSI and performance, however, this can be only reported as a "trend" since not enough data points were available to make any statements about statistical significance. Nevertheless, the trend supports the hypothesis.

Situational Awareness

Ten goals or knowledge statements are identified that, if completed, would constitute high Situational Awareness (SA: see Table 3). At the end of each segment, the final tactical plot picture (Ground Truth) was captured and stored. Participants were asked to recreate the entities' positions and any other pertinent information about the situation on a blank paper tactical plot (SA re-creation). The re-creations were scored with respect to the rules described in Table 3. A point was given for each SA criterion satisfied, for a maximum of 10 points. If an SA re-creation sheet or Ground Truth were not available for that segment, then a score of negative one was assigned. Since the SA re-creation was done freehand on paper while the Ground Truth has specific longitude and latitude numbers on an electronic map, the assessor used their human judgement to determine whether a point was warranted.

TABLE 3: SITUATION AWARENESS GOAL DESCRIPTION AND CRITERIA

Goal ID	Goal Description	Goal pass/fail criteria
2.3.2	Location of friendly units	Friendly units are identified and their locations in the SA Re-creation match the friendly unit locations in the Ground Truth.
2.3.4	List mission activities of friendly units	Mission activities of the friendly units are specified in the SA Re-creation.
2.4.2	Location of neutral units	Neutral units are identified and their locations in the SA Re-creation match those from the Ground Truth.
2.5.2.1	Location of all unknown unit icons on tactical plot	Unknown units are identified and their locations in the SA Re-creation match the unknown unit locations in the Ground Truth.
2.5.2.2	Relative location of own position to unknown units	Relative location of own position to unknown units in the SA Re-creation match the relative location in the Ground Truth.
2.6.2.1	Location of all known terrorist unit icons on tactical plot	Terrorist unit is identified and its location in the SA Re-creation matches the terrorist location in the Ground Truth.
2.6.2.2	Relative location of own position to known terrorist units	Relative location of own position to terrorist unit in the SA Re-creation match the relative location in the Ground Truth.
6.4.1	The probable position of the terrorist vessel	The probable position of the terrorist vessel is specified in the SA Re-creation and not in the Ground Truth.
6.4.4	Search area is appropriate for	Search area in the SA Re-creation matches that shown on the

	the current situation	Ground Truth.
6.4.5	Display on workstation is appropriate	Ground Truth is scaled appropriately to see the majority of the scenario's operational theatre.

Table 4 shows a small but negative slope for VO JSI and PO JSI versus SA. One explanation is that those with a high JSI would have already performed a real ISR mission in a littoral environment and may have preset expectations of what the situation should be, and thus the notion of strategic persistence (Farrell, 1999) may produce poor SA results. Meanwhile, participants with a low JSI may have fewer expectations on how the mission is to unfold and are more receptive to details about their surroundings. Another explanation is that the slope is negative due to experimental noise since the slope is close to zero, which would indicate no relationship between JSI and SA. Also, MD values for SA are the largest amongst all the variables meaning that there is very little confidence that any trend line implications can be applied to the data.

TABLE 4: JSI VERSUS SITUATIONAL AWARENESS RESULTS

JSI (%)	SA (%)	Slope	Intercept	R	MD (%)
JSI	Reference (null hypothesis)	**0**	**100**	**1**	**0**
VO JSI	SA	-0.02	58.3	-0.02	13.7
PO JSI	SA	-0.04	58.5	-0.06	14.3
MC JSI	SA	0.05	60.6	0.09	14.6
JSI	Reference (hypothesis)	**1**	**0**	**1**	**0**

Path Metric

The Path Metric is an attempt to derive an objective measure of performance from the path data. The UAV path metric represents a measure of the difference between the actual path taken by the UAVs and a reference path as depicted in Figure 9. The figure shows two ways to calculate the difference: non-time based and time-based. Both calculations are used in this analysis. If the UAV were to track the reference path exactly, then the two paths would lie on top of each other in time and space, and the path metric would be zero. If the UAV would veer away from the reference path in time or space then the path metric would grow. The reference path, for each UAV, is designed with a set of heuristics (e.g. a UAV should prosecute the closest target). The actual UAV paths are generated from the position data recorded in the system log files. The path metric is computed by comparing the actual and reference paths (see ANNEX D for details).

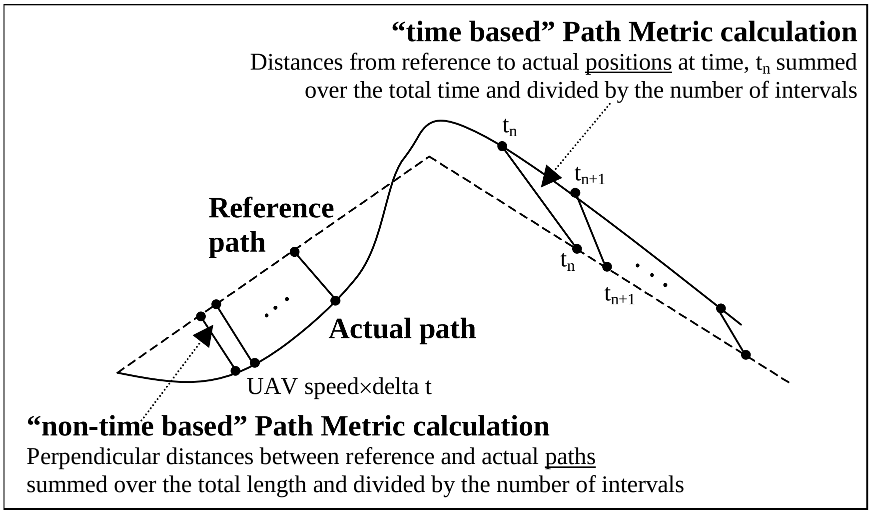

Figure 9. Visualizing the Path Metric Calculation

Figure 10 is a representative graph that shows the UAV 9 Path Metric results. Note that, Path Metric calculation is converted to a performance score out of 100. That is, the run with the lowest path difference was set to 100% and the run with the highest path difference was given 0%. The performance scores for all other runs were interpolated between these two anchors. The graph shows the "time based" result for all participants as MC and for UAV 9 only (for illustrative purposes). The metric shows the deviation of the actual path flown by UAV 9 from the reference path for UAV 9. In some cases, participants performed more than one segment as MC, and so it is possible to calculate either the maximum or the average path metric value. The average calculation is displayed below.

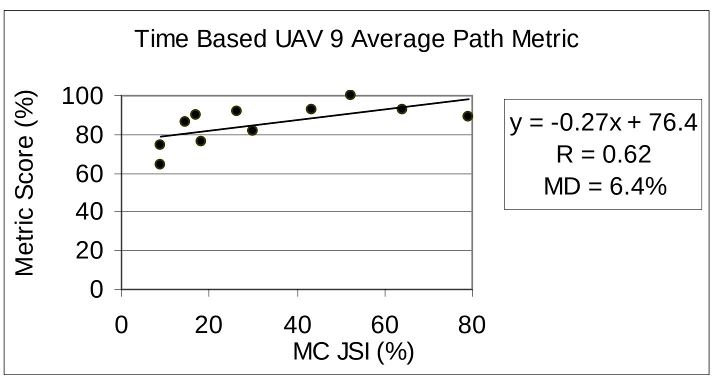

Figure 10. JSI versus UAV Path Metric Performance Score

The Path Metric results are summarized in Table 5. Similar to the other variables, the Path Metric is compared to the JSI and a trend line is generated. There are 36 conditions:

- Three positions (VO, PO, and MC).
- Two types of calculations (non-time based and time based);
- Two values for multiple runs (maximum and average); and
- Three UAVs (UAV 9, UAV 10, and UAV4).

The PO performance scores are generally better than MC and then VO (i.e., intercepts are higher and MD is smaller). This may be attributed to the white cell expertise that occupied the VO and MC positions, which would be primarily responsible for the UAVs' planned and actual paths, when the participant was in the PO position. The VO slopes are generally negative with large MD values. Recall that the participants started the experiment in the VO position. Finally, the non-time based intercepts are consistently higher than the time based results for the most part.

TABLE 5: JSI VERSUS PATH METRIC RESULTS

JSI	Calculation	Value	UAV	Slope	Intercept	R	MD
VO JSI	Non-time based	Maximum	9	-0.13	78.1	-0.20	10.2
			10	-0.13	80.6	-0.20	11.8
			4	0.05	78.6	0.15	5.9
		Average	9	-0.12	77.8	-0.19	10.2
			10	-0.09	77.6	-0.15	11.8
			4	0.02	77.5	0.05	6.1
	Time based	Maximum	9	-0.35	72.1	-0.48	10.5
			10	-0.35	76.1	-0.38	14.9
			4	-0.12	75.7	-0.33	6.4
		Average	9	-0.14	61.2	-0.20	13.2
			10	-0.26	68.9	-0.28	16.4
			4	-0.10	74.6	-0.27	6.5
PO JSI	Non-time based	Maximum	9	0.04	89.1	0.18	3.6
			10	0.05	87.9	0.19	4.6
			4	-0.12	92.4	-0.32	5.8
		Average	9	0.05	88.6	0.21	3.7
			10	0.06	87.3	0.22	4.6
			4	-0.12	91.9	-0.32	5.5
	Time based	Maximum	9	-0.07	79.9	-0.15	8.4
			10	0.05	76.2	0.10	7.9
			4	0.04	76.6	0.20	3.6
		Average	9	0.01	75.0	0.03	7.1
			10	0.08	74.1	0.16	7.7
			4	0.13	71.4	0.35	5.1
MC JSI	Non-time based	Maximum	9	0.00	83.4	0.01	9.7
			10	0.05	77.0	0.06	14.8
			4	0.23	67.7	0.35	9.5
		Average	9	0.00	83.2	0.01	9.4
			10	0.09	74.9	0.12	14.1
			4	0.25	66.6	0.38	9.3
	Time based	Maximum	9	0.22	79.9	0.54	6.4
			10	0.17	85.7	0.47	5.6
			4	-0.06	86.2	-0.12	9.3
		Average	9	0.27	76.4	0.62	6.4
			10	0.20	82.8	0.51	6.2
			4	-0.04	84.4	-0.1	8.6

The Path Metric as an objective performance measure remains under scrutiny. That is, the results must be carefully interpreted, just like the other performance measures. This metric is a relative measure in two ways. First, the actual path is relative to a semi-arbitrary reference path. The reference path is generated based on a "shortest distance" heuristic, which may not be an optimal path. For example, we know that one participant spotted the terrorist vessel within minutes of the start of the run because the vessel was perpendicular to the current. The participant sent UAV 9 to the terrorist ship and identified the ship in 4 to 6 minutes while everyone else spent 15 to 20 minutes to find the terrorist ship. The average value for the non-time based path metric calculation for this participant is 81.3% for UAV 9, 28.6% for UAV 10, and 12.9% for UAV 4 (the lowest value). Yet this participant was arguably the best performer even though UAV 10 and 4 results do not reflect the participant's performance.

Second, the percentages are relative to the lowest and the highest path difference generated by participants. The result would be the same if all paths were compared to a single participant's actual path rather than a reference path. The Path Metric is only one of many other variables that may provide insight into performance and it is recommended that the metric be further developed because of its potential to be a single objective measurement of performance.

Experimentation Issues

As with all complex experimentation, various issues arise that are either unavoidable or unexpected. The first issue is that the limited number of subjects made it difficult to collect the data and perform a statistical analysis. And so, only trends are reported herein. It is recommended to continue experimenting until reasonable significance levels are reached.

The second issue is that the experimental protocol was altered during the conduct of the experiment, and the second performance run was eliminated. Thus the transfer of training and learning effects can only be analysed with 10 participants. The recommendation is that the second run be re-instated in future experiments.

The third issue is that there are multiple ways of calculating the JSI: position-based, time varying person-based, maximum person-based, even job-based. The JSI may also include time on existing tasks, task importance, and other job elements in order to converge onto a "true" JSI for a person, position, or job. The recommendation is to develop a coherent model for the derivation of the JSI that takes into consideration not only the number of matches between existing and predicted statements, but also time on task and task importance for the matching tasks.

The final issue is that an accurate and repeatable measure for human performance needs to be developed. This would require a good understanding of the definition of human physiological and psychological performance, the variables that comprise human performance, and the methods for probing human performance. Typically, there are three parameters that are used to measure human performance: the degree to which a task is completed, the quality (accuracy and precision) of the task completed, and the time to complete the task (an objective measure). A model is required that combines these three parameters into a single coherent metric. For example, only when the task is completed can the quality and timeliness be measured, however, the time to complete the task may also be inversely related to the quality of the task for the majority of tasks (i.e., speed-accuracy trade-off). On the other hand, as the participant becomes an expert at performing the task, the task would be performed faster with the same or better quality. The relationship is complex and beyond the scope of this study.

Nevertheless, it is recommended that completion times be an integral part of the data collection and analysis in future experiments.

Conclusions

A method for crew selection based on matching existing and predicted job elements was developed and tested. The null hypothesis (there is no difference in performance over a range of the JSI) was not falsified due to the small number of participants. However, the assessed average performance increased slightly as a function of JSI starting from 60%, thus providing some evidence that JSI can be used to discriminate between jobs.

Participants performed more than 94% of the tasks regardless of their JSI value. Thus, the scenario seemed to be simple enough that tasks could be completed with a general level of skill and knowledge. Although the scenario involves about 600 job elements, it includes only those activities associated with detection, identification, targeting, and tracking, which would favour the PO and MC positions. If the scenario were to focus on takeoff, cruising, and landing, then perhaps the aviation, navigation, and communication job elements would discriminate between jobs (e.g., pilot versus driver versus sailor). If the scenario were to include the control of land or sea uninhabited vehicles with driving or sailing job elements then one could expect that the JSI calculation would discriminate between jobs.

On the other hand, removing the human from the vehicle and incorporating more computer control does have tremendous implications on the level of skill and knowledge required to operate these vehicles. The control of uninhabited military vehicles may only require general skills and knowledge, particularly as navigation, communication, and collision avoidance algorithms become more sophisticated, and UMV systems incorporate intelligent/adaptive interfaces to assist the operator. At the same time, a person who can manage multiple systems simultaneously should do well in such an environment.

More work is required to understand the interactions between all the variables that impact job performance before understanding the slope value. The slope represents the impact of not only the JSI on job performance but also other variables such as age, GCA, and computer familiarity to name a few. However, more participants are needed to produce a stable slope with an MD tending towards zero.

Although there are indications of a positive relationship between JSI and performance, further testing is required to determine if the crew selection method is a viable alternative for selecting crews particularly when job incumbents do not exist. Steps one and two alone provide a good prediction of new job requirements from which selection, job descriptions, roles and responsibilities, and training requirements may be derived. With the aid of a synthetic environment one can test, redesign, and optimize not only the technology but also the crew roles and responsibilities prior to implementation in an operational unit. The method is not limited to UAV applications but could also be applied to other manned systems the CF plans on operating in the near future.

Recommendations

Both the ALIX data and these experimental results suggest that steps one and two of this method are fairly robust in predicting job elements. It is recommended that DRDC work with DHRRE to determine the reliability of the method in predicting job elements using historical data and/or tracking new scenarios over a number of years.

Determining the appropriate balance between roles and responsibilities amongst multiple operators is more of an art than a science. In our case, the division of labour and responsibility between VO, PO, and MC was based on a Medium Altitude Long Endurance UAV crew. It is recommended that DRDC and DHRRE investigate human/machine goal allocation based on workload predictions. Once the goals are properly allocated, the roles and responsibilities should follow naturally.

Recall that existing and predicted job elements were linked manually. It is recommended that DRDC in conjunction with industry develop a sophisticated phrase recognition engine that links statements with similar meaning. Some of this research is underway at DRDC Toronto.

The interface for the control of multiple UAVs is a novel design that works in concert with the crew compliment and the sophistication of the technology. It is recommended that DRDC, the Air Force Experimentation Centre, and the UAV JPO investigate optimal designs for the control of multiple UAVs. The research on Intelligent Adaptive Interfaces conducted at DRDC Toronto and the DRDC TIF project on Trusted Autonomy (Lauzon and Hubbard, 2003) will provide valuable direction for the interface design.

Job performance depends on variables in addition to the JSI, such as GCA, training, maintenance of skill, Rank, Force status, educational levels, and secondary duties. It is recommended that DHRRE investigate relationships between job performance and other variables. The Masters thesis by Captain Glen Smith should go a long way to identifying the variables, but more work is required in developing and validating a robust model.

The Path Metric has potential as an objective measure of performance when the job involves moving vehicles. This metric can be used for not only crew selection but also determining the transfer of training. It is recommended that DRDC develop a Path Metric that could be used in the UAV RTB and other simulators. Part of this research would be to determine how this objective measure is related to subjective assessments of performance.

As suggested in the conclusions section, interpreting the value of the trend line slope is a key outstanding issue. It is recommended that DRDC in conjunction with academia develop a heuristic that would provide insight into this issue.

Finally, it is recommended that DHRRE take the lead in conducting a second series of experiments that provide more data over the entire range of the JSI so that statistical significance levels can be obtained. The experimental design should carefully consider the scenario and control subjects in order to establish baselines for the JSI versus performance relationship. The series may include a learning effect investigation by including multiple runs per participant.

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ANNEX A: Experimental Protocol

Executive Summary

Protocol #L-497

Title: An alternative crew selection method
Principal Investigator: Dr. Philip S. E. Farrell, Canadian Forces Experimentation Centre
Co-Investigator: Captain Glen Smith, University of Western Ontario
Co-Investigator: Dr. Paul Hubbard, DRDC Ottawa

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DRDC Thrust:
Project 20cq “Support to Joint Exercises/Experiments”

Experimental Purpose:

The study’s purpose is to present an alternative crew selection method that is based on matching job elements from new jobs to job elements from existing jobs. Thus, the experimental purpose is to evaluate the alternative crew selection method by showing whether the method discriminates between jobs.

Previous Related Study:

The previous related studies include the Pacific and Atlantic Littoral ISR eXperiments (PLIX and ALIX) sponsored and performed by CFEC. A current related study is Intelligent Adaptive Interfaces and the control of multiple UAVs from an airborne platform (Dr. Ming Hou, principal investigator, DRDC Toronto), where we share the same synthetic environment.

Short Background for CF Relevance:

Emerging Technologies have generated new jobs that do not exist in the Canadian Forces (CF). The current crew selection process focuses, primarily, on career progression and less on whether crews have the skill and knowledge to perform the new jobs. Thus, an alternative crew selection method is proposed that considers a candidate’s current tasks and knowledge.

Risks of Injury to Human Subjects:

There is no risk to the health of participants above or beyond that of normal daily activity.

Other Information:

The results from this experiment will be used in Captain Glen Smith’s Masters Thesis out of the psychology department at the University of Western Ontario. His co-supervisors are Dr. Mitch Rothstein of the Ivey Business School at UWO, and Dr. Philip S. E. Farrell at CFEC.

Protocol #L-497

Title: An alternative crew selection method

Principal Investigator:	Dr. Philip S. E. Farrell, Canadian Forces Experimentation Centre
Co-Investigator:	Captain Glen Smith, University of Western Ontario
Co-Investigator:	Dr. Paul Hubbard, DRDC Ottawa

Acronyms:

CF	Canadian Forces
CFEC	Canadian Forces Experimentation Centre
DRDC	Defence Research and Development Canada
HGA	Hierarchical Goal Analysis
JI	Job Index
MC	Mission Commander
PO	Payload Operator
RTB	Research Test Bed
UAV	Uninhabited Aerial Vehicle
UWO	University of Western Ontario
VO	Vehicle Operator

Background:

New technologies require new jobs that do not exist in the Canadian Forces (CF). Current crew selection for these emerging technologies might be based on career progression, legal considerations, availability, and ownership of the new asset. CF Human Resources interview incumbents and determine their job elements (e.g., tasks, skills, and knowledge). A list of job elements includes, but are not limited to:

- task
- task importance (assumes secondary duties)
- time spent on task (assumes secondary duties)
- knowledge
- skill
- general cognitive ability
- personality
- current job performance
- training environment

These job elements are used to generate legal documents that describe a position's roles and responsibilities – but not for crew selection. Thus, an alternative method is proposed based on comparing new jobs produced by new technologies to the CF job element inventory.

The alternative crew selection method has four steps as follows:

1. Decompose a composite scenario involving new technologies into a hierarchy of goals.
2. Propose and link the new job elements to the goals.
3. Compare the new job elements to the CF job element inventory.
4. Select positions based on the best match.

The results from this experiment will be used as part of Captain Glen Smith's Masters thesis out of the psychology department at the University of Western Ontario. His co-supervisors are Dr. Mitch Rothstein of the Ivey Business School at UWO, and Dr. Philip S. E. Farrell at CFEC. The thesis is to examine various matching algorithms (step 3) and evaluate them with experimental data.

That is, task and knowledge statements have been generated for three emerging jobs – UAV Mission Commander (MC), UAV Vehicle Operator (VO), and UAV Payload Operator (PO). Also, task and knowledge statements are available in a CF job elements inventory. The simplest matching algorithm, called the Job Similarity Index (JSI), is as follows:

JSI =

$$\tfrac{1}{2}\frac{\text{number inventory tasks that match new tasks}}{\text{total number of new tasks}}+\tfrac{1}{2}\frac{\text{number of inventory knowledge that match new knowledge}}{\text{total number of the new knowledge}}$$

As the Job Index (JSI) approaches one, then the CF job is 'highly correlated' to the new job. The hypothesis is that the MC, VO, and PO performance is directly related to the JSI value. Thus, those CF personnel who have a high JSI will perform well in the new job and will require minimal training, since they do most of the tasks and have most of the knowledge required for the new job.

Alternative JSI calculations might be considered. For example:

JSI =

$$\frac{\sum_{\text{inventory tasks}}\text{task importance}\times\text{percent of members performing}}{\text{total number inventory tasks that match new tasks}}+\frac{\sum_{\text{inventory knowledge}}\text{task importance}\times\text{percent of members performing}}{\text{total number inventory knowledge that match new knowledge}}$$

or: JSI =

$$\sum_{\text{inventory tasks}}(\text{A+B task importance}+C\text{percent of member performing})+\sum_{\text{inventory knowledge}}(\text{D+E task importance}+\text{Fpercent of member performing})$$

Note the first JSI is a subset of the last JSI calculation (a weighted average of a number of quantities).

The experiment is designed to determine if JSI is directly related to performance. Thus, a participant's performance in the three jobs will be measured and correlated with his or her JSI calculation. If the JSI is shown to be highly correlated with actual performance, then we can be confident that those jobs that have a high JSI will perform well and will require the least amount of training compared to those jobs who have medium or low JSI. If the data confirms this hypothesis then one can say that the alternative method for crew selection can discriminate between existing jobs.

This protocol supports Thrust 20cq entitled, "Support to Joint Exercises Experiments."

Purpose of Study:

The study's purpose is to investigate an alternative crew selection method based on matching new job elements generated from a goal analysis to existing job elements in the CF job element inventory. *The CF plans to add two Uninhabited Aerial Vehicles (UAVs) to their aircraft inventory: the SPERWER (a tactical UAV) and the SILVER FOX (a mini UAV)*[*]. The alternative crew selection method is applied to a multiple UAV scenario and new job elements are generated using the hierarchical goal analysis technique. Experimental subjects are chosen based on their JI and asked to fly the UAVs in a simulated environment. The experiment is designed not to test their proficiency but to test the crew selection method.

<u>Experimental aim</u>: The experimental aim is to evaluate the alternative crew selection method by showing whether the JSI is a predictor of performance. The first three steps of the alternative selection method are done and then 90 CF personnel from 252 jobs are selected to participate in performing the UAV jobs in a simulated environment. The prediction is that the individual's performance is directly related to JSI.

<u>Hypothesis</u>: *Job performance is directly related to JSI.*

Selection of Human Subjects:

The subject pool is limited to CF personnel who have existing jobs described in the CF job element inventory. A portion of the CF job element inventory was made available to us upon request. These job elements are about five years old. The inventory contains job elements from 252 operational jobs and from all three services. It is expected that the participants will be tasked through the appropriate chain of command, and the Commander will ask for volunteers from their unit to participate in the experiment.

A minimum of 90 participants is required to produce typical significance levels (e.g., between $p = 0.1$ and $p = 0.05$). Each participant will try all three positions: MC, VO, and PO. We hope to get a representative sample of participants from across all 252 jobs. Two *white cell*[*] personnel will complete the three-person crew, and they will be very familiar with all three positions.

Methodology:

The participant will perform a one-hour UAV mission in DRDC Ottawa's UAV Research Test Bed (RTB): 20 minutes as MC, 20 minutes as VO, and 20 minutes as PO. Then, he or she will be trained to a predetermined level of proficiency on each of the three positions. And finally, the participant will run through the scenario again. Thus, "as is" performance, training time and proficiency, and final performance will be measured (see Appendix A). Participants will be asked to fill out general demographic information and a general cognitive ability test (see Appendix B).

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[*] Upon review of this ANNEX, it was noted that this statement is in error. See pg. 16 for a more accurate statement of the CF's plans.
[*] A white cell player is part of the experimental team, and act on behalf of the experimental director.

Equipment: The UAV RTB consists of two workstations for the VO and PO positions, while the MC sits overhead these two positions (a typical layout for UAV Control Stations). The MC has a workstation as well. The UAV RTB also has an experimenter's control station where the scenario injects are set up, and the data are collected.

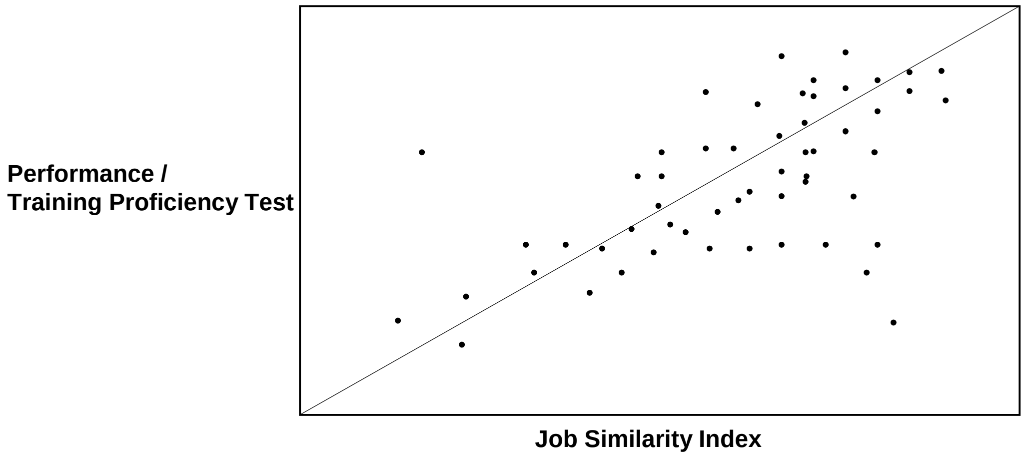

Figure A.1. Anticipated results showing that performance is directly related to JSI.

Data Analysis

The data collection and analysis should show whether the alternative method discriminates between jobs. Figure A.1 is a fictitious example showing how UAV job performance is related to the JSI calculation. There are two aspects to the analysis. First, we want to know if performance and JSI are correlated. Second, we want to know which JSI formula is the best predictor of performance. Demographic information (years of experience), and results from the cognitive general ability test may be added to the weighted average JSI to calculate their influence on performance. A multiple regression analysis would be appropriate in this case.

The primary performance measures are task completion/accuracy and task completion time. These measures will be collected by one of three means: automatically by computer, observers recording crew performance, and self-assessment.

Another measure is the amount of training required. Training time and a score on a proficiency test will be the primary training measures. It may be possible that all groups perform equally well (a horizontal line in Figure A.1) because the task is relatively simple, yet the high correlated individuals take a much shorter time to reach some level of proficiency. The training time will help us investigate if this is indeed the case.

Other measures include number of experimenter "course corrections." That is, the run director may need to steer participants through the scenario to some extent. It is anticipated that there will be fewer interjections with the high correlation group than with the low correlation group.

Medical Screening

No medical screening is required.

Physician Coverage

As participants will be wearing communication headsets and using computer equipment, there is no risk to the health of participants above or beyond that of normal daily activity. Consequently, no Physician Coverage is required.

Roles and Qualifications of Team Members

Dr. Philip S. E. Farrell will act as principal investigator; he can be reached at 613 990 6732. The investigators will design and manage the experiment through to reporting the final results. The setup and the support of the UAV RTB have been contracted out and Dr. Hubbard (613) 990 5894 will manage the contract. Captain Glen Smith will train participants, and oversee the experimental operations as run director. He will also be responsible for collecting and analysing the data, and reporting the results.

Withholding of Information

It is preferable that participants, run director, and observers do not know which group (high, medium, or low) the subjects belong to, making this study double blind. It is anticipated that Participants will have complete disclosure of their own information, and access only to results in the final report. All raw data will be protected B (stored in CFEC's locking file cabinet) and all analysed data will be striped of any identifiers.

Risks of Injury to Human Subjects

There is no risk to the health of participants above or beyond that of normal daily activity.

Risks to experimentation and mitigation strategies

There are four major risks to this experiment:

1. unable to compare new jobs to CF job inventory
2. unable to build the UAV RTB in time for the experiment
3. unable to recruit the number of crews for reporting statistical significance
4. unable to verify and validate the synthetic environment

The risk mitigation strategy is as follows:

1. The only link between the new job elements and the CF job element inventory is the actual words in the job element statements – and the phrases are not exactly the same. A contract was let to manually check nearly 12,000 statements of the CF job element inventory for the 220 jobs, and find a match to the job elements generated from the goal analysis. Work is ongoing under by the investigators to now link the common job elements to existing jobs and personnel who perform those jobs.
2. As a level of effort contract, it is possible that the budget will be exhausted before the simulator is built. The risk mitigation strategy is to do a "wizard of oz" experiment where crews verbally walk through the scenario. The performance measures will become subjective opinion.

3. CF personnel have extremely full schedules and it is possible that the desired number of crews will not be available in the time allotted. However, experimentation and data collect could continue until we are able to report statistical significance.
4. A verification and validation of the synthetic environment is being conducted in parallel to this study. A pilot test is scheduled to show that the experimental apparatus is 'fit for purpose.'

Benefits

The key benefit of the experimentation is towards developing an alternative crew selection method that is required when jobs do not exist. The method is designed to be generic and apply to any new system that involves either new technology or new procedures. The sponsors (and expected end users of the method) are CFEC, UAV Joint Project Office, ADM (HR-Mil), and DHRRE. The benefit to the participant is a unique opportunity to experience UAV operations first hand in a synthetic environment, and the type of mission envisioned for UAVs within the Canadian Forces.

Potential Conflict of Interest

There is no foreseen conflict of interest.

Approximate Time Involved

0.5 hour – welcome, pre-brief, and introduction to simulator
hour – demographic information and personality and GCA tests
0.25 hour – break
1.0 hour – pre-run
0.5 hour – lunch
1.0 hour – training
0.25 hour – break
1.0 hour – post-run
0.5 hour – de-brief and final surveys
Total 6.0 hours.

Remuneration

It is expected that the participants will be tasked by their home organization to participate in the experiment. Thus, all TD expenses will be covered by CFEC. It is also anticipated that Commanders will send out a request for volunteers within the unit in response to the Tasking Order. Already there is interest in participation through informal channels. In either case, a stress allowance will be provided at $10.15 per day to all participants in accordance to DCIEM Memorandum, Stress Allowance for DND Experimental Subjects, 7200-2 (BIO), 2 December 1992.

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VOLUNTARY CONSENT FORM FOR HUMAN SUBJECT PARTICIPATION

Protocol Number: L-497

Research Project Title: An alternative method for selecting crews

Principal Investigator (PI): Dr. Philip S. E. Farrell
Co-investigator(s): Captain Glen Smith and Dr. Paul Hubbard

I, ______________________ (name) of ___________________________________ (address and phone number) hereby volunteer to participate as a subject in the study, "An alternative method for selecting crews_________________________________" *(Protocol # **L-497**).* I have read the information package on the research protocol, and have had the opportunity to ask questions of the Investigators. All of my questions concerning this study have been fully answered to my satisfaction. However, I may obtain additional information about the research project and have any questions about this study answered by contacting Dr. Farrell at 613 990 6732.

I have been told that I will be asked to participate as a member of an Uninhabited Aerial Vehicle (UAV) crew conducting an anti-terrorist operation, and will require approximately six (6) hours in total that involves an hour of briefs, an hour of surveys, an hour of training, two hours of performing the mission, and an hour of break time.

I have been told that the principal risks of the research protocol are the risks of operating in a desktop computer environment.

I have been given examples of potential minor and remote risks associated with the experiment and consider these risks acceptable as well.

Also, I acknowledge that my participation in this study, or indeed any research, may involve risks that are currently unforeseen by DRDC.

For Canadian Forces (CF) members only: I understand that I am considered to be on duty for disciplinary, administrative and Pension Act purposes during my participation in this experiment and I understand that in the unlikely event that my participation in this study results in a medical condition rendering me unfit for service, I may be released from the CF and my military benefits apply. This duty status has no effect on my right to withdraw from the experiment at any time I wish and I understand that no action will be taken against me for exercising this right.

I have been advised that no medical support will apply during the experiment.

Medical screening assessment(s) is not required to participate in this experiment.

I understand that I am free to refuse to participate and may withdraw my consent without prejudice or hard feelings at any time. Should I withdraw my consent, my participation as a subject will cease immediately, unless the Investigator(s) determine that such action would be dangerous or impossible (in which case my participation will cease as soon as it is safe to do so). I also understand that the Investigator(s) or their designate responsible for the research project may terminate my participation at any time, regardless of my wishes.

I have been informed that the research findings resulting from my participation in this research project may be used for commercialization purposes.

I understand that for my participation in this research project, I am entitled to remuneration of $10.15 stress allowance according to DCIEM Memorandum, Stress Allowance for DND Experimental Subjects, 7200-2 (BIO), 2 December 1992.

I have informed the Principal Investigator that I am currently a subject in the following other DRDC research project(s): ____ (cite Protocol Number(s) and associated Principal Investigator(s)), and that I am participating as a subject in the following research project(s) at institutions other than DRDC: ____ (cite name(s) of institution(s))

I understand that by signing this consent form I have not waived any legal rights I may have as a result of any harm to me occasioned by my participation in this research project beyond the risks I have assumed.

Volunteer's Name ______________________ Signature: _______________________________

Date: ________________

Name of Witness to Signature: ____
Signature: _____________________________________ Date: ____________________________

Family Member or Contact Person (name, address, daytime phone number & relationship)
____

Section Head/Commanding Officer's Signature (see Notes below)____________________
CO's Unit: ___________________________

Principal Investigator: _______________________ Signature: ______________________________
Date: ______________

Notes:
For Military personnel on permanent strength of CFEME: Approval in principle by Commanding Officer is given in Memorandum 3700-1(CO CFEME), 18 Aug 94; however, members must still obtain their Section Head's signature designating approval to participate in this particular research project.
For other military personnel: All other military personnel must obtain their Commanding Officer's signature designating approval to participate in this research project.
For civilian personnel at DRDC: Signature of Section Head of appropriate research centre is required designating that volunteer subject is considered to be at work and that approval has been given to participate in this research project.

FOR SUBJECT ENQUIRY IF REQUIRED:

Should I have any questions or concern regarding this project before, during, or after participation, I understand that I am encouraged to contact the appropriate DRDC research centre cited below. This contact can be made by surface mail at this address or by phone or e-mail to any of the DRDC numbers and addresses of individuals listed further below:

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2	Dr. Paul Hubbard Defence R&D Canada - Ottawa 3701 Carling Avenue Ottawa, Ontario, K1A 0Z4 (613) 990 5894
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Chair, DRDC Human Research Ethics Committee (HREC):

Jack Landolt, (416) 635 2120, jack.landolt@drdc-rddc.gc.ca
(type name, phone number, e-mail address)

I understand that I will be given a copy of this consent form so that I may contact any of the above-mentioned individuals at some time in the future should that be required.

An Alternative Crew Selection Method
Information Sheet

Background	The acquisition of Unihabited Aerial Vehicles – SPERWER and SILVER FOX – has generated new jobs that do not exist in the Canadian Forces (CF). Thus, an alternative crew selection method is proposed that considers potential crewmembers' existing tasks and knowledge. The method involves matching the new tasks and knowledge developed with a hierarchical goal analysis technique to the CF inventory of tasks and knowledge being developed under the MOSART project.
Experiment Overview	The experimental aim is to evaluate the alternative crew selection method by showing whether the method discriminates between jobs. CF personnel with high, medium, and low matches are identified, and ask to participate in this experiment. Selected crews will perform a one-hour UAV mission in DRDC Ottawa's UAV Research Test Bed (RTB) before and after training on the system.
Your Rights as a Participant	Participants may refuse to participate and may withdraw their consent without prejudice or hard feelings at any time. Also, investigators may terminate a participant's participation at any time.
Confidentiality	We have made every effort to protect your confidentiality. All raw data will be protected B and all analysed data will be striped of any identifiers.
Benefits	The benefit to the participant is a unique opportunity to experience UAV operations first hand in a synthetic environment, and the type of mission envisioned for UAVs within the Canadian Forces.
Risks	There is no risk to the health of participants above or beyond that of normal daily activity.
Contact Information	Dr. Philip S. E. Farrell Canadian Forces Experimentation Centre National Defence Headquarters (Shirley's Bay) 101 Colonel By Drive Ottawa, Ontario Canada K1A 0K2 (613) 990 6732 FAX (613) 991 5819 Dr. Paul Hubbard Defence R&D Canada - Ottawa 3701 Carling Avenue Ottawa, Ontario, K1A 0Z4 (613) 990 5894 *You may also contact*: Human Research Ethics Committee Defence R&D Canada – Toronto 1133 Sheppard Avenue West P.O. Box 2000 Toronto, Ontario Canada M3M 3B9

Appendix A to ANNEX A

Observer's Form

The Observer must answer "y" or "n" to all of the questions. Time of observation is required. In some cases, the duration to accomplish the goal should be recorded. Observer must be very familiar with the scenario, and may refer to the original spreadsheet for the context of Goal Description.

Goal I.D.	Goal Descriptor	y or n	Time (h.m.s)	Duration
	all			
2.6.3	identification of known terrorist units			
7.2.7	MALE UAV systems are monitored and managed			
	MC			
2.1.1	radar plot of an area of interest is current			
3.5.1	command & control of tactical situation is assessed			
3.5.2	a determination of the SAC (OSC) is completed			
5.1.3	relevant rules of engagement are reviewed			
5.2.1	overt actions of terrorist unit personnel are observed			
5.3.1	potential weapons onboard terrorist unit			
5.3.8	risk to neutral units			
5.5.2	selection of best units to counter to terrorist threat			
5.5.6	selection of best offensive system(s)			
5.6.3	tasking message has been transmitted			
5.7.8	damage report provided to friendly unit			
6.4	terrorist's potential location			
6.8.1	the need for contingency plans is addressed			
6.8.2	contingency plans are created			
6.8.3	contingency plans are discussed			
7.3.1.2	Mini UAV search pattern is planned			
7.3.1.10	crew is briefed on use of Mini UAVs			
7.3.1.11	crew have been requested to launch Mini UAV			
7.3.8.1	previous minutes of video are reviewed			
9.3.2.2	request for surface plot is passed to ROC			
9.3.2.3	fighter aircraft are directed to attack threat			
9.4.1.5	information of a general nature			
	PO			
2.1.4	tactical plot icons are current			
5.6.4	tasking message has been acknowledged			
7.1.4.2	VTUAV EO sensor is used for a test observation			
7.1.5.6	VTUAV EO images are monitored			
7.1.9.3	initial system settings on VTUAV are reviewed			
7.3.7.5	Mini UAV image file is stowed			
9.4.1.3	identification and activities of contact			
	VO			
6.9.1	VTUAV piloting aspects are studied			
7.1.3	VTUAV flight path is monitored			
7.1.5.6	VTUAV EO images are monitored			
7.1.9.2	initial system checks on VTUAV are conducted			
7.1.9.4	VTUAV systems are monitored			
7.3.1.8	Mini UAV route is plotted			
7.3.7.2	initial system checks on Mini UAV are conducted			
7.3.7.3	Mini UAV systems are monitored			
7.3.7.4	Mini UAV systems are managed			

9.4.1.1	VTUAV refuelling location is transmitted			
9.4.1.2	VTUAV calculated time on task is transmitted			
9.4.1.4	specific information regarding a UAV			

The following list indicates a map task that subjects are asked to complete. That is, subjects are asked to mark on a paper map the location of unit 1) as individuals during the experiment, and 2) as a crew after the experiment. Also, in one instance the crew plans the mission using a map. This map is analysed after the experiment.

2.3.2	location of friendly units
2.3.4	list mission activities of friendly units
2.4.2	location of neutral units
2.5.2.1	location of all unknown unit icons on tactical plot
2.5.2.2	relative location of own position to unknown units
2.6.2.1	location of all known terrorist unit icons on tactical plot
2.6.2.2	relative location of own position to known terrorist units
6.4.1	the probable position of the terrorist vessel
6.4.4	search area is appropriate for the current situation
6.4.5	display area on workstation is appropriate

The following list indicates the automatic data collection tasks. Although the computer will capture start and stop times of certain events, there will be a post analysis done by the analyst to generate duration times and confirm that the task was indeed done.

2.6.1	workstation is formatted to display the tactical plot
4.1.5	latest position of all unknown contacts is plotted
4.1.10	search plan for airborne threat is produced
4.2.5	contact is sought using UAV radar
4.2.6	contact is visually sought using UAV EO suite
7.1.2.1	VTUAV heading has changed to a new heading
7.1.2.2	VTUAV altitude has changed to a new altitude
7.1.2.4	VTUAV autopilot set to autonomous mode
7.1.2.5	VTUAV transitions to a hover
7.1.4.1	VTUAV EO sensor settings are optimized
7.1.5.4	VTUAV EO zoomed in on a portion of boat
7.1.5.5	VTUAV EO used to record images of contact
7.1.5.7	VTUAV EO image file is stowed
7.1.6	VTUAV radar is configured
7.1.7.1	VTUAV radar is used to search for lost contact
7.1.7.2	VTUAV radar is used to vector another asset
7.1.7.3	VTUAV radar is used to GENTRACK contact
7.1.9.1	VTUAV data up-link is maintained
7.3.1.3	Mini UAV waypoint is inserted
7.3.1.12	Mini UAV opening height is set
7.3.2.1	Mini UAV heading has changed to a new heading
7.3.2.2	Mini UAV altitude has changed to a new altitude
7.3.2.4	Mini UAV altitude change has been initiated

7.3.2.5	Mini UAV automatic over-flight function is initiated
7.3.2.6	Mini UAV is set to autonomous operations
7.3.2.7	Mini UAV initiates a pre-planned route about a contact
7.3.2.8	Mini UAV initiates a self-destruct manoeuvre
7.3.2.9	manual control of Mini UAV is initiated
7.3.2.10	Mini UAV is manoeuvring about contact
7.3.3.1	Mini UAV symbol has appeared on the surface plot
7.3.3.2	Mini UAV is in descent following deployment
7.3.3.3	Mini UAV is following the planned flight path
7.3.3.4	Mini UAV is establishing level flight
7.3.3.5	Mini UAV is autonomously following contact
7.3.4.1	Mini UAV EO sensor settings are optimized
7.3.5.2	Mini UAV EO sensor is used to study a contact
7.3.5.4	Mini UAV EO zoomed in on a portion of boat
7.3.5.6	Mini UAV EO sensor is used to track a contact
7.3.5.7	Mini UAV EO is used to record high definition images
7.3.5.8	Mini UAV FOV trapezoid is over contact
7.3.5.9	Mini UAV EO video recording is operating
7.3.5.10	EO images are organized on desktop
10.1.2.1	MC workstation is configured
10.1.2.2	VO workstation is configured
10.1.2.3	PO workstation is configured

The following list indicates two Critical Task Sequences – the first is collected automatically, and the second requires the observer to manually indicate the start and stop times.

4.4	**identification of contacts (auto)**
4.4.5	crew identifying vessel using UAV EO suite
4.4.6	ISAR imagery is downloaded and analysed
4.4.7	UAV images of boat are compared with database
4.4.8	crew classify vessel using UAV EO suite
4.4.9	legality of fishing boat activities
4.4.10	contact can be identified
7.1.1	**VTUAV navigation is conducted (manual)**
7.1.1.1	VTUAV route to the next operating area is planned
7.1.1.2	VTUAV search pattern is planned
7.1.1.2.1	selection of an appropriate search pattern
7.1.1.2.7	location of contact symbol is determined on tacplot
7.1.1.2.8	direction of movement of contact symbol
7.1.1.3	VTUAV waypoint is inserted
7.1.1.6	VTUAV time on task is calculated
7.1.1.6.1	location of potential VTUAV refuelling platforms
7.1.1.6.2	estimated CPF location at time off task
7.1.1.6.3	VTUAV fuel on board and average fuel flow
7.1.1.6.4	rough VTUAV time on task is calculated

7.1.1.6.5	precise VTUAV time on task is calculated
7.1.1.6.6	any problems associated with refuelling
7.1.1.8	VTUAV activities are planned
7.1.1.9	VTUAV planning activities are monitored
7.1.1.10	VTUAV route is plotted
7.1.1.11	handover of VTUAV has been prepared

Appendix B to ANNEX A

Wonderlick Personnel Test

The Wonderlick Personnel Test is a CGA test. The test is dated, however, this experiment is not interested in the absolute score of participants, but their relevant score (ranking).

WONDERLIC

PERSONNEL TEST

FORM B

NAME..Date.......................................
(Please Print)

READ THIS PAGE CAREFULLY. DO EXACTLY AS YOU ARE TOLD.
DO NOT TURN OVER THIS PAGE UNTIL YOU ARE
INSTRUCTED TO DO SO.

This is a test of problem solving ability. It contains various types of questions. Below is a sample question correctly filled in:

REAP is the opposite of

1 obtain, 2 cheer, 3 continue, 4 exist, 5 sow .... [5]

The correct answer is "sow." It is best to underline the correct word. The correct word is numbered 5. Then write the figure 5 in the brackets at the end of the line.

Answer the next sample question yourself.

Gasoline sells for 23 cents per gallon. What will 4 gallons cost?... [___]

The correct answer is 92¢. There is nothing to underline so just place "92¢" in the brackets.

Here is another example:

MINER MINOR—Do these words have .... [___]

1 similar meaning, 2 contradictory, 3 mean neither same nor opposite.

The correct answer is "mean neither same nor opposite" which is number 3 so all you have to do is place a figure "3" in the brackets at the end of the line.

When the answer to a question is a letter or a number, put the letter or number in the brackets without underlining anything. All letters should be printed.

This test contains 50 questions. It is unlikely that you will finish all of them, but do your best. After the examiner tells you to begin, you will be given exactly 12 minutes to work as many as you can. Do not go so fast that you make mistakes since you must try to get as many right as possible. The questions become increasingly difficult, so do not skip about. Do not spend too much time on any one problem. The examiner will not answer any questions after the test begins.

Now, lay down your pencil and wait for the examiner to tell you to begin!

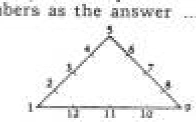
Do not turn the page until you are told to do so.

Form B

1. PAIN is the opposite of
   1 poison, 2 torment, 3 agony, 4 comfort, 5 punish .... [___]
2. One number in the following series is omitted. What should that number be?
   100 97 94 ? 88 85 82 .... [___]
3. GENEROUS is the opposite of
   1 noble, 2 popular, 3 moody, 4 neighborly, 5 stingy .... [___]
4. LUXURY is the opposite of
   1 plenty, 2 rapture, 3 poverty, 4 devotion, 5 failure .... [___]
5. In the following set of words, which word is different from the others?
   1 Methodist, 2 Easter, 3 Lutheran, 4 Catholic, 5 Quaker .... [___]
6. LINGER is the opposite of
   1 maintain, 2 hasten, 3 require, 4 remain, 5 tarry .... [___]
7. Assume the first two statements are true. Is the final one: 1 true, 2 false, 3 not certain? The violin is in tune with the piano. The piano is in tune with the harp. The harp is in tune with the violin. .... [___]
8. Suppose you arrange the following words so that they make a complete sentence. If it is a true statement, mark (T) in the brackets; if false, put an (F) in the brackets.
   water Ice than colder always is .... [___]
9. FURTHER FARTHER—Do these words have
   1 similar meaning, 2 contradictory, 3 mean neither same nor opposite? .... [___]
10. A man's car traveled 16 miles in 30 minutes. How many miles an hour was it traveling? .. [___]
11. Are the meanings of the following sentences: 1 similar, 2 contradictory, 3 neither similar or contradictory?
    A faithful friend is a strong defense. They never taste who always drink. .... [___]
12. A dealer bought some cars for $2,000. He sold them for $2,400, making $50 on each car. How many cars were involved? .... [___]
13. How many of the six pairs of items listed below are exact duplicates? .... [___]

3421	1243
21212	21212
558956	558956
10120210	10120210
612986896	612986896
356471201	356571201

14. A boy is 6 years old and his sister is twice as old. When the boy is 10 years old, what will be the age of his sister? .... [___]
15. In the following set of words, which word is different from the others?
    1 armada, 2 band, 3 brood, 4 boy, 5 crowd .... [___]
16. Suppose you arranged the following words so that they make a true statement. Then print the last letter in the last word as the answer to this problem.
    is world The round .... [___]
17. VOCATION WORK—Do these words have
    1 similar meaning, 2 contradictory, 3 neither same nor opposite? .... [___]
18. Look at the row of numbers below. What number should come next?
    81 27 9 3 1 ⅓ ? .... [___]
19. This geometric figure can be divided by a straight line into two parts which will fit together in a certain way to make a perfect square. Draw such a line by joining two of the numbers. Then write the numbers as the answer .... [___]



20. How many of the five items listed below are exact duplicates of each other? .... [___]

Patterson, A. J.	Paterson, A. J.
Smith, A. O.	Smith, O. A.
Bleed, O. M.	Bleed, O. M.
Petersen, O. W.	Peterson, O. W.
Cash, I. O.	Cash, I. O.

21. Suppose you arrange the following words so that they make a complete sentence. If it is a true statement, mark (T) in the brackets; if false, put an (F) in the brackets.
    all are Americans countries of citizens .... [___]
22. Assume that the first 2 statements are true. Is the final statement:
    1 true, 2 false, 3 not certain?
    All red-headed boys are mischievous. Charles is red-headed. He is mischievous. .... [___]
23. Two of the following proverbs have similar meanings. Which ones are they? .... [___]
    1. A friend in need is a friend in deed.
    2. Fields have eyes and woods have ears.
    3. A fox is not caught twice in a snare.
    4. A setting hen never gets fat.
    5. A rolling stone gathers no moss.
24. A rectangular bin completely filled, holds 900 cubic feet of lime. If the bin is 10 feet long and 10 feet wide, how deep is it? .... [___]

Form B

25. A watch lost 1 minute and 12 seconds in 24 days. How many seconds did it lose per day? [___]

26. Assume that the first 2 statements are true. Is the final statement: 1 true, 2 false, 3 not certain? Most business men are progressive. Most business men are Republicans. Some progressive people are Republicans. [___]

27. Gasoline is 15 cents a gallon. How many gallons can you buy for a dollar? [___]

28. Are the meanings of the following sentences: 1 similar, 2 contradictory, 3 neither similar nor contradictory? Every pumpkin is known by its stem. Like father, like son. [___]

29. If 2½ tons of coal cost $20, what will 3½ tons cost? [___]

30. How many of the five pairs of items listed below are exact duplicates? [___]

Silverstein, M. O.	Silverstien, M. O.
Harrisberg, L. W.	Harrisberg, L. M.
Seirs, J. C.	Sears, J. C.
Wood, A. B.	Woods, A. B.
Johnson, M. D.	Johnson, M. D.

31. Two men caught 75 fish. A caught four times as many as B. How many fish did B catch? [___]

32. In the following set of words, which word is different from the others?
1 faculty, 2 fleet, 3 flock, 4 friend, 5 force [___]

33. Assume the first 2 statements are true. Is the final one: 1 true, 2 false, 3 not certain?
Bert greeted Alice. Alice greeted Lou. Bert did not greet Lou. [___]

34. Which number in the following group of numbers represents the smallest amount?
2 1 .9 .999 .88 [___]

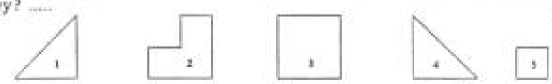
35. A side of beef weighs 250 lbs. The average daily beef consumption of a family is 1⅓ lbs. How long will this beef last them? [___]

36. Are the meanings of the following sentences: 1 similar, 2 contradictory, 3 neither similar nor contradictory?
Friends agree best at a distance. Friends are one soul in two bodies. [___]

37. How many square yards are there in a floor which is 9 feet long by 21 feet wide? [___]

38. One number in the following series does not fit in with the pattern set by the others. What should that number be? 8 9 12 13 16 17 18 [___]

39. Three of the following 5 parts can be fitted together in such a way to make a triangle. Which 3 are they? [___]



40. A soldier shooting at a target hits it 40% of the time. How many times must he shoot in order to register 100 hits? [___]

41. Which number in the following series represents the smallest amount?
2 1 .8 .888 .99 [___]

42. CENSOR CENSURE—Do these words have
1 similar meaning, 2 contradictory, 3 mean neither same nor opposite? [___]

43. Are the meanings of the following sentences: 1 similar, 2 contradictory, 3 neither similar nor contradictory? A chip off the old block. A beggar's son struts like a peer. [___]

44. A clock was exactly on time at noon on Monday. At 8 P.M. on Tuesday it was 32 seconds slow. At that same rate, how much did it lose in ½ hour? [___]

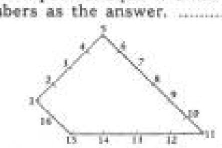
45. Are the meanings of the following sentences: 1 similar, 2 contradictory, 3 neither similar nor contradictory? He who demands, does not command. He that complies against his will is of his own opinion still. [___]

46. For $2.40 a grocer buys a case of oranges which contains 12 dozen. He knows that two dozen will spoil before he sells them. At what price per dozen must he sell the good ones to gain ⅓ of the whole cost? [___]

47. Are the meanings of the following sentences: 1 similar, 2 contradictory, 3 neither similar nor contradictory?
Where there's a will there is a way. The gods sell everything for labor. [___]

48. The hours of daylight and darkness are nearest equal in
1 June, 2 September, 3 May, 4 December [___]

49. This geometric figure can be divided by a straight line into two parts which will fit together in a certain way to make a perfect square. Draw such a line by joining 2 of the numbers. Then write these numbers as the answer. [___]



50. Three men form a partnership and agree to divide the profits equally. X invests $5500, Y invests $3500, and Z invests $1000. If the profits are $3000, how much less does X receive than if the profits were divided in proportion to the amount invested? [___]

ANNEX B: Results using the Position-Based JSI

The results using the position-based JSI illuminated certain limitations of the JSI calculation based on the MOSART database. The most obvious limitation was that the JSI was calculated for a position that participants had formerly in their career, since participants had staff positions at the time of the experiment. Secondly, the MOSART database was 5 years old at the time of the experiment. Thus, there developed a lack of confidence in the position-based JSI calculation truly reflected the person's JSI, and an additional survey was administered and the data were collected so that a person-based JSI could be calculated.

The position-based JSI range from Table 1 clusters into three areas. The lowest cluster is at a JSI value of zero. That is, the civilian (computer technician) and the two engineers were given a "zero JSI" value because their jobs were not part of the 252 operational positions. One of the engineers returned the additional survey and had a person-based JSI value of 7%, which would support the "zero JSI" assumption. The second cluster is between 40 and 50%. One would expect participants in this cluster to have similar performance but in fact there were large deviations in performance. The third cluster and the highest JSI belonged to Line Pilots and Air Navigator. One would assume that these positions would be best suited for a UAV crew and yield the highest performance however they produced average performance.

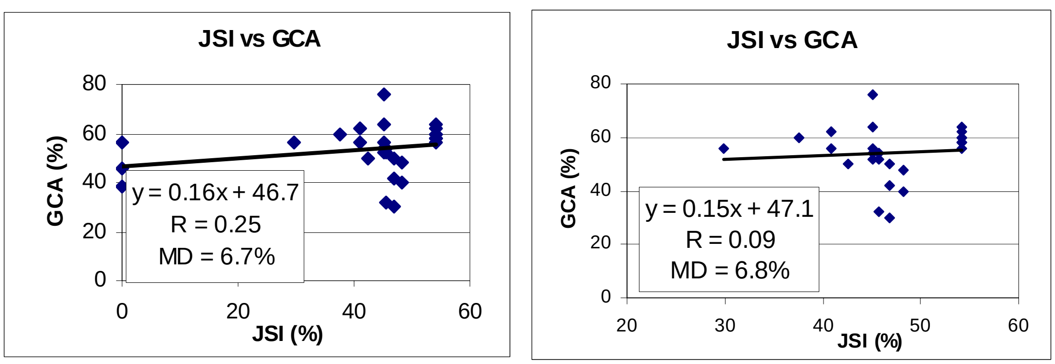


Figure B.1. Position-based JSI versus GCA with and without "zero JSI" Data

Figures B.1 and B.2 are plots of the Position-based JSI versus GCA and Proficiency Test, with and without the "zero JSI" data. The three clusters are apparent in these plots and clearly the spread of data is large. If the "zero" cluster were moved or even removed then the slope and intercept value would be different. Clearly, the choice of JSI and the assumptions that are made will affect the results and ultimately the conclusions made.

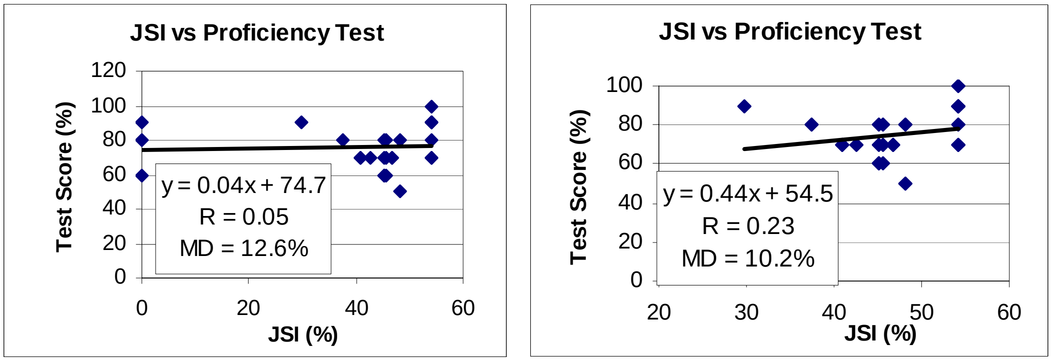


Figure B.2. Position-based JSI versus Proficiency Test with and without "zero JSI" Data

Table B.1 lists the slope, intercept, correlation, and Mean Difference values for the position-based JSI versus all other variables. Note that all but four relationships have an MD value greater than 10%. In other words, there is little confidence that the real data can adopt the trend line conclusion. JSI versus GCA has a shallow slope of 0.16 with MD = 6.7. The conclusion would be that there is little to no relationship between JSI and GCA, while the slope using the person-based JSI is not as shallow (slope = 0.32, MD = 5.2). The Yes/No performance results and conclusions are similar for both analyses: that is, most participants completed over 90% of the tasks since they had general skills and knowledge coupled with the fact that the scenario was straightforward.

TABLE B.1: POSITION-BASED JSI VERSUS OTHER VARIABLES

x (%)	y (%)	Slope	Intercept	R	MD (%)
JSI	Reference (null hypothesis)	**0.00**	**100**	**1**	**0**
JSI	GCA	0.16	46.7	0.25	**6.7**
JSI	Proficiency Test	0.04	74	0.05	12.6
VO JSI	SA	-0.28	65.5	-0.2	19.5
	Yes/No	**0.15**	**91.4**	**0.59**	**1.9**
	Maximum	0.05	68.5	0.06	11.3
	Average	0.16	58	0.21	11.3
PO JSI	SA	0.25	43.1	0.19	16.1
	Yes/No	**0.08**	**95.8**	**0.70**	**2.1**
	Maximum	0.18	63.7	0.19	12.9
	Average	0.25	55.7	0.29	10.4
MC JSI	SA	-0.17	67.2	-0.20	17.6
	Yes/No	**0.18**	**90.4**	**0.65**	**1.8**
	Maximum	0.19	61.2	0.22	10.8
	Average	0.25	55.5	0.30	10.1
JSI	Reference (hypothesis)	**1.00**	**0**	**1**	**0**

Table B.2 lists the results when the civilian and two engineers are removed from the data set. Many of the slopes that were positive have turned negative, the correlation values are smaller and negative, and the Mean Distance values are larger and positive (correlation = 0.12 between R and MD). The Yes/No performance results and conclusion remains the same and has been robust regardless of how the data are manipulated.

TABLE B.2: POSITION-BASED JSI VERSUS OTHER VARIABLES (EXCLUDING ZERO JSI DATA)

x (%)	y (%)	Slope	Intercept	R	MD (%)
JSI	Reference (null hypothesis)	**0.00**	**100**	**1**	**0**
JSI	GCA	0.15	47.1	0.09	6.8
JSI	Proficiency Test	0.44	54.5	0.23	10.2
VO JSI	SA	-1.05	102.3	-0.37	9.0
	Yes/No	**0.01**	**97.9**	0.03	**1.5**
	Maximum	-0.24	82.5	-0.12	11.1
	Average	-0.36	82.8	-0.21	10.7
PO JSI	SA	-0.11	60.8	-0.03	17.0
	Yes/No	**-0.03**	101.3	-0.17	**1.3**
	Maximum	-0.39	92.2	-0.15	11.6
	Average	-0.30	83.2	-0.13	10.4
MC JSI	SA	-1.29	121.1	**-0.44**	6.0
	Yes/No	**-0.07**	**102.8**	-0.18	**1.4**
	Maximum	-0.21	81.0	-0.08	10.8
	Average	-0.37	86.3	-0.15	9.2
JSI	Reference (hypothesis)	**1.00**	**0**	**1**	**0**

Table B.3 provides the Path Metric results using the position-based JSI and assuming. The Mean Distance values are larger on the whole than the same results using the person-based JSI, giving us less confidence to draw any conclusions about the data from the trend line.

TABLE B.2: PAIR WISE COMPARISONS BETWEEN THE POSITION JSI AND PATH METRIC

JSI	Calculation	Value	UAV	Slope	Intercept	R	MD
VO JSI	Non-time based	Maximum	9	0.00	78.4	0.00	11.1
			10	-0.02	78.4	-0.02	12.1
			4	0.01	71.1	0.01	15.7
		Average	9	0.03	74.6	0.04	10.0
			10	0.07	72.3	0.09	11.7
			4	0.05	66.1	0.05	14.6
	Time based	Maximum	9	-0.44	70.9	-0.41	12.5
			10	-0.41	72.2	-0.33	15.7
			4	-0.02	70.0	-0.04	7.7
		Average	9	-0.34	62.9	-0.32	14.4
			10	-0.47	70.5	-0.40	14.3
			4	0.05	63.9	0.09	9.1
PO JSI	Non-time based	Maximum	9	-0.13	94.0	-0.26	6.1
			10	-0.03	92.9	-0.13	4.1
			4	-0.04	88.9	-0.10	5.5
		Average	9	-0.08	90.9	-0.17	6.8
			10	-0.02	89.7	-0.05	5.7
			4	-0.01	86.9	-0.04	5.9
	Time based	Maximum	9	0.27	61.5	0.38	9.8
			10	0.20	69.6	0.34	8.4

			4	0.15	71.2	0.43	4.0
		Average	9	0.25	60.7	0.36	9.7
			10	0.19	67.7	0.27	9.6
			4	0.19	67.2	0.33	6.5
MC JSI	Non-time based	Maximum	9	0.04	81.7	0.07	9.0
			10	-0.14	84.3	-0.15	15.6
			4	0.14	72.1	0.19	12.1
		Average	9	0.06	80.5	0.09	8.9
			10	-0.14	82.3	-0.15	15.3
			4	0.19	69.2	0.26	11.6
	Time based	Maximum	9	0.03	80.5	0.04	11.6
			10	0.18	77.9	0.25	13.7
			4	0.01	82.8	0.02	11.4
		Average	9	0.06	77.5	0.08	11.7
			10	0.19	75.8	0.25	14.3
			4	0.02	80.8	0.03	11.8

ANNEX C: Mean Distance Calculation

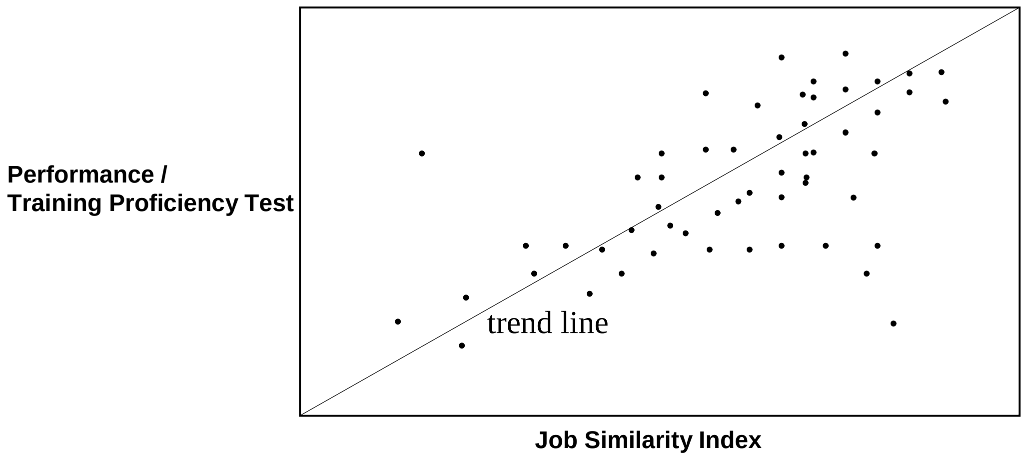


Figure C.1 Anticipated results showing that performance is directly related to the JSI

Recall that Figure C.1 is a fictitious example showing how UAV job performance would be related to the JSI. The measured data points are dispersed around a trend line. The closeness of the data points to the trend line indicates the level of confidence that any conclusions drawn for the trend line would be true for the measured data points. In the extreme, if all the data points fell on the trend line then we would have the highest level of confidence that what is true about the trend line is true about the measured data points. Conversely, if the data points were all far away from the trend line then our confidence would be low. The Mean Distance (MD) calculation is a metric for the closeness of the data points to the trend line.

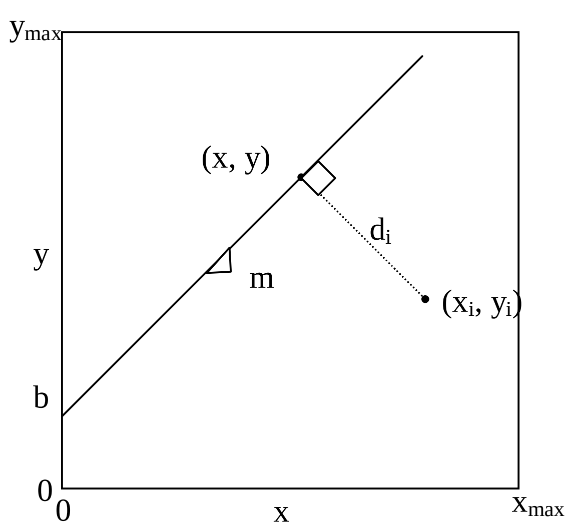


Figure C.2 Shortest distance between a point and a line is the perpendicular bisector

Let (x_i, y_i) be the i[th] measured data point (e.g., (JSI, performance)). Let (x, y) be the intersection point between the trend line and a perpendicular bisector that goes through (x_i, y_i)

as shown in Figure C.2. The slope, m, and the intercept, b, of the trend line are calculated from the performance data and JSI calculations.

The equation for the trend line is as follows:

$$y = m x + b \tag{C.1}$$

The equation for the perpendicular bisector is as follows:

$$y_i = -\frac{1}{m} (x_i - x) + y \tag{C.2}$$

The shortest distance, d_i, between (x_i, y_i) and the trend line is calculated using Pythagorean's theorem as follows:

$$d_i^2 = (x - x_i)^2 + (y - y_i)^2 \tag{C.3}$$

Substituting C.2 into C.3 yields:

$$d_i^2 = \frac{m^2 + 1}{m^2} (x - x_i)^2 \tag{C.4}$$

One can express equation C.4 in terms of (x_i, y_i) by finding $x - x_i$ from equations C.1 and C.2. That is:

$$x - x_i = \frac{m}{m^2 + 1} (y_i - b - m x_i) \tag{C.5}$$

Substituting C.5 into C.4 yields:

$$d_i = \sqrt{\frac{(y_i - b - mx_i)^2}{m^2 + 1}} \tag{C.6}$$

The distance can be normalized with respect to the maximum distance possible for that point as illustrated in Figure C.3. That is:

$$n_i = \frac{d_i}{d_{max}} \tag{C.7}$$

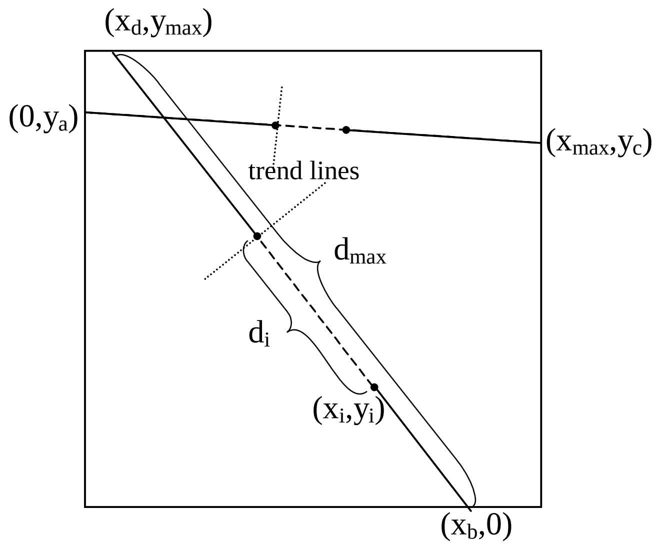


Figure C.3 Two possible lengths for d_{max} that depend on the slope and maximum values.

However, there are several choices for d_{max}. In this case, d_{max} is calculated based on the slope of the trend line and the maximum values of the two axes. Figure C.2 shows two possible lengths for d_{max}. The line from (x_d, y_{max}) to $(x_b, 0)$ shows the case where:

$$|m| \leq 1 \tag{C.8}$$

Thus:

$$d_{max}{}^2 = (1+m^2)\, y_{max}{}^2 \tag{C.9}$$

The line from $(0, y_a)$ to (x_{max}, y_c) shows the case where:

$$|m| \geq 1 \tag{C.10}$$

Thus:

$$d_{max}{}^2 = \frac{m^2+1}{m^2}\, x_{max}{}^2 \tag{C.11}$$

After examining the data for this analysis, the absolute value of the trend line slope is always less than one, and therefore the condition in equation C.8 is always true for this data set and equation C.9 is used. Thus the normalized Mean Distance (MD) calculation would be the sum of all n_i divided by the total number of points, N as follows:

$$MD = \frac{\sum_{i=1}^{N} \sqrt{(y_i - b - mx_i)^2}}{N(m^2+1)y_{mzx}} \tag{C.6}$$

The slope and intercept of the trend line helps us determine whether there is a relationship between the x variable (JSI) and the y variable (performance). If the trend line slope is diagonal (close to one) and positive then the conclusion is that the performance is directly related to the JSI. If the trend line slope is horizontal (close to zero) then performance is not related to the JSI. If the trend line were diagonal and negative then there would be an unexpected inverse relationship between performance and the JSI. Note that diagonal and horizontal are fuzzy descriptors and “close to” has been defined for this analysis up to and including 10% of the slope value. A “slight” relationship between the x and y variables is the designation outside of the 10% range, although further research is required to validate this heuristic.

The Performance Assessments, SA, and Path Metric variables are the primary measures used to test the hypothesis. The Performance Assessments include the typical measures of task completion, task completion time, and task performance. These measures were collected by one of three means: automatically by computer, observers recording crew performance. Only task completion and performance measurements were included in the final analysis. Determining a single metric to indicate performance has proved to be more difficult than first expected, and more study is required to determine if this is possible for such a complex situation.

Another measure is the amount of training required. Training time and a score on a proficiency test would be training measures. It may be possible that all groups perform equally well (a horizontal line in Figure 1) because the task is relatively simple, yet the high correlated individuals take a much shorter time to reach some level of proficiency. The training time would help us investigate if this is indeed the case. Comparing the performance between the first and second runs and relating the difference to the training measures could determine a learning effect.

Other measures include number of experimenter “course corrections.” That is, the run director may need to steer participants through the scenario to some extent. It is anticipated that there will be fewer interjections with the high correlation group than with the low correlation group.

ANNEX D: Generating a Reference Path

The UAV reference paths are generated from the average initial positions of the entities in the scenario and use the maximum speed for UAVs (155 knots), and an assumption of constant heading (315 degrees) and speed (5 knots) for the contacts.

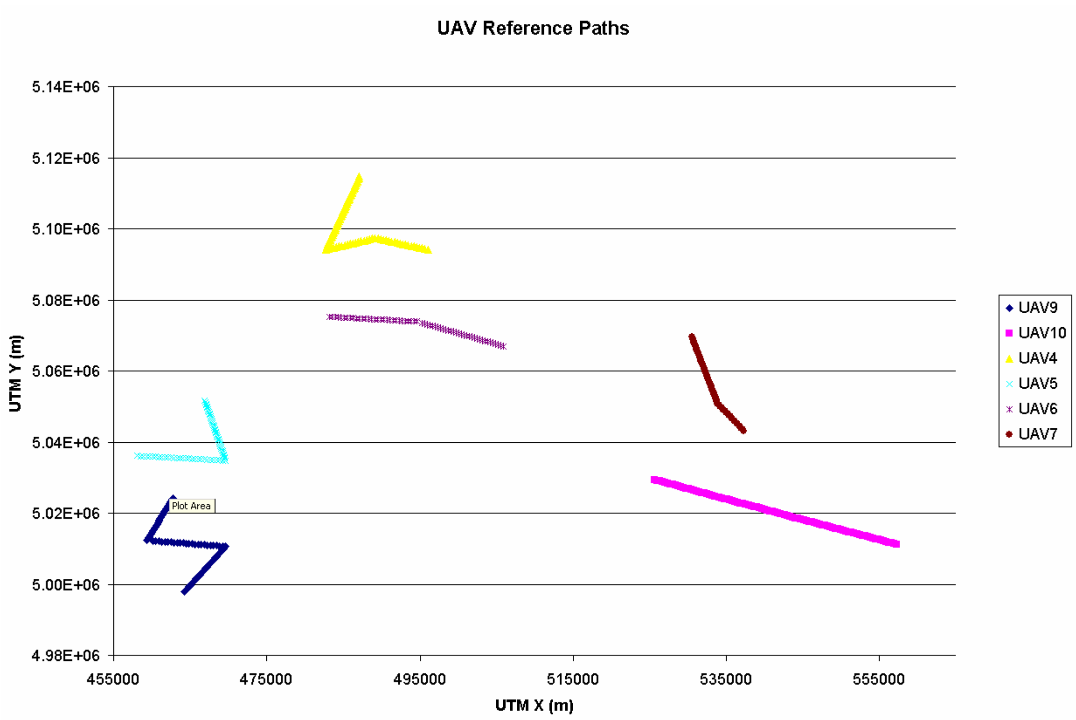


Figure D.1 Reference Paths for all UAVs

Figure D.1 shows the reference paths for the six UAVs. The reference path is calculated using a two-step process. The first step is to find all permutations of UAV paths based on a stationary contact. Only the shortest paths are retained. The second step is to use an iterative process to determine the distance, heading, and time to the now-moving contacts, starting with the initial headings given by the six shortest paths. The contact position is updated and the UAV heading is adjusted accordingly for an intercept path after each iteration. A solution is deemed "found" for that leg of the reference path once the distance between the UAV and the contact for subsequent iterations is within 50 metres. Assumptions are made to reduce the number of permutations required to generate the reference path for each UAV. The assumptions are that:

i. Two UAVs are assigned for each of the three groups of five contacts,

ii. Each UAV is assigned to the closest group of contacts,

iii. A primary UAV will investigate three contacts and the secondary UAV will investigate the remaining two contacts within a group.

The primary UAVs are identified as UAV4, UAV9 and UAV10 and are tasked at the start of the scenario. The secondary UAVs are identified as UAV5, UAV6 and UAV7 and are dropped from the CP140 at one-minute intervals after the scenario begins.

Two UAV path metrics are generated: time based and non-time based. The time based path metric involves differences between the reference and actual UAV positions at the same time interval. This calculation starts when the participant connects to the UAV and finishes when the reference path time ends. At each time interval (5 seconds), the difference between the actual UAV position and the reference UAV position is measured and added to a sum of differences. When the UAV reaches the end time, the sum of differences is divided by the total number of time intervals. This metric is normalized between the best and worst participant runs and inverted so that 100% represents the best participant.

The non-time based path metric compares the perpendicular distance between the reference and actual UAV paths. This calculation starts when the participant connects to the UAV and finishes when the experimental scenario ends or the participant disconnects from the UAV. At every time interval, the difference between the actual UAV position and the closest distance to the reference path is measured and added to a sum of differences. When the UAV reaches the end of its path, then the sum of differences is divided by the total number of time intervals. As before, this metric is normalized between the best and worst participant runs and inverted.

List of Symbols

ALIX	Atlantic Littoral ISR Experiment
CF	Canadian Forces
CFEC	Canadian Forces Experimentation Centre
DHRRE	Directorate of Human Resources Research and Evaluation
DRDC	Defence R&D Canada
GCA	General Cognitive Ability
I2	Intelligence and Information
IISRA	Integrated ISR Architecture
IAI	Intelligent Adaptive Interfaces
ISR	Intelligence, Surveillance, and Reconnaissance
JPO	Joint Project Office
JSI	Job Similarity Index
MALE	Medium Altitude Long Endurance
MC	Mission Commander
MD	Mean Distance
Mil Pers Gp	Military Personnel Group
MOS ID	Military Occupational Structure Identification
MOSART	Military Occupational Structure, Analysis, Redesign, and Tailoring
PLIX	Pacific Littoral ISR Experiment
PO	Payload Operator
SA	Situational Awareness
S&T	Science and Technology
UAV	Uninhabited Aerial Vehicle
UMV	Uninhabited Military Vehicle
UWO	University of Western Ontario
VO	Vehicle Operator

Glossary

JSI	A mathematical formula that reflects the number of matches between existing task and knowledge statements and predicted task and knowledge statements.
Tier 1	A Medium Altitude Long Endurance (MALE) UAV in the class of a Predator B variant or Eagle II;
Tier 2	A Tactical UAV such as the SPERWER or Eagle Eye;
Tier 3	A Small UAV similar to Scan Eagle or the Grasshopper, a mini UAV such as the Skylark Raven, and a micro UAVs for experimental purposes are expected by 2010.

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The Canadian Forces Experimentation Centre (CFEC) investigated a novel crew selection method that could be used to staff new defence systems. The method involved matching existing job elements (task and knowledge statements) to predicted job elements generated from an Uninhabited Aerial Vehicle (UAV) scenario. A Job Similarity Index (JSI) was developed that provided a number to represent the degree to which existing job elements matched predicted job elements for any given CF position or member. Theoretically, the JSI value could be used as a 'first cut' at selecting crewmembers for new equipment and procedures operated by the CF. (U)

The postulate is that a person in a CF position that has more existing job elements in common with the predicted job elements will perform better in the scenario than a person in a CF position with fewer Job elements in common. An experiment was designed and conducted to determine the relationship between JSI and performance. If performance is directly related to JSI then JSI can be used to discriminate between jobs, positions, or people. (U)

The main conclusion was that the null hypothesis – there is no relationship between JSI and performance – was not falsified. However, there are indications from the analysis that performance varies directly with JSI to some degree. The data seem to suggest that the participants had enough general skill and knowledge to perform the straightforward scenario tasks and successfully complete the mission. Further testing is required to determine if the crew selection method is a viable alternative for selecting crews particularly when job incumbents do not exist. As additional subjects are tested, the results should eventually reach levels of statistical significance. (U)

It is recommended that a second set of experiments be conducted with careful consideration to the design of the composite scenario. The scenario should include baseline activities that are known to discriminate amongst the population. (U)

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Crew Selection
Personnel Selection
Job Analysis
Task Analysis
UAV
Uninhabited Aerial Vehicle
UMV
Uninhabited Military Vehicle