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Human factors and space common operating picture development

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Abstract

The report is based on the results of a survey developed for members of the Canadian Space Operations Centre (CANSpOC) to reveal and understand the Human Factors (HF) issues relevant to operations at the CANSpOC. The results of this survey were first presented to the members of CANSpOC as a Scientific Letter (DRDC-RDDC-2017-L119). The current report provides an expanded version of the original Scientific Letter in terms of the detail of the findings and the inclusion of the raw data obtained in the survey. The findings revealed that there are significant HF issues that impact the effectiveness and efficiency with which members of the CANSpOC operate. These findings will contribute to the development of HF evaluation methodology to augment the current space common operating picture concept development and evaluation process.

Significance to Defence and Security

The significance of this work is to inform defence scientists about the importance of the role of Human Factors (HF) issues in the Space Common Operating Picture (SCOP) Concept, Development and Evaluation (CD&E) process. Moreover, this work should help in the design of a HF evaluation methodology that can augment the current SCOP CD&E process. The goal of this work is to assist researchers to develop a SCOP that meets the needs and requirements of CANSpOC operators to better facilitate space situational awareness in order to ensure intelligence superiority for the Canadian Armed Forces.

Résumé

Le rapport est fondé sur les résultats d'un sondage destiné aux membres de la Cellule des opérations spatiales canadienne (CANSpOC) et visant à déterminer les facteurs humains (FH) pouvant poser problème dans les activités de la CANSpOC. Les résultats du sondage ont d'abord été présentés aux membres de la CANSpOC sous forme de lettre scientifique (DRDC-RDDC-2017-L119). Le présent rapport donne des précisions additionnelles sur les données brutes tirées du sondage et les conclusions qui en ont été tirées. Selon les résultats, certains enjeux liés aux facteurs humains ont une incidence importante sur l'efficacité et l'efficience des activités des membres de la CANSpOC. Les résultats devraient permettre de concevoir des méthodes d'évaluation des facteurs humains en vue d'améliorer le processus actuel d'élaboration et d'évaluation du concept d'image commune de la situation opérationnelle dans l'espace.

Importance pour la défense et la sécurité

Le présent document vise à informer les scientifiques de la défense sur l'importance des enjeux liés aux facteurs humains dans le processus d'élaboration et d'évaluation du concept (EEC) d'image commune de la situation opérationnelle (ICSO) dans l'espace. Ces travaux devraient également permettre la conception de méthodes d'évaluation des facteurs humains de nature à améliorer le processus actuel d'EEC d'ICSO. L'objectif est d'aider les chercheurs à élaborer une ICSO répondant aux besoins des opérateurs de la CANSpOC pour maximiser les connaissances sur la situation dans l'espace et assurer la supériorité des Forces armées canadiennes en matière de renseignement.

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Acknowledgements

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1 Introduction

The Canadian Space Operations Centre (CANSpOC) was stood up in 2012 to maximize and optimize the effective use of space-enabled capabilities by the Canadian Armed Forces (CAF) operations at home and abroad [1]. In order to accomplish this goal, the CANSpOC needs to have good Space Situational Awareness (SSA) of the space environment. To assist and support the mandate of the CANSpOC, the Space Operations program for the CFD/DG Space, CFINTCOM and ADM(IM) seeks to develop SSA by pursuing concepts, techniques, analysis, and tools to characterize and identify space objects and weather and to compile a Space Common Operating Picture (SCOP) of the space environment [2]. To this end, The Space Systems and Operations (SSO) group at DRDC – Ottawa Research Centre was tasked by Director General (DG) Space with developing a visualization capability that will provide CANSpOC with a SCOP that will facilitate SSA [3].

According to the CAF and NATO, a COP is defined as, "an interactive and shared visual representation of operational information from various sources" [4]. Similarly, the US Department of Defence defines a COP as, "a single identical display of relevant information shared by more than one command. A common operational picture facilitates collaborative planning and assists all echelons to achieve situational awareness (SA)" [5]. It is important to understand that the COP is not a static entity. Rather, it is a living entity that is continuously updated with data shared between integrated sensor systems for communication, information, management, intelligence, and information sharing processes across response organizations at all levels [6]. The COP enables shared situational awareness that provides information which supports operators, leadership, and allied agencies to make effective, consistent, coordinated, and timely decisions for collaborative planning responses to various threats [7]. Thus, the COP is a "picture" of a particular environment that evolves via the interaction between visualizations and information sharing and decision-making processes: it is very much a socio-technical process.

Broadly, SA is a cognitive construct that refers to our awareness, knowledge, and understanding of events in our immediate and future environment [8]. Since World War I, researchers and practitioners have come to view SA as critical for accurate decision making and performance in a variety of work domains such as air traffic control, nuclear power plant management, aviation, medicine, and driving [9]. Situation awareness has also been viewed as an integral component in successful operational net assessments [9]; effects based approaches to operations [10], battlespace management [11] joint fires support [12] and cyber defence [13]. Situation awareness is no less important for the space domain as well. Knowledge of space weather and enemy satellite activity as well as information on ground activity garnered from our own space assets is a key component for knowledge superiority and synchronization of effort. Not surprisingly, COP and SA development are dependent on each other. The successful development of both a COP and SA require similar processes (e.g., information sharing) and related constructs (e.g., workload). Changes in one environment should ultimately lead to concomitant changes in the other.

Outwardly, the development of SSA appears to be a simple process of utilizing complex technologies to monitor space searching for naturally occurring and man-made anomalies. Historically, this work, and related Intelligence, Surveillance and Reconnaissance (ISR) work, has been a technologically driven environment insofar as COP development has typically involved the development and evaluation of competing technical systems and System-of-Systems (SoS) architectures to solve a particular problem [14]. To be sure, technology is a key driver in the development and evaluation of competing COP platforms' ability to improve information sharing, SA, and decision-making. However, the SCOP process,

like other COP processes, is a very complex process that is most appropriately viewed as a SoS that involves both technological and human components. That is, the SCOP is more accurately viewed as a socio-technical process than a purely technical process and accordingly needs to be developed and evaluated as such and more accurately reflects the working definitions of COPs presented above.

A SoS is a "particular kind of complex system and refers to systems that can be described as collections of components that in themselves may be regarded as complex systems and are operationally and managerially independent" [15] although designed to perform a specific function [16]. Together, these systems are able to pool their capabilities to provide more functionality than the sum of the individual systems. Moreover, the SoS can possess individual systems that are geographically distributed, exhibit emergent behaviour, and develop in an evolutionary manner [15]. Simply, a SoS contains many interconnected nodes (i.e., components and/or capabilities) that exist across a variety of levels and sublevels. To this end, researchers are beginning to view and understand how complex behaviour can emerge from interactions between many simpler highly interconnected nodes and processes [17].

The SSA process is a complex set of interconnected activities that comprise concept of operations, planning and direction, collection, processing and exploitation, analysis and production, dissemination and integration, and evaluation and feedback [18]. The technologies that support these activities do not occur in isolation. Rather, these technologies exist in and are part of a highly interconnected SSA architecture with various sub-levels containing human operators and decision-makers. From this perspective, it should be understood that the development of a SCOP and SSA as a SoS process is a process performed by humans for humans [19] in which human operators play important organizational and decision-making roles key to information sharing and SSA [20]. Accordingly, there are important Human Factors (HF) issues associated with the development of a SCOP that need to be identified, understood and incorporated into the SCOP Concept Development and Evaluation (CD&E) process [21]. A complete evaluation of a space COP concept must include an analysis of the concept's technological and procedural abilities to meet the needs of the users. This is especially important because of the Tasking, Collection, Processing, Exploitation, and Dissemination (TCPED) procedures required to develop and execute SCOP operations. The TCPED environment is overwhelmingly tied to human information sharing and decision-making processes within and across the various levels of the SCOP SoS architecture.

Human factors and ergonomics researchers are emphasizing the need for HF research within SoS environments [22]. Like many technical and socio-technical systems that humans find themselves in on a daily basis, humans can be characterized as SoS themselves. Indeed, humans are composed of numerous independent nodes that are interrelated in one way or another where the whole is larger than the sum of the parts [23]. To the extent that this perspective is true, impacting one element of the human system is likely to impact another element. Humans live, work and operate in SoS environments and should thus be studied within SoS environments [15, 24]. Accordingly, the cognitive and physical elements that humans work in should be studied in tandem to understand how changes to these elements impact human performance. In this way, we are able to develop a more holistic understanding of which parts of a socio-technical environment impact the different cognitive components of human performance and ultimately the quality of operator performance. Unfortunately, designers of man-made systems generally fail to consider the behavioural and cognitive aspects of the operator thus leaving researchers with an incomplete picture of why people perform the way they do under different circumstances [14, 25].

In addition to the technical evaluation of SCOP concepts, the SSO group at DRDC – Ottawa Research Centre is utilizing and developing a HF methodology to support this technical evaluation and the equally

important socio-technical components of SCOP development. The primary purpose of this current work is to ensure that the development of SCOP sensors and other socio-technical developments meet the HF requirements of the operators and improve operator performance. Researchers [14, 26, 27] have identified the long overdue need to incorporate a HF analysis in the CD&E process. Since the SSA environment can be characterized as a complex SoS environment that relies on human information processing and decision-making processes, a full understanding of how the development and employment of SCOP sensors or sensor platform concepts impact human performance is an essential component of the SCOP CD&E process. However, before this work can be done, researchers need to know and understand the relevant HF issues within all echelons of the SCOP environment.

The HF methodology espoused here to elucidate the HF issues important to a SCOP is rooted in Cognitive Systems Engineering (CSE) [25]. The goal of CSE is to provide developers of Man-Made Systems (MMS) with an understanding of how humans function at a cognitive level. An important goal of CSE is to make the MMS's characterization of the human operator more explicit and intentional because the adequacy of this characterization is crucial for the proper functioning of the system. Designers and researchers need to have as realistic an understanding of the human operator as possible in order to provide him/her with the insights needed to properly develop and evaluate the concepts for a SCOP [25]. Unfortunately, designers of MMSs generally fail to consider the behavioural and cognitive aspects of the operator [14, 25]. So, in order to properly design and build a sensor or sensor platform that is compatible with human cognitive characteristics rather than force the human to adapt to the machine, developers require a clear description and understanding of the operators' socio-technical requirements. To this end, CSE must develop methods for cognitive task analysis to identify the characteristics of human cognition and provide the tools to build machines with explicit and appropriate understanding of the user [25].

The purpose of this paper is to begin to develop an understanding of the HF issues relevant to the development of a SCOP for the CANSpOC. The work is predicated on previous similar research on HF and SA research to understand the HF issues required to build an effective and efficient SCOP for SSA. The goal is to use this identified HF information to augment the current SCOP/SSA CD&E process. By understanding and including a HF component to the current SCOP CD&E process, which currently is a predominately technology-based CD&E process, researchers will have a more complete and better CD&E process for evaluating SSA concepts as espoused by CSE.

2 Method

2.1 Participants

Fifteen members (military and non-military) of the CANSpOC participated in this study.

2.2 Instrument

In order to develop an understanding of the HF issues and gaps pertaining to space COP and SSA development at the CANSpOC, a survey (Annex A), based on informal discussions with members of CANSpOC and related DRDC HF and SA research [26, 28, 29, 30, 31] was designed which included both qualitative and quantitative data on 7 HF categories: Organizational Structure; Visualization; Information Management; Information Quality; Workload; Personnel; Skills/Training. For each category, the participants were presented with statements specific to that category and were required to rate each statement using a 5-point ordinal scale with the following anchors: "strongly disagree", "disagree", "neutral", "agree", "strongly agree", "not applicable." Additionally, at the end of each category, the participants had the opportunity to provide written feedback about the HF issues and gaps they believed exist within that category for the CANSpOC.

2.3 Design and Procedure

Prior to the participating in the survey, the author briefed the members of the CANSpOC about the goals and nature of the survey. The members of the CANSpOC were told that this survey work was part of a research program to inform defence scientists about the importance of the role of HF issues in the SCOP CD&E process. This work would help in the design of a HF evaluation methodology that can augment the current SCOP CD&E process to meet the needs and requirements of CANSpOC operators to better facilitate space situational awareness in order to ensure intelligence superiority for the Canadian Armed Forces. Following the briefing, the members of the CANSpOC were provided with the details of the survey that was to be given to them. Finally, the members of the CANSpOC were provided with a consent form which they were required to read and signed before they could participate. A sample of 15 members from the CANSpOC filled out the paper and pencil survey in December 2016. They were given one month to complete the survey.

3 Results

The rating data for all questions of the survey are presented Annex B and the written responses are presented in Annex C.

3.1 Organizational Structure

The section on "organizational structure" was included in the survey to examine how the current CANSpOC organizational structure supports information sharing, decision-making, and shared understanding.

Examination of the rating date for each of the 12 organizational structure statements revealed that the modal response was "agree" with ratings of "agree" and "strongly agree" having an average response rate of 58.9%. These findings suggest that the members of the CANSpOC see the organizational structure of the CANSpOC as meeting their information sharing, decision-making, and shared understanding needs. However, there were a number of findings in the rating data that characterized the current organizational structure as sub-optimal. For example, only 26.7% of the respondents agreed that the CANSpOC organizational structure supports SA across the different branches of the CAF and only 46.7% of the respondents agreed that the CANSpOC organizational structure supports the development of shared understanding and provided adequate resources to enhance the development of shared understanding.

Analysis of the written feedback revealed that a number of the participants indicated that there is a need for increased personnel at the CANSpOC. According to these participants, an increase in the number of personnel would improve the CANSpOC in three main ways. It was proposed that increasing the number of personnel would help to expedite the decision-making process. Presumably, an increase in personnel would ensure a wider range of in-house expertise to draw upon to help the decision-making process. An increase in personnel would improve the space watch capability at the CANSpOC by ensuring that an appropriate number of persons are available to perform space watch duties on a 24/7 operational cycle. Members indicated that they are often one person deep in a space area. If the expert or person responsible for a specific task is absent, nothing moves forward or gets shared. Related to this, workload is increased because personnel often have to be "double-hatted" to get tasks done that are not their primary duty. An increase in personnel is seen as necessary to create a dedicated team to manage the administrative duties at the CANSpOC. Some members indicated that a lack of personnel in this area forces them to do administrative duties that take them away from their primary duties at the CANSpOC. Presumably, a dedicated team of administrators would allow CANSpOC members to focus all of their efforts to their primary tasks making them more effective and efficient.

The written feedback also indicated that information sharing and SA can be improved and a number of solutions were proposed. Participants indicated that weekly meetings and training sessions would be a good way to ensure the information was shared among the members which in turn would promote a higher level of SA within the CANSpOC. Some members suggested the need for more opportunities beyond their initial training and positional knowledge to improve their knowledge development and shared understanding of space and CANSpOC issues. Deployments and temporary duty assignments were proposed as ways to improve knowledge development and shared understanding.

Members noted that there is a need for a centralized COP and co-location of team members to ensure better collaboration and synchronization of effort which would lead to better SSA and decision-making. A centralized COP display was seen as a way to improve information sharing and SA. Moreover, the proposal to collate personnel in a centralized area would ensure better dissemination of information and discussion of issues with the required and appropriate staff thereby enhancing synchronization of effort. Related to this, members revealed the need for a web-based near time status display dashboard to track CANSpOC significant events and system statuses. Although somewhat vague, members indicated that there is the need for better tools to better promote the sharing of national and international information and a better visualization capability of information and data.

3.2 Information Management

The section on information management was included to examine how information is exchanged both internally and externally within the CANSpOC.

Broadly, the rating data revealed that the participants were generally in agreement with the statements that information management at the CANSpOC is conducted well. Examination of the rating date revealed that 73.3% of the respondents provided "neutral" (30.5%) or "agree/strongly agree" (42.8%) ratings for the statements about information management. However, for two statements pertaining to the "lessons learned" capability of the CANSpOC and the ability to find SOPs for all tasks in the SSA cycle, respectively, the modal response was "disagree." These three negative ratings are reflected and expanded upon in participants' written responses.

In the written feedback, the participants indicated that there needs to be work around solutions to national caveats on information sharing that hinders their ability to collaborate with national and international allies. Sharing restrictions are seen as limiting the fidelity of and the sharing of information while at the same time delaying the exchange of information due to the releasability review process. As well, sharing restrictions have prevented members of the CANSpOC from participating in important military exercises with their U.S. allies.

A lessons learned capability was identified as necessary to better train and inform staff about operational issues. Once a lessons learned capability is established, lessons learned can then become an integral part of training exercises to better prepare personnel for working in the CANSpOC. Moreover, participants mentioned that without a good lessons learned capability, effective and efficient information sharing is difficult to achieve. This would help to address the concern from some members that that better lines of communication need to be established in order to better understand information and intelligence requirements.

The development and implementation of a Lessons Learned capability and the amending of national caveats for information sharing would greatly augment the work being done by a co-located team. Certainly a Lessons Learned capability would inform and thus expedite procedural, communication and discussion processes and thus facilitate decision-making. By amending national caveats on information sharing, CANSpOC staff would have a wider and deeper access to, for example, U.S. space information that would improve Canadian SSA and decision-making.

Finally, the members wrote that information is often presented in an inconsistent or improper manner. That is, information is often presented on disparate and segregated systems with separate classifications often without appropriate context, which makes the information hard to collate. The respondents also

indicated a requirement for formalized/standardized checklists, SOPs, guidance documents, work flows, points of contacts to correct this as well as a cross-referencing capability to more easily retrieve information. A single deposit site/folder with a dedicated info manager was postulated to enhance the retrieval and location of various SOPs and other information. One member noted that information management would benefit from a tighter storage structure, perhaps only exposing and allowing manipulation of information through the visualization interface with expert or transmission options with commentary ability to other impacted points of contact.

3.3 Visualization

The section on visualization was developed to get an understanding of the CANSpOC members' views on the current physical layout and visualization capability at the CANSpOC.

A majority of the respondents (53.4%) indicated that they were unsatisfied with the physical layout of the CANSpOC. Written feedback indicated the need for a bigger operational space that would co-locate all members of the CANSpOC. Members of the watch cell indicated that they are disconnected from the main CANSpOC team. In conjunction with the comments made about the need for a centralized COP, the respondents noted that a larger physical space that had all of the CANSpOC members collocated in it would enhance the efficiency and synchronization of effort of the CANSpOC personnel. Finally, the participants also indicated that the efficiency of operations could be improved if all of the monitors could be located on the same wall in a more logical format than is the current situation.

The rating data suggests that the members were generally satisfied with their current multi-monitor set up. The modal response to the statements about the multi-monitor visualization capability was "agree" with 71.3% of the responses indicating an "agree" or "strongly agree" rating. However, the written feedback indicated that there are a number of improvements that can be made to their current multi-monitor visualization capability. Some members indicated that their monitor set up is ad hoc and not well coordinated in terms of the information display. Instead, members indicated that they would like to have more control over the setup of their monitors and be able to customize the location of information and the level of detail. Related to this point, members of the CANSpOC suggested that the CANSpOC needs centrally located large screens that also have the capability to customize the location of information and the level of detail. Moreover, the members indicated that centrally located large screen set ups would facilitate group analyses and briefings thereby facilitating information sharing, SA, and decision-making.

3.4 Information Quality

The section on information quality examined a variety of characteristics about the information that the members of the CANSpOC receive.

Examination of the rating data revealed that overall, the members of the CANSpOC view the quality of the information they receive positively. The modal response was "agree" with ratings of "agree" or "strongly agree" accounting for 68.1% of the rating responses for this category.

Despite the positive rating data about the quality of information received by members of the CANSpOC, a number of respondents highlighted some specific issues regarding the information that they receive that need to be improved. Respondents indicated that much of the information sources available to them have mixed security levels and different formats which limits their ability to interact with other sources. The respondents also noted that the information they receive is largely text/table based. According to the

respondents, text/table based information requires significant manual processing in order to visualize and to determine impacts on military operations which can impact the need for timely decision-making.

The respondents wrote that there are too many sources that change frequently and this can cause confusion and missed or dismissed events. The feedback showed that all relevant space data/information should be obtained from a single source. A common complaint was that message formats are not always provided or easily available, information often needs to be pulled vise pushed, and much of the received data lacks content about the data itself, its operational impact, and what other information it can be fused with.

Feedback indicated that it is often a challenge to prove or disprove information that someone has passed on to you. Respondents indicated they need the ability to verify and cross-reference information independently as well as to correlate and compare it among multiple data sources quickly. The respondents noted a need for more explanations of potential outcomes/impact that should be presented with outage/degradation alerts. However, the respondents acknowledge that this may increase classification levels and therefore this should be conducted with discretion to ensure accessibility of information.

3.5 Workload/Personnel

The sections on workload and personal are combined here because many of the workload issues are interrelated with issues pertaining to personnel. Accordingly, the presentation of the written feedback encompasses both the Workload and Personnel sections of the survey.

The rating data for the six workload statements revealed that on average, 60% of respondents indicated that workload is perceived as equitably distributed and manageable with most staff reporting that they do not have a greater workload than others, are not frustrated by the workload, and have sufficient time and resources to complete tasks. However, a subset of respondents noted that the workload that they do incur is more the result of being under-staffed and under-resourced then a result of their prescribed duties. This finding corresponds to the personnel rating data that 60% of the respondents indicated that the CANSpOC is under-staffed in a manner that negatively impacts their ability to accomplish their tasks efficiently and effectively.

The respondents noted that because they are under-staffed, they are required to perform tasks that go beyond their prescribed roles which adds to their workload. As with the comments provided in the section on Organizational Structure, some respondents reiterated the need for a dedicated civilian staff to take care of all administrative duties. Related to this point is the need for a staff dedicated to training.

The written portion of the survey revealed that there is a need to increase the number of personnel at CANSpOC in order to cover the wide variety of tasks/positions required of the CANSpOC that are currently not filled. For example, a number of participants reported that there is a requirement to have more personnel in the space watch and a greater integration of staff from the watch, intel and operations analysts in the space watch. The increase in personnel would also alleviate also personnel from having to be “double-hatted”, especially taking on tasks that they are not sufficiently expert and would lessen the burden on staff members when other staff are absent from work.

Finally, the participants reported that there needs to be more clearly defined roles for the current personnel and for those who will join the CANSpOC. This would alleviate the workload associated with trying to decipher who is doing what which allows more efficient lines of communication and information flow and thus would promote greater situational awareness within the CANSpOC.

3.6 Skills and Training

On average, 68.9% of the respondents provided positive ratings about the training they received at the CANSpOC with a modal rating of "agree". However, although an average of 80% of the respondents indicated that they were taught skills through mentorship and coaching, and that team members held the requisite competencies to facilitate information sharing and situational awareness across the sections, only 46.7% of respondents agreed that they received sufficient training to become proficient in their jobs.

Respondents reported that there should be a more "formal" method of training new personnel so that all members have the same training. Consistent training to all members of the CANSpOC is valuable to ensure that there are no discrepancies on performing tasks and that proper SSA is achieved among all members. Although there appears to be much "self-teaching" and learning from peers, respondents indicated that there is too much diversity in teaching styles and knowledge for this type of self-training to be truly effective. To this end, members advocated for a dedicated staff to provide proper training to all members of the CANSpOC to ensure shared understanding of CANSpOC SOPs and general SSA. With a dedicated training staff, personnel would achieve a more solid grounding in space knowledge and standards as a group at the CANSpOC, rather than by having to ask individual members at the CANSpOC when the time arises.

Finally, one participant indicated that training can make a quantum leap in capability in personnel at the CANSpOC. Whether it is an individual or an organization, "we don't know what we don't know." Most if not all SWCC are viewing the systems and not using them properly; this owing to our extreme lack of knowledge. The more we train the better we will become. Additionally, and this is super important, we have developed a habit of sending day staff on operations training courses and exercises; the members who need this exact training are the SWCC working shift. If the requirement is to choose between staff and SWCC, I would argue to have the day staffer cover the mission floor while the SWCC goes and gets the training. Conversely, having one day staffer receive the training or mission experience loses the effect as that knowledge isn't taught back in the unit.

4 Discussion

In this study, fifteen members of the CANSpOC responded to a survey designed to identify and rate the significance of various HF issues deemed important to the development of a SCOP to facilitate SSA. Broadly, the findings support the notion that a SCOP CD&E process is more than simply developing sensors and sensor systems. In order for a space COP to be successful, a SCOP needs to ensure that a variety of HF issues operate effectively and efficiently. The respondents in this study did not dismiss the importance of the role of the HF in SCOP development. On the contrary, the respondents acknowledged the importance of the HF issues presented to them and in fact discussed how these HF issues could be improved upon to advance SCOP and SSA development.

It should be acknowledged that due to the small sample size of this study (N = 15), it was difficult to interpret the rating data. The rating data provided did not provide the depth or breadth of responses that was expected to highlight HF gaps in the development of a SCOP. Broadly, the majority of the respondents provided positive ratings with regard to the various statements about the different HF issues in each section of the survey. In contrast, however, it was the written feedback from the respondents that primarily identified a number of HF gaps at the CANSpOC that can negatively impact the development of a SCOP and SSA that are not discernable from the rating data. The written feedback provided a greater breadth and depth of insight into the HF gaps at the CANSpOC for developing a SCOP and SSA.

It is possible that the disparity between the rating and written data is due to at least three possible explanations. These findings could speak to a lack of fidelity in the statements used for making ratings. Second, the seemingly, at times, contradictory results may reflect the responses of different team members with different duties; this will require further investigation. Third, the sample size could have been too small to get a diverse set of rating data. Accordingly, because of the richness of information contained in the written feedback of the survey, it is the written feedback about the HF gaps at the CANSpOC that is discussed in this report.

The findings from this study revealed that SCOP development can be viewed as a HF centric process where the data collection process via sensors and sensor platforms, represents only one aspect of the space COP development. In fact, this makes sense when we view the SCOP process as a SoS environment utilizing the TCPED process. Once tasking orders are given, which are based on a variety of human information sharing processes and the data is collected, the SCOP and ensuing SSA and decision-making processes are a direct product of human information processing. The findings from this study bear this out. In fact, this study revealed that the HF issues integral to SCOP development are procedural in nature; focusing on how to improve organizational structure, lines of communication, lessons learned, amending national caveats, information sharing, decreasing workload, and the better utilization of personnel. Arguably, these findings can be viewed as being part of a category distinct from technological issues involved in sensor and sensor platform development. In fact, these procedural issues might constitute a larger share and more critical component of the SCOP CD&E process then sensors and sensor platform development. Of course, socio-technical issues such as proper visualization development and manipulation surrounding issues of information quality and monitor configurations will facilitate the success of the SCOP process, too. However, a large portion of the SCOP process relies on HF issues that are in some cases orthogonal to sensor and sensor platform development, which has overwhelmingly dominated research in this area. The summary of these findings and their subcategories are presented as follows:

1. Need for better Information Sharing and Information Management:
    a. Central COP;
    b. Co-location of team;
    c. Easing of national caveats;
    d. Lessons Learned; and
    e. Clearer lines of communication.
2. Better Visualization Techniques:
    a. Monitor configuration;
    b. Information display; and
    c. Physical layout.
3. Improvements to Information Quality:
    a. Data sources; and
    b. Data content.
4. Increase in Personnel:
    a. Workload; and
    b. Training.

To be sure, this is not an exhaustive list of HF issues that impact SCOP and SSA development. However, the respondents did indicate that good SSA, the desired outcome of a SCOP, can be achieved though improvements to the various HF issues presented to them in the survey. For example, within the Organizational Structure Section, members indicated that more resources need to be applied to improving SA within and between branches of the CAF. As well, the members revealed that more personnel are required to ensure that there is proper in-house expertise to facilitate decision-making and all required positions are filled which will decrease the amount of workload experienced by members of the CANSpOC. These findings parallel the findings from the Workload and Personnel section with the addition that the CANSpOC needs to do a better job of defining the roles of personnel so that so that members of the CANSpOC can quickly and efficiently contact required personnel as operations unfold. As with the responses from the section on Visualization, the members also indicated that many of the issues that plague the development of SA can be overcome by centrally locating the SCOP and co-locating personnel which would better facilitate collaboration, discussion, decision-making and synchronization of effort than is currently the situation at the CANSpOC. Co-locating all members in the same space allows equal access to monitors that can update everyone simultaneously thereby ensuring good shared awareness and understanding.

The section on Information Management revealed that the CANSpOC needs to develop a Lessons Learned capability to better train and inform staff about operational issues. An appropriate Lessons Learned capability would lead to effective and efficient information sharing and better lines of communication to be established in order to better understand information and intelligence requirements. Similarly, the respondents noted that there needs to be a change to the issue of national caveats that prevent information sharing with allies. The participants indicated that there needs to be work around solutions to national caveats on information sharing that hinders their ability to collaborate with national and international allies which thus limits the fidelity and the sharing of information while sensitive information can be delayed.

Responses from both the Information Management and Information Quality sections revealed that there needs to be better standardization of information received in the CANSpOC. Too many pieces of information on presented on disparate and segregated systems with separate classifications often without appropriate context, which makes the information hard to collate. Also, information is often presented in mixed security levels and different formats which limits their ability to interact with other sources. According to the respondents, the inconsistency with which information is presented requires significant manual processing, which is time consuming, in order to visualize and to determine impacts on military operations which can impede timely decision-making and action.

Finally, the responses from the Skills and Training section revealed that the respondents see the need for a more formalized training capability to ensure all have equal knowledge of all CANSpOC activities and group structures. Members indicated that currently, training is based primarily on "self-teaching" and learning from peers. The respondents indicated that the problem with these two methods of learning is that there is too much diversity in teaching styles and knowledge for this type of self-training to be truly effective. It is too difficult to develop proper information sharing methods and shared awareness and understanding when a variety of training techniques are being employed. A formal mode of training is being sought to ensure that members of the CANSpOC have a shared understanding of all things CANSpOC.

In sum, the findings from this study support the notion that a SCOP CD&E process is more than simply developing sensors and sensor systems. SCOP development is largely dependent upon communication, information sharing and decision-making processes. To be sure, this study demonstrates that there is a need to develop a HF evaluation methodology for the SCOP CD&E process that ensures the needs and requirements of the CANSpOC operators are being achieved.

5 Conclusion

The findings from this research, like similar nascent research [18, 31] revealed that, in addition to technological requirements, there are important HF issues that need to be considered when developing a SCOP. This study represents the start of an effort to identify and understand the HF issues that are integral to the development of SCOP and SSA in order to develop a HF evaluation methodology to augment the current SCOP CD&E process. The research represents a new and fruitful research venue for SCOP CD&E.

It was determined that the SCOP process is best viewed as a SoS process [7, 8, 9]. This process also utilizes TCPED activities within and across the various levels and sublevels within the SCOP SoS. As such, the very nature of the SCOP most assuredly contains HF issues integral to the development of a SCOP and SSA. Accordingly, a HF factors research methodology should be an important component alongside the obvious sensor technologies work in this field of research to help ensure that a SCOP is developed in such a way as to meet the operational needs of the CANSpOC operators, analysts and decision-makers [10, 11, 12].

According to Thomas, Capshaw and Franken [16], a SoS evaluation should study all of the factors involved in SoS employment, applying a multidiscipline methodology to achieve a multidiscipline measure of operational effect. To this end, both technical and human elements need to be studied in order to achieve a holistic understanding of how a concept of a SCOP will impact operator performance [15]. From a HF perspective, the challenge for an SCOP concept evaluation process is to develop efficient and reliable methodologies and metrics to properly evaluate the impact of SCOP concepts on operator performance.

In pursuit of developing a HF methodology for the SCOP CD&E process, the next phase of this work will aim to gain a deeper understanding of the HF issues raised in this study by prioritizing which HF issues needs to be instantiated first and seek to discover from members of the CANSpOC how best to address and implement these issues. Moreover, this next phase will also look at issues pertaining to the visualization of space information and a proposed physical layout in the CANSpOC where members will be co-located. There is much work to be done to uncover the HF issues relevant to SCOP develop, but in the end, the findings should facilitate better SSA and facilitate intelligence superiority for the CAF.

References

[1] Concept of Operations, Department of National Defence / Canadian Forces (DND/CAF), Canadian Space Operations Cell (CANSpOC) (Draft). April 25, 2016.

[2] ADM(S&T) project charter. Space situational awareness (SSA) characterization of space objects and space-enabled capabilities.

[3] Lichacz, F. M. J. (2017). Human factors considerations for the development of a space common operating picture for space situational awareness. Scientific Letter, DRDC-RDDC-2017-L119, Defence Research and Development Canada, April 2017.

[4] Defence Terminology Standardization Board; DND/CF Manual of Abbreviations; APP-15; January 27, 2011.

[5] Dictionary of Military and Associated Terms. US Department of Defense 2005, www.thefreedictionary.com/common+operational+picture (Access date: October 19, 2017).

[6] NRF Resource Center. [28h Governor's Hurricane Conference], May 13, 2013.

[7] FEMA National Incident Support Manual. 28th Governor's Hurricane Conference, May 13, 2013; IT Program Assessment Department of Homeland Security (DHS) Analysis and Operations (A&O) Common Operating Picture (COP), US Department of Homeland Security, 2012, https://www.dhs.gov/xlibrary/assets/mgmt/itpa-ao-cop2012.pdf (Access date: October 19, 2017).

[8] Endsley, M. R. (2000). Theoretical underpinnings of situation awareness: A critical review. In M. R. Endsley & D. J. Garland (Eds.), Situation awareness analysis and measurement (pp. 3–32). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

[9] Lichacz, F. M. J. & Farrell, P. S. E. (2005). The Calibration of Situation Awareness and Confidence Within a Multinational Operational Net Assessment. *Military Psychology* 17(4), 247–268.

[10] Farrell, P. S. E., Allen, D., Burrows, P., Comeau, P., Hughes, S., Kachuik, J., Labbé, P., Lichacz, F. M. J. (2006). Multi-National Experiment 4 on Effects Based Approach to Operations. DRDC Ottawa TR 2006-230, Defence R&D Canada – Ottawa, December 2016.

[11] Allen, D., Hill, A., Breton, R., Jeffrey, A., Lichacz, F. M. J., Robbins, W., & Rehak, L. (2012). Analysis of Human Factors 4 Experiment: Battlespace Management Capability. DRDC CORA TR 2012-107, Defence R&D Canada – Centre for Operational Research and Analysis, May 2012.

[12] Allen, D. & Lichacz, F.M.J. (2010). Joint Fires Support Human Factors Experiment 1 Analysis Report, DRDC CORA TR 2010-004, Defence R&D Canada – Centre for Operational Research and Analysis, June 2010.

[13] Franke, U. & Bryneilsson, J. (2014) Computer Situational Awareness – A systemic review of the literature. *Computer & Security*, 46, 181–31.

[14] Bakdash, J. Z., Pizzocaro, D., & Precee, A. (2013). Human factors in intelligence, surveillance, and reconnaissance: Gaps for soldiers and technology recommendations. In Proceedings of the IEEE Military Communications Conference, pp. 1900–1905.

[15] Dogan, H., Pilfold, S. A., & Henshaw, M. (2011). The role of human factors in addressing systems of systems complexity. In the Proceedings of the IEEE Systems, man, and Cybernetics (SMC' 11) Conference, Anchorage, AK. IEEE.

[16] Thomas, R. S., Capshaw, N. C., & Franken, P. M. (2010). A Framework for System of Systems Evaluation within an Airborne Intelligence, Surveillance, and Reconnaissance, Environment. A Publication of the Defense Acquisition University, http://www.dau.mil (Access date: May 5, 2017), pp. 436–449.

[17] Svendsen, A. D. M. (2015) Advancing "Defence-in-depth": intelligence and systems dynamics, *Defense & Security Analysis*, 31:1, 58–73.

[18] Mahaffey, J. L. (2005). Observations in the Dissemination of Intelligence Surveillance and Reconnaissance (ISR) Data and Information within a Coalition Environment. In Analytical Support to Defence Transformation. Meeting Proceedings RTO-MP-SAS-055, Paper 26. Neuilly-sur-Seine, France: RTO, pp. 26-1–26-16.

[19] Aleva, D., Ianni, J., & Schmidt, V. (2010). Space Situation Awareness Human Effectiveness Research Trend. Air Force Research laboratory Wright-Patterson Air Force Base, Ohio, USA, #88ABW-2010-2273.

[20] Henshaw, M. (2015). A Socio-Technical Perspective on SOSE. NATO Report, STO-EN-SCI-276.

[21] Lichacz, F. M. J. (2017). Human Factors Considerations for the Development of a Space Common Operating Picture for Space Situational Awareness. Scientific Letter, DRDC-RDDC-2017-L119, Defence Research and Development Canada, April 2017.

[22] Marras, W. S. & Hancock, P. A. (2014). Putting mind and body back together: A human-systems approach to the integration of the physical and cognitive dimensions of task design and operations. *Applied ergonomics*, 45, 55–60.

[23] Hollnagel, E. (2014). Human factors/ergonomics as a systems discipline? The human use of human beings revisited. *Applied Ergonomics*, 45, 40–44.

[24] Wilson, J. R. (2014). Fundamentals of systems ergonomics/human factors. *Applied Ergonomics*, 45, 5–13.

[25] Hollnagel, E. & Woods, D. D. (1999). Cognitive Systems Engineering: New wine in new bottles. *International Journal of Human-Computer Studies*, 51, 339–356.

[26] Jassemi-Zargani, R., Kashyap, N., & Lichacz, F. M. L. (2013). ISR Concept Evaluation Environment for Addressing NEC Situational Awareness Requirements, NATO SCI-254 Symposium. DRDC Ottawa SL 2013-040, Defence R&D Canada – Ottawa, May 2013.

[27] Jassemi-Zargani, R., Brookes, D., Kashyap, N., Lichacz, F. M. J., & Wong, S., (Unpublished). Feasibility study of the operational effectiveness of ISR technologies for NORAD maritime warning and the replacement of the aerospace systems.

[28] Banko, K. M. & Lichacz, F. M. J. (2013). Support to J2 Automation: Process Assessment and Human Factors Issues, DRDC CORA LR 2013-073, Defence R&D Canada – Centre for Operational Research and Analysis, May 2013.

[29] Yanakiev, Y., Bjornstad, S. L., Sutton, J., Lichacz, F. M. J., Blais, A. R., Bisig, E., Resteigne, D., Lyons, J., Valaker, S., Szvircsev Tresch, T. (2012). NATO HFM-13-63: Improving Organizational Effectiveness of Coalition Operations, January 2012.

[30] Lichacz. F. M. J. (2009). Multinational Experiment 5 analyst report: Analysis of the Organizational Data from the Multinational Experiment 5 major Integrating Event, Enköping, Sweden, 7–18 April 2008. DRDC CORA TN 2009-042, Defence R&D Canada – Centre for Operational Research and Analysis, September 2009.

[31] Lichacz, F. M. J. & Jassemi-Zargani, R. (2016). Human Factors and Intelligence, Surveillance, and reconnaissance (ISR): Making the case for a Human Factors Capability in the ISR Concept Development & Evaluation Process. Reference Document, DRDC-RDDC-2016-D011, Defence Research and Development Canada, April 2016.

Annex A Survey Questions

Section 1: Organizational Structure

1. The CANSpOC organizational structure supports information sharing (flow) across the CAF.
2. The CANSpOC organizational structure supports information sharing within my section.
3. In the CANSpOC, there are adequate resources that facilitate information sharing.
4. In the CANSpOC, there are adequate communication channels to facilitate information sharing.
5. The CANSpOC organizational structure supports quick decision-making.
6. In the CANSpOC, there are adequate resources to facilitate quick decision-making.
7. In the CANSpOC, there are adequate communication channels to facilitate quick decision-making.
8. The CANSpOC organizational structure supports situational awareness within my section.
9. The CANSpOC organizational structure supports situational awareness across the different branches of the CAF.
10. The CANSpOC organizational structure supports the development of shared understanding.
11. In the CANSpOC organizational structure, there are adequate resources to enhance the development of shared understanding.
12. In the CANSpOC, there are adequate communication channels to enhance the development of shared understanding.
13. Are there any changes that you would recommend to the organizational structure that would improve information sharing, decision-making, and shared understanding at the CANSpOC that would benefit the development of a space COP? Please write on the back of the sheet if you need more space.

Section 2: Visualization

14. I am satisfied with the physical (room) layout of the CANSpOC.
15. What changes would you recommend to the physical (room) layout to improve the COP at the CANSpOC? Please write on the back of the sheet if you need more space.
16. The multi-monitor station is helpful in the execution of my tasks.
17. The multi-monitor station is useful in maintaining situational awareness.
18. The multi-monitor station is useful in minimizing workload.

19. The multi-monitor station is useful in terms of its flexibility to re-organize tools and content display.

20. The multi-monitor station is useful in organizing different kinds of functions/activities in separate displays areas.

21. The layout of the current visualization capability is easy to use.

22. Navigating within this multi-monitor station is straight-forward.

23. Navigating within this multi-monitor station is easy.

24. I seldom have problems using this multi-monitor station.

25. The functionalities associated with this multi-monitor station are sufficient for my job.

26. The functionalities associated with this multi-monitor station make my job easy to accomplish.

27. Using the multi-monitor's functionalities is easy.

28. The organization of the multi-monitors' interface makes accomplishing my tasks easy.

29. The multi-monitor station's design is well thought-out.

30. I am generally satisfied with my experiences using this multi-monitor station.

31. I would change aspects of my current multi-monitor station in order to improve my ability to do my job.

32. What changes would you recommend to your current multi-monitor visualization capability to improve the space COP at the CANSpOC? Please write on the back of the sheet if you need more space.

Section 3: Information Management

33. The information flow within the CANSpOC is well managed.

34. Space information is exchanged between the relevant members of the headquarters.

35. The collection of space information is done efficiently and in a timely manner.

36. The information requirements for my work are clearly defined.

37. I understand the space information requirements of other relevant sections.

38. I understand how intelligence requirements are prioritized.

39. I have clearly defined and written SOPs to do my work.

40. I receive clear external direction from decision makers (CCIRs and PIRs).

41. Information (SIGINT, GEOINT) is cross-referenced for easy retrieval.

42. The CANSpOC has a formal mechanism for capturing lessons learned.

43. I know where to find all the documents I need to accomplish my work.

44. I know where to find SOPs for all the tasks in the SSA cycle.

45. I receive clear direction from my immediate manager when given a task.

46. Key persons are accessible for rapid decision making.

47. Lessons learned are integrated into the problem-solving process.

48. In the CANSpOC, national caveats hinder information sharing.

49. In the CANSpOC, national caveats impair the ability to make quick decisions.

50. In the CANSpOC, national caveats reduce the ability to develop shared awareness.

51. Event logs of anomalies trigger COAs effectively.

52. We have well defined COAs for all detected anomalies.

53. We have easy access to COAs in response to all detected anomalies.

54. What changes would you recommend to the information management process to improve the space COP at the CANSpOC? Please write on the back of the sheet if you need more space.

Section 4: Information Quality

55. The information I receive in the CANSpOC is concise (to the point).

56. The information I receive in the CANSpOC is consistent (free of contradictions).

57. The information I receive in the CANSpOC is correct (free of error).

58. The information I receive in the CANSpOC is current (up to date).

59. The information I receive in the CANSpOC is comprehensive (adequate scope).

60. The information I receive in the CANSpOC is accurate (precise and close to reality).

61. The information I receive in the CANSpOC is clear (understandable).

62. The information I receive in the CANSpOC is objective (unbiased).

63. The information I receive in the CANSpOC is believable (credible).

64. The information I receive in the CANSpOC is reputable (trusted).

65. The information I receive in the CANSpOC is relevant (applicable).

66. The information I receive in the CANSpOC is value-added (beneficial).

67. The information I receive in the CANSpOC is timely (age of data).

68. The information I receive in the CANSpOC is consistent representation (format).

69. The information I receive in the CANSpOC is accessible (available).

70. The information I receive in the CANSpOC is secure (restricted).

71. The information I receive in the CANSpOC is complete (scope).

72. The information I receive in the CANSpOC is the right amount (quantity).

73. The information I receive in the CANSpOC is convenient (easily accessed).

74. The information I receive in the CANSpOC is timely (from creation to publication).

75. The information I receive in the CANSpOC is traceable (author, date etc. is provided).

76. The information I receive in the CANSpOC is interactive (information process adaptability).

77. The information I receive in the CANSpOC is accessible (continuous and unobstructed access).

78. The information I receive in the CANSpOC is secure (protected against loss or unauthorized access).

79. The information I receive in the CANSpOC is maintainable (information organizability and updatable).

80. The information I receive in the CANSpOC is received quickly (infrastructure response time).

81. The information I receive in the CANSpOC is interpretable (language, units, definitions).

82. The information I receive in the CANSpOC is easy to understand (comprehendible).

83. The information I receive in the CANSpOC is represented concisely (compact).

84. List 5 negative and 5 positive things about the information quality you receive and what recommendations would you make to improve the quality of the information you receive. Please write on the back of the sheet if you need more space.

Section 5: Workload

85. The workload is distributed equitably within the people in my section.

86. I rarely have enough time to accomplish my tasks.

87. My workload is greater than it should for my job.

88. Compared to others in my section, I have much more work to do.

89. I am often frustrated with the amount of work that I am assigned.

90. I have the resources to respond quickly and accurately to time critical responses.

91. What recommendations would you make to improve the level of workload in your job? Please write on the back of the sheet if you need more space.

Section 6: Personnel

92. I have access to key personnel for rapid information exchange.

93. We have enough staff to accomplish our tasks efficiently and effectively at the CANSpOC.

94. What changes to personnel could be made to improve the space COP at CANSpOC? Please write on the back of the sheet if you need more space.

Section 7: Skills/Training

95. I have received sufficient training to become proficient at my job.

96. Skills are taught to me through mentorship and coaching.

97. The members of my team have the core competencies to facilitate information sharing and enhance situational awareness across the sections.

98. If you answered “Disagree” or “Strongly Disagree” to any of the previous questions, please explain your answer.

99. Do you have any other comments about how to develop/improve the space COP at CANSpOC? Are you aware of any new technologies that you would like to see used by the CANSpOC that you believe could be used to improve the space COP? Please write on the back of the sheet if you need more space.

Annex B Number of participant responses for each response category per question

Table B.1: *CANSpOC Survey Responses.*

Sections	Questions	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Not Applicable
Organizational Structure							
	1	0	3	1	9	2	0
	2	0	2	1	7	5	0
	3	0	4	2	9	0	0
	4	0	5	2	8	0	0
	5	0	2	5	7	1	0
	6	0	2	4	9	0	0
	7	0	3	2	9	1	0
	8	0	2	2	10	1	0
	9	1	2	8	4	0	0
	10	0	3	5	6	1	0
	11	0	2	6	7	0	0
	12	0	2	3	10	0	0
Visualization							
	14	4	4	4	1	2	0
	16	0	0	2	5	8	0
	17	0	0	2	4	9	0
	18	0	3	1	2	9	0
	19	2	0	1	4	8	0
	20	0	2	1	2	9	1
	21	0	4	1	4	5	1
	22	0	1	2	6	5	1
	23	0	1	1	7	5	1
	24	0	0	2	7	5	1
	25	0	3	1	6	4	1
	26	0	2	2	6	4	1
	27	0	0	3	8	3	1
	28	0	4	1	6	3	1
	29	2	2	2	5	3	1
	30	0	3	0	7	4	1
	31	0	4	2	6	2	1
Information Management							
	33	0	4	6	5	0	0
	34	1	3	3	6	1	1
	35	0	2	5	8	0	0

Sections	Questions	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Not Applicable
	36	2	3	1	9	0	0
	37	0	4	4	6	1	0
	38	2	3	1	8	1	0
	39	0	2	6	6	1	0
	40	2	2	5	5	1	0
	41	3	4	7	1	0	0
	42	1	6	5	3	0	0
	43	0	4	3	6	2	0
	44	1	4	4	3	3	0
	45	0	1	1	7	6	0
	46	0	1	3	9	2	0
	47	1	6	4	4	0	0
	48	0	4	6	2	3	0
	49	0	4	6	3	2	0
	50	0	2	7	3	3	0
	51	0	1	8	5	0	1
	52	0	3	7	4	0	1
	53	0	4	4	6	0	1
Information Quality							
	55	0	2	4	9	0	0
	56	0	1	4	10	0	0
	57	0	2	3	10	0	0
	58	0	1	5	9	0	0
	59	0	4	5	6	0	0
	60	0	1	2	12	0	0
	61	0	2	3	10	0	0
	62	0	0	2	12	1	0
	63	0	0	3	10	2	0
	64	0	0	2	11	2	0
	65	0	0	1	12	2	0
	66	0	1	3	10	1	0
	67	0	1	3	10	1	0
	68	0	1	3	10	1	0
	69	0	4	2	8	1	0
	70	0	1	2	9	3	0
	71	0	3	3	9	0	0
	72	0	4	4	6	1	0
	73	0	4	4	6	1	0
	74	0	1	3	10	1	0
	75	0	1	4	9	1	0
	76	0	3	5	6	1	0
	77	0	3	3	8	1	0
	78	0	2	1	10	2	0

Sections	Questions	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Not Applicable
	79	0	2	5	7	1	0
	80	0	1	2	11	1	0
	81	0	1	2	11	1	0
	82	0	1	2	11	1	0
	83	0	2	5	7	1	0
Workload							
	85	1	0	2	12	0	0
	86	0	8	2	2	3	0
	87	1	7	2	2	3	0
	88	1	6	6	0	2	0
	89	3	7	4	1	0	0
	90	0	2	4	8	1	0
Personnel							
	92	0	1	0	12	5	0
	93	3	6	4	2	0	0
Skills/Training							
	95	0	3	5	6	1	0
	96	1	1	1	9	3	0
	97	0	2	1	11	1	0

Annex C Written Feedback

Organizational Structure

Question 13: Are there any changes that you would recommend to the organizational structure that would improve information sharing, decision-making, and shared understanding at the CANSpOC that would benefit the development of a space COP?

- More personnel to help quicken decision making.
- I have recently been introduced to the Signals branch ACIMS page. I recommend a view of this as an example of resource sharing.
- I would like to see more situational awareness across the board.
- A great way to accomplish this is to have a weekly meeting to discuss current ops and personnel.
- Enhancement of space watch capability—up to 2-person team for 24/7 ops.
- There are only 14 Sgt/MCpl members in the CANSpOC; there are only 2–3 day staff positions available to Sgt/MCpl.
- OA Sgt—great position to expand knowledge and shared understanding.
- Stds Trg Sgt—limited ability to expand knowledge and shared understanding. Is still focused on the watch (more info than watch members).
- Deployments—great opportunity to expand knowledge and shared understanding.
- TD—good opportunities to expand knowledge and shared understanding:
  - Limited chance for SWCC/watch members to attend.
- Watch Members—limited opportunity to expand knowledge and shared understanding:
  - SWCC is an information conduit…information comes in and is merely passed on to the appropriate user to act upon.
- Overall—The majority of enlisted personnel are not given many opportunities to expand the understanding of the role that CANSpOC plays in the CAF.
- We do learn a lot but further expansion is limited beyond initial training and positional knowledge.
- A user friendly info depository with a dedicated person to manage (in order to avoid space expertise performing non-expert role).
- Would be better to utilize existing systems, e.g., unclass (sharepoint), Class (web publishing).
- ORG STRUCTURE: we need an admin assistant, preferably civilian to facilitate:
  - Inquiries from CAF
  - Help with large amount of travel files
  - Ensure less repetition of work
  - Allow space—experts to focus on space operations instead of proper filing techniques

- The structure seems to work as expected, but there is limited opportunity for the group to coordinate effort.
- A central COP display, combined with a regular team meeting would help to improve situational awareness.
- Information sharing is the most important challenge the CANSpOC faces. Two ideas could be implemented to increase information flow are:
  - Perform CANSpOC wide recurring training one day a week for a few hours. The training, ideally, would have one new concept or instructional brief. Following the brief would be an update from each section, ending with a round table discussion of CANSpOC news and events. The training day should only take an hour and a half to two hours in order to not become burdensome or repetitive. To maximize the training day SWCC's who are on standby days should attend. As well, swap yellow days with a standby day for crew member who are off shift so they too can attend while bot being robbed of time. Training days serve to standardize CANSpOC knowledge while informing its members on each section's initiatives.
  - Anecdotally, I really get so much out of the CSPO VTC days, not because of the CSPO VTC, but once it was turned off, LCol Peck went around the room and asked each and every person what they were working on. It was very insightful for me as a shift worker to catch up on what was happening at the CANSpOC and in space in general:
    - Create a web based near time status display dashboard to track CANSpOC significant events and system statuses. For example the dashboard could display the real time status of Sapphire, R2, PDS-M/SADS, WIDOW, networks as well as a "notes" section for upcoming events. The dashboard could be housed on command view which is secret and will automatically update.
- We are small unit, but have clearly defined sections with roles and responsibilities.
- Sometimes (often) we are 1 deep in an area, so if the expert or responsible party is absent, nothing moves forward or gets shared.
- Often we have overlapping span of control out of necessity, but it violates our org structure.
- We need tools to share info/collaborate with mission partners out of Canada or in NATO.
- Organization structure and information sharing resources in general are adequate, however, information displays requires more education to interpret than those CANSpOC needs to share information with generally have/are able to get.
- Information displays needs to be consolidated and simplified.
- Due to lack of easy communicability internal and external sharing of situational awareness is less effective and takes more time to achieve and therefore also decision making is slowed.
- We are located in the CJOC which facilitates verbal info from and to other branches and commands within the NCR; however, there doesn't seem to be a rigorous/formal info sharing mechanism to other commanders/commands within Canada.
- This perception may be due to my inexperience as I am relatively new to CANSpOC (< 3 months).

Visualization

Question 15: What changes would recommend to the physical (room) layout to improve the COP at the CANSpOC?

- Bigger room for CANSpOC.
- Size of the watch is too small; bad positioning of the watch room compared with the rest of the CFICC watch floor.
- Establishment of proper Ops centre floor with adequate room for: (1) space watch [2 persons] 24/7; (2) operational analysis [4 pers]…day workers, on-call/duty; (3) Int cell [2 pers]; surge pxns [2 pers]; Need a 10 person team [2@24/7].
- Proper multi-monitor displays.
- Additional work stations.
- KVM switches for larger monitor displays.
- All of the screens could be on the same wall/closer together.
- The space is good if only one member is working; it can get a little crowded when training. I know space is limited but a little extra room (1 ft) could make a difference with chairs.
- More space will be required if watch grows beyond 1 person.
- A turn-over/significant events tracking board (digital or physical) for SA and in event computers or networks are down.
- It is disconnected from the main "team", space if off in the corner.
- Needs and increase in footprint to be able to increase the size of the space watch.
- Dedicated wall-mount status screens to inform the watch.
- Being located in the corner away from the rest of the crew has the effect of out of sight out of mind…it would be preferable to be closer, integrated in the watch crew.
- Watch Cell: we're in a corner, tucked away, not really a part of the CFICC floor.
- No room for 2 people…cramped…we have a lot of monitors, but some are duplicates.
- Backshops (4th floor): Cube form layout is not ideal.
- Few private spaces to work and individuals in the same section tend not to be right next to each other.
- There is no central call #, so it is hit or miss to get anyone.
- Dedicated and planned space for CANSpOC by function.
- Increased and planned Watch Floor space to allow 4–5 concurrent duty space pers with common space COP access while encouraging information sharing & physical contact with supported organization (currently CFICC).
- Current setup "ostracizes" space into a corner with primarily virtual (email and phone) external interfaces.

- Intelligence cell co-located with CANSpOC.
- SOC collocated with CANSpOC.
- A centralized “mini-ops-center” needs to be at the centre of CANSpOC.
- Continued need for a non-distributed space team.

Question 32: What changes would you recommend to your current multi-monitor visualization capability?

- We have monitors on 2400.
- Too much keyboard to operate the system.
- The SIPR printer is not in a good place:
  - There are two monitors directly in front of my station that are rarely in use and 4 stations to my far left that would be better situated in direct view.
- Multi-monitor displays have been put together ad-hoc (watch floor) and are disparate systems requiring scanning of RT displays via KVM switches and many displays/monitors.
- OA section dual-monitor displays adequate but lack large-screen projection capability for conducting group analysis/briefings.
- We need to work on several networks at once; I don’t see another better way to display them.
- An outward facing display to convey info t o a large group would be useful.
- Nothing.
- No issue.
- None.
- Larger screens with the ability to customize location of info and level of detail.
- “NCR Net” or the dirty internet should be on a separate monitor so you can see DWAN, NCR net and CSNI all at the same time.
- NCR Net is a research tool; it should be easy to access.
- We have two monitors: I’d like to be able to display one system on one screen and simultaneously display the other system on the other screen…it would prevent constant switching back and forth.
- Visualization of all information capable of being geo-referenced or system-referenced into a single or 2 screens capable of showing any combination of info sets on a single map/globe and single system status/characteristics display.

Information Management

Question 54: What changes would you recommend to the information management process to improve the space COP at the CANSpOC?

- The Lessons Learned not really sharing with the watch crews.

- At this moment, the CAVEATS is a big problem…too much information FVEY (?) are on noform site.
- Lessons Learned need to be better captured.
- CCIRs are email based and often lack context or amplifying information.
- Information is often on disparate, segregated systems of separate sec. classifications; (?) hard to collate.
- Better checklists (that are currently under revision).
- Possibly a secret cell phone for the watch O for after hour decision-making.
- Standardized/reformatted checklists.
- Formalized SOPs/guiding documents.
- During exercised with the US, due to national caveats, there were times when we were ready to participate but were excluded.
- We've encountered issues with documents claiming to be 5-eyes but we were unable to receive it (FM SKIWERS?) without contacting JSpOC.
- Day staff for ops room seem overtasked and appear to have difficulty maintaining SOPs/COAs…more personnel may help.
- A single deposit site/folder with a dedicated info manager.
- An intel database to access to provide context when Int Op not available.
- Useful to display friendly and non-friendly disposition of forces.
- A way to provide context to non-space trained personnel—visual aids, historical info, and relative strength.
- Training can make a quantum leap in capability in personnel at the CANSpOC. Whether it is an individual or an organization; we don't know what we don't know. Most is not all SWCC are viewing the systems, not using them, this owing to our extreme lack of knowledge. The more we train the better we will become. Additionally, and this is super important, we have developed a habit of sending day staff on operations training courses and exercises; the members who need this exact training are the SWCC working shift. If the requirement is to choose between staff and SWCC, I would argue to have the day staffer cover the mission floor while the SWCC goes and gets the training. Conversely, having one day staffer receive the training or mission experience loses the effect as that knowledge isn't taught back in the unit.
- Create a web based near time status display dashboard to track CANSpOC significant events and system statuses. For example the dashboard could display the real time status of Sapphire, R2, PDS-M/SADS, WIDOW, networks as well as a "notes" section for upcoming events. The dashboard could be housed on command view which is secret and will automatically update.
- We are spread thin, so ensure clear understanding of who is where and what the current chain of command is.
- Implement a Lessons Learned system that informs training/ops.

- Roll lessons from exercises into training/ops.
- Establish more clearly defined rule sets, work flows and points of contact along with better defined information requirements.
- Information management would benefit from a tighter storage structure in-line with the above, perhaps only exposing and allowing manipulation of information through the visualization interface with expert or transmission options with commentary ability to other impacted points of contact.
- Again I have a limited perspective as I have only been at CANSpOC for 3 months; this has reduced my ability to answer all questions. If in doubt, I answered Neutral or N/A.

Information Quality

Question 84: List 5 negative and 5 positive things about the information quality you receive and what recommendations would you make to improve the quality of the information you receive.

- Need to search the good information on too much system.
- Some information is available only on TS system but the information is S.
- The references about space are available only in English.
- Often we received too much information and that takes time to sort out the good information.
- All systems are available in one place (CFICC Watch).
- Easy to get login name/password for each system (except SIRR rel) (is this a good/bad thing).
- Negative:
  - occasionally duplicated
- Positive:
  - information flow is easy
- Positive:
  - many different info sources
  - some easily interactive
  - some comes rapidly
- Negatives:
  - Info sources are mixed—different security levels;
  - Differing formats—many are not interactive (e.g., scan of msg then emailed);
  - Info comes after the fact (late) e.g., launch alerts from JSpOC;
  - Msg formats not always provided or easily available.
- Skiweb:
  - Timely, accurate, good source of information (p);
  - A lot of random messages to sift through to find pertinent info (n);

- Occasionally important non-routine info may be lost or overlooked due to mass of information on the system and lack of knowing what to look for by operator(n);
- Occasionally issues with incorrect classification of important info “noform” (n).

- PDSM:
  - Great tool, NRT info (p);
  - Limited in depth knowledge of features (s).
- CDRSN:
  - Fast direct source of info (p)
- Limited capabilities to transfer info between computer systems.
- Positive:
  - Speed
  - Consistent
- Negative:
  - Lacks content about:
    - Data itself
    - Operational impact (why we care)
    - What other information this should/can be fused with
- Positive:
  - Genuine desire to share quality info from allies
  - Quantity of into allows watch to stay informed
  - Wide range of products
- Negative:
  - Sharing restrictions limit fidelity;
  - Sensitive info can be delayed (releasability review process);
  - Quantity of info from different systems can be difficult to juggle;
  - Lack of conformity/similarity in style of received products;
  - Received slides are very information-dense, difficulty in determining critical info quickly.
- To improve:
  - Highlight critical info for quick ref
- Positive:
  - Detailed and sourced information about on-going or upcoming events is great. Int is really on missile launched with detailed underlying information at multiple classification levels. The CSPO helps the floor track what’s coming up for the day, week, month.

- Negative:
  - It can be a challenge to prove or disprove what someone has passed on to you. It's not enough to have someone say this is what's happening; we need the ability to verify information independently.
- To improve the quality of our information and the people who give it we should exercise, exercise, exercise! Once we have additional people to assist the training shop we should build a series of "canned" exercises. This would allow the training shop to drop to a small 45 minute to 2 hour exercise on the duty SWCC each shift. The more situation training and exercises that are performed, the better SWCC we will have.
- Positive:
  - Wide net of information sources theoretically prevents missing significant event/data.
- Negative:
  - Largely text/table based;
  - Requires significant manual/processing in order to visualize;
  - Requires significant manual processing in order to determine impacts on military ops;
  - Correlation and comparison among multiple data sources;
  - Varying and sometimes poorly understood quality of data reliability between sources;
  - Too many and changing sources of information can cause confusion and missed or dismissed events.
- Positive:
  - Information comes from credible sources and is generally accurate and relevant.
- Negative:
  - Sources too varied—should be able to get all relevant space data/info from a single source;
  - Some information is specific and requires detailed user information/experience to decipher;
  - More explanation of potential outcomes/impact should be presented with outage/degradation alerts—but this may increase the classification level and if so should be conducted with discretion to ensure accessibility of information.

Workload

Question 91: What recommendations would you make to improve the level of workload in your job?

- Small section that is growing; thus the heavy workload…this will self-correct as pers are added.
- Resources also growing.
- To improve:
  - Integration of info in a manner that provides easy scan of most pertinent and time critical info.
  - Creation of job-specific UDOP for display of space info.

- WL will improve through increases in personnel and resources.
- Better define lines of external requests for assistance.
- More people, ideally civilian staff to perform admin roles and remove small but numerous tasks that everyone is doing.
- Subordinates for business continuity if I am sick, on exercise/deployed or posted.
- Wide variety of tasks requires extra training and focus to be divided among them.
- Recommend increase manning with clearly defined roles.
- Given that the CANSpOC is limited in personnel yet unlimited in need of effort (bold mine); the SWCC's should each be given a project to complete in reasonable amount of time. This has the added benefit of assisting with work product as well as educating the member doing the work, Mission first absolutely, but there is room in a shift, a go several goes, to get some staff work completed.
- More manning.
- Focus on key tasks.
- Clear authorities.
- More trained and experienced space personnel would be a strong asset to this unit and the CF.

Personnel

Question 94: What changes to personnel could be made to improve the space COP at CANSpOC?

- We need someone (or two) are able to maintain the COP software...Ex if the software crash during the x-most leave.
- More staff, more shift workers would allow additional staff in day shift are to complete tasks.
- More day staff to accomplish goals of CANSpOC, currently one staff officer position is empty.
- Increase manning of space watch.
- Integrate (i.e., collocate) watch, int, and Ops analysis in same workspace with same access to information.
- Everything is good so far.
- I have little understanding of what the day staff does day-to-day (other than training) so do not know if they need more personnel.
- Watch O makes himself available at all times.
- DSOR—responds to after hour emails/alerts on a timely/consistent basis.
- More personnel required to maintain standards and training.
- Huge influx of new personnel with different skillsets/knowledge which demanded a lot of focus on training.
- We work together to support each other and get critical tasks done.

- We shouldn't need to do this as frequently as we are.
- We are forced to do this due to limited staff.
- More people.
- Increased number of people to cover the wide variety of tasks/responsibilities and provide the 24/7 coverage.
- More personnel, more on shift exercise, more cross communication between sections Really comes down to "more, more, more."
- I do think that the CANSpOC is rank heavy on the NCM side, not that we need less senior NCOs, we need some junior NCMs…there are many opportunities for an NCM to advance a project or inject an idea.
- See Maj. Maskell's draft CANSpOC 2025+ plan.
- The operations section barely has enough trained pers to support its mandate of 24/7 CJOC support and maintain a deployment cycle of 2 JSST (deployment) teams.
- This section will only get sores (sic) as we grow and the CF realizes its need for our services.

Skills and Training

Question 99: If you answered "Disagree" or "Strongly Disagree" to any of the previous questions, please explain you answer.

- I have received sufficient training IOT accomplish my assigned tasks. However, IOT advance further in both my abilities and understanding of the space environment further formal training will be required.
- As a member (leader) of an esoteric section and given my personal knowledge levels and SME, no one else can really mentor me from a technical/ops POV. This is only specific to me, though.
- There should be a more "formal" method of trg new pers so we all have the same trg. Learning from your peers is great to learn in different styles, however, some have more knowledge than others. A more forma trg before doing your own watches would help.
- Training was a bit short to feel entirely comfortable.
- Trg NCM was also the evaluator so could not spend too much time trg me (more manning needed).
- Consistent training to all watch members so that there are no discrepancies on performing tasks.
- I did a lot of "self-taught" training due to the timeline of my formal training.
- Other members aren't always keen on broadening their knowledge unless taught or directed.
- Mission assurance: not well defined in Canada and not well defined what my tasks should be.
- I had previous SATCOM experience and general interest in space so I learned a lot on my own initiative.
- Although I am doing my best to create SOPs and handover document, that shouldn't be my job.
- We are vacant in many positions.

- We have fewer people than we need to run the space watch 24/7 and match the CFICC schedule.
- “noform” over classification makes things very difficult at times.
- I am new to the unit and cannot comment on my training yet.
- I have an experienced co-worker who is helping me greatly.

List of Symbols/Abbreviations/Acronyms/Initialisms

ADM(IM)	Assistant Deputy Minister (Information Management)
CAF	Canadian Armed Forces
CANSpOC	Canadian Space Operations Centre
CD&E	Concept Development and Evaluation
CFD/DG	Chief Force Development/Director Genera;
CFINTCOMM	Canadian Forces Intelligence Command
COP	Common Operating Picture
CSE	Cognitive Systems Engineering
DRDC	Defence Research and Development Canada
HF	Human Factors
ISR	Intelligence, Surveillance and Reconnaissance
MMS	Man-Made Systems
NATO	North Atlantic Treaty Organization
SA	Situational Awareness
SCOP	Space Common Operating Picture
SoS	System-of-Systems
SSA	Space Situational Awareness
SSO	Space Surveillance Operations
TCPED	Tasking, Collection, Processing, Exploitation, Dissemination

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The report is based on the results of a survey developed for members of the Canadian Space Operations Centre (CANSpOC) to reveal and understand the Human Factors (HF) issues relevant to operations at the CANSpOC. The results of this survey were first presented to the members of CANSpOC as a Scientific Letter (DRDC-RDDC-2017-L119). The current report provides an expanded version of the original Scientific Letter in terms of the detail of the findings and the inclusion of the raw data obtained in the survey. The findings revealed that there are significant HF issues that impact the effectiveness and efficiency with which members of the CANSpOC operate. These findings will contribute to the development of HF evaluation methodology to augment the current space common operating picture concept development and evaluation process.

Le rapport est fondé sur les résultats d'un sondage destiné aux membres de la Cellule des opérations spatiales canadienne (CANSpOC) et visant à déterminer les facteurs humains (FH) pouvant poser problème dans les activités de la CANSpOC. Les résultats du sondage ont d'abord été présentés aux membres de la CANSpOC sous forme de lettre scientifique (DRDC-RDDC-2017-L119). Le présent rapport donne des précisions additionnelles sur les données brutes tirées du sondage et les conclusions qui en ont été tirées. Selon les résultats, certains enjeux liés aux facteurs humains ont une incidence importante sur l'efficacité et l'efficience des activités des membres de la CANSpOC. Les résultats devraient permettre de concevoir des méthodes d'évaluation des facteurs humains en vue d'améliorer le processus actuel d'élaboration et d'évaluation du concept d'image commune de la situation opérationnelle dans l'espace.

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Human Factors; Space Common Operating Procedure