Multinational Experiment 7 Collaborative Space Mitigation Concept

An Assessment of Political Acceptability

Ian M. Chapman
DRDC CORA

The opinions expressed in this paper are those of the author and should not be interpreted as the official position of the Canadian Forces or the Department of National Defence.

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Abstract

Within the scope of the Multinational Experiment 7, the Canadian Forces have developed a Collaborative Space Mitigation Concept (CSMC) to mitigate the risk of losing access to existing space capabilities. This concept proposes the development of partnership agreements for the sharing of space capability in the event that space assets or the access to them are lost.

The formation of a space mitigation agreement is dependent on the partnering nations being able to negotiate politically acceptable provisions and limitations. A limited objective experiment was held in Lucerne, Switzerland to investigate the factors necessary to obtaining politically acceptable space mitigation agreements. International subject matter experts participated in the experiment, using two methodologies (an open tabletop discussion and a Swiss military decision support system, known as CREDO) in the investigation.

This report provides results from the limited objective experiment, discussing the level of political acceptability for a number of partnership agreements which were created by the participants. Findings on the likelihood of obtaining political acceptability, the degree of political acceptability, and the necessary provisions and limitations are discussed.

Résumé

Dans le cadre de l'Expérimentation multinationale 7, les Forces canadiennes ont élaboré un Concept collaboratif d'atténuation des pertes de capacités spatiales (CSMC pour *Collaborative Space Mitigation Concept*) qui vise à atténuer les risques de perte d'accès aux capacités spatiales actuelles. Ce concept propose de conclure des ententes de partenariat permettant le partage des capacités spatiales dans l'éventualité où certains biens spatiaux, ou l'accès à ces biens, seraient perdus.

La signature d'une entente visant l'atténuation des pertes d'accès aux capacités spatiales dépend de la capacité des pays partenaires à négocier des dispositions et des limites acceptables sur le plan politique. Une expérience à objectif limité a été menée à Lucerne, en Suisse, afin de déterminer les facteurs essentiels à l'élaboration d'ententes politiquement acceptables. Les experts internationaux qui ont participé à cette expérience ont eu recours à deux méthodes dans le cadre de ces recherches, soit la tenue de discussions ouvertes et l'utilisation d'un système d'aide à la décision de l'armée suisse désigné sous le nom de CREDO.

Le présent rapport contient les résultats de cette expérience à objectif limité et traite du niveau d'acceptabilité, sur le plan politique, de diverses ententes de partenariat élaborées par les participants. On y présente les conclusions relatives à la probabilité de parvenir à des ententes acceptables politiquement, au degré d'acceptabilité sur le plan politique ainsi qu'aux dispositions et aux limites nécessaires.

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Executive summary

Multinational Experiment 7: Collaborative Space Mitigation Concept: An Assessment of Political Acceptability

Ian M. Chapman; DRDC CORA TM 2013-122; Defence R&D Canada – CORA; August 2013.

Background: The goal of the Multinational Experiment 7 (MNE 7) was to develop and test concepts and capabilities for anticipating, deterring, preventing, protecting against and responding to a disruption or a denial of access to the global commons domains (maritime, space, and cyber) and for ensuring freedom of action within them, while taking into account their inter-relationships. Within the scope of MNE 7, the Canadian Forces Director General Space (DG Space) developed a Space Mitigation Concept called the Collaborative Space Mitigation Concept (CSMC). This concept assumes that two nations can develop and agree to a partnership agreement according to which one nation would provide some space capabilities in the event that the other nation would suffer from degradation and/or loss of space capabilities.

The effectiveness of the developed concept depends on three aspects: the partnering nation's space capacity (which will impact on its capacity to share); the interoperability between the two nations (which will impact on the time required for the sharing of the space products); and the factors affecting the political acceptability of potential partnership agreements between the two nations. This technical memorandum provides an assessment of the political acceptability aspect.

Methodology: In October 2012, the Canadian Forces Warfare Centre (CFWC) conducted a limited objective experiment with international participants in Lucerne, Switzerland to investigate factors affecting the political acceptability of space mitigation agreements based on the CSMC. Using a scenario-based approach, the political acceptability of partnerships in the Intelligence, Surveillance, and Reconnaissance (ISR), Satellite Communications (SATCOM), and Space Situational Awareness (SSA) pillars was discussed.

Participants used two methodologies during the experiment: open tabletop discussions and a Swiss military decision support system known as CREDO. Participants worked in two groups to discuss the conditions necessary to obtain politically acceptable mitigation agreements and data were collected using the two methodologies.

Results: The results from the limited objective experiment confirmed that CSMC is a viable framework for creating space mitigation partnerships, as both groups of participants were able to obtain politically acceptable agreements for some of the scenarios in each of the space pillars considered.

The experiment revealed that the most important factor affecting the political acceptability of a space mitigation agreement is the type of partner being considered. Partnering with an Ally or Peer nation was highly preferred over partnering with a Questionable nation. The participants indicated that they would not consider partnering with an Antagonistic nation for space mitigation. Furthermore, a commercial arrangement was seen to be more preferable than a partnership with a less friendly nation in the absence of political mandates to develop a closer

relationship. The capability of the partner nation played a far less important role in determining the political acceptability of the partnerships.

The scenarios involving the SSA pillar allowed participants to discuss the need for an international body to coordinate the space traffic management function. This would allow for an increase in the number of opportunities to observe space objects, improve location and tracking data, and provide a forum for collaboration on difficult problems such as debris field simulation.

Significance: The results from the limited objective experiment confirmed that the CSMC is a valid framework for the establishment of partnerships for space mitigation and confirmed the identification of important factors to consider when negotiating the terms of the agreements. This confirmation will lead to the refinement of CSMC as a concept, and could result in a reduction in the risk of losing access to space capabilities for Canada and its international partners.

The limited objective experiment also represented an important demonstration of the viability of CREDO in supporting decision makers. By reducing the question of political acceptability to a relatively simple model, analysts were able to identify important data trends, including the most important factor in the decision.

Future plans: Further concept development and experimentation is required for CSMC. In particular, experimentation using red teaming to represent the mitigating partner is required to identify the trade-offs that will be negotiated in order to obtain agreements. Further work investigating policy and legal implications is also required.

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Multinational Experiment 7: Collaborative Space Mitigation Concept: An Assessment of Political Acceptability

Ian M. Chapman ; DRDC CORA TM 2013-122 ; R & D pour la défense Canada – CARO; août 2013.

Contexte : L'objectif de l'Expérimentation multinationale 7 (EMN 7) était d'élaborer et de mettre à l'essai des concepts et des capacités visant à prévoir et à empêcher l'interruption ou le blocage de l'accès aux domaines du patrimoine mondial (mer, espace et cyberespace), à se protéger contre ces situations et à y réagir, ainsi qu'à jouir d'une liberté d'action à l'intérieur de ces domaines, en tenant compte de leurs rapports mutuels. Dans le cadre de l'EMN 7, le directeur général – Espace (DG Espace) des Forces canadiennes a élaboré un concept d'atténuation spatial appelé Concept collaboratif d'atténuation des pertes de capacités spatiales (CSMC). Ce concept suppose que deux pays peuvent élaborer et conclure une entente de partenariat selon laquelle un des deux pays fournirait certaines capacités spatiales à l'autre si ce dernier venait à subir une dégradation ou une perte de capacités spatiales.

L'efficacité du concept proposé dépend des trois facteurs suivants : les capacités spatiales du pays partenaire (desquelles dépendra sa capacité à partager), l'interopérabilité entre les deux pays (qui aura une incidence sur le temps requis pour le partage des produits spatiaux) et les facteurs influant sur l'acceptabilité, sur le plan politique, des ententes de partenariat potentielles entre les deux pays. La présente note technique contient une évaluation de l'aspect lié à l'acceptabilité sur le plan politique.

Méthode : En octobre 2012 à Lucerne, en Suisse, le Centre de guerre des Forces canadiennes (CGFC) a mené une expérience à objectif limité en collaboration avec des participants internationaux afin d'étudier les facteurs ayant une incidence sur l'acceptabilité, sur le plan politique, d'ententes d'atténuation des pertes de capacités spatiales fondées sur le CSMC. En se fondant sur divers scénarios, les participants y ont discuté de l'acceptabilité, sur le plan politique, de différentes ententes relatives aux domaines phares suivants : renseignement, surveillance et reconnaissance (RSR), télécommunications par satellite (SATCOM) et connaissance de la situation dans l'espace.

Les participants ont eu recours à deux méthodes au cours de cette expérience : des discussions ouvertes et un système d'aide à la décision de l'armée suisse appelé CREDO. Les participants ont travaillé en deux groupes afin de discuter des conditions requises pour parvenir à des ententes d'atténuation acceptables sur le plan politique. Des renseignements ont été obtenus par le biais de ces deux méthodes.

Résultats : Les résultats de l'expérience à objectif limité ont permis de confirmer que le CSMC constitue un cadre de travail viable pour l'établissement d'ententes d'atténuation des pertes de capacités spatiales, puisque les deux groupes de participants sont parvenus à obtenir des ententes politiquement acceptables pour certains des scénarios dans chacun des domaines phares considérés.

L'expérience a révélé que le type de partenaire envisagé est le principal facteur influant sur l'acceptabilité, sur le plan politique, d'une entente d'atténuation des pertes de capacités spatiales. On privilégie largement les partenariats conclus avec des pays alliés ou semblables plutôt qu'avec des pays sujets à méfiance. Les participants ont indiqué qu'ils n'envisageraient pas d'établir un partenariat avec un pays antagoniste pour l'atténuation des pertes de capacités spatiales. En outre, on considère qu'il est préférable de passer un accord commercial plutôt que d'établir un partenariat avec les pays moins amicaux en l'absence de mandats politiques pour établir une relation plus étroite avec ces pays. Les capacités des pays partenaires constituent un facteur beaucoup moins important pour déterminer l'acceptabilité des partenariats sur le plan politique.

Les scénarios liés à la connaissance de la situation dans l'espace ont amené les participants à discuter de la nécessité de mettre en place un organisme international pour coordonner la gestion du trafic spatial. La création d'un tel organisme multiplierait les possibilités d'observation des objets spatiaux, améliorerait les données de localisation et de suivi, et permettrait aux divers pays de relever conjointement des défis de taille, par exemple la simulation de champs de débris.

Importance : Les résultats de l'expérience à objectif limité indiquent que le CSMC est un cadre de travail valable pour l'établissement de partenariats visant l'atténuation des pertes d'accès aux capacités spatiales et confirment les facteurs importants à prendre en compte au moment de négocier une entente de partenariat. Ces conclusions contribueront à améliorer le CSMC et pourraient permettre de réduire les risques, pour le Canada et ses partenaires internationaux, de perdre leur accès aux capacités spatiales.

L'expérience à objectif limité a également permis de démontrer très clairement la viabilité du CREDO en tant qu'aide à la décision. En réduisant la question d'acceptabilité politique à un modèle simple, les analystes ont été en mesure d'établir les tendances relatives aux données, y compris le facteur le plus important de la prise de décision.

Recherches futures : Le CSMC nécessite une élaboration et une expérimentation plus poussées. Il faudra notamment utiliser des équipes rouges pour représenter les partenaires d'atténuation dans le cadre des expériences afin de déterminer les compromis qui devront être négociés pour obtenir des ententes. Les implications politiques et juridiques devront également être examinées plus en profondeur.

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1 Introduction

1.1 Background

The goal of the Multinational Experiment 7 (MNE 7) was to develop and test concepts and capabilities for anticipating, deterring, preventing, protecting against and responding to a disruption or a denial of access to the global commons domains (maritime, space, and cyber) and for ensuring freedom of action within them, while taking into account their inter-relationships [1]. Three domain Outcomes were identified during the campaign planning and design meetings: Maritime, Space and Cyberspace. In addition, a separate Outcome focused on Inter-domain Understanding. The Space Outcome (Outcome #2) addressed the following three objectives:[1]

- Objective 2.1: Delivering a space handbook that identifies dependencies, vulnerabilities and threats to space-based systems;
- Objective 2.2: Developing strategic analysis of influence and deterrence with the intent to investigate how actor behaviour may be modified in a constructive way in order to protect our access to space; and,
- Objective 2.3: Proposing concepts to mitigate the effects of efforts to disrupt or deny access to space in the event that influence or deterrence fails.

With regards to the first objective (2.1), the United Kingdom led the development and publication of a space handbook [2]. This handbook describes military and civilian dependencies on space systems, the vulnerabilities of such systems and the threats that they face. Within the scope of Objectives 2.2 and 2.3, concepts were developed to identify mechanisms to deter or influence actors that could threaten (voluntarily or not) space systems [3], as well as concepts to mitigate the impact following the disruption or denial of access to space capabilities [4]. These two concepts were tested in October 2012 within the MNE 7 Space Limited Objective Experiment (LOE). The results from this experiment were also used to update and refine the Space Handbook developed within the scope of Objective 2.1 to incorporate recommendations for the deterrence of space threats and mitigation in the event of a loss of assets.

Canada led the efforts to meet Objective 2.3: Space Mitigation. For this purpose, several activities were initiated. Between August 2011 and January 2012, Canada developed, disseminated, and analyzed a space mitigation survey to identify existing and planned mitigation means used by military and civilian organizations. The survey has confirmed existing gaps in the mitigation means available [5]. The development of a collaborative space mitigation approach was also identified as a promising approach for mitigating possible loss of space assets. With the possible exception of high-altitude airships, all non-space-based means were judged inadequate to appropriately mitigate the loss of space access to Positioning, Navigation, and Timing. Furthermore, a collaborative approach to space mitigation was judged ideal for the following reasons:

[1] Initially a list of eight objectives was developed for the Space Domain [1]. These initial objectives were later grouped into the three objectives provided here.

- Nations desire redundant capabilities and this implies a certain amount of excess capacity beyond their required level. This excess could be shared across nations through the establishment of interoperable systems.
- The establishment of an optimized, collaborative constellation of satellites will provide an increased capability compared to the sum of the capabilities provided by independently-operated groups of satellites (with the same total number of satellites and same payload).

Based on these assumptions, the Collaborative Space Mitigation Concept (CSMC) was developed by the Canadian Directorate General for Space (hereafter referred to as DG Space). This concept suggests the development of space partnership agreements between nations as a risk management mechanism so that upon the loss of a given space asset, the impact of this loss can be mitigated through the use of assets provided by the partnering nations (assuming that their assets have not been affected).

Although the CSMC appears promising, a few aspects of this concept were questioned. Specifically, the following three aspects of the concept required further analysis:

- Performance. For the CSMC to be useful, it must provide as efficient mitigation means as those available through other mitigation concepts.
- Interoperability. For the CSMC to be useful, some degree of interoperability needs to be reached between the participating nations. If the collaborative interoperability requires too much effort for its implementation, it is unlikely that the CSMC will be successfully implemented.
- Political Acceptability. For the CSMC to be useful, the nations involved in the partnership agreement need to agree to increase their interdependence as implied by the agreement. A major factor impacting on the political acceptability is the nations' respective trust since there are no enforcement measures to ensure that each signing party of CSMC will obey and respect the included provisions of the agreement (this is a similar issue as the one encountered in international trade law [6]).

The Space Mitigation experiment campaign focused on assessing these three aspects of the CSMC. Different approaches were used for each aspect. The performance of the CSMC was analyzed through the use of constructive simulations, specifically the Systems Tool Kit (STK). The interoperability aspect was assessed through the use of case studies based on a well-known model for organizational integration. Finally, the political acceptability aspect was investigated during the Space Mitigation limited objective experiment (LOE), involving subject matter experts from the international community. This LOE was held at the Swiss Armed Forces College in Lucerne, Switzerland from 1 to 5 October, 2012.

1.2 Aim of the Report

The Space Mitigation LOE investigated the conditions and limitations necessary for a mitigation agreement to be considered a politically acceptable partnership. Two methodologies were used in this investigation: an open-form tabletop discussion and a Swiss decision-support tool, known as CREDO [7].

This report provides a brief summary of the Collaborative Space Mitigation Concept and its application for facilitating international space mitigation partnerships. The report includes a detailed description of the Space Mitigation LOE design and the methodologies used to collect data from space subject matter experts. The report discusses the analysis of the collected data and presents results and recommendations from the analysis. This report also discusses the lessons learned during the execution of the LOE, which can be applied to similar future events.

1.3 Outline of the Report

The report is divided in 5 different sections. The content of each of the subsequent sections is as follows:

- Section 2 provides a description of the CSMC and the different types of partnership agreements.
- Section 3 describes the methodologies used in the LOE to investigate the political acceptability of CSMC partnership agreements.
- Section 4 provides the initial results from the LOE.
- Section 5 concludes the report and provides lessons learned.

2 Collaborative Space Mitigation Concept

2.1 Overview

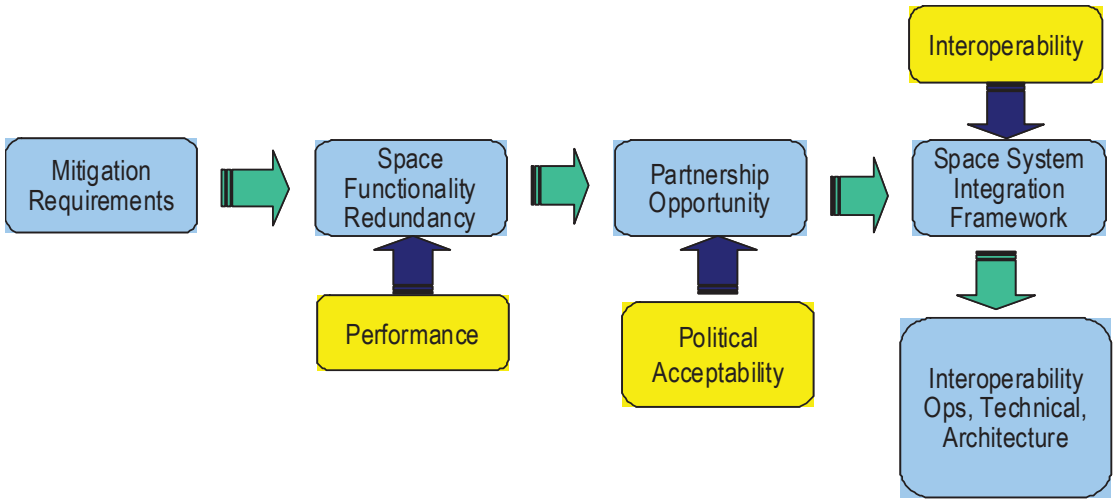

Figure 1: Overview of the five steps of the CSMC (from reference [4]).

The CSMC [4] proposes to leverage latent space capacity across various nations as an efficient approach to manage the risk of space defence and space deterrence failure. The main assumption of the CSMC is that in the event that a space asset is lost or degraded due to threats and hazards, the partnership agreement would provide access to alternate space assets for a period of time while the degraded or lost assets are being repaired or replaced or other means are being made available. It is assumed that the alternate space assets would only mitigate the lost capacity and it would not replace fully and/or completely the lost capabilities.

The two key ingredients to the CSMC are the development of partnership agreements and the implementation of some degree of space interoperability. It is assumed that these two ingredients would be developed and implemented well before the sharing of space capabilities would be requested due to the loss or degradation of one of the partnering nation's assets.

The CSMC proposes a five-step approach for the development and implementation of partnership agreements [4]. These steps are illustrated in Figure 1. The five steps are shown in blue with green arrows indicating the following step. Each of the three aspects of interest mentioned earlier (performance, political acceptability, and interoperability) figures primarily in one of the steps as indicated in this figure by the yellow boxes.

In the first step of the CSMC, the capability developer needs to identify the operational requirements that the mitigation measure must satisfy in the event of loss or degradation of a space asset to threats or hazards. The mitigation operational requirements identify the payload (e.g. sensor) capacity and capability as well as the readiness (i.e. how quickly it will need to be implemented) and duration (i.e. for how long the mitigation would be needed).

In the second step of the CSMC, the capability developer needs to identify the space system functional redundancy needed to achieve the mitigation operational requirements. This can include payload redundancy, platform redundancy, communication link redundancy, etc.

The third step consists of the identification of partnership opportunities likely to yield the required functional redundancy. More precisely, it requires the identification of potential partners that could provide the needed redundancy and determine the feasibility and viability of a partnership agreement with such partners.

The fourth step assists in identifying the cost of the space mitigation strategy by using frameworks such as the Doctrine, Organisation, Training, Materiel, Leadership, Personnel, Facilities and Interoperability (DOTMLPFI). This step consists of identifying the various integration mechanisms that will be required to implement the mitigation means. This is an important step, within which the capability developer needs to determine the type of control that would be provided under the partnership agreement to meet the mitigation requirements identified in step 1. In particular, the capability developer should identify whether direct access to the satellite raw data and payload command and control would be needed.

The fifth and last step to CSMC consists of the articulation of the operational, technical and architectural interoperability to achieve the required system integration. Operational interoperability would be articulated through documents such as operating concepts, functional concepts, and Techniques, Tactics and Procedures. Technical interoperability would be articulated in data format and exchange protocols. The architectural interoperability would be articulated through the communication infrastructure, data volume and exploitation, and distribution.

Although interoperability is the focus of the fourth step, this aspect is of importance in the last three steps. In fact, the importance of space interoperability for coalition operations is not new to the CSMC and has been highlighted by various NATO members. In particular, Thomas Single from the Joint Air Power Competence Centre stated: “It seems though, that the major hurdle is not the technology or availability of space-based ISR systems, rather, it is the lack of data policy and management for space-based intelligence. There is a tremendous amount of existing capability if we can only connect our customers in the field with those Space Capabilities” [8]. Although interoperability is often treated as a technical problem, the most significant barriers in this instance appear to be the policies that interfere with information exchange.

2.2 Types of CSMC Agreements

The various types of partnership agreements developed through the CSMC approach can be categorized according to the following considerations:

- Data access: Whether the partnering nation will have direct access to the signal from the satellite payload or whether only the owner of the satellite has direct access and only processed data is provided.
- Payload control access: Whether the partnering nation will have direct access to the control of the satellite payload (for example to determine the size of the swath and direction of look

for ISR payload) or whether only the owner of the satellite has control of the payload and the partnering nation has to request tasking of the payload settings.

- Satellite Tracking, Telemetry, and Control (TT&C): Whether the partnering nation will have access to the satellite TT&C or whether only the owner of the satellite has access to the TT&C.
- Incidents coverage: What types of incidents that cause denial or degradation of space capabilities assets will result in the activation of the mitigation measures? Are incidents due to human error covered by the mitigation agreement? What amount/type of incident reporting is required?
- Compensation: Whether some monetary compensation is provided by the nation requesting mitigation for the loss of capability to the owner of the satellite and how this compensation might evolve through the duration for which space capabilities are provided.
- Readiness: The gap time between the reporting of a loss or degradation by one country and the establishment of the sharing of the space capability.
- Duration determination mechanism: The mechanism that will be used to determine the length of time space capability will be shared. Is space capability provided for as long as the space failure not been resolved? Is it only provided for a short duration and in case of emergency?
- Caveats: Whether any caveats are imposed to the requesting nation with regards to the purpose of use of the provided space capability and/or geographical limitations. For example, a nation can be willing to provide ISR capabilities to its partnering nation except if this ISR capability is used to survey its own territory or for military use.

These various aspects are not all independent. For example, if more access (access to payload control, etc.) is required this could impact on the readiness of implementing the sharing of the space capabilities. Furthermore, one could argue that some aspects, such as the sharing of satellite TT&C would never be considered.

From a technical point of view, the three “Access” aspects are not independent, but rather represent an increase in the degree of access shared. In fact, the access shared can be limited to four different values:

- No direct access is provided. Only processed data is shared with the partnering nation.
- Direct access is limited to the provision of raw data. All requirements for changes to the payload configuration and satellite TT&C has to be requested to the nation owning the satellites.
- Direct access includes access to the payload control and raw data. No access to the satellite TT&C is shared.
- Access to raw data, payload control, and satellite TT&C is shared between nations. The sharing is based on agreed scheduling and prioritization.

2.3 Challenging the CSMC

As discussed in Section 1.1, the CSMC was challenged in three areas:

- Performance: Does the CSMC provide mitigation as effective as that available through other means?
- Interoperability: What level of effort is required to achieve the interoperability required to make a CSMC agreement work?
- Political Acceptability: What provisions and limitations should a CSMC agreement include in order to make it sufficiently acceptable to the participating nations?

While separate analyses have been conducted for the first two questions [9], [10], the question of Political Acceptability was investigated during the LOE held in Switzerland in October 2012. For the purposes of the LOE, Political Acceptability was defined as "the perceived level of comfort with committing to a mitigation agreement, from a nation's overall point of view."

The main goals of the LOE were to identify the factors with the most impact on Political Acceptability. Furthermore, the experiment sought to provide an understanding of the specific provisions and limitations in a partnership agreement for space mitigation that would result in the best chance for political acceptance.

Section 3 describes the design of the LOE and the methodologies used for investigating Political Acceptability.

3 Experiment Design and Methodologies

3.1 Scope

As a part of the MNE 7 campaign plan, a five-day event was planned for the exploration of factors affecting the political acceptability of CSMC agreements. This event included a series of introductory briefings on the first day, three full days of experimentation, and a final day for After-Action Reviews, back briefings, and an analysis hot wash.

Because of the novelty of the CSMC as a concept, the Space Mitigation LOE was seen as a discovery activity, exploratory in nature. However, as this was a *limited* objective experiment, the scope of the investigation was highly constrained (especially due to the limited amount of time available). Although there are many factors that might impact the political acceptability of a specific CSMC agreement, only a small portion of these could be addressed during the LOE. Hence, the focus for the Space Mitigation LOE was constrained to bilateral partnerships and only three different groups of factors were considered:

- Partnering context: The type of nation with which the partnership agreement is established and the experience and capability level of the partner nation in a given space pillar.
- Sharing provisions: The degree of access provided to each party with regards to satellite signals and payload command and control as well as the type of compensation required from each party.
- Caveats: The constraints imposed on each party with regards to the purpose for which the capability will be used, as well as the limitations on where the capability can be used.

For simplicity, the values for the partnership context were limited to a few options describing the partner nation type and its capability level. For the LOE, the type of nation for the partnership was limited to four generic types (specific nation names were not used):

- Ally: Long-term ally with pre-existing commercial and military partnership agreements.
- Peer: Have engaged in a limited number of previous partnerships. The nation is perceived positively by ally nations.
- Questionable Nation: Existing partnership is limited to commercial exchange and there are concerns whether the nation can be trusted.
- Antagonist: The nation has had recent political conflicts with ally nations.

The capability level of the partner was limited to the following three options:

- Advanced: The partner nation is among the most advanced nations in the world with respect to the space capability being discussed. It has demonstrated consistent success in deploying such a capability and/or possesses state-of-the-art technology in the field.
- Average: The partner nation has a limited history of successfully deploying similar space capabilities and/or possesses technology which is widely available amongst other nations.

- New to Space: The partner nation has not yet successfully deployed a similar space capability.

The space pillars discussed during the LOE were:

- Intelligence, Surveillance, and Reconnaissance (ISR): Capability to perform the synchronized and integrated planning and operation of all collection capabilities, as well as the processing and dissemination of the resulting data to the right people, at the right time, in the right format, to support operations.
- Satellite Communications (SATCOM): Capability to transport information using a satellite link. This includes both voice and computer data.
- Space Situational Awareness (SSA): Capability ability to obtain information and knowledge about the space beyond the Earth atmosphere. For the purpose of this LOE, this refers to the capability to gather information for Space Traffic Management (STM). Another subset of SSA, called Space Object Identification (SOI) was not considered due to the sensitive nature of the information.

Taken together, the partner type, partner capability, and space pillar were the input, or controlled, variables for the LOE, and permutations of these variables were presented as scenarios for the participants to consider.

3.2 Experimental Design

A series of three vignettes was written, one for each space pillar discussed in the previous subsection. Full text reproductions of the vignettes can be found in Annex B, Annex C, and Annex D. Scenarios based on the vignettes were created by iteratively changing the type of partner and partner capability, such that a full exploration of the data space was accomplished.

Discussion of each of the scenarios allowed analysts to capture data on the sharing provisions and caveats required to obtain a politically acceptable mitigation agreement. These factors represented the output, or dependent variables, along with the level of political acceptability.

In terms of sharing provisions, there were two sub-factors identified as impacting the political acceptability. The first sub-factor was access limitation, which referred to the amount of control that the mitigated nation has over the mitigating access. For example, the mitigating nation may only provide processed data or could provide raw data to the partner. The other sub-factor identified was compensation. This sub-factor refers to the compensation (monetary or otherwise) that would be required in order to make the mitigation agreement work.

In terms of the caveats, two other sub-factors were identified as having impact on the political acceptability. The first sub-factor was the limitation that the mitigating nation would impose on the purpose for which the capability could be used. For example, the mitigating nation may require that any ISR data that it provides must not be used where the potential for collateral damage involving human life is high. The second sub-factor was geographic limitation, which refers to exclusions that the mitigating nation would enforce on the data provided to the partner nation. An example of an exclusion could be any imagery that contains data that would endanger the mitigating nation's national interests.

Table 1: Schedule of Partnership Limitations Development Methodology for Each SMEs Group

Experiment Day	Group 1	Group 2
Day 2 (AM & PM)	Open discussion	CREDO exercise
Day 3 (AM)	Open discussion	CREDO exercise
Day 3 (PM)	CREDO exercise	Open discussion
Day 4 (AM & PM)	CREDO exercise	Open discussion

Participants in the LOE were split into two groups and tasked with developing CSMC agreements based on the vignettes. The groups made use of two methodologies in their discussions, but reversed the order in which they proceeded, as seen in the experiment schedule in Table 1. Group 1 used an open tabletop discussion first then used a Swiss decision-support system, known as CREDO[2] [7]. Group 2 started with CREDO and then moved to the open discussion method. Each of these methods is discussed in the following sections.

3.3 Open Tabletop Discussion

Space Mitigation Partnership Agreement Constraint

Objective: Determine the constraints required for the partnership agreement to be politically acceptable.

Vignette description:	Space Pillar: (PNT, SATCOM, ISR, SSA)	Partnering Nation: (Ally, Peer, Questionable, Antagonist)	Partner Capability: (Advanced; Some Capabilities; New to Space)	
Limitations, Constraints:	Level of Access Provided to the Nation Requesting Space Capability	Compensation Provided by the Nation Requesting Space Capability	Purpose Limitations Imposed on the Nation Requesting Space Capability	Geographical Limitations Imposed on the Nation Requesting Space Capability
Relative to Nation A:				
Relative to Nation B:				
Other Limitations:				
Reasons for lack of Politically Acceptable agreements if no option appears feasible:				
Level of Political Acceptability:				

Figure 2: Data capture form for the open tabletop discussion methodology.

During the open tabletop discussion, a group of Subject Matter Experts (SMEs) knowledgeable of their national space policies were asked to develop partnerships that would be considered politically acceptable, based on the factors identified for discussion. A data capture form, seen in Figure 2, was projected onto the board in order to focus the SMEs on the factors to be discussed. This also allowed the SMEs to ensure that their discussion points were captured accurately in the experimental record.

This exercise was repeated, subsequently considering each possible partnering nation type and each possible space pillar. Due to time constraints, only one partner capability level was investigated in each space pillar. For the ISR and SSA pillars, the partner was assumed to have an

[2] CREDO [7] is a tool developed by the Army of Switzerland that allows the development of credal network to model the decision process of decision makers. Credal networks are a generalization of Bayesian networks that are suitable for handling incomplete, contrasting, and unfeasible information.

advanced level of capability. For the SATCOM pillar, the partner nations were assumed to have average capabilities.

Full partnership agreements were not developed during the discussions; the development was limited to the identification of limitations and constraints that would be required to make the partnership politically acceptable. Specific vignettes were presented to the participants to provide context with regard to the use of the partnership (see Annex B, Annex C, and Annex D for vignette details).

The discussions were facilitated by an analyst, who also acted as the data recorder. Findings from the open discussion sessions can be found in Section 4.1.

3.4 CREDO Exercise

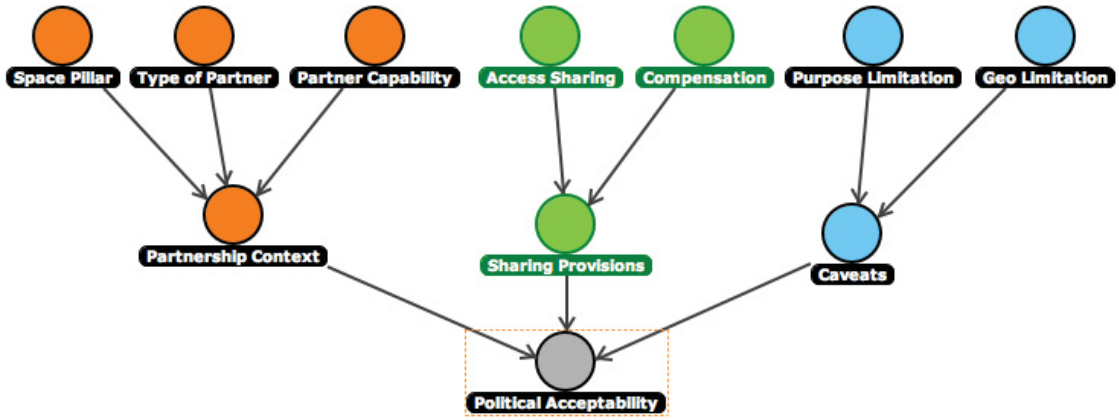

Figure 3: Visual representation of a simplified model of the political acceptability of a space mitigation partnership agreement used in the CREDO exercise.

During the CREDO exercise the SMEs considered a simplified model of a decision on the political acceptability of forming a partnership agreement for mitigation of a given space capability. This model, represented in Figure 3, was developed by members of the experimentation team in the months leading up to the LOE. The model consists of a decision variable (i.e. Political Acceptability), summary variables (i.e. Partnership Context, Sharing Provisions, and Caveats), and a number of input variables which were dependent on the scenario and the SMEs' decisions.

Summary variables are used in CREDO in order to reduce the number of permutations of variables that must be considered when evaluating the summary variable. For this model, the summary variables were restricted to three values each. The Partnership Context variable could take the value of Favourable, Neutral, or Unfavourable. The Sharing Provisions variable took the value of Altruist-Broad, Limited Monetary, or Commercial. The Caveats variable took the value of No Limitations, Mildly Limited, or Strongly Limited. The decision variable, Political Acceptability, could take one of two values: Acceptable or Unacceptable. Full definitions of all variables and their states can be found in Annex A.

In the first phase of the CREDO exercise, SMEs were asked to develop a dictionary of terms describing the likelihood of a variable taking a given value. The first group to take part in the CREDO exercise developed the terms and upper and lower bounds of probability for each, as shown in Table 2. The second group to take part in the CREDO exercise adopted the first group's dictionary, rather than develop its own.

Table 2: Dictionary of terms used in CREDO exercise.

Term	Lower Bound	Upper Bound
No - idea	0%	100%
Most likely	90%	100%
Very likely	80%	90%
Likely	65%	80%
Fifty-fifty	35%	65%
Unlikely	20%	35%
Very unlikely	10%	20%
Most unlikely	0%	10%
Certain	100%	100%
Impossible	0%	0%

In the next phase of the CREDO exercise, the SMEs used the dictionary to evaluate the likelihood of Political Acceptability being Acceptable for all 27 permutations of the summary variables (three variables with three states each). The likelihood of Political Acceptability being Unacceptable was calculated by CREDO as the complement of the likelihood of it being Acceptable. The results for both groups' evaluations can be seen in

Table 3. Note that, in general, Group 2 was more conservative than Group 1. Also note that Group 2 did not differentiate between the Favourable and Neutral Partnership Contexts in their evaluations.

Table 3: SME evaluations of Political Acceptability for all permutations of summary variables.

Partnership Context	Sharing Provisions	Caveats	Probability for 'Acceptable'	
			Group 2	Group 1
Favourable	Altruist-Broad	Strongly limited	Very likely	Likely
Favourable	Altruist-Broad	Mildly limited	Most likely	Very likely
Favourable	Altruist-Broad	No limitations	Certain	Most likely
Favourable	Limited	Strongly limited	Likely	Unlikely
Favourable	Limited	Mildly limited	Likely	Fifty-fifty
Favourable	Limited	No limitations	Very likely	Likely
Favourable	Commercial	Strongly limited	Fifty-fifty	Very unlikely
Favourable	Commercial	Mildly limited	Likely	Fifty-fifty
Favourable	Commercial	No limitations	Likely	Likely
Neutral	Altruist-Broad	Strongly limited	Likely	Likely
Neutral	Altruist-Broad	Mildly limited	Very likely	Very likely
Neutral	Altruist-Broad	No limitations	Most likely	Most likely
Neutral	Limited	Strongly limited	Likely	Unlikely
Neutral	Limited	Mildly limited	Likely	Fifty-fifty
Neutral	Limited	No limitations	Very likely	Likely
Neutral	Commercial	Strongly limited	Fifty-fifty	Very unlikely

Partnership Context	Sharing Provisions	Caveats	Probability for 'Acceptable'	
			Group 2	Group 1
Neutral	Commercial	Mildly limited	Likely	Fifty-fifty
Neutral	Commercial	No limitations	Very likely	Likely
Unfavourable	Altruist-Broad	Strongly limited	Unlikely	Very unlikely
Unfavourable	Altruist-Broad	Mildly limited	Fifty-fifty	Fifty-fifty
Unfavourable	Altruist-Broad	No limitations	Likely	Likely
Unfavourable	Limited	Strongly limited	Most likely	Very unlikely
Unfavourable	Limited	Mildly limited	Unlikely	Unlikely
Unfavourable	Limited	No limitations	Fifty-fifty	Fifty-fifty
Unfavourable	Commercial	Strongly limited	Most unlikely	Most unlikely
Unfavourable	Commercial	Mildly limited	Unlikely	Very unlikely
Unfavourable	Commercial	No limitations	Fifty-fifty	Very unlikely

Using the same dictionary, the SMEs then evaluated the Partnership Context, based on the permutations of the input variables Space Pillar, Type of Partner, and Partner Capability. The possible values for these variables were discussed in Section 3.1 and full definitions can be found in Annex A, although the SMEs did not consider the possibility of partnering with an Antagonist nation during the CREDO exercise. This meant that there were a total of 27 permutations (three variables with three possible states each) to be evaluated. The results of the group evaluations are shown in Table 4. Note that in addition to the dictionary terms, CREDO allowed the SMEs to input numerical values. Thus, a value of '1' represents 100% certainty and a value of '0' represents 0% chance. As before, CREDO fills in blank spaces with the complementary term from the dictionary.

Table 4: SME evaluations of Partnership Context

#	Input Variables: Space Pillar	Input Variables: Type of partner	Input Variables: Partner Capab.	Group 2 Partnership Context (favourable)	Group 2 Partnership Context (neutral)	Group 2 Partnership Context (unfavourable)	Group 1 Partnership Context (favourable)	Group 1 Partnership Context (neutral)	Group 1 Partnership Context (unfavourable)
1	ISR	Ally	Advanced	V. likely	-	0	1	0	0
2	ISR	Ally	Average	V. likely	-	0	1	0	0
3	ISR	Ally	Newbie	Likely	-	0	M. likely	-	-
4	ISR	Peer	Advanced	Likely	-	0	V. likely	-	-
5	ISR	Peer	Average	Likely	-	M. unlikely	Likely	-	-
6	ISR	Peer	Newbie	Fifty-fifty	Fifty-fifty	V. unlikely	Fifty-fifty	Fifty-fifty	-
7	ISR	Questionable	Advanced	M. unlikely	Likely	V. unlikely	Fifty-fifty	Fifty-fifty	-
8	ISR	Questionable	Average	M. unlikely	Fifty-fifty	Fifty-fifty	-	-	Likely
9	ISR	Questionable	Newbie	M. unlikely	Unlikely	-	-	-	M. likely
10	SATCOM	Ally	Advanced	M. likely	-	0	1	-	-
11	SATCOM	Ally	Average	V. likely	-	0	M. likely	-	-
12	SATCOM	Ally	Newbie	Likely	-	M. unlikely	V. likely	-	-
13	SATCOM	Peer	Advanced	V. likely	-	0	M. likely	-	-
14	SATCOM	Peer	Average	Likely	-	M. unlikely	V. likely	-	-
15	SATCOM	Peer	Newbie	Fifty-fifty	Fifty-fifty	M. unlikely	Fifty-fifty	-	Fifty-fifty
16	SATCOM	Questionable	Advanced	M. unlikely	Likely	V. unlikely	-	-	Likely
17	SATCOM	Questionable	Average	M. unlikely	Fifty-fifty	Fifty-fifty	-	-	M. likely
18	SATCOM	Questionable	Newbie	M. unlikely	-	Likely	-	-	1
19	SSA	Ally	Advanced	V. likely	-	0	1	-	-

#	Input Variables: Space Pillar	Type of partner	Partner Capab.	Group 2 Partnership Context: (favourable)	(neutral)	(unfavourable)	Group 1 Partnership Context: (favourable)	(neutral)	(unfavourable)
20	SSA	Ally	Average	Likely	-	0	M. likely	-	-
21	SSA	Ally	Newbie	Fifty-fifty	Fifty-fifty	0	Fifty-fifty	-	Fifty-fifty
22	SSA	Peer	Advanced	Likely	-	0	1	-	-
23	SSA	Peer	Average	Likely	-	M. unlikely	V. likely	-	-
24	SSA	Peer	Newbie	Fifty-fifty	Fifty-fifty	V. unlikely	Fifty-fifty	-	Fifty-fifty
25	SSA	Questionable	Advanced	M. unlikely	Likely	V. unlikely	V. likely	-	-
26	SSA	Questionable	Average	M. unlikely	Fifty-fifty	Fifty-fifty	Likely	-	-
27	SSA	Questionable	Newbie	M. unlikely	Unlikely	-	Fifty-fifty	-	Fifty-fifty

As the groups evaluated the Partnership Context, they also attempted to set conditions of the input variables to Sharing Provisions and Caveats in order to be most likely to reach a politically acceptable partnership agreement. As with the summary variables, there were a certain number of allowable states defined for each input variable. The input variables' states represented what Nation A (i.e. the nation being played by the SMEs) required from the partner in order to mitigate the loss of space capabilities. Definitions of the input variables Access Sharing, Compensation, Purpose Limitation, and Geographic Limitation, and their allowable states, are listed in Annex A.

The results of the SMEs' evaluations of the Sharing Provisions and Caveats summary variables are shown in Table 5 and Table 6, respectively. These results have been separated according to the group number. Note that due to the unique nature of the SATCOM pillar, different terms were substituted for the Access Sharing variable: Beam Management for Raw Data, Bandwidth Control for Data Products, and Fixed Bandwidth for No Direct Access.

Once this phase of the CREDO exercise was completed, the likelihood of obtaining a partnership agreement with a Political Acceptability rating of Acceptable was calculated by the CREDO software. The results of these calculations are reported in Section 4.2.

Table 5: SME evaluations of the Sharing Provisions summary variable.

	Input Variables			Group 2		Group 2			Group 1		Group 1		
	Space	Type	Partner	Access	Compensation	Sharing Provisions			Access	Compensation	Sharing Provisions		
#	Pillar	of partner	Capab.	Sharing		(altruist)	(limited)	(commercial)	Sharing		(altruist)	(limited)	(commercial)
1	ISR	Ally	Advanced	No direct	Medium	0	1	0	No direct	In-kind	1	0	0
2	ISR	Ally	Average	Raw data	Medium	-	M. likely	-	No direct	In-kind	1	0	0
3	ISR	Ally	Newbie	Raw data	In-kind	V. likely	-	0	No direct	In-kind	1	0	0
4	ISR	Peer	Advanced	No direct	Medium	0	1	0	No direct	In-kind	1	0	0
5	ISR	Peer	Average	Raw data	Medium	-	M. likely	-	No direct	In-kind	1	0	0
6	ISR	Peer	Newbie	Raw data	Small	M. unlikely	Likely	V. unlikely	No direct	In-kind	1	0	0
7	ISR	Questionable	Advanced	Raw data	Small	M. unlikely	Likely	V. unlikely	No direct	Medium	-	M. likely	-
8	ISR	Questionable	Average	Raw data	Small	M. unlikely	Likely	V. unlikely	No direct	Small	-	V. likely	-
9	ISR	Questionable	Newbie	Raw data	Small	M. unlikely	Likely	V. unlikely	No direct	Small	-	V. likely	-
10	SATCOM	Ally	Advanced	Beam Manage	In-kind	V. likely	-	0	Beam Manage	In-kind	V. likely	-	0
11	SATCOM	Ally	Average	Beam Manage	Small	V. likely	-	0	Beam Manage	In-kind	V. likely	-	0
12	SATCOM	Ally	Newbie	Beam Manage	Medium	M. unlikely	V. likely	-	Beam Manage	In-kind	V. likely	-	0
13	SATCOM	Peer	Advanced	Beam Manage	In-kind	V. likely	-	0	Bandwidth	In-kind	V. likely	-	0
14	SATCOM	Peer	Average	Beam Manage	Small	V. likely	-	0	Bandwidth	In-kind	V. likely	-	0
15	SATCOM	Peer	Newbie	Beam Manage	Medium	M. unlikely	V. likely	-	Bandwidth	In-kind	V. likely	-	0
16	SATCOM	Questionable	Advanced	Fixed	In-kind	-	Likely	0	Fixed	Medium	0	M. likely	M. unlikely
17	SATCOM	Questionable	Average	Bandwidth	Medium	M. unlikely	V. likely	V. unlikely	Fixed	Medium	0	M. likely	M. unlikely
18	SATCOM	Questionable	Newbie	Beam Manage	Medium	M. unlikely	V. likely	-	Fixed	Small	0	M. likely	M. unlikely
19	SSA	Ally	Advanced	No direct	In-kind	Fifty-fifty	Fifty-fifty	0	Products	In-kind	1	0	0
20	SSA	Ally	Average	Raw data	Small	-	V. likely	M. unlikely	Products	In-kind	1	0	0
21	SSA	Ally	Newbie	Raw data	Medium	M. unlikely	V. likely	V. unlikely	Products	In-kind	1	0	0

	Input Variables			Group 2		Group 2			Group 1		Group 1		
	Space	Type	Partner	Access	Compensation	Sharing Provisions			Access	Compensation	Sharing Provisions		
#	Pillar	of partner	Capab.	Sharing		(altruist)	*(limited)*	*(commercial)*	Sharing		(altruist)	*(limited)*	*(commercial)*
22	*SSA*	*Peer*	*Advanced*	*No direct*	*In-kind*	*Fifty-fifty*	*Fifty-fifty*	*0*	*Products*	*In-kind*	*1*	*0*	*0*
23	*SSA*	*Peer*	*Average*	*Raw data*	*Small*	*-*	*V. likely*	*M. unlikely*	*Products*	*In-kind*	*1*	*0*	*0*
24	*SSA*	*Peer*	*Newbie*	*Raw data*	*Small*	*-*	*V. likely*	*M. unlikely*	*Products*	*In-kind*	*1*	*0*	*0*
25	*SSA*	*Questionable*	*Advanced*	*Raw data*	*Medium*	*M. unlikely*	*V. likely*	*V. unlikely*	*Products*	*Medium*	*0*	*M. likely*	*M. unlikely*
26	*SSA*	*Questionable*	*Average*	*Raw data*	*Medium*	*M. unlikely*	*V. likely*	*V. unlikely*	*Products*	*Medium*	*0*	*M. likely*	*M. unlikely*
27	*SSA*	*Questionable*	*Newbie*	*Raw data*	*Medium*	*M. unlikely*	*V. likely*	*V. unlikely*	*Products*	*Small*	*0*	*M. likely*	*M. unlikely*

Table 6: SME evaluations of the Caveats summary variable.

	Input Variables			Group 2		Group 2			Group 1		Group 1		
	Space	Type	Partner	Purpose	Geo	Caveats			Purpose	Geo	Caveats		
#	Pillar	of partner	Capab.	Limitation		(strongly)	*(mildly)*	*(no)*	Limitation		(strongly)	*(mildly)*	*(no)*
1	ISR	Ally	Advanced	No	Partner exclusion	0	-	Likely	No	Partner exclusion	-	V. likely	0
2	ISR	Ally	Average	No	Partner exclusion	0	-	Likely	No	Partner exclusion	-	V. likely	0
3	ISR	Ally	Newbie	No	Partner exclusion	0	-	Likely	No	Partner exclusion	-	V. likely	0
4	ISR	Peer	Advanced	No	Peace/Partner Exclusion	0	-	Likely	No	Partner exclusion	-	V. likely	0
5	ISR	Peer	Average	No	Peacekeeping	Fifty-fifty	Likely	M. unlikely	No	Partner exclusion	-	V. likely	0
6	ISR	Peer	Newbie	No	Peacekeeping	Fifty-fifty	Likely	M. unlikely	No	Partner exclusion	-	V. likely	0
7	ISR	Questionable	Advanced	Peaceful	Peace/Partner Exclusion	V. likely	-	0	No	Partner exclusion	-	V. likely	0
8	ISR	Questionable	Average	Peaceful	Peacekeeping	V. likely	-	0	No	Partner exclusion	-	V. likely	0
9	ISR	Questionable	Newbie	Peaceful	Peacekeeping	V. likely	-	0	No	Partner exclusion	-	V. likely	0
10	SATCOM	Ally	Advanced	No	No	0	0	1	No	No	0	0	1
11	SATCOM	Ally	Average	No	No	0	0	1	No	No	0	0	1
12	SATCOM	Ally	Newbie	No	No	0	0	1	No	No	0	0	1
13	SATCOM	Peer	Advanced	Peaceful	No	-	Likely	M. unlikely	No	No	0	0	1
14	SATCOM	Peer	Average	Peaceful	No	-	Likely	M. unlikely	No	No	0	0	1
15	SATCOM	Peer	Newbie	Peaceful	No	-	Likely	M. unlikely	No	No	0	0	1
16	SATCOM	Questionable	Advanced	Peaceful	No	-	Likely	M. unlikely	No	No	0	0	1
17	SATCOM	Questionable	Average	Peaceful	No	-	Likely	M. unlikely	No	No	0	0	1

#	Input Variables: Space Pillar	Type of partner	Partner Capab.	Group 2: Purpose Limitation	Group 2: Geo Limitation	Group 2 Caveats: (strongly)	(mildly)	(no)	Group 1: Purpose Limitation	Group 1: Geo Limitation	Group 1 Caveats: (strongly)	(mildly)	(no)
18	SATCOM	Questionable	Newbie	Peaceful	No	-	Likely	M. unlikely	No	No	0	0	1
19	SSA	Ally	Advanced	No	Partner exclusion	0	-	V. likely	No	No	0	0	1
20	SSA	Ally	Average	No	Partner exclusion	0	-	V. likely	No	No	0	0	1
21	SSA	Ally	Newbie	No	Partner exclusion	0	-	V. likely	No	No	0	0	1
22	SSA	Peer	Advanced	No	Peacekeeping	Fifty-fifty	Likely	M. unlikely	No	No	0	0	1
23	SSA	Peer	Average	No	Peacekeeping	Fifty-fifty	Likely	M. unlikely	No	No	0	0	1
24	SSA	Peer	Newbie	No	Peacekeeping	Fifty-fifty	Likely	M. unlikely	No	No	0	0	1
25	SSA	Questionable	Advanced	Peaceful	Peacekeeping	M. likely	-	0	No	Partner exclusion	-	V. likely	0
26	SSA	Questionable	Average	Peaceful	Peacekeeping	M. likely	-	0	No	Partner exclusion	-	V. likely	0
27	SSA	Questionable	Newbie	Peaceful	Peacekeeping	M. likely	-	0	No	Partner exclusion	-	V. likely	0

4 Results

4.1 Tabletop Findings

Based on the observations collected from the groups in the open tabletop sessions, a number of insights emerged regarding the provisions and limitations required to create politically acceptable mitigation agreements. In general, both groups of SMEs provided similar conditions and comments to the data collection tool. This was seen as confirmatory evidence, strengthening the validity of the insights.

The following subsections discuss the tabletop findings, or insights, for each of the space pillars investigated. These findings were derived from the SME comments. Note that the SMEs took the perspective of Nation A, while there was no Red Team to negotiate the partnership agreement from the perspective of Nation B. In the following discussions, any mention of Nation A should be understood to be the nation represented by the LOE participants, and Nation B should be understood to be an unnamed potential partner. In the case of the SATCOM vignette, the three potential partner nations were designated as Nations B, C, and D.

4.1.1 ISR Pillar

Within the ISR pillar, several insights applied broadly, regardless of the partner type engaged. For instance: in general, access to processed data was preferred over raw data in the ISR pillar. This was especially the case where the mitigation partner had advanced capabilities and processing expertise. Part of the reason for this preference was technical; in order to create data products, the mitigated partner would require a good deal of knowledge about the sensor used and result in a large interoperability burden. The SMEs also stated that it was preferable for the mitigating partner to provide processed products as this would reduce the cost (monetarily and in resources) for the mitigated party.

Another broad insight was that a partnership within ISR would require a tasking prioritization and planning scheme to manage the requirements of the mitigated partner in consideration of the requirements of the mitigating partner. This would likely require extensive negotiations between the two partners, especially if the ISR capability's capacity is largely used up by the mitigating partner.

In the case of partnership with an Ally nation, it was expected that both nations would be able to share processed data relatively easily, with raw data to be shared in special cases. Compensation amongst the allies was seen to be reciprocal in nature, with each partner sharing in-kind data or some other military capability. This compensation could either be in effect prior to or after the loss of the capability. As allies are seen to be nations of fairly similar motivations, the only limitation is that the use of the data would have to be publicly acceptable to the mitigating nation. For example, some nations may take issue with their data being used in situations where the potential for collateral damage involving human life is high, and would thus restrict its use in those circumstances. In terms of geographic limitations, both nations would likely protect their own national interests when sharing the data. This type of partnership agreement was seen to be strongly acceptable to the participants.

When partnering with a Peer nation, the subject matter experts saw very little difference from the partnership involving an ally. Processed data could be easily shared between the nations, with raw data available, depending on if the relationship was trending towards an Ally relationship. The expected compensation for this type of partnership was in-kind, either in terms of sharing data or other capabilities. As with an Ally partner, the purposes for which the capability could be used were limited to those that would be publicly acceptable for the mitigating nation. However, there would likely be more restrictive limitations on issues such as 3rd party use of shared data. Furthermore, military use of the data against the allies of the mitigating nation would be restricted. The geographic limitations of the mitigating capability were the same as for an Ally, with the added exclusion of the mitigating nation's *other* partners' national interests. The political acceptability of this type of mitigation agreement was perceived to be strongly acceptable, albeit at a slightly lower level than with the Ally.

Unlike partnering with Allies or Peer nations, a mitigation partnership with a Questionable nation was seen to be less of a reciprocating relationship. Rather, the mitigated nation would not be willing to share as much as they would like to receive. In this case, Nation A would request raw/and or processed data, but would only be willing to share processed data up to commercial quality with Nation B, should they require mitigation. In such a partnership, the compensation would be monetary on both sides at an at-cost level. The nations would likely require that the data not be used for military purposes; with an added restriction that Nation B not use any data they receive against their own citizens. In terms of the geographic limitations, the limitations would be even more restrictive than those described for Peer nations, with added exclusions for any areas of concern for the mitigating nation. A mitigation agreement with a Questionable partner was seen to have a low level political acceptability due to the low level of trust between the partners. The restrictions required for this agreement would severely limit the utility of the data, and thus this type of CSMC agreement would only be sought if there were no other options available. Participants expressed a preference for commercial arrangements in this scenario as they avoided the negative political implications dealing with a Questionable partner.

The SMEs indicated that no permanent mitigation agreement could be reached with an Antagonist nation. Rather, data would only be provided on a case-by-case basis in emergency situations, such as natural disasters or for humanitarian aid. A full risk assessment of the potential misuse of the provided data would have to be conducted before any data could be shared.

4.1.2 SATCOM Pillar

There were a number of general considerations and insights that emerged for the SATCOM pillar. The main consideration for this vignette had to do with the operation of the SATCOM constellation. During the tabletop exercise, both groups of participants independently assumed that the partners would agree to an operational concept where the four satellites would all contribute to the constellation from launch, rather than reserving a single satellite as an on-orbit spare. Under this concept, the nations would share the capacity of the constellation according to the partnership agreement conditions.

Other considerations for the communications constellation have to do with the bandwidth, frequency, and encryption standards which would be employed. These are common considerations for any communications constellation, but would be more complicated due to the

required concurrence amongst the partners. It was stated that this would require extensive negotiation between the partnering nations.

The final general insight from this vignette had to do with the source of the fourth satellite in the constellation. Given that in the vignette, Nations B, C, and D had average capability in the SATCOM pillar, it was assumed that they would either build a satellite themselves or seek one out from a more advanced source. The participants discussed several options for outside procurement, including Nation A or approaching a third party, such as another nation or commercial body. In any case, the fourth satellite would be inserted into an advantageous orbit in order to complete the constellation.

When partnering with Ally nations, participants indicated that Nation A would likely retain both TT&C and C2 of the entire constellation. In return for their contribution to the constellation, Nations B, C, and D would be guaranteed a total of 25% of the bandwidth of the constellation. This bandwidth level would stay at 25%, even in the event of the loss of satellites from the constellation. In terms of compensation, the nations would share the bandwidth of each satellite, in exchange for an overall increase in the capability of the constellation. Furthermore, the nations could provide ground stations, or resources for their construction, as another form of compensation. In terms of limitations of the purpose of use or geographical area, there would be none for Ally partners. The SMEs stated that this type of partnership was likely to be highly politically acceptable.

Partnership with a group of Peer nations was seen to be largely the same as a partnership with a group of Ally nations. Nation A would still seek to retain TT&C and C2 of the constellation and Nations B, C, and D would receive 25% of the bandwidth of the constellation in return for their contribution. Compensation was viewed largely the same as for Ally partners. One difference in working with Peer partners was that Nation A would seek to limit resale of the Nations B, C, and D's bandwidth of the constellation only to customers it approves of. Approved customers could either be negotiated in advance of the constellation becoming operational, or Nation A could require that its partners seek its approval for sales on an individual basis. Again, this type of partnership was seen to be highly acceptable by the SMEs, although to a lesser extent than the partnership with an Ally nation.

When considering a partnership with a group of Questionable nations, a number of changes in the partnership agreement were seen to be necessary. In terms of control of the satellites in the constellation, Nation A would seek to retain TT&C and C2 of its own satellites. Nations B, C, and D would likely seek to retain TT&C and C2 for their satellite (split according to their own internal negotiations). Thus, no single nation would have control over the full constellation. This would require a significant amount of coordination in order to ensure that the constellation functions properly. Another change from the Ally/Peer partnerships is that Nation A would likely guarantee access to 25% of the capacity of the constellation, but not necessarily to the satellites that Nation A controls. In this manner, Nation A could establish controls on the use of the constellation should the partner nations take actions disagreeable to Nation A. The SMEs stated that this partnership would require monetary compensation for the exchange in bandwidth on the constellation. The SMEs stated that limitations on the use of the constellation would be unworkable, other than to deny Nations B, C, and D access to Nation A's satellites, should the need arise. Once again, Nation A would require approval over any sale of the other nations' bandwidth to third parties. The political acceptability of this partnership agreement was seen to be

lower than that for the Ally or Peer nation partners. The SMEs believed that, ultimately, the acceptability of the agreement was highly dependent on the conditions of the service agreement that was reached.

The SMEs did not believe that it was possible to reach a formal partnership agreement with Antagonist nations for a SATCOM capability. However, it was stated that access to Nation A's SATCOM capabilities might be provided to an Antagonist nation in the event of a natural disaster or humanitarian crisis. This access would be strictly controlled by Nation A to ensure its national interests are preserved.

4.1.3 SSA Pillar

One group of SMEs performed the open tabletop discussion with the SSA pillar while the other provided its input via a discussion concerning space traffic management. The insights discussed in this subsection are only derived from the tabletop discussion while the other group's insights are discussed in Section 4.1.4.

One of the first general insights on the SSA pillar was that it could only function if the goal was Space Traffic Management (STM). Also, SMEs noted that within the STM mission, certain data would have to be filtered out. Specifically, data on Allied military satellites would not be shared amongst the partners in order to preserve national interests.

With an Ally partner, the SMEs decided that a partnership would work best if it was set up to operate in advance of a failure of SSA assets on either side. The partnership would likely result in the creation of a space traffic database, into which space objects' orbital parameters are maintained. In terms of compensation, the SMEs believed that a mutual contribution of data would be sufficient to satisfy the partnership requirements. Since the sharing of data would be continuous, any loss of capability would be shared by both partners. The only limitation mentioned by the SMEs was with regard to the sharing of data on sensitive satellites. The political acceptability of a partnership of this type was seen to be high, depending on Nation B's capability to provide useful, accurate data to the database.

The SMEs stated that work with a Peer nation would require some changes to the partnership agreement developed for an Ally. In this partnership, the SMEs did not envision a shared database being created. Rather, once a SSA asset failed, the partner would be brought in for mitigation. Nation A would likely request raw data, but Nation B might only be willing to share processed data. In terms of compensation, the SMEs stated that an exchange of in-kind data might suffice if the Peer was trending toward an Ally. If this trend was not happening, the SMEs stated that some monetary compensation would likely be required to obtain data from Nation B Also, data on sensitive assets would not be shared between the partners. The SMEs stated that it was highly likely that an agreement of this type would be politically acceptable, although to a lesser extent than an agreement with an Ally nation.

In the case where the partner was a Questionable nation, the SMEs again preferred to create a partnership agreement that would only be activated if a SSA asset was lost. The SMEs stated that the shared data would likely only be processed filtered data. Also, to ensure that the data was useful to Nation A, there would likely be a need for periodic exercises or testing to ensure that the provided data is sufficient for the mission. In this type of partnership, the SMEs believed that

monetary compensation would be required, likely at a level giving Nation B a profit. Data usage would be required to be for peaceful purposes only. The SMEs stated that Nation B would likely filter out any data on sensitive national interests, as well as data on any of *their* allies sensitive satellites. It was judged that this type of partnership agreement had a fair chance of being politically acceptable, as long as the provided data were of acceptable quality for Nation A.

A partnership with an Antagonist nation was not believed to be possible in this space pillar.

4.1.4 Commentary on SSA Pillar Scenario

While Section 4.1.3 presented findings from the group that participated in the open tabletop discussion, the other group of SMEs took issue with the realism of the SSA scenario. The participants from this group decided that as an alternative, one participant would lead the group in a discussion of issues with space traffic management and how an international body might contribute a solution to these problems, as opposed to focusing on the SSA scenario. This subsection presents the discussion and commentary that resulted.

One of the first challenges to setting up an international body for STM is to overcome the notion that SSA is especially sensitive, and thus no data could be shared. Position and velocity data for the vast majority of space objects can be freely shared, only withholding data on sensitive satellites. In fact, the unclassified US Spacetrack Catalogue (the recognized international standard) is shared through a secure internet site for those requiring access for legitimate purposes.

An international body for STM would have several tasks in order to perform its mission. First of all, the body would need to create and maintain a database of space object traffic data. The database would need all of the data necessary to perform conjunction analyses, which allow space traffic controllers to predict collisions between space objects and provide early warning services. There are currently a number of space object traffic databases available internationally which may be candidates for amalgamation, should an international body be stood up. Ultimately, by combining worldwide space object observations and tracks, an international body would provide an increased number of data points for the STM mission.

The SMEs also saw a coordination role for the international body. Representatives would be required to negotiate data formats and standards, data translation protocols, and disambiguation of data in the database. One benefit of using an international body is that it could potentially prioritize space objects for observation and request collection from a sensor in an advantageous location. Furthermore, the international body could facilitate technical working groups, dedicated to solving some of the hard problems in the STM field, such as determining changes to orbital parameters and modelling the evolution of clouds of space debris.

Overall, the group of SMEs felt that the discussion was positive, especially since it illuminated the need for an international body dedicated to STM in a multinational forum.

4.2 CREDO Findings

The following subsections present the results from the CREDO method. In these subsections, the groups have been named Group 1 and Group 2 in order to differentiate between their results.

For each of the pillars discussed, the political acceptability results from Group 1 and Group 2 in terms of percentages are compared. The combined results of Group 1 and Group 2 are also presented. Note that in this CREDO exercise, the output of a single run could indicate that the political acceptability of a partnership agreement was acceptable, unacceptable, or undecided.

4.2.1 ISR Pillar

Figure 4 depicts the political acceptability arising from the CREDO ISR scenarios, separated according to the partner type. In the figure, green bars indicate the percentage of partnership agreements that were evaluated as "Acceptable", yellow bars indicate the percentage of agreements evaluated as "Undecided", and red bars indicate the percentage of agreements evaluated as "Unacceptable". A number on each bar gives the exact percentage value for ease of interpretation. Note that results for Groups 1 and 2 are labelled G1 and G2, respectively and the combined results are labelled as G1&2. All other figures in Section 4.2 are formatted in a similar fashion.

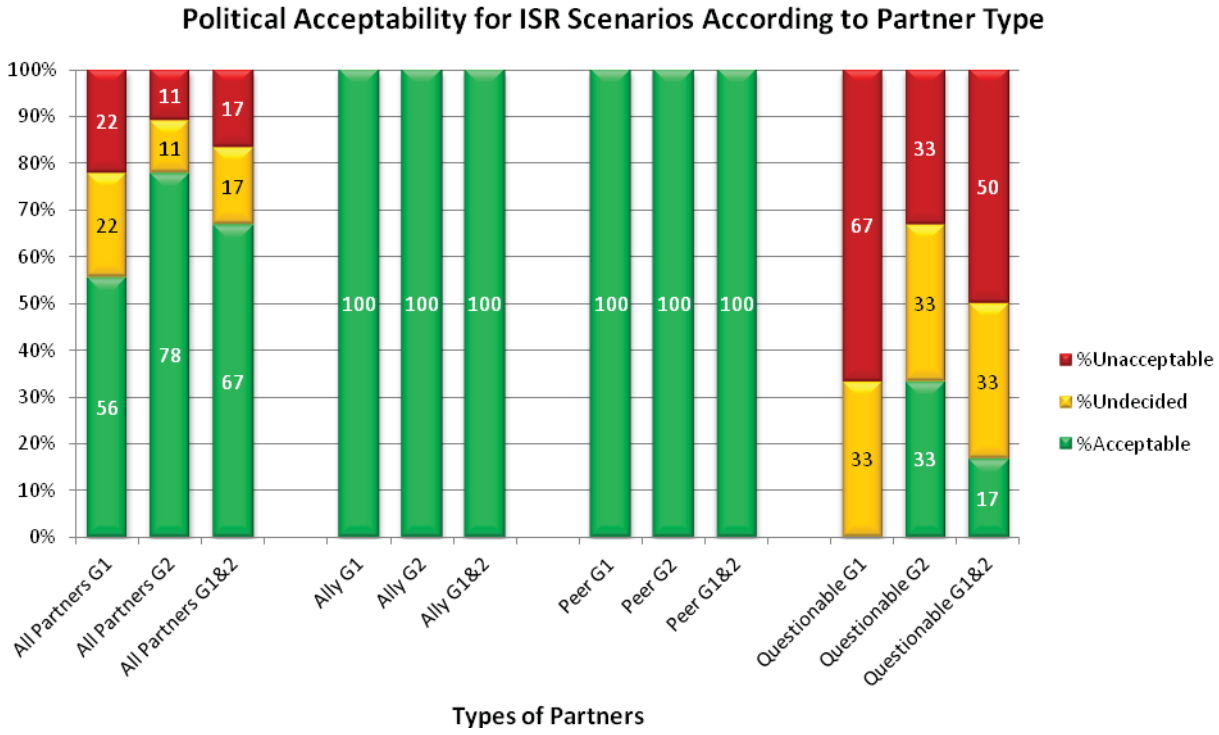

Figure 4: Political acceptability results for the ISR pillar scenarios considering the partner type.

From Figure 4, it is easy to see that the political acceptability of a partnership for ISR is highly dependent on the partner type. Both groups of SMEs were able to obtain acceptable ISR partnership agreements in 100% of the scenarios involving Ally nations and Peer nations. With Questionable nations, Group 1 did not obtain any acceptable partnership arrangements while Group 2 did in 33% of the scenarios.

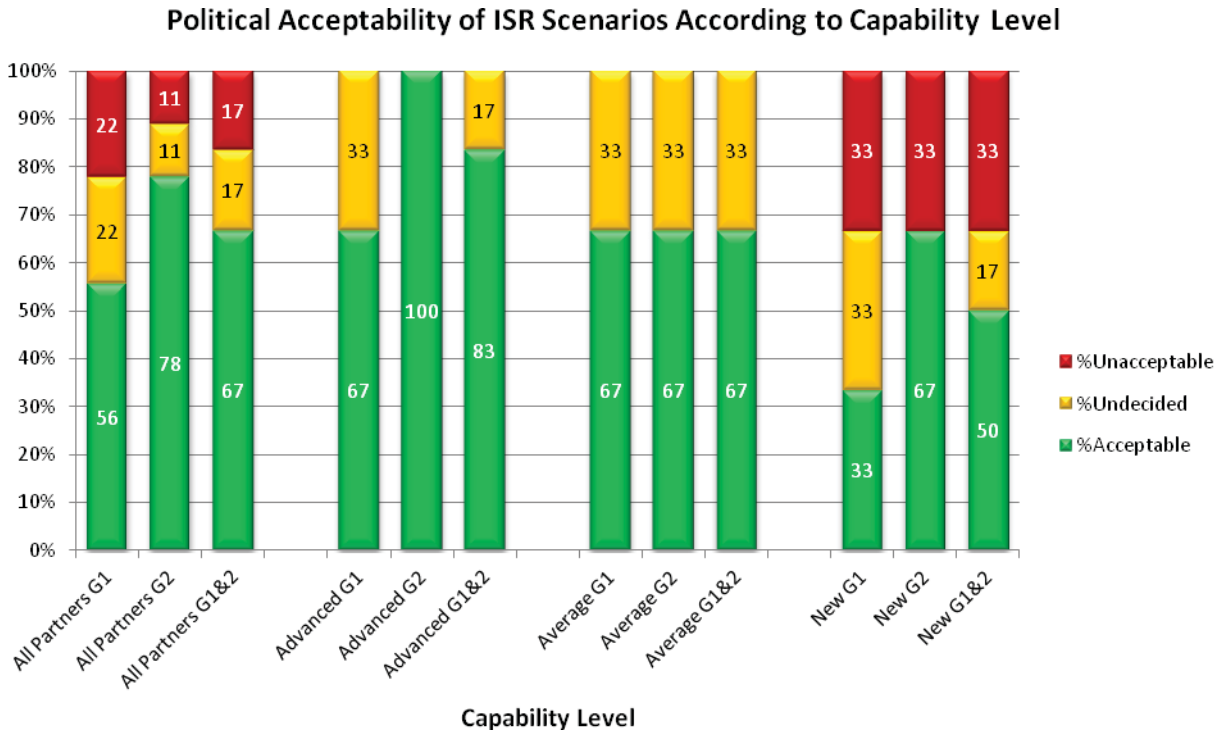

Figure 5: Political acceptability results for the ISR pillar scenarios considering the partner's capability level.

Figure 5 shows the political acceptability of the ISR scenarios, separated according to the capability level of the partner being considered. From the figure, it appears that both Groups 1 and 2 are more willing to form ISR partnership agreements with nations that have advanced or average capabilities, as opposed to nations that are new to the capability. Discussion during the CREDO session about why it would be less acceptable to partner with a nation that was new to the ISR capability had to do with the perceived value of the partnership. In certain cases, it was seen as valuable to help certain nations develop their capability, particularly if these nations were likely to be involved in friendly relationships with Nation A. In other cases, it was seen as poor return on investment to partner with a nation that could not be relied upon to provide the required ISR capability, should the need for mitigation arise.

4.2.2 SATCOM Pillar

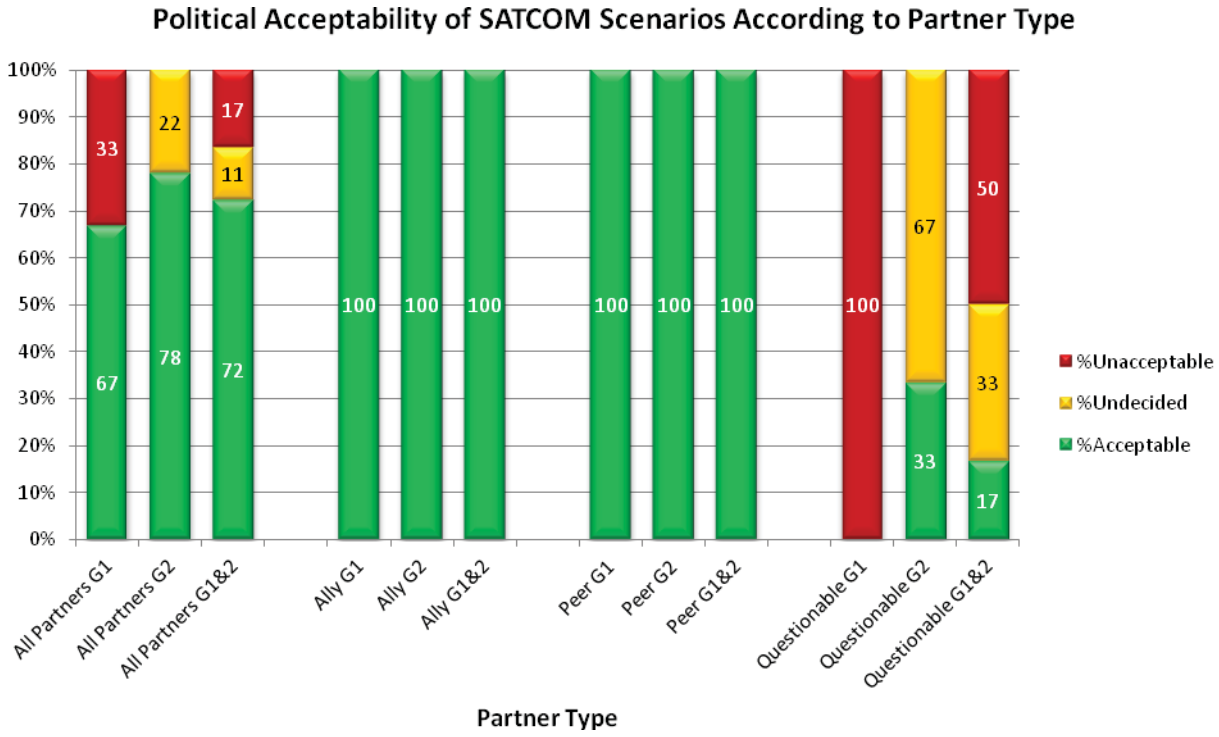

Figure 6: Political acceptability results for the SATCOM pillar scenarios considering the partner type.

Figure 6 gives the political acceptability results for the SATCOM scenarios, separated according to the partner type. From the figure, one can easily see that the political acceptability of SATCOM partnership agreements is highly dependent on the partner type. Both groups reached acceptable partnerships with Ally and Peer nations. When considering Questionable nations, Group 1 evaluated all of the potential partnerships as unacceptable, while Group 2 was less cautious in their partnership evaluations (33% acceptable and 67% undecided). One reason that SATCOM partnerships with Questionable nations had a lower acceptability rate was that the participants felt that a commercial option would be more acceptable than working with a nation is less than trustworthy.

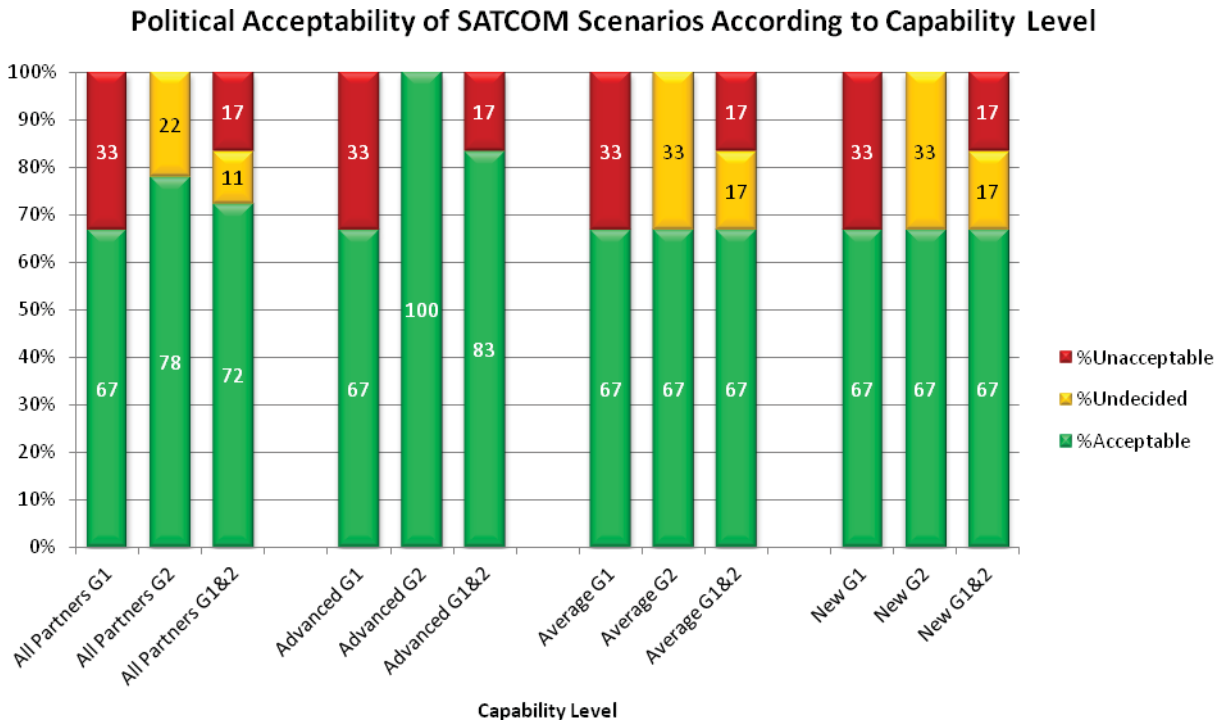

Figure 7: Political acceptability results for the SATCOM pillar scenarios considering the partner's capability level.

The political acceptability results for SATCOM scenarios, based on the partner's capability level, can be seen in Figure 7. Based on the data in the figure, the political acceptability of SATCOM partnership agreements is not especially dependent on the capability level of the partner nation. Again, Group 2 appeared to be more accepting than Group 2 of partnerships with nations that could be considered more risky.

4.2.3 SSA Pillar

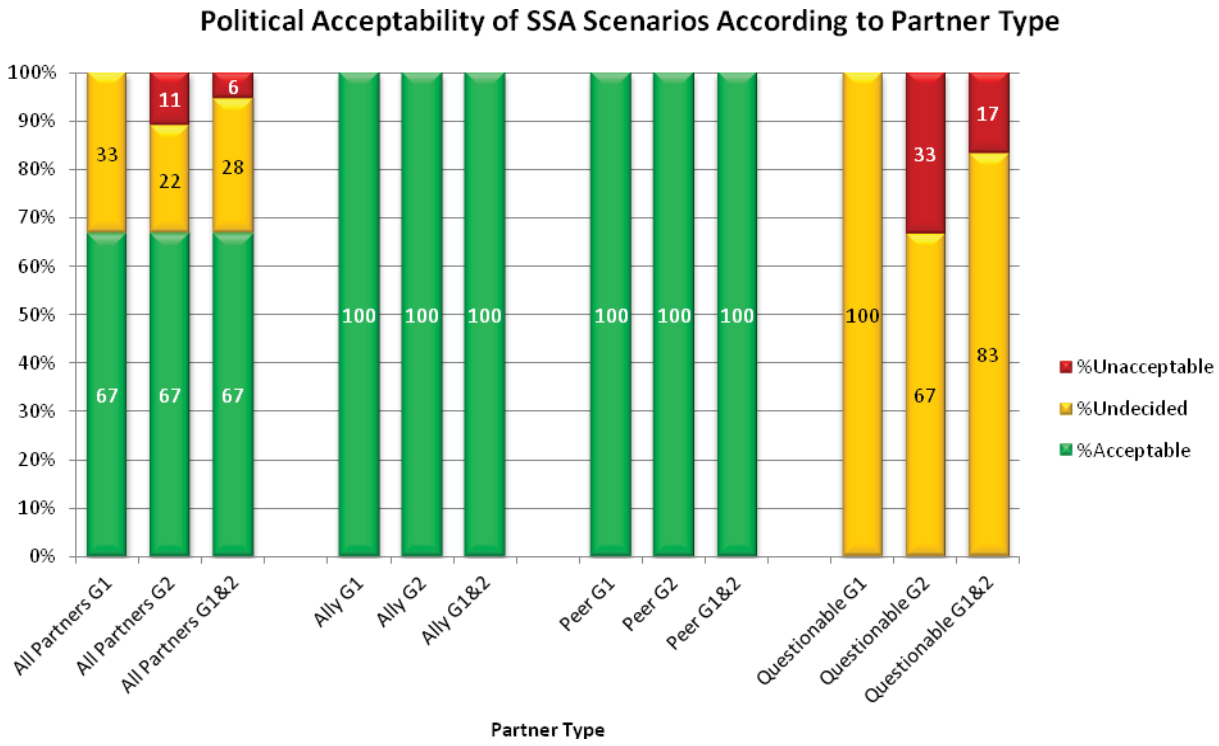

Figure 8: Political acceptability results for the SSA pillar scenarios considering the partner type.

Figure 8 depicts the political acceptability data for the SSA pillar scenarios, separated by the partner type being considered. As with the ISR and SATCOM scenarios, the political acceptability of the agreements is highly dependent on the type of partner being considered in the mitigation. As before, both groups were able to obtain acceptable evaluations in 100% of the scenarios involving Ally and Peer nations. In contrast to the other scenarios, neither group evaluated any partnerships with Questionable nations as acceptable. Also in contrast to the previous scenarios, Group 2 appears to be more cautious in their evaluation than Group 1. The lower level of acceptability of partnerships with Questionable nations in the SSA scenarios is likely due to the fact that SSA data was considered to be very sensitive, and thus difficult to share.

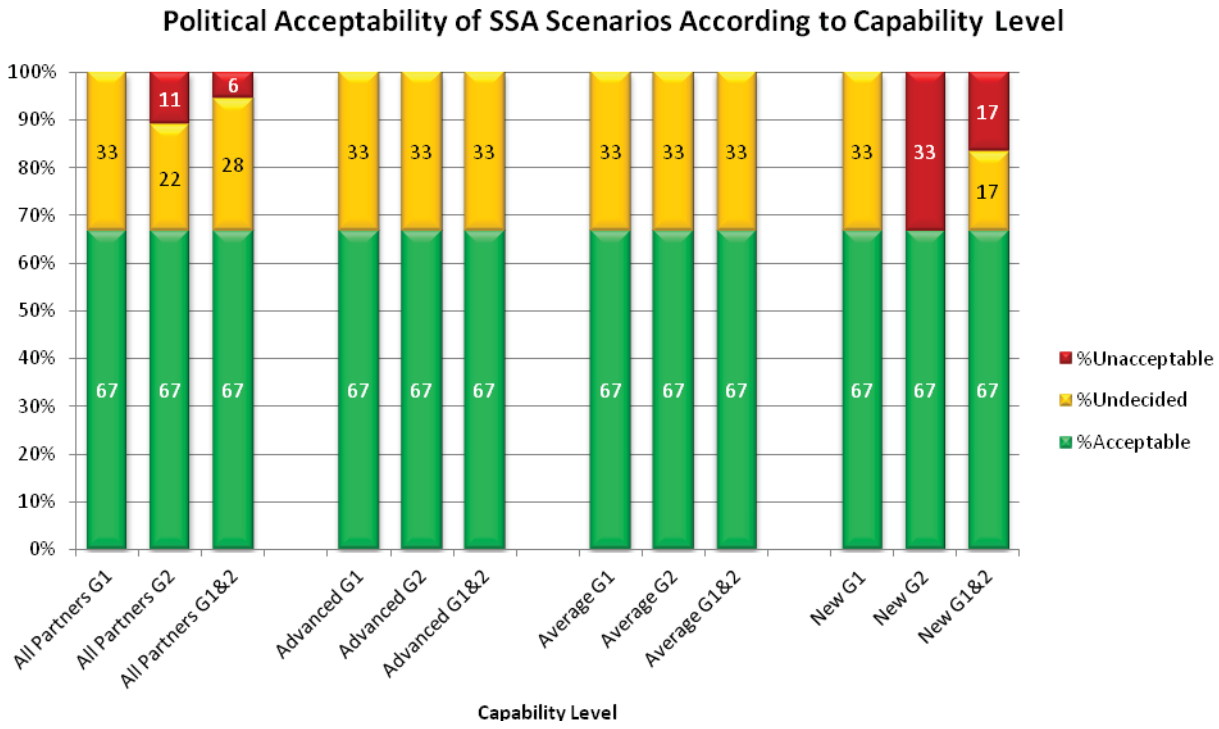

Figure 9: Political acceptability results for the SSA pillar scenarios considering the partner type.

The political acceptability of the SSA pillar scenarios, separated by the partner's capability level is shown in Figure 9. The acceptability of the partnership agreements does not appear to be strongly dependent on the partner's capability level, as evidenced by the constant level of 67% of the partnerships being evaluated as acceptable. This level of acceptability was mainly due to the SMEs' desire to establish international partnerships on SSA in order to increase the number of observation opportunities.

4.2.4 Overall CREDO Results

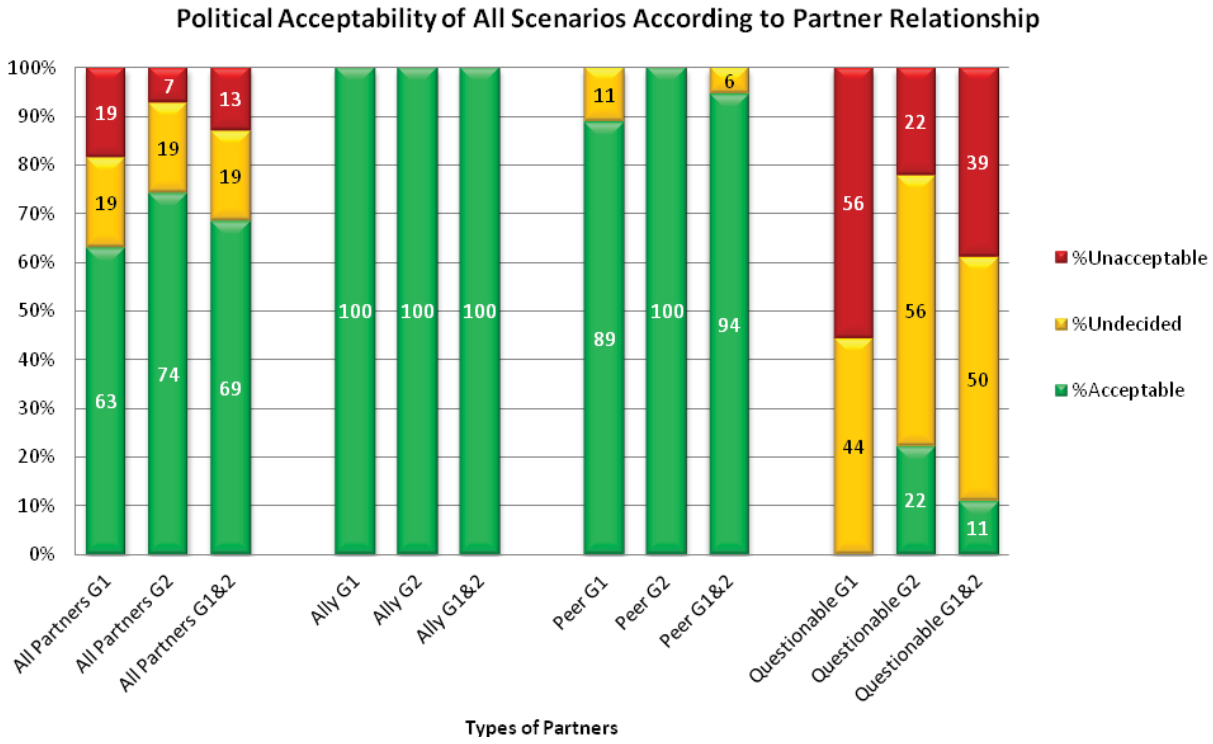

Figure 10: Political acceptability results for all scenarios considering the partner type.

Figure 10 shows the political acceptability of partnership agreements, regardless of the space pillar considered, separated by the type of partner. The data in this figure show that, based on the data collected by CREDO, the likelihood of obtaining a politically acceptable partnership agreement is highly dependent on the type of partner. If the partner was an Ally or Peer nation, there was a high probability that an acceptable partnership agreement could be reached. In contrast, if the partner was a Questionable nation, it was highly unlikely that a politically acceptable agreement could be reached.

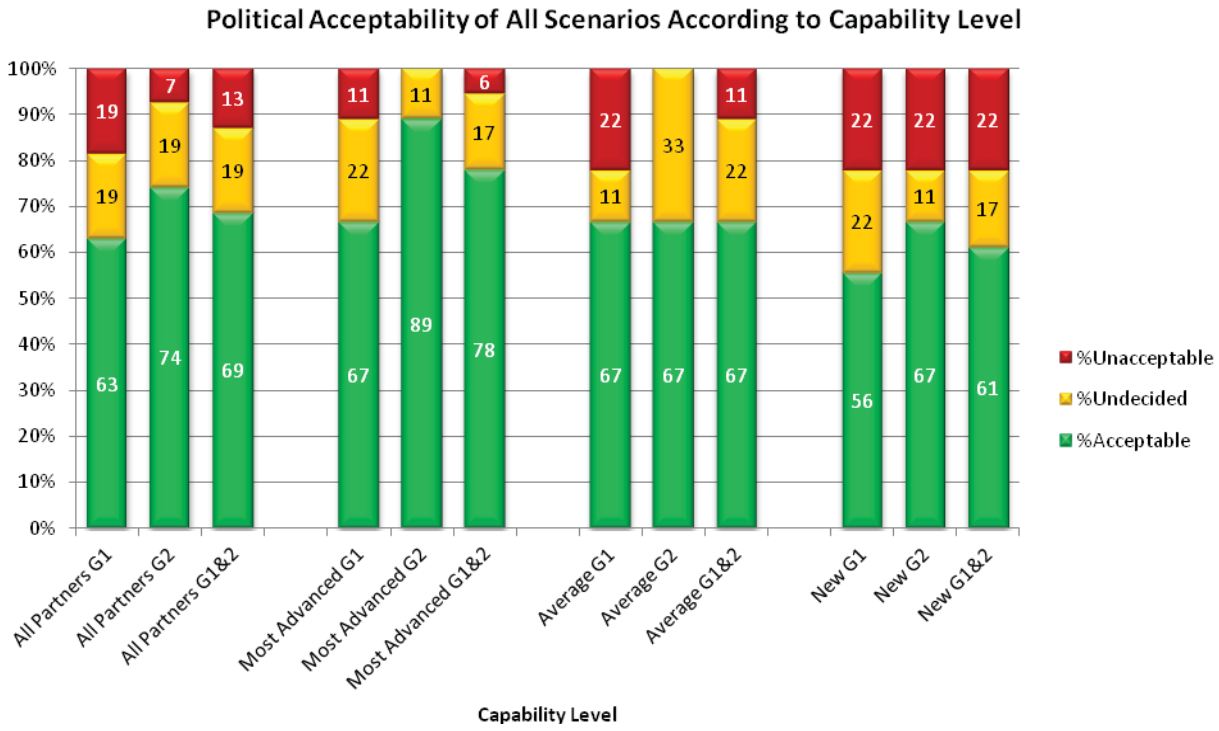

Figure 11: Political acceptability results for all scenarios considering the partner capability.

The political acceptability of the scenarios, regardless of the space pillar investigated, separated according to the partner's capability level is depicted in Figure 11. The data in the figure show that there is a weak dependence of political acceptability on a partner's capability level. This is evidenced by the relatively small variation in the percentage of acceptable agreements between the three capability levels.

4.3 Assessment

Results from both the open tabletop discussion and the CREDO exercise generally conformed to the expectations of both the participants and the analysts. Findings that showed that a politically acceptable agreement was more likely with an Ally or Peer as opposed to a Questionable nation were consistent with early expectations. Several participants commented that a commercial solution was much more likely than partnering with a less friendly nation, unless the development of a closer relationship with the partner was mandated by the political leadership.

Reviewing open tabletop discussion methodology has shown that the data capture tool was able to record the pertinent data and comments in order to perform the analysis. Furthermore, by projecting the tool onto a screen, the participants were able to ensure that the analyst was accurately recording their comments. One weakness of the data capture tool was that it did not have sufficient space to record all of the conversation that established the background assumptions and limitations necessary before the groups could proceed with discussing the partnership agreement factors.

The use of an analyst to facilitate the group discussions proved to be successful in keeping participants focused on the data points selected for capture. Within both groups, a high level of consensus was achieved, although this may have been due to the lack of diversity in the groups' make up.

A review of the CREDO methodology has shown that it produced results that generally conformed to the participants' expectations. This was in contrast to the participants' impression of the decision model, which many stated was too simple to produce reliable results. The analysts expected a certain amount of discomfort with the decision model, as it was developed without the participants' input. This discomfort was often manifested as dissatisfaction with the states available for a number of the variables.

A benefit of using CREDO is that it was able to quantify the probability that certain partnership agreements would be found to be politically acceptable; something the open discussion method could not provide. The tool also provided a useful visualization of the results to the participants, allowing them to track how an evaluation was made and to verify the logic behind it.

A weakness of the CREDO method was that it did not have a built in way to capture the background discussions that took place in order to establish the context of the scenario being considered. An additional data capture tool, based on the one used in the open tabletop discussion methodology, would be useful during future CREDO exercises.

In general, both groups took longer to complete the first experimental methodology they engaged in. This was most likely due to the fact that the groups had to set context for the scenarios during the first session. Decisions were reached much sooner when using the second methodology, as the groups had already set the context.

The first experimental methodology used also affected the group members' comfort with the second methodology. For Group 1, participants felt very uncomfortable with the constraints enforced by the CREDO model since they had previously been free to establish whatever provisions or limitations they wished in the open tabletop discussion. Conversely, the participants in Group 2 used very similar language in their provisions and limitations in the open tabletop discussion as they did using CREDO. It appeared that CREDO limited the Group 2 participants' creativity.

Participants from both groups commented that the vignettes being discussed were too vague for the purposes of the discussion. There was general agreement that the vignettes should have been more focused on a specific partnership in order to be able to discuss the types of provisions and limitations in the partnership agreements. Participants also recommended that in future activities the vignettes be reviewed by a group of international space SMEs in order to ensure their validity.

The participants took special issue with the SSA vignette, stating that it was unrealistic. The participants in Group 1 felt that their time would be better spent in a discussion of STM in general, as opposed to focusing on a vignette. The Group 1 participants indicated that the SSA discussion was valuable and provided a chance for important issues to be put forward in a public forum.

5 Conclusion

5.1 Summary

The CSMC has been proposed as a method for mitigating the loss of access to national space capabilities such as ISR, SATCOM, and SSA. Successful mitigation is dependent on identifying international capabilities that will meet or exceed domestic mitigation performance requirements, obtaining a partnership agreement which is acceptable to all parties involved, and implementing a level of interoperability which will allow the effective use of partner assets. While other studies have investigated the performance and interoperability issues, an investigation of political acceptability was accomplished through an MNE 7 LOE at the Swiss Armed Forces College in Lucerne, Switzerland.

The Space Mitigation LOE made use of open tabletop discussions and a Swiss decision support system, CREDO, to explore the factors that affect the political acceptability of CSMC agreements. Two groups of SMEs participated in the LOE, alternating between the two methodologies.

Results from the LOE showed that the formation of politically acceptable CSMC partnership agreements is possible. Based on the participants' input, the most important factor in obtaining an acceptable partnership agreement was the type of partner nation. Ally and Peer nations were found to be more preferable as partners than Questionable nations. Furthermore, the participants stated that commercial arrangements would likely be sought before partnering with less friendly nations. The participants stated that partnerships with Antagonist nations were not possible.

Participant comments during the LOE highlighted the particular importance of initiating an international dialogue for the Space Traffic Management aspect of SSA. Participants believe that it is in the best interests of all space-faring nations to cooperate in order to increase opportunities for observing space objects in order to prevent collisions. An early discussion of the potential benefits of establishing an international body for Space Traffic Management provided a valuable opportunity to discuss this issue in an international forum.

The findings from the Space Mitigation LOE will be useful to the international community when developing future space capabilities. Given the role of these systems in daily life and the threat posed by the environment they operate in, mitigation against the loss of access to these capabilities will be essential. MNE 7 provided a baseline investigation of the CSMC as a potential solution to the mitigation challenge and confirmed that it is a viable approach.

5.2 Future Work

Much of the work on the CSMC during MNE 7 was exploratory. Now that the experimentation campaign has ended, continued development of the concept is required before it can be put into practice.

The MNE 7 LOE allowed analysts to investigate the formation of CSMC agreements from the domestic perspective. One of the main limitations of the LOE was that the partner's perspective

in the negotiations was not investigated. Further experimentation is recommended to address this limitation, potentially requiring the use of red teams to act as potential partners.

Other areas for future work include policy and legal issues. A realistic treatment of various national policies was not included in the LOE, and many assumptions had to be made in this area to allow participants to proceed in discussing the scenarios. Legal definitions of the various terms used during the LOE were also not considered. Indeed, the term "partnership agreement" could be interpreted in a manner unintended by the experiment developers when considered from a legal viewpoint. Further work in precisely defining terms in the Space Mitigation field is recommended as the CSMC continues to be developed.

Annex A Definitions and States of CREDO Variables

Political Acceptability: The perceived level of comfort with committing to a mitigation agreement, from a nation's overall point of view.

Possible States:

- Acceptable: Good level of comfort about the mitigation agreement.
- Not Acceptable: There are concerns about whether my own nation could accept this mitigation agreement.

Partnership Context: List of factors defining the context surrounding the establishment of the space partnership.

Possible States:

- Favourable: The context do not brings concerns for the establishment of a partnership agreement.
- Neutral: The context is neither favourable, nor unfavourable.
- Unfavourable: The context brings concerns for the establishment of a partnership agreement.

Sharing Provisions: List of factors defining the type of space capability sharing that will occur in the event of a space capability degradation and/or loss.

Possible States

- Altruist-Broad: A broad access with no monetary compensation is provided to the partner.
- Limited: Some limitations are imposed to the access provided and some monetary compensation is required.
- Commercial: Only processed products are shared and with monetary profit.

Caveats: List of factors limiting the use of the shared space capabilities.

Possible States:

- Strongly Limited: Strong limitations on both the purpose and geographical use of the provided space capability.
- Mildly Limited: The limitations are limited to own nation's defence.
- No limitations: No limitation is imposed.

Space Pillar: One of the main capabilities to which space assets are contributing.

Possible States:

- SATCOM: Term intended to describe all command, control, communication and computer systems that are dependent on satellites communication capabilities.
- ISR: Term used to describe the synchronized and integrated planning and operation of all collection capabilities, as well as the processing and dissemination of the resulting data to the right people, at the right time, in the right format, to support operations.
- SSA: Term used to describe the ability to obtain information and knowledge about the space beyond the Earth atmosphere.

Type of Partner: Categories used to classify the type of partners.

Possible States:

- Ally: Long term ally with pre-existing commercial and military partnership agreements.
- Peer: Have engaged in a limited number of previous partnerships. The nation is perceived positively by ally nations.
- Questionable: Previous partnerships have been limited to commercial exchange and there are concerns about whether the nation can be trusted.
- Antagonistic: The nation has had recent political conflicts with ally nations.

Partner Capability: Categories describing the overall relevant space capabilities of the partnering nation.

Possible States:

- Most advanced: The partnering nation is among the most advanced nations in the world in terms of the relevant space capabilities considered within the agreement.
- Average: The partnering nation possesses some capabilities relevant to the space capabilities considered within the agreement.
- New to space: The partnering nation is new to the type of capabilities considered within the partnering agreement.

Access Sharing: Categories describing the type of access shared with the partnering nation.

Possible States:

- C2 Payload and Raw Data: Both access to the C2 payload and direct raw data access are provided.
- Raw Data: Only access to the raw data is provided.
- No Direct Access: No direct access is provided. Only indirect access to the satellite payload is provided.

Compensation: Categories describing the monetary compensation provided in exchange to the space capabilities shared.

Possible States:

- In-kind: No monetary value is provided.
- Small Compensation: A small monetary compensation is provided.
- Medium Compensation: The monetary compensation is similar to the overall cost associated with the provided space capability.
- Large Compensation: The monetary compensation includes profit (similar to the cost requested by commercial organizations).

Limitations of Purpose: Categories describing the limitations imposed on the purpose of use of the shared space capability.

Possible States:

- Peaceful non-economic: The use of the shared space capability has to be peaceful and non-commercial.
- Peaceful: The use of the shared space capability has to be peaceful.
- No limitations: No limitation of purpose is imposed.

Geographical Limitations: Categories describing the geographical limitation imposed on the use of the shared space capability.

Possible States:

- Peacekeeping exclusion: Geographical exclusion of all territories belonging to a nation which would be discontent with the partnering nation using this shared capability over its territory.
- Partner exclusion: Geographical exclusion limited to the nation providing the shared space capability and its close allies.
- No limitations: No geographical limitation is imposed.

Annex B Collaborative Space Mitigation for ISR

B.1 Background

As a space capability developer for Nation A, you are mandated to develop a surveillance space capability to support the following missions, as defined in the space handbook:

- Military and Civilian Maritime operations
- Disaster Monitoring and Humanitarian Relief
- Governance and Security in Remote Districts

Your project team concluded that an unclassified constellation composed of 2 satellites; one with a Synthetic Aperture Radar (SAR) sensor and the other with an Electro Optic (EO) sensor meet the operational requirements.

B.2 Mitigation Plan

Your submission to senior authority for approval must include a mitigation plan to manage the risk of space defence and space deterrence failure. The threats and hazards to the satellites are described in the space handbook.

5.2.1 Collaborative Mitigation

Another country, Nation B, has offered to develop a partnership agreement with your country to share SAR and EO capability that would meet the mitigation requirements. Your task consists of determining partnership agreement constraints and limitations that would lead to a politically acceptable partnership agreement.

In terms of limitations, you are requested to consider each nation respective limitations of access to each other satellite raw data, payload command and control, and satellite tracking, telemetry, and control (T,T&C).

In term of constraints, you are requested to consider the constraints imposed on the purpose of use of the satellite data (civilian only, both military and civilian, etc.), as well as, any reporting or monitoring constraints that would be imposed to ensure that the partnership agreements are adequately observed.

You are requested to repeat this exercise for each of the following partnering nation:

- **Ally Nation**: Long-term ally with pre-existing commercial and military partnership agreement.
- **Peer Nation**: Limited number of previous partnership, but the nation is democratic and is perceived positively by other Western nations.

- **Questionable Nation**: Existing partnership is limited to commercial exchange and there are concerns whether the nation can be trusted.
- **Antagonistic Nation**: The nation is not democratic and has had numerous recent political conflicts with several Western nations.

For each type of nation, fill a copy of the following form to indicate the least restrictive partnership agreement that you would consider politically acceptable for your country.

<table>
<tr><td>Vignette description:</td><td colspan="2">Space Pillar:_____
(PNT, SATCOM, ISR/SSA)</td><td colspan="2">Partnering Nation: _____
(Ally, Peer, Questionable, Antagonist)</td><td colspan="2">Contribution: _____
(A=B, A>B, or B>A)</td></tr>
<tr><td>Limitations, Constraints:</td><td>Data Access</td><td>Payload C2 Access</td><td>Satellite T,T&C</td><td>Oversight Committee</td><td>Reporting Requirements</td><td>Purpose Limitations</td></tr>
<tr><td>Desired Level:</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Other Limitations:</td><td colspan="5"></td></tr>
<tr><td colspan="2">Level of Political Acceptability:</td><td></td><td colspan="3">Reasons for lack of Politically Acceptable agreements:</td><td></td></tr>
</table>

Annex C Collaborative Space Mitigation for SATCOM

C.1 Background

Your country, Nation A, has a requirement for global and continuous communication for the conduct of military and civil operations above 70 degree north latitude. After completing a thorough Option Analysis which considered fibre-optic, micro-wave and satellite communication, it was established that a constellation of 3 small satellites placed on highly elliptical geosynchronous orbit, called tundra orbit, presented the best option. Other countries, Nations B, C and D, identified similar requirements for polar.

Your modeling of the constellation also shows that excess space communication will be available from time to time. Also, on a tundra orbit, each satellite will be travelling through the Van Allen radiation belt twice a day. The interaction between the highly charged particles present in the belt and the electronic equipment on-board the satellites significantly increase the risk of communication degradation.

C.2 Mitigation Plan

As the space capability developer for Nation A, you are requested to provide a mitigation plan to manage the risk of space defence and space deterrence failure. Your threat analysis clearly indicates that environmental hazards present the most significant threat to the constellation.

C.2.1 Collaborative Mitigation

Nations B, C and D, each offered to develop a partnership agreement with your country to share the excess space communication capacity and contribute a 4^{th} communication satellite to address the mitigation requirements. Your task consists of determining partnership agreement constraints and limitations that would lead to a politically acceptable partnership agreement.

In terms of limitations, you are requested to consider each nation respective limitations of access to each other satellite data, payload command and control, and satellite tracking, telemetry, and control (T,T&C).

In term of constraints, you are requested to consider the constraints imposed on the purpose of use of the satellite data (civilian only, both military and civilian, etc.), as well as, any reporting or monitoring constraints that would be imposed to ensure that the partnership agreements are adequately observed.

You are requested to repeat this exercise for each of the following partnering nation:

- **Ally Nation**: Long-term ally with pre-existing commercial and military partnership agreement.
- **Peer Nation**: Limited number of previous partnership, but the nation is democratic and is perceived positively by other Western nations.

- **Questionable Nation**: Existing partnership is limited to commercial exchange and there are concerns whether the nation can be trusted.
- **Antagonistic Nation**: The nation is not democratic and has had numerous recent political conflicts with several Western nations.

For each type of nation, fill a copy of the following form to indicate the least restrictive partnership agreement that you would consider politically acceptable for your country.

<table>
<tr><td>Vignette description:</td><td colspan="2">Space Pillar:_____
(PNT, SATCOM, ISR/SSA)</td><td colspan="2">Partnering Nation: _____
(Ally, Peer, Questionable, Antagonist)</td><td colspan="2">Contribution: _____
(A=B, A>B, or B>A)</td></tr>
<tr><td>Limitations, Constraints:</td><td>Data Access</td><td>Payload C2 Access</td><td>Satellite T,T&C</td><td>Oversight Committee</td><td>Reporting Requirements</td><td>Purpose Limitations</td></tr>
<tr><td>Desired Level:</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Other Limitations:</td><td colspan="5"></td></tr>
<tr><td colspan="2">Level of Political Acceptability:</td><td></td><td colspan="3">Reasons for lack of Politically Acceptable agreements:</td><td></td></tr>
</table>

Annex D Collaborative Space Mitigation for SSA

D.1 Background

As noted in the Space Handbook, SSA is necessary to successfully operate in space. SSA is achieved by integrating information from various missions; ranging from launch detection to tracking deep space objects, and including space weather monitoring. To that end, SSA relies on space and ground assets using different types of sensors such as radar, electro-optic (EO) and infrared.

The information associated with SSA presents various degrees of sensitivities; some of the information may be restricted and cannot be easily shared, while other information may be time sensitive demanding broad and quick dissemination. For example, the collection of track data and measures of a given satellite may yield knowledge of its purpose. For many satellite owners, this type of information is considered sensitive and may not be easily shared. Conversely, information regarding space debris tracks and subsequent conjunction analysis may result in manoeuvring a satellite in order to avoid a collision. Information regarding space debris may require quick, broad and unrestricted dissemination.

The space environment is becoming more congested, contested and competitive. In order to avoid collision in space, your government is acquiring a satellite equipped with an EO sensor to track deep space objects from 6000 km out to 40,000 km. While space deterrence and space defence synergistically contribute to protecting that space asset, there is a risk that they will fail, resulting in loss or degradation of the satellite leading to disruption or denial of SSA information on deep space objects. Consequently, your government seeks to improve deep space SSA capability resiliency.

D.2 Mitigation Plan

As the lead space capability developer you are requested to develop a mitigation plan to manage the risk of space defence and space deterrence failure. The threats and hazards to the satellites are described in the space handbook. Finding the balance between practical redundancy and smart resiliency is critical.

D.2.1 Collaborative Mitigation

Another country, Nation B, has offered to develop a partnership agreement with your country to share a deep space SSA capability that would meet the mitigation requirements. Your task consists of determining partnership agreement constraints and limitations that would lead to a politically acceptable partnership agreement.

In terms of limitations, you are requested to consider each nation respective limitations of access to each other satellite data, payload command and control, and satellite tracking, telemetry, and control (T,T&C).

In term of constraints, you are requested to consider the constraints imposed on the purpose of use of the satellite data (civilian only, both military and civilian, etc.), as well as, any reporting or

monitoring constraints that would be imposed to ensure that the partnership agreements are adequately observed.

You are requested to repeat this exercise for each of the following partnering nation:

- **Ally Nation**: Long-term ally with pre-existing commercial and military partnership agreement.
- **Peer Nation**: Limited number of previous partnership, but the nation is democratic and is perceived positively by other Western nations.
- **Questionable Nation**: Existing partnership is limited to commercial exchange and there are concerns whether the nation can be trusted.
- **Antagonistic Nation**: The nation is not democratic and has had numerous recent political conflicts with several Western nations.

For each type of nation, fill a copy of the following form to indicate the least restrictive partnership agreement that you would consider politically acceptable for your country.

Vignette description:	Space Pillar:_____ (PNT, SATCOM, ISR/SSA)		Partnering Nation: _____ (Ally, Peer, Questionable, Antagonist)		Contribution: _____ (A=B, A>B, or B>A)	
Limitations, Constraints:	Data Access	Payload C2 Access	Satellite T,T&C	Oversight Committee	Reporting Requirements	Purpose Limitations
Desired Level:						

D.3 Terminology

Resident Space Object (RSO): include all satellites, their component parts as well as their launch vehicle and parts thereof; decommissioned satellites and their component parts; non-allied military satellites; civil satellites which support non-allied military forces; re-entering space objects that can survive re-entry and fall over Nation A territory; and, any other space object that may be of national interest.

Magnitude: RSO's magnitude is often associated with its brightness. Hipparchus was the first astronomer to classify stellar objects according to their brightness, where the brightest star had a "magnitude 1", followed the next brightest "magnitude 2", and so on until he reached "magnitude 6", which was the faintest he could see. This makes the scale about 2000 years old. There are two factors that affect RSO's magnitude, its brightness and its distance from the observer.

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List of symbols/abbreviations/acronyms/initialisms

C2	Command and Control
CFWC	Canadian Forces Warfare Centre
CORA	Centre for Operational Research and Analysis
CSMC	Collaborative Space Mitigation Concept
DG Space	Director General Space
DND	Department of National Defence
DOTMLPFI	Doctrine, Organisation, Training, Leadership, Personnel, Facilities and Interoperability
DRDC	Defence Research & Development Canada
EO	Electro Optical
ISR	Intelligence, Surveillance, Reconnaissance
LOE	Limited Objective Experiment
MNE	Multinational Experiment
RSO	Resident Space Object
SAR	Synthetic Aperture Radar
SATCOM	Satellite Communications
SME	Subject Matter Expert
SOI	Space Object Identification
SSA	Space Situational Awareness
STK	Systems Toolkit
STM	Space Traffic Management
TT&C	Tracking, Telemetry, and Control

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Within the scope of the Multinational Experiment 7, the Canadian Forces have developed a Collaborative Space Mitigation Concept (CSMC) to mitigate the risk of losing access to existing space capabilities. This concept proposes the development of partnership agreements for the sharing of space capability in the event that space assets or the access to them are lost.

The formation of a space mitigation agreement is dependent on the partnering nations being able to negotiate politically acceptable provisions and limitations. A limited objective experiment was held in Lucerne, Switzerland to investigate the factors necessary to obtaining politically acceptable space mitigation agreements. International subject matter experts participated in the experiment, using two methodologies (an open tabletop discussion and a Swiss military decision support system, known as CREDO) in the investigation.

This report provides results from the limited objective experiment, discussing the level of political acceptability for a number of partnership agreements which were created by the participants. Findings on the likelihood of obtaining political acceptability, the degree of political acceptability, and the necessary provisions and limitations are discussed.

Dans le cadre de l'Expérimentation multinationale 7, les Forces canadiennes ont élaboré un Concept collaboratif d'atténuation des pertes de capacités spatiales (CSMC pour *Collaborative Space Mitigation Concept*) qui vise à atténuer les risques de perte d'accès aux capacités spatiales actuelles. Ce concept propose de conclure des ententes de partenariat permettant le partage des capacités spatiales dans l'éventualité où certains biens spatiaux, ou l'accès à ces biens, seraient perdus.

La signature d'une entente visant l'atténuation des pertes d'accès aux capacités spatiales dépend de la capacité des pays partenaires à négocier des dispositions et des limites acceptables sur le plan politique. Une expérience à objectif limité a été menée à Lucerne, en Suisse, afin de déterminer les facteurs essentiels à l'élaboration d'ententes politiquement acceptables. Les experts internationaux qui ont participé à cette expérience ont eu recours à deux méthodes dans le cadre de ces recherches, soit la tenue de discussions ouvertes et l'utilisation d'un système d'aide à la décision de l'armée suisse désigné sous le nom de CREDO.

Le présent rapport contient les résultats de cette expérience à objectif limité et traite du niveau d'acceptabilité, sur le plan politique, de diverses ententes de partenariat élaborées par les participants. On y présente les conclusions relatives à la probabilité de parvenir à des ententes acceptables politiquement, au degré d'acceptabilité sur le plan politique ainsi qu'aux dispositions et aux limites nécessaires.

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