Leaping Tall Barriers in a Single Bound: Knowledge Sharing, Simulations and NATO

Louise Hoehl
NCI Agency
The Hague
NETHERLANDS

Mark Rempel
DRDC
Ottawa
CANADA

Guido Veldhuis
TNO
The Hague
NETHERLANDS

louise.hoehl@ncia.nato.int

mark.rempel@forces.gc.ca

guido.veldhuis@tno.nl

ABSTRACT

Modelling and Simulation (M&S) is a key method used by Operational Analysts to support decision makers as it has the ability to provide clear insights into complex problems. Given its benefits, many NATO nations and organizations within NATO have significant M&S expertise and have applied it to a wide range of problems. However, these simulations, in particular those with high complexity, can be costly, time intensive to develop and validate, and require specialist knowledge and resources to use. While sharing this expertise and these simulations across NATO may lead to more efficient decision support, it is fraught with barriers including time pressures related to project schedules, intellectual property rights, and at times sharing of classified material. Overcoming these barriers will help NATO gain the decision advantage it deserves from the M&S investment and expertise across the Alliance. However, to overcome these barriers, practical and implementable solutions are required.

In this paper, we present an overview of the work of MSG-SAS-178, whose aim is to develop an approach to mitigate such barriers. We discuss the group's two main contributions. First, the group's identification and categorisation of common barriers to sharing M&S software, resources, and simulations themselves within NATO. Second, we present a barrier exchange framework that serves as a decision support tool when considering barriers in multiple dimensions, including data, software, suppliers, and the decision makers. The framework provides an actionable way to shape a collaboration by carefully considering the model and data exchange requirements as well as barriers resulting from the exchange. This enables greater M&S sharing across the Alliance.

1.0 INTRODUCTION

Modelling and Simulation (M&S) has been successfully used to support decision making within NATO for decades and is a key analytical capability. Areas of application include advanced operational planning, capability-based planning, capability and/or concept development, and support to experimentation and wargaming [1, 2, 3, 4, 5, 6]. M&S takes many forms, from large complex campaign simulations designed to be used over many years, to simulations built quickly for a single purpose. Large and complex models can be costly to develop and maintain, and many models require specialist expertise that is in short supply. The cost and required expertise make M&S an area where NATO's collective capabilities and willingness to collaborate should give the Alliance the advantage over its adversaries.

Typically, there are four sources to provide simulation services: (1) NATO entities, (2) national governments, (3) industry, and (4) academia. All four of these have expertise, tools, and data. Expertise and tools can be expensive and time-consuming to develop and maintain, especially in specialised or niche areas. For data, the classification levels used in defence can be an issue, constraining both industry and academia and affecting sharing at the national and NATO levels.

NATO entities and national governments have become the preferred choice for simulation services for

NATO. Contracting for services within NATO is relatively easy, but experience has shown that with national governments or other entities it is fraught with difficulties. There are barriers to the provision of simulation services across NATO, leading to stovepipes and inefficiencies. Under NATO's Science and Technology Organisation (STO) a joint Modelling and Simulation Group (MSG) and Systems Analysis and Studies (SAS) activity (MSG-SAS-178) was initiated in 2019. The activity's aim is to consider how barriers may be overcome to the benefit of NATO and all its members. This paper discusses this group's two main contributions. First, the group's identification and categorisation of common barriers to sharing M&S software, resources, and simulations themselves within NATO. Second, a barrier exchange framework that serves as a decision support tool when considering barriers in multiple dimensions, including data, software, suppliers, and the decision makers. The framework provides an actionable way to shape a collaboration and create the conditions for success by carefully considering the model and data exchange requirements as well as barriers resulting from the exchange. This enables greater M&S sharing across the Alliance.

The remainder of this paper is organised as follows. Section 2 outlines the approach used in this study. Next, Section 3 discusses barriers to sharing: first, those identified through a review of the knowledge sharing literature, and second those specifically related to sharing simulations within NATO and between nations as identified through the MSG-SAS-178 activity. Section 4 presents a method to navigate model and data exchange, perhaps one of the most significant groups of barriers within defence. Drawing from the MSG-SAS-178 more elaborate case study repository, we present how the data and model exchange framework may be used in real-world scenarios. Section 5 provides concluding remarks.

2.0   APPROACH

This study employed an approach based on a combination of academic literature, case studies, and the breadth of experiences of the MSG-SAS-178 members. The activities performed within this approach were:

- **Discovery through experiences**: A common level of understanding was developed through group discussions on the broad range of experiences of the members of MSG-SAS-178 with M&S, and sharing of M&S.

- **Structured data capture using case studies**: Using a common format, case studies on M&S sharing were collated. This included information on what was being shared, the sharing mechanism, any issues encountered, and how / if they were overcome. A PESTEL analysis[1] of the case studies was undertaken.

- **Literature review**: A literature review was undertaken on the topic of overcoming barriers in knowledge sharing. The review considered both literature on technical knowledge / models, as well as knowledge sharing within organisations in general.

- **Captured and categorised the barriers to sharing M&S**: Taking the knowledge from the previous three steps, a list of barriers was generated. These barriers were categorised from a time aspect, and cross-checked with the case studies for completeness.

- **Developed an overall approach to overcoming barriers**: Practical and actionable were at the forefront of the group's thinking during this step. The group developed a novel way of thinking about overcoming barriers in general, followed by a practical framework to enable it to be put it into practice.

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[1] PESTEL analysis is a strategic framework used to evaluate the external environment breaking down the opportunities and risks into Political, Economic, Social, Technological, Environmental, and Legal factors.

The current paper does not present the full breadth of the panel's results from these activities; rather, it draws some of the most significant practical implications from the activities conducted by the panel. It should be noted that the second and third activities listed above were conducted in parallel. In the next section, we first discuss the results of the knowledge sharing literature review, followed by those identified through case studies.

3.0   IDENTIFYING BARRIERS

3.1   Knowledge Sharing

Sharing a simulation model between analysts, organisations, or nations is akin to *sharing knowledge*: "the process of exchanging knowledge (skills, experience, and understanding) among researchers, policymakers, and service providers" [7, p. 5]. This process of sharing is in essence the act of "guiding someone through one's own thinking, making others aware of one's personal insights by capturing, organising, transferring, and reusing an organisation's experimental knowledge" [8, p. 29]. Generally, the knowledge exchanged consists of two types: *tacit knowledge* that includes knowledge, skills, and abilities that are difficult to put into words (Polanyi, 1966); and *explicit knowledge* that includes formal or codified knowledge [9]. The transformation of knowledge from tacit to explicit, and vice versa, occurs because of these exchanges, as well as the creation of new knowledge [10].

The knowledge sharing and knowledge management literature have discussed sharing both tacit and explicit knowledge in a wide variety of domains: health and life sciences research [11], software development [12], and Six-Sigma process improvement [13]. See [14] for further examples. This literature has also documented numerous barriers to sharing knowledge. In particular, [8], [15], [16], and [17] each conducted a systematic review on the topic. While the barriers listed may not be exhaustive, they do provide a representative sample as evidenced by the fact that these sources identified many of the same barriers—albeit with small differences in their names and / or descriptions. For example, a lack of time to share knowledge was identified in [8], [15], and [17]; poor communication skills was identified in [8] and [15]; and differences in national culture was identified in [15] and [17]. Mapping the barriers identified in these four articles to common names resulted in 41 unique barriers.

In addition to the identification of barriers, these articles and others have proposed barrier classification schemes. For example, [15] suggested grouping barriers into three categories: individual, organisational, and technological. Likewise, [18] clustered barriers into two groups, individual and organisational. The authors' argument for this grouping was that advances in technology have reduced technology-based barriers to knowledge sharing and thus the primary ones are either individual-driven or organisation-driven. Within the context of software development, [17] proposed barriers may be classified as either individual, organisational, technological, cultural, or geographical. As an alternative, [8] discussed barriers in the context of knowledge contributing, defined as exchanging information between groups in order to provide assistance, and knowledge seeking, that is active searching of information for a specific purpose.

Figure 1 depicts the 41 unique barriers and classifies each as either individual, organisational, or technological, as proposed in [15]. These categories were chosen because they are the ones most commonly used across the sources examined, or were a subset of those used.
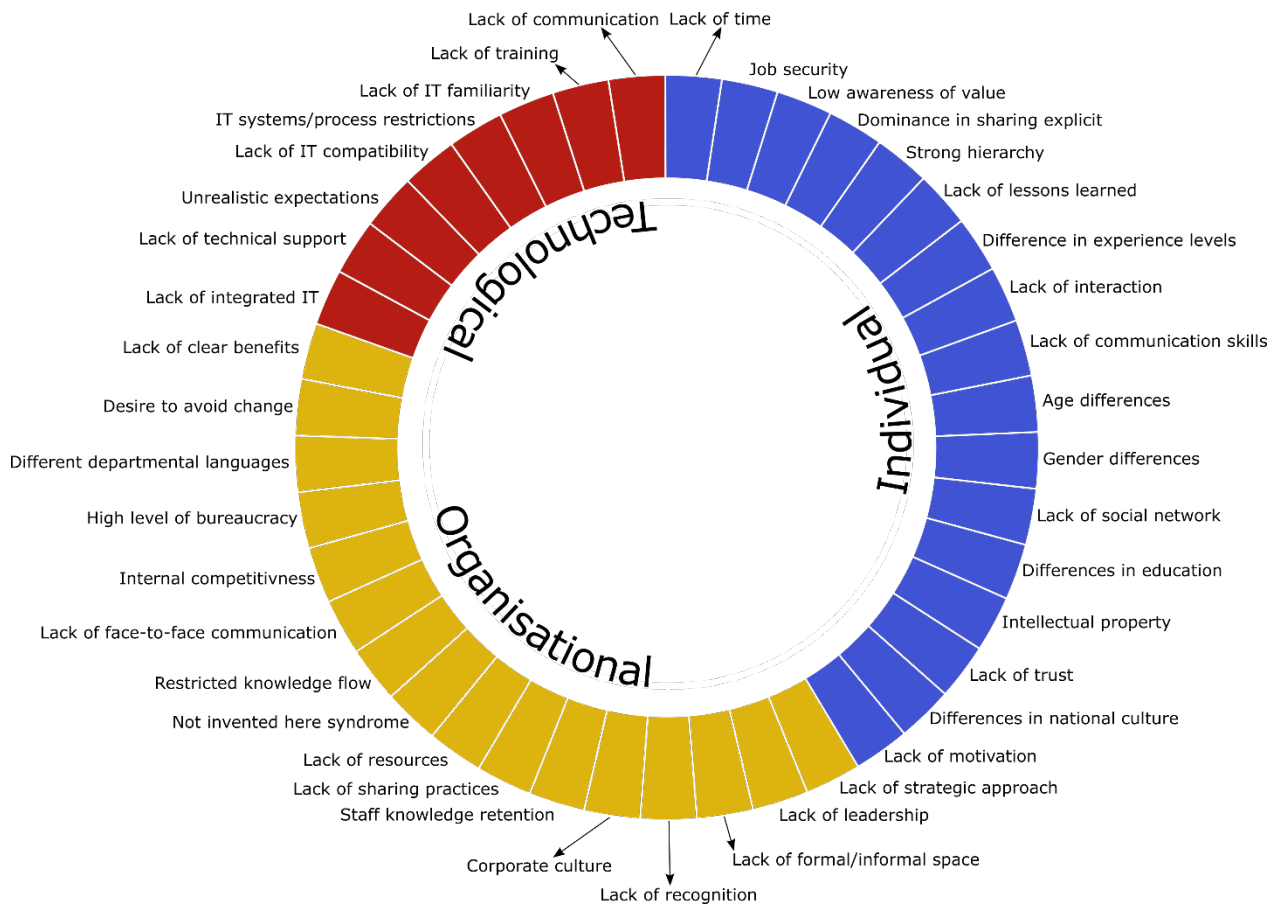
Figure 1 Identified knowledge sharing barriers.

3.2   Sharing simulations between NATO Entities and NATO Nations

The knowledge sharing and knowledge management literature provide a set of barriers that may appear when sharing M&S within a NATO setting or between nations themselves. However, this set does not capture specific barriers that may appear in the context studied in this paper, such as classification of data or export controls. To identify such issues, the MSG-SAS-178 group identified barriers using two approaches. First, the group used brainstorming [19] to propose barriers primarily from their own experiences. Secondly, the group's members collected use cases from their respective organizations. In general, these use cases included studies in which it was deemed advantageous to share a simulation between NATO organisations, between a nation and NATO, or between two nations. Based on the information collected, 23 barriers were identified and grouped into three categories. Table 1 through Table 3 lists a name for each barrier and a brief description. The three categories, which each focus on a different phase of the sharing process, are described as follows.

- Decision to outsource: This first phase includes barriers related to preventing the decision to outsource an M&S requirement. For example, a lack of trust in M&S capabilities, an organisational preference to conduct the study in-house, and time pressures.

- Enabling mechanisms: Barriers in this second phase focus on the procedures and processes required to enable the sharing arrangement, or contract, to occur. Examples include the availability of a suitable contracting mechanism, intellectual property rights, and the sharing of classified material.

- Achieving success: Barriers in this third phase arise once the sharing mechanisms are in place.

Barriers in this category include building trust with decision makers, awareness of verification and validation, and the time required to understand the M&S provided.

Table 1 Barriers to outsourcing.

Barrier	Description
No advocate with both will and ability	Success often requires an advocate, a person that has the ability and will, within their authority to take appropriate actions to make the sharing of capabilities a reality. A willingness but no ability, or an ability but no willingness are both insufficient and result in a barrier.
Lack of strategic direction	Strategic direction within an organisation that clearly states a desired goal to share M&S, including externally, opens doors to make that goal a reality. When direction is not provided, people do not tend to identify opportunities, create supporting policies and mechanisms, or free up required resources.
Low awareness of benefits of sharing M&S	The benefits of sharing M&S are clear to those in the analytic and M&S arenas but may not be to everyone. With a low awareness of the benefits, opportunities maybe passed over, and the additional activities required to begin a sharing activity may not be as easily accessed.
Perceptions of difficulty	A perception that outsourcing M&S requirements is difficult is generally the result of experiences, differences in languages, etc. The perception leads to decisions not to attempt to outsource. Without strategic direction, it can be difficult to overcome such perceptions often passed through unconscious biases.
Lack of trust in other M&S capabilities	There can exist a perception that if it is not in-house M&S then it will not be good enough, or sufficiently trusted, for our requirements. A lack of trust frequently stems from limited awareness and knowledge of others capabilities.
Organisation preference for in-house	This can be seen in either a bias for work to remain in-house, or a lack of incentives to consider outsourcing work as a viable option. It presents itself as an overall internal resistance to outsourcing. As the effectiveness and benefit of sharing practices (especially across organisations) is difficult to measure, the preference is difficult to challenge using evidence.
Time pressures	There is a perception, which experience has often shown to be true, that outsourcing M&S will take longer than conducting the analysis with in-house M&S or finding an alternate methodology to assess the issue. Especially where deadlines are tight, this can represent a significant barrier.
Gaining and maintaining situational awareness of appropriate M&S	It can be difficult to gain / maintain awareness of the M&S capabilities that could be brought to bear on a specific problem. There is presently no known catalogue or mechanism to quickly or easily gain this awareness.
Ability to refine issue with multiple parties involved	The ability to have two-way communication between a potential M&S client and the supplier is essential to identify a best-fit M&S approach. This is more difficult when multiple organisations / nations / parties are involved and potentially before any specific contracts are in place. There may also be a cost barrier to be overcome to enable such discussions.
Reduction in pool of M&S available	Factors that results in a reduction in the availability of M&S within NATO nations include: a trend towards single use specific models; the significant cost of maintaining M&S capability, especially in the area of combat modelling; and documenting use of M&S in relation to a decision rather than documenting M&S for the purpose of reuse.
Suitable national M&S for NATO issues	National M&S capabilities do not always have the ability to represent NATO requirements in terms of multi-national representation or scale. Additionally, they can have built-in national policy, doctrine, or tactics that are not applicable across the complete NATO spectrum.
No perceived reward	Without a perceived recognition system that rewards people for their activities to share in the area of M&S, be that the models themselves or their expertise, there can be a lack of motivation to do so. At an organisational or national level, this may be seen as a lack of reciprocal benefits to compensate for the additional activities involved in sharing.

Table 2 Barriers to enabling mechanisms.

Barrier	Description
Cultural and bureaucratic reluctance for new mechanisms	Sharing arrangements can often require new mechanisms, or new processes, to enable them. Organisation culture and bureaucratic reluctance can be an issue when trying to put these enablers in place. This often results in time delays.
Suitable contracting mechanism	Having, or identifying, an actual funding and contracting mechanism that is usable in the specific situation can often be a significant hurdle. Additionally, contracts and associated funding are often linked to a specific financial year—which differs across NATO Nations, creating funding hurdles and impacting contract delivery schedules.
Suitable memorandum of understanding (MoU)	Sharing of information between nations often requires a MoU to be in place between the relevant parties. While many MoUs exist, they are often not created for the purposes of sharing M&S and need to be modified, or a new one created specifically for purpose.
Resource availability	The availability of the resources, at the required time and place, can hamper the ability to share M&S facilities. Resources include, but are not limited to: subject matter experts (SME), personnel with tacit knowledge of the specific M&S; hardware; software licences; and high performance computing facilities.
Sharing classified materiel	Defence M&S comes with classification issues around data and assumptions. Working across national boundaries, or between NATO and a nation, can further hamper existing classification issues with national caveats. This includes both the ability / willingness to share information, available IT and networks, or even the ability to access sensitive locations.
Intellectual Property Rights (IPR)	Ensuring an upfront understanding and any resolution of any IPR issues between parties related to: (1) use of the M&S, (2) data associated with the M&S, and (3) potentially reuse of any outputs from the M&S.
Export/National control issues	Export control issues related to the M&S, e.g., U.S. capabilities subject to International Traffic in Arms Regulations (ITAR). This can also appear in other ways, for example if a specific piece of M&S has a national security importance categorisation.
Sponsor permissions and agreements	With M&S used by analysis organisations being conducted on behalf of a sponsor or customer, an additional layer of permissions and agreements may need to be in place. The hierarchical nature of many Defence organisations can further exacerbate this issue, especially when authority for external sourcing are not devolved to the appropriate level.

Table 3 Barriers to achieving success.

Barrier	Description
Time to understand M&S	It can take time to develop an understanding of the specific limitations, capabilities, key data and assumptions, for any given M&S. The model specialists or analysts experienced with the use of a particular M&S can provide this if time and resources allow.
Building trust with the decision maker	To be successful, analysts using a specific M&S must have the trust of the decision maker for whom it is destined. M&S can often be seen as a black box and this can be exacerbated if a model unknown to the decision maker has been used.
Awareness of verification and validation (V&V)	Understanding the V&V associated with the any specific M&S ensures that it can be used appropriately and with confidence. A national M&S capability is likely to have V&V conducted for national use, so use with either NATO or a different nation will already need careful consideration to ensure the correct level and interpretation on outputs can be provided.

Based on a systematic review of the knowledge sharing barriers' definitions and those definitions listed in Table 1 through Table 3, a mapping between these two sets—depicted in Figure 2—was completed.[2] Each coloured cell, where the colours represents the knowledge sharing barrier categories, reflects that a relationship exists between two respective barriers. For example, *Cultural and bureaucratic reluctance*

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[2] The descriptions of the knowledge sharing barriers are not included in this paper for the sake of brevity. These descriptions will be included in the forthcoming MSG-SAS-178 final report.

(Enabling mechanisms) is related to the knowledge sharing barriers *Lack of communication skills*, *Age differences*, *Gender differences*, etc.
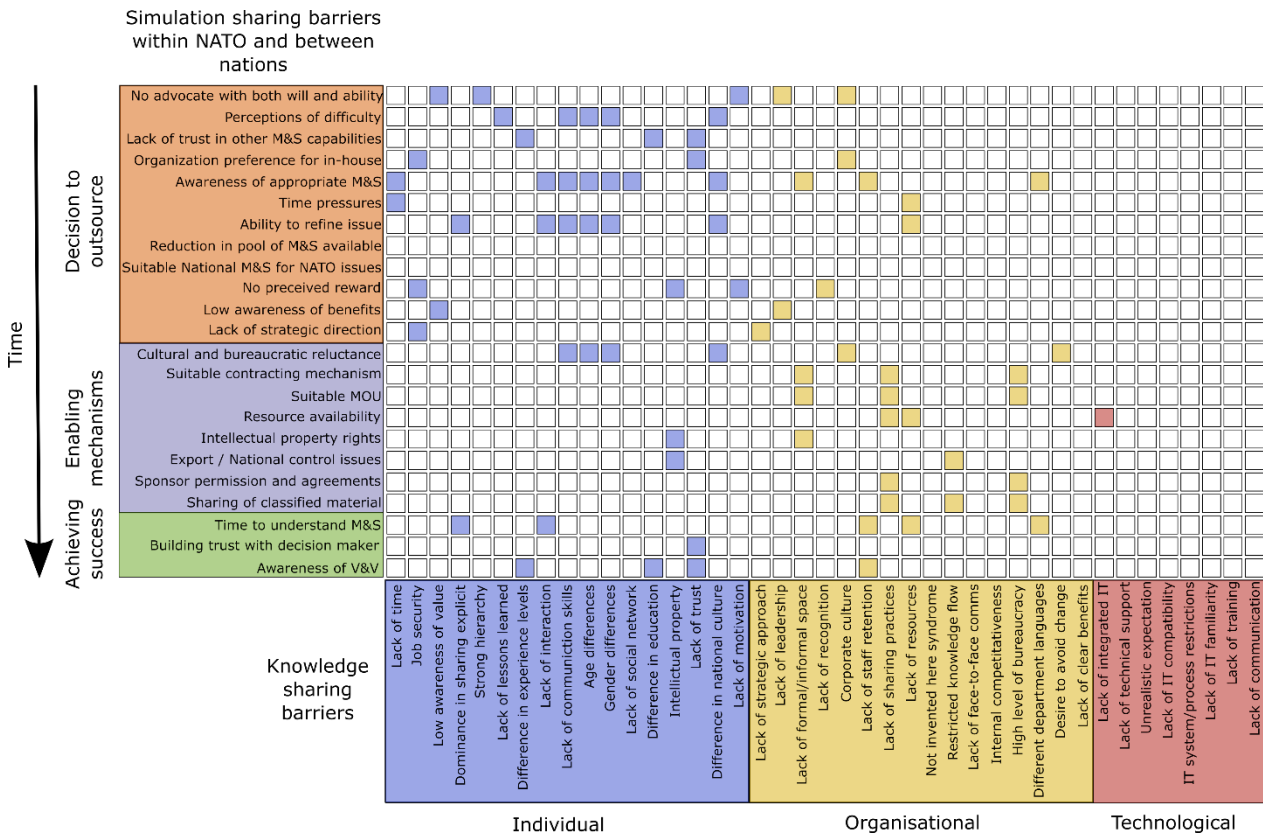

Figure 2 Mapping between barriers to sharing simulations and those identified from the knowledge sharing and knowledge management literature.

Inspection of Figure 2 reveals that roughly half (13) of the simulation sharing barriers are related to both individual and organisational barriers. The remaining 10 barriers are split into four groups: (a) three are related to only individual barriers; (b) four are related to only organisational barriers; (c) one is related to organisational and technological barriers; and (d) two are not related to any knowledge sharing barriers. Thus, with the exception of two, all simulation sharing barriers are related to either individual or organisational barriers, suggesting that these are the primary areas of concern with respect to sharing simulations. This result aligns with [18], which concluded that the vast majority of barriers exist within these two domains. The lack of technological related barriers could be a limitation of the data collected to date, but the authors' opinion is that a more likely explanation is that although technical difficulties are common in M&S projects, they are almost never insurmountable.

4.0   LEAPING BARRIERS

4.1   Change the mind-set

The terminology of barriers is suggestive, and puts everyone in a certain mind-set. Barriers provoke a feeling of needing destruction; barriers hold people back and must be broken down. To others, barriers are something to be overcome, similar to obstacle courses designed to test your strength and endurance. Many of the barriers identified in the previous sections are unlikely to be overcome any time soon. For example, how

long will it be until we reach the panacea of complete trust and openness in all data across NATO, with no national caveats?

> Example: Satellite Navigation. For all journeys, the user puts the required destination into the Satnav and a route is identified. Sometimes it presents options, perhaps a longer more scenic drive, or paying a toll. If there is an event during the journey, it finds an alternate route. However, my Satnav has never asked the user to fix the road. It has never told the user to build a bridge because that would make a simpler straighter route.

Instead, we need to think about a route to the destination, our destination being to make greater use of the M&S in existence across NATO and NATO nations, for the benefit of all. There are ways we can do this now, without waiting for panaceas to arrive that my never come. For example:

- If we do not have a catalogue of possible M&S to look through... can we identify a set of people who work in the area that would get us a different path to potential M&S?

- If we cannot have a nation's simulation delivered and packaged to use ourselves, can we utilise them as a service to run it for us?

- If we cannot see all data and assumptions in a national model to build confidence and trust in the outputs, can we substitute for the reputation and confidence in the organisation that built it?

- If we do not have time to put in place a specific contract of MoU for the service required, is there an existing one that can be utilised?

One of the most significant barriers identified within the Alliance, which is not discussed in the broader knowledge sharing literature, is the manner in which the model and data are shared due to issues related to classification. Next, we introduce a model and data exchange framework which can be used to identify different routes to M&S collaboration, followed by examples in Section 4.3 of the framework in action. Lastly, Section 4.4 returns to the knowledge sharing literature to provide some indications of how to tackle those barriers that are not unique to the Alliance.

4.2   A model and data exchange framework

Barriers encountered in the process of initializing and executing an M&S analysis depend on what is exchanged between the different parties involved. When an opportunity is identified to utilize an M&S capability, it is important to consider what type of exchange is actually necessary in order to achieve the goal of the analysis. In other words: Check your Satnav before you start your drive.

In this section we provide a framework to assist in determining how different options for exchange influence the degree to which barriers are encountered and the relative effort that is likely required to clear them. This presents a number of key questions to be answered when formulating a project. Answering these questions requires a solid understanding of the purpose and requirements of the analysis. We will discuss these questions and present some generic alternatives for both a model axis and data axis of the framework. We will first define the elements of the framework, then introduce the framework itself.

Elements of the framework

The two main dimensions of the framework concern:

- **Model**: The algorithms, code, software, etc. that is used to conduct the analysis; and

- **Data**: The data that is used by the model to generate output.

The framework distinguishes two types of actors:

- **Supplier side**: The owner of the model; and

- **Client side**[3]: The actor that requires a question to be answered and wants to conduct an M&S analysis to this end.

The model axis

The analysis can be performed in the environment of the client or the supplier with varying degrees of access of the client to the model. Important questions to consider are:

- Does the client side <u>need</u> to operate the model?

- Does the client side <u>need to alter</u> the model?

- Does the analysis <u>require the model to be installed and/or integrated</u> in client side systems?

- Does the client <u>need in-depth understanding</u> (data, information, code) of the model operations?

As the model is owned by the supplier side, more obstacles will be encountered when the model is transferred to the client side, e.g., intellectual property, export control, and security clearance. In addition, barriers can be encountered at the client side if a model is transferred to client IT systems; in particular if that system is a networked environment.

Six model exchange options are identified in the framework. Actual barriers encountered will depend greatly on intellectual property rights, export control and classification of the model code (not to be confused with data used by the model). The six options fall into two categories:

- **Analysis on supplier side**: situations in which the supplier uses the model to perform the analysis

  1. Share only aggregate output (e.g. graphs)

  2. Share detailed output

  3. Share detailed model description

- **Analysis on client side**: situations where the model is physically located in the client side environment. (noting the supplier might still have a role in operating the model)

  4. Share model on dedicated hardware

  5. Run model on client system

  6. Share source code and right to alter

Note that supplier side analysis will require a considerable amount of trust by the client, whereas client side analysis might require the client to invest considerable effort in learning how to operate the model. Two innovations in collaboration might blur the line between supplier and client-side analysis and data sharing requirements in the future: Secure Multi-Party Computation (MPC) uses cryptography to enable parties to use data without that data being revealed to the other party. Modelling and simulation as a service (MSaaS) enables parties to remotely use models.

The data axis

Either the supplier, the client, or both might possess data required for execution of the analysis. In addition, open source or otherwise non-classified materials might be available. Often more stringent regulation and procedures concern the data used by a model rather than the model itself, especially with regards to

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[3] Both the client and supplier side is often composed of different stakeholders, e.g., decision makers, sponsors, client, owners, analysts, steering committee and various controlling or regulatory actors. In order to keep our argument concise, we will simplify the situation.

classification of the data. A barrier to access data by the supplier might exclude supplier side analysis all together and vice versa. Therefore, it is crucial to consider:

- Is the usage of classified data essential for (part of) the analysis?

- Does the supplier require access to client-side classified data?

- Does the client require access to supplier-side classified data?

We identify four data exchange options. Use of non-classified data will encounter the least barriers. Using classified data from either client, supplier, or both sides will require the most effort to overcome barriers. Actual barriers encountered will depend greatly on the classification level of the data concerned and the availability of legal and security frameworks to facilitate the use of the data. The identified data exchange options are:

1. use unclassified data;

2. use supplier side classified data (not accessible to client);

3. use client side classified data (not accessible to supplier); and

4. use classified data (accessible to both parties).

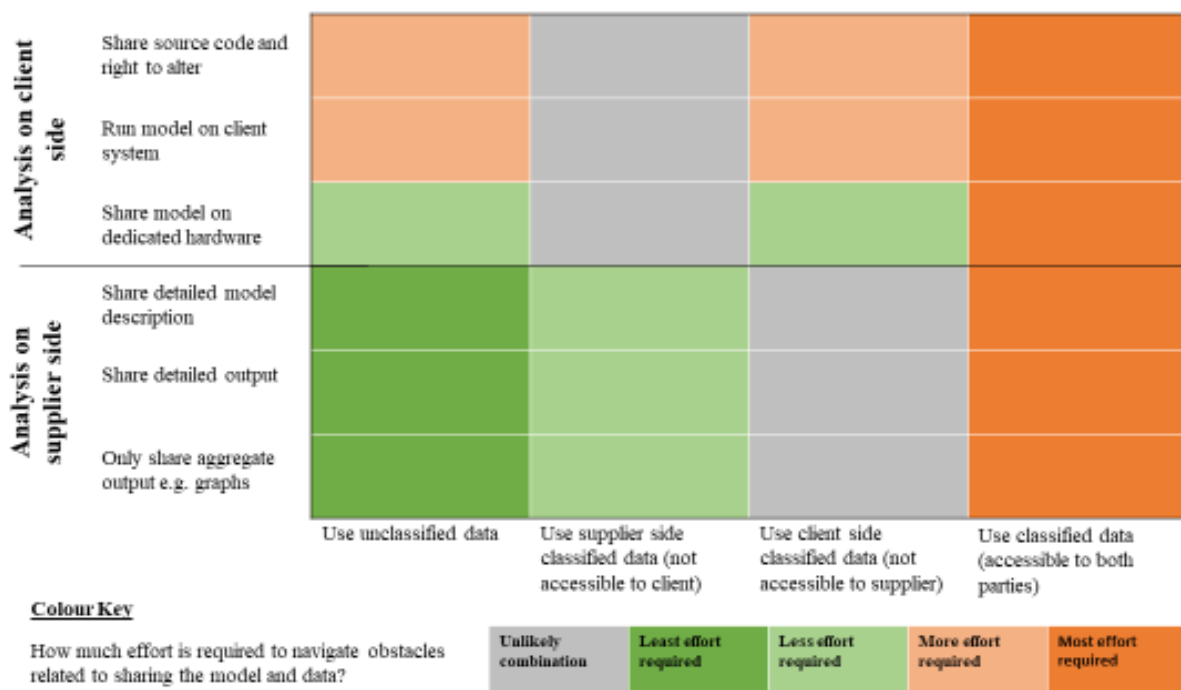The axis and elements presented above create the framework depicted in Figure 3.

Figure 3 A framework for considering model and data usage.

The exchange framework

A project can be located in any of the 24 boxes in the framework, although it is most likely that a project will appear in one of the 18 that are deemed feasible (green or orange). Different types of barriers, costs, and benefits can be exchanged by making different choices with regards to the degree in which model and data is exchanged. For example, by contracting a supplier who owns a simulation to perform the analysis, barriers

regarding the model IP are circumvented as the simulation does not need to be transferred to the client. However, a barrier regarding trust in the supplier's ability might be introduced. Creating the conditions for success will require the supplier and client side to together select a box that is in line with the project's purpose and their ability to remove barriers. For example, exchange of classified data might not be problem if legal and technical measures are in place. Both client and supplier should therefore carefully consider which barriers are present in which box and how they can be overcome. The lists of barriers provided in chapter three can serve as an aid in this process.

4.3   Examples of applying the framework

Outsourcing A2AD Modelling

Situation: In 2019, NATO Allied Command Transformation required the use of a simulation to inform and support an analytical study tasked by the International Military Staff on behalf of the Military Committee. For the initial request, relating to Anti-Access/Area Denial (A2AD), no suitable simulations were available within NATO entities, but an appropriate national simulation was identified.

The **key barrier** identified concerned the input data required by the simulation. The breadth and depth of the data could not be sourced by NATO (client), and the nation's (supplier's) existing data within the simulation had national caveats and proprietary restrictions and could not be fully shared. Additionally, the expertise to run and assess the simulation outputs lied within the nation (supplier), and NATO (client) had no subject matter experts in the specific simulation.

Using the Exchange Framework

Although not all input or output data could be shared, a compromise allowed the national (supplier) data to be used and aggregate outputs to be made available to NATO (client), with the bulk of the analysis undertaken by the national (supplier) analysts. With this solution, two specific exchanges were made:

1. **The manner in which trust and confidence was built in the simulation outputs:** instead of building through transparency of data and use of known staff, the team had to trade on the reputation of the national (supplier) capability.

2. **Decisions on relevant outputs**: instead of NATO (client side) assessing the detailed outputs of the simulation to gain the required information, staff spent time imparting their analytic aims and requirements to the national analysts (supplier side) so that the appropriate aggregate outputs could be provided.
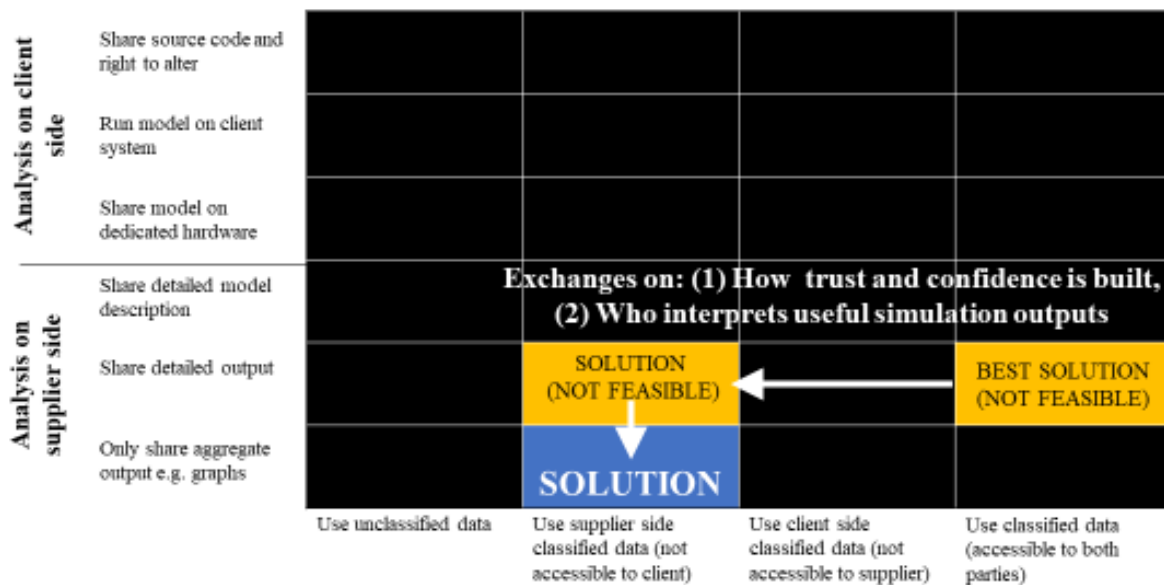
Figure 4: Matrix for in action for NATO A2AD modelling.

Theatre Missile Defence Integration Testing

Situation: NATO has a requirement to undertake ensemble testing of ballistic missile defence (BMD) integration experiments and theatre missile defence design. This provides an assessment of the interoperability of various systems. A national model was identified as the most appropriate model for the requirement to create some of the synthetic systems required for the test.

The **key barrier** identified was around the transfer of the model. The national (supplier) model identified was classified as an export control regulated asset, which brings with it a host of national regulations on its use and transfer to others.

Using the Exchange Framework

The model was made available as a voluntary national contribution. The exchange was initiated from an active role of the nation in the Conference of National Armament Directors (CNAD) BMD working group. Execution was assisted by the NATO/national MOU and further facilitated by financial support by the nation. A physical system with national (supplier) modelling capability was placed within the NATO (client) facility and national staff were provided to facilitate its use in the testbed. This was provided, as it had been before, as a National Voluntary Contribution (NVC). The model remained the property of the nation (supplier). With this solution, two specific exchanges were made in:

1. **Reliance on a supplier for access to the capability:** By hosting a national (supplier) capability, NATO (client) gained access in a (relatively) quick and inexpensive manner, in exchange for granting some physical access and having a reliance on the nation for continued use.

2. **Development time for breadth of usability:** The nation built modular algorithms and separate databases to meet different security requirements (i.e. national only, unclassified.). The nation (supplier) exchanged upfront additional development time, for the ability to deploy the model in a greater range of situations.

Figure 5: Matrix for in action for Theatre Missile Defence Integration Testing.

4.4   Suggestions for overcoming knowledge sharing barriers

While the proposed exchange framework aims to help analysts shape a collaboration by considering the model and data exchange requirements as well as potential barriers, it does not explicitly identify how to overcome these barriers. Many of the barriers identified to sharing M&S within the Alliance are not unique and much can be learnt from the general literature. However, often "[t]here is little guidance for managers on how to overcome diverse barriers or the benchmarking of the effectiveness of diverse actions put in place to tackle sharing barriers" [15, p. 31]. The effectiveness of different approaches will be situation dependent; however, general suggestions to tackle barriers do exist. Those that may be the most useful with respect to sharing M&S across the Alliance are listed below.

- **Riege** [15]: Creating a knowledge sharing culture and depends on the synergy of three main factors. First, encourage individuals to capture, disseminate, transfer, and apply both existing and newly generated knowledge, especially tacit knowledge. Second, create flat and open organisational structures that facilitate transparent knowledge flow and a continuous learning organisation culture. Third, use technology that integrates processes and systems to provide a sharing platform.

    – *Insight: Senior leaders need to create the culture that encourages dissemination and transfer of M&S, and be the advocate and example that others will follow.*

    – *Insight: Organisational processes need to be reviewed with the purpose of creating the right balance between enabling information flow within the Alliance and data protection from adversaries.*

- **Hung et al.** [18]: Employ conversational knowledge sharing, that is, enable individuals to "create and share knowledge through dialog with questions and answers" [20, p. 266] based on communities of practice and web-based technology.

    – *Insight: Provide opportunities for individuals to network and converse across the Alliance, e.g., conference attendance, communities of practice, software sharing platforms.*

- **Samuelson et al.** [21]: Provide recognition in order to encourage sharing, and focus on approaches that have a high-probability of success.

– *Insight: Ensure success in sharing knowledge about and the M&S itself within the Alliance is recognised and rewarded at the individual and team level.*

- **McDermott and O'Dell** [22]: Ensure that databases, knowledge systems, and knowledge initiatives have a clear business purpose and clearly link knowledge sharing to organizational goals. This includes making knowledge sharing a direct part of the business strategy; integrating knowledge sharing on key initiatives; and ensuring that knowledge sharing is routine and part of the common business practice.

    – *Insight: Include sharing of M&S within the organisation strategies and integrate considerations on potential multi-use into the development of new M&S.*

5.0   CONCLUSION

One of the core strengths of the Alliance is to leverage and connect the joint capabilities of its members. Much of the M&S capability available within the Alliance resides not within the NATO organisations but within separate member nations, institutes, and industry. The ability to call upon those capabilities when required can greatly benefit the Alliance; funds and time can be saved, and decision makers can gain analytical insight by having access to the best available M&S capability.

Utilising M&S capability from outside any organization has historically been fraught with barriers and more so in an international setting. This paper identified 23, including cultural and bureaucratic reluctance, contractual limitations, trust, cultural gaps, and even language barriers. However, we the analytical community should not be despondent, success will be achieved not by waiting for a perfect world where barriers have all disappeared but instead by making a mental shift. We need to think about a route to the destination, our destination being to make greater use of the M&S in existence across the Alliance, for the benefit of all. There are ways we can do this now. This paper proposes a way to consciously consider barriers upfront, and enable choices on a path that can be navigated in the particular M&S sharing instance to achieve success. It does not provide solutions for removing all barriers, a panaceas that may never come.

This paper has presented a model and data exchange framework with guiding questions to assist in determining an appropriate depth of the model and data exchange. We challenge the user to critically reflect on added value versus effort of the different exchange mechanisms available to them. Within defence analysis the barriers often result from pushing towards transfer of model ownership or use of detailed classified data; we forget there are trade-offs available in these areas. To avoid barriers before they are encountered, it may be preferable to limit the extent that models and data are exchanged and classified data are only used when necessary to achieve the analytical objective.

The framework presented here only deals with part of establishing a successful collaboration, and some of the barriers to doing so. Potential solutions to other aspects have been identified in the broader literature on knowledge sharing, but SAS-MSG-178 still has work to do to align these recommendations to the NATO environment. A full Technical Report from SAS-MSG-178, including more information on the model and data exchange framework and overcoming other barriers is expected to be released in 2022.

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ACKNOWLEDGEMENTS