NORTH ATLANTIC TREATY ORGANIZATION

SCIENCE AND TECHNOLOGY ORGANIZATION

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STO TECHNICAL REPORT **TR-SAS-155**

Operations Research and Analysis (OR&A) Model Sharing Guidance to the Alliance

(Recommandations à l'Alliance sur le partage de modèles de Recherche et analyse opérationnelles (OR&A))

This report presents updated guidance for sharing Analysis models in the Alliance, originally developed for publication by TTCP JSA.

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The NATO Science and Technology Organization

Science & Technology (S&T) in the NATO context is defined as the selective and rigorous generation and application of state-of-the-art, validated knowledge for defence and security purposes. S&T activities embrace scientific research, technology development, transition, application and field-testing, experimentation and a range of related scientific activities that include systems engineering, operational research and analysis, synthesis, integration and validation of knowledge derived through the scientific method.

In NATO, S&T is addressed using different business models, namely a collaborative business model where NATO provides a forum where NATO Nations and partner Nations elect to use their national resources to define, conduct and promote cooperative research and information exchange, and secondly an in-house delivery business model where S&T activities are conducted in a NATO dedicated executive body, having its own personnel, capabilities and infrastructure.

The mission of the NATO Science & Technology Organization (STO) is to help position the Nations' and NATO's S&T investments as a strategic enabler of the knowledge and technology advantage for the defence and security posture of NATO Nations and partner Nations, by conducting and promoting S&T activities that augment and leverage the capabilities and programmes of the Alliance, of the NATO Nations and the partner Nations, in support of NATO's objectives, and contributing to NATO's ability to enable and influence security and defence related capability development and threat mitigation in NATO Nations and partner Nations, in accordance with NATO policies.

The total spectrum of this collaborative effort is addressed by six Technical Panels who manage a wide range of scientific research activities, a Group specialising in modelling and simulation, plus a Committee dedicated to supporting the information management needs of the organization.

- AVT Applied Vehicle Technology Panel
- HFM Human Factors and Medicine Panel
- IST Information Systems Technology Panel
- NMSG NATO Modelling and Simulation Group
- SAS System Analysis and Studies Panel
- SCI Systems Concepts and Integration Panel
- SET Sensors and Electronics Technology Panel

These Panels and Group are the power-house of the collaborative model and are made up of national representatives as well as recognised world-class scientists, engineers and information specialists. In addition to providing critical technical oversight, they also provide a communication link to military users and other NATO bodies.

The scientific and technological work is carried out by Technical Teams, created under one or more of these eight bodies, for specific research activities which have a defined duration. These research activities can take a variety of forms, including Task Groups, Workshops, Symposia, Specialists' Meetings, Lecture Series and Technical Courses.

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List of Acronyms

AMSP	Allied Modelling and Simulation Publication
AUS	Australia
CAEn	Close Action Environment
CAN	Canada
DC	District of Columbia
DoD	Department of Defence
DoDI	Department of Defense Instruction
GBR	United Kingdom of Great Britain and Northern Ireland
GM-VV	Generic Methodology for Verification and Validation
IP	Intellectual Property
IPR	Intellectual Property Rights
JCA	Joint Concepts and Analysis
JSA	Joint Systems and Analysis
M&S	Modelling and Simulation
NATO	North Atlantic Treaty Organization
NATO CSO	NATO Collaboration Support Office
NATO OR&A	NATO Operations Research and Analysis
NATO SAS	NATO Systems Analysis and Studies
NATO SAS ST	NATO SAS Specialist Team
NATO STO	NATO Science and Technology Organization
NCIA	NATO Communications and Information Agency
NMSG	NATO Modelling and Simulation Group
NZL	New Zealand
OR&A	Operations Research and Analysis
PC	Personal Computer
PSOM	Peace Support Operations Model
SISO	Simulation Interoperability Standards Organization
ST	Specialist Team
TP	Technical Panel
TTCP	The Technical Cooperation Program
UK	United Kingdom of Great Britain and Northern Ireland
US	United States of America
USA	United States of America
VV&A	Verification, Validation, and Accreditation

Preface

During the Chicago Summit in 2012[1] "Smart Defence" was proclaimed as one of NATO's priorities. 'Smart Defence'[2] provided a new way of thinking about generating the modern defence capabilities the Alliance needed. Although this initiative is now nine years old, the principles are still highly relevant to the Alliance. It is a renewed culture of cooperation that encourages Allies to cooperate in developing, acquiring and maintaining military capabilities to undertake the Alliance's essential core tasks agreed in the then new NATO Strategic Concept[3]. That means pooling and sharing capabilities, setting priorities and coordinating efforts better. This activity aims to increase Smart cooperation in the development and use of OR&A models, which is to say models produced for the purposes of Analysis so as to derive the benefits of cost reduction and improved efficiency through leverage of good practice on sharing models.

[1] Chicago Summit 20-21.V.2012 Sommet. https://www.nato.int/chicago2012/mobile/ accessed 15 Mar. 2021.

[2] Smart Defence, dated 20 Feb. 2017 13:31. https://www.nato.int/cps/en/natohq/topics_84268.htm accessed 15 Mar. 2021.

[3] Active Engagement, Modern Defence: Strategic Concept for the Defence and Security of the Members of the North Atlantic Treaty Organisation adopted by Heads of State and Government in Lisbon. Dated 19 Nov. 2010, updated 23 May. 2012, accessed 15 Mar. 2021.

Acknowledgements

The authors would like to thank the members of TTCP[4] Joint Systems Analysis (JSA) Group[5] Technical Panel (TP) 3 who first developed and updated guidance on good practice for sharing OR&A models from July 1999 to October 2002[6] and then subsequently curated this material. We would also like to thank the members of NATO SAS-ST-115 on S*MART*[7] *Cooperation on Operation Analysis Simulation Models* who reviewed the last published version of that guidance (v0.3 dated Oct 2002) in October 2015 and recommended a small number of updates. We further acknowledge the work that was separately conducted to revise the guidance, prior to the closure of the TTCP JSA group that resulted in a top copy of that work[8] and the update to this that incorporated the comments made by NATO SAS-ST-115[9]. We would additionally like to acknowledge the contribution made by the 2019 ISMOR workshop on *Providing Operations Research and Analysis (OR&A) model sharing guidance to the NATO Alliance* that served to test and validate the contemporary relevance and completeness of this advice, and the continued presence provided by the other members of this ST.

[4] TTCP is a long-standing international research collaboration programme between five nations (AUS, CAN, GBR, NZL USA).

[5] TTCP JSA Group, whose terms of reference are comparable with the NATO SAS Panel, was disbanded in 2016.

[6] Guidance on good practice for sharing models, TR-JSA-TP3-7-2000, v0.3 dated Oct 2002.

[7] No acronym is intended in the use of the textual form SMART: instead, this reflects how SAS-115 referred to their own activity; SMART Cooperation on Operation Analysis Simulation Models.'

[8] Guidance on good practice for sharing models, TR-JSA-TP3-7-2015, v0.7 dated March 2015.

[9] Guidance on good practice for sharing models, TR-JSA-TP3-7-2018, v0.8 dated Oct 2018.

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Operations Research and Analysis (Or&A) Model Sharing Guidance to the Alliance

(STO-TR-SAS-155)

Executive Summary

This report updates guidance on sharing Operational Research and Analysis (OR&A) models originally developed through The Technical Cooperation Programme (TTCP). It incorporates updates from findings from NATO STO Specialist Team SAS-115 titled SMART Cooperation on Operation Analysis Simulation Models and participants in a 2019 International Society for Military Operational Research (ISMOR) conference workshop, some of whom became part of this Specialist Team. The guidance is based on a combination of lessons identified from model sharing experiences and an awareness of future opportunities. It primarily relates to sharing at the whole-model level. It does not address other ways of sharing models, such as assuring interoperability through use of a High-Level Architecture, Distributed Interactive Simulation standard or the establishment of common software libraries.

SUMMARY OF MODEL SHARING GUIDANCE

Model acquisition:

- A model should not be acquired unless it addresses a clearly defined requirement.
- The nation or organization considering acquisition of a new model should ensure it conforms to extant strategy and practice.
- Check whether it is actually a data-driven model.

Sound model development practices:

- Try to use common hardware, software and data formats.
- Produce and maintain full, releasable documentation of the model.

Donor responsibilities to facilitate sharing:

- When a model is shared, the donor should be prepared to do more than simply transfer the model and its associated documentation: support training, set-up, bug-fixing and proactively communicate information on future developments.
- Consider releasing the source code.
- Release a demonstration problem and dataset.
- Participate actively in ongoing collaborative management of the model.
- Have model configuration managers.
- Receive honest feedback.

Responsibilities of the recipient:

- Train and maintain an appropriate team of users.
- Actively participate in ongoing model management.
- Contribute to mutual verification and quality assurance activities:
  - Test the model using the donor's supplied dataset(s) and provide feedback.
  - Run initial parallel modeling tasks.
- Give honest feedback.
- Be prepared – to establish the credibility of the model with own stakeholders.

Release agreements:

- Release agreement documents carry considerable value for international model sharing.
- They can articulate arrangements and responsibilities for: training provision; future modifications and configuration control; dataset sharing; documentation updates; release of source code; further dissemination; Intellectual Property constraints; security arrangements; costs and other legal and administrative details.

Recommandations à l'Alliance sur le partage de modèles de Recherche et analyse opérationnelles (OR&A)

(STO-TR-SAS-155)

Synthèse

Le présent rapport met à jour les recommandations relatives au partage des modèles de Recherche et analyse opérationnelles (OR&A) initialement élaborés dans le cadre du Programme de coopération technique (TTCP). Il incorpore les dernières conclusions tirées par l'Équipe spécialisée SAS-115 de la STO de l'OTAN, appelée Coopération intelligente à propos du modèle de simulation d'analyse opérationnelle, et les participants à un atelier-conférence tenu par la Société internationale pour la recherche opérationnelle militaire (ISMOR) en 2019, dont certains ont rejoint l'Équipe spécialisée susmentionnée. Les recommandations reposent à la fois sur les leçons tirées d'expériences de partage de modèles et sur la connaissance d'opportunités futures. Axées sur le partage au niveau du modèle tout entier, elles ne prennent en compte aucune autre forme de modèle de partage, comme le fait d'assurer l'interopérabilité par le recours à une architecture de haut niveau, une norme de simulation interactive distribuée ou la création de logithèques courantes.

SYNTHÈSE DES RECOMMANDATIONS RELATIVES AU PARTAGE DE MODÈLES

Acquisition d'un modèle :

- Un modèle ne doit être acquis que s'il remplit une exigence clairement définie.
- La nation ou l'organisation envisageant l'acquisition d'un nouveau modèle doit s'assurer qu'elle respecte la stratégie et les pratiques en vigueur.
- Vérifier s'il s'agit effectivement d'un modèle axé sur les données.

Bonnes pratiques de développement d'un modèle :

- Chercher à utiliser des matériels, logiciels et formats de données courants.
- Produire et tenir à jour une documentation complète et communicable sur le modèle.

Responsabilités incombant au donateur pour faciliter le partage :

- Lorsqu'un modèle est partagé, le donateur doit se préparer à aller au-delà du simple transfert du modèle et de la documentation correspondante : formation au support, configuration, réparation des bogues, et communication proactive d'informations sur les évolutions futures.
- Envisager la publication du code source.
- Communiquer une démonstration de problème et un lot de données.
- Participer activement à la gestion collaborative permanente du modèle.
- Désigner des chargés de configuration du modèle.
- Recevoir des retours d'expérience honnêtes.

Responsabilités du bénéficiaire :

- Former et animer une équipe d'utilisateurs adaptée.
- Participer activement à la gestion permanente du modèle.
- Contribuer aux activités de vérification mutuelle et d'assurance qualité :
  - Tester le modèle à partir du ou des lots de données fournis par le donateur, et transmettre vos observations.
  - Exécuter des tâches de modélisation parallèles initiales.
- Transmettre des retours d'expérience honnêtes.
- Se préparer à l'établissement de la crédibilité du modèle auprès de ses parties prenantes.

Contrats de cession :

- Les contrats de cession présentent une valeur considérable pour le partage de modèles à l'international.
- Ils peuvent prévoir des dispositifs et des responsabilités pour : la fourniture d'une formation ; les futures modifications et le contrôle de la configuration ; le partage de lots de données ; l'actualisation de la documentation ; la publication du code source ; d'autres activités de diffusion ; des contraintes en matière de propriété intellectuelle ; des clauses de sécurité ; les frais et d'autres dispositions légales et administratives.

OPERATIONS RESEARCH AND ANALYSIS (OR&A) MODEL SHARING GUIDANCE TO THE ALLIANCE

1.0 INTRODUCTION

1.1 Background

International OR&A discussions and meetings frequently focus on modelling approaches and modelling methodologies. This can lead to an offer by one nation to export a developed methodology – implemented as a computer model or software – to another nation[1].

At best the recipient could acquire a coherent and consistent logical structure, pertinent to a military matter of interest, bypassing all the costs and time of software development. At worst the potential gains could be more than offset by the necessary investment of effort in understanding and (where necessary) adapting the nuances and details of the analysis model for national purposes[2]. Having worked to gain familiarity with the model, it could then be abandoned if deemed to be inappropriate for the problem in hand. There may also be hidden costs, such as importing the software of the model from one computer system to another.

This document offers guidance that is intended to maximize the likelihood of model exchanges leading to positive outcomes and minimize the occurrence of negative outcomes and unpleasant surprises.

This guidance is based on a combination of lessons identified from previous model sharing experiences and an awareness of future opportunities. The former helps to ensure that both positive and negative experiences of the past are captured, enabling good elements to be repeated and, more importantly, so that past mistakes are not repeated. The latter looks forward to ways of successfully sharing models through improved and enhanced software model development (and maintenance) practices.

The guidance contained in this document is firmly rooted in practical experience. The gestation of this guidance is outlined in Annex A. It is written with awareness of the current technologies available, rather than placing hope in a future technology that will solve all the challenges associated with model sharing. Key enablers are often procedural, such as identifying the need to support model sharing arrangement[3] with supporting model sharing agreement[4], setting out the terms of collaboration.

1.2 Scope

The guidance provided here primarily supports sharing a whole-model, which is where the experiences that led to the development of this guidance are primarily founded. It also offers some guidance on sharing model components at Annex D. The guidance is primarily procedural, rather than technical and does not address certain technical approaches, such as assuring interoperability through use of a High-Level Architecture, Distributed Interactive Simulation standard or the establishment of common software libraries.

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[1] The origin of this document has led to the term ‘nation’ being used in the context of sharing, due to the international nature of this ST. The guidance is however equally relevant to model sharing between organizations within the same nation and to work with non-national agencies, such as NATO Communications and Information Agency (NCIA). Therefore, the term ‘nation’ should be interpreted – where appropriate – to mean any organization.

[2] This document focuses on the sharing of ‘analysis models’, which is to say models produced for the purposes of generating quantifiable ‘analytical’ insight, as opposed to models that have been produced for the purpose of ‘experimentation’ or ‘training’, which only need to produce plausible outputs in any given circumstance. Henceforth in the text, whenever the term ‘model’ is used, it should be understood to mean ‘analysis model’.

[3] The term ‘arrangement’ is used in this report to describe an instance of model sharing.

[4] The term ‘agreement’ is used in this report to describe the document defining an ‘arrangement’.

Although the guidance contained in this document can be expected to increase the probability of a successful model sharing, it should not be seen as guaranteeing success. A degree of obsolescence and the occasional failure in a model is to be expected – both for those built locally and for those imported. It is also worth noting that the purpose of the guidance contained in this document is as much about avoiding inappropriate model sharing (i.e., those likely to fail) as it is about improving the experience of appropriate model sharing.

As with all guidance, specific cases may have special factors associated with them that necessarily override this general guidance. Nevertheless, explicit consideration of all factors identified below is recommended to ensure the rationale for a particular decision is fully understood.

It should also be recognized that there are different types of models and different purposes to which those models are put. For example, models required for 'front line' use in support of imminent or ongoing operations may have different constraints when compared to other types of model – timeliness, speed of response, etc.

Similarly, some of the guidance contained in this document may be more relevant to 'large' models than to 'small' models, or to models that are expected to be maintained and used for a long time rather than those of the 'build-use-throw away' variety. Nevertheless, explicit consideration of all factors identified below is recommended in order to determine those factors which require greater – or lesser – emphasis when considering sharing a model.

1.3 Guidance Layout

Section 2 outlines key elements of model sharing good practice.

The main body of guidance is in Section 3. It lists and prioritizes key factors that need to be considered by both donor and recipient in determining whether model sharing is appropriate. If so, the guidance then advises how to improve the experience of, and hence increase the probability of success in, sharing the model. Here, increased success is measured both in terms of the overall success or failure of the model transfer, and the ease with which the recipient incorporates the model into their collection of models.

The perceived importance of the guidance in Section 3 is indicated by the font used:

- **CAPITALIZED BOLD TEXT**. For the most important factors.
- **Bold text**. For important considerations.
- Normal text. For explanation, comments and to indicate other practices that are recommended for (but unlikely to dictate success or failure of) a model sharing agreement.

In addition to the guidance itself, the following annexes provide supporting information:

- Annex A: A brief history of the gestation of this work.
- Annex B: Verification, Validation and Credibility: Across borders.
- Annex C: Ongoing model management: user groups and related issues.
- Annex D: Sharing model components.
- Annex E: Model catalogues.

2.0 GOOD PRACTICE FOR MODEL SHARING

2.1 General Points

The most important point to make at the outset is that one nation or organization's model import is another's export; there is both a recipient[5] and donor in any model sharing. This has three significant implications:

- Both donor and recipient should consider these general points and the specific points (below) to ensure that both parties fully understand the model sharing arrangement, and the necessary obligations for it to succeed. It is important to recognize that a successful model sharing arrangement is likely to place requirements on the donor as well as the recipient. Model sharing arrangements should therefore be seen as an ongoing commitment to a relationship between donor and recipient rather than as a one-off transfer.
- Collaborative development of new models is a natural extension of the ideas of model sharing. Such a venture would require all parties to agree to a common purpose and methodology and determine appropriate management processes to realize the collaboration to the benefit of all[6].
- Common approaches to describing models, and agreement on associated terminology, is key in facilitating model sharing arrangements – as it is in any sharing of research. This reduces the scope for delays as a result of misunderstandings, including the effect of subtle (and not so subtle) nuances of language and differing interpretations of 'common' terms. It would also be advantageous if model descriptions could be captured – and therefore shared – in common databases and catalogues. Examples include Model Databases and Catalogues (electronic and hard copy) maintained by various nations and organizations. These are invaluable in identifying and determining models that might be of interest to other nations and organizations.

Time is another important issue. There are no hard rules as to how quickly a new model can be assimilated and put to use by a recipient. There is often a trade-off between the model's speed of introduction and the confidence the recipient has in the model's output. In particular, a major model can take significant time to assimilate so that a recipient can trust it. Such assimilation time can be reduced for smaller models or those that are already well known to the recipient: for example, a model that a secondee brings back to their home organization. Any formal paperwork necessary to finalize a transfer is another significant time aspect to consider. Ensuring such paperwork is completed early should expedite the process of sharing (in this case, transferring) the model.

Model sharing agreements should be independent of one another. This allows each model sharing agreement to have the freedom to develop and be altered as required without being influenced or impacted by other model sharing activities.

2.2 Model Sharing Benefits

Sharing models can have significant, additional benefits (intentional or otherwise), many of which can affect both donor and recipient. Such factors – although important – are unlikely to justify the sharing of a model on their own. Examples include:

- Associated user information exchanges. This includes access to a broader peer review forum for the design, functionality and validation of the model.

[5] There may be more than one recipient in a model sharing arrangement.

[6] Limited experience currently exists of such formally shared development. However, numerous examples exist of models whose development is effectively progressed via informal exchange of ideas and versions between active users (for example through User Groups – see Section 3.3 on Facilitating Sharing, Section 3.4 on Responsibilities of the Model Recipient, Section 3.5 on Release Arrangements (below) and Annex C).

- Facilitation of possible future joint studies. The tendency towards combined operations (military and otherwise) is increasing worldwide. There is a benefit to using common analytical approaches in both joint and independent studies. However, there is also benefit from the triangulation of different approaches being used to study the same problem, with each approach's respective findings being compared.
- A better, mutual understanding of the problem, approach or model.
- Enhancing the credibility of study results. Potential contributions from the receiving nation can assist in the process of validating and verifying the model – contributions that may enhance the overall credibility of a model.
- Widening the recipient's experience of different approaches or techniques.
- Earning goodwill between nations and organizations. The recipient may return the favor someday.

2.3 Model Sharing Agreements

Consider carefully the need for, and scope of, a model sharing agreement. A model sharing arrangement's benefits can be overstated, and its costs (both time and financial) can be underestimated. Defining an agreement can help mitigate these risks.

The recipient of a shared model does not gain the same depth of knowledge and understanding of the problem the model was designed to address compared to developing their own model. Furthermore, a failure to appreciate the complexity of a model sharing agreement can occur – particularly if it has come about as a result of an informal model sharing arrangement.

Section 3.3 on Facilitating Sharing and Section 3.4 on the Responsibilities of the Model Recipient describe various activities the donor and recipient should be prepared to do to support a model sharing activity.

3.0 GUIDANCE ON GOOD PRACTICE

3.1 Model Acquisition

A MODEL[7] SHOULD NOT BE ACQUIRED UNLESS IT ADDRESSES A CLEARLY DEFINED REQUIREMENT. Acquiring a model simply because it is offered for free is not advised since there is no such thing as a 'free' model. There are always personnel costs (in time, and hence either financial or opportunity cost) in accepting and assimilating any new analysis tool into one's inventory, even when there are no additional associated financial costs (hardware, software licenses, etc.). For example, the effort spent by a receiving nation to understand the perspective of, and approach used, by the donor nation that resulted in the development of the model being shared might be better spent by the recipient nation to understand the subject matter under study.

The nation or organization considering acquisition of a new model should ensure it conforms to extant strategy and practice. Models are not generally used in isolation. Any new model that is intended for long-term use needs to fit into the overall philosophy and modelling structure adopted by the recipient. This includes, for example:

- **CHECK WHETHER IT IS ACTUALLY A DATA-DRIVEN MODEL.** In particular, whether the model contains any embedded assumptions that make it unsuitable for the recipient, given the recipient's doctrine, national force development needs or other circumstances.

[7] The term model is used throughout this guidance. However, similar considerations will apply to sharing of model components. See Annex D for more on model sharing at component level.

- The model's ability to input data from and output data to other relevant models of the recipient, particularly if it is to act as a feeder model to other models.

The nation or organization offering the model should make it clear if there are any additional software components on which the model depends. This is especially important when it involves third party (academic, commercial, other government, etc.) tools without which the shared model cannot be used. The recipients may not be able to access or acquire the third party tools – because they are prohibitively expensive, not commercially feasible for the recipient or not releasable to the recipient[8].

- The use of such additional software components, whilst impossible to avoid, should be minimized in the case of models which nations or organizations might wish to share.

The model characteristics described in Annex E (model catalogues) can also be used by a potential recipient as a checklist to assess model suitability for their needs.

3.2 Sound Model Development Practices

MODEL DEVELOPERS SHOULD ALWAYS FOLLOW SOUND DEVELOPMENT PRACTICES. Although this appears self-evident, there are some practices that will facilitate the sharing of a model that are worth remembering from the outset:

- **Try to use common hardware, software and data formats.** Specialized computer platforms, programming languages, operating systems or data formats can make model transfers a difficult and frustrating experience for the receiving party.
- **Produce and maintain full, releasable documentation of the model.** The recipient (and any new users) will rely on the model's documentation to learn and properly apply the model. The documentation should:
  - Include information on how best to (correctly) use and interpret the model, in addition to the model's technical and design documentation (including key assumptions)[9]. Such documentation should include good practice guidance on the model's scope, use and range of validity, and potential misuse, including tricks and traps that have been identified through experience of using the model.
  - Clearly identify and include any requirements to support the model[10], such as additional software or licenses. Relevant information about the requirements should be provided at the appropriate locations in the model documentation (e.g., installation instructions).
  - Be fully releasable to potential recipients – including overcoming (or effectively managing) issues like national caveats or any issues associated with Intellectual Property Rights (IPR) (commercial or otherwise).
  - Be in an appropriate language for the user community of the model, since translation of documentation (core and auxiliary) can be costly both in time and resources.

The IPR of the model (and its requirements and supporting material) needs to be well managed and understood to ensure effective sharing of the model. Poor management of IPR may hinder or prevent sharing (including at the development stages). In particular, this issue may be exacerbated if there has been third party involvement in the development or maintenance of a model (e.g., through use of contracted support),

[8] Noting that running a model in a different operating environment may result in the model behaving differently.

[9] Furthermore, model software code could be written in an intuitive manner (e.g., self-documenting) to improve the accessibility of the code to a human reader.

[10] Furthermore, some of the requirements may themselves have requirements (e.g., software frameworks and operating systems), and so on.

as the donor nation or organization may not have the rights to share the model (in whole or parts), its requirements or supporting material. Worse, failure to understand IPR issues can result in inadvertent transfer of IP from a donor to third part contractors thereby complicating any further development.

- Where third party Intellectual Property (IP) is associated with the model, suitable IPR should be obtained (and limitations understood) to allow the model to be shared. Recording and maintaining a register of third party IPR associated with the model will make identifying and – where necessary – resolving IPR issues hindering or preventing model sharing easier.

3.3 Facilitating Sharing

The donor and recipient should consider opportunities to partner in studies using the model to create mutual resilience in their ability to use and understand the model.

When a model is shared, the donor should be prepared to do more than simply transfer the model and its associated documentation to the recipients. The donor should be prepared to:

- **Provide resources to support initial training and setup.** Consideration and agreement over how the costs of providing such resources, and how this will be provided by the donor, should be addressed early in the model sharing activity, identifying in what ways this will involve the donor. For example, should the recipient expend resources or rely on the goodwill of the donor? The agreement as to what the support arrangements are should be made clear and explicit to minimize the possibility of misunderstanding between the parties involved.
- Provide a form of 'help desk' service, for example by phone or e-mail, to answer the (inevitable) questions about the model's operation, features, etc. As in the previous point, consideration and agreement for this should be done early in the model sharing activity. It is desirable that such a help desk provides model experts throughout the year, so timely advice and support can be delivered when required (e.g., during holiday periods).
- Proactively communicate and be transparent about future developments and decision points for the model, particularly if it affects the recipients. For example, a decision to retire or stop supporting a model might be unpalatable for some recipients involved in the model sharing activity. Those still making use of the model might therefore wish to make alternative arrangements to enable the model to continue to be supported (e.g., move the configuration manager role for the model).
- **Correct bugs found by the recipient when applying the model in new – or different – situations.** This includes being transparent about existing bugs within the model and the expected time to fix said bugs (and – where necessary – communicating the priority order for the bugs to be fixed).
- **CONSIDER RELEASING THE SOURCE CODE.** Making the source code available makes it easier for the recipient to understand and – if necessary – debug the model. It also makes it possible to adapt or modify the model to better address the immediate demands of the recipient's studies[11]. There are broader issues (e.g., proprietary concerns) that might deter releasing the source code, but every effort should be made to overcome such issues to maximize the value of the model to the recipient[12]. Models shared in a spirit of openness and mutual trust have been observed to succeed; releasing the source code tends to contribute towards such a spirit. However, releasing the source code should not be used as a substitute for good model design and documentation. Neither should release of the source code be considered to be an invitation to make changes as having multiple users changing source code makes configuration management more complex.

[11] Alternative approaches exist to avoid the excessive adapting or modification of the core of a model, such as the development and use of models designed to be modular in nature.

[12] Where the model has been developed by a third party, then the need to request delivery of, and secure appropriate IP rights in relation to the source code is important (see Section 3.2 on Sound Model Development Practices).

- Contribute to mutual verification (and quality assurance) activities: for further discussion see Annex B. To support this, the donor should:
    - **RELEASE A DEMONSTRATION DATASET.** Having a working dataset is of immense help to new users of the model, particularly if accompanied by written descriptions of the data items and expected results to enable the user to check the model is working correctly. Although the most benefit is realized if the data items are real, sanitized or otherwise unrealistic data values (because of classification, confidentiality considerations, etc.) still provide a significant benefit.
        - **Release a demonstration problem for the model, and the associated model datasets (including expected outputs).** In addition to releasing a demonstration dataset, this should help ensure the configuration and use of the model is consistent and as intended by the donor (formulation of data sets, interpretation of outputs, etc.). This naturally leads to sharing experience and use of the model, and reviewing each other's work, hence maintaining the consistent use and configuration of the model between donor and recipient.
        - **Run parallel modelling tasks.** Early in the recipient's usage of the model, it might be beneficial for the model donor to use the model in parallel with the recipient in support of the recipient's work. By comparing outputs and how the model was used, the recipient can be more confident that they are using and interpreting the model as intended by the donor.
- **Participate actively in the ongoing management of the model through a model User Group or similar**[13]. Although two or more users constitute a user group (lower case), it is advisable to formalize this arrangement into a User Group (capitalized). Such a group can meet on a regular basis to discuss, prioritize and – where appropriate – harmonize or collaborate on model development or improvements. Such groups can share common experiences and datasets and – where feasible – exchange results from studies that have used the model. Alternatively, the group might operate primarily as a network of contacts that can interact by videoconference, e-mail and phone as required. See Annex C on User Groups and ongoing model management post initial transfer and related issues.
- **Have model configuration managers.** Once there is a user group for a model then it is important someone takes control over the configuration management of the model (it being more important that the role is fulfilled rather than who assumes the role). The original developers are the logical first choice to fulfil such a role, with appropriate governance structures in place to support them in their role. Assuming there is still a user group, it is important that the role be transferred to another member of the user group if the current configuration manager no longer exists or no longer uses the model.
- Maintain adequate records of correspondence and agreements. Maintaining a corporate memory of the model external to the model's developer and user bases should better ensure the longevity of the model.
- **Be receptive to honest feedback.** The model might have some known and unknown problems. New users of the model are as concerned about the overall quality of the model as the donor. Therefore, the developer must be prepared for any observations about the model (and its associated products) the new users offer – both positive and negative.
- Provide the model recipient with updated versions and/or updated modules and algorithms and openly communicate concerns or issues that will affect the recipient's model performance in a timely manner.

[13] The term User Group is not universally used. Some models use alternative terms or mechanisms, such as a Management Board. Nevertheless, User Group is used throughout the text for such a cooperative forum for managing and/or exchanging experiences about a model.

3.4 Responsibilities of the Model Recipient

When a model is shared the recipient should be prepared to do more than accept the model. The recipient should be prepared to:

- **TRAIN AND MAINTAIN AN APPROPRIATE TEAM OF USERS.** One of the most critical aspects determining the likely success of a model sharing exercise is the recipient's ability to assimilate and use the new model. This requires investment in both gaining and maintaining the appropriate expertise to use the model effectively. Formal and informal training combined with gaining practical experience in the model all contribute to developing and maintaining expertise in the model. Maintaining expertise in the model is as important as initially developing that expertise. Continuity of staff with expertise in the model is particularly valuable, supplemented by planned staff rotations or movements (where possible).
- Plan, fund and support the assimilation and use of the model. This includes enabling users who have developed expertise in the model (through training or otherwise) to exercise their expertise in the model before significant fade in their expertise occurs.
- **Participate actively in ongoing model management through a model User Group or equivalent.** See similar point in donor points (above) and Annex C (Ongoing Model Management: User Groups and Related Issues).
- Contribute to mutual verification (and quality assurance) activities. To support this, the recipient should:
  - **Test the model using the donor's supplied dataset(s) and provide feedback.** These might be artificially generated (input/output) datasets for testing the model or 'real' datasets used to support a study. If the recipient finds differences in the model's behavior or outputs when using the dataset then they may need to be investigated by the donor. Furthermore, if the model's behavior and outputs are consistent with the demonstration datasets provided then the donor should be informed – if only as a matter of courtesy.
  - **Run initial parallel modelling tasks.** Early in the recipient's usage of the model, it might be beneficial for the model donor to use the model in parallel with the recipient in support of the recipient's work. By comparing outputs and how the model was used, the recipient can be more confident that they are using and interpreting the model as intended by the donor.
- Maintain adequate records of correspondence and agreements. Maintaining a corporate memory of the model external to the model's developer and user bases should better ensure the longevity of the model.
- **Give honest feedback.** Feedback – positive or negative – should be given to the developers of the model. Whether the recipient uncovers deficiencies in the model, perceived strengths of the model or opportunities for developing the model, they should all be fed back in a useful manner to the developer.
- **Be prepared to establish credibility of the model with own stakeholders.** A model's credibility does not transfer between nations as simply as the model itself. The recipient should be prepared to spend – potentially significant – effort establishing the model's credibility amongst their own stakeholders.

3.5 Release Agreements

RELEASE AGREEMENT DOCUMENTS CARRY CONSIDERABLE VALUE FOR INTERNATIONAL MODEL SHARING. Such documents are likely to become increasingly necessary in future to meet legal requirements. Even when it is not mandatory, such documents are of great assistance in

clearly identifying and articulating arrangements and responsibilities – including those involving resources (e.g., funding). The agreement should address (though is not limited to):

- Provision of appropriate training (full or otherwise) for the recipient nation to develop sufficient expertise to effectively – and correctly – use the model.
- **How future modifications of the model should be implemented and how future versions of the model should be released** (see Annex C for more detail).
- **Which** (if any) **datasets or databases will be part of the model sharing arrangement?**
- **Development, release and dissemination of the model's current and future documentation.**
- **If the model's source code is to be released as part of the model sharing arrangement.**
- **If the recipient can further disseminate the model.** If so, under what conditions and constraints.
- **The involvement of non-government agencies, organizations or persons in the maintenance or use of the model by the recipient.**
- **Any IP constraints associated with the model sharing activity, including those involving third party IP, should be considered** (e.g., access to, and ownership of, any IPR associated with developments (initial and subsequent) of the model, and the rights of the receiving party to copy (including generating and using back-ups), use and further release/propagate the model).
- **Any security issues associated with the model sharing agreement.**
- Possible personnel exchanges of mutual benefit to both nations.
- Version control and schemes for the source code, executable software model, datasets and documentation (as appropriate).
- **COSTS OR OTHER LEGAL/ADMINISTRATIVE DETAILS ASSOCIATED WITH THE ABOVE.**
- Recipients should be made aware by the donor of the extent of additional costs (fiscal and resource) when new model functionality and new capabilities are requested. Model expansion can be a part of the release agreement or included within the agreed upon responsibilities of the model user group, the help desk or configuration management process.

Annex A – A BRIEF HISTORY OF THE GESTATION OF THIS WORK

A.1 ORIGINS

At The Technical Cooperation Program (TTCP)[1] Joint Systems and Analysis (JSA) Group[2] meeting held in July 1999, the Group accepted a recommendation for the Joint Concepts and Analysis (JCA) Panel[3] to address the issue of Sharing Models. The Group reasoned this was an important role for the Panel as it would enable the Group to act as a catalyst in developing and disseminating guidance on good practice for use within and across the TTCP nations. It was also agreed that such guidance should be appropriate to model sharing considerations outside of TTCP and between different agencies within a single nation or organization.

In addressing this recommendation, the Panel convened a workshop – in Washington DC in April 2000 – attended by delegates from the TTCP nations. The workshop first considered inputs for the guidance contained in this document on various aspects of sharing models, including:

- Their experiences with the importing and exporting of models and any consequent lessons identified. This included the circulation of relevant papers.
- The importance of a model's validation status and evidence in establishing a model's capabilities and credibility.
- The effect of data management practices.
- The impact of national modelling strategy.

The workshop went on to identify critical factors likely to influence the success of future model sharing, through a combination of group discussion and plenary feedback. These findings were then structured to provide Version 1 of the guidance contained in this document. This was released in June 2001, with an internet releasable version in December 2001.

A.2 DEVELOPMENT

Subsequent versions of this document [1] incorporated feedback based on application of the guidance contained in this document and on other – more recent – model sharing experiences. It also incorporated extensive discussions within and beyond the TTCP nations on the issue of model sharing. This incorporated the findings of a UK hosted TTCP workshop in March 2002, which included discussion on:

- How to find out what models might be available for sharing.
- How to manage ongoing model sharing activities.
- How to share model components.
- How to conduct collaborative model development.

It was recommended that this document continued to be revisited and (if necessary) updated in light of further experiences. This was prevented by closure of the JSA group prior to publication of the guidance.

[1] TTCP is a long-standing international research collaboration programme between five nations (AUS, CAN, GBR, NZL, USA).

[2] TTCP JSA Group, whose terms of reference are comparable with the NATO SAS Panel, was disbanded in 2016.

[3] This Panel was subsequently called the Joint and Combined Analysis Panel. Both designations were names of Technical Panel 3 (TP 3) of the JSA group.

In consequence, further work was undertaken to develop an unpublished 2015 update to coincide with the closure of TTCP JSA Group [2]. This update was designed to take greater account of IPR issues associated with model sharing and to reflect further model sharing experience gained since 2002.

In parallel with the production of this updated version, members of NATO SAS ST 115 on *SMART Cooperation on Operation Analysis Simulation Models* were asked to review the last extant version of the guidance (v3 dated Oct 2002) in October 2015. The members of NATO SAS ST 115 recommended a small number of additional updates. In October 2018 this led to the production of a further version of the guidance [3].

A.3 REFERENCES

[1] Guidance on Good Practice for Sharing Models, TR-JSA-TP3-7-2002, v0.3, October 2002.

[2] Guidance on Good Practice for Sharing Models, TR-JSA-TP3-7-2015, v0.7, March 2015.

[3] Guidance on Good Practice for Sharing Models, TR-JSA-TP3-7-2018, v0.8, Oct 2018.

Annex B – VERIFICATION, VALIDATION AND CREDIBILITY ACROSS BORDERS

B.1 INTRODUCTION

Different nations – and different organizations in each nation – vary in how they understand and approach the issue of verification, validation and accreditation. This annex briefly describes some similarities and differences in these, using the US and UK approaches as examples to identify differences that may affect any potential model sharing.

Definitions. Although there are a number of definitions used, the following [1] are most widely used:

- **Verification.** The process of determining that a model or simulation implementation and its associated data accurately represent the developer's conceptual description and specifications.
- **Validation.** The process of determining the degree to which a model or simulation and its associated data are an accurate representation of the real world from the perspective of the intended uses of the model.[1]

B.2 NATIONAL APPROACHES

Similarities in Approach. Most nations have a similar approach to, and interpretation of, verification and validation. For verification, improvements in software engineering practices and process have reduced the errors in turning model concepts and designs into useable computer code. For validation, the underlying concept of having confidence in the credibility of the model is shared between nations. The details of validation are dependent on the situation and context of the validation exercise. Demonstration of the credibility of the model can be achieved by inspecting:

- The model's underpinning logic.
- The applicability of the model's algorithms and other modelling constructs it contains.
- The model's ability to recreate historical events.[2]
- Comparison with peer models – such as those of other nations.
- Through peer review.

Key Similarities. All nations take a pragmatic, experiential approach to validation and credibility. Although they implicitly rely on the factors discussed above, they principally rely on the generation of user-trust in a model by working with it for a significant period of time. This enables them to develop and maintain knowledge of the model's strengths and weaknesses.

[1] An accepted useful variant: '…determining the ability of a logic construct or set of algorithms *to accurately represent the significant and salient features of the outcome distribution* of the respective real-world system, event, or scenario.' (This variant usefully circumvents some of the potential misconceptions surrounding the word 'accurate' in the original definition, in particular greater accuracy need not imply more detailed modelling – the essence of good analysis is to illuminate key aspects of a problem in as simple, yet appropriate, a way as practicable.) [2].

[2] Typically in terms of plausible flow of battle and overall statistics rather than in absolute detail. This is because any historic event is only a single run of a highly stochastic process – and one from which many of the relevant data can never be collected.

Key Differences. The following differences are worthy of note:

- The **US** has a formal process called 'accreditation'[3] to explicitly express that a model is acceptable for a specific process. This accreditation does not imply acceptability for all purposes of the model, rather acceptability in the terms envisaged at the time of the accreditation.
- The **UK** focuses on a context-based assessment of fitness for purpose.[4] A formal Validation Logbook is maintained for each significant model, which takes account of (amongst other things):
  - The software model itself;
  - The model's supporting data and data management processes;
  - The availability and expertise of users of the model; and
  - The validation status of the model.[5] For example, whether it has been compared against real or historic events, compared against other similar models, or compared through peer review.

B.3 ADDITIONAL POINTS

Based on the workshop held in 2000, the following additional points on the nature of model validation shed further light on the key issues that underpin the search for validity and credibility in modelling:

- In essence, the process of validation is to provide auditable assurance that the model is an adequate representation of reality for the purposes for which it is intended. Therefore a model is not valid or invalid in general but for a class of applications.
- Validation must encompass both the algorithms and logic constructs within the model in addition to the key associated databases.
- It is noteworthy that the development and application of operations analysis models is both part art and part science. By definition, all models are abstractions of reality and are therefore incorrect to some degree. Validation determines whether the model is *acceptably* incorrect or not.
- There is no set process or procedure to model validation. However, within the Simulation Interoperability Standards Organization (SISO) and NATO Modelling and Simulation Group (NMSG), a standard has been developed that can be used as a guideline [3].
- Subjectivity can sometimes form a large component in the process of validation of a model.
- Concrete documentation of validation history is a firm requirement for international usage and sharing. The UK method of producing a validation logbook has much merit to support this.

B.4 REFERENCES

[1] Department of Defense Instruction (DoDI) 5000.61, DoD Modeling and Simulation (M&S) Verification, Validation, and Accreditation (VV&A), December 9, 2009.

[2] Sargent, R.G. (2014). Verifying and Validating Simulation Models. In: A. Tolk, S.Y. Diallo, I.O. Ryzhov, L. Yilmaz, S. Buckley, and J.A. Miller (Eds.), Proceedings of the 2014 Winter Simulation Conference, pp. 118-131.

[3] **Accreditation.** The official certification that a model, simulation, or federation of models and simulations is acceptable for use for a specific purpose [1].

[4] A model is deemed 'fit for purpose' in the UK when it is considered both verified and valid for the problem it is modelling – including any associated context linking it to the real world.

[5] And – where appropriate – the model's components (particularly where they too are models).

[3] SISO guide 001.1-2012, Generic Methodology for Verification and Validation (GM-VV) to Support Acceptance of Models, Simulations and Data, 13 January 2012.

Annex C – ONGOING MODEL MANAGEMENT: USER GROUPS AND RELATED ISSUES

C.1 INTRODUCTION

The management of issues related to model sharing post the initial transfer is at least as important as the initial transfer itself. Formal User Groups (or equivalent) are particularly useful in ensuring that the process of model sharing is seen as a joint venture embracing both donor and recipient, particularly when there are multiple users of the same model. The factors outlined below need to be considered when considering whether a formal User Group (or similar) should be set-up. (Note, in some cases alternatives to a User Group might be more effective or efficient.)

The guidance below was derived at a workshop in 2000, which included participants from two successful User Groups: the JANUS war game and the US THUNDER model. This guidance was revisited during the workshop in 2002, with small further amendments made in 2015.

C.2 USER GROUP GUIDANCE

It is highly recommended that a User Group be established when two or more users exist. It makes sense for the original model developer to run the User Group, unless there is mutual agreement to the contrary.

The Terms of Reference for a User Group should clearly define:

- The group's and participants' role in the model's configuration management:
  - It is essential to agree early on how potentially divergent strands of national developments are to be managed, united and incorporated in the model's release program.
  - Common configuration management arrangements for sharing and collaborating on models include:
    - Explicit agreement that different nation's versions of the model will diverge.
    - The donor will hold a master version of the model, and changes to the model are implemented by both donor and recipients in an agreed fashion (e.g., the donor issues updated versions of the model to recipients, or the donor instructs the recipients how to update the model).
  - Once agreed, changing between different configuration management arrangements may be difficult to efficiently achieve if not pre-planned and coordinated.
  - What aspects of the model sharing experience the model's user group wish to share through the User Group. For example, members of the User Group may wish to share:
    - Model usage experiences, both positive and negative.
    - Ideas for model improvement, and – by extension – potential cooperation on delivering such enhancements (see Section C3 below).
    - Datasets or databases.
    - Study results of mutual interest.
    - Model briefing materials.
- Agreement by all parties to participate in a formal User Group should be clearly laid out in the Release Agreement of the model.

- Agreement by all parties of the User Group about IP ownership, rights and responsibilities associated with the model.
- The arrangements for a User Group should address how the User Group should manage the adding of members to the User Group.

The group may wish to consider a User Group registration fee to:

- Pay for training, documentation, etc.
- Assist in funding a help-desk function.
- Ensure a disproportionate burden does not fall on the donor.

The benefits of meeting on a regular[1] basis are high. Some activities of the User Group might be difficult to accomplish effectively without face-to-face meetings. Such meetings are invariably expensive in time and money, so every effort should be made to exploit meetings of chance (e.g., travelling as part of other business).

There is considerable benefit in electronic communication on a regular basis – this may be the dominant mechanism in many cases. For example, for small models or for mature models that are unlikely to be developed significantly. Electronic mechanisms include:

- E-mail.
- Telephone or video teleconferencing (the latter becoming an increasingly viable option, especially if the participants already know one another).
- A model website or internet server (a shared space for the development and maintenance of the model).

C.3 SUPPORT OF COLLABORATIVE DEVELOPMENT

One natural extension of the user group concept is the idea of a collaborative development forum, where such co-development is planned at the outset. As of now, there is little experience of fully shared collaborative development in the Operational Analysis arena, as national requirements frequently do not align closely enough. However, there are many examples of good synergy being delivered through harmonized programs of work on particular models, including through extant user groups. Factors to consider when contemplating collaborative development are outlined below, based on discussion at the workshop in 2002.

There is a range of options for collaborative development, including:

- Joint, co-located team (very rare).[2]
- Shared or harmonized development (quite frequent).[3]
- Run by one, funded by many (infrequent).[4, 5]

[1] Experience suggests an annual or 18-month cycle is sufficient in most cases.

[2] Only likely to occur where requirements are totally co-incident.

[3] Examples have included international co-operation on models such as the Peace Support Operations Model (PSOM), realized through an online wiki.

[4] For example, when international co-operation enabled the port of the Close Action Environment (CAEn) to Personal Computer (PC).

[5] Despite the fact that this approach has not been adopted very frequently it is potentially attractive where needs are sufficiently common, as it mitigates any integration risk associated with shared or harmonized developments. However, it can require a large amount of up-front planning, for example to put in place necessary contractual and financial details, and a large degree of trust in the nation chosen to lead the enterprise.

Additionally, collaboration may be more beneficial during some stages of the software model life-cycle than others. In particular, it may be:

- Practical and beneficial to collaborate at early and late stages of model development, where complementary skills and experience may be available from different nations; whilst
- Better to work separately during the mid-stages of model development, where in any case expertise is likely to be more uniformly available across the nations.

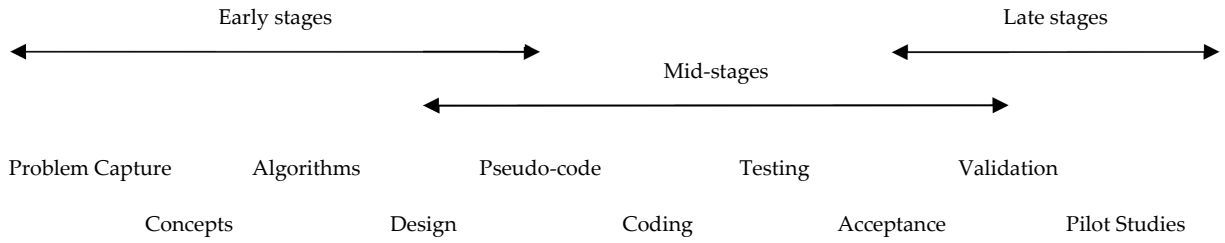

Figure C-1: An Idealized Ordered List of the Software Model Life-Cycle for Model Development.

The software design process is iterative for most Operational Analysis model development and thus the above distinctions are not black-and-white. For example, if Rapid Prototyping / Rapid Application Development techniques are important as part of understanding the problem to be solved then they would usefully be conducted with some collaboration, even though they do involve software development of a kind.

Annex D – SHARING MODEL COMPONENTS

D.1 INTRODUCTION

There is some experience in sharing models at component level for the purposes of Operational Analysis in NATO. The guidance below is principally based on discussion at a TTCP JSA workshop in 2002 and on some limited experience between the UK and US sharing and collaborating on model components. This component of the TTCP JSA guidance was reaffirmed during the 2015 update of the TTCP guidance; but should none the less continue to be revised in light of further experience.

D.2 DEFINITION

The term component can be applied to any element smaller than a whole model. This could range from individual algorithms through to self-contained code (such as functional sub-models or infrastructure elements).

D.3 ADVANTAGES OF COMPONENT SHARING

The potential advantages of component sharing are very similar to those of whole model sharing. Principally: efficiency gains through re-use which should result in lower development costs. Additional advantages include:

- Faster development of new models may be possible through the potential availability of a library of already developed components.
- Verification, Validation and Accreditation may be easier if conducted at component level.
- Common frameworks could potentially provide the boost to effective component sharing although experience with frameworks is not yet sufficiently mature to prove this in practice.

D.4 DISADVANTAGES OF COMPONENT SHARING

There are also significant potential disadvantages or difficulties that need to be overcome if component sharing is to succeed. In particular:

- Interoperability of components may not be straightforward to achieve, particularly if they are for different levels of detail.
- Furthermore, interoperability of components will likely require a single, agreed modelling (and computational) framework with well-defined interactions between components.
- There may be a need to develop a framework.
- Possible runtime overheads can arise from use of a common modelling framework.
- There is a need to establish trust in a component before it can be used with confidence.
- Sharing can require components to be developed to a common denominator in terms of detail.[1]
- IPR issues may prevent or inhibit effective sharing if not appropriately managed or considered.

[1] i.e., The level of detail could be determined by the lowest-level model for which the component is intended and this may be inappropriate for all models in which that component may be used.

D.5 ASSESSING THE BALANCE OF ADVANTAGE

The balance between the advantages and disadvantages can only be judged on a case-by-case basis, particularly with respect to any difficulties that might need to be overcome. Although the technologies and practices of component sharing have improved, its advantages may still not outweigh the disadvantages. Therefore, component sharing should be considered with the awareness of its potential disadvantages and efforts to mitigate any associated risks.

Annex E – MODEL CATALOGUES

E.1 INTRODUCTION

A number of model catalogues[1] currently exist in either electronic or hard copy format. In particular, many nations and individual organizations hold information on their own models. There are also model repositories in some areas, including the NATO Modelling and Simulation Group.

E.2 USING MODEL CATALOGUES

Model catalogues can be valuable in enabling re-use and preventing 'wheel reinvention'. However, care needs to be taken to ensure any re-use is appropriate. Clearly, any re-used model must be fit for the purpose to which it is put – for example care is needed not to inappropriately constrain consideration of the problem at hand by virtue of the models available to tackle it.

There is currently no common, internationally agreed template for describing models (see next section). Neither is there a single, simple way of finding out what models might be available for sharing since extant catalogues and repositories have been developed separately and without built-in methods to exchange information.

E.3 THE POTENTIAL VALUE OF A COMMON TEMPLATE FOR MODEL CATALOGUES

A common template for describing models would be beneficial in supporting 'paper assessment' of models, prior to model sharing enquiries and associated discussion. If constructed at an appropriate level of detail, then such a template could help a potential model recipient compare the features of possible donor models against a target set of features that are assessed as being either essential or desirable for the receiving nation's purpose.

The following descriptors could potentially be used in a common template for cataloguing Operations Research and Analysis models:

- **Level 1 Descriptors.** *What the model is.*
  - **Environment/Domain.** Is the model primarily for Land, Sea, Air or Joint Operations – or some combination or sub-division thereof? Similarly, which aspect(s) of the spectrum of conflict can it address? For example, is it for warfighting, non-warfighting or both?
  - **Military Level.** Is the model directed at tactical, operational, theatre, or strategic issues?
  - **Problem class.** What class (or range of classes) of problems does it address? For example:
    - Force structure.
    - Balance of investment.
    - Equipment acquisition.
    - Concepts/Doctrine/Tactics.
    - Mission rehearsal.
    - Training.

[1] A catalogue lists and describes models but does not contain source or executable code, whereas a repository typically contains sufficient information to enable the model to be run.

- **Resolution.** The level of aggregation and type of representation in terms of:
  - Co-ordinate system.
  - Features:
    - Properties: e.g., construction material, damage status, dimensions, emitter placement, pre-prepared (for stated purpose/s), quality of work, salinity, sub-components, trafficability.
    - Type: e.g., arable, beaches, bogs, buildings, built-up, craters, culverts, ditches, estuaries, forests, fording points, fords, fortifications or entrenchments, glaciers, hills, inter-tidal zone, lakes, mangrove swamps, marshes, mountains, mudflats, obstacles (of stated type/s), paths, power-lines, railway lines, reefs, rivers, roads, rubble, sabkha, sand dunes, scrub, sewers, shallows, space debris, streams, suburban, tracks, trenches, valleys, urban, utilities and woodland.
  - Scales of activity represented (from sub-system to global focus).
  - Spatial representation: e.g., free form, grid, hex, node-and-arc, region and/or sub-region.
  - Units: e.g., individuals, aggregated entities (including size of typical and smallest unit), to formation/s.
- **Computing and Infrastructure needs.** This includes, though should not be limited to:
  - Hardware Requirements.
  - Operating System/s.
  - Software Language/s.
  - Software products or licenses required.
- **Model Features.** For example:
  - Is it an 'automatic', Man-in-the-loop, or both?
  - What aspects of conflict are modelled? For example:
    - What is the problem domain of interest? Engineering, combat, logistics, force planning, mobility, etc.
    - What type of operation or activity is it modelling? Warfighting, Operations Other Than War, etc.
  - What is the primary analytical process employed? For example:
    - What is the Operations Research and Analysis modelling type? Simulation, systems dynamics, linear programming, etc.
  - Is it deterministic or stochastic?
- **Version number;** noting capabilities and issues at version number;
  - **Resource requirements.** For example:
    - Typical team size and expertise to support use and maintenance of model.
    - Data requirements of model.
  - **Time Factors.** For example:
    - Model run time.
    - Model set-up time.

- **Related Models.** For example:
  - Models that are similar.
  - Models that complement the model.
  - Models that the model is dependent on.
  - Models that are dependent on the model.
- **Model 'Pedigree'.** For example:
  - What state is the model in? In development, in use, obsolete, etc.
  - Is the data required to run the model available? Furthermore, is it available to be shared?
  - Is documentation for the model available?
  - What is the model's validation and accreditation status?
- **IPR:**
  - Who owns the IPR for the model (either in whole or in parts)?
  - What are the limitations of the use/release of the model (in whole or in parts)?

Further work is needed between the nations to develop and translate the above checklist into a template with which model information can be captured in a common format and share amongst nations. Existing model descriptions, taxonomies, standards and catalogues should be used – and where appropriate: adopted – within and across the nations at present. For example, the UK Models Database, US model taxonomies and UK Logbook templates.

E.4 RELATED STANDARDS AND WEBSITES

It is hoped that further guidance can be incorporated in future releases of this annex, including information on associated standards. This will be undertaken either by building further explicit information into this annex or by cross-referencing to other relevant sources.

The reader is referred to the following for general information:

- The Defense Modelling and Simulation Office at https://www.msco.mil/.
- The NATO Science and Technology Organization (STO) Collaboration Office at https://www.sto.nato.int/Pages/collaboration-support-office.aspx.
- The Simulation Interoperability Standards Organization at https://www.sisostds.org/.

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This report presents updated guidance for sharing Analysis models in the Alliance, originally developed for publication by TTCP JSA.

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14. Abstract

The objective of this NATO STO Specialist Team (ST) has been to produce updated model sharing guidance for Analysis from earlier material developed by The Technical Cooperation Program (TTCP) Joint Systems and Analysis (JSA), for publication and dissemination through the NATO STO Collaboration Support Office. To achieve this the team has conducted a review of the unpublished draft of the earlier advice, incorporating recommendations made by NATO STO Specialist Team SAS-115 titled SMART Cooperation on Operation Analysis Simulation Models.

The contemporary relevance and completeness of this advice has been tested and validated through a Workshop, primarily involving representatives of the supply chain, at the 2019 International Symposium for Military Operational Research (ISMOR). The specific purpose of this work has been the dissemination of the revised and updated guidelines within national and NATO OR&A capabilities and their supply chains.

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