MAnaged Readiness Simulator (MARS)

A first-time user report

François Cazzolato
DRDC – Centre for Operational Research and Analysis

Defence Research and Development Canada

Reference Document
DRDC-RDDC-2016-D030
July 2016

Abstract

In 2015 a force readiness analysis was completed for CANSOFCOM. The MAnaged Readiness Simulator (MARS) was used for the first time by the CANSOFCOM operational research team. While the tool shined overall, certain hurdles were met which hampered part of the study. This report recounts the challenges that arose and discusses potential improvements.

Significance to defence and security

MARS is a powerful tool for force readiness studies. It allows the input of large databases (establishments and theatre demands) and provides users with built-in output templates that facilitate analyses. Modifications to the tool's data output structure and user's manual as recommended in this report would improve MARS and facilitate its use in future.

Résumé

En 2015, une analyse de la disponibilité opérationnelle de la force a été réalisée pour le compte du Commandement des Forces d'opérations spéciales du Canada (COMFOSCAN). À cette occasion, l'équipe de recherche opérationnelle du COMFOSCAN a utilisé une première fois le simulateur de gestion de la disponibilité opérationnelle (MARS). Bien que, dans l'ensemble, l'outil se soit comporté de brillante façon, certains obstacles rencontrés ont compromis une partie de l'analyse. Le présent rapport recense les problèmes qui sont survenus et traite des améliorations possibles.

Importance pour la défense et la sécurité

MARS est un outil très efficace pour appuyer les études portant sur l'état de préparation de la force. Il met à contribution des bases de données volumineuses (exigences des théâtres d'opérations et des effectifs) et met à la disposition des utilisateurs des modèles intégrés de données produites qui facilitent l'analyse. Les modifications que le présent rapport recommande d'apporter à la structure des données générées par MARS et au guide de l'utilisateur devraient permettre de l'améliorer et d'en faciliter l'utilisation.

Table of contents

List of figures

List of tables

Acknowledgements

The author would like to show his appreciation to MARS' primary developer, Mr. Mike Ormrod. Thank you for your patience.

1 Introduction

In 2015, the Canadian Special Operations Forces Command (CANSOFCOM) Operational Research Team was asked to analyze the force structure of the operational component of CANSOFCOM [1]. The MAnaged Readiness Simulator (MARS) [2] was chosen for the study since it was well adapted for the task at hand and was readily available. The tool was deemed a strong contributor to the overall success of the project. Despite the lack of comprehensive tutorials, the CANSOFCOM Operational Research team managed to become autonomous with the tool thanks to access to its developer through all phases of the project.

In the world of software development, programs tend to get new features and functionalities based on the experience gained from their use. The CANSOFCOM study can bring an outsider's vision to MARS' development and thus help steer future improvements that would be beneficial not only to SOF-related studies but to other MARS-based projects as well.

This report should not be seen as a compilation of negative critiques that tries to expose MARS' weaknesses. On the contrary, this document praises the tool by indicating how relevant it is and by suggesting some improvements. CANSOFCOM's first study using MARS has shown that the tool is critical for force structure studies. The fact that the author and the sponsor of [1] have already started another major study involving MARS is a vote of confidence in the tool.

If possible, upcoming modifications to the tool should be based on the observations described in this report.

1.1 Structure

The report is structured as follows: Section 2 summarizes how MARS was used and presents some of its core functionalities. Section 3 describes the strengths of the tool from the author's perspective. Section 4 discusses some challenges that hampered the study.[1] Finally, Section 5 concludes with a list of recommendations.

[1] All elements of this report pertain to MARS version 3.22.06. Newer versions most probably show fewer bugs and a few more features. Known improvements in later versions are noted if applicable.

2 Utilization

MARS is a resource allocation tool. The tool allocates establishment resources one by one to meet theatre demands. In the case of personnel, resources and theatre demands can be constrained by rank, military occupational structure identification (MOSID),[2] or qualifications. As such, MARS is well suited for force structure analyses of military organizations. During a simulation, MARS logs successful and unsuccessful personnel assignments and provides results using a suite of pre-defined output templates.

This section summarizes some of MARS' main components in order to better understand the benefits and challenges discussed in Sections 3 and 4 respectively.

2.1 User interface

MARS allows the user to create or modify many aspects of force structures through a multitude of graphical user interface forms, each of which is tied to a key concept.

For example, MARS contains a form dedicated to the structure and content of the establishment (the supply), a similar one for theatre elements (the demand), and one that manages how (and when) the establishment will fill the demand. Figure 1 shows an example of an establishment called "Sample Establishment" that contains three units: the Canadian Special Operations Regiment (CSOR), Joint Task Force 2 (JTF 2), and a Military Police Unit (MPU).[3] Each unit is composed of two personnel slots only. The CSOR unit contains one Master Corporal (MCpl) medical technician (MED TECH [334]) and one Corporal (Cpl) special forces operator (SF OP). The JTF 2 unit contains two Cpl assaulters (called "S1 ASLTR"). Finally, the MP unit contains two MCpl military police (MP [161]). In Figure 1, the entire establishment was selected for display. Selecting a specific unit instead of the entire establishment would show only that unit's personnel slots.

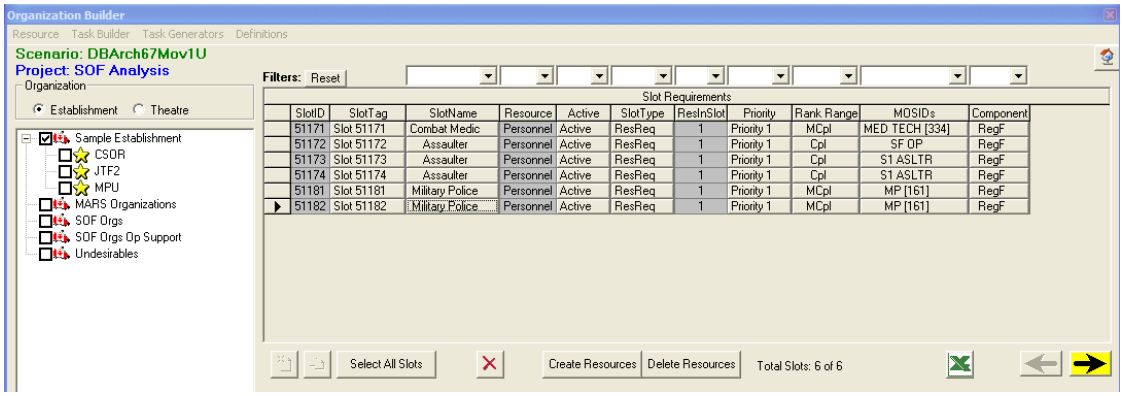

Figure 1: Establishment form.

[2] In this paper the term MOSID and trade will be used interchangeably.
[3] To keep this report unclassified, fake data are used.

Figure 2 shows an example for the theatre demand template (called "Sample Theatre Element"). It is composed of two sub-elements: CSOR and JTF 2 and contains only three theatre positions. The CSOR sub-element requires a Special Forces Operator (SF OP) and an MP while the JTF 2 sub-element requires a single S1 ASLTR. For this specific example, the theatre positions accept rank ranges rather than a specific rank.[4]

Note that the demand of Figure 2 is just a template. Multiple copies of the theatre can be requested in MARS with the use of *tasks* and *activities*. In MARS, the operations and events being simulated are called *tasks*. Tasks are further broken down into *activities*. Activities assemble resources to fill out theatre positions[5] and set how long these resources will be required (i.e., how long they are removed from the establishment). Tasks and activities can be set in specific chronological orders or launched simultaneously. Activities are linked to theatre elements that are required to be filled with resources each time they are called. A task usually contains a number of activities. Multiple instances of the same activity can be present within a given task. [6]

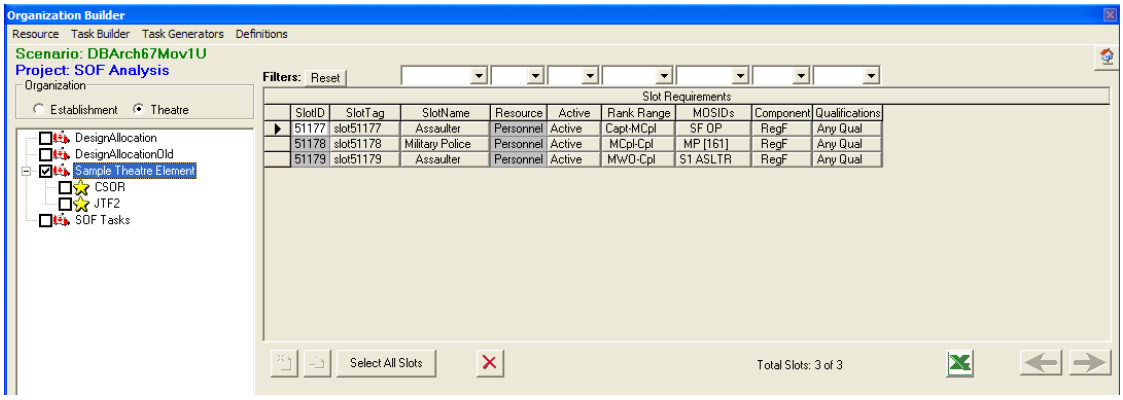

Figure 2: Theatre form.

Once the establishment and the theatre units are built (or imported) by the user and resource candidates are assigned to each activity, the chronological order used to fill up the theatre positions must be set. The left part of Figure 3 shows that on day 0[7] of the simulation an LOB[8] reduction will take place. Then, on day 10, MARS will start "Sample Task 1" (highlighted in

[4] Both establishment and theatre slots can accept trade and rank ranges. For establishment slots, if a range is provided then MARS creates resources randomly from the trade and rank ranges provided.
[5] The term "theatre position" is used loosely and refers to any activity that removes resources from the establishment (permanently or temporarily).
[6] The form for tasks and activities is purposely not shown. The reader is encouraged to read [2] for more information. First-time users will find the concepts of tasks and activities and their implementation challenging and difficult to master.
[7] While *days* are used here, the time unit is arbitrary for the current application.
[8] LOB—Left out of battle—accounts for personnel who are unavailable for tasking due to factors such as injury, paternity/maternity leave, individual training, or professional development. LOB accounts for the many reasons why an establishment is not 100% available. Section 3.2 discusses LOB in more detail.

white) and launch its activities. If tasks and activities must be filled in a specific sequence, the timing of this step is crucial.[9] This is the case in the current example as Sample Task 2 and 3, exact copies of Sample Task 1, are started on days 11 and 12 respectively.

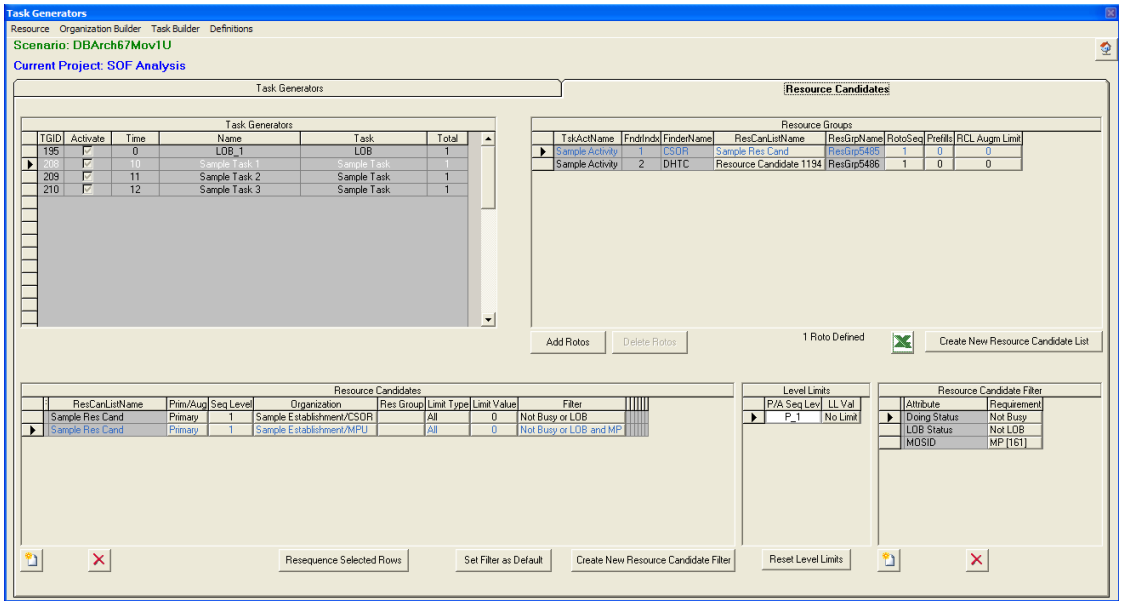

Figure 3: Task Generators form.

The allotment of establishment personnel to theatre positions is straightforward. This operation is set in the Task Generators form (Figure 3). For each theatre element, the user designates the establishment units from which MARS can choose. This process is shown in the lower-left portion of Figure 3. In this example the CSOR theatre sub-element is allowed to pick resource candidates from both the CSOR and the MPU. This feature is quite versatile since entire units or smaller sub-units can be targeted. Moreover, a filter can be applied to ensure a specific characteristic is sought among the resource candidates. For example, Figure 3 (bottom right corner) shows that only personnel whose "doing status" and "LOB status" is *not busy* and *not LOB*, respectively, can be picked. Additionally, while the CSOR theatre element is allowed to pick candidates from the MPU, it can only choose candidates with a MOSID of "MP [161]" (i.e., military police).

In the example discussed so far, it is evident that the small establishment unit (6 individuals) would not meet the operational requirements of 9 positions (3 x Sample Task Element). Beyond just the shortage of personnel, CSOR's Med Tech and SF OP cannot actually fill any theatre position. The former's trade does not meet any requirement while the latter's rank is outside the required rank range for SF OP.

When filling up positions with resources, MARS uses a ranking system to determine the fill order. First, establishment positions are sorted based on the weight of each position. Rank, trade,

[9] A simulation which studies the impact of the deployment, reconstruction, and training phases through multiple cycles is a good example where timings are critical, since personnel from previous tasks could be freed and added to the pool of available personnel for the tasks of the following cycles.

and qualifications all play a role. A Major is typically given a higher weight than a Corporal and is thus ranked higher. Theatre positions are also sorted in a similar fashion. They are ranked in order of expected difficulty to fill (i.e., the most difficult slots are ranked first). Again, rank and MOSID play a role in determining the difficulty (high-rank positions are given more weight since high-rank personnel are less common). Once both lists are sorted, the theatre positions are filled one by one from top to bottom. The slots that are more difficult to fill will thus be matched first with establishment resources. However, to maximize the number of successful matches overall MARS will do so using establishment resources starting with the least qualified / lower rank candidates first (bottom-up). Positions that accept rank ranges will thus be filled using lower ranks first. In [1], theatre positions that accepted multiple MOSIDs were given less weight than those that could only be filled by single MOSIDs. This ensured that single-MOSID positions would be filled earlier (on average) than the less stringent multi-MOSID positions.[10]

As far as ranks and trades are concerned, the MARS database contains a large number of ranks, rank ranges, and trades. New ranks or trades can be added to the database if they do not exist. For [1], modifications to ranks and trades were required to better model CANSOFCOM's reality. Most modifications pertained to the combination of trades into broader ones.

Unless stochastic processes are invoked in the modelling, MARS is a purely deterministic model. If the modelling includes stochastic elements such as allowing rank-ranges for theatre positions instead of specific ranks, trade ranges, or tasks involving randomness such as an LOB reduction, then multiple runs of the same simulation can be requested in order to get statistically significant results. A run can take a few minutes for small establishments/theatres to a few hours for the more complex ones. Whenever multiple runs are required, complete calculations can take a few hours. From a modelling perspective, the relative small size of CANSOFCOM was a benefit.

The content of the output is decided by the user once all runs are complete. If more runs are desired at a later time using the same scenario (assuming no changes were made to the scenario content), MARS can add new runs to the original batch in order to increase the sample size using the naming convention of previous runs.

The output types, called output templates, generally revolve around tracking filled and unfilled theatre positions as well as tracking the unused personnel of the establishment. A filled position is a theatre position requirement that was filled by an establishment resource successfully, i.e., the resource filled the position requirements successfully and completely. An unfilled position is a theatre position that was not filled by any of the establishment resources because personnel with the right rank and trade did not exist among the establishment units allowed to choose from, or were not numerous enough to fill all theatre requirements. Unused personnel are establishment resources left over after the simulation, unable to fill theatre positions. These are individuals with either the wrong rank or the wrong trade or simply individuals that have the appropriate rank and trade requirements but for whom all position requirements were already filled successfully by other individuals, thus leaving them unused.

[10] The "Army Communication & Information Systems Specialist Any" ("ACISS Any") MOSID for example was given less weight than the "ACISS Communication & Infrastructure Systems Technology Manager" ("ACISS CISTM") MOSID since the former accepts all ACISS MOSIDs whereas the latter accepts only one type.

The left part of Figure 4 shows the 24 output templates available at the time of [1].

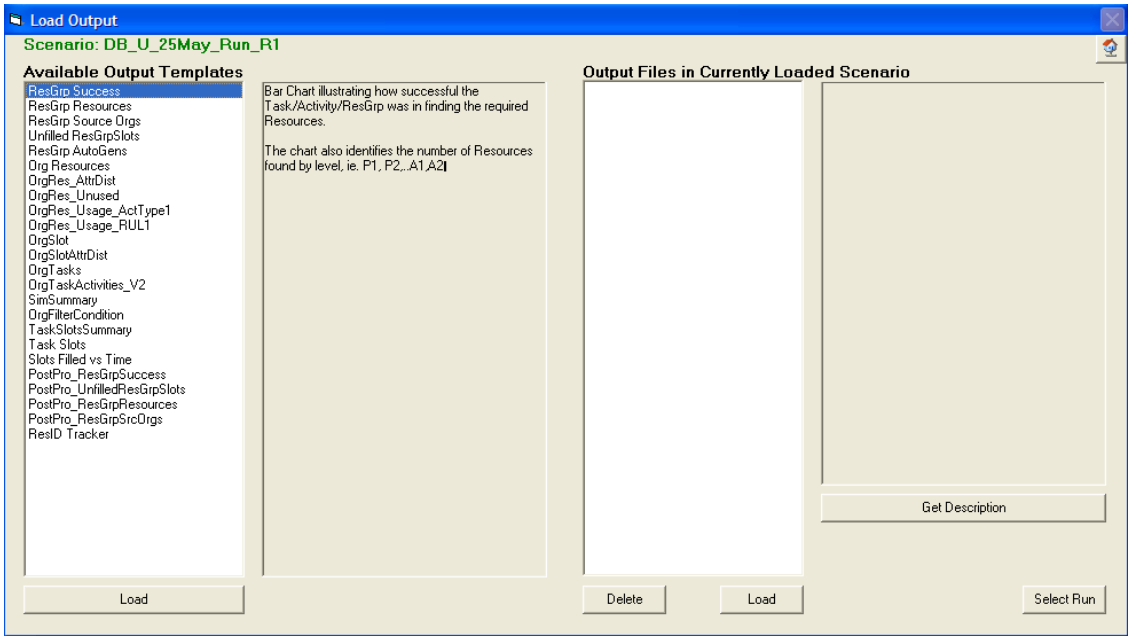

Figure 4: Output templates.

The structure of the output follows that of the establishment and the theatre in MARS. It is customary to structure the MARS establishment by units (and sub-units) therefore the output pertaining to the establishment (the usage for example) is structured by unit (or sub-unit) or an aggregated value of all units (i.e., the total establishment). The same logic applies to the theatre. However, since the theatre is not always built unit by unit but rather by force elements, more options are usually available. For example, given a theatre requirement composed of three theatre elements, all requesting certain resources from CSOR and JTF2, one could obtain the unfilled position breakdown of each theatre element (containing values from CSOR and JTF2 indistinguishably), or the overall unfilled positions exclusive to CSOR or JTF2 (irrespective of the theatre elements). It was found in [1] that structuring the establishment by units and the theatre by theatre elements with sub-units (as in Figure 2) facilitated the comprehension and analysis of the data.

The output data is usually presented in the form of bar charts and/or tables depending on which output template is chosen. For [1] and current studies, the following output templates were deemed the most useful:

PostPro_ResGrp Success: This template produces bar charts showing the total number of filled and unfilled positions for each of the theatre elements. It is the average of all the runs. It shows at a glance how well the demand was met by the establishment. Figure 5 displays a fictitious example of the PostPRo_ResGrp Success output. One can appreciate the fraction of each Force Element that was filled up successfully by personnel (green). If each theatre element was composed of sub-elements, PostPRo_ResGrp Success could display them all individually as well (not shown).

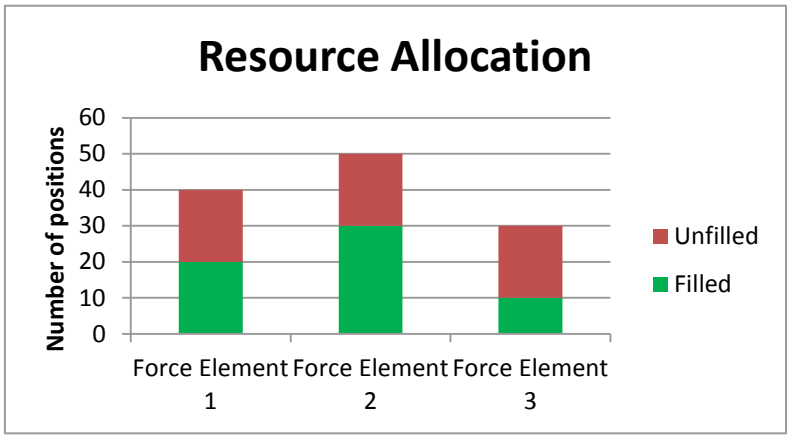

Figure 5: Example of ResGrp Success results.

Results are also given in table form (not shown). In addition to averages, these also provide standard deviations.

Unfilled_ResGrpSlots: This template logs all unfilled positions of the theatre force elements. The user can display the information by activity or task, or combinations of activities and tasks.[11] For [1] it was seen as the most important output as it alone could inform the Command on where the shortages were (by rank and trade). The unfilled data are outputted in the form of tables that contain rank and trade information for every single unfilled position. Table 1 shows an example of unfilled results using fictitious data.

Table 1: Unfilled ResGrpSlots results example.

	RANK			
MOSID	**Cpl**	**Sgt**	**CWO**	**Maj**
CBRN OP	4		1	
INT OP				1
SF OP	3	1		

The example shows a shortage of 3 MOSIDs spread among four ranks with Cpls leading the ranks for a total of 10 unfilled positions. More realistic outputs tend to be more complex.

A multi-run version of this template is called PostPro_Unfilled_ResGrpSlots and allows the computation of averages over all runs automatically. Standard deviations are also provided for each rank-trade combination.

OrgRes_Usage_RUL1: This template logs the usage of establishment resources. Those that are assigned to a theatre position during the simulation are tagged as "used" while those that are not are tagged as "unused". The data is outputted in the form of tables. Table 2 shows a fictitious example of usage data using the same source data as Table 1.

[11] Depending on the structure of the activities and tasks, the user can also display the information by unit as well, whether for a given task or some/all tasks the unit is involved in.

Table 2: Usage results example.

MOSID	RANK Cpl	MCpl	Sgt	CWO	Maj	LCol
CBRN OP (used)	3	2		1		
CBRN OP (unused)			1			1
INT OP (used)	3	1	1			
INT OP (unused)		1				
SF OP (used)		2	1			
SF OP (unused)					1	

The usage results show the "used" portion which tracks establishment personnel used to fill out theatre positions and the "unused" portion which tracks the establishment personnel that were left untasked throughout the simulation. Of note in the example is:

- A MCpl Int Op is present in both the used and unused data bins. This means that two were present in the establishment but only one MCpl was required by the theatre. One was thus left unused.
- If a rank-trade combination shows unused personnel then it should not have unfilled position at the same rank-trade combination.[12]
- When combining Table 1 and Table 2 one finds that three Cpl CBRN Op were used and four are unfilled. The total demand was thus seven.

OrgRes_Usage_RUL1 does not have a multi-run counterpart.

PostPro_ResGrpResources: This template strictly logs the personnel successfully filling the selected force elements (or sub-elements). It is similar to OrgRes_Usage_RUL1 but focuses solely on providing a listing of who filled theatre positions. While not used extensively in [1], it is used in the follow up studies as a surrogate for the multi-run form of OrgRes_Usage_RUL1 which does not exist (see Section 4.2.1).

As shown in Figure 4, MARS hosts an array of template options. Unfortunately, most have no in-tool description (more on that in Section 4.2.1). Moreover, for simulations containing multiple runs, in order to get statistics (such as averages) one needs to request the output for each run manually which can be a tedious and time-consuming exercise unless a multi-run template exists (Section 3.4 and Section 4.2 discuss this issue).

MARS is of course not limited to the aspects described so far. The above information summarizes some basic but key functions, a step necessary to understand the next sections. For a complete description of MARS' capabilities one should refer to the draft user's manual [3] or the official MARS report [2].

[12] This is true only for single runs. Multiple-run averages will sometimes show both unfilled and unused personnel for the same rank-trade combination. This arises when the number of personnel able to fill a certain rank-trade combination is able to meet the theatre demand with very few personnel left over. The randomness of LOB will sometimes reduce the available supply just enough to create shortages in some runs and surpluses in others. In the end, the average unfilled positions will show a small shortage while the average usage data will show extras.

3 Benefits

The fact that a tool like MARS was available is a major benefit as it allowed the study to be undertaken in a timely fashion in the first place. This section lists some of MARS' secondary features which played a significant role in moving the project forward, mostly by making some operations easier. All main features that *make* MARS what it is are obviously as important (if not more so) even though they are not discussed.

This section was written from the perspective of a first-time user who was discovering MARS' functionalities and maturing as a user as the project progressed. A new user would benefit from learning about them early.

3.1 Import/export of data

Inputting the establishment and theatre elements is straightforward. It can be done either by typing the data manually for each entry (a long and tedious process for establishments and theatre elements containing 100s or 1000s of personnel) or by using the MARS import function if the data are readily available and the proper file structure is respected.[13] The import tool has a few "safety" features that will warn the user if it cannot match elements of the input file with its internal database (unknown ranks or trades for example). Moreover, MARS will display its interpretation of all ranks and trades it recognizes thus allowing the user to ensure they are mapped correctly. This validation is essential as mistakes here would most probably affect multiple entries. Additionally, if certain headers are missing, MARS will fill the columns with default values.

Of note with the import function is the ability to import data into an existing establishment unit or theatre force element that already contains a structure (i.e., units/elements or sub-units/elements). This feature is extremely handy as it allows the user to import multiple files into the same structure. The import function also supports the tab structure of Excel spreadsheets. The user can select which tab to import. This proved particularly useful when each tab contained data specific to each of the units under study.

For [1] the import feature was used to import the theatre portion numerous times as its content changed frequently during the duration of the study. The theatre portion in [1] was in fact built from scratch in Excel. It was modified to suit MARS' file input requirements using purpose-built Excel macros. Once complete and validated by the units, the import's safety features helped fine-tune the final product.

[13] A few trials might be necessary in order to ensure error-free imports because the proper file structure is not documented. A simple trick was found to ensure proper headers. One simply needs to create an establishment unit with one slot. The actual trade, MOSID, rank, or occupations are inconsequential but need to be entered. Exporting this establishment using the "Save summary spreadsheet" (i.e., the MS Excel logo seen in the top pane of Figure 1) will result in a file with the proper headers, ready for import.

Interestingly, imports also apply to whole MARS scenarios (which include establishments, demands, tasks, and activities). Once during [1] a critical scenario was deleted by mistake. Backups were found and imported through the import function without a hitch.

The export function is similar to the import function. One can export the establishment or theatre database to an Excel spreadsheet. The export feature was used often in the modelling phase when the establishment required validation by the units, usually after a series of substantial modifications in MARS. Since the exports follow the same file layout as imports, they could be submitted to the units, modified by them, and imported back into MARS without issues. Since a lot of back and forth with the units was required, the import/export feature proved quite valuable throughout the study.

3.2 LOB status

The LOB attribute randomly removes personnel from an establishment to account for injuries, paternity/maternity leave, individual training, or professional development. While it is called LOB in MARS, the reduction factor can represent any source of attrition of establishment personnel. This option is versatile enough that it can be applied in different ways: to the entire establishment or to only certain units (or sub-units). In addition, LOB values can vary from one unit to the next. The latter feature could be useful for any establishment where one has reason to believe that attrition is not uniform among its components.

In [1], LOB was applied once at the start of the simulation and removed 15% of the personnel within each unit randomly. It is realistic to think that there could be instances where LOB would be applied more than once during a multi-cycle simulation. In these cases, LOB personnel would be "freed" at the end of each cycle before a new LOB factor is applied. In effect this would vary the LOB personnel from cycle to cycle.

3.3 Data repository

In the context of the study described in [1], it was suggested by the sponsor that MARS could be used as a repository for the validated establishment of CANSOFCOM. Technically, the same effect could be achieved with Excel spreadsheets, but having the information already formatted in MARS would save time when quick analyses are requested. However, this suggestion comes with a significant drawback: the reliance on a complex model accessible to only one in-house expert.

3.4 Multi-run output templates

MARS has a few multi-run output templates available to the users. These templates are similar to their single-run versions. They save the user significant time as they output data for all runs in a single operation. In effect, it saves the user n-1 operations where n is the number of runs since the user must do the proper parameter selection for the initial run. One additional benefit of multi-run output templates is that they remove manual operations from the equation. This reduces potential mistakes thus increasing the confidence in the results.

Not all template outputs have a multi-run version available. For example, a multi-run version of OrgRes_Usage_RUL1 is not available. Also, one key multi-run output template (PostPro_UnfilledResGrpSlots) was not comprehensive enough to be used by [1].

Even though multi-run output templates were not used because of limitations, they are listed as beneficial since they do save significant time for some users. They are in fact just a few modifications away from being perfect for the present needs of the CANSOFCOM OR team.[14] Improvements are suggested in Section 4.2.

3.5 Log

MARS' main menu has space to log changes or comments. This space is very convenient as the user can log notes about the scenario. While simple, this feature was found to be extremely helpful and played a significant role in tracking past changes thus facilitating the validation steps. Figure 6 shows MARS' main menu and the large description box used to log changes.[15]

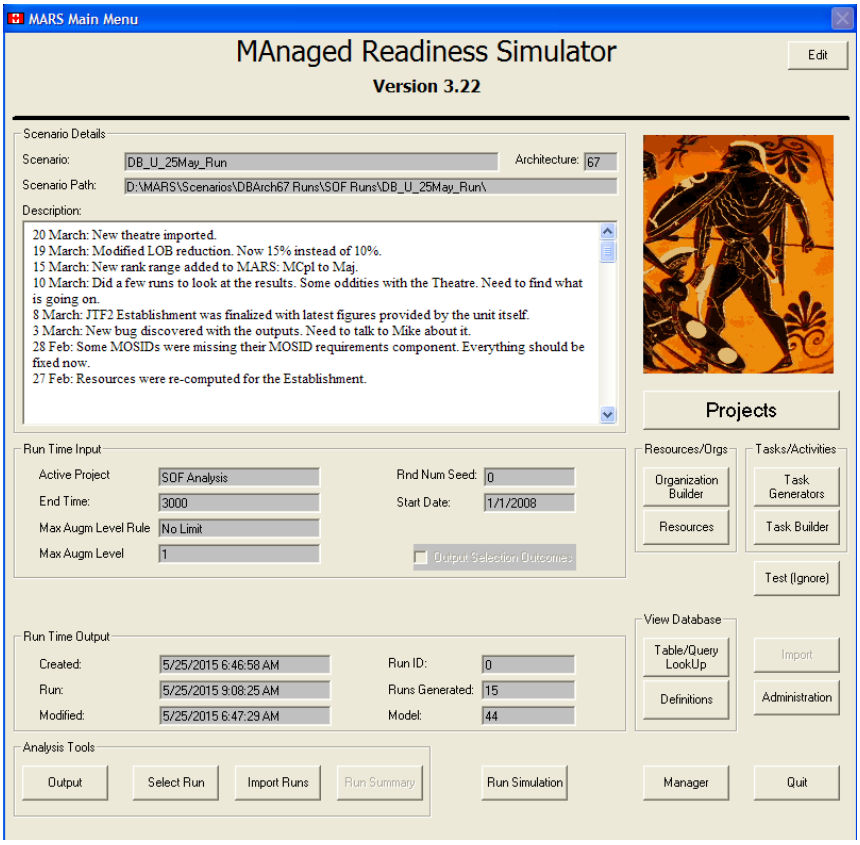

Figure 6: MARS main menu.

The user is encouraged to log as much information as possible in the description box.

[14] Follow up studies at CANSOFCOM made extensive use of multi-run output templates.
[15] Fabricated (but realistic) notes were added.

4 Challenges

This section lists some of the challenges encountered during [1]. They are discussed in no particular order. Recommendations are listed after each subsection in order to better track what could be done to improve MARS.

4.1 User's manual

MARS simply cannot be used unless its developer is fully available to teach its operation. The availability of the developer was critical in [1] and it is the author's opinion that a qualified user should be fully present at the start of any similar project. It took the present author months to feel comfortable enough with the tool to run analyses independently.

The development of a good users' manual would certainly facilitate the learning of MARS and reduce the dependency on the developer. Therefore, the still-unpublished MARS user's manual [3] would need to be completed. In its current form it is outdated and some figures do not match the text. While it is understood that one cannot learn how to use a complex tool such as MARS with only a user's manual, examples of the most basic actions required for a typical study should be presented and taught in a pedagogical fashion. While there is an attempt at such an example in the current manual (Section 3.4), it is still incomplete.[16]

It is understood that completing such a manual would require time and effort but the long-term benefits seem to warrant it. At least, key concepts should be discussed thoroughly so that a new user could, following the manual, end up with a complete work template that could be used for real studies just by changing some of its aspects. The example should take the reader by the hand by first exposing what will be modelled and then introducing the following key concepts:[17]

- creation of new trades and trade requirements:
  - modification of existing ones;
  - creations of new ones; and
  - creation/modification of trades using the "and" and "or" operators;
- creation of new ranks, rank ranges, and rank requirements:[18]
  - combination of ranks using the "and" and "or" operators;
- creation of establishment and theatre organizations manually;
- creation of establishment or theatre organizations using the import function:

[16] A few mistakes were also found, which hampered comprehension.
[17] The example of [3] should be expanded and include the elements of the list it is missing. Image support is also key to comprehension so each concept should be well supported with screen captures.
[18] Of note here is the concept of rank/trade versus rank/trade requirements in MARS. One can create ranks and trades in MARS but unless their equivalent requirements are created, they will not be assignable to theatre positions. In a nutshell, for each rank or trade, there needs to be an equivalent rank or trade requirement. Failure to create rank/trade requirements would prevent the creation of theatre positions characterized by these ranks/trades. This concept is not obvious to a new user.

    - examples of typical errors during import;
- creation of a complex establishment organization comprised of units and sub units;
- creation of a complex theatre organization comprised of force elements and sub elements/units;
- building activities and tasks:[19]
    - building of resource requirement lists;
    - building tasks with similar activities; and
    - building tasks with different activities;
- building the task generator:
    - building of resource candidate lists;
    - adding custom filters:
        - applying an LOB reduction:
            - to the entire establishment or just some units;
    - overlapping task start/end times;
    - use of multi-cycles;
- running MARS:
    - single vs multiple runs;
- introduction to the different output templates:
    - discuss the usefulness/purpose of each one;
    - show examples of typical scenarios for each template;
- recovery actions required after certain types of software crashes.

Recommendation:

- An official teaching aid should be produced in order to reduce the dependency towards the main developer.[20] This document should take a future MARS user by the hand and help him/her build a complete MARS scenario, including extracting the data with an array of output templates, based on the key steps listed above.

[19] Clear examples of tasks and activities are crucial since their creation for [1] was by far the most complex modelling operation in MARS.
[20] The developer has 30 years in DRDC and can retire any time.

4.2 Output

4.2.1 Output template options

The study documented in [1] required multiple runs of the same scenario in order to get statistically significant results since there were a few stochastic elements present. Unfortunately, data extraction required repetitive manual operations that could introduce errors if not done carefully and thus amounted to a significant delay. Cutting down on the post-calculation process would not only reduce the time required to obtain data for a given scenario, it would also reduce the potential for the introduction of error through repetitive data manipulation. This improvement could potentially make future studies more robust if multiple scenarios are explored in parallel (for comparison purposes), a feat that could not be achieved in [1] given time constraints.

For a given run, the user must first choose an output template and select what is to be produced. For example, if the unfilled positions for a given unit are desired, the user first selects "Unfilled ResGrpSlots" and then selects the desired unit under each of the theatre elements as shown in the fictitious example of Figure 7.

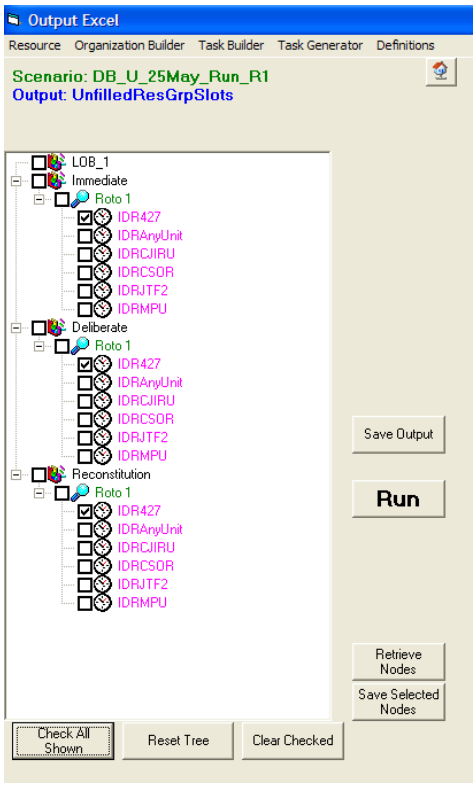

Figure 7: Unfilled selection.

MARS then displays the data requested and saves it under a pre-set name (not chosen by the user) as soon as the RUN button is pushed. For the above example, the file is called UnfilledResGrpSlots.xls. To save it under a specific name, the user must use the "Save Output"

option. If the user were to close all files and select the same output template again, the new file would be saved automatically under the same default name. Unless explicitly saved under a new name, any call of the template will overwrite any pre-existing UnfilledResGrpSlots.xls file. This is not a problem as a user will typically give the output file a specific name of his or her choosing when actively saving it.

For simulations that contain multiple runs, the above procedure must be repeated for each iteration unless a multi-run output template is chosen. Four such templates are available in MARS. Unfortunately, there are no templates that track resource usage over multiple runs automatically in a fashion similar to OrgRes_Usage_RUL1, a key metric in [1].

Recommendation:

- Create the automated version of OrgRes_Usage_RUL1.

That being said, during follow up studies to [1] it was found that a "fake" theatre demand that collected all unassigned personnel at the end of a simulation using unrestricted position requirements such as "any trade" and "any rank" for each of the establishment's units (or sub-units) essentially mimicked the "unused" part of OrgRes_Usage_RUL1. For that to work, the composition of the fake demand, now filled essentially with unused personnel, needed to be obtained through PostPRo_ ResGrpResources, which averaged the composition of all files, listing in effect the establishment leftover. This method works well and only requires the creation of a single fake force element in the theatre organization and the corresponding task/activities (and task generator links). A sufficiently high number of positions is required in order to ensure all "unused" personnel at the end of the simulation will be gathered and none will be missed. The creation of units within the force element is usually beneficial.[21]

For [1] the multi-run output template (PostPro_UnfilledResGrpSlots) was examined for the unfilled positions in the hope it could calculate all relevant unfilled position metrics for each unit. This output template calculates the average number of unfilled positions for the selected unit, the average number of unfilled positions per rank-MOSID combination, and the standard deviation for the latter. It does not however calculate the standard deviation for the overall unit metric which was problematic in [1] because, with the average number of unfilled positions, it is used to inform the client on probable shortages of personnel.

Because the MOSIDs and ranks were not totally independent within themselves (due to rank/MOSID ranges and LOB affecting all entries) the standard deviation for each rank-MOSID combination calculated by the output could not be used to calculate the unit's overall standard deviation.[22] Unfortunately, only the tedious manual data extraction method (followed by the development of new macros to reduce the data) could calculate the desired metric. The multi-run output would have been chosen had it displayed the total number of unfilled positions for each run (which the template uses already to calculate the average) so that a unit's standard deviation could be computed. Thankfully, only slight modifications to the information displayed by the output file are required to obtain the desired results. The template's calculations themselves would not be affected in any way.

[21] For example, the theatre force element could contain units such as 427, CJIRU, CSOR, JTF 2, and MPU to collect all unassigned personnel from 427 under 427 and so on.
[22] Tests showed that doing so would have overestimated the unit standard deviation significantly.

Recommendation:

- Add the overall standard deviation value for the chosen selection's total number of unfilled positions in PostPro_UnfilledResGrpSlots or simply display each of the run's total number of unfilled positions in an additional tab of the output template so that the user can quickly compute the standard deviation.

Currently, there are ways to reduce the number of manual operations already in place in MARS for the single-run templates. MARS has built-in options called "save selected nodes" and "retrieve nodes" that save the user's selections for the other runs within a given template. This feature reduces the number of manual operations (the selection process happens only once) and the potential for mistakes as well. The user must still load the new run, select the output template, and then load the previously saved selections. While this option does save time, it still requires manual operations.

For [1], the following outputs were required for each run: bar charts (PostPro_ResGrpSuccess), personnel usage (OrgRes_Usage_RUL1), and unfilled positions (UnfilledGrpRes). The bar graph was a single output for the entire simulation. The usage data for each unit (427 SOAS, CSOR, JTF2, CJIRU, and MPU) meant five files per run, and the unfilled positions for the same units, plus an extra one called "common" that contained unfilled positions that could be filled by all units, added up to six files. A total of 11 files were thus requested and saved manually per run (+ PostPro_ResGrpSuccess once). With 15 runs, this amounted to a total of 166 files. Multi-run options (with the desired output data) for the unfilled and usage templates would have cut down that number to 12 and saved an enormous amount of time. The time saved could be put into doing more runs, exploring variant scenarios or doing sensitivity analyses.

Of note with the output templates pane is the absence of descriptions for most of the templates. As shown in Figure 4, there is a large space reserved for template description. Of the 24 templates options, only 10 have an actual description. Moreover, most are quite brief. Each description should be complete and describe the purpose of the template and what type of study it is suited for. Space does not seem to be an issue so the developer is encouraged to maximize the description.

Recommendation:

- Enhance the templates' descriptions by maximising the information in the description box so that a user can fully understand what the output template is and how it should be used.[23]

During [1] the sponsor sometimes expressed interest in rank-mitigated results for unfilled positions. Rank mitigation consists in collapsing all ranks together thus displaying all MOSIDs' personnel shortage as a single value per MOSID (and per unit). As an example, Table 3 shows the rank-mitigated unfilled positions of Table 1.

[23] Newer versions of MARS show enhanced template output descriptions.

Table 3: Rank-mitigated unfilled positions example.

MOSID	Number of positions
CBRN OP	5
INT OP	1
SF OP	4

While the detailed data displayed by the UnfilledResGrpSlots output template is what is truly sought, the rank-mitigated results usually speak more when looking at each unit's results from a wider perspective.

In order to obtain rank-mitigated results from the output templates directly, it is suggested that MARS collapse all ranks of the unfilled positions output. This operation appears somewhat trivial as it would require only one additional calculation step. The resulting table could be displayed in an additional tab of the UnfilledResGrpSlots.xls output file.

Recommendation:

- Add rank-mitigated results in an additional tab for UnfilledResGrpSlots.

4.2.2 Output menu

While analyzing output results, the user might wish to open MARS forms in order to verify some database parameters. The top row of the output template pane allows the user to select the following forms: Resource, Organization Builder, Task Builder, Task Generator, and Definitions. Clicking on any of these calls the chosen form. However, if any output is open and displayed on the screen, the form is displayed *behind* the currently shown results. The user can be oblivious to this and try to call the function again (without success).

Recommendation:

- New windows should be displayed on top of older windows.

Note: This issue was fixed in newer versions of MARS.

4.3 Random establishment resource creation

The user must tell MARS to fill establishment slots with resources each time an establishment is constructed, modified, or imported otherwise it will stay empty (or keep its old values). Resources will not change until they are updated by the user, presumably because of changes to the establishment. The user must actively update the resource in the slot to ensure it complies with the new characteristics of the slot. Omitting the update will result in an establishment filled with resources that do not match their personnel slots. If a slot is characterized by rank ranges or trade ranges, MARS will select one according to rules specified by the user (random, high first, low first, etc.), otherwise it will simply put a resource in the slot according to the specific rank and trade of that slot.

Resources must be assigned to establishment slots before running MARS. A user can either import the resources or have MARS generate them according to their slot requirements. Simulation results depend on which resources were generated (or not) by MARS. Unfortunately it is easy to skip the resource creation step. Running a simulation with empty slots in the establishment does not trigger any warning. The absence of resources is usually easy to notice in the results once the simulation is complete. However if a small fraction of resources is missing they could be missed entirely. The same applies if certain slots were changed but their resources were not updated. In the best case scenario time is lost and the user must load the scenario again, fill establishment slots with resources and run the simulation once more. In the worst case, results are kept and missing or inappropriate resources go unnoticed, affecting the results critically.

Of note is the fact that a scenario requiring multiple runs will not create a new set of resources for each run but rather use whichever resources MARS created last. Multiple runs are used when stochastic processes are present in the modelling. For fully static establishments, updating resources does not change the state of the resources at all. The frequency of needing establishment resources to change from run to run for scenarios involving establishment slots that allow rank ranges or random trades is rare but lacking the capability to vary them when required is worrisome.

Recommendations:

- Ensure a warning system informs the user if MARS is about to be run and establishment resources were not updated after changes were made.
- Ensure a warning system informs the user if unfilled establishment slots are present before running simulations.
- Allow the ability to create resources automatically if establishment slots are imported into MARS.
- Provide the option to automatically create resources (and overwrite previous ones) for slots with access to multiple ranks or trades (or other multi-choice characteristics) at the beginning of every run.

4.4 Crashes and important bugs

Like any software under development, MARS crashes from time to time. In no case did the crashes prevent the running of MARS. A simple restart usually takes care of issues. Since changes are saved automatically as the data are entered, none of the information is ever lost. Only the Microsoft Access-related crash (Section 4.4.2) requires more steps to debug. Known crashes should be fully disclosed in the user's guide (and removed when fixed).

4.4.1 Organization Builder

One specific operation was found to cause MARS to crash inevitably. In the Organization Builder form, after selecting an Establishment unit on the left and a MOSID from the top filters of Slot Requirements, picking a rank from the filters will cause MARS to crash if the rank-MOSID

combination does not exist for this unit.[24] Figure 8 shows an example where an SF OP MOSID filter was applied to CSOR followed by a MCpl filter. Using the initial example of Figure 1, since the only SF OP of the establishment is of rank Cpl, this procedure caused MARS to crash.

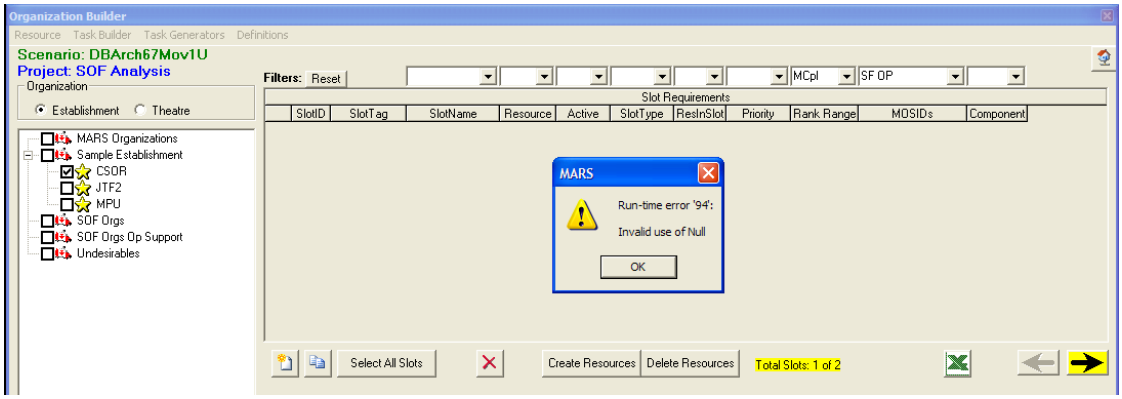

Figure 8: Bug example.

Strangely, the exact same procedure will not crash the Theatre form or the Resource form even though both are nearly identical to the Establishment form. After selecting a MOSID with the top filter, all ranks still appear in the rank filter option but choosing one that does not exist for the pre-selected MOSID will just show an empty list.

The above bug could be fixed by simply ensuring that filters only display data that actually exist. Even if the theatre and the resources forms are not affected by this bug, displaying all ranks in the rank filter if only a handful exist for the selected MOSID appears flawed.

Recommendation:

- The establishment, theatre, and resources forms should only display the ranks that truly exist for the selected MOSID if the rank filter is used (and vice-versa).

Note: This issue was fixed in newer versions of MARS.

4.4.2 Generic crashes

One type of crash, known by the developer, sometimes arises after many modifications to the MARS database. To the user they might appear to be random. When one occurs the user needs to exit MARS, open the MARS Microsoft Access database, and run the "Compact & Repair" option found under File. MARS should then restart and work properly. Thankfully though, no data are ever lost as data are saved as they are entered in MARS.

---

[24] Likewise, this bug will cause MARS to crash if one picks a rank first followed by a MOSID that does not exist for the chosen rank.

This crash is the only one encountered that required more than a simple restart of the program. As such, it is a crash that can seriously halt a user's progress until he is given the solution.[25]

Recommendation:

- The source of this crash should be identified and fixed.
- Otherwise, if it cannot be fixed, the crash should be advertised in the manual and a solution provided to mitigate its impact.

4.4.3 Output crashes

The output calculations can sometimes cause MARS to crash.

The crash occurs after the user selects the units/force elements to be used in the chosen output template. After hitting RUN (to display the data), a spreadsheet containing all the data appears on the right-hand side of the screen. The user can use the "Save Output" button on the output pane on the right or manually save the data within Excel.

If other data need to be displayed, the user should select new units/force elements *without* closing the spreadsheet on the right. Closing the spreadsheet will cause MARS to crash after the RUN button is hit again. The user is then forced to exit to the main output template menu and repeat his actions.

Moreover, many selections and deselections (while hitting RUN after each change) may lead MARS to freeze and becomes unresponsive. An error message does appear to warn the user but it does so *behind* the Excel spreadsheet. The user is thus oblivious to the issue until the unresponsiveness is noticed.

Recommendation:

- Fix the software so that leaving the spreadsheet open will not cause a crash.

Note: This issue was fixed in newer versions of MARS.

4.4.4 Unsolicited data

MARS can sometimes show unsolicited data to the user. The ResGrpResources output template can display default values that have no relationship to the chosen scenario. When a user chooses ResGrpResources for a totally empty force element, MARS will output default values that appear legitimate instead of an empty file. The values are always as shown in Table 4.

[25] The author actually lost a few days at the very beginning of the study as MARS would not start at all until the developer troubleshot the issue and suggested the "Compact & Repair" solution.

Table 4: Unsolicited data.

	RANK	
MOSID	**Sgt**	**WO**
CBRN OP	3.75	
INT OP	6.25	6.25

Failure to notice the odd outcome will result in acceptance of the results and taint the overall analysis.

Recommendation:

- Ensure a null output results in an empty file.

5 Conclusion

MARS has become the *de facto* tool for force structure studies at CANSOFCOM. Continued improvement to the tool would certainly benefit CANSOFCOM as well as a number of other Canadian Armed Forces clients.

To realize the full potential of MARS, however, a number of upgrades are required. They should be focused on the following two aspects:

OUTPUTS

The Automated OrgRes_Usage_RUL1 output template should be created. Currently, the inability to use certain multi-run output templates can slow down the analysis process. Moreover, human involvement in data extraction is a potential source for errors that could be alleviated with the introduction of automation. Confidence in the results would thus be increased as well.

USER'S MANUAL

A formal user's manual that exposes an in-depth example touching all aspects of MARS modelling would constitute an invaluable handbook for future MARS users. CORA needs to ensure the corporate knowledge of this tool is maintained. Without such manual, such knowledge could be in jeopardy.

References

[1] Cazzolato, F., French, N., Gongora, T., and Ormrod, M. (2015). Personnel requirements for CANSOFCOM force employment. DRDC-RDDC-2015-R078. CLASSIFIED. Defence Research and Development, Canada.

[2] Okazawa, S., Ormrod, M., and Young, C. (2009). Managed Readiness Simulator (MARS) V2. DRDC CORA TM 2009-057. Defence Research and Development, Canada.

[3] Ormrod, M. (DRAFT). Managed Readiness Simulator (MARS) Version 2: User's Guide. Technical Report, Draft. Defence Research and Development, Canada.

This page intentionally left blank.

List of symbols/abbreviations/acronyms/initialisms

ACISS	Army Communication & Information Systems Specialist
ACISS CISTM	Army Communication & Information Systems Specialist. Communication & Information Systems Technology Manager
ASLTR	Assaulter
CANSOFCOM	Canadian Special Operations Forces Command
CBRN OP	Chemical, Biological, Radiological, Nuclear Operator
CJIRU	Canadian Joint Incident Response Unit
CORA	Centre for Operational Research and Analysis
CSOR	Canadian Special Operations Regiment
DND	Department of National Defence
DRDC	Defence Research and Development Canada
DSTKIM	Director Science and Technology Knowledge and Information Management
JTF 2	Joint Task Force 2
LOB	Left out of battle
MARS	Managed Readiness Simulator
MED TECH	Medical Technician
MOSID	Military Occupational Structure Identification
MPU	Military Police Unit
R&D	Research & Development
SF OP	Special Forces Operator
SOAS	Special Operations Aviation Squadron

This page intentionally left blank.

DOCUMENT CONTROL DATA

(Security markings for the title, abstract and indexing annotation must be entered when the document is Classified or Designated)

1. ORIGINATOR (The name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g., Centre sponsoring a contractor's report, or tasking agency, are entered in Section 8.)

DRDC – Centre for Operational Research and Analysis
Defence Research and Development Canada
101 Colonel By Drive
Ottawa, Ontario K1A 0K2
Canada

2a. SECURITY MARKING (Overall security marking of the document including special supplemental markings if applicable.)

UNCLASSIFIED

2b. CONTROLLED GOODS

(NON-CONTROLLED GOODS)
DMC A
REVIEW: GCEC DECEMBER 2013

3. TITLE (The complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S, C or U) in parentheses after the title.)

MAnaged Readiness Simulator (MARS) : A first-time user report

4. AUTHORS (last name, followed by initials – ranks, titles, etc., not to be used)

Cazzolato, F.

5. DATE OF PUBLICATION (Month and year of publication of document.)	6a. NO. OF PAGES (Total containing information, including Annexes, Appendices, etc.)	6b. NO. OF REFS (Total cited in document.)
July 2016	36	3

7. DESCRIPTIVE NOTES (The category of the document, e.g., technical report, technical note or memorandum. If appropriate, enter the type of report, e.g., interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

Reference Document

8. SPONSORING ACTIVITY (The name of the department project office or laboratory sponsoring the research and development – include address.)

DRDC – Centre for Operational Research and Analysis
Defence Research and Development Canada
101 Colonel By Drive
Ottawa, Ontario K1A 0K2
Canada

9a. PROJECT OR GRANT NO. (If appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant.)	9b. CONTRACT NO. (If appropriate, the applicable number under which the document was written.)

10a. ORIGINATOR'S DOCUMENT NUMBER (The official document number by which the document is identified by the originating activity. This number must be unique to this document.)	10b. OTHER DOCUMENT NO(s). (Any other numbers which may be assigned this document either by the originator or by the sponsor.)
DRDC-RDDC-2016-D030	

11. DOCUMENT AVAILABILITY (Any limitations on further dissemination of the document, other than those imposed by security classification.)

Unlimited

12. DOCUMENT ANNOUNCEMENT (Any limitation to the bibliographic announcement of this document. This will normally correspond to the Document Availability (11). However, where further distribution (beyond the audience specified in (11) is possible, a wider announcement audience may be selected.))

Unlimited

13. ABSTRACT (A brief and factual summary of the document. It may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall begin with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (S), (C), (R), or (U). It is not necessary to include here abstracts in both official languages unless the text is bilingual.)

In 2015 a force readiness analysis was completed for CANSOFCOM. The MAnaged Readiness Simulator (MARS) was used for the first time by the CANSOFCOM operational research team. While the tool shined overall, certain hurdles were met which hampered part of the study. This report recounts the challenges that arose and discusses potential improvements.

En 2015, une analyse sur l'état de préparation de la force a été réalisée pour le COMFOSCAN. Le simulateur de gestion de la disponibilité opérationnelle (MARS) a été utilisé pour la première fois par l'équipe de recherche opérationnelle COMFOSCAN. Bien que l'outil ait brillé dans l'ensemble, certains obstacles ont été rencontrés et ont entravé l'étude partiellement. Ce rapport relate les défis qui sont survenus et discute des améliorations possibles.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (Technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus, e.g., Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

Managed readiness; force structure; MARS; CANSOFCOM.