Distributed Simulation for Training: Promises, Barriers and Pathways

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ABSTRACT

Distributed simulation has been used extensively to support collective training within the Canadian Armed Forces (CAF), and in particular the Royal Canadian Air Force (RCAF), based on expected advantages over live collective training. For instance, distributed simulation holds out the promise of reducing costs (e.g., vehicle maintenance, fuel, other consumables), increasing convenience for trainees (e.g., no need to travel to a remote training base), ability to train otherwise unsafe or impractical scenarios (e.g., natural disasters in multinational settings), among others. However, recent observations at distributed simulation events and feedback from subject matter experts within CAF reveal that, despite these promises of distributed simulation, there are still a number of barriers to its full adoption. Some of these barriers require policy-based and organizational solutions (e.g., adequate resourcing levels for conducting exercise), whereas some others could benefit from technical solutions (e.g., supporting exercise content designers with automated tools). This paper will discuss the barriers to successful distributed simulation-based training observed within the CAF (with a focus on recent RCAF distributed simulation events), possible solutions to these, and which of these solutions still require research and development efforts to achieve fruition.

1.0 BACKGROUND: THE PROMISES OF DISTRIBUTED SIMULATION FOR TRAINING

The use of simulation for military training has a long and well-attested history (see, e.g. [1]; [2]). A significant development in simulation-based training was the networking of physically remote simulators via computer networks, that is, distributed simulation for training. This particular application has progressed substantially since the first attempts at networking simulators by the US Department of Defence with the Simulator Networking (SIMNET) project in the early 1980s [2]. Today, many NATO nations, make extensive use of distributed simulation for preparing their forces for operations, and many researchers continue to advance the state of the art in distributed simulation (see [3] for a description of efforts for the US Air Force, and [4] on the NATO First WAVE events). However, the ongoing research activities in NATO and elsewhere also point to the fact that, despite extensive interest in, and widespread use of, distributed simulation in the past few decades, there are still a number of challenges in optimizing the use of distributed simulation in the "real world." In particular, we have observed some of these challenges in the Royal Canadian Air Force (RCAF), Royal Canadian Navy (RCN) and Canadian Army (CA) training system. Additionally, one of the authors conducted interviews with Canadian simulation subject matter experts (SMEs), which provided additional insights. Our discussions with CAF SMEs about these issues also suggest some avenues for overcoming the challenges facing distributed simulation, some of which may involve further research activities. We are also aware of work by researchers systematically documenting and proposing evidence-based remedies to similar barriers to adopting new technologies in the broader fields of education and training (e.g., [5]). Accordingly, we will use our observations of distributed simulation in the CAF context to frame a wider discussion on barriers that still exist to the effective use of distributed simulation for military training, as well as possible solutions to these barriers, with a special consideration to where R&D efforts may play an important role in the solution. We will start by discussing some of the benefits "promised" by distributed simulation for military training, which, while well documented already, will serve to make sense of the barriers or challenges observed in actual usage. Following this, we provide a brief overview of the current state of distributed simulation for military training in Canada. We will then present the barriers and challenges to distributed simulation we noted in our own observations and interviews with SMEs, and discuss these barriers in the context of Reid's [5] framework. Finally, we will discuss how Reid's framework can help us consider pathways for enabling the success of distributed simulation, and mitigating the barriers we observed.

1.1 Overview of distributed simulation for training and its promises

As a general principle, simulation-based training offers some well-documented advantages over live training (e.g., [1]; [3]; [4]). Notably, difficult, unsafe and rare scenarios can be practiced to develop emergency response skills and critical thinking in challenging situations. Wear and tear on vehicles, fuel and expendable costs (ammunition, tires), maintenance and support to equipment and vehicles are all greatly reduced. For instance, cost savings ratio estimates for real to simulated training in the US ranges from 7/1 for a CH-47 helicopter to 30/1 for an S-3A anti-sub aircraft, and cost avoidance for missile systems in the US has been estimated at $320M [6]. Further, simulation training preserves vehicles and equipment for operational use. Training in digital synthetic environments also offers the opportunity to record, analyse and play back trainee performance to a degree difficult to achieve with human observers and assessors alone. Distributed simulation further provides advantages, especially for team and collective training: personnel can participate in large collective or even international training events from their home bases, using local simulation facilities interconnected by high-speed networks, thus reducing the burdens of travel time and budgets, as well as the burden to simulation resources, personnel and infrastructure at local sites, and allowing for interoperability and joint or coalition training that may be otherwise difficult to arrange, considering the administrative and logistical barriers often associated with organizing large multi-national live events [7] [3]. For collective joint and multinational training in particular, which by nature tends to emphasize training for operations rather than basic skills, distributed simulation can offer a security advantage, allowing collectives the opportunity of practicing sensitive manoeuvres or procedures away from the prying eyes of unauthorized onlookers. Finally, as with individual simulation-based training, distributed simulation provides opportunities to capture and analyse collective training outcomes for collective after-action review (AAR) and performance analysis typically unavailable in live training environments [3, 4].

1.2 Canadian use of distributed simulation: general situation and "what we do well"

In the CAF, as in other militaries, the Air Force led the way in advancing distributed simulation. Efforts in the late 1990s and early 2000s [8] were mainly for the purpose of allowing pilots to train together without taxing the operational fleet and issues with air traffic control near busy civilian airspace, producing the RCAF's Advanced Distributed Combat Training System (ADCTS) and the Canadian Advanced Synthetic Environment (CASE). This work was supported by research and development within the Department of National Defence to examine the requirements for effective distributed simulation. In 2004, Defence Research and Development Canada (DRDC) and partners from academia and the private sector used an unclassified, non-dedicated network to perform a proof of concept distributed military simulation scenario, then followed in 2006 with a national security scenario [9]. These events led to the development of recommendations on the conduct of distributed simulation events, and a unique "spoke-to-spoke" solution to provide secure, easily configurable connections for distributed simulation across public internet, featuring segregation of synthetic environment (SE) partner networks, and "on-demand" connectivity. As a further development, the Synthetic Environment Core (SECore) initiative was begun in 2008 with the intention to improve interoperability through the creation of a reference baseline and standards, formalisation of simulation development processes, and the provision of guidelines to generate common content and models for entities and behaviours across distributed simulation environments [10].

Today the RCAF has an established Distributed Mission Operations Capability (DMOC) capability [11]. Having demonstrated the viability of distributed sim for operational training, the RCAF DMOC experience has led the Royal Canadian Navy (RCN) to start developing its own DMOC capability [12, 13]. The Canadian Army (CA), which also has an established simulation capability for individual and commander-level tactical training, is now looking to develop a broader capability that networks together simulators to support collective training [14]. Thus, the CAF has a number of established simulation-based training capabilities and is looking to expand and strengthen its distributed simulation capabilities. As with the original RCAF DMOC capability, the motivation is largely to avoid taxing operational fleets, the preserving of expensive consumables (e.g., fuel and ammunition) for operations, the ability to conduct certain tasks that might be difficult to conduct in proximity to civilian space – as well as a desire to avoid travel costs and time away from home for CAF personnel who are posted in bases covering a large portion of Canada's vast geographic extent.

2.0 BARRIERS TO TRAINING WITH DISTRIBUTED SIMULATION

Despite the many benefits distributed simulation has the potential to provide, its use is not without challenges. It is not uncommon for there to be challenges in adopting and employing novel training technologies, and simulation for training in particular [1, 5]. As Reid points out, a systematic understanding of these challenges and barriers is essential in taking steps to ensure that novel training technologies, such as distributed simulation, are used most effectively. However, to our knowledge, no systematic study has been undertaken of the challenges with distributed simulation faced by training communities in the CAF. In the following sections, we discuss the informal and anecdotal observations we have made on barriers to the use of distributed simulation in the course of various research projects on simulation-based training. We will then relate them to Reid's [5] general framework to barriers to the use of training technologies.

2.1 Canadian observations

2.1.1. Early attempts

While DRDC's early proof-of-concept attempts at developing effective distributed simulation in the Canadian defence and security context were eventually "successful" [9], the researchers identified the lack of access to a persistent and seamless national connectivity as a barrier, imposing high costs in terms of time and effort. This led to the "spoke-to-spoke" network architecture proposed by the researchers. Rafei & Vallerand produced guidance and recommendations, including a code of best practices for promoting anticipation and planning of future connectivity and bandwidth requirements. These capabilities were well-developed and applied in both DRDC and The Technical Cooperation Panel (TTCP) contexts; however the infrastructure was deemed no longer necessary, and decommissioned (N. Rafei, personal communication, September 06, 2018). Loss of this solution without an equivalent or better replacement may result in renewed challenges to effective networking. This also reveals another potential barrier, namely the institutional inability to maintain successful solutions.

2.1.1 RCAF observations

In order to develop and refine its distributed simulation capability, the RCAF has been conducting the Exercise Virtual (EV) series of events, and DRDC was tasked with observing EV serials and providing insights on their effectiveness [15-17] . EV serials typically have the objective of allowing different training communities within the RCAF and other CAF environments to develop an initial distributed simulation capability and pave the way for future collective training. Accordingly, the various EV serials to date have varied in size, structure and participating communities (e.g., including the RCN in the most recent serials). While these events were deemed technical successes, they were not without their challenges.

Below are a number of observations based on informal discussions with RCAF staff, anecdotal observations and a review of limited documentary evidence pertaining to the EV serials we attended. They are meant neither as a criticism of the EV organizers nor as a systematic audit of RCAF distributed simulation. They do, however, suggest broader issues which may pose challenges to more effective and widespread use of distributed simulation for training in the RCAF, and which bear further investigation. With that in mind, we noted the following impediments or concerns

- The degree of communication and coordination between the various sites was variable from event to event and was not always optimal. Information about objectives, overall design, specifics of scenarios was not always passed, nor were all stakeholders included in all phases;
- Lack of clear training objectives, and lack of shared vision/goals among sites & players. Part of this challenge relates to a general lack of systematic methodologies for training needs analysis and event design at the collective levels [18], which can be exacerbated by reduced interaction and coordination between exercise planning teams and stakeholders in a distributed construct;
- Inconsistent collective AAR opportunities (sometimes each site did their own debrief); also collecting performance data and event outcomes in order to assess value and produce lessons learned did not always happen, nor were there dedicated personnel available to perform AAR;
- Lack of resources (especially human) to plan, design & execute EV serials. Despite best efforts, organizers were not always able to access the personnel and expertise required to fully deal with the surge of effort required by an event like EV, due to competing operational and administrative demands. Part of the human "cost" also involves challenges with being able to retain personnel long enough to develop the expertise required to effectively run a distributed event.
- Negative perceptions about distributed simulation: it was suggested that some Air Force training communities may not see much training value in the EV construct, and some may hesitate to participate due to concerns about performing sensitive procedures over a computer network, even though the EV DMOC provides for secure connections. Also, despite the RCAF's relatively longer history with simulation, informally many aircrew still feel that live flying is preferable to simulation;
- While largely successful technically, "glitches" occasionally still caused major issues with scenarios throughout the 3 EV serials we observed. One recurring technical challenge is the coordination and compatibility of M&S assets at each site (geographic models vehicle models, imagery) despite existing standards, such as the Distributed Interactive Simulation (DIS) and High-Level Architecture (HLA) standards meant to alleviate such problems [19].
- Experienced role players were not always available for certain roles, requiring the use of less experienced personnel, providing potentially less training value to other players.

2.1.2 Royal Canadian Navy and Canadian Army experiences.

The RCN and the CA have only started developing distributed simulation capabilities, following the RCAF's lead. Thus, this section will of necessity be speculative, considering mainly the lessons that may be applied to the RCN and CA contexts.

We were not able to directly observe the RCN DMOC during EV17 [17], and thus we cannot comment directly on the challenges it faced. However, based both on the RCAF experience and on some RCN particularities, we can make some inferences:

- With the CAF in general being a relatively small and resource-constrained force, we can expect the human resource and expertise issue to be a challenge for the RCN as well;
- Given that new training frequently suffer initially from negative perceptions and adoption challenges [1, 5], it would not be surprising if negative perceptions of distributed training within the RCN also resulted in challenges to its use;
- As noted in the RCAF case, the existing lack of systematic methodologies for collective training needs analysis and design can be compounded by the effects on inter-team coordination and communication that can result in distributed scenarios;
- Effective AAR capabilities will be just as crucial for the RCN as for the RCAF; performing AAR in a distributed environment introduces challenges of its own, related largely to instructors and training audience not always being co-located, and difficulties with coordinating and reconciling events happening on different systems into a coherent "picture" for AAR [20];
- Particular to the RCN, their distributed simulation construct will entail the networking of potentially very disparate platforms; the FNTS [13]. calls for networking embedded simulators on operational vessels, fixed crew/mission simulators and medium-fidelity multi-role reconfigurable trainers (MRTTs; [21]), all with very different user interfaces and image generators. Including embedded trainers in operational vessels brings the RCN use case for distributed simulation into the Live-Virtual-Constructive (LVC) realm, which adds additional complexity and challenges [22].

The CA does not yet have a DMOC capability, though it has participated in international distributed simulation events (e.g., [23], and has extensive experience with local collective training with simulation. The CA regularly conducts Exercise Unified Resolve, a headquarters-level computer-assisted training event as part of its high-readiness work-up schedule[24]. Unified Resolve involves hundreds of participants and support staff and makes heavy use of virtual and constructive simulators. The heavy draw on local resources (personnel, equipment and infrastructure) point to the type of situation that distributed simulation looks to alleviate, as was noted during the CA's participation in ALLIED AURORAS 11 [23], however, they also bring to mind that distributed simulation still requires adequate local resources and expertise at each site, as was discussed in the RCAF context above. The CA also has experience with locally networking virtual simulators for small team and crew training [25]. Such use of local networked simulators for collective training has, and continues to be, been successful; however, the continued success of such a training approach requires ensuring adequate resources and expertise to operate the simulators. This is a point so obvious and general that it hardly bears making, but we repeat it because it is not uncommon for resource-constrained organizations to have competing demands for resources that can impact the use of elaborate simulation systems. Nevertheless, the CA has experienced success with networked simulation for training and is looking to build on that by establishing a national network of simulation systems spanning various training centres [14]. As the intent and design for this capability is still being developed, we can only suggest that the challenges faced by the RCAF and likely by the RCN in implementing a distributed simulation capability will loom large for the CA as well. One additional potential challenge is that, unlike the RCAF and the RCN, the CA will be looking to include in their distributed simulation construct simulators that support not only vehicle crews but also personnel that normally operate in environments outside of vehicles (e.g., dismounted infantry, artillery, combat engineers), which increases the challenges on providing a coordinated synthetic training environment for all participants.

2.1.3 SME Interviews

As noted above, one of the authors interviewed with SMEs from Canadian industry, academia, and from public security and defence. The interviews sought to uncover the simulation state of the art in Canada, considering the themes of what is being done well or successfully and what impediments exist. The SMEs revealed several positive points for simulation (including distributed simulation) in Canadian defence and security; however, they also revealed several challenges, many of which were consistent with the challenges noted above in our own observations. Some key points made by the SMEs include:

- Access to simulators can be limited in the CAF, particularly for Reservists, who tend to have more limited training opportunities to start with.
- Consistent with our own observations, in the SMEs' experience requirements with respect to collective training in simulation were often inadequately specified, which often was an impediment to effective training?
- Some SMEs felt that the leadership of some organizations may be looking for "gold plated solutions" from commercial suppliers, thereby engaging in slow and inflexible procurement processes that may not meet the organization's needs.
- For distributed simulation, there is the issue of remote management of local resources, which presents particular challenges. Many SMEs noted the cost of scenario development and the cost of white forces and support contractors.
- Some SMEs noted that the Air Force is not always maintaining and updating the simulators purchased with operational aircraft. Further, organizational process-related barriers have impeded growth of this capability for the RCAF with the particular example that the CASE distributed simulation system development was limited because the sustainment plan put in place provided for services, but not equipment. Additionally, one SME commented that the Air Force has not achieved broad use of simulation because they are not committing to one tool, and have failed to develop a common architecture.
- The SMEs suggested that a number of CAF members still have negative impressions of simulation for training, for instance "simulation isn't training" and "if a bullet doesn't come out of a gun, then training has not occurred". One SME observed that such comparisons of 'reality vs simulation' may be a result of confusion over what exactly is being trained in a simulator. Further, some who have risen through the ranks and are now in the roles of training stakeholders may think of simulation in terms of the last simulator they saw, leading to rejection of the technology based on inaccurate perception. With respect to distributed simulation in particular, one SME commented that there is little willingness to explore and apply distributed simulation training, that it is something that is done additionally "if we have time". Another noted there is scarcely enough time and resources to do regular training so learning, incorporating and applying new technology is difficult, and despite any purported benefit, it may be the first to go. Another observation was that training audiences are not yet "used to" distributed simulation for collective training, and that there is a "cultural impediment" against its use.

2.2 Making sense of the observed barriers: a conceptual framework

2.2.1 Previous research on barriers

First, it is worth nothing that the barriers and challenges to effectively using distributed simulation observed in the CAF are not unique or unusual. In a report where the USAF DMO concept was described as "one of the most successful applications of Modelling and Simulation (M&S) for warfighter training," a number of challenges in executing DMO events were still noted [3]. Similarly, a report on the NATO First WAVE distributed simulation event [4] also noted a number of challenges.

More generally, it is typical for new and emerging learning and training technologies to experience barriers and impediments to their adoption (see the annual Gartner Hype Cycle reports; [26] for the most recent one), and the same is true of simulation for training in general [1]. While much of this evidence is anecdotal, some training communities have taken steps to examine the barriers simulation-based training in their communities more systematically. For instance, in anaesthesiology training, Savoldelli, Naik and Hamstra [27] surveyed almost 100 anaesthesiologists and anaesthesiology students about their perceptions of simulation-based training, and found evidence for a number of perceived barriers to taking advantage of such training. The barriers related to respondents' perceptions of the value of the training, of the time required for the training, and the perceived organizational value of the training. The findings led to the authors suggesting changes to the use of simulation-based training aimed at further encouraging its use.

There is clearly value in taking a systematic look at the barriers and challenges in distributed simulation for training; doing so could lead to identifying improvements and avenues of investigation for overcoming the barriers. Doing so would benefit from a solid conceptual framework. Reid [5] has developed a framework for examining barriers to the adoption and use of instructional technology, based on a thorough literature review on reported barriers to the adoption and use of instructional technologies. The framework consists of five categories of barriers, namely: (1) technology, (2) process, (3) administration, (4) environment, and (5) faculty. We describe each briefly below and adapt the definition to the context of distributed simulation training. In doing so, we propose two changes to Reid's framework: we take five categories in the framework more as dimensions that can either facilitate or obstruct implementation, rather than barriers per se, and we replace the Faculty category with a Training Stakeholders category, which includes military instructors, Training Development Officers, schools within the CAF, and Training Authorities (who set out training policy, doctrine and are responsible for defining and maintaining Qualification Standards and Training Plans), and specific training communities at operational units.

The Technology dimension refers to the student and faculty access to resources, as distributed among departments; its reliability in continued and various use; and the complexity of the technology as it relates to usability.

Process refers to systems and procedures needed to identify, procure, implement and promote the use of a new technology, including appropriate professional development for faculty members and ongoing technical support and training. Notably, a project management approach, including faculty consultation, plans to anticipate and reduce unintended consequences of implementation, and solicitation of buy-in are critical to the notion of Process. The Support sub-dimension addresses the idea that help is need by faculty, students and staff for the effective adoption of a given technology. Specifically, Training Stakeholders using a new technology need support and encouragement from other training stakeholders; technical assistance that is approachable, available when needed and knowledgeable of teaching as well as technology; administration, instructional design and development. Staffs need to understand how to schedule technology use, and make it easy through provision of passwords, and appropriate software, and skills needed for working with teachers and students. Finally, students must be recognized since new approaches to learning are often mandated by new technology and the associated pedagogy. In this respect, appropriate, thoughtful and sufficient professional development is a critical consideration. It must consider the nature of the technology and new pedagogical models as well as the needs of the students.

For military purposes, Process should be expanded to include development and implementation within the specific instance of Collective Training, which has unique project management challenges (specifically, requirements analysis, training event design and performance measurement), particularly at higher levels [18]. When more than one element interacts for the purposes of training, unique constraints are imposed with respect to competing training objectives, personnel and asset availability, and scheduling and coordination between stakeholders.

Administration includes financial, information technology and leadership functions of the learning institution, with sub-categories of control, institutional support, required effort, compensation, and time. Control pertains to the degree to which training stakeholders feel they have a say in what technology gets used and how. Institutional support concerns the perception of how much the organization is actually behind adoption of a new technology, and the evidence supporting that perception. The Required Effort to implement a new technology is frequently underestimated, and can lead to its abandonment, and with this, organizations must recognize the effort of the personnel concerned through appropriate Compensation. Last, Time, to learn the technology, adapt or create new learning opportunities, and to deal with technical problems and lack of access can thwart the uptake of a new instructional technology.

Here, Environment denotes the broader context of the institution or organization in which the instructional technology is used. Environment encompasses organizational change, tensions between Training Stakeholders and other organizational elements, legal issues, and the effectiveness of courses and technology. Change management is necessary because of imposed changes to the organization by way of policy, new tactical considerations, and frequently changing personnel. Equally, the roles of Training Stakeholders change as the culture, educational demands and techniques, and technology within the military evolve. Additional tensions may exist between the organization and Training Stakeholders, as demands for improved efficiency, new training or educational priorities and policy changes push against established or enculturated training practices or contrary knowledge of the trainers. In terms of legal concerns, the military may require customization of technology beyond a consumer off-the-shelf model, and methods of procurement, and ownership of intellectual property may impede this requirement. Finally, course and technology effectiveness is extremely difficult to assess, since randomized controlled trials are very difficult to apply in the CAF, and the overall demonstrable benefit of training may be masked by behaviour in a non-permissive environment. The technologies themselves may be used differently by different instructors, and successive versions of a technology may vary in effectiveness. In a military context the frequent absence of training objectives, in particular Collective Training objectives, means that the impact of a given technology cannot even be guessed at.

The final dimension for implementation of instructional technology is that of Training Stakeholders. In Reid’s original, the dimension is referred to as Faculty and is presented as a second order barrier, that is, the barrier is internal to the instructor rather than factors within the institution. Sub-dimensions include the training stakeholder’s own effective use of technology, their resistance to change, as well as their self-efficacy and background with respect to technical understanding, instructional experience, and self-percept of their ability to use the technology. The last sub-dimensions for the Training Stakeholder is their perception of the instructional technology’s effectiveness, and their participation in PD. The sub-dimensions in the category can be mitigated through effective and anticipatory change management at the level of the institution, but still require positive support from the Training Stakeholders themselves.

We contend that these categories can not only help to identify challenges in implementing and employing training technologies such as distributed simulation, but also point to factors which, when well implemented or managed, can facilitate the successful use of a training technology. Therefore, in the next section we categorize our observations on barriers to distributed simulation within the CAF according to the framework above, and subsequently consider possible ways of addressing these barriers in light of these categories.

2.2.2 Summary of barriers observed within the CAF

Our observations fit easily into our adaptation of Reid's [5] categories, as is shown in Table 2-1. This suggests that Reid's framework is a useful one for examining the challenges facing the use of distributed simulation. Further, that framework may be useful for a more systematic investigation of these challenges. While some categories contain more observations than others, we cannot at this point assess their relative importance. A more systematic and quantitative approach would likely reveal more specific barriers, and their relative urgency and severity. Nevertheless, one finding worth dwelling on is that the vast majority of the barriers to distributed simulation we identified are not technological in nature, suggesting that improving the effectiveness of distributed simulation for training may involve more than simply improving technology.

Table 2-1: Barriers to distributed simulation according to category

Barrier Category	Observed Barriers
Technology	Challenges in applying existing distributed simulation standards Distributed AAR technology not mature LVC integration not mature Distributed sim networks (systems of systems) are complex and not "plug and play" Technology not always updated Inadequate access to simulators
Process	Lack of collective event methodology, including unclear training objectives, lack of systematic approaches to measuring performance in distributed simulation. Challenges in coordinating planning team objectives, vision across multiple sites. Challenges with procurement and system life-cycle management for distributed systems that don't consider all life cycle costs (including non-monetary).
Administration	Personnel and resources: insufficient local resources due to high cost, competing demands Difficulty of managing systems remotely
Environment	Concerns around network security

	Unclear buy-in from chain-of-command in certain training communities Cultural “bias” in favour of live training over simulation, resistance to change
Training Stakeholders	Negative perceptions of distributed simulation Lack of time and opportunities to gain experience, understanding of distributed sim Lack of expertise in employing distributed simulation, variable expertise in employing sim technology in general

3.0 IMPROVING IMPLEMENTATION OF DISTRIBUTED SIMULATION: FROM BARRIERS TO PATHWAYS

While some may look primarily to improvements technology to address the barriers in using distributed simulation for training, it is clear from our observations on distributed simulation that organizational and individual resources, attitudes and processes will have to be addressed just as much as technological issues. By considering the categories we adapted from Reid [5] as “health” factors that can either facilitate or impede distributed simulation, depending on their status, we can start to examine the barriers we identified in search of solutions

Technology: The generational progress and obsolescence of technologies, as well as market forces ensure that simulators will continue improve [28], and development of the technologies underlying distributed simulation (e.g., simulation networks and standard, LVC integration, distributed AAR) is ongoing. However, to improve users’ experiences with distributed simulation, these developments must take a user-centred design approach, and be responsive to trainees’ and instructors’ usability, reliability and instructional requirements. In addition, it is clear from our discussion of the technology-related barriers that organizations must take steps to improve access to simulation within their organizations, and apply best practices such as regularly updating their equipment and complying with distributed simulation standards. While these improvements would be largely non-technological, it is worth nothing that some technologies may support some of these organizational and process improvements. For instance, work currently being conducted by DRDC is aimed at developing a decision-support tool to help optimize simulator scheduling and location so that more trainees will have access to simulation devices.

Process: It is clear from our observations that process-related barriers figured prominently for the CAF. Technology use must be actively and intentionally advanced. The RCAF’s, RCN’s and CA’s visions for future training all emphasize an intent to rely more heavily on simulation, including distributed simulation, for training [13, 14, 29]. However a clearly structured plan for revising curriculum, procuring and implementing simulators, preparation of the Training Stakeholders and students must still be developed to realize this pathway. Collective training enterprises involving multiple elements and training objectives must be carefully planned. Suggestions for improving this aspect include comprehensive multi-year planning with an exercise portfolio to respond to constraints over multiple years, with sufficient data collection and time to amend future planning based on lessons learned; to create machine-readable plans and outcomes [30]. Research and development around improving and validating methodologies for conducting collective training needs analyses [18], collective training event design (e.g., see discussion of Event-Based Approach to Training, or EBAT, in [31], automated scenario design tools (e.g., see [32] and automated performance measurement in simulation (e.g., see [33] are all crucial in helping Process become a pathway rather than a barrier in distributed simulation.

In addition to the issues around designing and executing collective training in simulation, the barriers within this category also included the more common process challenges in large organizations, namely those around procurement, life-cycle management, and communication and coordination across multiple sites. These are likely best addressed through applying best practices from their respective domains. Regarding procurement in the CAF, several of the SMEs we spoke with noted some improvements along these lines. For instance, some SMEs noted that the RCAF's CASE project was well-served by a number of process-level decisions, namely: flexible, service- (rather than product-)oriented mechanisms for contracting external support that did not require solutions to be fully specified from the start, and government ownership of the simulation architecture and intellectual property on significant parts of the system, which allowed the RCAF to exercise considerable flexibility in managing the system, and to apply simulation and process standards (e.g., ISO standards) to the project.

Administration: One of the features that makes distributed simulation attractive to the high-level financial and strategic leadership of the CAF is the possibility of reducing the financial and resource burden on any given site within a distributed network [3, 4, 23]. However, our observations show that the burden on personnel and resources can still be considerable in a distributed simulation construct, mainly in terms of the added burden of coordinating various sites, and in the increase in specialized expertise and equipment required at each site to engage in distributed simulation. This may be particularly acute for the DMOC site in a distributed simulation, which takes on extra command-and-control responsibilities. Addressing these issues are largely a matter of making strategic and policy decisions to put in place the local and organizational-level resources and expertise to make distributed simulation successful, and to leverage any best practices already developed in the CAF (see [9, 30]. Additional research and analysis to capture the true costs and benefits of distributed simulation would be helpful to CAF leadership in that regard.

Research and development efforts on automating aspects of distributed training, as discussed in the Technology and Process categories, may also assist in making the Administration category a more effective pathway.

Environment: Of particular importance in the military context is addressing the notion that simulation based training is not "real" training. Culture is difficult to change and enforce, but a concentrated effort, with clear anecdotal and evidence-based support must be applied. Further, a clarification of expected outcomes in simulator-based training could refine specific anticipated benefits of the training and relieve disappointment when simulation fidelity to physics is lower than desired. One key factor in addressing organizational perceptions of distributed simulation is providing evidence for its benefits. Conducting research to determine the training effectiveness of distributed simulation, in the form of human-in-the-loop experimentation and transfer of training studies [34, 35].

Training Stakeholders: To help address the attitudes and dispositions of the training stakeholders, it is necessary to provide necessary support, professional development and recognition for those trying to use distributed simulation technology. On a positive note, the interviews with the simulation SMEs suggested that a "cultural shift" is happening in the CAF with respect to the ways in which simulation and virtual reality can be used at various levels of training: for example, air crews receive simulation training *ab initio*; there has been approval from senior executive to build larger simulator-only training facilities; and tactics development is being trained on simulators, particularly in the Navy. These indicators suggest that Training Stakeholders are becoming increasingly amenable to using simulation-based training solutions. Further, one SME noted that some CAF personnel enlist with degrees related to modelling and simulation, or achieve them while in the service. These observations suggest there is considerable promise that newer generation of war-fighters will readily accept and promote simulation-based training.

Nevertheless, current leadership must take steps to ensure this "cultural shift" continues and that training stakeholders are supported. As mentioned in the Environment pathway, more research on the training effectiveness of distributed simulation would also help address stakeholders' attitudes – so long as the required professional development and institutional buy-in are present. Technological support for training stakeholders, as mentioned in the other categories, could also improve stakeholders' capacity and willingness to use distributed simulation.

In concluding this section, we emphasize two points. First, while the interventions that can facilitate the development and use of distributed simulation can be classified along the same categories as the barriers, solutions do not necessarily fall within the same category as the barrier they address. That is, addressing the barriers is not always a matter of "treating like with like" – a fact that may make certain solutions counter-intuitive, and which decision-makers and leadership should bear in mind. Second, several solutions involve the applications of established standards and best practices, whereas other solutions require further research and development to come to fruition. Some of this research is more technical in nature, whereas much of it falls under more human-sciences related domains. Thus, decision makers should be aware, and ideally supportive, of the requirement of conducting further research in both technology and the human sciences in order to build pathways to effective distributed simulation.

4.0 CONCLUSION

Building on early successes with distributed simulation in the RCAF and Joint contexts, and on other experiences within NATO, the CAF continues to develop its distributed simulation capabilities. As these capabilities evolve, we are observing signs of issues which may become barriers to the effective use of distributed simulation in the CAF. By applying and adapting Reid's [5] framework for understanding barriers to the adoption of training technologies, we have taken some initial steps at a more systematic investigation of the barriers that may interfere with the effective use of distributed simulation in the CAF, as well as started to consider factors that could transform them into pathways for success. Further investigation of these barriers and pathways, including further research and development in a number of both technical and human sciences areas, is warranted. Given similar challenges with distributed reported in other military training communities [3, 4], we propose that a systematic look at barriers to, and pathways for, distributed simulation for training be undertaken more broadly across NATO.

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