Human performance modelling

Future capability for Toronto Research Centre

F. Buick
F. Bouak
C. Burrell
A. Nakashima
H. Peng
D. Pickering
DRDC – Toronto Research Centre

Prepared For:
S. Grant
A/H/IBPS

Defence Research and Development Canada

Reference Document
DRDC-RDDC-2017-D043
May 2017

Abstract

Human Performance/Human Effectiveness is an essential Defence Research and Development Canada (DRDC) S&T capability that will operate in a greater "breadth" mode. This Working Group studied the Human Performance Modelling Capability (HPMC) within IBPS to produce a plan for evolving the current capability into a future capability making greater use of collaboration with the external S&T community (Allies, academia, and industry). With individual study and group sessions, and using explicit questions and free thought drawing on resident knowledge, the capability in Human Performance Modelling (HPM) in the external S&T community was determined to be developed enough to engage for collaboration. Potential partners may be attracted to collaborate with us because of, among other things, access to unique human performance data and facilities, but may be hesitant, for example, due to administrative bureaucracy and not-fully-developed expertise in DRDC scientists. The HPMC can better position itself for engaging potential collaborators by identifying the external HPM experts, learning about collaboration best practices, discovering what incentives would interest collaborators, and supporting DRDC S&T workers with guidance on collaborative procedures and with developing recognized expertise.

Résumé

La performance humaine ou l'efficacité humaine est une capacité essentielle en S et T dont la portée sera élargie à Recherche et développement pour la défense Canada (RDDC). Le groupe de travail a étudié la capacité de modélisation de la performance humaine au sein de la SCPI, et ce, en vue d'élaborer un plan pour transformer la capacité actuelle en une capacité future qui permettra de collaborer davantage avec la collectivité de S et T externe (c.-à-d. les pays alliés, le milieu universitaire et l'industrie). Dans le cadre d'une étude individuelle et de séances de groupe, des participants ont répondu à des questions précises et ont exprimé librement leur pensée en fonction de leurs connaissances de l'organisation et, en conséquence, on a déterminé que la capacité de modélisation de la performance humaine dans la collectivité de S et T externe était suffisamment développée pour permettre la collaboration. Des partenaires éventuels pourraient être incités à collaborer avec nous, notamment pour avoir accès aux installations et à des données uniques sur la performance humaine, mais pourraient hésiter à le faire en raison du fardeau administratif et de leur connaissance insuffisante des scientifiques de RDDC. En améliorant la capacité de modélisation de la performance humaine, c'est-à-dire en déterminant quels sont les experts externes en la matière, en s'informant des pratiques exemplaires en matière de collaboration, en découvrant les avantages qui intéressent les collaborateurs et en aidant les travailleurs en S et T de RDDC à suivre les procédures de collaboration et à développer une expertise reconnue, il sera plus facile de mobiliser des collaborateurs éventuels.

Table of contents

List of figures

List of tables

This page intentionally left blank.

1 Introduction

1.1 Task

DRDC Science and Technology (S&T) Capability 4.3 Human Performance, together with two other capabilities, will be subsumed by a new, broader capability of Human Effectiveness [1]. Human Performance Modelling (HPM), generally performed within the current Individual Behaviour and Performance Section, will remain a key sub-capability within Human Effectiveness when the Toronto Research Centre re-organizes in 2017.

In the current context, and with high-level direction from the Defence S&T Strategy [2] (STS), "capability" is viewed as the capacity to deliver S&T solutions (ideas, technology and know-how) in support of defence and security objectives. The HPM Capability (HPMC) will perform more of its knowledge generation activities using a "breadth" approach, meaning greater emphasis on: (i) access—S&T/knowledge will be accessed directly from industry and academic institutions, then integrated and delivered; and (ii) collaboration—jointly delivering S&T with partners (e.g., federal S&T departments and agencies, Allied S&T organizations, industry, academia) via reciprocal use of unique expertise, information, and/or facilities. Collaboration is understood to generally exclude contracting.

The present Working Group (WG) was tasked to study the HPM capability for the purpose of developing a plan for how the breadth strategy might be implemented [3, 4].

1.2 Objectives

Our specific objectives were to address these questions:

1. What S&T would be required of this capability over the next 5–20 yrs?

2. What type of capability could deliver this S&T?

3. How can the current capability develop into the future capability with a focus on collaboration?

4. What are potential incentives and mechanisms for forming collaborations?

1.3 Describing human performance modelling

A model is a representation of reality intended for some definite purpose [5]. It may be "a concept, a formula, or a drawing" [6]. Trying to understand something about the real world can help guide such things as predictions, making decisions, selecting actions, and summarizing evidence [7]. As purposes of models vary, so too are descriptions of human performance modelling. Some, relevant to the current context, are:

1. Human performance models are abstractions, usually mathematical or computational, that attempt to explain or predict human behavior in a particular domain or task [8]. The model may be a representation of integrated, multi-level, biological functions in the form of mathematical equations where the parameters are physiologically meaningful [9].

2. Military performance modelling involves computational optimization strategies to sustain health and performance by combining the effects of multiple stressors [10].

3. Human performance models refer to "quantitative (analytic or computer-based) models of human operators". The models vary by their "characteristics along different dimensions: output versus process orientation, predictive versus descriptive, prescriptive (normative) versus descriptive, top-down versus bottom-up, and single-task versus multitask". The types of theories or tools used in their development can also distinguish them [11].

4. Human performance is sometimes described by a statistical model, a "formalization of relationships among variables in the form of mathematical equations" in which the variables are related stochastically rather than deterministically [12]. One type makes use of structural equation modelling, "a series of statistical methods that allow complex relationships between one or more independent variables and one or more dependent variables" [13].

Mathematical models are powerful tools to delineate processes and thereby offer a conceptual framework for the analyses of hypotheses and big data [14]. In addition, population variability can be captured by 'personalized' modelling based on an set of parameters from the data of individuals [15]. Performance modelling is expected to retain its importance as models offer the potential to save time. Modelling can exploit data in databases to turn unconnected records into integrated, valuable information.

2 Methods

The primary base of information for reviewing HPMC was the WG members' resident knowledge. The members represented the disciplines of biomedical engineering, mechanical engineering, physics, social psychology, and biomedical science. All had at least ten years of experience as defence scientists. We followed the general procedures of the thinking tools "lateral thinking", "backcasting" [16], "logic models" [17] and brainstorming to help stimulate and organize resident and new information. A step-by-step approach was used so that each objective could be considered without interference from thinking about the ultimate purpose. Work was performed individually and in group sessions. Group discussions used both provoking preamble and spontaneous dialogue. Sometimes, for individual work and group sessions, knowledge was elicited in response to explicit questions, in the process trying to position ourselves to use lateral thinking, i.e., avoid vertical logic, and to use third-party perspectives.

Objectives 1, 2, and part of 3 were addressed using backcasting. Backcasting provides a four-step method towards planning the future HPMC.

1. Imagine the future environment in which HPMC will operate;

2. Conceive the S&T that HPMC might be expected to deliver;

3. Describe the abilities of HPMC necessary to deliver that S&T; and

4. Consider how the current HPMC should evolve so that those necessary abilities are accessible.

The following figure illustrates how backcasting can be applied, in this case to the design process leading to Canada's Army of Tomorrow [16]. The four circled numbers in the figure correspond to the four backcasting steps above.

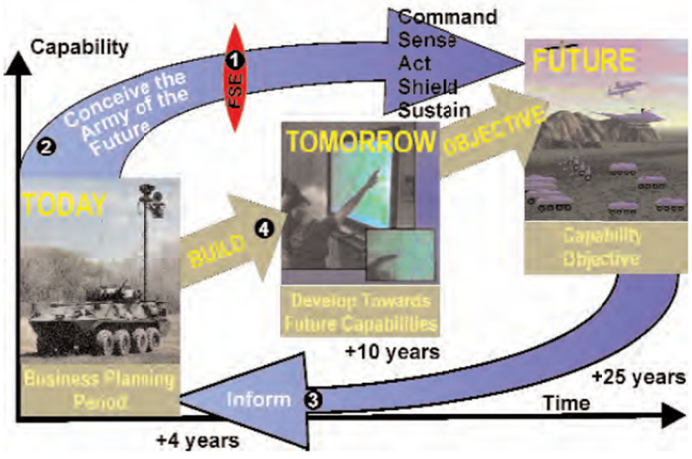

Figure 1: *Backcasting in the design process [16].*

With responses proximate, the explicit questions used in the backcasting process will be detailed in the Findings and discussion section.

A logic model was used to carry out step four of the backcasting method, that is, evolving the current HPMC to the future capability. A full logic model would include analysis of the relationships of resources/inputs, activities, outputs, immediate and intermediate outcomes, and ultimate outcomes/impact. We used a contracted logic model comprising only activities, outputs, and outcomes (Fig. 2). The logic model develops from a "chain of reasoning" [17] when using a series of "if, then" statements, i.e., if these activities, then these outputs; and if these outputs, then these outcomes. With a look to the future in this current application, the outputs of the activities were replaced by the objectives of the activities, and these objectives would, in turn, be acting on the elements which are the components of the capability (Fig. 2).

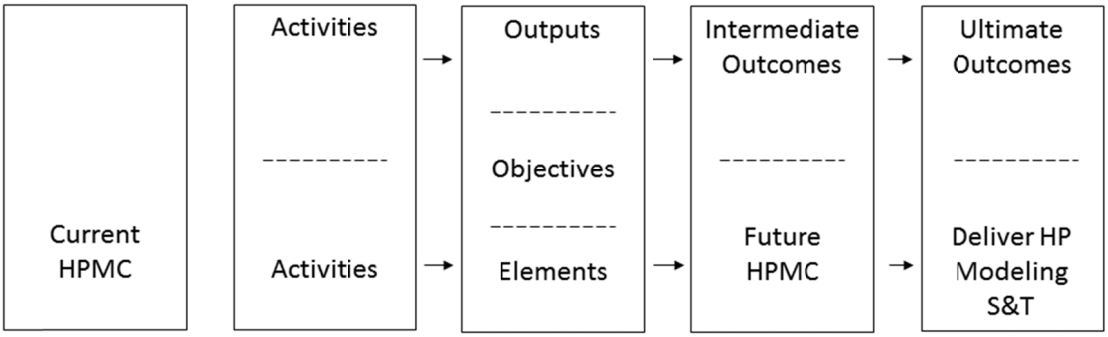

Figure 2: *Logic model.*

Group brainstorming was used to address Objective 4 and part of Objective 3.

3 Findings and discussion

3.1 Future capability

To envisage the S&T that the future HPMC would be expected to deliver, i.e., from backcasting steps 1 and 2, we addressed two statements as detailed in the following two sub-sections.

3.1.1 Future S&T delivered

The first statement asked: "what do you see as the Client's (i.e., DND, CAF and safety and security partners) two most important issues for which a solution would require a prominent role for human performance modelling?" In this context, some example "issues could be:

1. a problem/gap leading to decreased readiness and/or military capability;

2. a technology/social/other development, which if exploited, could lead to a new military capability;

3. economic/logistic situation, which if improved, would help maximize affordability and sustainability of DND/CAF;

4. a technology enabler required for developing concepts in a broad range of applications for client; or

5. any other type of major issue that comes to mind."

The detailed responses to the above question are provided in Annex A, Table A.1, and from that table, the issues that the HPM capability would help solve are summarized below as:

1. Reduce performance degradation/maintain and restore performance

    a. auditory performance (audiometry, speech understanding, sound localization, susceptibility for hearing loss, etc.), w/wo hearing protection devices;

    b. situations of vehicle-induced vibration, motion disturbance;

    c. mitigating operational stressors e.g., fatigue (physical and mental), physical/extreme environment, sleep deprivation, lack of food, motion;

    d. physical and cognitive effects of soldier burden e.g., communications, personal protective equipment;

    e. achieving pre-deployment readiness;

    f. simple/combined stressors;

g. uncertainty and unexpected situations.

2. Counteract threats to health and performance degradation

3. Enhance performance

The HPM capability would contribute to the S&T solutions by helping to explain, assess, improve, and/or inform:

- equipment performance and/or design standards
- training
- simulation
- effects of stressors
- interventions and countermeasures
- equipment procurement
- individual variability
- procedures
- decision-making
- personnel selection and assessment
- simple vs integrated models (this summary derived from right column of Table A.1).

3.1.2 Important asset if…

To envisage future S&T from an alternate perspective, a differently worded statement was used. WG members were asked to complete this sentence: "The highest ranking Client making use of performance modelling would argue that the Performance Modelling Capability was an essential asset if ...". The responses are shown in Table 1 below.

Table 1: *Important client issue for performance modelling.*

	"The highest ranking Client making use of performance modelling would argue that the Performance Modelling Capability was an essential asset if …"
1	… it demonstrates which kit ensemble (e.g., combination of new technologies) enables optimal performance in a given environment.
2	… the commander and team member could remotely monitor state of readiness.
3	… it leads to increased soldier effectiveness and resilience.

4	… it could enhance the efficiency, safety, and success of CAF operations by promoting better mitigation of the impairment by stressors and challenges faced by our soldiers.
5	… it could indicate factors impacting positively or negatively on soldier performance in extreme conditions such as in the Arctic.
6	…it demonstrated the effectiveness (i.e., enhanced performance) of new technologies/capabilities.
7	… it could help CAF determine the human resource cost of future/new platforms/fleet (air, maritime, land).
8	… it assists in crew design, analysis and validation.

3.2 Elements of S&T capability

Capability was described in the Introduction as "the capacity to deliver S&T solutions". To guide a more structured view of the elements of capability, DSTL's (Defence Science and Technology Laboratory) characterization was useful, defining "capability as the combination of people (their knowledge, expertise and experience), the enabling infrastructure, knowledge bases, licences to practice and relationships" [18]. The elements can be thought of as the abilities and assets (i.e., backcasting step 3) of the capability (Table 2, left and middle columns). The capability sub-elements were realized as a result of the responses (summarized in Table 2, right column) to the question: "What is/are the required essential sub-element(s)? (There might be one to several required sub-elements, unique to achieving objectives of Human Performance Modelling.)". These responses applied to the individual member's important Client issues (Annex A).

Table 2: *The elements of capability and the sub-elements realized by responses.*

Element	Example	Sub-elements realized by responses
Knowledge (know-what, know-why[19])	a body of information (e.g., a physical repository, what people know, knowledge bases)—its generation, collation, accessibility to and exploitation;	mathematical modelling, physiology, psychology & cognitive performance, biomedical engineering, statistical modelling, heuristic modelling, vibration engineering, speech/linguistics, environmental physiology, neurobiology
Skills (know-how [19])	ability to do/execute/perform something well	mathematical modelling, software coding using modelling languages, human protocols, sensors use and data acquisition methods, analysis of human data, statistical analysis
Experience	a history of applying skills and/or knowledge	lab & field studies with human participants, conducting studies in extreme/deployment environments, integrated physiological and cognitive modelling

Element	Example	Sub-elements realized by responses
Knowledge of client / client needs	problems troops might experience during deployment	operational stressors, operational situations, kit configurations, environmental effects, Army future requirements, operational readiness, human in complex systems
Facility/ Infrastructure	(e.g., large generally immovable (could be vehicle-based system but not considered portable); hypobaric chamber, human centrifuge, VR multi-shooter interactive weapon system)	environmental chambers, multi-stressor facilities, field studies space, LEAP (load effects assessment program), pressure chambers, motion simulators, noise/anechoic laboratory, biomedical laboratory, high performance computation and data storage centre (with real-time processing, data fusion)
Tools	(think hand-held/operated; can be specialized or generic; e.g., calculators, surveys, formulae, models, pistol, computers, readily-available databases, guidelines (e.g., doctrine), software)	modelling & simulation software (e.g., finite element modelling, MATLAB, Labview) statistical software, computerized cognitive test batteries, portable computing for psychological/cognitive tests, real-time data acquisition systems
Equipment/ Machines	(e.g., mass spectrometer, wearable physiological monitors and wireless tracking/recording system, truck, virtual reality single-shooter weapon system, grenade launcher, treadmill, super-computers)	full-systems human data monitoring systems, wearables, military kit including replicas of kit of future soldiers, mass spectrometer, high performance liquid chromatography, microplate reader, cerebral oximetry technology, psychoacoustic hardware/software, audiological/neurological test devices, powerful computer system to use large databases
Processes/ Methods/ Procedures/ Relationships/ Networks	(e.g., human research ethics review & medical oversight, licenses, procurement mechanisms, access to Statscan database, MOUs/Agreements, adjunct appointments, personnel exchanges, DND-NSERC Research Partnership Program, collaborations)	MOUs, DND-NSERC Research Partnership Program, Project Arrangements, Master Data Exchange Agreements, post-doctoral fellowships, human research ethics review & medical oversight, student hires, arrangements to relocate/loan our equipment/tools to collaborator's site

3.3 Evolving to the future HPM capability

3.3.1 HPMC sub-elements and extent developed in external S&T community

In completing their response sheets about the essential sub-elements, the WG members were asked to also indicate the extent to which the sub-element was developed in the external S&T community. A total of 82 sub-elements spanning the nine Capability Elements in the collaborator groups were produced, and from that, they were "partially developed" at 80 potential collaborator sites, and "completely developed" at another 83 sites (with six of the sub-elements left blank).

3.3.2 HPMC sub-element evolution

WG members were asked to think, in private study, about how the current HPMC should evolve so that those necessary sub-elements are accessible. The general instruction was:

- "(i) How do we treat this sub-element so that it is ready to be used effectively and efficiently when needed? (ii) How do we preserve this current sub-element? (iii) How do we evolve this sub-element if it needs modification? (iv) How do we create a new sub-element capability when it doesn't exist? Single step processes or multi-step processes may be required."

There were no responses for the questions focusing on sub-element evolution, i.e., questions (iii) and (iv) from the above instruction. The large number of sites with at least some capability could explain the lack of responses as it is our sense that the external partnering community is generally equipped with the capability elements and sub-elements needed for collaboration.

3.3.3 Readiness to collaborate

The aim of the above group of questions was to stimulate ideas about how HPMC could be shaped to be in position for fully contributing to the S&T solutions needed by the Clients' issues, i.e., addressing backcasting step four. Group members worked individually. To confirm that we had no recommendations about how to evolve the sub-elements, a meeting was convened on a subsequent occasion to discuss[1] the question:

- "Could we begin tomorrow to plan the specific COLLABORATION (or ACCESS) projects for solving the Problems in the Table (i.e., the Clients' issues)?"
    - This question was prefaced with the situational conditions: "(i) with all future HPM performed by DRDC to be done by ACCESS (includes contracts) and/or COLLABORATION; (ii) with in-house S&T capabilities retained to the extent they attract COLLABORATION; (iii) with the CAPABILITY described in the left Table (i.e., Table 2); (iv) with our current informal, formal, contractual, and Allied relationships and networks; and (v) ignore gaps that can be filled by procurements".

[1] This discussion, i.e., Section 3.3.3, is presented here as logical follow-up to the content of Section 3.3.2. However, chronologically, the deliberations occurred after the meetings/work producing Sections 3.4–3.6 as per the order of Objectives (Section 1.2).

The general consensus was that we could begin tomorrow to plan the specific collaboration projects. This suggests that the envisioned future HPMC is, for the most part, already today's HPMC, i.e., it is ready for collaboration. If planning the specific collaboration projects could not begin tomorrow, then we would have probed what, in today's capability, was missing or needed to be changed.

Satisfied that HPMC "could" collaborate, the discussion then shifted to whether the external HPMC "would" collaborate. Industrial psychology informs that work performance requires at least two factors to be in place, technical competency to do the work and motivation to do the work [20]. In the current context, HPMC has much of the knowledge and goods for collaboratively producing S&T solutions, but will the external partnering community be motivated to work with us? Not-fully-developed in-house expertise in human performance modelling was expressed as the predominant reason for questioning that we would be able to attract collaboration. This repeated the sentiment expressed during a brainstorming session of potential hurdles to collaboration convened earlier (but to be described subsequently in Section 3.6).

3.4 Current S&T partnering networks

Working Group members were asked to list their current or recent collaborative/contractual networks and sources of knowledge access for their work related to human performance modelling. If there were no active/recent collaborations, they were to identify who they would approach immediately for collaboration interest. The responses are shown in Annex B. The table shows the S&T project, the collaborating individual/department and their establishment, the partnering category, the nature of the partnership (collaboration or contractual), and the service provided by the collaborator (e.g., coding, conducting experiments, statistical modelling expertise, etc.). All partnering categories were identified for collaboration, i.e., allies, industry, and knowledge institutions (e.g., academia, institutes, hospitals).

3.5 Incentives to collaborate

The STS expects that collaboration will be "characterized by reciprocal access between DRDC and partners to

- specialized facilities, or
- sensitive information,
- personnel exchanges,
- joint initiatives and
- coordinated investment" [21].

From individual thinking, and by way of brainstorming to the prompt "what would our collaborators see as high value?", other possible incentives for partners to collaborate with DRDC are:

- opportunity to add to publications output for career development;

- opportunity to broaden HPM skills/experience;
- access to unique human performance data with which to test theories or do something original and/or creative;
- providing medical oversight for conducting human research above level of minimal risk;
- develop unique experience relevant to possible future contractual arrangements (competitive advantage);
- providing scenario/raw data for student thesis projects in HPM;
- engage in cognitive avocation, intellectual hobby;
- support for uniformed personnel and/or patriotism and/or public good;
- contribute to solving practical problems;
- for recognition;
- in a "quid pro quo" arrangement, possibility of exchanging a "good" for a "service" (perhaps not exactly a "good" but a loan of a good, the point being that it doesn't need to be exchanging services);
- collaborate today in exchange for considerations in the future;
- see us as more trustworthy than their competitive, academic peers;
- access to foreign collaborations through TTCP and NATO.

3.6 Hurdles to collaboration

So that the HPMC or other working groups might discover other potential incentives, we employed the critical thinking tool of assuming a negative stance and asking ourselves "why would this current list of potential incentives not be enough to attract/engage collaborators?". The following table lists our responses to this question. The possible hurdles fall into two categories, problems that collaborators might perceive in DRDC, and problems collaborators might see about collaborating in general. Potential collaborators might look at our expertise, infrastructure, the nature of the S&T work, and that we are part of the federal government. We felt that what we project to potential collaborators needs to appeal on at least two levels, one that attracts the interest of those actually performing the intellectual work of human performance modelling, and the other at the level of the administration/organization who will assess the merits of collaboration on strategic outcomes and financial soundness. This applies whether the collaborator comes from the allied, academic, or industrial communities.

Table 3: *Possible hurdles to collaboration.*

Possible hurdles when collaborators look at us	
Expertise	Our expertise in HPM, individually (DS and/or EG) or as organization, not seen as expert enough to make collaboration worthwhile. [Concerns—(i) Expertise not built if time spent "looking for collaboration" (time for know-what/how (technical) competes with time for know-who (non-technical); competing objectives in Performance Agreement); (ii) Difficult to convince collaborator of our expertise if we don't attend conferences to get "face time". How often do cold calls work? (iii) Mandate to breadth creates the risk of our S&T workers needing to cover more topic areas than they can maintain currency.]
Supporting infrastructure	Research facilities not unique/capable enough.
	Administrative and/or ROG support staff insufficient to carry out the non-scientific/mundane parts of collaboration (think of admin burden of contracts DSs must look after).
S&T project	S&T project/problem(s) seen as too unique and not generalizable to other populations to warrant their time.
	S&T project/problem(s) seen as not unique enough. The viewpoint during the review of agency Capabilities that saw Human Performance less relevant and less unique, and thus a candidate for operating in breadth mode, may also be the viewpoint of academics.
	S&T project/problem(s) not seen as having longevity, therefore unlikely to "churn out" many publications.
	S&T project/problem(s) seen as too big/cumbersome/expensive and will deliver too few results/papers for the time that they're prepared to commit.
	Not enough experimental control in field trials, therefore data less reliable for academic precision.
	Sharing of data may be proscribed by confidentiality agreements with government or industrial sponsors.
Government	We may be seen as wanting/needing their services but not prepared to pay for it.
	Governments use RFP's. High effort put into a proposal is out of proportion to the likelihood of success.

	Despite statement that "bridging" gives students inside track for full employment, reality is that actual employment opportunities are low.
	Will require higher level of security.
	Governments are restrictive, applying too many controls; red-tape slows down processes; our publication process is taking too long.
	Concern about S&T project inflexibility because S&T workers don't have authority to make important decisions.
	Because of uncertainty in government budgets, sustainability of S&T project funds and/or DRDC personnel is not secure.
	Uncertainty about the specifications of the collaboration. Will the collaboration be informal, that is, between scientists, or formal with a signed-off agreement? Will the collaboration contributions be loosely-worded, e.g., to participate, or specified firmly as to date and end-product, e.g., similar to a contract?
Possible hurdles when collaborators look at selves	
Modellers	University faculty want to study their own interests.
	Most faculty study main stream problems e.g., elite athletes, patients.
	For career advancements, papers from grants more important than papers and reports from contracts; attracting grant money more important.
	They want to be at/near front of author list.
	Concerned that the research cannot be published in scientific literature.
	They want copyright/IP ownership.
	Just as we might want to collaborate with the best, they will want to collaborate with the best and decline our invitations if we don't meet that standard.
Administration/ modeller's organization	Concerns that they and/or us will underestimate the complexity of the S&T problem and/or the collaborative relationship leading to future frustration/disappointment and wasted effort.
	If need to work through CIMVHR, this results in lower overhead money going to administrators than other contracting methods.

	Concerns that our time with collaborators will distract their faculty from fulfilling their responsibilities to the university.
	Uncertainty that reciprocal contribution will be equitable.
	Associating with us doesn't help their strategy for advancement.

As a result of thinking about the potential hurdles to collaboration, our discussion raised other possible incentives:

- honorarium position to DRDC – Toronto Research Centre with staff-like privileges, similar to university adjunct appointment [22];
  - easier access to facilities.
- "bridging" for graduate students;
- "favoured" status for contracts for collaborators (e.g., sole source);
- let academics work on problems long term, highly focused;
- develop a database of human behaviour and performance in military tasks/scenarios (database needs to be populated);
  - multi-allied database; CA only database might be too small.

It is not possible to assess which incentive(s) will attract collaboration or which hurdle(s) will interfere, but whatever DRDC is able to offer, it will need to be seen as high value by the partner. Whereas money is the currency of exchange in contracts, in collaborative/quid pro quo relationships the high value currency is likely to be services and knowledge/intellectual property/expertise. External partners who are eager for collaboration may require less enticing, whereas researchers near the top of their field who are able to choose collaborators, and if we meet their trust and reputation standards, will require stronger incentives.

3.7 Collaboration mechanisms

Some possible collaboration mechanisms have already been suggested [23]:

1. "increasing our investment through granting councils to access academic expertise
2. developing the Institute for Research in Defence and Security
3. Washington day, November 2014
4. developing a grants and contributions program
5. reworking the TTCP MOU."

Other, non-contractual, means for formalizing collaboration between in-house S&T workers and external S&T partners are:

- US-CA Master Data Exchange Agreements (MDEA)
- Memoranda of Understanding
- Bi/multi-lateral Project Agreements
- Status-only Appointments
- NATO Working Groups
- Collaborators submitting to U.S. Broad Agency Announcements, e.g., Office of Naval Research
- Communities of Practice
- University Affiliated Research Centers (UARC) in U.S.
- Research Agreements
- Materials Transfer Agreements

Following are possible methods for engaging the external partnering community:

- Public Services and Procurement Canada—invitations to submit an expression of interest (EOI);
- offer bait, e.g., access to a data bank;
- search opportunities to make that good, first impression, i.e., that you're someone with whom it's worth collaborating? (scholarly advertising):
  - peer letter comments to authors regarding their published paper(s);
  - peer comments to presenters at oral communications;
  - offer to give a scholarly presentation/lecture(s) at universities;
  - give presentations and network at conferences;
  - publish papers with unique perspectives on modelling;
  - be interviewed by media;
  - join communities of practice, specialist societies/working groups;
  - offer journals to be manuscript reviewer/editorial board member;
  - government grants (e.g., NSERC Discovery) reviewer.

4 Recommendations for next steps

Our findings and discussions lead us to propose the following five "next steps".

4.1 Who is doing what in HPM?

Most of our discussions were based on resident knowledge, personal experiences, and "sense" of actuality. We don't know all the experts in HPM. Searching academia for "human performance" typically generates hits associated with athletics divisions and overlooks many scientists working in departments/faculties encompassing psychology, physiology, engineering, and biochemistry. A list of HPM experts would guide our efforts for targeted collaboration. The data sources for such a list could include: (i) Public Services and Procurement Canada list of contractors who have conducted HPM; (ii) literature search [24] performed with the assistance of the TRC librarian; (iii) internet and media searches; and (iv) bibliometric study [25, 26] showing such things as the most active researchers, clusters of collaboration, and the breadth of the knowledge/disciplines base involved in HPM. Part of this effort should identify any centres of excellence relevant to HPM.

4.2 Partitioning HPM

While modelling per se could be considered a generic capability able to be applied to numerous problems, human performance encompasses a broad range of academic disciplines to study individual abilities and behaviours, and can require high degrees of specialization within those disciplines. Therefore, all human performance modelling should not be regarded as the same. And if this is the case, some types of HPM may be more suitable for collaboration, and some may face more hurdles to collaboration, than other types. DRDC's recent review differentiated the 37 agency-level capabilities along the simultaneous scales of military relevance and of uniqueness (breadth of interest) in the external S&T community [27]. A similar analysis could be applied to the range of topics covered by defence HPM to produce the four categories: (i) high relevance, high uniqueness; (ii) high relevance, low uniqueness; (iii) low relevance, high uniqueness; and (iv) low relevance, low uniqueness. Types of HPM fitting in categories (i) and (ii) will be of interest to us for establishing collaboration because of the high military relevance, but determining whether high or low HPM type uniqueness increases or decreases enticement for the external science community will need more thought, perhaps after the upcoming TRC re-organization and the priority projects assigned to the proposed Human Effectiveness section(s).

4.3 Learn about best practices

We should learn what is known about collaborations and access. There is likely to be extensive experience but it needs to be shared and documented, i.e., workshop/conferences with published proceedings.

4.3.1 In-house workshop at the centre

- In-house workshop with presentations from TRC personnel about success stories in collaborations;
- From low-level informal collaborations to high-level, formal collaborations involving access to external funds for knowledge generation;
- Illustrating the path from initial contact to S&T delivery;
- Sharing of speaker's notes for attendees;
- Could use a call for speakers or invite certain presenters with known accomplishments in collaborations.

4.3.2 Workshop with allies

- Workshop for sharing best practices/successes for establishing collaboration with industry and academia (collaboration understood to exclude contracting);
- Successive or separate workshop for organizing collaboration among allies;
- Workshop for discussing interest in shared repository/database of human performance data for data-mining/modelling;
- Workshop participants to represent defence S&T laboratories (e.g., Defence Science and Technology Organisation, Australia) and institutions (e.g., Office of Naval Research, US) from members of TTCP and NATO.

4.4 Effective incentives workshop with academia and industry

There was much discussion about what potential partners could gain from collaborating with DRDC and about possible hurdles interfering in the development of such relationships. We could move from speculation to fact-finding by hosting a workshop/conference with academia and industry to learn what incentives need to be in place to elevate their interest in collaboration. It's important to know what they would see as high value.

- Participants to include representatives from both executive and S&T worker levels as they might see incentives differently;
- Participants might include some identified in the "who is doing what in HPM" study;
- Workshop sessions could be partitioned by discipline/capability areas, e.g., human effectiveness;
- Workshop representatives could evaluate DRDC's pre-prepared list of proposed incentives and mechanisms for collaboration on the basis of generating interest, manageability, productivity, etc.;
- DRDC to present how it plans to "nurture and maintain diverse S&T innovation networks" [28].

4.5 Support to S&T workers

The STS gives broad direction that DRDC will move towards a "breadth" mode of operations in certain areas such as human effectiveness/performance and agency employees will "implement the new approaches to program formulation, partner engagement and service delivery". To prepare to be effective in this additional role, DRDC S&T personnel need a how-to document that details the means for implementation and the support that the Agency will provide. High-level documents are insufficient in this regard. Without advice on courses of action, S&T workers are left to hunt for the best arrangements for collaboration. One example of the guidance needed concerns the extent of commitment to convey during the early formative stages of partnering. Another example, what means of engagement and support will be in place for inviting a potential partner to work in a capability area that is not based in an existing centre of excellence, such as IRDS? A third example, what will be the activities expected of individual Centre S&T workers in DRDC's plan to "nurture and maintain diverse S&T innovation networks" [28]. And others: Will the collaboration(s) need formal sign-off (and if so, at what level)? Will the collaboration need to be established at the time of S&T project proposals?

All WG members had experience in collaboration at some point in their careers as defence scientists, capitalizing on their varied knowledge and skills, and expected to continue collaborations in the future. However, in two separate discussions about incentives for partners to collaborate, WG members unanimously felt that the depth of their expertise in HPM was not at a level that would attract and maintain collaboration with any of the three potential external partner groups. We recommend a plan for in-house S&T workers to develop expertise and to demonstrate that expertise to potential collaborators. This is consistent with the STS statement about opportunities for employees to "widen their expertise, acquire needed skills and collaborate across the broader innovation community", although it is unclear if "widen" should be taken to mean to broaden or to amplify, that is, add new expertise or intensify existing expertise. In either case, the objective will to produce "a person with an intensive knowledge and/or unusual ability and who is recognized by superiors and peers as a source of current, knowledgeable and dependable data, information, opinion and advice in that person's area of expertise" [29]. And after having developed expertise, a formal plan is required about how to best preserve that expertise, e.g., continue to conduct and publish research in the area. If the expertise is allowed to fade, the knowledge becomes static and dated, and the capability ceases to be recognized for potential future collaboration. Breadth operations rely on this as "effective knowledge access and integration is subject to retention of sufficiently deep expertise" [27], which applies at both the scientist and the capability levels. One advantage for developing collaboration-level expertise in HPM is that many of the skills developed during the modelling processes are "generalizable" [30] and could be applicable to other problem areas, thus enhancing the agility of the S&T workforce.

We see becoming experts and demonstrating expertise as a two-stage process: (i) learn-what and learn-why, e.g., academic courses, internal and external mentoring relationships, followed by (ii) learn-how, e.g., active role in a series of S&T projects which make use of the HPM capability, culminating in peer-reviewed publications.

Supervising and publishing with graduate students is one method defence scientists could use to help build expertise. This Centre has a history of productive associations with graduate students, having generated S&T knowledge for the benefit of the students, the DRDC thesis supervisors, and the agency. In its former form as the Defence and Civil Institute of Environmental Medicine,

the Centre had a policy for on-site supervision of graduate students [31], however experience by defence scientists indicates that current administrative procedures are unclear. If Centre personnel are to take advantage of adjunct appointments at universities, which are seen as a vehicle to S&T collaborations, then the policy and procedures for hosting graduate student research requires clarification and support.

Employee supervision and expectations for presence during core hours at the Centre will need to be modified. It is quite certain that seeking and conducting collaborations will mean more time out of the Centre for S&T workers.

The last three of the above five next steps could be relevant to any DRDC S&T capability for which collaborate/access will be the preferred model.

5 Limitations

Our analysis of the current and future HPMC has several limitations.

1. The working group had narrow representation:

    a. consisted only of defence scientists (the ROG representative was on long-term leave) from the scientific stream and no one had expertise in capability assessment;

    b. consisted only of personnel from IBP; some modelling capability also exists in the Human Systems Integration Section.

2. The working group used only resident knowledge and experience with no outside consultations; some reports, slide decks, journal papers were referenced. We admit that we don't know what we don't know.

3. Although experienced in allied and contractual arrangements, the working group was not familiar with all the current external partner engagement tools therefore discussion of potential collaboration mechanisms was limited.

6 Conclusions

We conclude that:

1. The Human Performance Modelling Capability is developed in the potential external partnering community to the extent:

   a. that DRDC could have productive collaborations; and

   b. that working collaboratively at least some of the time provides the capability to address Clients' future problems where HPM could make S&T contributions.

2. There are incentives for the potential external partnering community to collaborate with DRDC, but they may also be discouraged by potential hurdles.

3. To position HPMC for engaging the potential external partnering community, we recommend that the next steps be:

   a. Discover who is doing what in HPM in the potential external partnering community;

   b. Assess if some types of S&T projects with central roles for HPM are more suitable for collaboration than others;

   c. Learn about best practices for collaboration with the potential external partnering community from in-house success stories and from Allies;

   d. Host a workshop with academia and industry representatives to discover what they would consider high-value incentives for collaboration;

   e. support DRDC S&T workers: (i) by providing guidance on engaging the potential external partnering community, and (ii) by investing in developing and maintaining knowledge and skills expertise that will entice collaborators.

This page intentionally left blank.

References

[1] Bergeron, D. (2016), S&T Capability Review – Implications for the Toronto Research Centre. Town Hall Briefing at Toronto Research Centre, 27 Oct, Toronto, ON.

[2] National Defence (2013), Science and Technology in Action: Delivering Results for Canada's Defence and Security. Defence and Security S&T Strategy, (Cat. No. D69-11/2013E-PDF). Ottawa, ON.

[3] IBPS Workshop (2016), Capability Development. Dennison Armouries, 7 Jul, Toronto, ON.

[4] IBP Section Meeting (2016), Capability Implementation Plans – Next Steps. Toronto Research Centre, Toronto, ON, 15 Sep.

[5] Pidd, M. (2000), Tools for Thinking—Modelling in Management Science, New York: Wiley.

[6] Kinabo, L.D.B. and McKellar, Q.A. (1989), Current models in pharmacokinetics: Applications in veterinary pharmacology, *Veterinary Research Communications*, 13 (2), 141–157.

[7] Hand, D.J. (2014), Wonderful examples, but let's not close our eyes, *Statist. Sci.*, 29 (1), 98–100.

[8] Byrne, M.D. and Pew, R.W. (2009), A History and Primer of Human Performance Modeling, *Reviews of Human Factors and Ergonomics*, 5 (1), 225–263.

[9] Gavaghan, D., Coveney, P.V. and Kohl, P. (2009), The virtual physiological human: tools and applications I, *Philos Trans A Math Phys Eng Sci*, 367 (1895), 1817–21.

[10] Friedl, K.E. and Santee, W.R. (Eds.) (2012), Military Quantitative Physiology: Problems and Concepts in Military Operational Medicine, Fort Detrick, MD: Office of the Surgeon General, Borden Institute.

[11] Baron, S., Kruser, D.S. and Huey, B.M. (Eds.) (1990), Quantitative modeling of human performance in complex, dynamic systems, Washington, D.C.: National Academy Press.

[12] Statistical model (online), Psychology Wiki, http://psychology.wikia.com/wiki/Statistical_model (Access date: 2017.04.20).

[13] Structural equation modeling (online), Purdue University, West Lafayette, IN, www.stat.purdue.edu/~bacraig/SCS/Structural%20Equation%20Modeling.doc (Access date: 2017.05.04).

[14] Gavaghan, D., Garny, A., Maini, P.K. and Kohl, P. (2006), Mathematical models in physiology, *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 364 (1842), 1099–1106.

[15] Van Dongen, H.P.A., Mott, C.G., Huang, J.-K., Mollicone, D.J., McKenzie, F.D. and Dinges, D.F. (2007), Optimization of Biomathematical Model Predictions for Cognitive Performance Impairment in Individuals: Accounting for Unknown Traits and Uncertain States in Homeostatic and Circadian Processes, *Sleep*, 30 (9), 1129–1143.

[16] National Defence (2007), Land Operations 2021. Adaptive Dispersed Operations – The Force Employment Concept for Canada's Army of Tomorrow, Directorate of Land Concepts and Design, Kingston, ON. p. 11.

[17] Kellogg, W.K. (2004), Logic model development guide, Battle Creek, MI: WK Kellogg Foundation.

[18] Ministry of Defence (2013), The Defence Science and Technology Laboratory Corporate Plan 2013–18. United Kingdom.

[19] Lundvall, B. and Johnson, B. (1994), The Learning Economy, *Journal of Industry Studies*, 1 (2), 23–42.

[20] Campbell, J.P. and Pritchard, R.D. (1976), Motivation Theory in Industrial and Organizational Psychology, In M.D. Dunnette (Ed.), *Handbook of Industrial and Organizational Psychology*, pp. 63–130, Chicago, IL: Rand McNally College Publishing Company.

[21] National Defence (2013), Science and Technology in Action: Delivering Results for Canada's Defence and Security. Defence and Security S&T Strategy, p. 20, (Cat. No. D69-11/2013E-PDF). Ottawa, ON.

[22] Status Only, Adjunct and Visiting Professors, In: Academic Administrative Procedures Manual (online), University of Toronto, https://aapm.utoronto.ca/status-only-adjunct-and-visiting-professors (Access date: 2017.05.15).

[23] Fortin, M. (2014), Science, technology and knowledge for Canada's defence and security. ADMS&T, Slide presentation to Toronto Research Centre, 24 Nov, Toronto, ON. Slide 12.

[24] Lu, Z. (2011), PubMed and beyond: a survey of web tools for searching biomedical literature, *Database*, 2011, baq036-baq036.

[25] Boyack, K.W., Klavans, R. and Börner, K. (2005), Mapping the backbone of science, *Scientometrics*, 64 (3), 351–374.

[26] Wiseman, E. (2016), Human Optimization Research, DRDC-RDDC-2015-C235, Defence Research and Development Canada, Ottawa, ON: National Research Council.

[27] Defence Research and Development Canada (2014), Comprehensive S&T Capability Review – Results Summary. 27 Oct, Ottawa, ON.

[28] National Defence (2013), Science and Technology in Action: Delivering Results for Canada's Defence and Security. Defence and Security S&T Strategy, p. 21, (Cat. No. D69-11/2013E-PDF). Ottawa, ON.

[29] Defence Research and Development Canada (2015), Defence Scientist Salary Administration System, Part IV – Defence Scientist Promotion and Salary Advancement Guidelines. Defence Research and Development Canada, March 2015, p. 77.

[30] Yates, F.E. (1978), Good manners in good modeling: mathematical models and computer simulations of physiological systems, *American Journal of Physiology – Regulatory, Integrative and Comparative Physiology*, 234 (5), R159–R160.

[31] Graduate Student Programme at DCIEM, Management Directive 14(99), 6000-1(DG), Defence and Civil Institute of Environmental Medicine, Toronto, 20 October 1999.

This page intentionally left blank.

Annex A Important client issues for which performance modelling would have a role

The following table identifies the important client issues for human performance modelling.

Table A.1: *Important client issue for performance modelling.*

	What do you see as the Client's (i.e., DND, CAF and safety and security partners) two most important issues for which a solution would require a prominent role for Performance Modelling?	Indicate how Performance Modelling would contribute to the solution.
1	Auditory fitness for duty (AFFD) Requires an integrated model of auditory performance (basic audiometry, speech understanding of non-native/accented speech, sound localization, susceptibility for hearing loss, etc.), with and without various hearing protection devices and headgear, to predict or assess a soldier's fitness for duty in different trades	Define standards for AFFD, specific to each trade, leading to improved performance Better training for AFFD Define requirements for new hearing protection and enhancement devices to inform design for MOTS companies
2	Performance modelling under vehicle-induced vibration and motion disturbance	Predict cognitive/task performance degradation caused by motion sickness and anti-emesis drugs Predict effectiveness of countermeasures New exposure limits for vibration (for fatigue, injury)
3	Understanding and mitigating operational stressors: Maximizing performance for military missions [from DRDC ST Hard Problems]	Evidence-based advice: experimental results informing practice, doctrine, tactics, and equipment choices Models and simulations of performance changes under stress In-theatre support: mitigation of stressors most relevant in-theatre New protocols: potential for new practices based on scientific findings

	What do you see as the Client's (i.e., DND, CAF and safety and security partners) two most important issues for which a solution would require a prominent role for Performance Modelling?	Indicate how Performance Modelling would contribute to the solution.
4	Soldier Burden [from DRDC ST Hard Problems] (pertaining to loads (physical and cognitive) that soldiers "carry" during training and operations; related to soldier systems, PPE, communications, physiology, and environments; future use of more electronics for communications, navigation, monitoring, etc. would make things worse, as would a move toward "dispersed operations" of smaller teams.)	Evidence-based advice: experimental findings showing how burden affects performance inform new equipment acquisitions, practices on ground Models and simulations extrapolate and interpolate experimental findings Test and evaluation of proposed new equipment or kit configurations
5	Success of military operations relies on human performance at the highest possible level in a complex environment involving a broad spectrum of hostile factors or stressors such as sleep deprivation, exposures to extreme temperature and altitude. Direct experimental assessment of complex biological and human systems in such environments is generally remarkably difficult and of ethical concern.	HPM provides a valuable tool to address these challenges. For example, a bio-mathematical model is not only to represent the biology that is already known, but also to provide a platform for computer simulation that can explain data, resolve controversies, predict results, and test hypotheses
6	Success of military operations requires countermeasures to prevent and treat health, readiness and performance degradation.	HPM is a powerful tool to delineate processes and thereby offer a conceptual framework for the analysis of existing hypotheses and big data. In addition, individual variability can be captured by 'personalized' modelling.

	What do you see as the Client's (i.e., DND, CAF and safety and security partners) two most important issues for which a solution would require a prominent role for Performance Modelling?	Indicate how Performance Modelling would contribute to the solution.
7	Pre-deployment performance prediction for the mission Detect performance degradation during mission Maintain/optimize performance at an acceptable level Restore performance if degraded	Evidence-based advice: the commander will use this information to assess the readiness level of his soldiers before the deployment, during ops for mission success and after ops. Evidence-based intervention: This will help decide when and what type of strategies (new training)/interventions/countermeasures to use to maintain or restore performance
8	Biomedical models to counter health threats and predict risks and performance decrement in sustained and adverse environments. (Personnel Health Protection)	Evidence-based intervention: This will help decide when and what type of strategies (new training)/interventions/countermeasures to use to maintain or restore performance
9	Advice on shift scheduling to reduce fatigue and improve cognitive and physical performance, exploitation/integration of fatigue management software for fast-jet/transport/helicopter aircrew, and best practices for psychological health and wellness for RCAF aircrew and instructors.	Evidence-based advice: the commander will use this information to assess the readiness level of his soldiers before the deployment, during ops for mission success and after ops. Evidence-based intervention: This will help decide when and what type of strategies/interventions/countermeasures to use to maintain or restore performance
10	Define human tolerance limits due to multiple stressors (internal and external) that can affect health and performance	Affect how/what the soldiers will be fed, rested, trained and equipped (e.g., clothing). PM involves scientific strategies to maintain sustain health and optimize performance
11	Given new threats (failing states, climate change and natural disaster), our soldiers have to react rapidly to changing situations and can be overwhelmed affecting their performance	Will help develop scientifically based guidance to help in decision making in situations in which our soldiers have not trained for

	What do you see as the Client's (i.e., DND, CAF and safety and security partners) two most important issues for which a solution would require a prominent role for Performance Modelling?	Indicate how Performance Modelling would contribute to the solution.
12	Performance in extreme conditions such as in the Arctic	PM can be used to assess performance in-theatre PM can be used to assess effectiveness of new training methodologies for use in extreme conditions information obtained from PM can be used to provide evidence based advice
13	Performance enhancement as a consequence of new technologies such as nanotechnology	The effectiveness/efficiency of prototype systems can be assessed through PM, leads to improved product PM can be used test and evaluate newly developed technology in a variety of settings/conditions (lab, field) PM can be used to assess performance in-theatre resulting from use of new technologies

Annex B Current collaborative networks

The following table shows recent, current, or recommended collaborative/contractual networks and sources of knowledge access for S&T related to human performance modelling.

Table B.1: *Collaborative/contractual networks for S&T related to human performance modelling.*

	Brief project title (e.g., muscle glycogen over 30 km weighted march with different feeding patterns)	Partnering individual and/or department (e.g., J. Smith, Metabolism Dep't)	Partnering establishment, city, country (e.g., Acme Inc., Vancouver, CA)	Partnering category (i.e., allies, industry, or knowledge institutions (e.g., academia, institutes, hospitals))	Nature of partnership (collaboration or contractual)	Service provided by the partner (e.g., coding, conducting experiments, statistical modelling expertise, etc.)
1	Operational pharmacology	Prof. Edginton, School of Pharmacy	University of Waterloo, Waterloo, ON, CA	Academia	Contractual	Expertise on physiologically-based pharmacokinetic modelling
		Dr. Willmann Computational Systems Biology	Bayer Technology Services GmbH, Leverkusen, Germany	Industry	Contractual	

	Brief project title (e.g., muscle glycogen over 30 km weighted march with different feeding patterns)	Partnering individual and/or department (e.g., J. Smith, Metabolism Dep't)	Partnering establishment, city, country (e.g., Acme Inc., Vancouver, CA)	Partnering category (i.e., allies, industry, or knowledge institutions (e.g., academia, institutes, hospitals))	Nature of partnership (collaboration or contractual)	Service provided by the partner (e.g., coding, conducting experiments, statistical modelling expertise, etc.)
2	Navy crewing generation modeling and analysis	Dr. Reifman, Dep't of Defense Biotechnol High Performance Computing Software Applications Institute;	US Army Medical Research and Materiel Command, Fort Detrick, MD, US	Allies	Collaboration	Expertise on cognitive modelling and mental fatigue countermeasures, and crewing generation modelling
		Prof. Van Dongen, College of Medical Sciences	Washington State University, Spokane, WA, US	Academia	Contractual	
		Joe Armstrong, Operational and enterprise solutions	CAE Canada, Ottawa, ON, CA	Industry	Contractual	
		Curtis Coates	CMC Electronics Inc., Ottawa, ON, CA			

	Brief project title (e.g., muscle glycogen over 30 km weighted march with different feeding patterns)	Partnering individual and/or department (e.g., J. Smith, Metabolism Dep't)	Partnering establishment, city, country (e.g., Acme Inc., Vancouver, CA)	Partnering category (i.e., allies, industry, or knowledge institutions (e.g., academia, institutes, hospitals))	Nature of partnership (collaboration or contractual)	Service provided by the partner (e.g., coding, conducting experiments, statistical modelling expertise, etc.)
3	Computation and modeling of human performance in the presence of environmental stressors	Dr. Allender Prof. Dancy, Dep't of Computer Science Dr. Wickens, Micro Analysis and Design	Army Research Laboratory, Human Research & Engineering Directorate, Aberdeen Proving Ground, MD Bucknell University, Lewisburg, PA, US Alion Science Corp., Boulder, CO, US	Allies, Academia, Industry	Collaboration	Expertise on complex cognitive performance, computational modelling of physiological and cognitive systems, meta-analyses and data gathering
4	Decompression risk assessment	A. Barbaud, J. Hugon	BF SYSTEMES SAS, France	Industry	Collaboration (no dollar exchange)	Modelling expertise, Risk assessment using new methods
5	Soldier performance	K.E. Friedl, Biophysics and Biomedical Modeling Division,	U.S. Army Research Institute of Environmental Medicine, Natick, MA, USA	Allies	Collaboration	Performance modelling expertise Enhancement of Soldier Performance Data sharing
6	Soldier performance (Nutrition, Fatigue, Physical)	H. Lieberman	USARIEM, USA	Allies	Collaboration	Cognitive/physical performance Data sharing

	Brief project title (e.g., muscle glycogen over 30 km weighted march with different feeding patterns)	Partnering individual and/or department (e.g., J. Smith, Metabolism Dep't)	Partnering establishment, city, country (e.g., Acme Inc., Vancouver, CA)	Partnering category (i.e., allies, industry, or knowledge institutions (e.g., academia, institutes, hospitals))	Nature of partnership (collaboration or contractual)	Service provided by the partner (e.g., coding, conducting experiments, statistical modelling expertise, etc.)
7	Cognitive and mathematical modeling	Hans P.A. Van Dongen	Sleep and Performance Research Center, Washington State University Spokane	Academia	Collaboration and contracting	Modelling expertise Cognitive
8	Development of Physiological Monitoring Software Suite	Undergraduate students	University of Toronto, Faculty of Engineering, Multidisciplinary Capstone Design Course	Academia	Collaborative	Design & implement software applications for managing, sharing, displaying physiol data for up to 10 individuals over network. Students had no HP modelling expertise, but used engineering skills to advance aspect of our program, they learned performance modelling in process.
9	Accurate prediction of core body temperature from non-invasive physiological measures	Mark Buller	USARIEM [Natick, MA]	Allies	Collaborative	Joint experimentation and algorithm development/validation

	Brief project title (e.g., muscle glycogen over 30 km weighted march with different feeding patterns)	Partnering individual and/or department (e.g., J. Smith, Metabolism Dep't)	Partnering establishment, city, country (e.g., Acme Inc., Vancouver, CA)	Partnering category (i.e., allies, industry, or knowledge institutions (e.g., academia, institutes, hospitals))	Nature of partnership (collaboration or contractual)	Service provided by the partner (e.g., coding, conducting experiments, statistical modelling expertise, etc.)
10	An undergarment for remote physiological monitoring	Marc Paquin (Director, Partnerships & Business Development)	Hexoskin [Montreal, QC]	Industry	Contractual	Modification of commercial product for suitability in military training and operational contexts
11	Readiness model development and validation	Dr. B. Levin	FOI Sweden	Ally	Collaboration	Organized & hosted field trial for data collection.
		Mr. Pierre Valk	TNO, Netherland	Ally	Collaboration	Assistance with collecting field data
		Dr. B. Adams	Humansystems Inc., Guelph, ON	Industry	Contractual	Co-developing questionnaire package; Collecting field data; Basic statistical analysis (no modelling)
12	Future S&T	Institute for Social Research	York University, Toronto, CA	Academia	Potentially either collaboration or contractual	expert statistical modelling, e.g., structural equation modelling

	Brief project title (e.g., muscle glycogen over 30 km weighted march with different feeding patterns)	Partnering individual and/or department (e.g., J. Smith, Metabolism Dep't)	Partnering establishment, city, country (e.g., Acme Inc., Vancouver, CA)	Partnering category (i.e., allies, industry, or knowledge institutions (e.g., academia, institutes, hospitals))	Nature of partnership (collaboration or contractual)	Service provided by the partner (e.g., coding, conducting experiments, statistical modelling expertise, etc.)
13	Impulse noise mitigation	1). Mr. Sadri Sarray, test engineer	1). Quality Engineering Test Establishment, DND (Gatineau, QC)	1). Government	1). Collaboration	1). Data sharing, joint test and evaluation
		2). Maj Dr. Nir Fink, Medical Corps	2). Israeli Defence Force Medical Corps, Tel Aviv, Israel	2). Allies	2). IDF-DND MOU	2). Data sharing, joint test and evaluation
		3). Dr. Dick Danielson and Mr. Jose Limardo, Johnson Space Center	3). NASA, Houston TX	3). Allies, other government organization (non-Defence)	3). via Canadian Space Agency, part of ISS Multilateral Medical Ops Panel, acoustics working group.	3). Information sharing via working group
		4). Various, NATO HFM-ET	4). USA, France, UK, Slovenia, Germany	4). Allies	4). Through NATO	4). Info sharing, possible future collaborative exp’ts

	Brief project title (e.g., muscle glycogen over 30 km weighted march with different feeding patterns)	Partnering individual and/or department (e.g., J. Smith, Metabolism Dep't)	Partnering establishment, city, country (e.g., Acme Inc., Vancouver, CA)	Partnering category (i.e., allies, industry, or knowledge institutions (e.g., academia, institutes, hospitals))	Nature of partnership (collaboration or contractual)	Service provided by the partner (e.g., coding, conducting experiments, statistical modelling expertise, etc.)
	Impulse noise mitigation, continued	5). Dr. Jeremie Voix, Ecole de technologie superieure/EERS (company) 6). Dr. Christian Giguere, Faculty of health sciences	5). Montreal, QC 6). University of Ottawa	5). Academia and Industry 6). Academia	5). No relationship yet, maybe pursue a DIR or contract 6). Past contractor	5). Currently tech watch on emerging in-ear technologies 6). Good fit for auditory fitness for duty research

This page intentionally left blank.

List of symbols/abbreviations/acronyms/initialisms

DSTL	Defence Science and Technology Laboratory
HPM	Human Performance Modelling
HPMC	Human Performance Modelling Capability
MDEA	Master Data Exchange Agreement
MOU	Memorandum of Understanding
STS	S&T Strategy
UARC	University Affiliated Research Centers
WG	Working Group

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 – Toronto Research Centre
Defence Research and Development Canada
1133 Sheppard Avenue West
P.O. Box 2000
Toronto, Ontario M3M 3B9
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.)

Human performance modelling : Future capability for Toronto Research Centre

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

Buick, F.; Bouak, F.; Burrell, C.; Nakashima, A.; Peng, H.; Pickering, D.

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.)
May 2017	50	31

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 – Toronto Research Centre
Defence Research and Development Canada
1133 Sheppard Avenue West
P.O. Box 2000
Toronto, Ontario M3M 3B9
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-2017-D043	

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.)

Human Performance/Human Effectiveness is an essential Defence Research and Development Canada (DRDC) S&T capability that will operate in a greater "breadth" mode. This Working Group studied the Human Performance Modelling Capability (HPMC) within IBPS to produce a plan for evolving the current capability into a future capability making greater use of collaboration with the external S&T community (Allies, academia, and industry). With individual study and group sessions, and using explicit questions and free thought drawing on resident knowledge, the capability in Human Performance Modelling (HPM) in the external S&T community was determined to be developed enough to engage for collaboration. Potential partners may be attracted to collaborate with us because of, among other things, access to unique human performance data and facilities, but may be hesitant, for example, due to administrative bureaucracy and not-fully-developed expertise in DRDC scientists. The HPMC can better position itself for engaging potential collaborators by identifying the external HPM experts, learning about collaboration best practices, discovering what incentives would interest collaborators, and supporting DRDC S&T workers with guidance on collaborative procedures and with developing recognized expertise.

La performance humaine ou l'efficacité humaine est une capacité essentielle en S et T dont la portée sera élargie à Recherche et développement pour la défense Canada (RDDC). Le groupe de travail a étudié la capacité de modélisation de la performance humaine au sein de la SCPI, et ce, en vue d'élaborer un plan pour transformer la capacité actuelle en une capacité future qui permettra de collaborer davantage avec la collectivité de S et T externe (c.-à-d. les pays alliés, le milieu universitaire et l'industrie). Dans le cadre d'une étude individuelle et de séances de groupe, des participants ont répondu à des questions précises et ont exprimé librement leur pensée en fonction de leurs connaissances de l'organisation et, en conséquence, on a déterminé que la capacité de modélisation de la performance humaine dans la collectivité de S et T externe était suffisamment développée pour permettre la collaboration. Des partenaires éventuels pourraient être incités à collaborer avec nous, notamment pour avoir accès aux installations et à des données uniques sur la performance humaine, mais pourraient hésiter à le faire en raison du fardeau administratif et de leur connaissance insuffisante des scientifiques de RDDC. En améliorant la capacité de modélisation de la performance humaine, c'est-à-dire en déterminant quels sont les experts externes en la matière, en s'informant des pratiques exemplaires en matière de collaboration, en découvrant les avantages qui intéressent les collaborateurs et en aidant les travailleurs en S et T de RDDC à suivre les procédures de collaboration et à développer une expertise reconnue, il sera plus facile de mobiliser des collaborateurs éventuels.

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.)

human performance modelling; capability; collaboration; breadth mode