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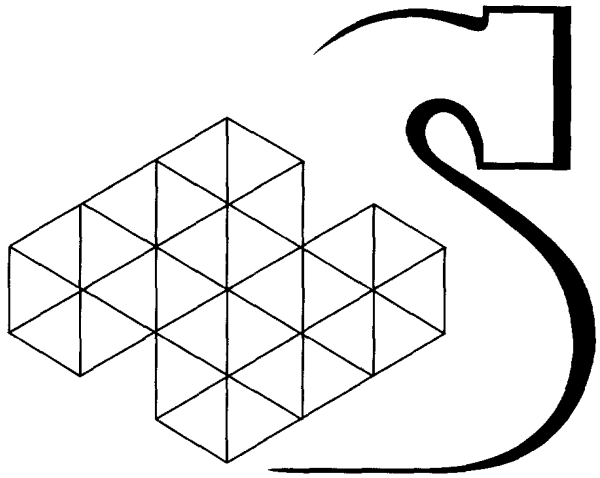

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Human Factors Integration Requirements for Armoured Fighting Vehicles (AFVs)

Part II: A Review of THE HUMAN SYSTEMS INTEGRATION Material Available for Armour Systems SORs and a Plan for Future HSI and R&D

PWGSC Contract No. W7711-7-7429/01-SRV
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HUMAN FACTORS INTEGRATION REQUIREMENTS FOR ARMOURED FIGHTING VEHICLES:

PART II: A REVIEW OF THE HUMAN SYSTEMS INTEGRATION MATERIAL AVAILABLE FOR ARMOUR SYSTEMS SORs AND A PLAN FOR FUTURE HSI R&D

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PWGSC Contract No. W7711-7-7429/01-SRV

Call-up No. 13

On behalf of
DEPARTMENT OF NATIONAL DEFENCE

as represented by

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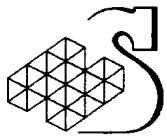


Executive Summary

This document is one of three reports on a project to review the Human Systems Integration (HSI) aspects of Statements of Requirements (SORs). The project was sponsored by the Defence Research and Development Branch (DRDB) Thrust 6K, using armour systems as an example, in response to a request from the Directorate of Land Requirements 3 (DLR 3). The project has been completed by Human*systems* Incorporated under contract to the Defence and Civil Institute for Environmental Medicine (DCIEM).

This report examines the HSI information requirements for future armour SORs and documents in terms of (i) what AFV HSI information is known, (ii) what information needs to be collected, (iii) how much of it requires R&D, (iv) what R&D needs to be completed, and (v) the outline of an AFV HSI R&D program to generate requirements for future SORs.

Meetings with a DLR 3 representative identified four areas where future SORs may be required, including vehicles, AFV subsystems and crew station upgrades, crewman clothing and equipment, and crew sustainment.

Immediately available literature related to armour system SORs was identified in four locations, including the DLR 3 filing cabinets, DCIEM archives of Scientific Authorities with previous experience on armoured projects, the Advanced Land Fire Control System (ALFCS) project library held at Human*systems* Incorporated (with a mirror copy at Computing Devices Canada Ltd), and new literature from recent conferences and a DRDIM literature search.

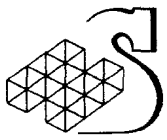
Over 500 articles were obtained, reviewed, and annotated using a literature organization taxonomy (40 categories in total) based on the types of SORs DLR 3 was likely to generate over the next several years and the new SOR structure.

This review of the literature identified a number of gaps in the existing knowledge. Gaps were defined as HSI related areas of the future SORs for which a reasonable requirement does not appear within existing literature.

A series of R&D projects were identified and described to address the gaps in existing knowledge about HSI requirements for future SORs. These projects included R&D in the areas of Deficiencies, Scenarios, Task Performance, Crew Characteristics, AFV and Subsystem Performance, Mounted Warriors Day, Crewman's Day, Crew Station Modeling, Threat Studies, Safety and Health, Human Error Frameworks, and Crew Sustainment. These projects are summarized in the main body of the report and detailed in Annex A.

Together the recommended R&D projects form an integrated program, with a series of R&D streams including Deficiencies, Missions-Tasks-Threats-Users-Error, Crewmans Day Software, Crewstation Modeling, Safety and Health Hazards, and Crew Sustainment.

The report finishes with a set of R&D priorities depending on the interests of the reader. The R&D projects have been prioritized in five different ways, including (i) R&D priorities to meet the original DLR 3 request, (ii) R&D priorities for purchasing COTS, (iii) R&D priorities for upgrades and enhancements, (iv) R&D priorities for FAVS TD, and (v) R&D activities that meet a "purple" requirement.



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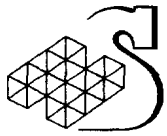

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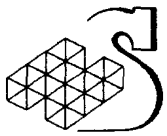

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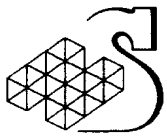


1 Introduction

This document is one of three reports on a project to review the Human Systems Integration (HSI) aspects of Statements of Requirements (SORs). The project was sponsored by the Defence Research and Development Branch (DRDB) Thrust 6K, using armour systems as an example, in response to a request from the Directorate of Land Requirements 3 (DLR 3). The project has been completed by Human*systems* Incorporated under contract to the Defence and Civil Institute for Environmental Medicine (DCIEM).

1.1 Background

Human Systems Integration (HSI) is the technical process of integrating the areas of (1) human engineering, (2) manpower, (3) personnel, (4) training, (5) systems safety, and (6) health hazards with a materiel system to ensure safe, effective operability (operational capability) and supportability.

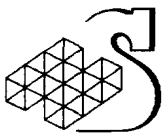
During the period 1994 to 1999 a number of activities conducted by the Defence Research and Development Branch (DRDB) focused on the level of HSI analysis in the acquisition and development process. These efforts culminated in 1998 with a project that generated a proposed new template for the Statement of Operational Requirements (SOR). At the request of the Directorate of Business Change Management (DBCM) this SOR template was merged with another proposed SOR template to create the new "Guideline on the Preparation of a Statement of Operational Requirement", which also included a recommended process for determining and validating requirements on an acquisition project.

Throughout 1999 the defence acquisition community has adopted the new SOR template. The Vice Chief of Defence Staff, through the Defence Management System (DMS) produced by the Directorate of Force Planning and Project Coordination (DFPPC), now directs project staff to the new SOR guideline hosted on the DBCM 2 intranet site.

The new SOR template includes Human Systems Integration (HSI) requirements in several areas including: Missions and Scenarios, Key Roles, Key Tasks; User Characteristics; Crew Station and Interface Design; User Acceptance; Operability; Survivability; Maintainability; Safety and Health; Performance Measures; Personnel and Training Requirements.

This breakdown of human factors into the topics listed above may change the nature of the demand for HSI information (requirements, specifications, performance measures) for future acquisitions. For example, the Soldier's Day database is a software tool that was previously developed to provide information on the activities of dismounted soldiers for use by desk officers preparing SORs and by contractors developing equipment. The information in the Soldier's Day database is structured by Organization, Tasks and Equipment, which may not be the most effective structure for the new SOR templates. It was determined that a worked example was required to explore how the new SOR templates may dictate the organization and types of HSI information needed for future acquisition projects.

HSI issues related to Armoured Fighting Vehicles (AFVs) were identified as a possible worked example for such a study. According to DLR 3-2-2, "Current AFVs lack valid HF requirements specifications,... battlefield days for Operations Other than War (OOTW) must be defined,... another weakness in AFV HF engineering has been the availability of valid anthropomorphic data [which are now available through Clothe The Soldier],... mounted and dismounted clothing and



equipment requirements must be harmonized in order to provide soldiers (such as section commanders) with personal clothing and equipment for both mounted and dismounted operations, ... mounted soldier performance can therefore be improved, and mounted/ dismounted requirements harmonized, by the accurate definition of AFV HF requirements."

DLR 3 staff proposed an AFV HSI initiative to maximize mounted soldier performance by:

- Improving the current and future vehicle environments;
- Improving personal equipment and clothing;
- Modifying mounted tactics, techniques and procedures (TTPs);
- Improving current recruiting, selection and training methods; and
- Enhancing the soldier's physiological state through food and drugs.

The aim of this project was to use the DLR-3 AFV HSI initiative as a worked example to explore the kinds of information required, and the information which is currently available, to complete the HSI sections of the new DND SOR templates.

1.2 Objective

The objectives of this project were to:

1. Review the SOR requirements of the DLR 3 and DLR 10 (Armour Systems and AFVs) and to identify what HSI requirements would then be required to complete those future SORs.
2. Review the immediately available literature and determine what future HSI requirements where known and where there might be gaps in current knowledge.
3. Develop a costed R&D program for HSI R&D to address the gaps in Armour Systems requirements for future SORs.

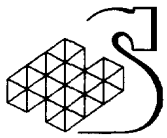
1.3 Deliverables

The deliverables from this project included:

- An annotated bibliography of available information relevant to HSI requirements for future AFV related SORs, organized to match the SOR templates.
- This report, on what AFV HSI information is known, what information needs to be collected, how much of it requires R&D, what R&D needs to be completed, and the outline of an AFV HSI R&D program to generate the requirements for the future.

Additional project work completed in parallel generated a companion report that provides:

- A report on how the HSI requirements in the new SOR templates can be addressed and how the AFV HSI information could be distributed as part of a www site using AFV HSI as a worked example.



2 Method

This section outlines the method followed in this project. The primary tasks completed by the project team are reviewed in the following sub-sections.

2.1 Start Up Meetings

The project was initiated with a series of start up meetings. These began with the Humansystems project team meeting to review the contract documents and conceptualizing their approach to the analysis. Two start up meetings followed in Ottawa, first with the DRDB scientific authority, and a second with the project sponsor in DLR 3.

In combination, this series of meetings refined the scope of the project, assisted in the development of the method for the project, and identified information sources that the project team should review.

The meeting with DLR 3 personnel was also used to identify the types of project for which SORs may have to be developed over the next 5 to 10 years. The identification of these projects was important to guide the analysis of future HSI requirements.

2.2 Develop Project Review Framework

The project team met on a number of occasions to develop the framework for analysis of HSI requirements during the project. This process started with a review of the new SOR in the Guidelines for the Preparation of a Statement of Operational Requirements (DBCM 1998) to identify SOR sections with HSI components.

This review generated a structure for classifying literature in relation to future AFV SORs. This structure was felt to be generic for all projects, with some minor tailoring to meet the specific needs of future Armour Systems projects.

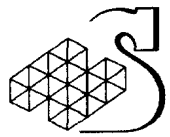
2.3 Obtain and Review Available Literature

The project team obtained any immediately available literature related to HSI for AFV SORs. This literature came from DRDB Laboratories, DLR 3 filing cabinets, and recent AFV related projects completed by the Humansystems team. Some literature was also obtained from related projects (eg: Clothe the Soldier) which was immediately available to the project team.

The available literature was reviewed, after which an assessment was conducted to determine if there were sufficient project resources to extend the search further. In the end, an enhanced literature search was not feasible due to the volume of initial materials obtained.

2.4 Organize and Prioritize Literature by SOR Section

The literature reviewed was annotated and categorized according to the SOR framework developed. All reviews and categorizations were entered into an Endnote (bibliographic software) database. The annotation of each article included a ranking of the relevance of the paper to future DLR 3 acquisition projects.



2.5 Develop HSI Information Distribution Concepts

Once the HSI framework for the new SOR template was established, and some of the AFV related literature was reviewed, the project team started to analyze how HSI related information could be effectively distributed to interested parties using electronic means.

This process began with a review of electronic distribution requirements identified in previous projects, including the SOR Spec Maker projects (Greenley, Tack, Angel, and Webb 1998; Greenley, 1999a, Greenley, 1999b) and the Human Factors Engineering Tools project (Greenley, 1999c).

Additional material reviewed included recent descriptions of the DRDB HSI Web Site (Vallerand 1999), and the latest description of the Soldier's Day database (Kumagai, 1999).

The user requirements were compared against the capabilities of the HSI Web Site and the Soldier's Day database to determine what the options might be for electronic distribution.

2.6 Identify Gaps in Existing Knowledge

The review of AFV related literature against the SOR categories resulted in the identification of areas where future Armour Systems SORs would have sufficient requirements, and areas where there are currently gaps in the existing knowledge about HSI requirements. These gaps were identified and briefly described.

2.7 Develop Future R&D Program

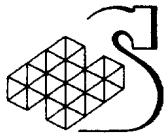
The gaps in the existing HSI requirements literature were mapped against R&D activities that could be completed to produce the missing requirements, which were then organized into a series of R&D projects to form the description for an AFV HSI R&D Program. Where possible, cost estimates were developed for elements of this HSI R&D Program as a tool for future planning.

2.8 Develop Final Reports and Presentation

The outputs of this work were integrated into two reports and one presentation. The two reports included:

1. Guidance for Addressing the Human Systems Integration Content of DND SORs
2. A Review of Human Systems Integration Material Available for Armour Systems SORs and a Plan for Future HSI R&D. (this report).

The results of both reports were integrated into one presentation that was delivered in Ottawa to the DRDB, DLR 3, and DLR 10 communities.



3 Results

This section outlines the results of the DLR 3 SOR review, the review of immediately available HSI literature, and the recommended HSI R&D plan with associated costs.

3.1 About DLR 3

The Directorate of Land Requirements (DLR) 3 is responsible for future systems and equipment for Armour Systems. These personnel define the future requirements for such systems, acting as the Requirements Officers and Project Directors on acquisition and development contracts.

Armour Systems projects (DLR 3) focus more on Armoured Fighting Vehicle (AFV) sub-systems and personnel clothing and equipment for the AFV crew, while full vehicle procurement is currently directed by staff in DLR 10.

3.2 Future DLR 3 SORs

Early project meetings with a DLR 3 representative identified four areas where future SORs may be required:

1. Vehicles.
2. AFV Subsystems and Crew Station Upgrades.
3. Crewman Clothing and Equipment
4. Crew Sustainment

Each of these SOR types is discussed further in the following sub-sections.

3.2.1 Vehicles

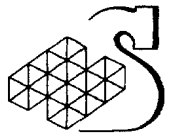
While DLR 10 may be responsible for directing any new Armour Vehicle purchase, DLR 3 personnel would provide support in requirements identification and would be reviewers of the resulting SOR based on their past experience in this area. Potential vehicles in this category include the Armour Combat Vehicle (ACV) and could include requirements for other mounted operations such as LAV 3 or Light AFVs in general.

DLR 3 input indicated that it is unlikely that future procurements priorities will result in many SORs in this category, therefore the focus for future HSI R&D should be on AFV subsystems and crewstation upgrades.

3.2.2 AFV Subsystems and Crew Station Upgrades

There are a wide range of candidate systems that could be acquired or developed over the next several years, including:

- Battlefield Management Systems (BMS)
- Battlefield Combat Identification Detectors (BCID)
- Sensors (Optical sights, CCTV sights, Thermal Sights, Millimetric Wave Radar, Acoustic Sensors, etc....)



- Defensive Aids Suites (DAS)
- Fire Control Systems (FCS)
- Communications Systems
- Vetronics (Vehicle Status, Driver Aids, Navigation)
- AFV Seating with 5 point harnesses and ballistic protection against the threat of land mines.
- Environmental Control Systems, especially cooling or air conditioning.

Any or each of these AFV sub-systems would require SORs which would include HSI related requirements.

3.2.3 Crewman Clothing and Equipment

A wide range of personal clothing and equipment will be required by the Armour Community over the next several years. DLR 3 staff expect that some of the clothing and equipment required will be provided by the Clothe the Soldier (CTS) Project, including the CVC Helmet, Protective Eyewear, a Lightweight Balaclava, Crewman Gloves, and Generic Boots.

However, additional clothing and equipment are candidates for procurement by DLR 3, including:

- Crewsuits (fire retardant, heat reducing)
- Body Armour (penetration, spalding, fragmentation), that is wearable in new turrets
- Load Carrying Vest (CTS variant may be sufficient)
- Helmet Mounted Displays
- Cordless Communications

3.2.4 Crew Sustainment

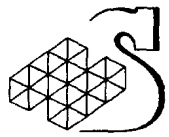
As the pace of battlefield scenarios continues to accelerate Armour Systems staff expect that they will be required to develop requirements related to crew sustainment. These requirements may be used for analysis of staffing concepts, work/rest patterns, or nutritional requirements and may also be used as the basis for procurement of pharmacological aids to extend physical or cognitive performance under periods of high fatigue (eg: ergogenic aids).

3.3 SOR Structure

The "Guidelines on the Preparation of a Statement of Operational Requirements" (DBCM 1998) outlines an SOR with the structure illustrated in Figure 1. The SOR contents result in solid traceability from the Defence Planning Guidance scenarios down to the performance requirements of an individual system

1. Introduction	4.5. Availability
1.1. Aim	4.6. Reliability
1.2. Background – Origin	4.7. Environmental Sustainability
1.3. Deficiency	4.8. Safety and Health
1.4. Project Constraints	4.9. Delivery Requirements
1.5. Current Situation	4.9.1. Quantity
1.6. Related Projects	4.9.2. Quality
2. System Operation	4.9.3. Location
2.1. Missions and Scenarios	**5. Sub-System Effectiveness Requirements**
2.2. Environment	**6. Performance Measures**
2.3. Threats	6.1. System Level Measures
2.4. Concept of Operations	6.2. Sub-System Level Measures
2.5. Concept of Support	**7. Personnel And Training Requirements**
2.6. Key Roles	7.1. Personnel – Staffing
2.7. Key Tasks	**7.1.1. Operational Staff**
2.8. User Characteristics	7.1.2. Maintenance Staff
3. Design and Concept Guidance	7.2. Training
4. System Effectiveness Requirements	7.2.1. Operational Training
4.1. General	7.2.2. Maintenance Training
4.2. Operability	7.2.3. Simulation
4.2.1. Performance Capability	**8. Scheduling Requirements**
4.2.2. Crew Station and Interface Design	**9. Requirements Table**
4.2.3. User Acceptance	
4.3. Survivability	
4.4. Maintainability	
4.4.1. Maintenance Task Performance	
4.4.2. Crew Station and Interface Design	
4.4.3. User Acceptance	

Figure 1: SOR Structure



3.3.1 Human Systems Integration in the new SOR Framework

Human Systems Integration is defined as:

The technical process of integrating the areas of:
1. *human engineering,*
2. *manpower,*
3. *personnel,*
4. *training,*
5. *systems safety, and*
6. *health hazards,*

with a materiel system to ensure safe, effective operability and supportability.

There are a number of the SOR sections and sub-sections that contain HSI requirements. These sections are not necessarily exclusive to the HSI domain, however, HSI requirements are expected to be included in the resulting content. HSI related sections and sub-sections are highlighted and bolded in Figure 2.

1. Introduction	**4.5. Availability**
1.1. Aim	**4.6. Reliability**
1.2. Background – Origin	4.7. Environmental Sustainability
1.3. Deficiency	**4.8. Safety and Health**
1.4. Project Constraints	4.9. Delivery Requirements
1.5. Current Situation	4.9.1. Quantity
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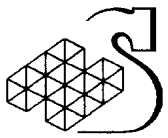
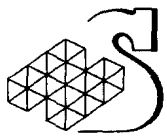
4. System Effectiveness Requirements	**7.2.1. Operational Training**
4.1. General	**7.2.2. Maintenance Training**
4.2. Operability	**7.2.3. Simulation**
4.2.1. Performance Capability	8. Scheduling Requirements
4.2.2. Crew Station and Interface Design	9. Requirements Table
4.2.3. User Acceptance	
4.3. Survivability	
4.4. Maintainability	
4.4.1. Maintenance Task Performance	
4.4.2. Crew Station and Interface Design	
4.4.3. User Acceptance	

Figure 2: SOR Structure with Highlighting Sections with *HSI Related* Content

The following points outline the type of HSI requirements that are typically defined in the highlighted sections of Figure 2:



- Deficiency. This section will often contain human centric deficiencies related to concerns with current system or task performance, training systems, staffing, or personnel safety.
- Missions and Scenarios. This section will contain a description of the missions and scenarios that the system will operate under. These scenario descriptions will define the operational environment, own force composition, threat force composition, typical deployment patterns, and scenario event sequences. The main body of the SOR will often contain only a summary of these scenarios, with more complete analysis in an Annex or a referenced report. These missions and scenarios are required as the basis for the subsequent analysis of future requirements for the system and provide a traceable link back to the Defence Planning Guidance scenarios for the entire Canadian Forces.
- Concept of Operations. This section will summarize the future concept under which the system will operate. This section will outline own force composition, deployment, and the general use of the system or sub-system in operations.
- Concept of Support. This section will define the concept for the maintenance and support of the future system. Of importance to HSI analysis is the relative role of military and commercial support in the future concept, and task performance concepts such as component repair versus component replacement.
- Key Roles. This section identifies and briefly describes the key positions related to operations and support as they in turn relate to the Concepts of Operation and Support.
- Key Tasks. This section identifies and briefly describes the key tasks to be performed by the personnel filling the key roles for both operation and support of the future system, using the new Concept of Operation and Concept of Support.
- User Characteristics. This section will identify the range of characteristics of the entire user community, not necessarily just those of the key users listed under Key Roles. These characteristics will include anthropometric ranges, gender, medical characteristics (vision, hearing), task skill sets, and qualification standards, among others.
- Operability - Performance Characteristics. This section of the SOR will contain a range of key performance characteristics many of which may be technical. However, the key user task performance requirements of the future systems will also be defined here as they relate to the key tasks to be performed within the identified scenarios, using the previously defined concept of operations.
- Operability - Crew Station and Interface Design. This section will identify key user centered requirements related to the layout of future crew stations or interfaces. These requirements will identify any critical layout issues or task performance requirements to ensure that each of the key roles will be able to perform their key tasks within the scenarios under the Concepts of Operation and Support identified. Often these requirements will list the critical equipment, displays, or controls that will need to be accessible by each class of user from their crew station.
- Operability - User Acceptance. This section of the SOR will identify requirements regarding how user acceptance will be evaluated on the project, any baseline criteria that must be met, and the criteria for meeting user acceptance thresholds for the project. In some cases these criteria may be linked to baseline surveys of existing products using ACCESS measures (Greenley 1999c) or comparable systems.



- Survivability. This section of the SOR will identify requirements for system survivability against the threats identified earlier in the SOR, however, from an HSI perspective it will also define requirements related to the survivability of the human while operating the future system. These requirements will often relate to personnel protection related to threats, with general safety and health hazard requirements identified later in the SOR.
- Maintainability - Maintenance Task Performance. This section will identify the primary maintenance task performance requirements of the future system for tasks to be performed within the scenarios, using the previously defined Concept of Support.
- Maintainability - Crew Station and Interface Design. This section of the SOR will identify any crew station or interface layout requirements associated with maintenance task performance. These may relate to maintenance specific displays or controls, or general access/egress to/from key equipment, as examples.
- Maintainability - User Acceptance. Any requirements related to future measurement of maintainer acceptance of the system will be included in this SOR section. These requirements may often be similar to the User Acceptance requirements in the operations section of the SOR.
- Availability. This section will identify system availability requirements, which should always include the human component of the availability equation. From an HSI perspective these requirements will often relate to sustained operations and the required availability of the entire system including its human operators. These requirements will also include skill fading requirements (the duration that a trained user will retain their skill level) related to training needs, and associated training frequency.
- Reliability. This SOR section will include requirements related to overall system reliability including the human error component in system.
- Safety and Health. This section of the SOR will include requirements related to preserving the safety and health of the future operators and maintainers within the physical and threat environments defined in the scenarios.
- Performance Measures. These requirements will include a range of system and task level performance measures to be used throughout procurement to evaluate the system. Many of these measures will require humans to be operating the system in order to measure them, and will therefore require HSI based analysis to establish and validate the measures in addition to HSI methods to collect performance data during future system user trials.
- Personnel-Staffing. This SOR section will include the staffing requirements based on the project scenarios, the Concept of Operations, and the Concept of Support. Alternatively, these HSI requirements may state limits on the staffing impact of the future system (eg: the new system shall not alter staffing requirements).
- Training - Operational and Maintenance. These requirements include the HSI requirements related to the training systems for both operators and maintainers, and will include requirements for both courses and facilities.
- Simulation. This section will include requirements for simulation in the training plan. This will include simulation based facilities for training key operational and maintenance tasks.

3.3.2 Human Systems Integration in the SOR Development Process

The Guidance on the Preparation of a Statement of Operational Requirements (DBCM 1998) also includes a recommended basic process for the development of new requirements. This process includes a series of steps, listed in Figure 3. Many of these steps include analyses or evaluations that centre on the human operators or maintainers of the future system, and their requirements. These more human centric elements of the sequence, highlighted in Figure 3, can utilize HSI methods, tools, and techniques to determine and validate user requirements.

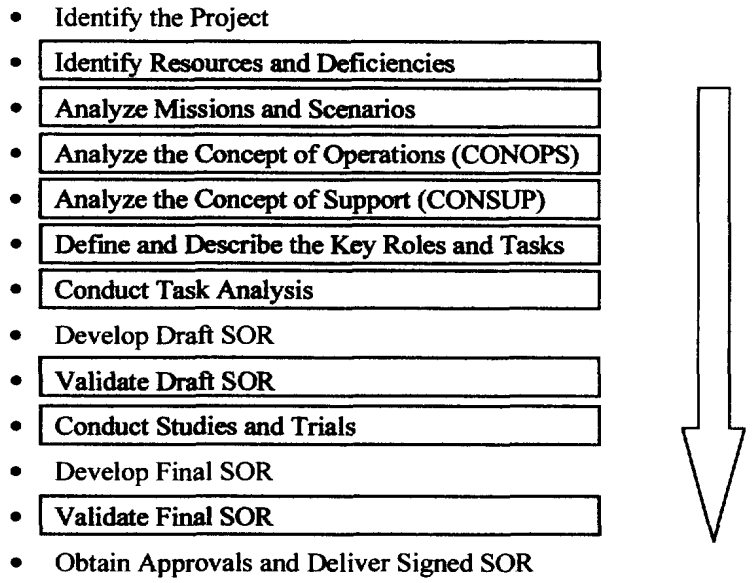
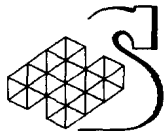


Figure 3: Recommended SOR Development Process with HSI Related Analyses Highlighted

At the core of the HSI component of this SOR development process is a very user centred sequence with many analyses linked to one another. The analysis begins with scenario definition and leads to analysis of key roles and tasks, after which the described tasks are analyzed for future requirements related to performance, displays, controls, safety, training, safety, etc.. HSI techniques are often then used to validate draft requirements with the user community through questionnaires or focus groups using mockups or prototypes. When more in depth investigation is still required to detail the requirements for a future system, studies are often conducted that include performance modeling, field trials, or human-in-the loop simulation. The sequence is completed with final validation of the requirements set through group meetings or further studies and trials.



3.4 Categorization of HSI Literature

This section provides more detail on the number and types of AFV SOR related literature reviewed during this project, with the conclusions from that review described in Section 3.5.

3.4.1 Literature Reviewed

Potential literature was identified in four locations:

1. DLR 3 filing cabinets, much of which was classified.
2. DCIEM archives of Scientific Authorities with previous experience on armoured projects.
3. Advanced Land Fire Control System (ALFCS) project library held at Human*systems* Incorporated with a mirror copy at Computing Devices Canada Ltd.
4. New literature from recent conferences and a DRDIM literature search.

3.4.2 Literature Categorization Scheme

3.4.2.1 Literature Categories

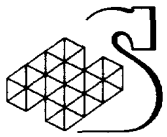
Literature review categories were developed based on:

1. The types of SORs DLR 3 was likely to generate over the next several years (see Section 3.2 of this report).
2. The New SOR structure.

The final categories (40 in total) used to classify the reviewed literature are summarized in Table 1. Any one paper could have been associated with more than one category.

Table 1: Literature Review Categories

#	Category
1	AFV Deficiencies
2	Missions – Scenarios
3	Environment
4	Threats
5	Concept of Operations
6	Concept of Support
7	Crew Roles
8	Crew Tasks
9	User/Crew Characteristics
10	Anthropometry
11	Target Audience Description
12	AFVs
13	AFV Performance
14	Crew Task Performance, including. Driving Gunnery Maintenance C3I
15	AFV Subsystems (General)
16	BMS
17	BCID
18	Sensors/Gunnery



#	Category
19	DAS
20	Communications
21	Vetronics
22	Crew Stations
23	Clothed anthropometry
24	Interior Design/habitability
25	Stowage
26	Design Checklists
27	Crew Sustainment
28	Ergogenic aids
29	Nutrition
30	Hydration
31	Sleep – Sustained Ops
32	Clothing
33	Equipment
34	User Acceptance
35	Survivability
36	Maintainability
37	Reliability
38	Safety, which included the full range of safety and health hazard assesment issues using the taxonomy from the USA HHA program. These potential topics included • Acoustical energy ▪ Steady state noise ▪ Impulse noise ▪ Blast overpressure • Biological substances ▪ Exposure to microorganisms, their toxins and enzymes • Chemical substances ▪ Weapon combustion products ▪ Engine combustion products ▪ Other toxic materials • Oxygen deficiency ▪ Displacement from an enclosed space • Radiation energy ▪ Ionizing radiation ▪ Nonionizing • Shock ▪ Mechanical impulse or impact from acceleration or deceleration (i.e. weapon recoil) • Temperature and Humidity ▪ High temperatures (i e. heatstroke) ▪ Low temperatures (i e. hypothermia) ▪ Surface Contact (i.e contact burns or cold induced dexterity loss) • Trauma ▪ Physical (i.e. Blunt impact damage to the eyes or body) ▪ Musculoskeletal (i e Strain due to lifting) • Vibration ▪ Whole body ▪ Segmental
39	Personnel
40	Training and Simulation

3.4.2.2 Relevance Rating

Each paper that was reviewed was assigned to the relevant categories in Section 3.4.2.1, and was then was rating in terms of the papers relevance to HSI requirements for future AFV SOR's . The three levels of relevance rating included:

1 – Relevant

2 – Somewhat Relevant

3 – Not Relevant

3.5 HSI Literature Available for DLR 3 SORs

This section provides a summary of the reviewed information by SOR category. The structure of this review, and the associated structure of the complete annotated bibliography, is was guided by the recommend literature structure in the first report from this project "Human Factors Integration Requirements for Armoured Fighting Vehicles; Part 1: Guidance for Addressing the Human System Integration (HSI) Content of Statements of Operational Requirements (SORs)". This structure is illustrated in Figure 4, showing common information for almost all SOR's, and specific information only where necessary but specifically in the area of Performance Requirements based on SOR type.

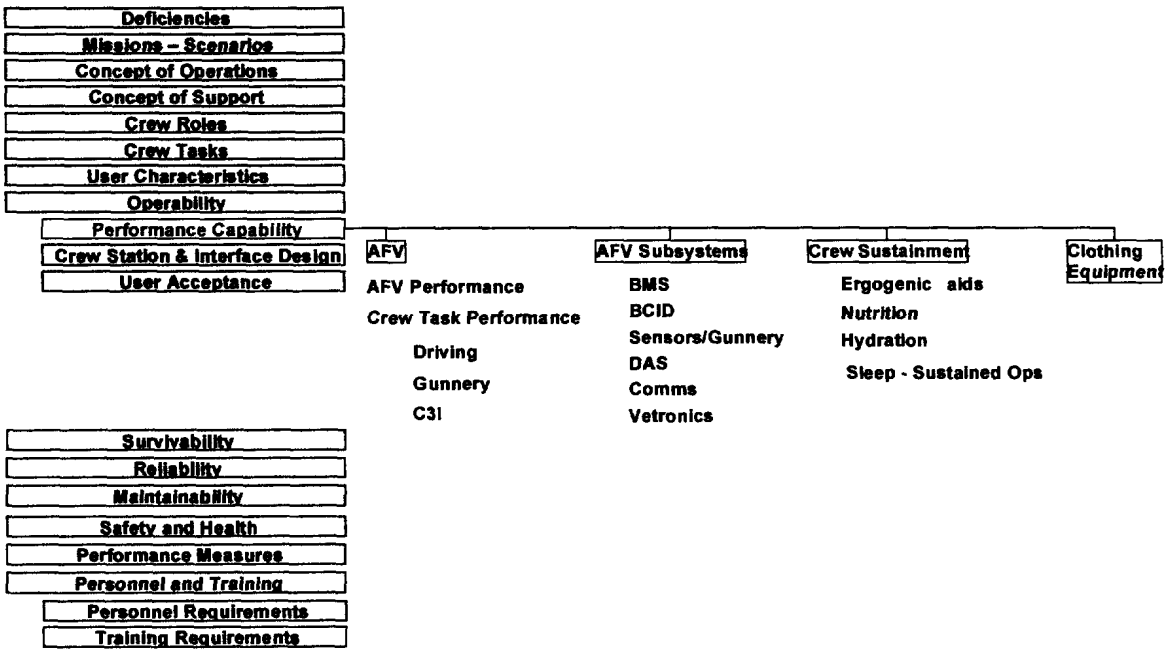
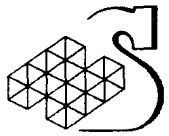


Figure 4: Structure of HSI Literature
(Grey boxes common across many SOR's, white box specific to SOR in any one domain, indented boxes are sub-sections in the SOR Template structure)

A summary of the status of the existing literature is provided in the sections below. An accounting of the actual literature, the full reference, and a more complete review of each paper is provided in the third report from this project, entitled "Human Factors Integration Requirements for Armoured Fighting Vehicles; Part 3: Annotated Bibliography of HSI Related Literature for AFV SORs". In total over 500 papers were reviewed, with approximately 100 rated as Level 1 or "Relevant".



3.5.1 Deficiencies

The literature reviewed did not contain much information on deficiencies with current AFV's in the Canadian armour community. Leopard task analysis reports did identify some concerns with the C1 (which about to be replaced with the C2 turret). The last formal report in this area was dated 1962 and was published in the USA. There were no UCRs identified in the filing cabinets at DLR 3, and there was no evidence that a systematic review of Canadian armour system deficiencies existed. The literature, and general project team knowledge, identified that there is a process in existence in DND (ACCESS) that is used for systematically identifying deficiencies, however, it has not been applied to AFVs.

3.5.2 Missions – Scenarios

There is information available on current scenarios based in the DND scenarios documented in the Defence Planning Guidance, and Army references on existing doctrine. In addition, information is available on the potential future role of Canadian AFVs through Army Doctrine documents, ALFCS scenarios and Lab Evaluation Descriptions, and Armour Combat Vehicle Operational Research studies.

While this available does provide a range of typical scenario descriptions it was found that the timelines of the scenarios were too short for HSI related analysis and trade off investigations, and many scenarios were clearly situated for specific project analysis requirements.

3.5.3 Concept of Operations

One future concept paper was available through the ACV project, however it did not provide much information on how a future AFV squadron or troop would deploy and what the resulting task performance or staffing requirements might be.

There were some useful papers found from allied nations that provided information on requirements related to reducing manning associated with future concepts.

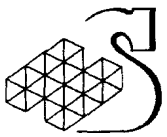
3.5.4 Concept of Support

Some ideas regarding future Concepts of Support were suggested in the ACV SOR, however, not much detail was provided. In addition, the literature from the Acquisition Reform project (such as the Acquisition Reform Guide) provides general guidance on some concepts such as Long Term Support Contracting, but this was at a very general level and not directly focused in terms of the impact on armour operations.

3.5.5 Crew Roles

There was a reasonable amount of useful information available regarding operational roles. This literature came from existing doctrine, training materials, and training criteria, as well as R&D projects with a human factors focus such as ALFCS, DAS, Combat Team Commander Cognitive Task Analysis, Land Force Command System Relevance for Battle Group and Below, and an assessment of the Integration of C2 Systems in the Leopard Turret.

Some literature was identified related to maintenance, primarily through the ACR SOR and maintenance related training courses.



3.5.6 Crew Tasks

The information available on crew tasks was the same as that related to crew roles. Again, this literature came from existing doctrine, training materials, and training criteria, as well as R&D projects with a human factors focus such as ALFCS, DAS, Combat Team Commander Cognitive Task Analysis, Leopard Crew Task Analysis, Land Force Command System Relevance for Battle Group and Below, and an assessment of the Integration of C2 Systems in the Leopard Turret.

Similarly, literature on maintenance tasks was identified through the ACV SOR and maintenance related training courses.

Some generic task information was also located in the literature on HFE Guide, a software tool produced by DCIEM which has been targeted for future conversion to a web based tool for distribution over the Intranet.

In general, while there was information in this area, it was in no way complete and was not integrated in a fashion that provided an overall description of the tasks associated with key roles and their interrelationships.

3.5.7 User Characteristics

The literature review concluded that general anthropometry information is available through the Canadian anthropometric survey of 1997. However, the sample size from the armour community in this survey was small and therefore the overall results may not be directly applicable to the armour community when used for critical decisions with small tolerances such as turret design.

From a Target Audience Description perspective, there was some information located on gender but little else. It is expected that further information is available in this area throughout the Forces, however, conducting further searches was beyond the scope of this project which focused on immediately available literature.

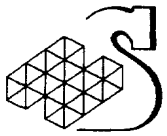
3.5.8 Operability - Performance Capability

The literature related to Performance Capability was categorized according to the type of SOR, including:

1. AFVs
2. AFV Sub-systems
3. Clothing and Equipment
4. Crew Sustainment

3.5.8.1 AFVs

There is a reasonable amount of information available regarding overall AFV performance, including human task performance (of interest to HSI). Information in this regard is available through references such as the ACV SOR, the performance requirements and feature descriptions of AFVs from the USA, and the firing tables and manuals from Canadian and American vehicles.



3.5.8.2 AFV Subsystems

Very little information was available on human task performance requirements for Battlefield Management Systems, Battlefield Combat Identification, Communications, or Vetronics.

The literature from the ALFCS and DAS projects (Design documents, Lab Evaluation Plans and Descriptions) provide a reasonable range of information regarding Fire Control System requirements, and Defensive Aids Suite requirements in addition to information on the training and personnel impacts of these future systems.

Very little information was located on future Operator Machine Interface requirements related to these AFV subsystems, other than the FCS and DAS information on the ALFCS series of projects.

3.5.8.3 Clothing and Equipment

In general there was a solid database of literature regarding HSI issues associated with clothing and equipment requirements from the Clothe the Soldier Project and the Integrated Protection Clothing and Equipment project. All of this information would be of relevance to future procurement of crew suits and body armour.

Very little information was located regarding personal equipment in the areas of cordless communications, dismounted Battlefield Management Systems, or Helmet/Head Mounted Displays.

3.5.8.4 Crew Sustainment

There was a good range of articles and associated requirements on basic human performance, nutrition, hydration, and fatigue effects.

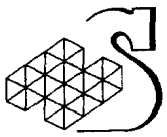
Information of a general nature was located regarding ergogenic aids, however, none of this addressed the specific requirements or benefits to military or AFV tasks. There is research on ergogenic aids ongoing in TTCP, being carried out by Technical Panel HUM TP-8 (the Canadian POCs are Dr. T. McLellan and Dr. J. Baranski, DCIEM).

3.5.9 Crew Station and Interface Design

As a result of command and control projects through DRDB there is some solid information regarding crew station design related to BMS installation. In addition, there is some information available on seating requirements.

From a human engineering design requirement perspective there appears to be an abundance of information to guide crew station design including tools such as COMBIMAN and SAFEWORK as well as references such as MIL-STD-1472 and MIL-STD-579B. Some of these standards are reflected in HFE Guide, which is targeted for conversion to a web based tool for use over the Intranet.

In terms of physical form, however, little information was located regarding the size and layout of in service AFVs to which upgrades and enhancements would apply. Some 2D versions of vehicles was available through R&D on the ARDS project (M113, M577, LSVW), and some rough 3D CADD files were identified from the ALFCS project and from the evaluation of the Leopard Turret for the TBCS project. In all cases these CADD files were created by contract teams measuring the actual vehicles.



3.5.10 User Acceptance

User acceptance requirements for a range of systems, including evaluation plans, measures, and criteria are available through the ALFCS literature, the DAS literature including Pronghorn, Clothe the Soldier, and IPCE.

3.5.11 Survivability

From a human survival perspective there was some literature available, but most was grouped under the health and safety categories. There was little information available on the threats to the individual crewman as they relate to requirements for body armour.

3.5.12 Availability

Some information on sustained operations and fatigue was located in the R&D literature. This information would relate to future requirements for human availability to perform tasks as one component of overall AFV availability.

3.5.13 Reliability

There was little information on human error and its potential contribution to overall AFV reliability. DCIEM studies in the 1980s identified that that two thirds of 51 Canadian Forces (CF) Leopard C1 tank gunners tested for their knowledge of one particular firing technique did not follow the correct procedure. The most frequent error was a reversal of tasks associated with fire control system calculation of lead and range leading to computation of an erroneous firing solution.

There is a base of generic literature on human error within the human factors community that could be adapted for human error related assessments for AFVs.

3.5.14 Maintainability

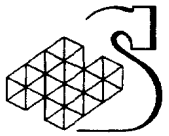
General maintenance instructions are available for Canadian vehicles, as well as literature that provides some task performance values on maintenance tasks for USA systems. No literature was located with specific information on maintenance task performance requirements, crewstation or interface design characteristics associated with maintenance, or support related scenarios. Interviews with DCIEM staff reported that there are UK studies on reduced crewing that highlight the importance of reducing maintenance requirements, even for simple things like track tensioning.

3.5.15 Safety and Health

Extensive information on most aspects of Health and Safety was located. In particular the USA has common guides and standards that DND should consider purchasing to support procurement projects.

3.5.16 Performance Measures

A solid data set exists for performance measures related to some aspects of C2, gunnery, navigation, firing tables, and other literature reviews. However, further information is still required related to specific task performance requirements within Canadian scenarios and operational concepts.



3.5.17 Personnel and Training Requirements

There was little to no information located on personnel characteristics and selection criteria for AFV crews or maintainers.

It has been reported that 30 days after qualification tank gunner skills decrease by 25% (US General reporting to NATO DRG Panel 7 workshop on Cost Effectiveness of Training, Ottawa: NDHQ CRAD/DRD L, 1990).

Some information on training requirements for AFV systems and related simulation was located in the immediately accessible literature, with some specific useful references from the USA.

Little information was located that indicated the future requirements for skill training as a result of future systems and technology concepts, however, a conference on the topic was held (NATO Defence Research Group Workshop on Tank Crew Training, held in Brussels) in 1986 which is reported to include material on the impact of technology on training requirements.

3.6 Gaps in Existing Knowledge

This review of the literature identified a number of gaps in the existing knowledge. Gaps were defined as areas of the future SORs for which a reasonable requirements does not exist within the immediately available literature. In summary, the gaps included:

- AFV deficiencies
- Missions/scenarios including:
  - Scenario Descriptions
  - CONOPS/CONSUP with links to technology
  - Threats to the AFV crew and associated clothing and equipment requirements
- Details of a wider range of AFV tasks, including:
  - Task performance criteria
  - Higher level performance measures (Crew/Troop/Squadron)
  - Training requirements for future systems and roles
  - Maintenance task performance requirements/scenarios
  - Basic kit lists and an accurate battlefield day
- Wider range of information on crew characteristics, including the need for validation of anthropometry data sources for precise AFV design
- AFV and sub-system requirements, including:
  - HMD and cordless communications requirements
- Crew station modeling and CADD drawings of all Canadian AFV's (3D)
- Current selection criteria and staffing requirements for future AFVs
- Human error framework for AFV tasks
- Crew sustainment, and the application of ergogenic aids to military AFV tasks

3.7 Future HSI R&D Program

In order to address the gaps in existing knowledge about HSI requirements for future SORs a series of R&D projects have been identified and described. Together they form an integrated program, with some of the components being slightly dependent on the others. Figure 6 illustrates the 11 research areas identified and their interrelationships. Each area is discussed further in the sub-sections that follow, with a full description of each area in Annex A to this report.

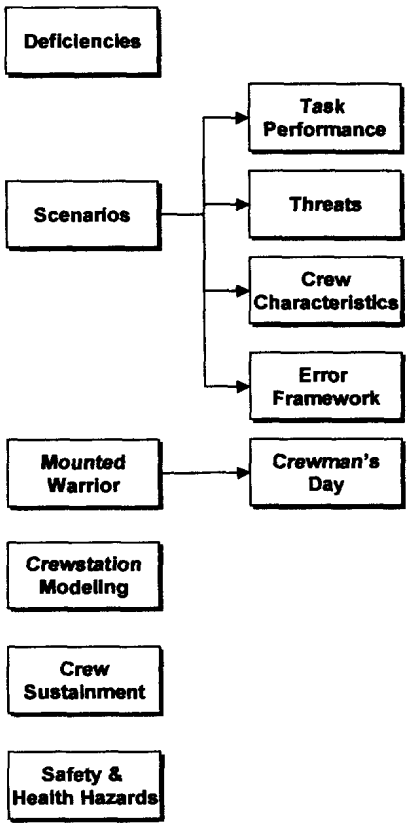
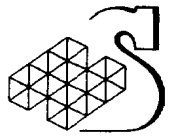


Figure 6: Integrated R&D Program



3.7.1 Deficiencies

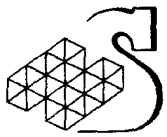
To support staff officers in the identification and quantification of capability deficiencies with armoured fighting vehicles and with related mounted soldier personal equipment and clothing related clothing the following steps have been recommended (see Annex A for more details):

1. Develop a database that collates and consolidates recognized engineering and safety deficiencies of armoured fighting vehicles, by vehicle or appropriate family of vehicles. Sources to include but should not be limited to the following:
   - UCR system
   - Safety investigations
   - Ad hoc equipment trials i.e., Trials and Evaluation (T&E) reports; DCIEM, DREV, DRES reports; contractor reports, etc.
2. Develop a database that collates and consolidates the operational deficiencies of armoured fighting vehicles, by vehicle or appropriate family of vehicles. Sources to include but not be limited to the following:
   - Exercise after action reports (AAR)
   - Mission after action reports
   - Visit Reports
   - Allied Nation lessons-learned reports, i.e. Leopard Club, USMC (LAV), Australia (LAV), US Army Lessons Learned Center, etc.
3. Develop an Armoured Fighting Vehicle - Army Combat Clothing and Equipment Survey System (AFV-ACCESS). Use this survey system to gather information on user concerns with armoured fighting vehicles and mounted soldier combat clothing and equipment. While this system can be used to survey the current state of the armoured fighting vehicle fleet, it can also be used to support mission and exercise after action reports.

3.7.2 Scenarios

Mission analysis is the first step for further human factors and engineering analysis. Development of validated missions and scenarios will impact on the following SOR sections:

- Missions and scenarios
- Concept of operations
- Concept of support
- Key roles
- Key tasks
- User characteristics
- Performance capability
- Crew station and interface design
- Reliability



- Performance measures
- Personnel and training requirements

The details of the DPG, ACV OR Studies, TBCS and ALFCS scenarios should be examined and a detailed set of validated scenarios should be developed for future armour systems, taking into consideration any developments from the Future Concepts groups within the army. The scenarios /mission descriptions must reflect all functional -mission requirements that have been identified. Composite missions should be developed to identify all the unique mission activities identified, avoiding duplication of common activities. These missions should be/include the following:

- Longer duration
- Sustained operations
- Range of missions anticipated
- Integrated operations and logistics tasks

The missions/scenarios should be analyzed using function analysis, and be used as the basis for the development of an up to date armour Battlefield Day (see Annex A for more details).

3.7.3 Task Performance

3.7.3.1 Task Performance

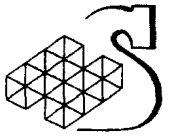
To support further research and analysis efforts (interface design, human error framework, performance measures, training design, selection, etc.) detailed task analysis should be performed. Areas for investigation include:

1. Operational tasks, e.g.
   - Command and control tasks
   - Troop and Squadron coordination
   - Target detection and tracking tasks
   - Reconnaissance tasks
   - Vehicle guidance tasks
2. Maintenance tasks
3. Replenishment tasks
4. Survivability tasks

3.7.3.2 Performance Measures

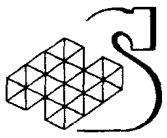
While task analysis will describe and analyze tasks, the development of desired performance levels is a function of overall mission and task goals. The Armour Battle task standards primarily deal with mission success and are not directed at performance goals per-se. Development of baseline performance measures will assist researchers and developers in the design or evaluation of future fighting systems. Areas for investigation include:

1. Develop a core set of performance measures from the literature for the following tasks:



- Command and control tasks
- Target detection and tracking tasks
- Reconnaissance tasks
- Vehicle guidance tasks
- Maintenance tasks
- Replenishment tasks
- Survivability tasks

2. Develop gunnery performance measures using ALFCS (first for vehicle level and then extend to troop level)
3. Validate measures
   - Previous experiments
   - Trials
4. Identify performance levels using validated measures, i.e.
   - Quantitative score
   - Reaction time
   - Task duration
   - Task completion rates
   - Classification of errors
   - Error frequency
   - Time spent in error
   - Task success
   - User satisfaction
5. Identify performance measurement tools for collective tasks. Development of vehicle, troop and squadron level performance measures suggests the need for acquiring weapon effect simulators. These tools will allow investigators to quantify performance.
6. Identify performance shaping factors:
   - External performance shaping factors, i.e.
     - Environmental conditions
     - Work space and work layout
     - Poor interface design
     - Inadequate training and job aids
     - Poor supervision
   - Internal performance shaping factors, i.e.



- Training /experience
- Stress level
- Fatigue level
- Perceptual abilities
- Social factors
- Physical condition
- Strength/endurance
- Gender differences
- Skills fading
- Psychological state (emotional state, motivation, attitude)

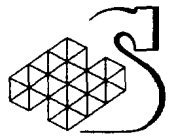
3.7.4 Crew Characteristics

To support staff officers in the identification and quantification of crew characteristics, the following steps are recommended (see Annex A for more detail):

1. Conduct a study to forecast the future impact of gender equality on operations and maintenance and associated OPCON/OPSUP.
2. Validate the 1997 Anthropometric Survey Land Force Survey to see if it's directly applicable to the Armour Corps.
3. Examine the applicability of the SAFEWORK clothing module for AFV design.
4. Examine the impact of the minimum medical colour vision standard for armour crew personnel vis-a-vis CRT based tactical maps, weapon sights, displays etc.
5. Examine the impact of multiple auditory warning tones in the AFV environment.
6. Use mission scenarios and task flows to analyze concepts of operations and concepts of support to estimate changes in armour crew skills and personnel characteristics.
7. Examine armour crew selection practices to identify better predictors of training and operational success.
8. Compare Canadian armour selection standards against U.S. army and U.K. selection standards. Examine the feasibility of utilizing existing human factor tools, i.e. IMPRINT with Canadian data.

3.7.5 AFV and Subsystem Performance and OMI Requirements

The determination of requirements for AFV's, technology based subsystems, and their associated operator machine interfaces (OMI) is an area that must be supported by ongoing research. R&D is required to be able to anticipate future requirements of these types of systems, but also to evaluate the potential impact of new technology of all types on armour system user performance.



There are not really any R&D activities in this regard that can be identified as "HSI driven" R&D like the other areas outlined in this section. Instead this class of R&D tends to originate with the technology centred R&D programs and must include an HSI component in order to determine future requirements related to human task performance, personnel levels, training, safety, and health hazards. Specific recommends to support this line of analysis include:

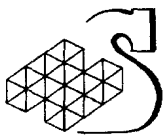
1. Continue to support ALFCS type studies. These studies should explore a range of issues related to human performance, including:
   - Fire Control System (FCS) -Battlefield Management System (BMS) integration,
   - Fire Control System / Battlefield Management System / Vetronics integration,
   - New Sensors,
   - Displays for Hatch Closed Operation and Situational Awareness (SA),
   - Cordless Communication concepts,
   - Helmet or Head Mounted Display (HMD) concepts.
2. Continue to take prototypes to field trials (eg: Pronghorn). Prototypes evaluated for future AFV systems should focus on FCS-BMS integration and more systematic evaluation of HMDs under a range of operational conditions.
3. All studies should extend analysis to the Troop and Squadron level for performance, workload, SA, etc. as this is where future systems will need to impact and where personnel and training issues will be felt. This may require linked simulators or more field trials.
4. All experiments should include any new crew or staffing concepts being considered or implied by the design of a proposed system (eg: 2 person turrets).
5. Some trials in simulators or the field should be conducted over longer periods to evaluate the full impact of new concepts on sustained operations, maintenance, and support.
6. Studies could/should explore alternate Concepts of Operation such as using multiple crews per AFV.

3.7.6 Mounted Warriors Day

A scoping study for expanding the Soldier's Day database to include mounted infantrymen was completed in 1998. Although recognized as a desirable follow-on product, priority was given to developing an Anthropometric Module for Soldier's Day at the time. In view of its direct connection to Armoured Fighting Vehicles it is recommended that the Soldier's Day database be expanded to include the mounted riflemen. Further details are provided on this recommendation in Annex A.

3.7.7 Crewmans Day

An enhanced Soldier's Day database - Crewman's Day has the potential to consolidate the various data streams that contribute to armoured vehicle SORs. The Crewman's day database can expand on the Soldier's Day database by adding vehicle and vehicle subsystems, deficiency reports, heath and safety reports, performance measures, etc. While Crewman's Day will consolidate information utilized in an SOR, a separate module is recommended to link the information from Crewman's Day into an SOR template.



The basic configuration of the recommended "Crewmans Day" is described in the companion report to this report, titled "Human Factors Integration Requirements for Armoured Fighting Vehicles; Part 1: Guidance for Addressing the Human System Integration (HSI) Content of Statements of Operational Requirements (SORs)".

3.7.8 Crew Station Modeling

In order to evaluate vehicle workstations, CAD drawings of vehicles and vehicle workstations should be acquired from vehicle manufacturers or developed using laser or sonic digitization techniques. These drawings must be in a suitable 3D CADD format for importation into SAFEWORK®, a human form mannequin tool that facilitates visualization and evaluation of work spaces. This will allow designers, engineers and human factors experts to conduct the necessary analysis to evaluate the impact of AFV upgrades, or the potential impact of new clothing and personal equipment on operator accommodation and task performance.

3.7.9 Threat Studies

Using the results of any mission and scenario analysis conducted, the R&D community should develop a valid matrix of personal threats outside and inside AFVs. Once the threats to the crew area known when inside (hatches open or closed) or outside the vehicle, the basic framework for identification of deficiencies and requirements for personal protection can be developed.

3.7.10 Safety and Health

To support staff officers in the identification and mitigation of armour system health hazards, the following steps are recommended:

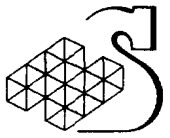
1. Develop a mechanism to track safety and health issues with current systems, and develop a method to present the information to project teams
2. Examine the desirability of developing a coordinated HHA program.
3. Critically examine the U.S. HHA program to see if it is suitable in structure for adoption by Canada.
4. Develop a formal Canadian Forces Health Hazard Assessment Program.

It is important to the note that the Human Systems Integration (HSI) project within DRDB is likely interested in co-ordinating an initiative such as this, and the staff within the Director of Science and Technology for Human Performance (DSTHP) should be contacted if this recommendation is flagged for implementation.

3.7.11 Human Error Framework

To quantify and qualify areas for improvement in crew reliability the following steps are recommended:

1. Develop scenarios on likely concepts of operation and concepts of support.
2. Describe system goals and functions of interest.
3. Describe task responsibilities and identify criteria for success.



4. Analyze tasks for potential human errors, using a range of potential techniques within the human factors community.
5. Estimate the likelihood of potential human errors.
6. Estimate the consequences of human errors.
7. Recommend changes to improve system/task performance, and identify any requirements for future systems to mitigate the probability of human error being introduced.

3.7.12 Crew Sustainment

The armour community should support basic research on the impact of ergogenic, psychogenic and anti-narcoleptic aids. Simulators such as ALFCS and LVIGS may have a potential role in evaluating purported aid effects.

4 Integrated Costed R&D Program

When the R&D activities recommended in Section 3 are decomposed and linked in terms of the dependencies between them an integrated R&D Program results. This integrated program has been costed as required under the deliverables for this project. The cost estimates are based on the approximate costs required to contract the work to human factors consultants with DND experience. Items rated with a $0.00 cost are those that would be conducted solely in a Defence Research Establishment.

The integration of the costed activities produced a series of R&D streams within the overall program. These streams included:

1. Deficiencies
2. Missions, Tasks, Threats, Users, and Error
3. Crewmans Day Software
4. Crewstation Modeling
5. Safety and Health Hazards
6. Crew Sustainment

Each stream is reviewed further in the following sections.

4.1 Deficiencies

The linked sub-projects in the Deficiency stream all work towards an accurate database of armour system deficiencies as the basis for future projects. Details and costing of each sub-project can be found in Annex A. The linked R&D activities are illustrated in Figure 7.

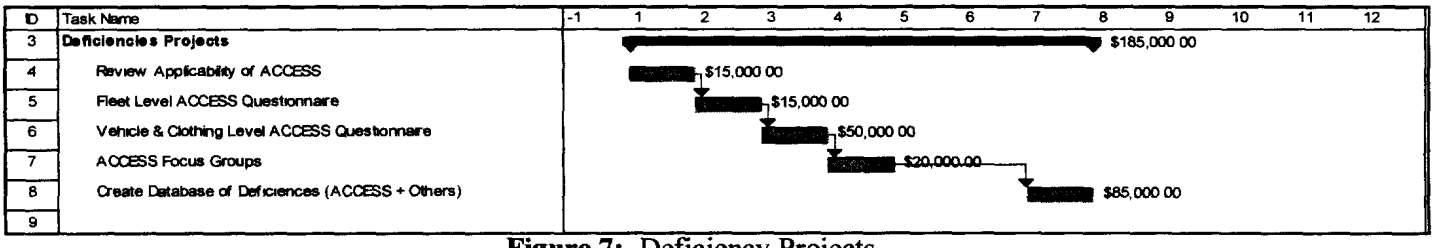


Figure 7: Deficiency Projects

4.2 Missions, Tasks, Threats, Users, and Error

The analysis of missions and scenarios forms the basis of a number of linked R&D activities. As scenarios are defined and analyzed a number of additional analyses are facilitated, including:

- further task analysis and measurement development
- threats to the human operator in AFVs can be identified and analyzed

- users can be identified and analyzed for their future characteristics, and
- error frameworks can be established.

The details and costing of these projects is established in Annex A. The linked R&D activities are illustrated in Figure 8.

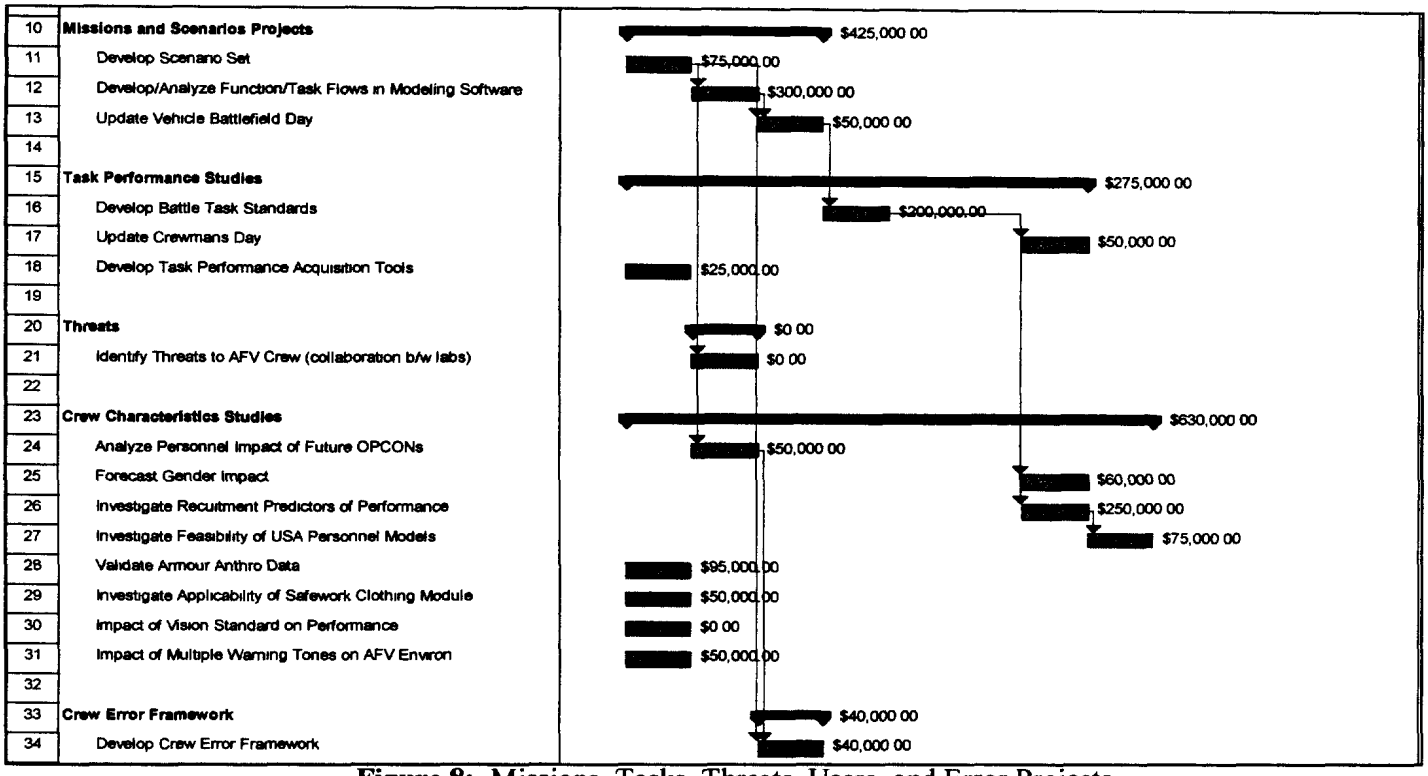


Figure 8: Missions, Tasks, Threats, Users, and Error Projects

4.3 Crewmans Day Software

The development of A Crewman's Day software is dependent on the completion of the Mounted Warrior proposal recently submitted to DND. Both of these activities have been linked in Figure 9, and the associated R&D description in Annex A.

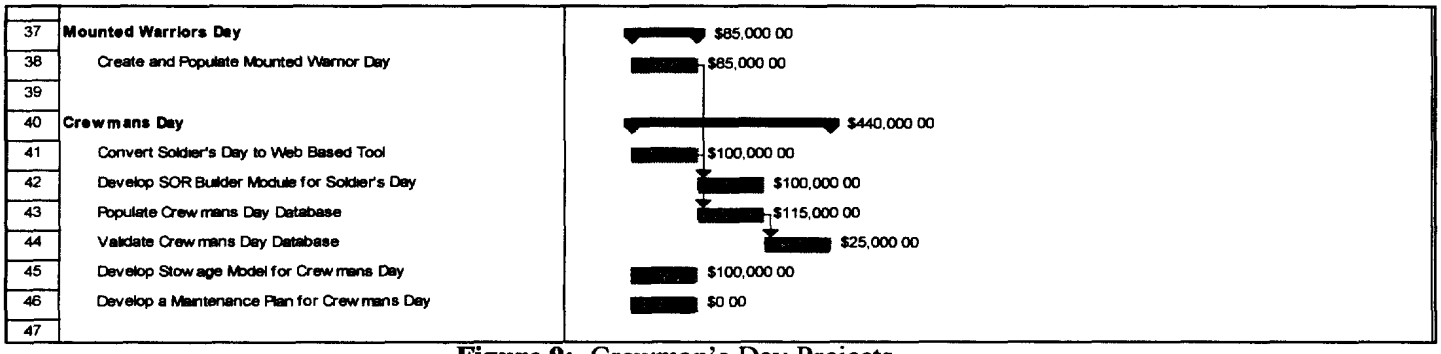


Figure 9: Crewman's Day Projects

4.4 Crewstation Modeling

Crewstation modeling generally stands alone as a series of projects that should be completed in support of future upgrade and enhancement projects. The details and costs of the sub-projects are outlined in Annex A, while the sequence of events is illustrated in Figure 10.

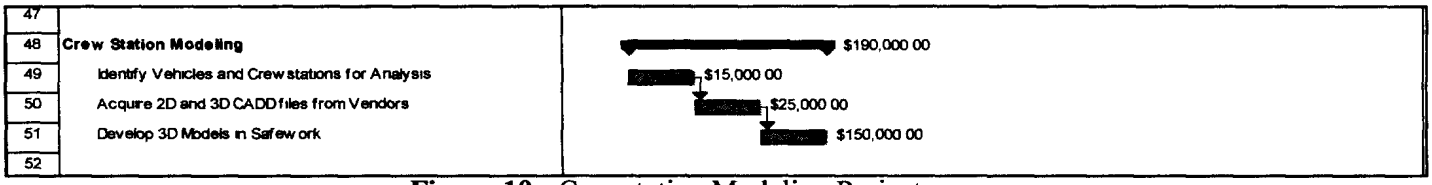


Figure 10: Crewstation Modeling Projects

4.5 Safety and Health Hazards

Safety and Health Hazard assessment are an integrated set of R&D activities within themselves. The details and costs of the sub-projects are outlined in Annex A, while the sequence of events is illustrated in Figure 11.

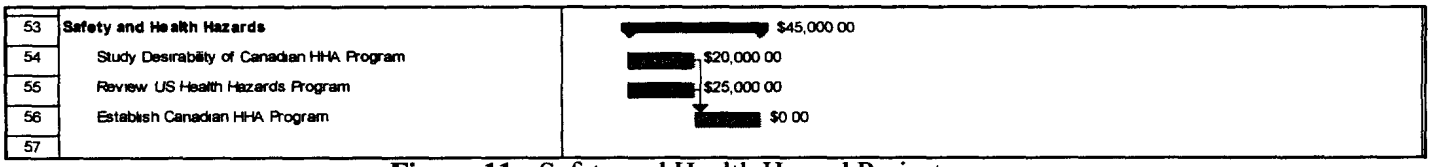


Figure 11: Safety and Health Hazard Projects

4.6 Crew Sustainment

Crew Sustainment research is composed of a series of projects that are relatively independent. The details and costs of the sub-projects are outlined in Annex A, while the parallel sequence of events is illustrated in Figure 12.

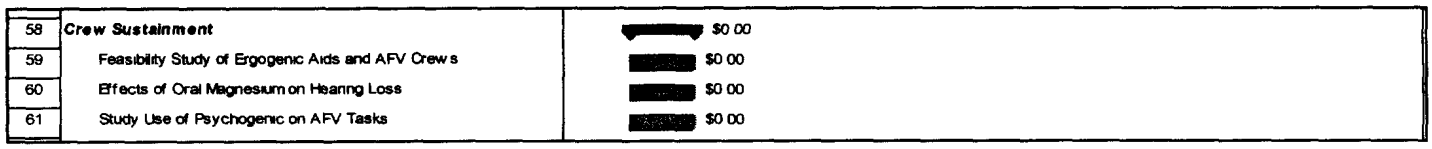
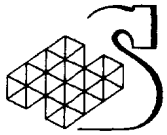


Figure 12: Crew Sustainment Projects



5 Prioritization of R&D Activities

During the presentation of the results of this project, the client community requested that future R&D activities be grouped or prioritized in a number of different ways. These groupings included:

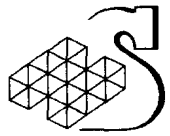
1. R&D Priorities to Meet the Original DLR 3 Request
2. R&D Priorities for Purchasing COTS
3. R&D Priorities for Upgrades and Enhancements
4. R&D Priorities for FAVS TD
5. R&D Activities that Meet a "Purple" Requirement

Each of these grouping is discussed further in the following sections.

5.1 R&D Priorities to Meet Original DLR 3 Request

This project was partially initiated through a request from DLR 3 to the R&D community indicating a number of areas where DLR 3 staff felt further Human Factors R&D was required. A number of the recommended R&D activities in this report align with areas in the original DLR 3 request. R&D activities recommended in this report that also meet the original DLR 3 request include:

1. Deficiency Projects.
2. Mission and Scenario Research Projects.
   - Development of agreed upon scenarios (especially for Operations Other Than War) and a solid Battlefield Day is more important than computer modeling of scenarios for this purpose.
3. Task Performance Research Projects.
4. Crew Characteristics Projects
5. A Crewman's Day Projects.
6. Crew Sustainment Projects



5.2 R&D Priorities for Purchasing COTS

DND project staff are increasingly asked to purchase Commercial Off The Shelf (COTS) products. The priority of R&D for COTS procurement is driven by the methods used when purchasing off-the-shelf. COTS procurement is focused on having a solid requirement, then conducting market research, determining performance measures, and testing or evaluating alternative candidate products against those requirements. As a result, any R&D that helps DLR 3 project staff understand operational scenarios, performance requirements, the interrelationships between existing equipment, and the development of performance measures for trials and evaluations are key to successful COTS acquisition. Therefore, R&D priorities for COTS procurement include:

1. Deficiency Projects.
2. Mission and Scenario Research Projects.
    - Development of agreed upon scenarios and a solid Battlefield Day is more important than computer modeling of scenarios for this purpose.
3. Task Performance Research Projects.
4. Crewman's Day Project.

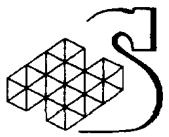
5.3 R&D Priorities for Upgrades and Enhancements

DLR staff have indicated that procurement over the next decade will focus more on upgrades and enhancements to existing vehicles and systems, as opposed to procurement of complete vehicles. In these situations it is most important to have a solid understanding of the current operation of the in service vehicles so that DND project staff can conduct "what if" analysis about the potential impact of upgrades and enhancements and so they can trade off different options in terms of their impact on current levels of importance. In order to facilitate these types of analysis the important R&D activities include:

1. Deficiency Projects.
2. Mission and Scenario Projects.
    - Especially the development of computer models of task networks to facilitate "what if" analysis.
3. Crewstation Modeling Projects.
    - To create a library of valid crewstation models that allow potential upgrades and enhancements to be evaluated.
4. A Crewman's Day Projects.

5.4 R&D Priorities for FAVS TD

Within the Defence Research and Develop Branch a number of Technology Demonstrator projects have recently been proposed. One of those is the Future Armour Vehicle Systems (FAVS) Technology Demonstrator (TD). FAVS TD is currently conducting a scoping study on the areas it should consider in the course of the TD project. FAVS is one of the AFV system and



sub-system projects that should ensure that a human-centric methodology is adopted, similar to the recent ALFCS program.

FAVS TD has been scoped as an R&D project to investigate technologies that can enhance armour fighting vehicle performance. Some of these technologies will be evaluating using a full scope simulator developed during the Advanced Land Fire Control System (ALFCS) project. Additional analyses may be completing using Operational Modeling, and there is a chance that some technologies could be developed and evaluated using actual vehicles in the field.

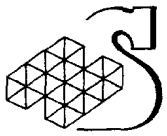
A project such as FAVS TD is in essence a futuristic upgrade and enhancement project. Therefore the project needs a sound understanding of future operational scenarios (not current, but future scenarios developed based on projections of future doctrine and operational concepts). These scenarios need to be analyzed to determine the future battlefield day and future operational performance measures. With this type of framework a project such as FAVS would then have a core set of scenarios and measures around which to measure task performance (in operational research studies, live simulation, or field trials) in a systematic fashion. Therefore, R&D priorities for FAVS TD include:

1. Mission and Scenario Research Projects.
2. Task Performance Research Projects.

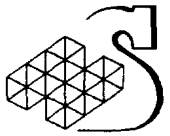
5.5 R&D Activities that Meet a "Purple" Requirement

This report was developed using funding from a "purple" R&D work unit. "Purple" refers to a group or funding source comprised on inputs from the Land, Maritime, and Air Environments of the Department of National Defence. Some of the R&D activities outlined in this report would be of benefit to all environments, and therefore should be considered not only by DLR 3 but by all environments and "purple" R&D committees. R&D activities of interest to all environments include:

1. Deficiency Projects.
    - The development of a vehicle based ACCESS questionnaire system could be easily tailored by other vehicle based systems such as an aircraft or ship.
2. Crewman's Day Project.
    - The transition of Crewman's Day to a Browser Based product would benefit all potential users of the Soldier's Day tool.
    - The modification of Soldier's Day to include a Vehicle information stream (Crewman's Day) would benefit any future users of the product that are responsible for a vehicle system. Once the database is modified to link a vehicle to equipment to users it can apply to any comparable system (eg: Ship-deck-room-equipment-user-links, or Helicopter-crewstation-equipment-user links).
3. Safety and Health Hazards
    - Any activity to develop safety and healthy hazard databases or reporting mechanisms can be applied to all environments.



4. Crew Sustainment
    - Studies of the impact of ergogenic and psychogenic aids on military task performance can be of benefit to all environments.



Annex A:
HSI R&D Project Descriptions

Overview

This annex contains brief summaries of each of the required HSI related R&D projects. These R&D projects have been identified and described as required to address the deficiencies in existing HSI related requirements knowledge throughout DLR 3 and DLR 10. They also provide an example of some of the R&D activities that might be done by any Directorate in anticipation of future SOR authoring requirements, and some of the projects actually are "purple" in nature.

In order, the projects covered in this annex include:

1. Deficiencies
2. Scenarios
3. Task Performance
4. Crew Characteristics
5. AFV and Subsystem Performance
6. Mounted Warriors Day
7. Crewman's Day
8. Crew Station Modeling
9. Threat Studies
10. Safety and Health
11. Human Error Framework
12. Crew Sustainment

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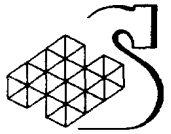


Deficiencies

Background

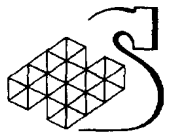
There are currently a number of uncoordinated mechanisms for identifying problems with armoured fighting vehicles and with crew clothing and equipment. Deficiencies are normally focused around vehicle mechanical defects, safety issues and operational effectiveness. The mechanisms for obtaining information include:

- Exercise after action reports (AAR)
- Mission after action reports
- Visit Reports
- Allied Nation lessons-learned reports, i.e. Leopard Club, USMC (LAV), Australia (LAV), US Army Lessons Learned Center, etc.
- UCR system
- Safety investigations
- Ad hoc equipment trials i.e., Trials and Evaluation (T&E) reports; DCIEM, DREV, DRES reports; contractor reports, etc.

Within NDHQ, DAVPM is the engineering directorate responsible for the life-cycle management of the various armoured fighting vehicles in the CF fleet. In addition to its life-cycle management duties, this directorate manages developmental projects, responds to UCRs and makes recommendations based on relevant accident and incident safety reports. The deficiency focus with DAVPM appears to be with mechanical and safety deficiencies and not on operator-machine interfaces or human factors performance related issues, deficiencies or concerns.

DLR 3 and DLR 10 Staff Officers are responsible for identifying armoured fighting vehicle and crew clothing and equipment capability deficiencies and for recommending system requirements and implementing projects to overcome these deficiencies. An examination of files held by DLR 3 and DLR 10 suggests that there is no systematic mechanism for identifying deficiencies with vehicles or crew clothing and equipment.

While the Soldier System group (DSSPM) have created ACCESS to gather user information on dismounted clothing and equipment, there is no comparable system to collect information on vehicle or mounted crewman clothing and equipment deficiencies. ACCESS has been successfully used to identify deficiencies with clothing and equipment, to set priorities for future development efforts. DLR has used the results of ACCESS and its precursors to identify where to focus its limited R&D efforts to achieve maximum benefit for the Land Forces. ACCESS is a proactive system and its survey results provide staff officers with valid and defensible information to support decisions.



Recommendations

To support staff officers in the identification and quantification of capability deficiencies with armoured fighting vehicles and with related mounted soldier personal equipment and clothing related clothing the following steps are recommended:

1. Develop a database that collates and consolidates recognized engineering and safety deficiencies of armoured fighting vehicles, by vehicle or appropriate family of vehicles. Sources to include but should not be limited to the following:
   - UCR system
   - Safety investigations
   - Ad hoc equipment trials i.e., Trials and Evaluation (T&E) reports; DCIEM, DREV, DRES reports; contractor reports, etc.
2. Develop a database that collates and consolidates the operational deficiencies of armoured fighting vehicle by vehicle or appropriate family of vehicles. Sources to include but not be limited to the following:
   - Exercise after action reports (AAR)
   - Mission after action reports
   - Visit Reports
   - Allied Nation lessons-learned reports, i.e. Leopard Club, USMC (LAV), Australia (LAV), US Army Lessons Learned Center, etc.
3. Develop an Armoured Fighting Vehicle - Army Combat Clothing and Equipment Survey System (AFV-ACCESS). Use this survey system to gather information on user concerns with armoured fighting vehicles and mounted soldier combat clothing and equipment. While this system can be used to survey the current state of the armoured fighting vehicle fleet, it could also be used to support mission and exercise after action reports.

Research and Development Program

The following R&D efforts will resolve a number of AFV program deficiencies. These efforts are aimed at supporting the new SOR process in the area of capability deficiencies. Economies of scale are reflected in the following estimates, and these estimates assume a coordinated project throughout. Based upon similar experience, it is estimated that the following five (5) tasks could be completed in 12 - 15 months of concerted effort.

1. Review Applicability of AFV-ACCESS. Develop proof of concept questionnaires and determine distribution matrix. Sample questionnaires to include:
   - Fleet level
   - Vehicle level
   - Vehicle Subsystem level, i.e.
     - Turret
     - Drivers station

- Clothing and Equipment level

Estimated contracting cost - $15K

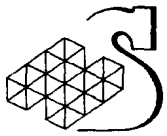
2. Construct and distribute the Fleet-level AFV-ACCESS questionnaire. This estimate assumes travel to four Armoured Regiment bases. Tasks to include:
   - Create/ refine Fleet-level questionnaire
   - Pilot Fleet-level questionnaire
   - Evaluate Fleet-level questionnaire and refine if necessary
   - Distribute Fleet-level questionnaire (full release)
   - Analyze results
   - Report results

   Estimated contracting cost - $15K
3. Construct and distribute the vehicle and clothing-level AFV-ACCESS questionnaires. This estimate assumes travel to four Armoured Regiment bases. The cost estimate assumes three (3) vehicle level questionnaires and five (5) equipment-level questionnaires. Tasks include:
   - Create/ refine vehicle-level questionnaire
   - Create/refine clothing & equipment-level questionnaires
   - Pilot vehicle and clothing questionnaires
   - Evaluate vehicle and clothing-level questionnaires and refine if necessary
   - Distribute vehicle and clothing -level questionnaires (full release)
   - Analyze results
   - Report results

   Estimated contracting cost - $50K
4. Conduct a series of focus groups with users to clarify feedback received from the AFV-ACCESS questionnaires.

   Estimated contracting cost - see Crewman's Day Database project
5. Develop a database to collate and consolidate operational and safety deficiencies with armoured fighting vehicles, crewman clothing and equipment. Database should be integrated/linked to the AFV-Crewman's Day. Establish mechanism to ensure that ACCESS, AFV-ACCESS, UCR, Safety reports, After-action reports, etc. are entered into the database on a quarterly basis. Tasks to include :
   - Develop the Crewman's day database
   - Identify existing safety, UCR, After-action reports, etc. for inclusion into the database
   - Enter reports on file into the database
   - Maintain the database (quarterly)

   Estimated contracting cost - see Crewman's Day Database project



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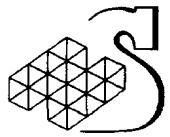


Scenarios

Background

Mission and scenario analysis help define the overall requirements of the system under development. Mission analysis is the first stage of system development defining system requirements, event profiles, operational environments, system constraints, and helps establish human factors design criteria. There are two analysis techniques involved in mission and scenario analysis:

- Narrative mission description
- Graphic mission profiles

Narrative mission descriptions describe the events of a mission in detail. The description describes in sufficient detail the mission phases, system functions, gross mission timings, and mission events (internal and external). For armoured fighting vehicles every mission will involve a number of combat functions. Combat functions include:

- Command
- Information operations
- Manoeuvre
- Protection
- Sustainment

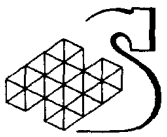
Graphic mission profiles describe system activities and mission events plotted against time and/or space. Most published mission profiles are for aircraft.

Although a number of operational scenarios have been developed for armoured fighting vehicles, the scenarios are limited in scope and duration.

Recommendations

Mission analysis is the first step for further human factors and engineering analysis. Development of validated missions and scenarios will impact on the following SOR efforts:

- Missions and scenarios
- Concept of operations
- Concept of support
- Key roles
- Key tasks
- User characteristics
- Performance capability
- Crew station and interface design
- Reliability



- Performance measures
- Personnel and training requirements

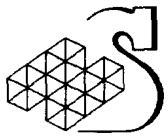
The details of the DPG, ACV OR, TBCS and ALFCS scenarios should be examined and a detailed set of validated scenarios should be developed. The scenarios /mission descriptions must reflect all functional -mission requirements that have been identified. Composite missions should be developed to identify all the unique mission activities identified, avoiding duplication of common activities. These missions should be/include the following:

- Longer duration
- Sustained operations
- Range of missions anticipated
- Integrated operations and logistics tasks

Research and Development Program

1. Develop a detailed set of scenarios. Tasks to include the following:
   - Obtain details of DPG, ACV OR, TBCS, ALFCS scenarios
   - Obtain details on any other relevant scenarios
   - Develop a framework for scenario analysis
   - Analyze scenarios
   - Develop missions/scenarios on likely concepts of operation and concepts of support. Scenarios to be/include:
     - Longer in duration
     - Contain sustained operations
     - Range of missions
     - Integrated operations and logistic tasks
   - Validate draft scenarios
     - Report results

     Estimated contracting cost - $50-75K
2. Develop detailed function flows/task flows of the missions and scenarios using computer software (IPME software recommended by DCIEM). Tasks to include the following:
   - Identify priorities for mission/scenario analysis and decomposition
   - Develop detailed scenario descriptions
   - Utilizing scenario descriptions, develop detailed function flows
   - Utilizing scenario descriptions, decompose functions into task flows
   - Validate function flows and task descriptions



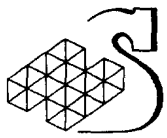
- Report results

Estimated contracting cost - $250 to $500K

Paper based descriptive analysis could be conducted as well at the lower end of this cost range, but if future computer based analysis was required it would have to be re-entered into the software. It is therefore cheaper to start with the software based analysis.

3. Update Vehicle Battlefield Day:
   - Link Vehicle battlefield Day to validated scenarios
   - Identify key tasks
   - Identify environmental demands
   - Identify performance criteria
   - Validate Vehicle Battlefield Day
     - Report results

   Estimated contracting cost - $50K



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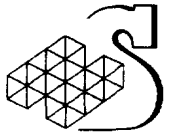


Task Performance

Background

Task analysis describes and analyzes the performance demands made on humans in a system, with a goal of providing a basis for integrating operators, machines and software into a successful man-machine system. Task analysis provides the basis for measuring system performance, as well as designing and developing effective systems and training requirements. Task analysis techniques include observing behaviour and eliciting information on non-observable or cognitive behaviour through interviews

Task analysis includes a number of steps and these include:

- System description and analysis
- Task description
- Analysis, interpretation

While tank gunnery tasks and some reconnaissance tasks have been examined in detail, few other armoured vehicle tasks have been analyzed. Frequently task analysis has been limited to discrete system functions and tasks (engagement and surveillance tasks) and have not examined other tasks which occupy the bulk of the operators time i.e. maintenance, replenishment, camouflage and concealment, etc.

While the Armour Corps has detailed battle task standards, these standards are primarily higher-level task descriptions with general baseline performance requirements.

Recommendations

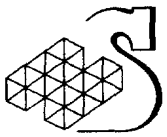
Task performance

To support further research and analysis efforts (interface design, human error framework, performance measures, training design, selection, etc.) detailed task analysis should be performed. Areas for investigation include:

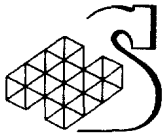
1. Operational tasks, e.g.
    - Command and control tasks
    - Target detection and tracking tasks
    - Reconnaissance tasks
    - Vehicle guidance tasks
2. Maintenance tasks
3. Replenishment tasks
4. Survivability tasks

Performance Measures

While task analysis will describe and analyze tasks, the development of desired performance levels is a function of overall mission and task goals. The Armour Battle task standards primarily deal with mission success and are not directed at performance goals per-se. Development of baseline performance measures will assist researchers and developers in the design or evaluation of future fighting systems. Areas for investigation include:



1. Develop a core set of performance measures from literature for the following tasks:
   - Command and control tasks
   - Target detection and tracking tasks
   - Reconnaissance tasks
   - Vehicle guidance tasks
   - Maintenance tasks
   - Replenishment tasks
   - Survivability tasks
2. Develop gunnery performance measures using ALFCS (first for vehicle level and then extend to troop level)
3. Validate measures
   - Previous experiments
   - Trials
4. Identify performance levels using validated measures, i.e.
   - Quantitative score
   - Reaction time
   - Task duration
   - Task completion rates
   - Classification of errors
   - Error frequency
   - Time spent in error
   - Task success
   - User satisfaction
5. Identify performance measurement tools for collective tasks. Development of vehicle, troop and squadron level performance measures suggests the need for acquiring weapons effect simulators. These tools will allow investigators to quantify performance.
6. Identify performance shaping factors:
   - External performance shaping factors, i.e.
   - Environmental conditions
   - Work space and work layout
   - Poor interface design
   - Inadequate training and job aids



- Poor supervision
    - Internal performance shaping factors, i.e.
- Training /experience
- Stress level
- Fatigue level
- Perceptual abilities
- Social factors
- Physical condition
- Strength/endurance
- Gender differences
- Skills fading
- Psychological state (emotional state, motivation, attitude)

Research and Development Program

The following R&D efforts will support parallel efforts. These efforts are aimed at supporting the new SOR process in the area of concept of operations, concept of support, key roles, key tasks, user characteristics, crew station design, user interface, maintenance task performance, reliability, sub-system effectiveness, and personnel and training requirements. Economies of scale are reflected in the following estimates and are based upon parallel development of operational scenarios and the development of validated performance measures.

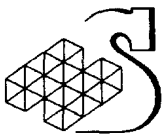
1. Develop and validate operational scenarios:
    - Develop scenarios on likely concepts of operation and concepts of support
    - Validate scenarios with representative users.
    - Analyze results
    - Report results

Estimated contracting cost - covered under Scenarios.

2. Develop function flows and task flows:
    - Develop function flows based on scenarios developed
    - Develop task flows based on scenarios developed
    - Validate function and task flows
    - Report results

Estimated contracting cost - covered under Scenarios.

3. Develop Battle Task Standards
    - Conduct task analysis for critical tasks



- Refine existing Battle task Standards for current systems
- Extend Battle Task Standards for new and future systems
- Identify performance measures
- Develop performance standards (not just pass/fail)
- Identify performance shaping factors
- Validate Battle Task Standards
    - Focus groups
    - Field trials and experiments
- Analyze results
- Report results

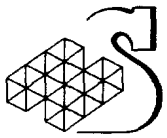
Estimated contracting cost - $200K

4. Develop Task Performance Acquisition Tools - WES
    - Analyze requirement for collective performance measurement tools
    - Develop performance requirements for data collection tools
    - Identify available tools and assess the suitability of these tools for performance assessment
    - Acquire tools for pilot testing
    - Validate tools for performance assessment
        - Field trials and experiments
    - Analyze results
    - Report results

Estimated contracting cost - $25k

5. Update Crewman's Day
    - Update SOR's "Battlefield Day"
    - Link to scenarios, accurate task descriptions and performance criteria for critical tasks
    - Update Crewman's Day database

Estimated contracting cost - $50K



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Crew Characteristics

Background

In order for bidders to successfully predict the performance of their proposed system they must have a clear understanding of the abilities and characteristics of the proposed operators and maintainers. CF operators are unique in their combination of size range, gender, training, skills and experience. For example, to date the opening of the armour trades and classifications to females has had limited, if any, impact on operations, due to their few numbers. The operational impact of gender equality on concepts of operations and concepts of support may be significant if the future mix significantly changes, i.e. 25% females in a squadron. A comprehensive description is required of the capabilities of future armour operators and maintainers, covering anthropometry, medical standards, selection, training and experience.

Armour Crew Anthropometry

DCIEM recently completed the 1997 Anthropometric Survey of the Land Force examining 708 Land Force males and females. While this survey examined 708 personnel, only 44 crewmen and women were measured. Due to the unique workstation demands imposed in armoured vehicles, the results of 1997 Anthropometric Survey of the Land Force should be examined to see if it is representative of the Armour Corps.

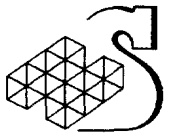
In 1996 DCIEM sponsored the development of a SAFEWORK Clothing module. Users were measured for girths and lengths, semi-nude and again while wearing successive layers of combat and winter clothing. Due to limitation in the supporting documentation it is uncertain if the girths registered were functional circumferences or maximal girths without compression. Clash algorithms within the SAFEWORK man model may be too conservative if functional girths were not registered (currently Leopard C1 gunners can squeeze into their gunner station wearing a winter parka). Clash limits predicted by the SAFEWORK clothing module should be compared to physical test results.

Minimum Medical Standards

Currently there are a number of minimum medical standards for entry and retention of crew persons in the Canadian Forces. These have been used for vehicle design guidelines, since any equipment/interface which can accommodate the worst case, will also accommodate the remainder of the population. While these minimum standards may have been relevant with past and current in-service equipment, they may limit the effectiveness of future technologies and systems.

Colour Vision

Colour vision may be an important factor to consider in the design of new equipment and interfaces for armoured vehicle crews. Canadian Combat Arms personnel are permitted to be colour defective-safe (CDS), failing the pseudoisochromatic colour plate test, and all except a few soldier trades (Artilleryman, Field Engineer, Lineman) are permitted to be colour defective-unsafe (CDU), failing both the plate test as well as the Holmes-Wright Colour Perception Lantern Test. Designing for the latter (CDU) should



accommodate the entire soldier population, but in view of this limitation, it is essential designers use colour only as a redundant coding mechanism. The use of new displays, digital maps etc may mean that armour crews may have to be CDS or better.

Hearing

The minimum hearing standard/category for soldiers in the Canadian Forces is H3 (hearing loss not greater than 30 dbs in the better ear in the 500 to 2000 cps frequency range). Designing to accommodate H3 category personnel should accommodate the vast majority of the CF soldier population, although auditory acuity, on its own, may not be an adequate predictor of communications effectiveness. The use of multiple warning tones (> 19) for the new TCCCS radio system and the use of multiple tones for proposed gunnery subsystems suggests the need to re-examine the hearing requirements for armour crewmen. Future use of 3D audio (if relevant) would also be impacted by these user characteristics.

Development of Selection Techniques for Armour Crew Persons

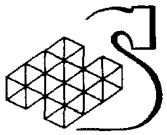
Current procedures for selecting armour crew persons are based primarily on the Canadian Forces Classification Battery (CFCB) and minimum medical conditions. This battery of tests was developed and validated with Canadian Forces personnel in military settings to predict success in Canadian Forces soldier trades/occupations. Due to changing tasks demands it is not known if these tests will predict crew success in future fighting vehicles.

Additionally, the cost of training failures amongst armour crews (including officers) is significant given the current financial restraints being imposed on the Canadian Forces. These factors suggest the need to examine current selection techniques and the need to explore the development of better predictors of armour crew success.

Selection Battery for Armour Crew Persons

The United States Army uses a variety of tests for the selection of their armour crewmen. These include the Armed Services Vocational Aptitude battery (ASVAB), PULHES scores and MEPSCAT ratings. The U.S. Army's MANPRINT (MANpower and PeRsonnel INTegration) program uses these soldier characteristics in the IMPRINT tool. IMPRINT, developed by the Human Research & Engineering Directorate of the U.S. Army Research Laboratory, is a stochastic network modeling tool designed to help assess the interaction of soldier and system performance throughout the system lifecycle—from concept and design through field testing and system upgrades. IMPRINT can be used as a system design and acquisition tool, to help set realistic system requirements; to identify soldier-driven constraints on system design; and to evaluate the capability of available manpower and personnel to effectively operate and maintain a system under environmental stressors. As a research tool, IMPRINT incorporates task analysis, workload modeling, performance shaping and degradation functions and stressors, and embedded personnel characteristics data. Using embedded algorithms, IMPRINT models the effects of personnel characteristics, training frequency, and environmental stressors on the overall system performance.

While Canada can obtain the U.S. Army's IMPRINT tool for examining armour tasks, vehicles and vehicle subsystems, the underlying personnel (crewmen and maintainers) characteristics are based on different metrics. Canada uses the Canadian Forces Classification Battery (CFCB), while the U.S. Army uses the Armed Services Vocational Aptitude battery (ASVAB), PULHES scores and MEPSCAT ratings. Investigation into the similarities and differences between Canadian and U.S. armour personnel may permit the use of this system design tool.



Recommendations

To support staff officers in the identification and quantification of crew characteristics, the following steps are recommended:

1. Conduct a study to forecast the future impact of gender equality on operations and maintenance and associated OPCON/OPSUP.
2. Validate the 1997 Anthropometric Survey Land Force Survey to see if it's directly applicable to the Armour Corps.
3. Examine the applicability of the SAFEWORK clothing module for AFV design.
4. Examine the impact of the minimum medical colour vision standard for armour crew personnel vis-a-vis CRT based tactical maps, weapon sights, displays etc.
5. Examine the impact of multiple auditory warning tones in the AFV environment.
6. Use mission scenarios and task flows to analyze concepts of operations and concepts of support to estimate changes in armour crew skills and personnel characteristics.
7. Examine armour crew selection practices to identify better predictors of training and operational success.
8. Compare Canadian armour selection standards against U.S. army and U.K. selection standards. Examine the feasibility of utilizing existing human factor tools, i.e. IMPRINT with Canadian data.

Research and Development Program

The following R&D efforts will resolve a number of outstanding research areas in characterizing armour crew personnel. These efforts are aimed at supporting the new SOR process in the area of crew characteristics. Economies of scale are reflected in the following estimates, and these estimates assume a corresponding effort in related projects.

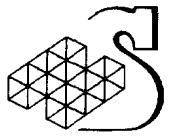
1. Conduct a study to forecast the future impact of gender equality on operations and maintenance and associated OPCON/OPSUP.

   DCIEM R&D Project or estimated contracting cost - $60K

2. Validate the 1997 Anthropometric Survey Land Force Survey to see if it's directly applicable to the Armour Corps.
   - Compare the armour personnel sub-sample across the entire Land Force Survey
   - If required, conduct an anthropometric survey of the Armour Corps
   - Analyze results
   - Report results

   DCIEM R&D Project or estimated contracting cost - $95K

3. Examine the applicability of the SAFEWORK Clothing Module for AFV design. Tasks to include:
   - Detail the Clothing Module measurement methods



- Examine the clash limits predicted by the SAFEWORK Clothing Module for known vehicles and measured subjects
- Analyze results
- Report results

DCIEM R&D Project or estimated contracting cost - $50K

4. Examine the impact of the minimum medical colour vision standard for armour crew personnel vis-à-vis CRT based tactical maps, weapon sights, displays etc.:

   DCIEM R&D study

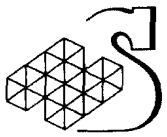
5. Examine the impact of multiple auditory warning tones in the AFV environment. Task to include:
   - Examine medical hearing standards and AFV and TCCCS warning tones
     - Utilize scenarios and missions to examine structure for alerts
     - Examine physical emitters and resulting tones
   - Develop tone strategy for the AFV environment
     - AFV
     - AFV sub-systems
     - Communication system

   DCIEM R&D Project or estimated contracting cost - $50K

6. Use mission scenarios and task flows to analyze concepts of operations and concepts of support to estimate changes in armour crew skills and personnel characteristics. Tasks to include :
   - Identify existing armour crew skill and personnel characteristics
   - Develop future concepts of operation and concepts of support
   - Examine effects of future concepts of operation and concepts of support on required personnel skills and staffing
   - Analyze results
   - Report results

   Estimated contracting cost - $50K

7. Examine armour crew selection practices to identify better predictors of training and operational success. Tasks to include :
   - Identify existing armour crew selection practices
   - Identify job criterion measures
   - Analyze selection practices personnel vis-à-vis training and operational success
   - If required, identify potential armour crew selection procedures
     - New selection test battery



- Armour crew selection board (similar to aircrew selection board)

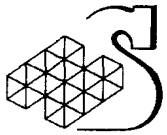
- Examine predictiveness of new selection procedures
- Analyze results
- Report results

Estimated contracting cost - $250K

8. Compare Canadian armour selection standards against U.S. army and U.K. selection standards. Examine the feasibility of utilizing existing human factor tools, i.e. IMPRINT with Canadian data. Tasks to include :

   - Identify existing minimum armour crew selection test scores from the Canadian Forces Classification Battery (CFCB)
   - Identify existing minimum armour crew selection test scores from U.S. and U.K selection test batteries
   - Examine feasibility of converting Canadian armour crew test scores into U.S. equivalents.
   - Examine feasibility and utility of using IMPRINT for s a system design and acquisition tool, specifically to assess crew-driven constraints on system design; and to evaluate the capability of available manpower and personnel to effectively operate and maintain armour systems under environmental stressors.
   - Analyze results
   - Report results

   Estimated contracting cost - $75K



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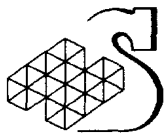


AFV and Subsystem Performance

Background

The determination of requirements for AFV's (vehicle level performance), technology based subsystems (fire control, defensive aids, C2 systems, sensors), and their associated operator machine interfaces (visual and auditory displays, display integration concepts) is an area that must be supported by ongoing research. R&D is required to anticipate future requirements for these types of systems, but also to evaluate the potential impact of new technology and technology integration on armour system user performance.

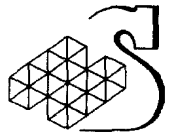
Currently these issues are investigated through programs such as the Advanced Land Fire Control System (ALFCS) project, or field trial based programs such as the Defensive Aids Suite international Pronghorn trial.

Recommendations

There are not really any R&D activities in this regard that can be identified as "HSI driven" R&D like the other areas outlined in this section. Instead this class of R&D tends to originate with the technology centred R&D programs and must include an HSI component in order to determine future requirements related to human task performance, personnel levels, training, safety, and health hazards. Specific recommends to support this line of analysis include:

1. Continue to support ALFCS type studies. These studies should explore a range of issues related to human performance, including:
   - Fire Control System (FCS) -Battlefield Management System (BMS) integration,
   - Fire Control System / Battlefield Management System / Vetronics integration,
   - New Sensors,
   - Displays for Hatch Closed Operation and Situational Awareness (SA),
   - Cordless Communication concepts,
   - Helmet or Head Mounted Display (HMD) concepts.
2. Continue to take prototypes to field trials (eg: Pronghorn). Prototypes evaluated for future AFV systems should focus on FCS-BMS integration and more systematic evaluation of HMDs under a range of operational conditions.
3. All studies should extend analysis to the Troop and Squadron level for performance, workload, SA, etc. as this is where future systems will need to impact and where personnel and training issues will be felt. This may require linked simulators or more field trials.
4. All experiments should include any new crew or staffing concepts being considered or implied by the design of a proposed system (eg: 2 person turrets).
5. Some trials in simulators or the field should be conducted over longer periods to evaluate the full impact of new concepts on sustained operations, maintenance, and support.

Studies could/should explore alternate Concepts of Operatoin such as using multiple crews per AFV.



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Mounted Warriors Day

Background

To effectively design new Canadian Forces' clothing and equipment, all participants in the acquisition cycle and development process must possess a sufficient understanding of the soldier system. This understanding includes information about current clothing, equipment, weapons, user characteristics, tasks performed, relevant human factors and military references, related compatibility implications and the role of human factors in procurement. "A Soldier's Day" is a tool developed to provide a common basis of understanding about soldiers and the tasks that they are required to perform.

While, information on dismounted soldiers is contained in the Soldier's day database, the database contains little information on mounted operations. Mounted soldiers include:

- Armour crewmen
- Sensor operators
- Drivers
- Infantry AFV crewmen
- Turret crews
- Infantry passengers
- Engineer AFV crewmen
- Artillery AFV crewmen

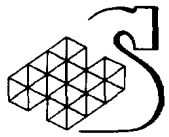
Infantry section carriers constitute the majority of Canada's AFV fleet thus; the unique needs of mounted infantrymen need to be addressed.

Recommendations

A scoping study for expanding the Soldier's Day database to include mounted infantrymen was completed in 1998. Although recognized as a desirable follow-on product, priority was given to developing an Anthropometric Module for Soldier's Day. If view of its direct connection to Armoured Fighting Vehicles it is recommended that the Soldier's Day database be expanded to include mounted riflemen.

Research and Development Program

1. Phase I of the Mounted Warrior's project will be to determine the data acquisition requirements for including mounted operations information into the Soldier's Day (SD) database. Tasks to include:
    - Determine data acquisition requirements
    - Identify sources of information
        - Text



- Photographs and video
- R&D reports
- Internet
- Focus groups, questionnaires

- Identify data requirements
  - Clothing and equipment
  - Vehicles
  - Organizational structure
  - Mission and tasks
  - Activities
- Identify the required modifications to the Soldier's Day database

2. Phase II will address the actual acquisition and integration of the information into the Soldier's Day database. This will include the review, formatting, entry, and validation of the data. Tasks to include:
   - Identify sources of information
   - Format data
   - Enter data into database
   - Build associations (internal links)
   - Validate data

   Estimated contracting cost for Phases I and II - $85K

Crewman's Day

Background

To effectively design new Canadian Forces' clothing and equipment, all participants in the acquisition cycle and development process must possess a sufficient understanding of the soldier system. This understanding includes information about current clothing, equipment, weapons, user characteristics, tasks performed, relevant human factors and military references, related compatibility implications and the role of human factors in procurement. "A Soldier's Day" is a tool developed to provide a common basis of understanding about soldiers and the tasks that they are required to perform.

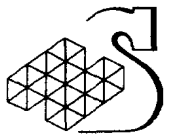
Uses for such a collection of information are not confined to Human Factors applications. Technical staff, trainers, or product manufacturers may also use the database to gain insight into Infantry operations. In general, A Soldier's Day supports the user in identifying:

- characteristics of in-service clothing, equipment and weapons;
- the organizational structure of military units;
- typical tasks and activities undertaken by soldiers in different military roles within those units;
- human factors affecting performance for given combinations of organization, task, clothing, equipment, and weapons.
- function and task flows of attack, defence, and patrolling tasks
- anthropometry (based on the 1997 Land Force Survey)
- soldier's load

The database information is separated into five main areas including clothing and equipment, organizational structure, missions and tasks, reference materials, and human factors basics. The database currently contains information addressing the dismounted infantryman. It covers missions, tasks and activities performed in Conventional or Nuclear, Biological and Chemical (NBC) warfare as well as in a Peacekeeping role. The multi-media format allows for the inclusion of video, audio, photographs, tables, diagrams, schematics and text to enhance the user's ability to explore and experience the "Soldier's Day". Navigation is conducted from a browse screen. The browse screen allows the user to view and hear multimedia representations of information on a selected topic. The browse screen also lists items that may be associated to the selected item. These associated items help to guide the user in developing an understanding of the equipment, tasks, activities, and user characteristics involved in the soldier system.

Recommendations

An enhanced Soldier's Day database- Crewman's Day has the potential consolidate the various data streams that contribute to armoured vehicle SORs. The Crewman's day database can expand on the Soldier's Day database by adding vehicle and vehicle subsystems, deficiency reports, heath and safety reports, performance measures, etc. While Crewman's Day will consolidate information utilized in an SOR, a separate module is recommended to link the information from Crewman's Day into an SOR template.



Research and Development Program

The following R&D efforts will support the development of a Crewman's Day and a tool for SOR production. These efforts are aimed at supporting the new SOR process in the area of concept of operations, concept of support, key roles, key tasks, user characteristics, crew station design, user interface, maintenance task performance, reliability, sub-system effectiveness, and personnel and training requirements. Economies of scale are reflected in the following estimates and are based upon the need to accommodate related data (health and safety, vehicle deficiencies, performance measures, etc.)

1. Convert Soldier's day into a Web-based tool:
   - Determine user requirements
   - Develop concept design
   - Conduct preliminary and detailed design
   - Test and evaluate design
   - Analyze results
   - Report results

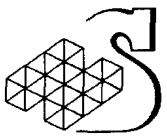
   Estimated contracting cost - $100K

2. Develop an SOR Module:
   - Determine user requirements
   - Develop concept design
   - Conduct preliminary and detailed design
   - Test and evaluate design
   - Analyze results
   - Report results

   Estimated contracting cost - $100K

3. Populate the Crewman's Day database -(Armour Corps Vehicles, the parallel Mounted Warrior's day will accommodate mounted infantrymen.)
   - Determine data acquisition requirements
   - Identify sources of information
   - Identify data requirements
   - Acquire data
   - Format data
   - Enter data into database
   - Make associations to items

   Estimated contracting cost - $115K



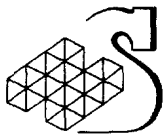
4. Develop stowage models for Crewmans Day.
   - Identify vehicle kit lists
   - Identify combat loads
   - Identify crew sustainment loads
   - Identify crew personal kit loads
   - Identify passenger equipment loads
   - Identify required passenger lift loads
   - Develop compressed load volumes
   - Digitize compressed load shapes
   - Translate files into format suitable for SAFEWORK®

   Estimated contracting cost - $100K
5. Validate the Crewman's Day database
   - Validate data
   - Conduct usability trials
   - Edit database as required

   Estimated contracting cost - $25K
6. Update Crewman's Day
   - Update SOR's "Battlefield Day"
   - Link to scenarios, accurate task descriptions and performance criteria for critical tasks
   - Update Crewman's Day database

   Estimated contracting cost - see Scenario and mission analysis
7. Develop a maintenance program for the Crewman's Day
   - Continual update of information
   - Edit data items as required

   Estimated contracting cost - $??K



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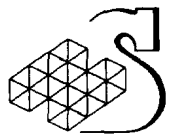


Crew Station Modeling

Background

Incorporation of new battlefield management tools, navigation aids, defensive aid displays will all compete for limited turret space. Ability to place representative human models in electronic turrets will allow developers to optimize system design.

Equipment stowage in armoured fighting vehicles is always a critical concern. The ability to stow ammunition, rations, water, mission essential kit etc. is limited. The ability to better utilize available space for equipment stowage and still allow easy access is a problem.

DND currently possesses a number of CADD tools for investigating and designing vehicle workstations. These tools include:

- AutoCADD
- Intergraph's I-EMS
- Intergraph's Microstation
- Pro-Engineer.

Several HF CADD tools are commercially available for use in DND. DND has access to the old SAMMIE man model via a ties contract with the Canadian Marconi Company (CMC). While SAMMIE has a significant number of limitations, it has been coupled to sonic digitization in the HEART tool to model airforce cockpits.

DCIEM currently possesses the sophisticated SAFEWORK® human modeling program by Genicom. SAFEWORK® provides 3D modeling of fully enfleshed anthropometric mannequins. The incorporation of the 1997 Land Force Survey allows SAFEWORK® to model Canadian Land Force personnel based on the latest anthropometric survey. SAFEWORK® can analyze CAD designs imported from CAD formats.

Recommendations

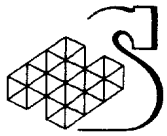
In order to evaluate vehicle workstations, CAD drawings of vehicles and vehicle workstations should be acquired from vehicle manufacturers or developed using laser or sonic digitization techniques. These drawings must be in a suitable 3D CADD format for importation into SAFEWORK®. This will allow designers, engineers and human factors experts to conduct analysis.

Research and Development Program

The following R&D efforts will support research in vehicle crew station modeling. These efforts are aimed at supporting the new SOR process in the area of crew station design in the SOR sub-system requirements area.

8. Identify an appropriate CADD system for vehicle workstation modeling.

   Estimated contracting cost - $5k



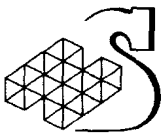
9. Identify vehicle and vehicle workstations for modeling in CAD.
    - Vehicle turrets
        - Gunner station
        - Commanders station
    - Drivers station
    - Passenger station

    Estimated contracting cost - $15K
10. Acquire 3D models of vehicle workstations.
    - Obtain electronic CADD files from vehicle manufacturers
    - Translate files into format suitable for SAFEWORK®

    Estimated contracting cost - $25k
11. Develop 3D models of vehicle workstations for modeling.
    - Identify suitable digitization methods
    - Digitize vehicle workstations
    - Translate files into format suitable for SAFEWORK®

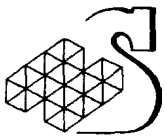
    Estimated contracting cost - $150k
12. Develop stowage models for each vehicle.
    - Identify vehicle kit lists
    - Identify combat loads
    - Identify crew sustainment loads
    - Identify crew personal kit loads
    - Identify passenger equipment loads
    - Identify required passenger lift loads
    - Develop compressed load volumes
    - Digitize compressed load shapes
    - Translate files into format suitable for SAFEWORK®

    Estimated contracting cost - see Crewmans Day
13. Examine the applicability of the SAFEWORK® Clothing Module for AFV design. Tasks to include:
    - Detail the Clothing Module measurement methods
    - Examine the clash limits predicted by the SAFEWORK® Clothing Module for known vehicles and measured subjects



- Analyze results
- Report results

DCIEM R&D Project or estimated contracting cost - $50K



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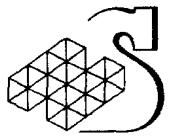


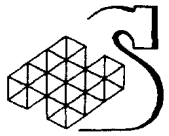
Threat Studies

Background

Mission and scenario descriptions describe in detail mission phases, system functions, gross mission timings, and mission events (internal and external). External events include threats to the vehicle and to the vehicle's crew. Knowledge of these threats helps guide any necessary design trade-offs later in development. Threats include:

- Ballistic
  - Fragments
  - Direct fire
- Blast
- Fire and flame
- NBCW
  - Chemical
  - Biological
  - Nuclear
- Environmental
  - Wet
  - Temperature and humidity
  - Solar
- Directed energy
  - Laser
- Noise
  - Impulse
  - Steady-state
- Mechanical
  - Puncture
  - Blunt impact
  - Vibration
  - Shock

A review of the literature suggests that most threat analyses for AFVs are vehicle oriented. DREV has purchased/developed a number of threat models and has conducted a number of trials investigating blast and fragmentation effects on vehicle passengers. Overall, personal threats to crew personnel outside and inside the vehicle are poorly described.



These threats define the requirements for personal protective items, i.e. body armour, flame retardant crew suits etc. While these threats could be linked to health and safety issues, health and safety issues are by definition related to systems generated threats.

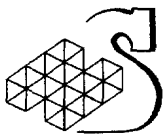
Recommendations

Based on the mission and scenario analysis develop a valid matrix of personal threats outside and inside AFVs.

Research and Development Program

1. Based on validated missions and scenarios develop a matrix of vehicle and crew threats:
    - Obtain details of validated mission and task scenarios
    - Identify and quantify probable threats for crews outside their vehicles
    - Identify and quantify probable threats for crews inside vehicles (hatches open)
    - Identify and quantify probable threats for crews inside vehicles (hatches closed)
    - Identify and quantify secondary threats to crews as a result of hull breach
    - Validate threat lists
    - Analyze threats
    - Develop priorities for enhanced protection
        - Report results

DRDB R&D Project or estimated contracting cost - $??K



Safety and Health

Background

There are several occupational health and safety standards for the development and fielding of military-unique equipment, armour systems, sub-systems and military operations. DCIEM and CFEME have been involved in evaluating existing systems (noise and vibration trials, toxicity trials, general safety, etc.) and in recommending health and safety requirements in vehicle SORs.

Unlike the U.S., Canada does not possess a mandated health hazard assessment program for the support of equipment acquisition programs. However, there are CF guidelines for Specification Preparation (D-01-300-100/SG-000 79-08-01, Interim) that make specific provision for "Safety, toxicity, caution, decontamination etc." to be addressed in the system specification. In addition, when requested, CFEME and DCIEM have been involved in health and safety audits of vehicle systems and have provided feedback to vehicle SORs. Areas of investigation and SOR comment have been in the following areas:

- Acoustical energy
- Chemical substances
- Oxygen deficiency
- Shock (acceleration/deceleration)
- Temperature extremes and humidity
- Trauma
- Vibration

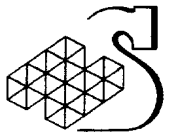
Coordination of SOR comments within DCIEM and CFEME has been through the project point of contact in the Human Engineering sector. The extent of other DRDB lab involvement in health and safety audits and SOR comments is unknown.

While a number of health and safety audits have been conducted on armoured fighting vehicles within Canada and amongst our NATO allies, there is no central point of consolidation or information dissemination to project teams.

U.S. Health Hazard Assessment Program

In the U.S. the Army Medical Department (AMEDD) organizations provide Health Hazard Assessment (HHA) support to system developers. Three components of the AMEDD, the Office of the Surgeon General, (OTSG), the U.S. Army Health Services Command (HSC), and thew U.S. Army Medical Research and Development Command (MRDC), exercise major roles in implementing this program.

- OTSG – establishes policy and central coordination
- HSC – provides HHA support
  - Medical input into requirements documents
  - Performs HHAs



- Provides input to safety documents
- Human Factors Engineering Analyses

- MRDC – conducts biomedical research to support HHA requirements
  - Assists in the conduct of HHAs

HHA reports (HHAR) are required for each material system, component, item and product improvement (including non-developmental items). The HHAR provides a standard structure for assessing systems-generated threats to the health of crewmembers, maintainers, trainers, and other troops. HHA activities are integrated throughout all phases of a systems development and acquisition cycle.

The Health Hazard assessment categories addressed by the U.S. HHA program include:

- Acoustical energy (steady-state noise, impulse noise, and blast overpressure)
- Biological substances (pathogenic microorganismms and sanitation)
- Chemical substances (weapon or engine combustion products and other toxic materials)
- Oxygen deficiency (crew/confined spaces and high altitude)
- Radiation energy (ionizing and non-ionizing radiation, including lasers)
- hock (acceleration/deceleration)
- Temperature extremes and humidity (heat and cold injury)
- Trauma (blunt, sharp, or musculoskeletal)
- Vibration (whole body and segmental)

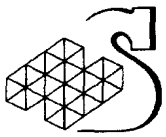
Recommendations

To support staff officers in the identification and mitigation of armour system health hazards, the following steps are recommended:

1. Develop a mechanism to track safety and health issues with current systems, and develop a method to present the information to project teams
2. Examine the desirability of developing a coordinated HHA program.
3. Critically examine the U.S. HHA program to see if it is suitable in structure for adoption by Canada.
4. Develop a formal Canadian Forces Health Hazard Assessment Program.

Research and Development Program

The following R&D efforts will resolve a number of outstanding coordination and research issues with Heath Hazard Assessment in armour systems. These efforts are aimed at supporting the new SOR process in the areas of heath and safety.



1. Develop a database to collate and consolidate health and safety deficiencies with armoured fighting vehicles, crewman clothing and equipment. Database should (must) be integrated/linked to the AFV-Crewman's Day:

   Estimated contracting cost - see Crewman's Day Database project

2. Establish mechanism to ensure that health and safety reports, related research reports, etc. are entered into the database on a quarterly basis. Tasks to include :
   - Identify existing health and safety reports, etc. for inclusion into the database
   - Enter reports on file into the database
   - Maintain the database (quarterly)

   Estimated contracting cost - see Crewman's Day Database project

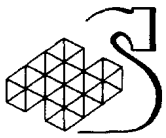
3. Examine the desirability of developing a coordinated and integrated HHA program in Canada
   - Conduct a stakeholder review
     - CHS
     - DRDB
     - Requirements staffs
     - Engineering staffs
   - Analyze results
   - Report results

   DCIEM and CHS Project or estimated contracting cost - $20K

4. Review the U.S. Health Hazard Assessment Program. Tasks to include:
   - Examine HHA policy and organization
   - Examine program documentation and coordination efforts
   - Examine HHA Tools in the nine assessment categories
     - Heath standards
     - Biomedical databases
     - Prediction models
     - Protection technology
     - Assessment and monitoring methods
   - Examine HHA resolution process
   - Report results

   DCIEM and CHS Project or estimated contracting cost - $25K

5. Utilize the nine U.S. HHA categories as areas for inclusion in the SOR template.



DCIEM and CHS

6. Develop an integrated and coordinated Canadian HHA program. Tasks to include:
    - Examine the applicability of using the U.S. Health Hazard Assessment categories in a Canadian HHA program.
    - Develop a HHA program
        - CF Policy
        - Coordination
        - Administration
        - Responsibilities and reporting structure
    - Identify required resources
        - Program administration and coordination (CHS)
        - Lead agencies/labs for assessment categories
    - Identify and acquire if necessary, HHA tools
        - Heath standards
        - Biomedical databases
        - Prediction models
        - Protection technology
        - Assessment and monitoring methods

DCIEM and CHS

Human Error Framework

Background

Vehicles and vehicle sub-systems continue to improve in performance and reliability. As vehicle systems improve in equipment reliability, the percentage of system failures due to electro-mechanical faults decrease while the percentage of failures resulting from human error increases. For complex tank gunnery systems the human operator is one of the main sources of error resulting in missed targets. Most errors are unintentional, inadvertent actions that are inappropriate in the given task situation. Human error can be studied independently of its consequences and factors that increase or decrease errors can be studied. The impact of errors however, is task dependent.

Reliability, as defined by Meister (1966) is "the probability that a job or task will successfully be completed by personnel at any required stage in system operation within a required minimum of time (if the time requirement exists)" is the antithesis of error likelihood. The aim of performing human reliability analysis is to identify human error, identify the consequences of error, identify performance shaping factors – internal and external that contribute to errors and finally to recommend practical solutions for reducing error.

Development of a human error framework for armour crew tasks will identify areas for improvement, i.e. modify tasks, change procedures, change equipment design, improve training, etc.

Recommendations

To quantify and qualify areas for improvement in crew reliability the following steps are recommended:

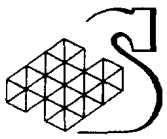
1. Develop scenarios based on likely concepts of operation and concepts of support
2. Describe system goals and functions of interest.
3. Describe task responsibilities and identify criteria for success
4. Analyze tasks for potential human errors
5. Estimate the likelihood of potential human errors
6. Estimate the consequences of human errors
7. Recommend changes to improve system/task performance.

Research and Development Program

The following R&D efforts will identify human error issues with armoured fighting vehicles. These efforts are aimed at supporting the new SOR process in the area of reliability. Economies of scale are reflected in the following estimates and are based upon parallel development of operational scenarios and the development of validated performance measures.

The human error framework for AFV tasks will developed at the following levels:

- operator level,



- vehicle level
- Troop leader level
- Squadron OC level

1. Tasks to identify the human error framework will include the following:
   - Develop scenarios on likely concepts of operation and concepts of support
   - Describe system goals and functions of interest.
   - Describe task responsibilities and identify criteria for success
   - Develop error framework
   - Study existing systems for any evidence that sources of error exist within this framework, through questionnaires, interviews, and analysis of any available task performance or safety/hazard data.
   - Analyze tasks for potential human errors
     - Potential and actual sources of errors
       - Active errors
       - Latent sources of error
   - Estimate the likelihood of potential human errors
   - Estimate the consequences of human errors
   - Recommend changes to improve system/task performance
     - Report results

   Estimated contracting cost - $40K

2. Incorporate human reliability values into any performance models developed:

   Estimated contracting cost - $??K

Crew Sustainment

Background

Considerable efforts are being undertaken around the world and within Canada in investigating ergogenic aids. Many of these ergogenic aids are being evaluated to examine their effects on physical performance, i.e. strength and endurance. While these aids will have a direct impact on individual conditioning, their benefits for armoured crew tasks is less well understood.

Preliminary results suggest that oral magnesium may be effective in lowering noise induced hearing loss. Thus, this mineral may have direct benefits for AFV crews and combat arms personnel in general.

Limited research is currently being conducted in the field of nutrition and rations. Recent efforts in Canada have primarily focused on the use of supplemental nutrient bars. Considering normal task demands, the need for unique rations is questionable, but due to stowage considerations in armoured vehicles, there may be a desire to reduce ration volume.

Within the U.S. there is a DOD Combat Feeding Program which is examining warfighter ration tailoring. This R&D effort has the following goals:

- 25% Weight Reduction
- Enhanced Eat-Out-Of-Hand
- Biosensors
- Non-thermal Shelf Stable Rations
- Computerized Ration Selection
- Extended Preservation
- Enhanced Physical Endurance

Efforts are underway within TTCP in investigating psychogenic aids. Psychogenic aids may have a direct impact on AFV-related tasks – command and control, gunnery, etc.

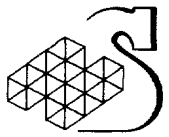
Efforts are underway inside and outside Canada in investigating anti-narcoleptic drugs (Modafinil) to enhance cognitive ability in sustained operations. Modafinil may have a direct impact on cognitive tasks during sustained operations involving sleep deprivation.

Recommendations

The armour community should support basic research on the impact of ergogenic, psychogenic and anti-narcoleptic aids. ALFCS and LVIGS may have a potential role in purported aid effects.

Research and Development Program

The following R&D efforts will support research in crew performance and nutrition. These efforts are aimed at supporting the new SOR process in the area of crew sustainment. Due to the "discovery" of new ergogenic aids, research and evaluation must be ongoing. DRDB has sponsored the development of a number of vehicle and gunnery simulators, which may be



particularly suited to support psychogenic and anti-narcoleptic aids research. DCIEM is the recognized Canadian center for excellence in these areas.

1. Monitor allied nation efforts in research and development on combat rations.
2. Examine the desirability or necessity of evaluating ergogenic aids with AFV tasks and crews on AFV vehicles and simulators.
   - Conduct a scoping study
   - Analyze results
   - Develop R&D plan
   - Report results

     DCIEM Project
3. Examine the effects of oral magnesium on hearing loss.
   - Conduct a scoping study
   - Analyze results
   - Develop R&D plan
   - Report results

     DCIEM Project
4. Examine the desirability or benefits of evaluating psychogenic aids with AFV tasks and crews on AFV vehicles and simulators
   - Conduct a scoping study
   - Analyze results
   - Develop R&D plan
   - Report results

     DCIEM Project
5. Examine the desirability or necessity of evaluating anti-narcoleptic aids with AFV tasks and crews on AFV vehicles and simulators
   - Conduct a scoping study
   - Analyze results
   - Develop R&D plan
   - Report results

     DCIEM Project

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Human factors integration requirements for armoured fighting vehicles: Part II A review of the Human Systems Integration material available for armour systems SORs and a plan for future HSI and R&D

4 AUTHORS (Last name, first name, middle initial)

Greenley, M , Angel. H., Brooks, J , and Kumagi, J

5 DATE OF PUBLICATION (month and year of publication of document)	6a. NO. OF PAGES (total containing information. Include Annexes, Appendices, etc)	6b. NO. OF REFS (total cited in document)
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Contractor report

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The aim of this project was to use the Directorate of Land Requirements (DLR)-3 Armoured Fighting Vehicle (AFV) Human Systems Integration (HSI) initiative to explore the kinds of information required, and the information which is currently available, to complete the HSI sections of the new Department of National Defence (DND) Statement of Operational Requirement (SOR) templates. The deliverables from this project included

1) A report on how the HSI requirements in the new SOR templates can be addressed and how the AFV HSI information could be distributed as part of a www site using AFV HSI as a worked example.
2) A report on what AFV HSI information is known, what information needs to be collected, how much of it requires R&D, what R&D needs to be completed, and the outline of an AFV HSI R&D program to generate the requirements for the future.
3) An annotated bibliography of the available information relevant to GSI requirements for future AFV related SORs, organized to match the SOR template.

This report examines the HSI information requirements for future armour SORs including vehicles, AFV subsystems and crew station upgrades, crewman clothing and equipment, and crew sustainment. A review of the relevant literature identified a number HSI related areas of future SORs for which a reasonable requirement does not appear within existing literature. A series of R&D projects were identified and described to address the gaps in existing knowledge about HSI requirements for future SORs. These projects included R&D in the areas of Deficiencies, Scenarios, Task Performance, Crew Characteristics, AFV and Subsystem Performance, Mounted Warriors Day, Crewman's Day, Crew Station Modeling, Threat Studies, Safety and Health, Human Error Frameworks, and Crew Sustainment. Together the recommended R&D projects form an integrated program, with a series of R&D streams. The report concludes with the R&D projects prioritized in five different ways⊗I) R&D priorities to meet the original DLR 3 request, (ii) R&D priorities for purchasing COTS, (iii)R&D priorities for upgrades and enhancements, (iv) R&D priorities for FAVS TD, and (v) R&D activities that meet a "purple" requirement.

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Human Systems Integration, Human Factors Engineering, Statements of Requirements, Armoured Fighting Vehicles

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