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Soldier Integrated Headwear System:
System Design Process

by

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Abstract

The aim of the Soldier Integrated Headwear System –Technology Demonstration Project (SIHS-TDP) is to empirically determine the most promising headwear integration concept that significantly enhances the survivability and effectiveness of the future Canadian soldier/warfighter. The SIHS-TDP will develop, evaluate, and demonstrate novel concepts for integrating enhanced protection, sensing, information display, and communications technologies into a headwear system.

To achieve this aim the SIHS programme will develop and demonstrate three unique technology concept types that represent different levels of integration. These concept types will range from a combined add-on system where components are added to existing headwear systems, to a modular/compatible approach where subsystem functionality can be added or removed as and when needed, to a fully and permanently encapsulated design where weight, space, protection and functionality are optimized The three systems would ideally used in comparative studies to determine the most suitable integration concept for the future Canadian soldier.

This document outlines a process for designing and developing the three alternative SIHS concept types to successfully meet the objectives of the programme. The process outlined in this document provides both a philosophical viewpoint on the SIHS design process as well as a framework for achieving these goals. This document is not intended as a detailed project plan with timings and taskings but serves as the framework for writing such a plan.

Résumé

Le but du Projet de démonstration de technologies – Casque intégré du soldat (PDT-SIHS) est de déterminer empiriquement quel concept de casque intégré est le plus susceptible d'améliorer la capacité de survie et l'efficacité du soldat/combattant canadien de demain. Le PDT-SIHS développera, évaluera et mettra à l'essai de nouveaux casques qui intègrent une protection accrue, des capteurs, un système d'affichage des informations et un système de communication.

Pour atteindre cet objectif, le programme SIHS développera trois concepts particuliers qui correspondent à différents niveaux d'intégration : ajout d'éléments à un casque existant; approche modulaire/compatible qui permet d'ajouter ou d'enlever des sous-systèmes au besoin; système pleinement intégré et permanent qui optimise le poids, l'espace, la protection et la fonctionnalité. Ces trois concepts devraient normalement faire l'objet d'études comparatives pour déterminer lequel est le meilleur pour le soldat canadien de demain.

Le document ci-joint propose un processus pour l'élaboration et le développement des trois concepts de SIHS, afin d'atteindre les objectifs du programme. Il décrit l'approche philosophique sur laquelle repose le processus, et il propose un cadre pour la réalisation de ces objectifs. Ce document n'est pas un plan détaillé pour la réalisation du projet, avec des tâches et un calendrier, mais plutôt un cadre pour l'élaboration de ce plan.

Executive Summary

The aim of the SIHS programme is to empirically determine the most promising headwear integration concept that significantly enhances the survivability and effectiveness of the future Canadian soldier/warfighter. The SIHS-TDP will develop, evaluate, and demonstrate novel concepts for integrating enhanced protection, sensing, information display, and communications technologies into a headwear system.

To achieve this aim the SIHS programme will develop and demonstrate three unique technology concept types that represent different levels of integration. These concept types range from a combined add-on system where components are added to existing headwear systems, to a modular/compatible approach where subsystem functionality can be added or removed as and when needed, to a fully and permanently encapsulated design where weight, space, protection and functionality are optimized The three integration options will ideally be assessed in comparative studies to determine the most suitable integration concept for the future Canadian soldier.

This document starts out by using the traditional systems design process as a functional foundation for developing the more customized SIHS design process, to balance the different contributions from research, development, and engineering expertise.

The SIHS design process is described in terms of three interdependent processes: system definition, the design cycle, and the evaluation process. The system definition process involves determining the requirements and the range of technology options available, as well as defining the constraints for the SIHS design. The definition process wil develop essential and desirable requirement specifications for the SIHS. Having established the design constraints and operational conditions of use, an Analytical Hierarchy Process (AHP) methodology will be used to provide an objective means for ranking the likely success of various technology options for achieving each of the requirement specifications.

The design cycle will comprise four developmental stages of design: concept design, digital models, physical mock-ups, and a final functional prototype. Given the challenges of technology integration it is unlikely that the "first choice" technologies, from the AHP for each requirement, could be combined in a single design. It is more likely that each concept will end up being a "best fit" of a mix of first, second, and third choice technologies, with each concept having uniquely different advantages and disadvantages. Concepts will then be developed and evaluated against the system requirements and goals identified in system definition, at each developmental stage of design. A number of concept designs will be conceived at the start of the design cycle for each of the concept types. These concept designs will then undergo a simultaneous process of design competition and development.

The evaluation process will be applied to each concept design at each developmental stage. This process comprises a wide range of analytical methods designed to assess the suitability of design ideas, determine the extent to which they meet the essential and desirable design requirements, and to support the design aspects of the development cycle. Following a rigorous series of evaluations at each stage, only the "fittest" designs

will survive to the next developmental stage. Therefore, the SIHS design process must use the evaluation process to systematically downselect design options by using evaluation methods that are most valid for the decisions required at each developmental stage.

The developmental stages of design progress a conceptual idea to a working model but not all concept types will necessarily be developed to a fully functional prototype. Depending on the results of the evaluation process for any given concept type it is possible that the programme could decide to cease development at a particular stage. The programme may be satisfied with the knowledge acquired for a concept type by a particular stage, or the concept type might be proving unsuccessful, or the programme may elect to be opportunistic by diverting resources to another concept type that is proving to be more successful.

This document outlines a process for designing and developing the three alternative SIHS concept types to successfully meet the objectives of the programme. The process outlined in this document provides both a philosophical viewpoint on the SIHS design process as well as a framework for achieving these goals. This document is not intended as a detailed project plan with timings and taskings but serves as the framework for writing such a plan.

Sommaire

Le but du Projet de démonstration de technologies – Casque intégré du soldat (PDT-SIHS) est de déterminer empiriquement quel concept de casque intégré est le plus susceptible d'améliorer la capacité de survie et l'efficacité du soldat/combattant canadien de demain. Le PDT-SIHS développera, évaluera et mettra à l'essai de nouveaux casques qui intègrent une protection accrue, des capteurs, un système d'affichage des informations et un système de communication.

Pour atteindre cet objectif, le programme SIHS développera trois concepts particuliers qui correspondent à différents niveaux d'intégration : ajout d'éléments à un casque existant; approche modulaire/compatible qui permet d'ajouter ou d'enlever des sous-systèmes au besoin; système pleinement intégré et permanent qui optimise le poids, l'espace, la protection et la fonctionnalité. Ces trois concepts devraient normalement faire l'objet d'études comparatives pour déterminer lequel est le meilleur pour le soldat canadien de demain.

Le document commence par utiliser le processus traditionnel de conception de systèmes comme outil fonctionnel pour développer des concepts plus précis de SIHS, en mettant à profit les contributions de la recherche, du développement et du génie.

Le processus de conception du SIHS est décrit comme la combinaison de trois processus interdépendants : définition du système, cycle de conception et processus d'évaluation. Le processus de définition du système consiste à déterminer les exigences et les options technologiques disponibles, ainsi que les contraintes liées à la conception du SIHS. Ce processus de définition permet d'établir les exigences essentielles et souhaitables pour le SIHS. Une fois que les contraintes de conception et les conditions d'utilisation ont été établies, un Processus de hiérarchie analytique (PHA) est utilisé en tant que moyen objectif d'évaluer le succès probable de diverses options technologiques pour répondre à chacune des exigences spécifiées.

Le cycle de développement du SIHS comprend quatre phases : élaboration de concepts, développement de modèles numériques, production d'une maquette, et production d'un prototype fonctionnel. Étant donné que l'intégration des technologies présente de nombreux défis, il est peu probable les technologies qui constituent le « premier choix », et qui sont le résultat du PHA pour chaque exigence, puissent être combinées au sein d'un même concept. Il est plus probable qu'au bout du compte, chaque concept sera la « meilleure combinaison possible » de technologies de premier, deuxième et troisième choix, chaque concept ayant ses avantages et ses inconvénients. Les concepts seront ensuite développés et évalués en fonction des exigences du système et des objectifs établis dans la définition du système, à chaque étape du cycle de développement. Un certain nombre de schémas théoriques seront élaborés dès le début du cycle de développement de chacun des concepts. Ces schémas théoriques feront ensuite l'objet d'un processus simultané de développement.

Le processus d'évaluation sera appliqué à chacun des concepts à chaque étape du cycle de développement. Ce processus fait appel à toute une gamme de méthodes analytiques conçues pour évaluer la pertinence des différents concepts, pour déterminer dans quelle

mesure ils répondent aux exigences essentielles et souhaitables, et pour appuyer les aspects conceptuels du cycle de développement. Après une rigoureuse série d'évaluations à chaque étape, seuls les « meilleurs » concepts survivront pour l'étape suivante du cycle de développement. Par conséquent, le processus de conception doit s'appuyer sur le processus d'évaluation pour réduire systématiquement le nombre d'options, et utiliser les méthodes d'évaluation les plus valables pour que les décisions appropriées soient prises à chaque étape du cycle de développement.

Les différentes étapes du cycle de développement permettront de passer d'un schéma conceptuel à un modèle réalisable, mais tous les concepts ne seront pas nécessairement développés jusqu'au stade du prototype pleinement fonctionnel. Selon les résultats du processus d'évaluation pour un concept donné, il est possible que le programme décide de cesser le développement à une certaine étape du processus. Le programme peut être satisfait des connaissances acquises pour un concept donné, ou ce concept peut s'avérer insatisfaisant, ou encore le programme peut choisir de transférer les ressources à un autre concept qui semble plus prometteur.

Le document ci-joint propose un processus pour l'élaboration et le développement des trois concepts de SIHS, afin d'atteindre les objectifs du programme. Il décrit l'approche philosophique sur laquelle repose le processus, et il propose un cadre pour la réalisation de ces objectifs. Ce document n'est pas un plan détaillé pour la réalisation du projet, avec des tâches et un calendrier, mais plutôt un cadre pour l'élaboration de ce plan.

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1 Introduction

The following section outlines the Soldier's Integrated Headwear System (SIHS) programme, and describes the purpose and the structure of the document.

1.1 Outline of the SIHS Programme

Effective integration of new technologies and materials to meet the complex demands of future infantry headwear systems is a challenge currently faced by all Soldier Modernization Programs (SMPs). While considerable technology advances are being made in the areas of sensors, information displays, and communications technologies, little progress has been made in fully integrating these technologies with enhanced ballistic, Chemical/Biological (CB), blast and thermal protection requirements in a single headborne system that adequately addresses future operational, personnel protection, and human factors requirements.

The aim of the SIHS programme is to empirically determine the most promising headwear integration concept that significantly enhances the survivability and effectiveness of the future Canadian soldier/warfighter by developing, evaluating, and demonstrating novel concepts for integrating enhanced protection, sensing, information display, and communications technologies into a headwear system.

To achieve this aim the SIHS programme will develop and demonstrate three unique technology concept types that represent different levels of integration. These concept types will range from a combined add-on system where components are added to existing headwear systems, to a modular/compatible approach where subsystem functionality can be added or removed as and when needed, to a fully and permanently encapsulated design where weight, space, protection and functionality are optimized maximally. The three systems will ideally be used in comparative studies to determine the most suitable integration concept for the future Canadian soldier.

1.2 SIHS Objectives:

The SIHS programme will seek to achieve the following objectives.

1. Validate the integration and sub-system performance requirements for future soldier integrated headwear systems.
2. Identify existing or develop novel technologies that will meet the SIHS system and sub-system requirements.
3. Develop three unique functional headwear system prototypes that represent the range of novel integration concepts for use as experimentation test-beds.
4. Demonstrate and validate the performance effectiveness of the three system concepts across representative mission scenarios, tasks, environments, and conditions of use.
5. Develop and apply novel evaluation methods, models, and tools as required to assist in the investigation, validation and development processes.
6. Produce an early development model of the most promising integration concept to support future Land Force headwear system acquisitions.

1.3 Purpose of this Document

This document outlines a process for designing and developing three alternative SIHS concept types to successfully meet the objectives of the programme. The process outlined in this document provides both a philosophical viewpoint on the SIHS design process as well as a framework for achieving these goals. This document is not intended as a detailed plan with timings and taskings but should serve as the framework for writing such a plan.

1.4 Document Outline

This document starts out by using the traditional systems design process as a functional foundation for developing a more customized process to balance the different contributions from research, development, and engineering expertise.

The design process is then described in terms of three interdependent processes: system definition, the design cycle, and the evaluation process. In short, the system definition process will determine the requirements, technology options, and constraints for the SIHS design. The design cycle will progress the three design concepts from ideas to functional reality and an evaluation process will be put in place to objectively support design decisions.

2 The SIHS Design Process

This section first describes the functional steps in a traditional design processand relates these to the need for a design model that integrates approaches from research, development, and engineering., The SIHS design process model incorporates research, development, and engineering approaches . This design process is described in more detail in subsequent sections.

2.1 Traditional Design Stages

The traditional system design model (Figure 4) comprises a series of discrete stages in the design process from system definition through to design, construction, and operational deployment. System definition defines what you want to design, allocates functions to subsystems, and explores some of the options for achieving these design functions.

The design cycle starts with preliminary concept design and development and then transitions in an orderly fashion to detailed design mock-up and prototyping.

The design mock-ups and prototypes are then evaluated using test criteria that are derived from the design requirements established during system definition. The final design is then built and put into service where it is assessed in-situ to determine if the system is meeting the initial aims.

The functional stages in the traditional design process appear distinct and linear. In reality, these stages often overlap considerably in time and space, and design activities often iterate frequently between all stages right up to the completion of final construction.

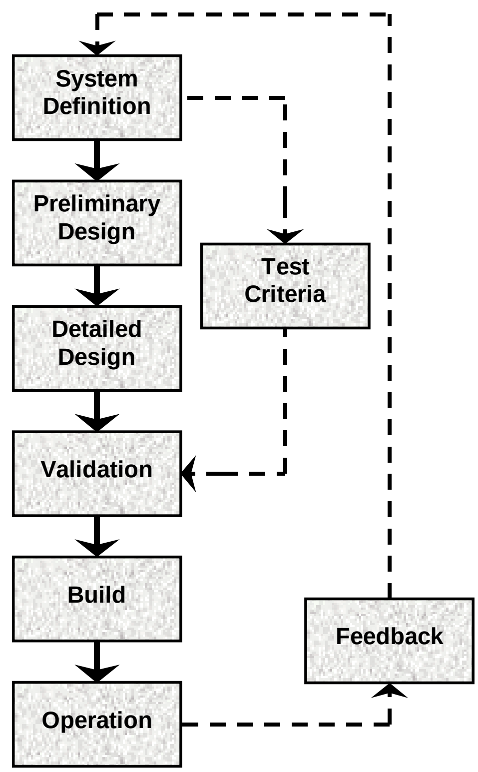

Figure 4: Traditional System Design Process

While the functions underlying these design stages are fundamental to SIHS, and most other design projects, the process for best achieving these functions requires consideration of the technical complexity of the SIHS aim, the need to integrate both Human Factors and Engineering Research and Development (R&D) activities, and the requirement for validation and traceability.

2.2 SIHS Process

While the SIHS design effort will need to undertake the functions outlined in the traditional design process described above, the SIHS design process described in the following sections proposes a means of integrating and managing these functions in a manner that preserves creativity, recognizes uncertainty, and reflects the need for iterative verification and validation imposed by the R&D nature of the project.

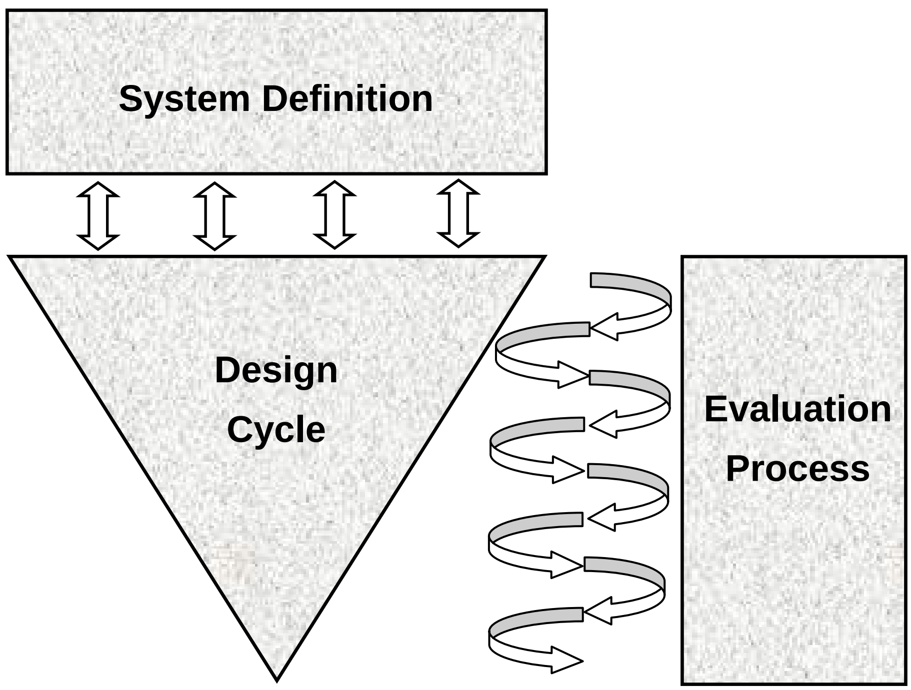

Figure 5: Outline SIHS Design Process

Figure 5 outlines a general model to introduce the SIHS design process. The model comprises three major activities: system definition, the design cycle, and an evaluation process. While the process does start with system definition activities, all three major activities will be interactive, iterative, and ongoing throughout the life of the design process.

> **System Definition:** The system definition activity will set out to define and delimit the design problem space and to gain a better understanding of the design options available to achieve the design goals.
>
> **Design Cycle:** The design cycle will employ the insights derived in system definition to guide the initial concept development activities. The insight acquired in the design cycle will stimulate the need for additions, deletions, and modifications to the system definition activities.

The design process will first seek to determine a wide range of conceptually different integrated headwear system design ideas. These concept ideas will be modeled and evaluated in a process of iterative downselection to determine the most successful candidate concept prototype.

Evaluation Process: An evaluation process of trade-off analyses, research, and development testing will be ongoing at each stage of the design process to assess the effectiveness of alternative technologies, sub-system and system integration

These three activities in the design process model will be expanded and elaborated on in the following sections.

3 System Definition

System definition is a process of defining the problem space prior to beginning any actual design effort. The stages of system definition are highlighted in Figure 6 below.

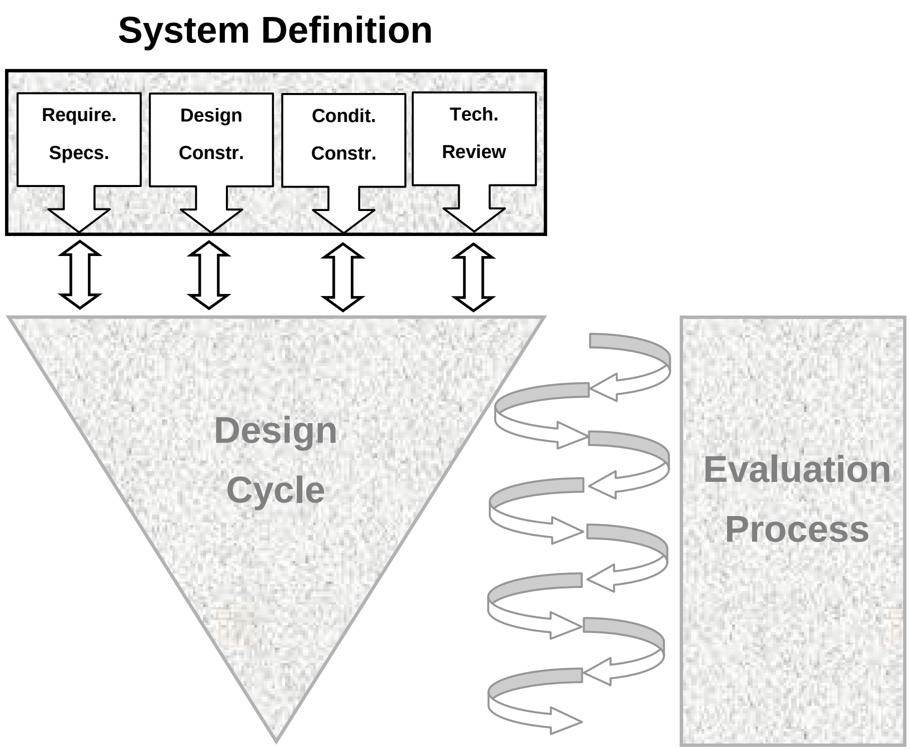

Figure 6: System Definition Activities

System definition first details the capabilities that are required, determines design constraints, and describes the intended conditions of use for the integrated headwear system. Next, the range of possible technologies available to satisfy these design requirements are identified and characterized. Finally, an objective method of relating the complex range of system requirements and constraints to the broad and diverse range of possible technology alternatives available to satisfy them is used. For this purpose, an Analytical Hierarchy Process (AHP) is proposed.

These four stages in System Definition are described in more detail in the following section.

3.1 Requirements Specification

The SIHS requirements specification activity has been configured to support the subsequent design effort by grouping requirements by functional areas of the head (see Figure 7). By spatially and functionally grouping requirements, the process of requirement trade-offs is more easily managed and more likely to be considered early in the design cycle. Requirements will include specifications for technical performance, sub-system and system integration, and usability (performance, comfort, acceptance).

Requirement groupings include:

Whole Head – including overall protection, thermal comfort, range of motion, load forces, physical comfort, fit/adjustability, power/data, and detectors.

Vision – including vision protection, local awareness, visual displays, and enhanced vision.

Respiratory – including CB protection and ventilatory demand.

Speech – including voice communications and computer speech input.

Hearing – including auditory protection, local awareness, auditory displays, and enhanced hearing.

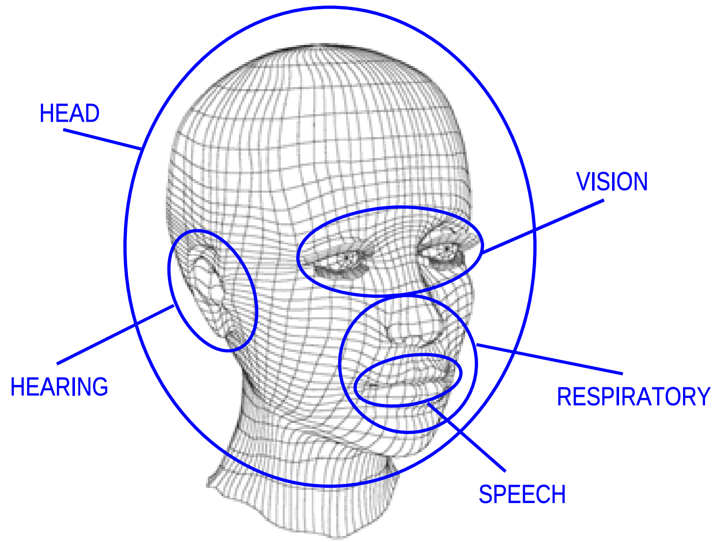

Figure 7: Requirement Groupings

Requirements will be specified for a range of acceptance, wherever possible. This range will include a lower limit (i.e. “essential”), which denotes the lowest acceptable level of a requirement, and an upper limit (i.e. “desirable”) to set the preferred ideal. This range provides a means for further differentiating the suitability of alternative technologies that meet the minimum or essential requirements.

Operational requirements will be derived from Army Subject Matter Experts (SMEs). These will include requirements relating to task and mission performance, equipment, weapons, and clothing compatibility, and camouflage detectability.

Technical requirements will be derived from the technical literature, previous DRDC studies, and SMEs from DRDC and industry. These requirements will include the minimum technical capability required to defeat a threat or achieve a minimum acceptable level of performance. Improved technologies in development, that are expected to be available in the next three to five years, will also be considered to determine the possible “desirable” levels of acceptance.

3.2 Design Constraints

The design space for any item is bounded by criteria that place real limits on the design process. Exceeding these design constraints could render the resulting design impractical or unachievable. These constraints are not intended to restrict creativity but they provide necessary reality checks in the design process. Given the research and development nature of SIHS these constraints are less restricting than a more traditional design-to-market item but they remain useful considerations. Typical design constraints for this type of project include:

- **Weight:** All up weight for the SIHS will necessarily have an upper limit based on load limits for the head and neck during static and dynamic activities. Load balancing and minimizing inertial moments can ameliorate weight effects to a point but limits to absolute weight are unavoidable.
- **Power:** The power demands of any devices selected for the SIHS will have an impact on the power requirements of any future soldier-worn computer system. However, power will likely be a secondary or lower priority constraint for this R&D effort.
- **Cost:** While cost is a major design constraint in most projects it could be overly restrictive for an R&D programme focussed on creativity and innovation. As well, over the three to five year duration of the SIHS programme, technology costs will continue to decrease in relation to performance, making final cost estimations unreliable.
- **Space:** Given the need for compatibility with existing equipment, clothing, vehicles, and weapon systems, and the need for a reasonably normal range of head and neck movement, the SIHS will face physical space constraints that will limit the size and shape of any resulting design.
- **Time:** The SIHS TD programme must be completed within three to five years. This time constraint places serious limitations on the testing and inclusion of any novel technology option in any physical prototype that is not sufficiently mature within the first or second year of the programme. Programme planning will need to identify the critical deadline dates for considering a technology: review only, assessment, design concept consideration, or inclusion in physical and functional prototypes.
- **Technical Risk:** The technical risk associated with the integration of different technology options will place limitations on the types of options SIHS can consider for a functional prototype in the time available.

3.3 Operational Conditions of Use

The intended tasks, missions, and operational conditions of use for the SIHS must be clearly defined prior to beginning the design process. Integrated headwear requirements for conventional warfare, CB warfare, peacekeeping, and operations other than war can be vastly different. Accommodating a broad range of missions and conditions of use will result in a much more demanding design process. Often the most demanding requirements are selected across all intended missions and conditions on the assumption that the missions and conditions with lower demands would still be accommodated. This approach will likely not be effective for a complex, headborne integration design. Selecting the most demanding requirement could pose serious, unnecessary penalties in weight, size, thermal and physical comfort, etc. for those missions and conditions which have less demanding requirements.

For these reasons, the SIHS system definition activities will need to clearly identify the missions and conditions of use for the SIHS design and then clarify the salient differences in critical requirements. These differences will then need to be considered early in the design process to determine the best design means of accommodating these differences.

3.4 Technology Review

Having determined the essential and desirable requirement specifications for the SIHS, information on available and future technologies must be gathered to determine which technologies can best fulfill these requirements. To this end a technology review will be carried out in the following areas:

- ballistic materials for shell, visor, spectacles, etc.
- CB materials and seals.
- thermal management.
- vision enhancement systems.
- vision protection.
- enhanced hearing.
- speech interface devices.
- power /data management (e.g. cabling and connectors).
- suspension and harness options.
- masking technologies.
- passive / active ventilation.
- visual display technologies.
- auditory display technologies.
- auditory protection.
- threat detection options.
- camouflage / detectability.

The technology review will include a survey of suppliers in each technical area and a collection of relevant technical data. This survey will be supplemented by consultation with experts in industry, DND and DRDC to better understand the capabilities and limitations of the various technology alternatives.

3.5 Analytical Hierarchy Process

Having developed essential and desirable requirement specifications for the SIHS and having established the design constraints and operational conditions of use, we are now faced with the onerous task of judging which technologies best fulfill these requirements on balance. We also need to be able to justify our technology choices, defend our trade-off decisions, and retain documented traceability for these decisions.

For this purpose an Analytical Hierarchy Process (AHP) methodology will be used to provide an objective means for ranking the likely success of various technology options for achieving each of the requirement specifications.

The AHP method will be applied in the following way:

1. For each requirement specification, industry and DRDC SMEs will determine measures which can be used to judge a technology option's ability to effectively meet the specification. An example table is provided in Figure 8 below. The table provides example measures, as columns across the top (e.g. weight, performance, multi-strike, etc.), for achieving the requirement specifications for shell protection from fragmentation threats.

HEAD REQUIREMENTS - Protection - Fragments - Shell

	WEIGHT		PERFORMANCE		MULTI-STRIKE		MANUFACTURABILITY		COST		SCORE
SHELL	35%		30%		15%		5%		15%		
OPTIONS	gm/cm3	Score	V50/cm	Score		Score		Score	$	Score	SUMS
Steel											
Titanium											
Ceramic Composites											
Aramid Composites											
Spider Silk											
High Impact Plastic											

Figure 8: Technology Options Assessment

2. SMEs then prioritize these measures for their level of importance in selecting the most successful technology option. The prioritization weightings are represented as percentages (e.g. weight (gm/cm^3) accounts for 35% of the decision) which sum across all measures to equal 100%.
3. The potential technology options then need to be evaluated for each of these measures. For each measure the technical data is provided (e.g. gm/cm^3 for weight). SMEs then score each technology on a common scale based on their judgement of the impact of any technical differences on the practical success of any option. Using a score value, based on a common scale for all measures, enables us to combine and compare measures equally.
4. The scores for each technology option are then factored by the prioritization weightings for each measure (i.e. (score x % weighting) + etc.). Each of the factored scores, for each technology option, is then summed to derive a total score. This total score enables us to objectively compare the likely success of achieving the requirement specification for each technology option.
5. At this point we are able to determine which technology options will be most effective at achieving each requirement. However, in order to progress to the business of

design integration and trade-off analyses, we must first prioritize the importance of the requirements themselves. Some requirements are more important for achieving a successful design than others. Army SMEs will be used to develop the prioritization weightings for these requirements.

Figure 9 helps to explain the process. Technical SMEs first develop the measure weightings to prioritize the influence of each measure in the successful achievement of each requirement (e.g. X, Y, Z). In Figure 9, the functions of direct fire protection (A), fragment protection (B), and flechette protection (C) are requirements that group together for the purpose of shell protection.

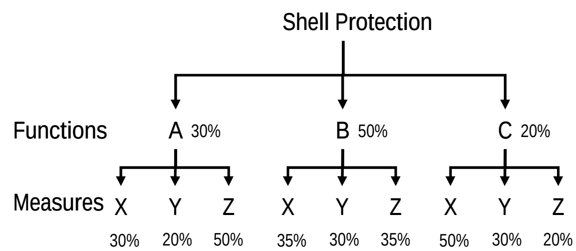

Figure 9: Prioritization Weightings

Any shell material selected for the SIHS must meet the requirements for all three functions but how do you choose the material technology that provides the best combination of protection? For this reason, Army SMEs will be required to indicate which functions are most important for successful shell protection, given their intended tasks, threats, and conditions of use. In Figure 9, function B has been given 50% of the weighting versus 30% for A and 20% for C. Therefore, a technology that scored highest in B would have a greater likelihood of selection.

4 Design Cycle

The SIHS design cycle must now employ the results of the AHP for the purpose of developing the three different SIHS concept types: the Add-on, Modular, and Permanently Encapsulated Systems. Each concept type will employ the same system definition baseline but the design of each type will be pursued independently within the scope of the design definition for each type. Summary design definitions include:

> **Add-on System:** This concept type must achieve the requirements specifications by adding capabilities to the existing Soldier's Helmet (CG634) and use a separate CB mask.
>
> **Modular System:** The modular concept must be designed from the ground up with a view to achieving a seamless, modular integration of technologies to fulfill the requirements specifications. Modular components would be added or removed to meet different mission requirements and operational conditions of use.
>
> **Permanently Encapsulated System:** This concept must be based on the notion that all of the technology capabilities would always be resident in the headwear system and that the wearer would be permanently encapsulated.

The following section describes the general design cycle process that would be employed for each concept type.

4.1 Concept Development

Figure 10 below depicts the general design philosophy for developing each concept type in the SIHS programme. In each case, the results of the system definition activity would be used to derive alternative design concepts for each type. Concepts would be developed by combining different technology options in different ways to fulfill the requirements of the SIHS system. Given the challenges of technology integration it is unlikely that the "first choice" technologies, from the AHP for each requirement, could be combined in a single design. It is more likely that each concept will end up being a "best fit" of a mix of first, second, and third choice technologies, with each concept having uniquely different advantages and disadvantages.

Concepts will then be developed and evaluated against the system requirements and goals, identified in system definition, at each developmental stage of design. A number of concept designs will be conceived at the start of the design cycle for each of the concept types. These concept designs will then undergo a simultaneous process of design competition and development. In a somewhat Darwinian fashion, design concepts will continue to be evolved at each developmental stage. However, following a rigorous series of evaluations at each stage, only the "fittest" designs will survive to the next developmental stage.

The design cycle, from a conceptual idea to a functional prototype, appears linear and orderlybut in fact there are a number of iterative, spiral interactions occurring at several levels.

1. The design cycle will iterate with the system definition activities. Activities in the design cycle will necessarily reveal unanticipated issues and opportunities for which requirement specifications will need to be amended or created or new technology options identified.
2. Design insights will also iterate between design concepts at a given developmental stage. It is unlikely that all aspects of a design concept will be rejected from advancing to the next developmental stage. Where appropriate, useful design attributes will be scavenged from rejected designs and applied to improve other design concepts.
3. It is also likely that design insights generated in one concept type will iterate with the development efforts from other concept type.
4. Lastly, the design cycle will also tend to iterate back and forth between developmental stages. Issues encountered in later design stages can often be best resolved by iterating aspects of the design back to earlier developmental stages.

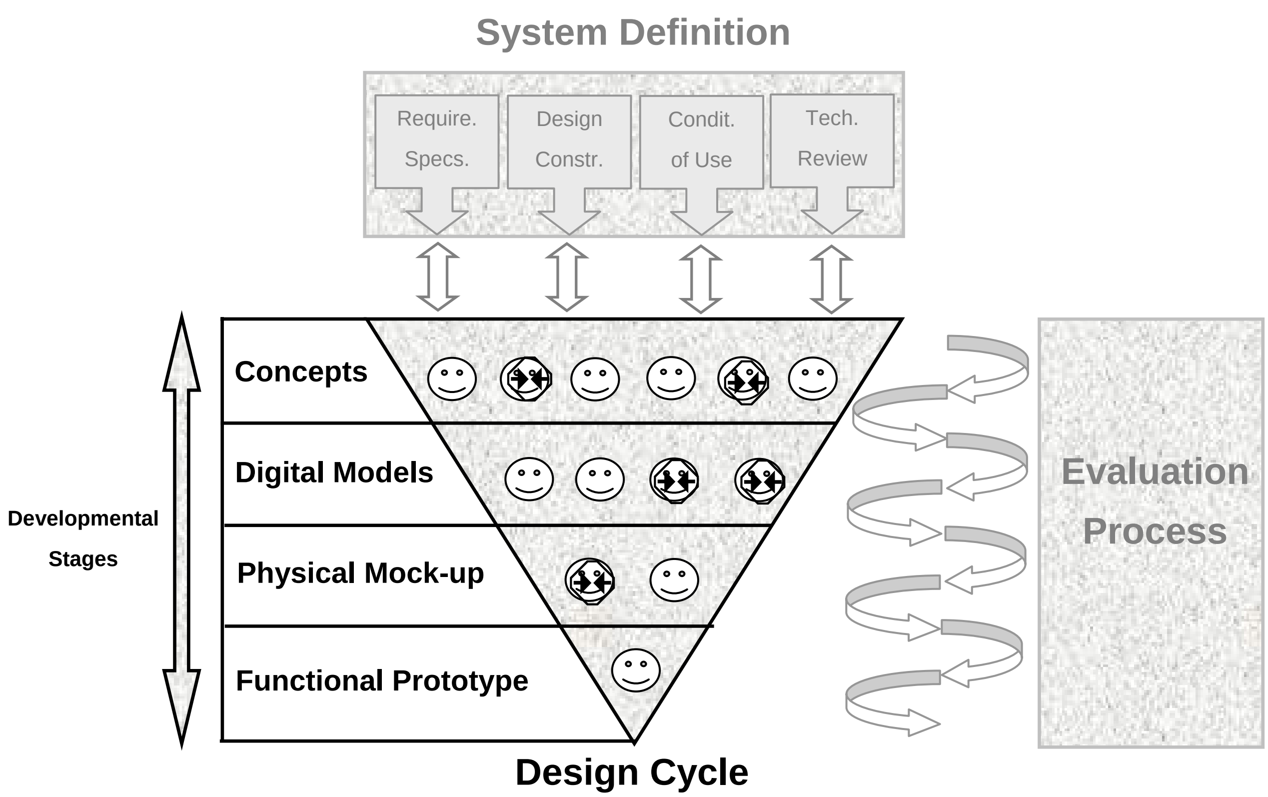

Figure 10: Design Cycle Activities

Where appropriate an AHP model will also be used to discriminate between the suitability of alternative design concepts at each developmental stage to provide an objective basis for accepting or rejecting a concept.

4.2 Developmental Design Stages

The design cycle will comprise four developmental stages of design: concept design, digital models, physical mock-ups, and a final functional prototype for each of the three concept types. The steps in the evaluation process are applied to each stage in an iterative manner to develop, define, and discard design attributes.

> **Concepts** are an abstraction of generalized ideas borne out of creative brainstorming. These concepts do not necessarily need to be conceived in great detail or even practically achievable at this stage. In the case of concept development, judgement is somewhat suspended in favour of creativity until imagination and ingenuity have been exhausted. At this point the design concepts can then begin to be challenged by the evaluation process.
>
> **Digital Models** are used to further define and refine a shape model for these concept designs (e.g. CADD). Digital models enable a rapid prototyping environment for the preliminary assessment of design integration, accommodation, compatibility, fit, thermal demands, visual field, etc.
>
> **Physical Mock-ups** provide a space and weight representation of the concept and provide the capability for the physical integration of componentry. Mock-ups are also necessary for initiating soldier-in-the-loop design testing and evaluation.
>
> **Functional Prototypes** include working componentry and hardware. While the functional prototypes must represent the finished product to a high fidelity not all aspects need to be "real". To save cost and time some aspects can be simulated for the purpose of human factors evaluations. For example, the helmet shell does not require high performance ballistic materials when a cheaper material could be used to simulate the space and weight effects of the shell.

These developmental stages progress a conceptual idea to a working model but not all concept types will necessarily be developed to a fully functional prototype. Depending on the results of the evaluation process for any given concept type it is possible that the programme could decide to cease development at a particular stage. The programme may be satisfied with the knowledge acquired for a concept type by a particular stage, or the concept type might be proving unsuccessful, or the programme may elect to be opportunistic by diverting resources to another concept type that is proving to be more successful.

5 Evaluation Process

The Evaluation Process is the engine that drives the design cycle. This process comprises a wide range of analytical methods designed to assess the suitability of design ideas, determine the extent to which they meet the essential and desirable design requirements, and to support the design aspects of the development cycle. The evaluation process will be applied to each concept design at each developmental stage.

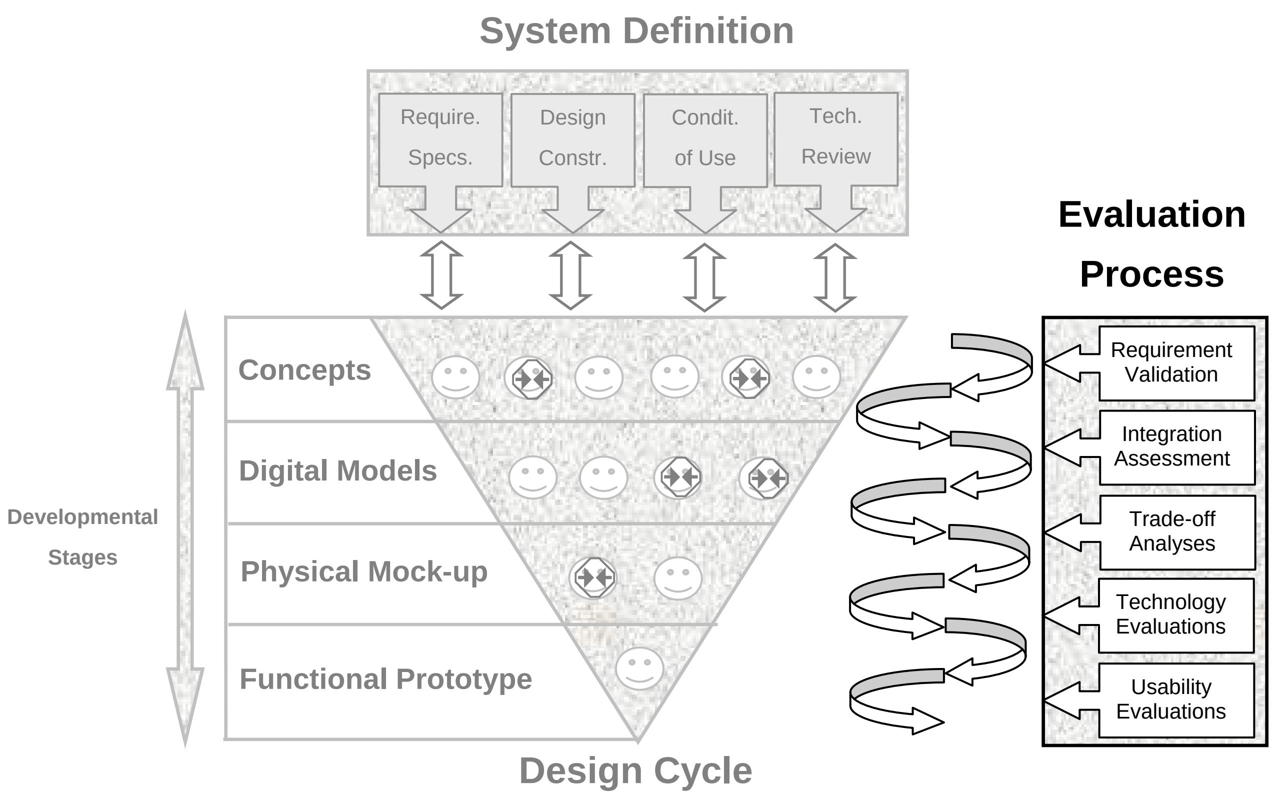

Figure 11: Evaluation Process Activities

Evaluations will include analytical methods from each of the research, development, and engineering domains. These methods are described in more detail in the following section.

5.1 Evaluation Activities

The following evaluation activities will employ a wide range of different analytical methods throughout the design process.

Requirements Validation: Requirement specifications are derived early in system definition using the scientific and technical literature, standards and guidelines, technical and military SMEs, and data from related research. Ideally, all of these requirements are valid and achievable but more often they only represent the best information we currently have for predicting the outcome goals we want to achieve (e.g. survival in the presence of fragmentation weapons, awareness of visual threats, etc.). The difficulty is in balancing risk with achievability. For example, if our goal is survivability against fragments we could set a specification that is so extreme as to have a very low risk of not achieving the survivability goal. However, setting such a high specification will likely make the design unachievable due to cost, weight, size, etc. The challenge then is to produce requirement specifications that have the highest likelihood of being practicable with the lowest risk of failing the intended goals of the requirement.

Therefore requirements and their specification levels (i.e. essential and desirable) will be constantly considered and challenged as part of the natural design process.

Integration Assessments: For a complex design programme such as SIHS, a considerable amount of effort will be invested in the integration of different technologies and components to meet the objective requirements. This integration effort will require ongoing analyses to assess the suitability of various integration decisions.

Trade-off Analyses: The design process is replete with trade-off decisions and the resulting designs typically reflect a balance of many such trade-offs. Trade-offs begin at the requirement specification level where some requirements are traded off in favour of others. Requirement trade-offs can occur as a result of early SME prioritization and later in the development of design options when choices are made which emphasize some requirements over others. Trade-offs are also made between technology choices. The most ideal technology may not be the most suitable choice for integration within a particular set of design solutions.

In either case, trade-off analyses are necessary to generate the objective data required to support critical decisions for lowering some capabilities in favour of others. As well, these trade studies are important for quantifying the impact of these decisions on overall system effectiveness.

Technology Evaluations: The characteristics and performance effects of different technology options may not be well known for a military headwear application. Technical data and feature descriptions are often inadequate for determining if a given technical option will be a suitable or effective design solution for a SIHS concept. Therefore human factors evaluations will be necessary to characterize the performance capabilities and limitations of these technology options.

Usability Evaluations: The ultimate goal of any SIHS design is to enhance the performance effectiveness of the dismounted soldier. While there are many paper, bench-top, and virtual modeling methods for evaluating and predicting the performance outcome of a given design only usability evaluations with soldiers provides the predictive validity necessary to confirm a design for production. Usability evaluations typically focus on the performance of soldier activities, tasks, and missions, in both laboratory and field settings.

5.2 Evaluation Validity versus Design Risk

The goal of the SIHS programme is to determine the most promising headwear integration concept that significantly enhances the survivability and effectiveness of the future soldier. When do you know when you've achieved this goal? When, in the evaluation process, is it acceptable to stop evaluating? In many respects these questions come down to the balance between the predictive validity of your evaluations for confirming that you have reached your goal versus the risk of being wrong. The use of a design progression through a number of developmental stages, with evaluations at each stage, helps to mitigate or manage this balance.

Table 1 below provides an example listing of evaluations that could be performed at each developmental stage of design; this listing is by no means exhaustive. During the digital modeling stage of development most of the evaluations test constructs of larger design goals. For example, load force modeling evaluates various physical variables (constructs) that should be predictive of physical comfort and the risk of neck injury. Evaluation of constructs is quite effective for comparing and developing different designs at an early conceptual stage but it would be very risky to confirm the final design at this point.

By moving to the next developmental stage (physical mock-ups) we can begin to involve soldiers and soldiering activities in the evaluation process. This addition of content valid testing greatly improves our confidence in the resulting design decisions. However, it would still be quite risky to confirm a design at this stage since many of the functional technologies that will affect soldier performance and survivability would not be available at this developmental stage.

The last developmental stage (functional prototype) includes all of the functionality, space, and weight characteristics of the design and now affords an opportunity for in-situ task and mission evaluations of the design against the outcome goals of the SIHS design process. Evaluating the working design for task and mission performance in typical operational conditions of use provides the highest measure of validity (i.e. criterion). Final design confirmation decisions at this stage pose the least risk that the programme goals have not been met. Therefore, the SIHS design process must use the evaluation process to systematically downselect design options by using evaluation methods that are most valid for the decisions required at each developmental stage.

To reiterate, the developmental stages outlined above progress a conceptual idea to a working model but not all concept types will necessarily be developed to a fully functional prototype. Depending on the results of the evaluation process for any given concept type it is possible that the programme could decide to cease development at a particular stage.

Table 1: Example Evaluations

Example Evaluations	Digital Models	Physical Mock-ups	Functional Prototypes
1. Ballistic dimensioning of shell and visor	♦		
2. Stand-off analyses with 3D headforms	♦		
3. Thermal modeling	♦		
4. Passive and Active ventilation modeling	♦		
5. Load force analyses (static and dynamic)	♦		
6. Field of View simulation	♦		
7. Range of motion assessments	♦	♦	
8. Anthropometric Form Factor Analyses	♦	♦	
9. Optics evaluations		♦	
10. CB seal evaluations		♦	
11. CB state transition assessments		♦	
12. Physical comfort assessments		♦	♦
13. Compatibility evaluations		♦	♦
14. Soldier free-field visual performance		♦	♦
15. Hearing protection evaluation		♦	♦
16. Individual infantry task performance		♦	♦
17. NBC task performance		♦	♦
18. Camouflage evaluation			♦
19. Thermal comfort			♦
20. Encapsulation demands			♦
21. System detectability assessments			♦
22. Visual display usability			♦
23. Auditory display usability			♦
24. Enhanced vision assessments			♦
25. Enhanced auditory assessments			♦
26. Free-field auditory evaluations			♦
27. Speech intelligibility evaluations			♦
28. Team Battle Task Performance			♦

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(U) The aim of the Soldier Integrated Headwear System –Technology Demonstration Project (SIHS−TDP) is to empirically determine the most promising headwear integration concept that significantly enhances the survivability and effectiveness of the future Canadian soldier/warfighter. The SIHS−TDP will develop, evaluate, and demonstrate novel concepts for integrating enhanced protection, sensing, information display, and communications technologies into a headwear system.

To achieve this aim the SIHS programme will develop and demonstrate three unique technology concept types that represent different levels of integration. These concept types will range from a combined add−on system where components are added to existing headwear systems, to a modular/compatible approach where subsystem functionality can be added or removed as and when needed, to a fully and permanently encapsulated design where weight, space, protection and functionality are optimized The three systems would ideally used in comparative studies to determine the most suitable integration concept for the future Canadian soldier.

This document outlines a process for designing and developing the three alternative SIHS concept types to successfully meet the objectives of the programme. The process outlined in this document provides both a philosophical viewpoint on the SIHS design process as well as a framework for achieving these goals. This document is not intended as a detailed project plan with timings and taskings but serves as the framework for writing such a plan.

(U) Le but du Projet de démonstration de technologies – Casque intégré du soldat (PDT SIHS) est de déterminer empiriquement quel concept de casque intégré est le plus susceptible d’améliorer la capacité de survie et l’efficacité du soldat/combattant canadien de demain. Le PDT SIHS développera, évaluera et mettra à l’essai de nouveaux casques qui intègrent une protection accrue, des capteurs, un système d’affichage des informations et un système de communication.

Pour atteindre cet objectif, le programme SIHS développera trois concepts particuliers qui correspondent à différents niveaux d’intégration : ajout d’éléments à un casque existant; approche modulaire/compatible qui permet d’ajouter ou d’enlever des sous systèmes au besoin; système pleinement intégré et permanent qui optimise le poids, l’espace, la protection et la fonctionnalité. Ces trois concepts devraient normalement faire l’objet d’études comparatives pour déterminer lequel est le meilleur pour le soldat canadien de demain.

Le document ci joint propose un processus pour l’élaboration et le développement des trois concepts de SIHS, afin d’atteindre les objectifs du programme. Il décrit l’approche philosophique sur laquelle repose le processus, et il propose un cadre pour la réalisation de ces objectifs. Ce document n’est pas un plan détaillé pour la réalisation du projet, avec des tâches et un calendrier, mais plutôt un cadre pour l’élaboration de ce plan.

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

(U) SIHS; Soldier Integrated Headwear System; concept design; digital models; helmet; lethality; survivability; mobility; sustainability; C4I; enhanced protection; sensing; information display; headwear system; modular helmet; encapsulated helmet