



DRDC Toronto CR 2007-024

**OPTICS (OPERATIONAL THREAT INTEGRATED CORRECTIVE
SPECTACLES) PRODUCTION AND INITIAL HUMAN FACTORS
TESTING**

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PWGSC Contract No. W7711-7-7429/001-TOR

Call-Up 7429-06

On behalf of

DEPARTMENT OF NATIONAL DEFENCE

as represented by

Defence Research and Development Canada

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Toronto, Ontario, Canada

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DRDC Scientific Authority

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June 2006

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Abstract

This report details the design, development and preliminary testing of three different Operational Threat Integrated Corrective Spectacles (OPTICS) concepts. The aim of the OPTICS project is to develop an integrated set of corrective eyewear inserts that will be compatible with ballistic protective eyewear and will be compatible for use inside the in-service C-4 respirator. Over the course of 13 months, three different OPTICS concepts were designed, developed and delivered to DCIEM. An iterative design approach with user feedback was utilized. Each concept employed a different approach for meeting the aims of the device; Concept 0 utilized a Commercial Off the Shelf sports-style prescription insert as its starting point, Concept 1 used a previously developed NBC spectacle as its inspiration and finally Concept 2 used a unique carrier approach. The concept of fielding a system that could utilize a prescription insert with ballistic eyewear and with a C4 respirator was well received. The participants also identified the need to have a minimum of two sets of OPTICS inserts. Advantages and disadvantages with all of the concepts developed were noted. Overall the participants believed that Concept 0 and Concept 1 were the most promising for further development and testing. Proposed modifications to all concepts were noted. The participants believed that further development should only proceed after CTS has identified a winner in its ballistic eyewear program. Additional test requirements were also noted.

Résumé

Le présent rapport détaille la conception, la réalisation et les essais préliminaires de trois concepts différents de lunettes correctrices intégrées à l'équipement de protection contre les menaces opérationnelles (OPTICS). Le projet OPTICS a pour but de développer un jeu intégré de lentilles correctrices rapportées qui soient compatibles avec les lunettes de protection balistique et qui permettent l'utilisation à l'intérieur du respirateur C-4 en service. Sur une période de 13 mois, trois concepts OPTICS différents ont été conçus, réalisés et livrés à l'IMED. On a utilisé une méthode de conception itérative avec rétroaction des utilisateurs. Chaque concept faisait appel à une méthode différente pour atteindre les buts du dispositif; le concept 0 a pris pour point de départ des lentilles rapportées de prescription commerciales courantes de type sportif, le concept 1 s'est inspiré de lunettes NBC existantes et le concept 2 faisait appel à une méthode de support unique. Le concept de mettre en service un système pouvant utiliser des lentilles de prescription intégrées à des lunettes de protection balistique et à un respirateur C4 a été bien reçu. Les participants ont également identifié le besoin d'avoir un minimum de deux paires de lentilles OPTICS rapportées. Les avantages et les inconvénients de tous les concepts sont décrits. Somme toute, les participants étaient d'avis que le concept 0 et le concept 1 étaient les plus prometteurs aux fins de développement et d'essais ultérieurs. Des modifications ont été proposées pour tous les concepts. Les participants pensaient qu'on ne devrait pas procéder au développement ultérieur avant que les responsables du projet HLS aient déclaré le vainqueur dans son programme de lunettes de protection balistique. On mentionnait également d'autres exigences d'essai.

Executive Summary

In 1990, Canadian Department of National Defence's (DND) started a development project to design plastic injection moulded Nuclear Biological Chemical (NBC) spectacles for used with the C4 respirator. In parallel to this development, an investigation began into the concept of corrective vision Inserts inside the C4 mask. The primary impetus for this development project was evidence revealing that the current combat spectacle developed in the 70s degrades the seal of the C4 mask. In addition to corrective inserts for use inside a C4 respirator the Land Force (LF) also employs two in-service ballistic protection devices; Sand/Wind/Dust Goggles with ballistic insert and Glendale Safety Spectacles. Both devices provide some degree of ballistic eye protection (V50 ~ 150 m/s) but are not intended to provide protection for higher energy fragments or to provide facial protection. While this approach has provided some degree of protection from ocular threats, it is a temporary fix for limited numbers of troops in specific operations. There are currently two related initiatives underway to improve eye and facial protection provided to soldiers; the Clothe-The-Soldier (CTS) ballistic eyewear project and the Soldier's Helmet Visor Attachment Sub-system project. The requirements of these two programs, ballistic protective eyewear and respirator spectacles, if viewed in isolation would require that the soldier be issued at least three pairs of prescription lenses; one for in-garrison/off-duty use, one for general field use and one for use with the respirator. This potentially unwieldy and expensive approach can be avoided by the integration of the prescription lens requirements into a single system for field use. Because the timelines and approaches differ significantly for these two separate eyewear projects, the in-house Operational Threat Integrated Corrective Spectacles (OPTICS) development project was initiated. The intention for the OPTICS project is to identify candidate concepts that integrate corrective vision for both the CTS and NBC protection programs

A focus group was held at CFB Edmonton with 18 regular force infantrymen from 1 PPCLI on 11 March 1999. The aim of this focus group was to explore the acceptability of having a single prescription insert that could function both with ballistic eyewear and with the C4 respirator. The concept of fielding a system that could utilize a prescription insert with ballistic eyewear and with a C4 respirator was well received and the participants identified the need to have a minimum of two sets of OPTICS inserts.

Based on an initial needs analysis, user focus group and stakeholder review, three concepts for the OPTICS project were developed and detailed in Pro-Engineer for prototype stereolithography fabrication. The development of the final designs involved a number of internal reviews. In preparation for a user design review, two concepts were photo-realistically rendered in Alias and manufactured in Delrin.

Upon receipt of the samples and drawings a focus group was held at CFB Petawawa on 15 April 2000. The participants included 15 regular force soldiers from armour, signals, military police and service battalion units. The aim of this focus group was to gain initial feedback on the acceptability of the three OPTICS concepts. Issues were raised with all of



the concepts presented on the time required to attach yoke arms, frames, straps, etc. The participants were concerned with the fact that if they were only issued one insert, then the prescription insert used with ballistic eyewear would have to be reassembled for use inside the mask. The time to transition to NBC conditions may be excessive. Concerns were also raised as to the security of the extra OPTICS parts if they were not attached to a frame. Advantages and disadvantages with all of the concepts developed were noted. Overall, the participants believed that Concept 0 and Concept 1 were the most promising for further development and testing. Proposed modifications to all concepts were noted. Given that Concept 0 is based upon the ballistic eyewear insert, the participants believed that further development should only proceed after the Clothe the Soldier Project has identified a winner in its ballistic eyewear program.

Given the concerns with fit and clash it is recommended that quantitative mask fit testing be conducted with future designs to optimize temple arm design. Furthermore, user evaluations are required to assess the acceptability of the systems and design features in normal and NBC conditions.

Sommaire

En 1990, le ministère canadien de la Défense nationale (MDN) a lancé un projet de développement de lunettes plastiques moulées par injection de protection nucléaire, biologique et chimique (NBC) pour utilisation avec le respirateur C4. Parallèlement à ce projet de développement, on a lancé une étude sur le concept de lentilles correctrices rapportées à l'intérieur du masque C4. Le principal élan donné à ce projet de développement reposait sur l'évidence révélant que les lunettes de combat du moment développées au cours des années 70 compromettent le sceau du masque C4. En plus de lentilles correctrices rapportées pour utilisation à l'intérieur d'un respirateur C4, la force terrestre utilise deux lunettes de protection balistique en service : lunettes de protection contre le sable, le vent et la poussière avec pièce rapportée de protection balistique et lunettes protectrices Glendale. Les deux types de lunettes offrent un certain degré de protection balistique pour les yeux ($V50 \sim 150$ m/s), mais ne sont pas conçus pour offrir la protection contre les fragments d'énergie supérieure ou la protection du visage. Bien que cette approche ait fourni un certain degré de protection contre les menaces pour les yeux, il s'agit d'une solution temporaire pour un nombre limité de soldats dans des opérations particulières. À l'heure actuelle, il y a deux initiatives connexes en cours pour améliorer la protection des yeux et du visage des soldats : le projet de lunettes de protection balistique dans le cadre du programme « Habiller le soldat » (HLS) et le projet du sous-système de fixation à la visière du casque du soldat. Les exigences de ces deux projets, à savoir les lunettes de protection balistique et les lunettes pour respirateur, considérées séparément signifieraient qu'au moins trois paires de lentilles de prescription seraient distribuées au soldat : une pour utilisation en garnison/pendant les heures de loisir, une pour utilisation générale en campagne et une pour utilisation avec le respirateur. On peut éviter cette approche potentiellement laborieuse et dispendieuse en intégrant les besoins de lentilles de prescription en un seul système pour utilisation en campagne. Comme les échéanciers et les approches de ces deux projets de lunettes distincts diffèrent grandement, on a lancé le projet interne de développement de lunettes correctrices intégrées à l'équipement de protection contre les menaces opérationnelles (OPTICS). Le projet OPTICS a pour but d'identifier des concepts potentiels qui intègrent la correction de la vue du programme de protection HLS et du programme de protection NBC.

Le 11 mars 1999, un groupe de discussion comptant 18 fantassins du 1 PPCLI de la force régulière s'est réuni à la BFC Edmonton. Ce groupe de discussion avait pour but d'explorer l'acceptabilité d'avoir une seule paire de lentilles de prescription rapportées qui puisse fonctionner tant avec les lunettes de protection balistique qu'avec le respirateur C4. Le concept de mettre en service un système pouvant utiliser des lentilles de prescription intégrées à des lunettes de protection balistique et à un respirateur C4 a été bien reçu, et les participants ont également identifié le besoin d'avoir un minimum de deux paires de lentilles OPTICS rapportées.

D'après une analyse initiale des besoins et la revue par le groupe de discussion composé d'utilisateurs et par les intervenants, trois concepts pour le projet OPTICS ont été

développés et détaillés dans le logiciel Pro-Engineer pour la fabrication du prototype par stéréolithographie. La mise au point de la conception finale impliquait un certain nombre de révisions internes. En vue de la révision de la conception par les utilisateurs, deux concepts ont été rendus de manière photoréaliste dans le logiciel Alias et réalisés en Delrin.

Sur réception des échantillons et des dessins, un groupe de discussion s'est réuni à la BFC Petawawa le 15 avril 2000. Les participants comprenaient 15 soldats de la force régulière venant d'unités de blindés, de transmissions, de police militaire et de bataillon des services. Ce groupe de discussion avait pour but d'obtenir une rétroaction initiale au sujet de l'acceptabilité des trois concepts de lunettes OPTICS. Des problèmes ont été soulevés dans le cas de tous les concepts présentés à l'égard du temps nécessaire pour attacher les branches, la monture, les courroies, etc. Les participants se préoccupaient du fait que, s'ils ne recevaient qu'une seule paire de lentilles rapportées, ils auraient à réassembler les lentilles de prescription rapportées utilisées avec les lunettes de protection balistique pour utilisation à l'intérieur du masque. Le temps de transition aux conditions NBC risque d'être excessif. Les soldats soulevaient également des préoccupations quant à la sécurité des pièces OPTICS supplémentaires si elles n'étaient pas attachées à la monture. Les avantages et les inconvénients de tous les concepts sont décrits. Somme toute, les participants étaient d'avis que le concept 0 et le concept 1 étaient les plus prometteurs aux fins de développement et d'essais ultérieurs. Des modifications ont été proposées pour tous les concepts. Étant donné que le concept 0 est basé sur les lentilles de protection balistique rapportées, les participants pensaient qu'on ne devrait pas procéder au développement ultérieur avant que les responsables du projet « Habiller le soldat » aient déclaré le vainqueur dans son programme de lunettes de protection balistique.

Compte tenu des préoccupations quant aux problèmes d'ajustement, il est recommandé qu'on effectue des essais quantitatifs d'ajustement aux masques sur les modèles futurs pour optimiser la conception des branches. En outre, des évaluations des utilisateurs sont nécessaires pour déterminer l'acceptabilité des systèmes et des caractéristiques de conception en temps normal et dans des conditions NBC.

Table of Contents

| | |
|------------------------------------------------------------------------|------------|
| ABSTRACT | II |
| RESUME..... | III |
| EXECUTIVE SUMMARY | IV |
| SOMMAIRE | VI |
| TABLE OF CONTENTS | VIII |
| LIST OF FIGURES..... | IX |
| 1. BACKGROUND TO EXISTING CANADIAN FORCES EYEWEAR PROGRAMS..... | 1 |
| 1.1 CLOTHE THE SOLDIER BALLISTIC EYEWEAR PROJECT | 1 |
| 1.2 CLOTHE THE SOLDIER CORRECTIVE VISION INSERT PROJECT | 4 |
| 1.3 NBC SPECTACLES PROJECT | 6 |
| 1.4 BACKGROUND TO THE CURRENT PROJECT | 10 |
| 2. AIM | 11 |
| 3. APPROACH..... | 12 |
| 4. RESULTS | 13 |
| 4.1 INITIAL CONCEPT DEVELOPMENT | 13 |
| 4.2 ACCEPTABILITY OF THE OPTICS CONCEPT | 13 |
| 4.2.1 <i>Modify the Ballistic Eyewear Insert.....</i> | <i>14</i> |
| 4.2.2 <i>Modify the NBC Mask Insert.....</i> | <i>14</i> |
| 4.2.3 <i>Stake Holder Reviews</i> | <i>15</i> |
| 4.3 DEVELOPMENT OF INITIAL PROTOTYPES | 15 |
| 4.4 OPTICS CONCEPTS FOCUS GROUP | 19 |
| 4.4.1 <i>Concept 0 Feedback.....</i> | <i>19</i> |
| 4.4.2 <i>Concept 1 Feedback.....</i> | <i>20</i> |
| 4.4.3 <i>Concept 2 Feedback.....</i> | <i>21</i> |
| 5. DISCUSSION | 22 |
| 6. REFERENCES..... | 23 |
| ANNEX A: TECHNICAL DRAWINGS | A-1 |

List of Figures

| | |
|-----------------------------------------------------------------------------------------|-----|
| FIGURE 1: SOLDIER WITH TIERED OCULOFACIAL PROTECTION | 2 |
| FIGURE 2: INCORPORATION OF CORRECTIVE PRESCRIPTION INTO A DUAL LENS DESIGN | 5 |
| FIGURE 3: INSERT SYSTEM BEHIND A MONO LENS PROTECTIVE SHIELD | 5 |
| FIGURE 4: IN-SERVICE NBC RESPIRATOR SPECTACLES | 6 |
| FIGURE 5: SCHEMATIC VIEW OF PROVIDING CORRECTIVE VISION TO C4 RESPIRATOR WEARERS) | 7 |
| FIGURE 6: TRADITIONAL SPECTACLE PROTOTYPE..... | 8 |
| FIGURE 7: INSERT ATTACHED TO NOSE CUP OF C4 RESPIRATOR..... | 8 |
| FIGURE 8: BOLLÉ EDGE SOS PRESCRIPTION INSERT | 13 |
| FIGURE 9: OPTICS CONCEPT 0 | 17 |
| FIGURE 10: OPTICS CONCEPT 1 | 17 |
| FIGURE 11: OPTICS CONCEPT 2 | 18 |
| FIGURE 12: OPTICS CONCEPT 2 ALIAS RENDERING | 18 |
| FIGURE 13: BOLLE PAROLE/VIGILANTE PRESCRIPTION SOLUTION..... | 20 |
| FIGURE 14: OPTICS CONCEPT 0 | 1-1 |
| FIGURE 15: OPTICS CONCEPT 0 FRAME | 1-2 |
| FIGURE 16: OPTICS CONCEPT 0 BRIDGE AND FOREHEAD PAD | 1-3 |
| FIGURE 17: OPTICS CONCEPT 0 SOFT STRAP..... | 1-4 |
| FIGURE 18: OPTICS CONCEPT 0 EAR LOOP..... | 1-5 |
| FIGURE 19: OPTICS CONCEPT 1 | 2-1 |
| FIGURE 20: OPTICS CONCEPT 1 FRAME | 2-2 |
| FIGURE 21: OPTICS CONCEPT 1 BRIDGE AND FOREHEAD PAD | 2-3 |
| FIGURE 22: OPTICS CONCEPT 1 SOFT STRAP..... | 2-4 |
| FIGURE 23: OPTICS CONCEPT 1 EAR LOOP..... | 2-5 |
| FIGURE 24: OPTICS CONCEPT 2 | 3-1 |
| FIGURE 25: OPTICS CONCEPT 2 FRAME | 3-2 |
| FIGURE 26: OPTICS CONCEPT 2 LENS SHIELD | 3-3 |
| FIGURE 27: OPTICS CONCEPT 2 TEMPLE ARM..... | 3-4 |
| FIGURE 28: OPTICS CONCEPT 2 EAR HOOK | 3-5 |
| FIGURE 29: OPTICS CONCEPT 2 TEMPLE ARM HINGE | 3-6 |
| FIGURE 30: OPTICS CONCEPT 2 T-FRAME..... | 3-7 |

1. Background to Existing Canadian Forces Eyewear Programs

The Canadian Department of National Defence's (DND) Land Force (LF) currently employs a number of vision protection and correction systems. In garrison all personnel requiring corrective vision are supplied with prescription glasses. The garrison glasses are based upon accepted fashion eyewear. The numbers of glasses provided depends on the deployment status of DND personnel. In addition to their garrison glasses a number of personnel have also been issued with Combat spectacles for use inside the C4 respirator. If required the Combat Spectacles can be used as normal glasses, typically by users who have damaged their glasses on training or during operational deployments. The garrison glasses and Combat spectacles do not provide ocular ballistic protection. The LF currently has two in-service ballistic protection devices; Sand/Wind/Dust Goggles with ballistic insert and Glendale Safety Spectacles. Both devices provide some degree of ballistic eye protection (V50 ~ 150 m/s) but are not intended to provide protection for higher energy fragments or to provide facial protection. While this approach has provided some degree of protection from ocular threats, it is a temporary fix for limited numbers of troops in specific operations. There are currently two related initiatives underway to improve eye and facial protection provided to soldiers; the Clothe-The-Soldier (CTS) ballistic eyewear project and the Soldier's Helmet Visor Attachment Sub-system project.

1.1 Clothe the Soldier Ballistic Eyewear Project

The CTS project is a near term soldier modernization program that will purchase, personal protective clothing and equipment items utilizing suitable Commercial Off The Shelf (COTS) items, Near Developmental items (NDI) and designed technologies to meet the specific requirements of today's LF soldiers. The CTS project is developing an integrated two-tiered system of protection to protect the eyes from low energy fragments, particles, laser, solar and UV radiation (ballistic eyewear) and to protect the eyes and face from high energy fragments (ballistic visor) -see Figure 1 (Clothe The Soldier, 1996). As part of a separate initiative, a prototype Visor Attachment Sub-system (VASS) is being developed and evaluated by the project team for the CF's new Soldier's Helmet (CG 634).



Figure 1: Soldier with tiered Oculofacial protection

This tiered approach will ensure that soldiers, based on the threat, can adopt the appropriate level of protection. Given that 42% of the LF requires vision correction, the integration of prescription lenses into ballistic protective eyewear has become a significant problem (Angel, 1996).

The threat to the soldiers' eyes and face by low velocity projectiles and fragments is well-documented (Madler et al., 1993). Even the most insignificant projectile that would cause little or no damage to the rest of the body can incapacitate a combatant for several hours if it comes in contact with the eye. The ballistic eyewear to be purchased by the Canadian Army should dramatically reduce this threat to the soldiers' eyes and in conjunction with a helmet visor, eliminate this threat to the oculofacial region entirely.

The Human Factors (HF) evaluation of ballistic eyewear concepts followed a systematic approach. The investigation included:

- Literature Review
- User Needs Analysis
- Technical/ Optical Requirements Analysis
- Controlled HF Field Trial
- Eyewear Durability Trial

HF performance and technical requirements for LF ballistic protective eyewear were drafted from insights gathered during the review of the scientific literature, casualty databases, military studies, product literature, and the draft Statement of Operational requirement. A range of representative COTS eyewear samples were then procured in small numbers to evaluate the features and capabilities of current protective eyewear

systems. A series of focus groups were then conducted with both prescription and non-prescription lens wearers from across the operational community to determine which features would be essential and/or desirable in a combat capable spectacle system (Humansystems, 1997).

The initial series of focus groups significantly reduced the number of options to be evaluated in the HF controlled field trial and in the laboratory technical and optical testing. The primary aim of field trial was to develop HF performance specifications that could be incorporated into the requirement package. The secondary aim of the trial was to evaluate the suitability of various eyewear features incorporated into specific COTS eyewear designs. The aim of the technical testing was to develop definitive optical and materials specifications that could be combined with the performance specifications provided to industry (Hovis et al, 1998).

A two-day field trial was then undertaken at Canadian Forces Base (CFB) Winnipeg, over the period 09-10 October 1997. Three COTS eyewear systems were evaluated by a total of 23 participants (15 non-prescription users and eight prescription users). For each group, a repeated measures comparison between eyewear conditions was possible (n=15 for non-prescription users and n=8 for prescription users). Human Factors tests included assessments of fit and adjustability, performance of selected obstacle and battle tasks and clothing and equipment compatibility assessment. Data collection included questionnaires, focus groups, performance measures and human factors observer assessments.

The utility and acceptability of a shield or mono-lens system was rated significantly more favourably than either a sealed goggle design or common dual lens designs. Goggles were deemed unacceptable from a comfort standpoint due to the constant contact of the face seal. They were also perceived to have more of problem with fogging than spectacle systems. Users did not believe it feasible to provide the varied types of protection desired in a system that would require the changing of two separate lenses, as would be the case in traditional spectacle designs. Participants attributed the superior acceptability of the shield systems to excellent aesthetics, comfort, stability, perceived compatibility, and optical performance. The interchangeable lenses required for solar and Laser protection can be made more cheaply, installed quickly, and are more easily stored than in other systems as well. The prescription and non-prescription wearers also selected a number of features that would give them a stable, comfortable fit, like adjustable temple arms, pantoscopic tilt, a non-slip nose bridge and interchangeable arms.

Overall, participants rated a number of criteria in the highest importance category for any future ballistic protective eyewear: Weapon Compatibility, Fit, Anti-Fog Protection, Durability, Prescription, Anti-Scratch, Optical Performance, Stability, Equipment Compatibility, Anti-Glare, Field of View, Physical Comfort, and Task Performance. Focus group discussions confirmed that a number of the criteria above were the most important features to consider for the selection of ballistic eyewear. Participants indicated that ballistic eyewear must fit (to minimize instability), provide protection (including ballistic, UV, anti-fog, anti-glare, and anti-scratch), be compatible with weapons and

equipment, and be extremely durable. As well, eyewear must not restrict optical performance. All participants recognized the need for providing a means of incorporating corrective lenses into any system that is to be on general issue.

Ballistic testing is currently underway at DND's Defence Research Establishment in Valcartier (DREV), to determine the ballistic protective standards that can be expected from Commercial Off the Shelf (COTS) systems. The target for ocular protection in eyewear is 215 m/s for a 1.1g FSP (fragment simulated projectile), accomplished with a 3mm polycarbonate lens. A protection level in the 400 m/s range will be pursued for the visor with a combination of polycarbonate and other materials.

1.2 Clothe the Soldier Corrective Vision Insert Project

In view of the significant percentage (36%) of LF combat arms personnel that wear or require corrective vision (Angel, 1996), a separate investigation was undertaken to determine the best approach for providing ballistic eye protection to prescription users. A study was conducted to determine the following: user needs, the current situation for personnel wearing prescription lenses, the general acceptability of possible future approaches, and finally the desirability of specific eyewear features.

Preliminary investigations with the various in-service and COTS protective eyewear systems, identified a number of approaches for providing ballistic protection to prescription users. These approaches included providing protection:

- In front of the current prescription eyewear:
 - Wind, Sand, Dust Goggles
 - Over the Glasses (OTG)
 - Visor
- In the prescription lens:
 - Use polycarbonate in the users prescription lenses (see Figure 2)
 - Industrial safety glasses with snap in polycarbonate prescription lenses; and
- In an insert system behind a protective shield (see Figure 3).



Figure 2: Incorporation of Corrective Prescription into a dual lens design



Figure 3: Insert system behind a Mono lens protective shield

Corrective ballistic protective eyewear systems were evaluated with 19 soldiers from 1st Battalion Royal Canadian Regiment (1RCR) and 2 Combat Engineer Regiment (2CER) at CFB Petawawa during the period 9 to 12 June 1997 and with 10 soldiers from 2nd Battalion Princess Patricia's Canadian Light Infantry (2 PPCLI) at CFB Winnipeg during the period 9 to 10 October 1997. The utility and acceptability of an insert system behind a one-piece shield was rated significantly more favourably than the other approaches. Participants attributed the superior acceptability of the insert systems to excellent aesthetics, comfort, stability, and perceived compatibility and optical performance. The insert system was seen to offer several system advantages: the interchangeable shield now allows prescription

wearers to have a tinted lens for sun or laser protection and having a shield in front of the insert will provide additional protection against scratches and abrasion from dust etc.

1.3 NBC Spectacles Project

In 1990, DND started a development project to design plastic injection moulded Nuclear Biological Chemical (NBC) spectacles for used with the C4 respirator. In parallel with this development, an investigation began into the concept of corrective vision Inserts inside the C4 mask. The primary impetus for this development project was evidence revealing that the current combat spectacle developed in the 70s (Dean et al, 1973) degrade the seal of the C4 mask.



Figure 4: In-service NBC respirator spectacles

Furthermore, the in-service metal framed spectacles are reportedly uncomfortable (i.e. pressure points on nose and ears -Donati et al, 1991), they do not accept bifocal prescriptions, and are expensive to make. A replacement spectacle development project was initiated with the following objectives (Meunier, 1992):

- to be compatible with the C4 and AC4 (Aircrew) respirator
- to minimize face seal leakage due to the spectacles
- to maximize comfort/wearability/stability/durability/usability
- to allow use of bifocals

- to minimize the cost and associated logistics of the end item
- to build in flexibility for other non-NBC uses

As with the provision of corrective lenses for use with ballistic eyewear, a number of different approaches were identified for incorporation of corrective vision with the C4 respirator (Figure 5). These approaches included:

- A spectacle system;
- An insert system inside the respirator; and
- Corrective vision incorporated in the C4 Respirator lens assembly.

The first approach was a traditional spectacle design, the second was an insert design to be attached inside the C4 respirator, while the third was grinding or bonding prescription lenses into the C4 respirator polycarbonate eye piece assemblies. An analysis of the cost and difficulties associated with built-in prescription lenses eliminated the third option of using specially manufactured C4 respirator lens systems. Using new materials and moulding techniques, prototypes of each of the first two designs were produced and refined through a series of testing and evaluation. The resulting frames for each alternative were very similar in appearance and dimension except for their respective retention systems and concept of use.

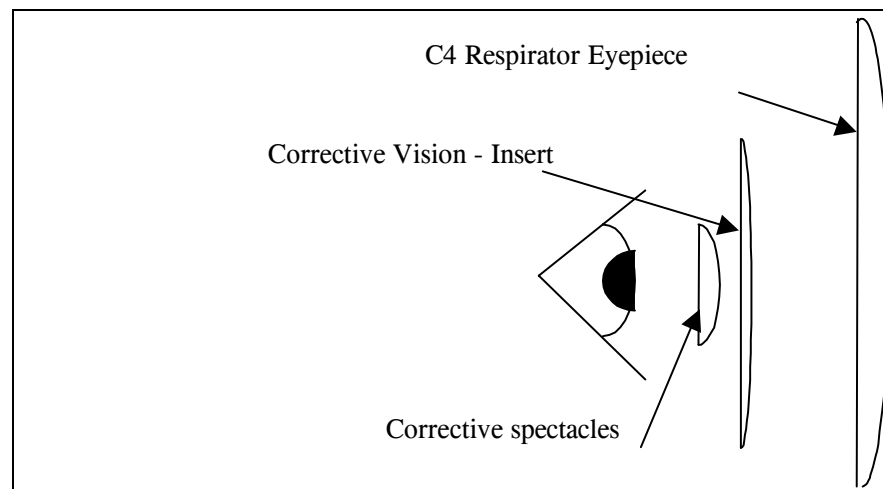


Figure 5: Schematic view of providing corrective vision to C4 respirator wearers)

The traditional spectacle option, (Figure 6) features a super tough nylon frame capable of retaining a 3mm-polycarbonate lenses with a silicone nose bridge (not shown) and rubber retention strap.



Figure 6: Traditional spectacle prototype

The yoke and harness system allow the user to adjust the pantoscopic tilt of the frame by simply sliding the retention strap up or down on the yoke. An adjustable harness is envisioned for the production model to further improve the fit of this item, but was not pursued in the prototyping phase.

The insert system has the same frame design but instead of using a yoke system, attaches directly to the respirator nose cup (see Figure 7).



Figure 7: Insert attached to nose cup of C4 respirator

The attachment to the nose cup is achieved through a simple clip that can be removed easily for eyewear cleaning or mask decontamination. In this concept, soldiers requiring visual correction would wear a separate combat spectacle for general field use that would be removed as part of the mask donning process. The potential benefits to mask fit were considered significant enough to consider this option and the need for multiple corrective lenses.

Humansystems Incorporated was tasked by the Defence and Civil Institute of Environmental Medicine (DCIEM) to undertake a human factors evaluation of the prototype plastic injection moulded NBC spectacles, and the prototype corrective vision Inserts (Humansystems, 1998). The results of this evaluation were designed to provide direction to DND as to which concept is best to pursue from a HF perspective. The aim of these field trials was to evaluate HF compatibility of the prototype NBC spectacles (Prototype) and the corrective vision inserts (Inserts), with the C4 respirator and various items of clothing, equipment and weapons systems. The Prototype and Inserts were compared using the in-service combat spectacles (In-service) a baseline for comparison. The HF trials included a controlled army field trial and a navy user trial.

A three-day trial was undertaken at CFB Petawawa during the period 10 – 12 June 1997 with soldiers from 3rd Battalion Royal Canadian Regiment (3 RCR), 2 Royal Canadian Horse Artillery (2 RCHA), 2 CER and the Royal Canadian Dragoons (RCD). Thirty-seven (37) soldiers (Infantry-9, Artillery-11, Armour-7, and Engineers-10) undertook a battery of HF tests. Participants wore each of the three possible eyewear systems in a repeated measures experimental design. The order of eyewear was balanced among participants. Human factors tests included assessments of fit, adjustability, stability, thermal and physical comfort; ease of use, battle tasks; equipment, crew station, and clothing compatibility; and durability. Data collection included questionnaires, focus groups, performance measures and HF observer assessments.

Thirty-three (33) regular forces sailors from CFB Halifax were selected for a user trial (November 1996 to March 1997). Each subject was issued concept spectacles and task diaries. Ten subjects returned Log booklets and participated in an exit focus group discussion.

Each combat spectacle concept had its pros and cons. Several manufacturing or design flaws were noted, but did not negatively affect the results of these trials. The subjects provided valuable feedback on the suitability of each concept as a NBC spectacle. When asked outright which concept they would select, 31 out of the 37 Army subjects (83.8%) chose the Prototype over the Insert. The results of the Navy trial converged to support this conclusion. Based on the results of the trial, no concept is ready for issue; however, the Prototype was believed to represent a more viable concept. Based on the results of these HF trials, it was recommended that further development and testing of a Prototype design concept be pursued.

1.4 Background to the Current Project

The requirements of these two projects, ballistic protective eyewear and respirator spectacles, if viewed in isolation would require that the soldier be issued at least three pairs of prescription lenses; one for in-garrison/off-duty use, one for general field use and one for use with the respirator. This potentially unwieldy and expensive approach can be avoided by the integration of the prescription lens requirements into a single system for field use. Because the timelines and approaches differ significantly for these two separate eyewear projects, the in-house Operational Threat Integrated Corrective Spectacles (OPTICS) development project was initiated. The intention for the OPTICS project is to identify candidate concepts that integrate corrective vision for both the CTS and NBC protection programs.

The work done to date on these two projects suggests that an integrated approach to providing corrective lenses offer the best chance for success. It is envisioned that the traditional spectacle concept for the respirator will be further refined to be compatible with the future ballistic eyewear system, thus fulfilling the needs of both projects. In situations where there is deemed to be no NBC threat the corrective lenses will be snapped on to the nosepiece of the ballistic eyewear (similar to the insert system), with the yoke and head strap removed. If an NBC threat becomes likely, the yoke and strap are replaced and the clip retaining the corrective lens frame undone. In the event of an NBC attack the ballistic eyewear can be removed easily and the respirator donned rapidly while the corrective lenses remain in place strapped to the head. In this way corrective lens wearers do not sacrifice clear vision for protection at any time. This will solve a longstanding dilemma faced by corrective lens wearers, lead to a significant increase in operational capability and result in a decrease in casualty rates due to eye injuries.

2. Aim

The aim of this report is to detail the development efforts of the OPTICS project. Goals of the project included the following

- Assess the acceptability of integrating NBC spectacles and BEW for field conditions.
- Identify any outstanding design issues for personnel working in a NBC threat environment.
- Incorporate previously recommended design revisions and provide options for item integration.

3. Approach

OPTICS concepts were developed over the period of March 1999 to April 2000. The development process included the following steps:

- Review acceptability of approach
 - User focus group discussions
- Concept(s) development
 - Modeling
 - Internal review
 - Photo-realistic rendering
 - Prototype samples x 4
- Review prototypes
 - User focus group discussions

4. Results

The results of the OPTICS development project are detailed below in chronological order.

4.1 Initial Concept Development

A number of approaches for the OPTICS concept were developed and they were based either on a Commercial Off the Shelf (COTS) Bollé Edge Sports Optical System (SOS) system (see Figure 8) or on the older NBC insert (see Figure 6).



Figure 8: Bollé Edge SOS prescription insert

A number of approaches to attaching temple arms were identified, these included:

- Open posts on the frame with holes in bridal arms,
- Closed posts on the frame with hooks on the bridal arms,
- Key slots on the frame with matching locks on the bridal arms, and
- Strap slots on the frame with a headband strap.

4.2 Acceptability of the OPTICS Concept

A focus group was held at CFB Edmonton with 18 regular force infantrymen from 1 PPCLI on 11 March 1999. The aim of this focus group was to explore the acceptability of having a single prescription insert that could function both with ballistic eyewear and with the C4 respirator. The participants were introduced to CTS ballistic eyewear and prescription insert concepts along with NBC eyewear concepts. A number of bridal mounting systems were presented, these included:

- Post with a side mounting hook bridal arm,
- Post with a top mounting loop bridal arm, and
- Simple strap loop.

Although the majority of the participants appreciated the logistic appeal of using only one insert system for both the ballistic eyewear and in the NBC mask, there are a number of organizational, operational and technical concerns. One major concern is the ease of reconfiguring the ballistic eyewear insert for use inside the NBC mask. Many of the soldiers interviewed did not believe it will be practical to rapidly attach an NBC strap assembly onto the insert. The results of the focus group indicated that the ease of adapting ballistic eyewear inserts for use in an NBC mask will depend on its reconfiguration system. This suggested that the system will have to be evaluated in the laboratory and in a mini user trial. The participants suggested two approaches for developing OPTICS concepts. These included:

- Modify the prototype CTS prescription insert presented with a set of bridal arms and a strap attachment so that it can function as a stand-alone system inside the NBC mask, and
- Develop a new NBC mask prescription insert carrier that could utilize the existing ballistic eyewear insert.

4.2.1 Modify the Ballistic Eyewear Insert

Many of the soldiers interviewed were concerned about the robustness of the bridal mounting systems displayed. Changing the insert to and from its "NBC" configuration will place increased stress on the mounting posts. The robustness of the bridal mounting system will depend on its design and material selection.

Based on the results of the feedback at the focus group session, the nose-piece of the prototype ballistic eyewear prescription insert will have to be redesigned to improve its upper eyebrow contact areas. Currently the nose-piece is designed to only provide support on the upper nose and attaching elastic retention straps will cause the insert to be pulled against the face. Thus, the CTS prescription insert will have to be modified to provide additional contact support against the brow bridge.

4.2.2 Modify the NBC Mask Insert

One possible solution suggested in this early focus group was to develop a prescription insert carrier that would fit inside the mask. Just as the ballistic eyewear insert snaps into the lens of the ballistic eyewear outer shield lens, there may be enough room inside the NBC mask for the same insert to snap into a new NBC insert carrier. The participants believed the potential advantages included the following:

- Eliminated the need to modify the existing prescription insert,
- Could incorporate simpler and more robust bridal arm attachment systems, and
- The new NBC insert carrier may provide greater potential for different attachment systems.

The advantages and disadvantages of NBC insert temple arm designs were discussed. The participants reviewed the advantages and disadvantages of:

- Cable arms,
- D-rings/Ear rings,
- Rubber straps,
- Spatula arms, and
- Ear loops/ear hooks.

The participants briefly discussed the relative merits of the different temple arm designs and concluded that only user trialing would be able to identify which system is effective in both the NBC task and the non-NBC environment. It should be noted that only a minority of the participants were issued with Combat spectacles and could address the comfort issues associated with the D-ring design.

4.2.3 Stake Holder Reviews

Stakeholder reviews were also held with representatives the Directorate of Health Services (DHS), Directorate of Nuclear Chemical and Biological Defence (DNBCD), Directorate of Clothing, General Engineering and Maintenance (DCGEM); and CTS concerning the viability of the OPTICS concept. Support for the Project was received from the Surgeon General's department because the fielding of a suitable OPTICS concept may satisfy two different requirements. Currently the Surgeon General pays for NBC combat spectacles (only for those personnel authorized) and garrison glasses for all personnel requiring corrective lenses. Although the Surgeon General currently only supports the fielding of two sets of prescription eyewear, the fielding of CTS ballistic eyewear may complicate this issue. Depending on funding responsibility, the Surgeon General may be responsible for the fielding of three different sets of prescription eyewear; garrison glasses, Combat spectacles (for use in the C4 respirator) and CTS ballistic eyewear inserts. A successful OPTICS program could eliminate the need for an extra prescription system. For the DNBCD and DCGEM representatives a successful OPTICS program could resolve a number of design problems identified in the concepts developed in the NBC Insert program.

While CTS was supportive of the OPTICS project, they believed that selection of any existing ballistic eyewear design to use in the OPTICS program was premature. Until an OPTICS solution was available CTS would pursue (as an interim solution) a prescription insert solution for the non-NBC environment.

4.3 Development of Initial Prototypes

Based on the results of the initial focus group discussion and stakeholder review a number of concepts were developed with an industrial design firm. The process for developing the initial concepts was as follows:

- Review of past insert development efforts at DCIEM,
- Identify product design firm (rapid prototyping),
- Develop focus group prototypes/samples, and

- Evaluate prototypes.

The scientist and the design firm (Ottawa Mould Craft) involved in the NBC Spectacles project were approached for their insights in the design of the two prototype systems (nose cup insert and spectacle system). Unfortunately, the original moulds have gone missing and were unavailable for this project.

An internet search was then conducted to identify an integrated rapid product development and manufacturing design firm in the Greater Toronto Area. Site visits were then conducted with a number of design and manufacturing firms. The background and scope of the project was delivered and the firms were asked for quotes for the proposed effort. The proposed efforts included the following:

- Design and manufacture two approaches for fixing attachment arms onto the CTS ballistic eyewear insert, and
- Design and manufacture a dedicated NBC carrier that would accept the CTS ballistic eyewear insert.

Based on the results of the site visit and quotations received, Hetherington Welch Design was selected as the industrial design partner for the OPTICS project.

Thumbnail concepts developed by Hetherington Welch Design were reviewed by Humansystems Inc. and the scientific authority. Following concept review 3-Dimensional CAD models (Pro-Engineer) were developed and reviewed. The compatibility of the inserts with the C4 respirator was assessed electronically with a digitized model of the mask. Concerns were raised with a number of cross section areas and frame widths and the three initial concepts were further revised.

The initial designs included Concept 0 which utilized a COTS ballistic eyewear insert (Bollé Edge SOS) as a starting point. The prescription insert is attached at the nose piece. Concept 0 included stirrup arms attached to the modified frame using open mounting posts. Thin cross section arms based on the in-service Combat Spectacle system were attached to the stirrup pivot points – Figure 9.

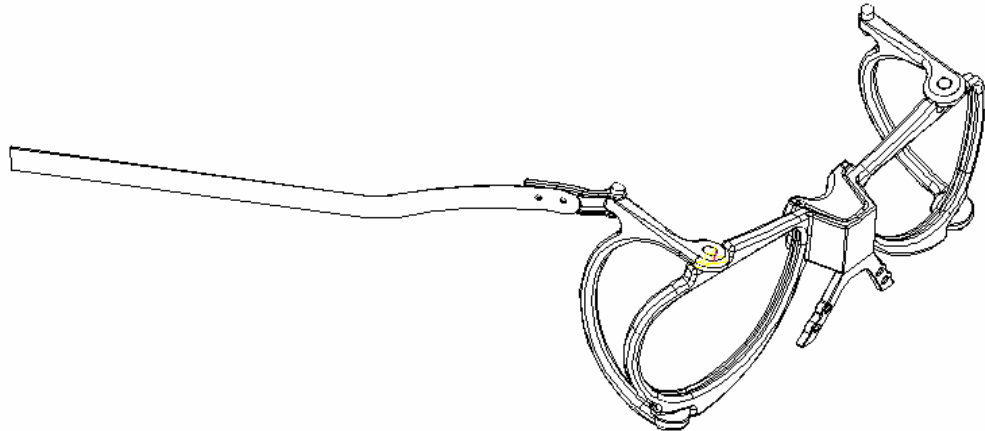


Figure 9: OPTICS Concept 0

Concept 1 utilized the NBC Spectacles Project glasses as a starting point. Concept 1 included a modified frame with posts with simple U-shaped side loops to hold soft head bands. The design also included a bridge/forehead pad- Figure

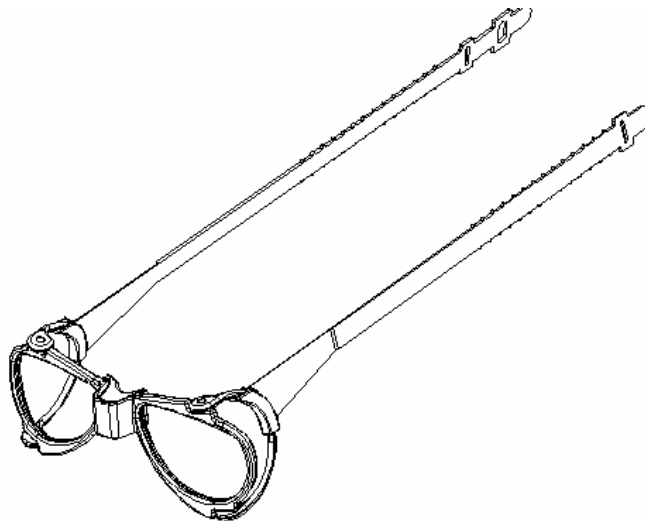


Figure 10: OPTICS Concept 1

Concept 2 involved the development of an NBC and shield carrier. A T-shaped insert carrier was developed to accept the CTS ballistic eyewear insert. The other parts of the concept included new arm hinges, lens straps, a lens shield and D-shaped ear loops – see Figure 11. A soft ear hook was also developed as an alternative with this design.

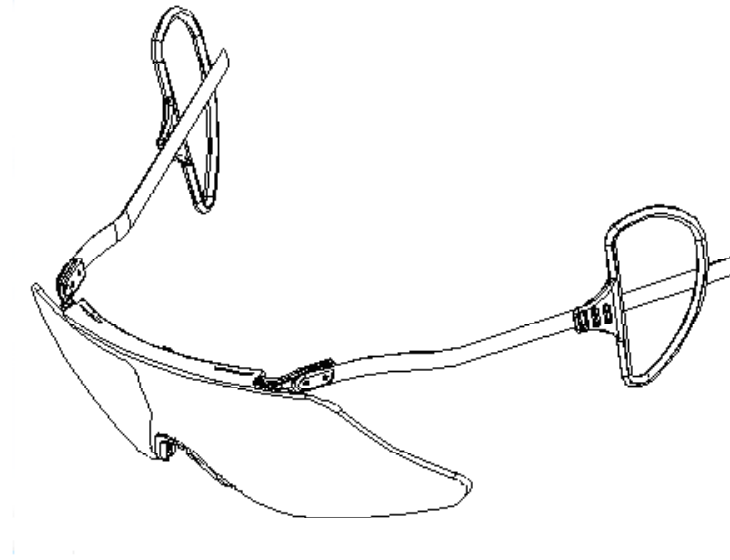


Figure 11: OPTICS Concept 2

Upon completion of the 3-Dimensional Computer Aided design (CAD) modeling & design effort, one model of each concept was produced from Delrin. Photorealistic rendering was also performed with Concept 1 and Concept 2 using the Alias Wavefront Program. A sample Alias rendition is detailed below at Figure 12.



Figure 12: OPTICS Concept 2 Alias rendering

4.4 OPTICS Concepts Focus Group

Upon receipt of the samples and drawings a focus group was held at CFB Petawawa on 15 April 2000. The participants included 15 regular force soldiers from armour, signals, military police and service battalion units. The aim of this focus group was to gain initial feedback on the acceptability of the three OPTICS concepts.

Issues were raised with all of the concepts presented on the time required to attach yoke arms, frames, straps, etc. The participants were concerned that if they were only issued one insert, then the prescription insert used with ballistic eyewear would have to be reassembled for use inside the mask. The time to transition to NBC conditions may be excessive. Concerns were also raised as to the security of the extra NBC parts if they were not attached to a frame.

A majority of the participants reported that they had only been issued with one set of garrison-style prescription glasses. Additionally, all but three participants had not been issued Combat Spectacles. The availability of Combat Spectacles and second sets of prescription eyewear was a concern to all. The participants believed the availability of Combat Spectacles was extremely limited and issued to those only on operational tour. The participants felt that issuing two prescription inserts would alleviate much of their concerns. An NBC set would be assembled and carried in the NBC carrier bag while the other was used in the ballistic eyewear. The time to transition would thus be the same as with the current system. This approach also had the advantage of the user possessing a back-up set of eyewear if their first prescription set was damaged. All of the participants noted that on at least one occasion their garrison eyewear had broken during training exercises. Those that were issued Combat Spectacles used them as a temporary replacement, while others used older glasses if possible.

Concerns were raised with the robustness of the prototypes presented. The participants were informed that although the models were made of Delrin, fielded systems would be made in robust materials.

4.4.1 Concept 0 Feedback

Although a model of Concept 0 was shown to the focus group participants, the upper/bridge nose piece was not in the proposed material. The bridge was machined in hard Delrin rather than the softer material envisioned. As well Concept 0 also required a redesigned NBC nose piece so that it will clear the top of the respirator nose cup. The redesign of the nose piece had yet to be developed. Straps from a MAG-1™ spectacle were used with this model.

The participants were generally supportive of Concept 0. They believed the ballistic eyewear insert modifications were minor and the concept as a whole was simple. Concerns were raised with the width of the insert shield and its compatibility with the C4 respirator. Several of the participants noted clash when they tried the system with a respirator. The participants identified the need to make the design compatible with the smallest mask size available.

Issues were also raised with the size of the arm yokes. Participants were concerned that the yoke arms were too long and could cause sealing problems at the side of the mask. The thickness of the soft straps was also a concern to the participants. The sample used straps from a MAG-1™ spectacle. Conversely the participants were concerned with the reliability of a very thin strap. While the straps from the MAG-1™ spectacle may have been too thick, the participants liked the size adjustment provided and the robustness of the design.

The participants were informed that Concept 0 was based upon a COTS eyewear solution (Bollé Edge SOS) and that the CTS system may be different. The participants believed that when a CTS contract is awarded, redesign efforts should be undertaken to see if minor modifications could make the generic solution work within a C4 respirator.

Detailed drawings of Concept 0 are enclosed at Annex A.

4.4.2 Concept 1 Feedback

Although a model of Concept 1 was shown to the focus group participants, the upper/bridge nose piece was not in the proposed material. The bridge was machined in hard Delrin rather than the softer material envisioned. Concept 1 also utilizes soft straps for head retention. Straps from a MAG-1™ spectacle were utilized in this model.

The participants were less supportive of Concept 1. They believed the ballistic eyewear design may require significant modifications to eliminate the ballistic eyewear nosepiece required for the Bollé Edge (CTS candidate system). It should be noted that other prescription insert systems do not attach at the nose piece – see Figure 3.

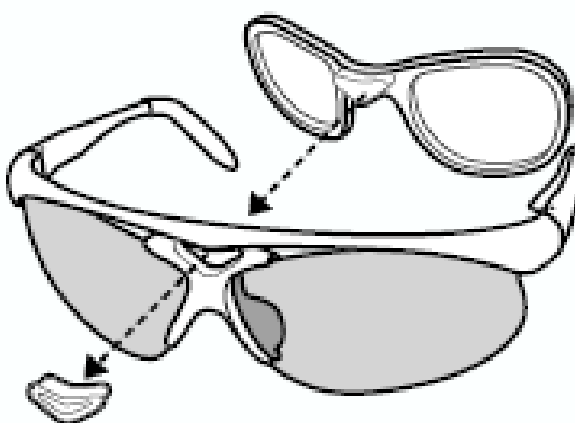


Figure 13: Bollé Parole/Vigilante prescription solution

Although a nose piece is required for general wear it causes clash problems inside a mask. Until a CTS concept is available the design team could not progress this design feature.

The participants believed the design was a minor improvement in the older NBC Spectacle Project spectacle design. Concerns were raised with the lack of a nose piece and how the system would fit on the face. Concerns were also raised with the width of the insert shield and its compatibility with the C4 respirator. Several of the participants noted clash when they tried the system with a respirator. As with Concept 0, the participants identified the need to make the design compatible with the smallest mask size available.

As with Concept 0 issues were also raised with the size of the arm yokes. Participants were concerned that the yoke arms were too long and could cause sealing problems at the side of the mask. The thickness of the soft straps was also a concern to the participants. The sample also used straps from a MAG-1TM spectacle.

The participants were informed that Concept 1 was based upon a COTS eyewear solution and that the CTS system may be different. The participants believed that when a CTS contract is awarded, redesign efforts should be undertaken to see if minor modifications could make the generic solution work within a C4 respirator.

Detailed drawings of Concept 1 are enclosed at Annex A.

4.4.3 Concept 2 Feedback

Concept 2 involved a radical departure from the first two concepts. The system utilized an insert carrier which would allow the insert to be worn under a mask or the system could mount a shield to act as an expedient set of ballistic eyewear. The focus group participants were shown all the components of the system as well as alternative temple arm systems.

The participants were not supportive of Concept 2. They believed the concept would not be stable or robust enough for military operations. The participants believed the use of a mounting frame would cause clash issues inside a mask. Concerns were also raised with the width of the insert shield and its compatibility with the C4 respirator when several of the participants tried the system with a respirator. As with Concept 0, the participants identified the need to make the design compatible with the smallest mask size available.

Concerns were also raised with the comfort of the D-rings provided with the concept. Several participants who had worn Combat spectacles stated that the D-rings were very uncomfortable after prolonged use. The participants were supportive of the efforts to develop a comfortable D-loop system but believed the samples provided were too big. The participants believed that the geometry of the temple arms needed to be refined so that the eyewear fit more comfortably and correctly on the head.

The participants were informed that Concept 2 was based upon a COTS eyewear solution and that the CTS system may be different. The participants believed that when a CTS contract is awarded, redesign efforts should be undertaken to see if minor modifications could make the generic solution work within a C4 respirator.

Detailed drawings of Concept 2 are enclosed at Annex A.

5. Discussion

Over the course of 13 months, three different OPTICS concepts were designed, developed and delivered to DCIEM. An iterative design approach with user feedback was utilized. Each concept employed a different approach for meeting the aims of the device; Concept 0 used the COTS Bollé Edge SOS insert as its starting point, Concept 1 used the Combat Spectacle Project design as its inspiration and finally Concept 2 used a unique carrier approach.

The following parts were fully detailed in Pro-Engineer for prototype Stereolithography (SLA) or Selective Laser Sintering (SLS) fabrication:

- One (1) modified prescription insert frame that incorporated side pivot arms,
- One (1) modified prescription insert frame that incorporated a simple side arm for strap loops,
- One (1) modified nose-bridge compatible with the prescription insert,
- One (1) set of prescription insert pivot arms,
- One (1) strap assembly compatible with the insert pivot arms,
- One (1) strap assembly compatible with the strap loop assembly,
- One (1) new NBC Insert Carrier frame,
- One (1) set of NBC Insert Carrier pivot arms, and
- One (1) strap assembly compatible with the NBC Insert Carrier pivot arms.

The following concepts were photo-realistically rendered in Alias:

- Concept 1, and
- Concept 2.

The following concept SLA samples were produced:

- Concept 1 with C style bridal arms and rubber head band,
- Concept 1 with D style bridal arms and ring-style ear pieces, and
- Concept 2 with D-style bridal arms and loop-style ear pieces x 2.

The concept of fielding a system that could utilize a prescription insert with ballistic eyewear and with a C4 respirator was well received. Provided two inserts are issued, the participants believed the OPTICS system would provide the user with redundant prescription lenses should one break on operations. The participants identified the need to have a minimum of two sets of prescription inserts.

Advantages and disadvantages with all of the concepts developed were noted. Overall the participants believed that Concept 0 and Concept 1 were the most promising for further development and testing. Proposed modifications to all concepts were noted. The participants believed that further development should only proceed after CTS has identified a winner in its ballistic eyewear program.

Given the concerns with fit and clash it is recommended that quantitative mask fit testing be conducted with future designs to optimize temple arm design. Furthermore, user evaluations are required to assess the acceptability of the systems and design features in normal and NBC conditions.

6. References

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OPTICS



Annex A to: OPTICS Development Report

Annex A: Technical Drawings

The detailed drawings of the OPTICS concepts are illustrated in Appendix 1 to 3.

Appendix 1: Concept 0 Drawings

- Overall concept
- Concept 0 frame
- Bridge forehead pad (also used in Concept 1)
- Soft strap (also used in Concept)
- Ear loop (also used in Concept 1)

Appendix 2: Concept 1 Drawings

- Overall concept
- Concept 1 frame
- Bridge forehead pad (see Concept 0)
- Soft strap (see Concept 0)
- Side loop (see Concept 0)

Appendix 3: Concept 2 Drawings

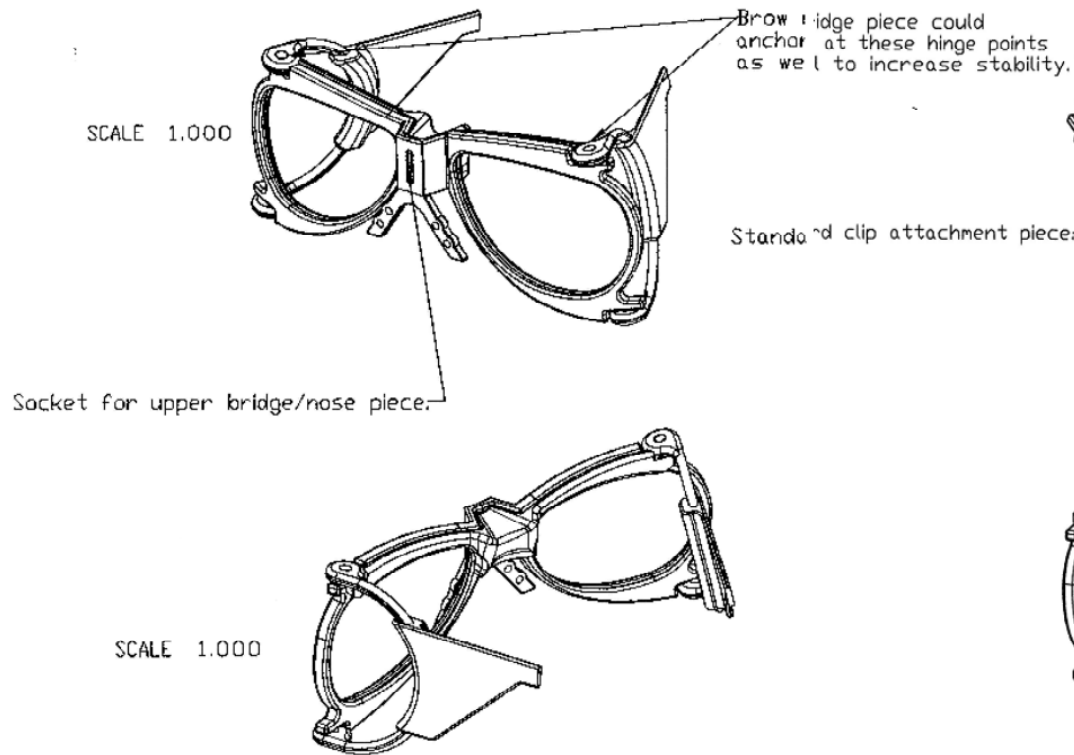
- Overall concept
- Lens Shield
- Temple arm
- Ear loop
- Arm hinge
- T- frame
- Concept 2 frame (see Concept 0)

OPTICS

Appendix 1 to Annex A: OPTICS Concept 0 Drawings

Appendix 1: OPTICS Concept 0

This assembly will have a nose piece that will occur above the standard position, clearing the nose cone on the NBC.



This unit can be used as the current model, by adding the existing nose clip, it will attach directly to the Bolle frame.

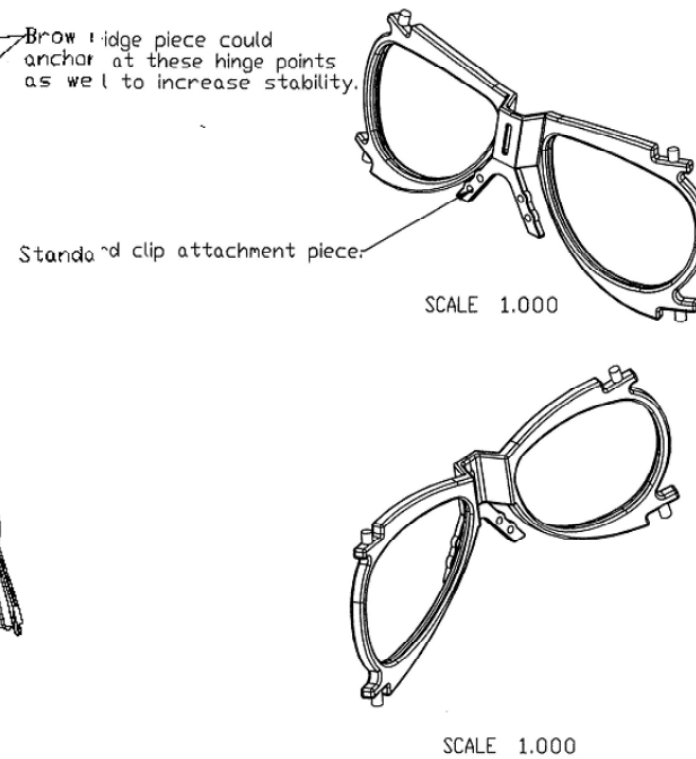


Figure 14: OPTICS Concept 0

OPTICS

Appendix 1 to Annex A: OPTICS Concept 0 Drawings

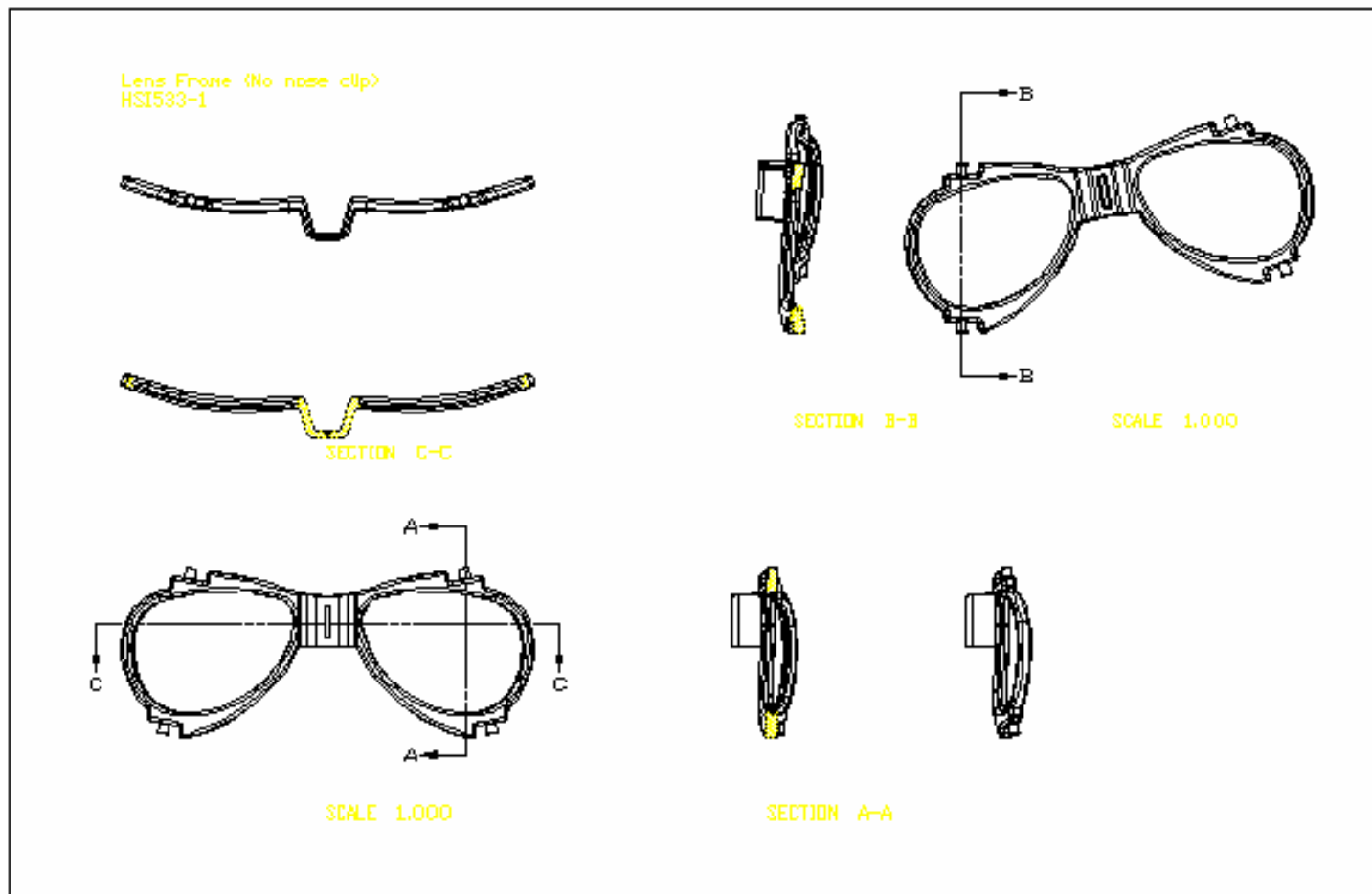


Figure 15: OPTICS Concept 0 frame

OPTICS

Appendix 1 to Annex A: OPTICS Concept 0 Drawings

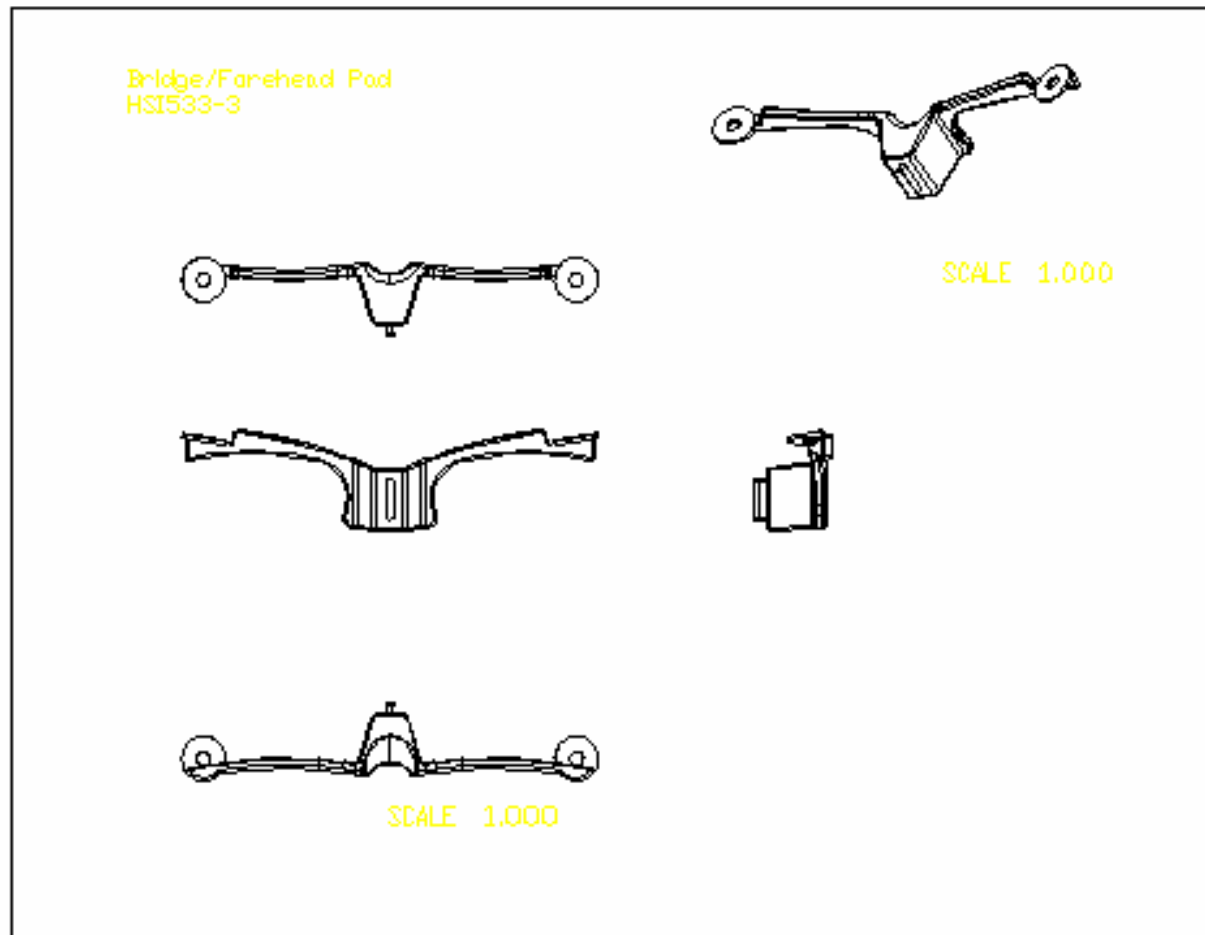


Figure 16: OPTICS Concept 0 bridge and forehead pad

OPTICS

Appendix 1 to Annex A: OPTICS Concept 0 Drawings

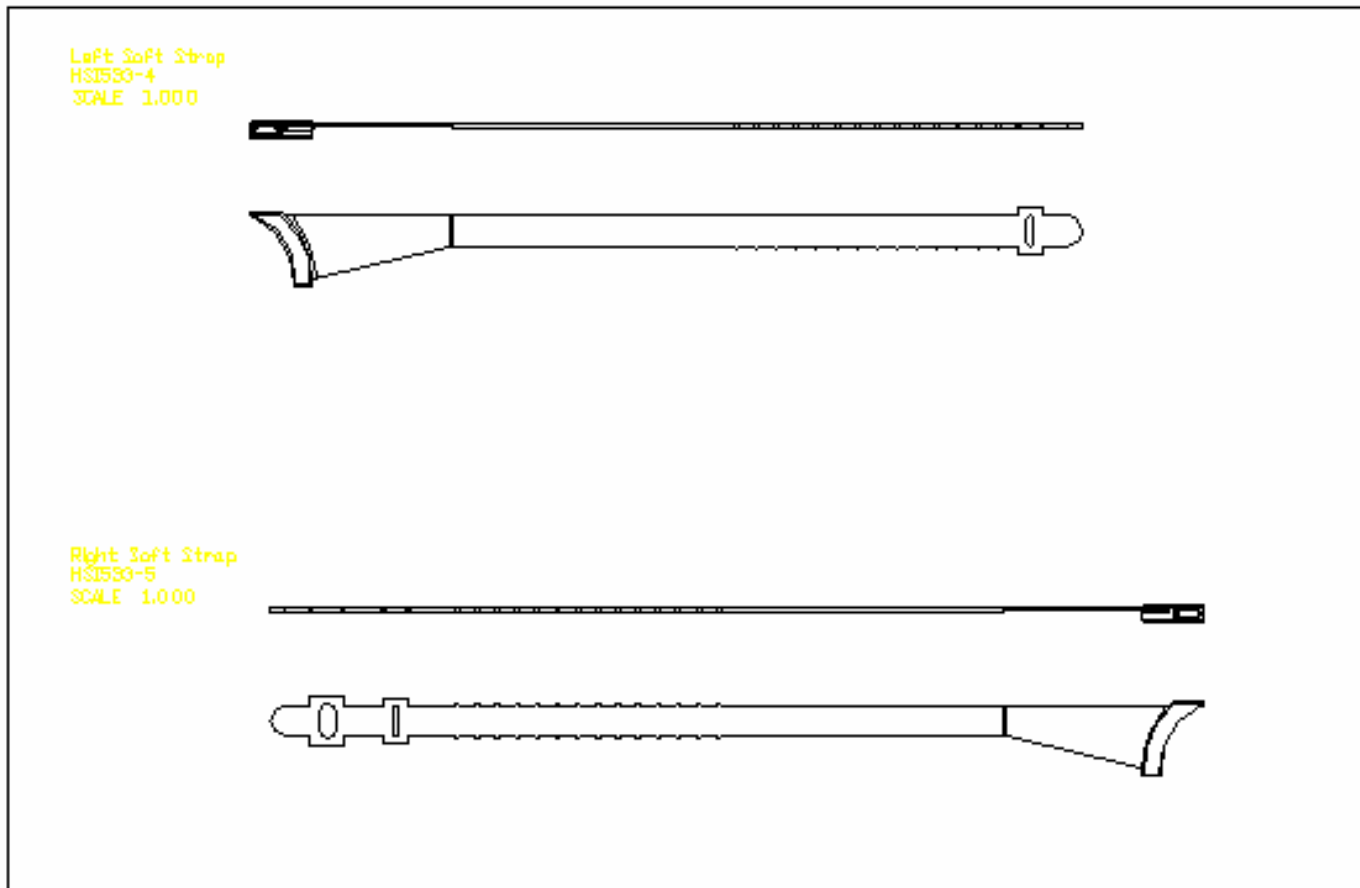


Figure 17: OPTICS Concept 0 soft strap

OPTICS

Appendix 1 to Annex A: OPTICS Concept 0 Drawings

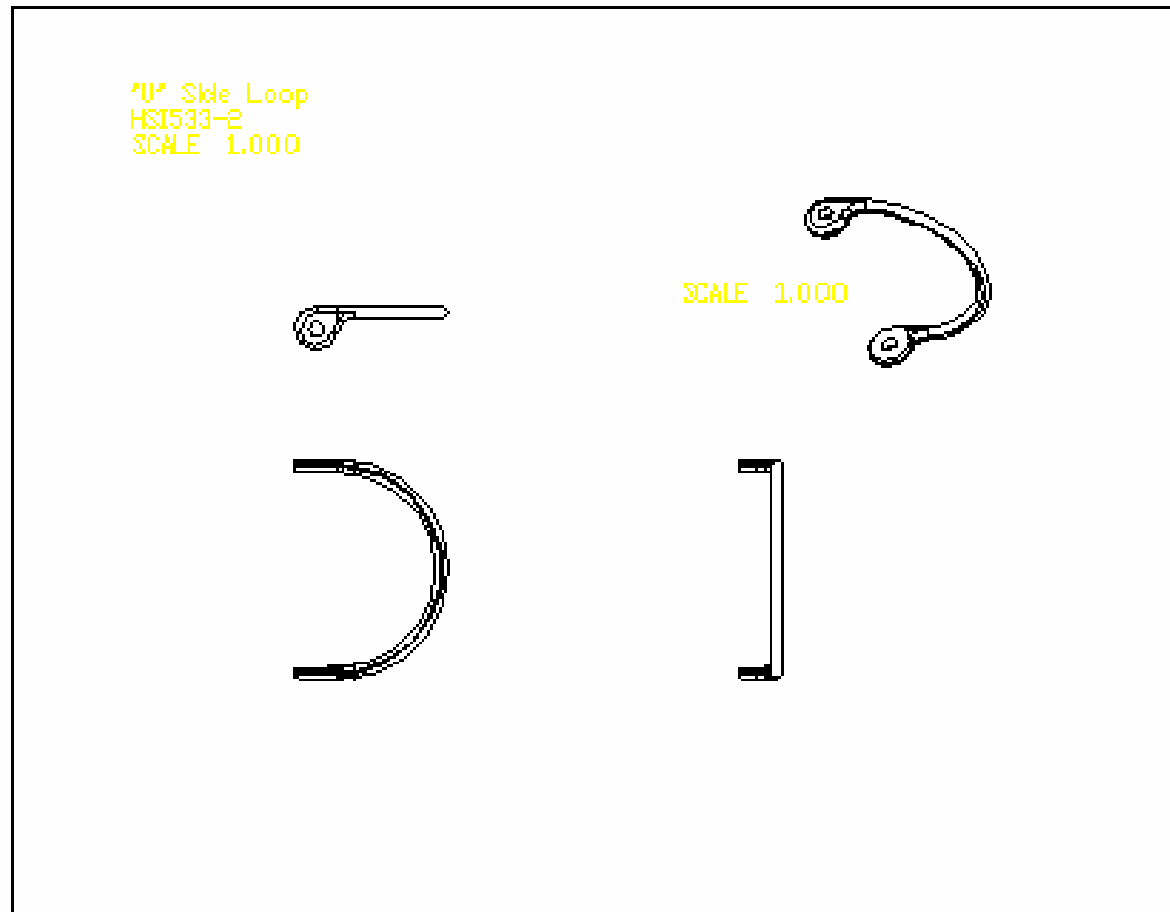


Figure 18: OPTICS Concept 0 ear loop

OPTICS

Appendix 2 to Annex A: OPTICS Concept 1 Drawings

Appendix 2 : OPTICS Concept 1

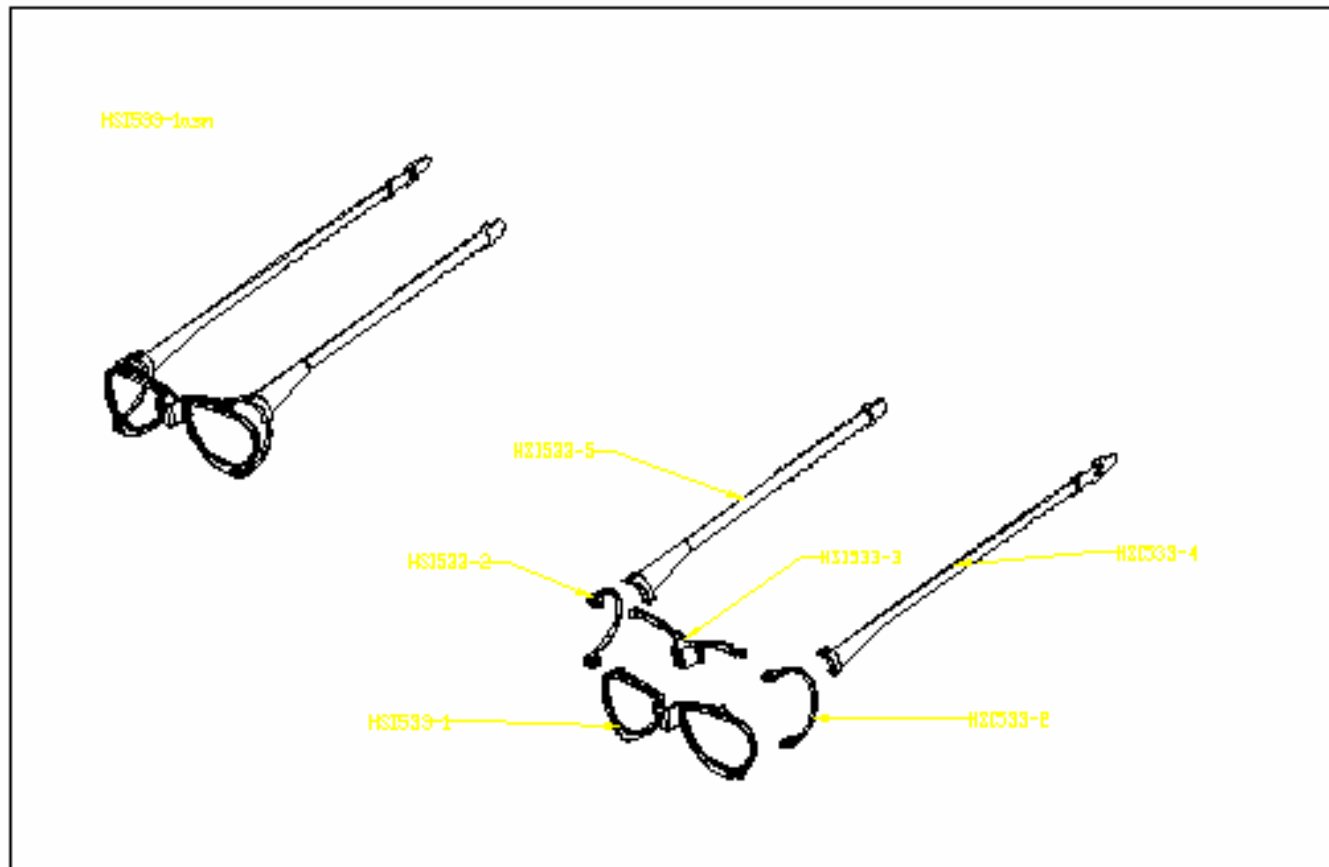


Figure 19: OPTICS Concept 1

OPTICS

Appendix 2 to Annex A: OPTICS Concept 1 Drawings

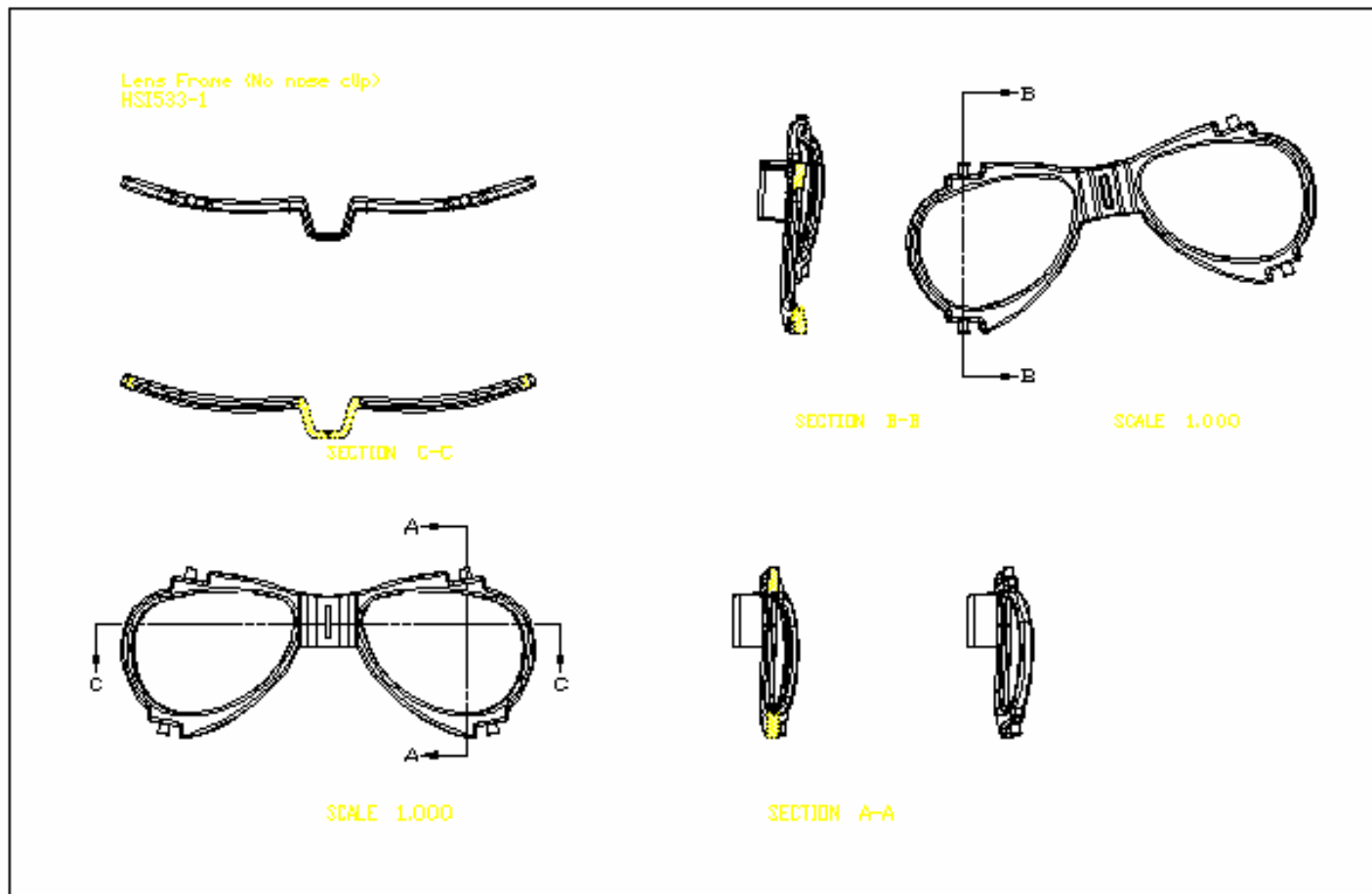


Figure 20: OPTICS Concept 1 frame

OPTICS

Appendix 2 to Annex A: OPTICS Concept 1 Drawings

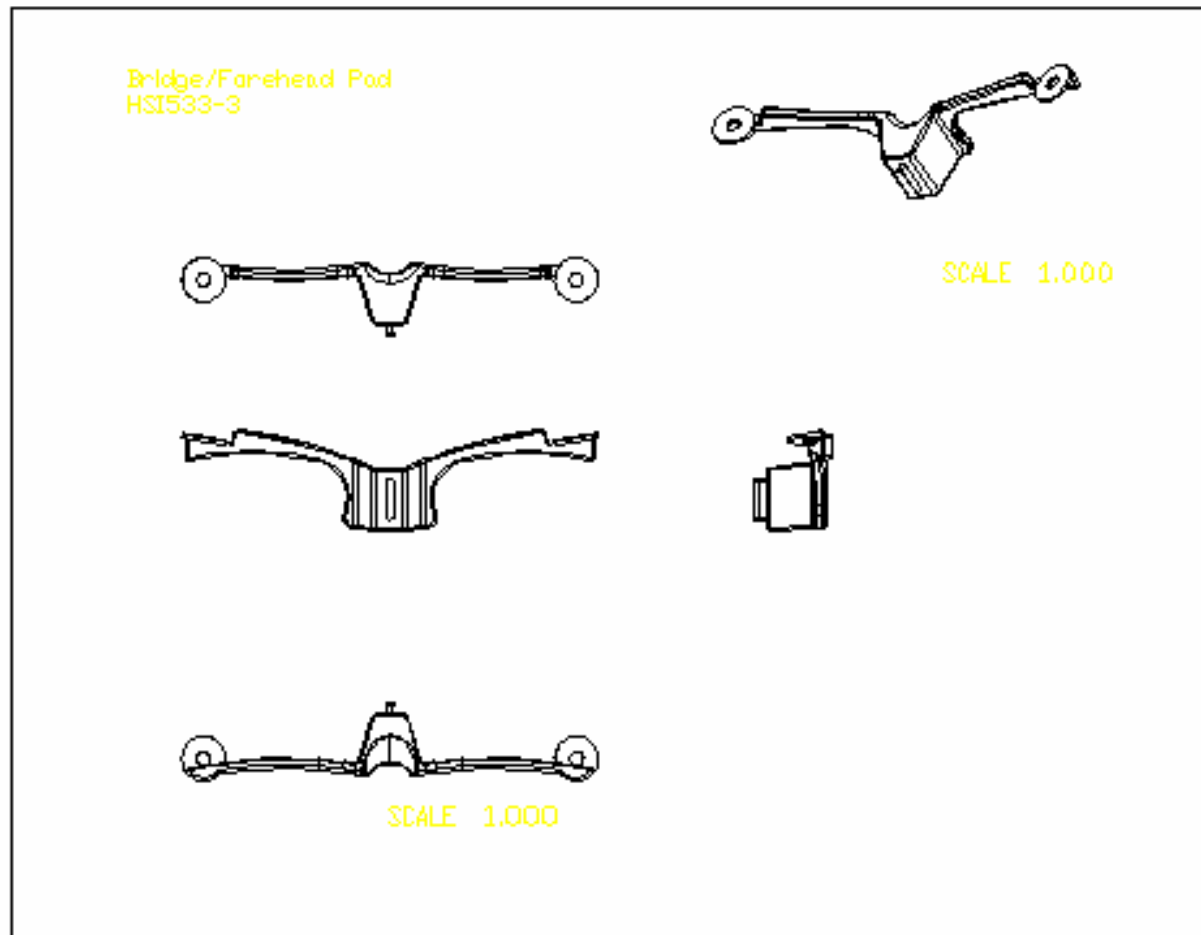


Figure 21: OPTICS Concept 1 bridge and forehead pad

OPTICS

Appendix 2 to Annex A: OPTICS Concept 1 Drawings

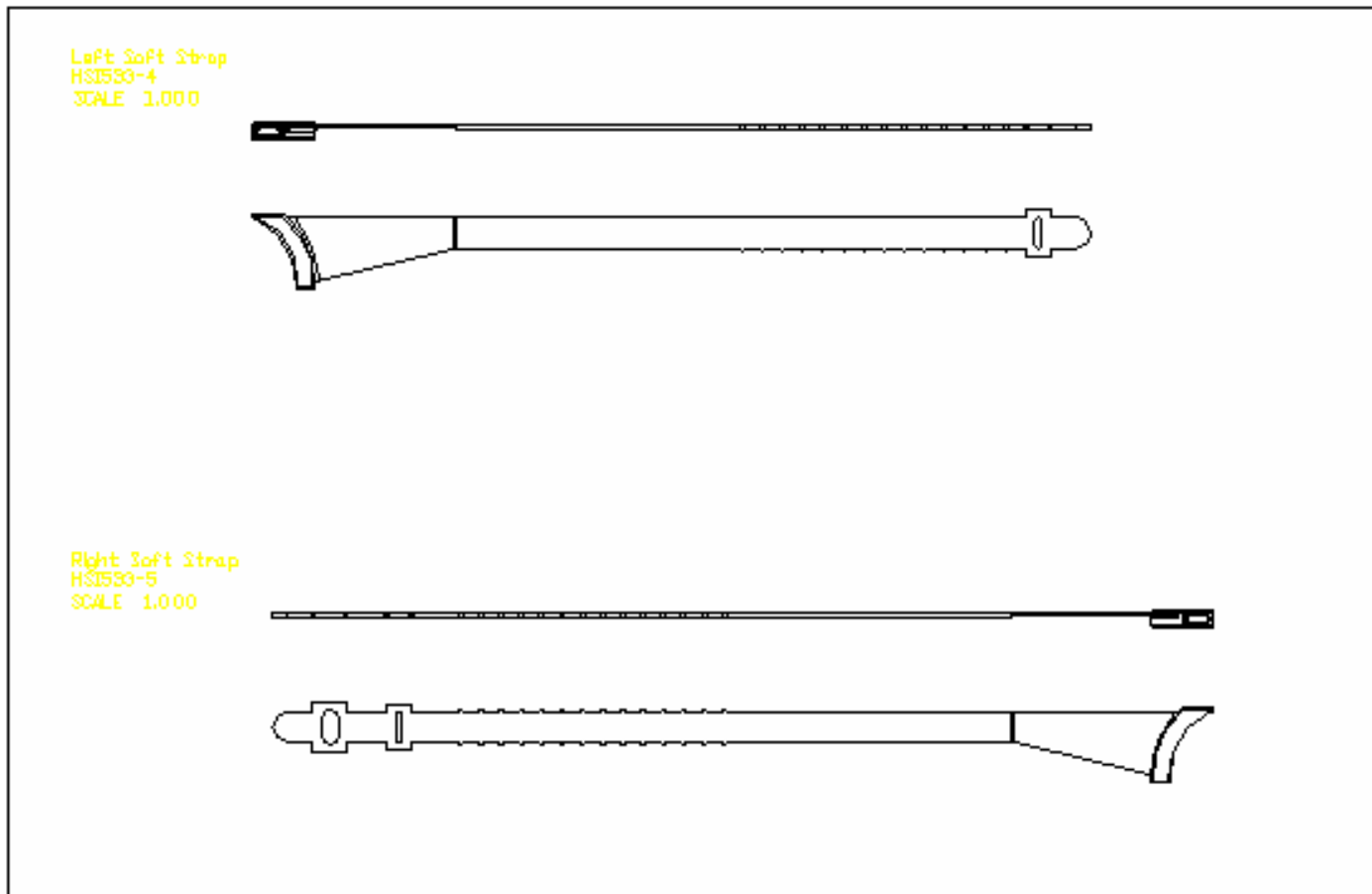


Figure 22: OPTICS Concept 1 soft strap

OPTICS

Appendix 2 to Annex A: OPTICS Concept 1 Drawings

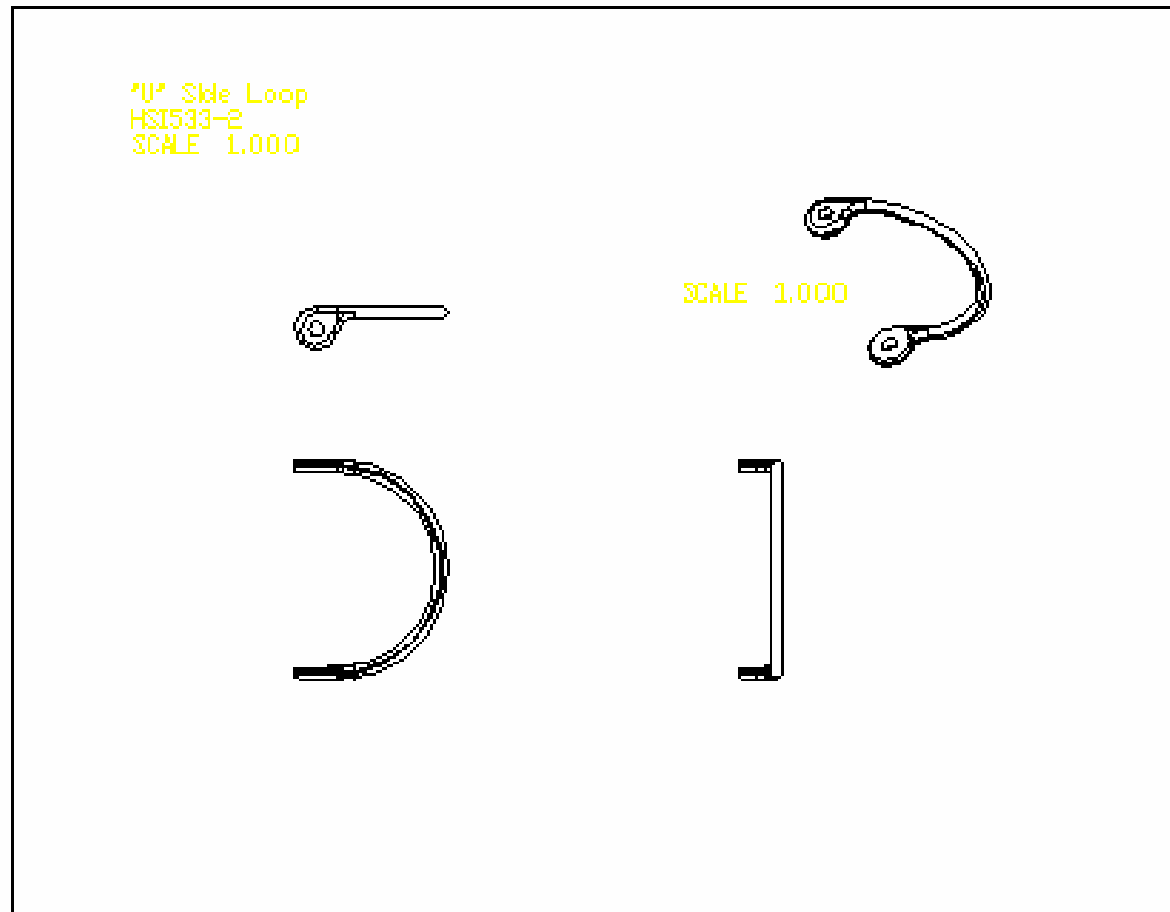


Figure 23: OPTICS Concept 1 ear loop

OPTICS

Appendix 3 to Annex A: OPTICS Concept 2 Drawings

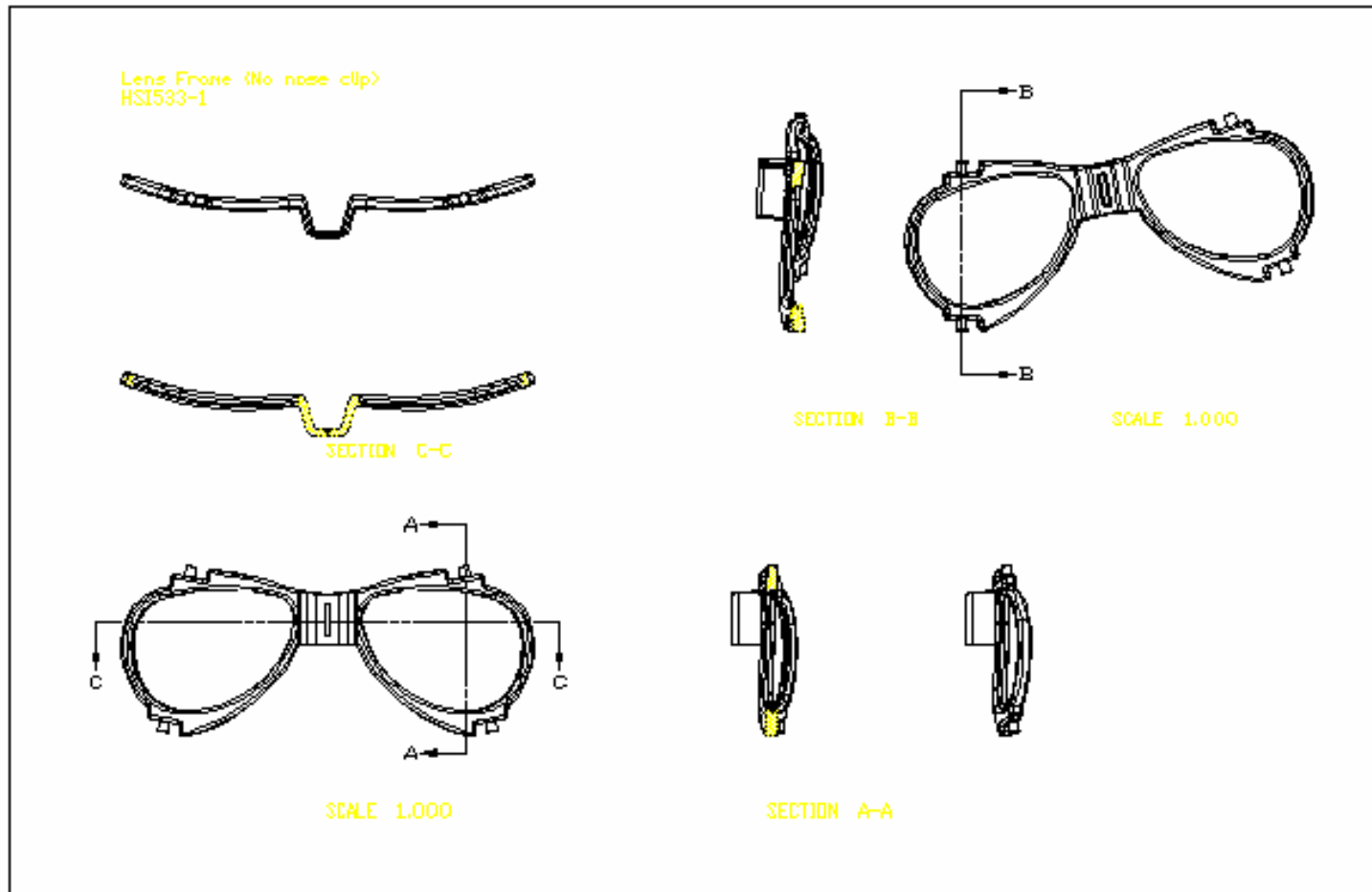


Figure 25: OPTICS Concept 2 frame

OPTICS

Appendix 3 to Annex A: OPTICS Concept 2 Drawings

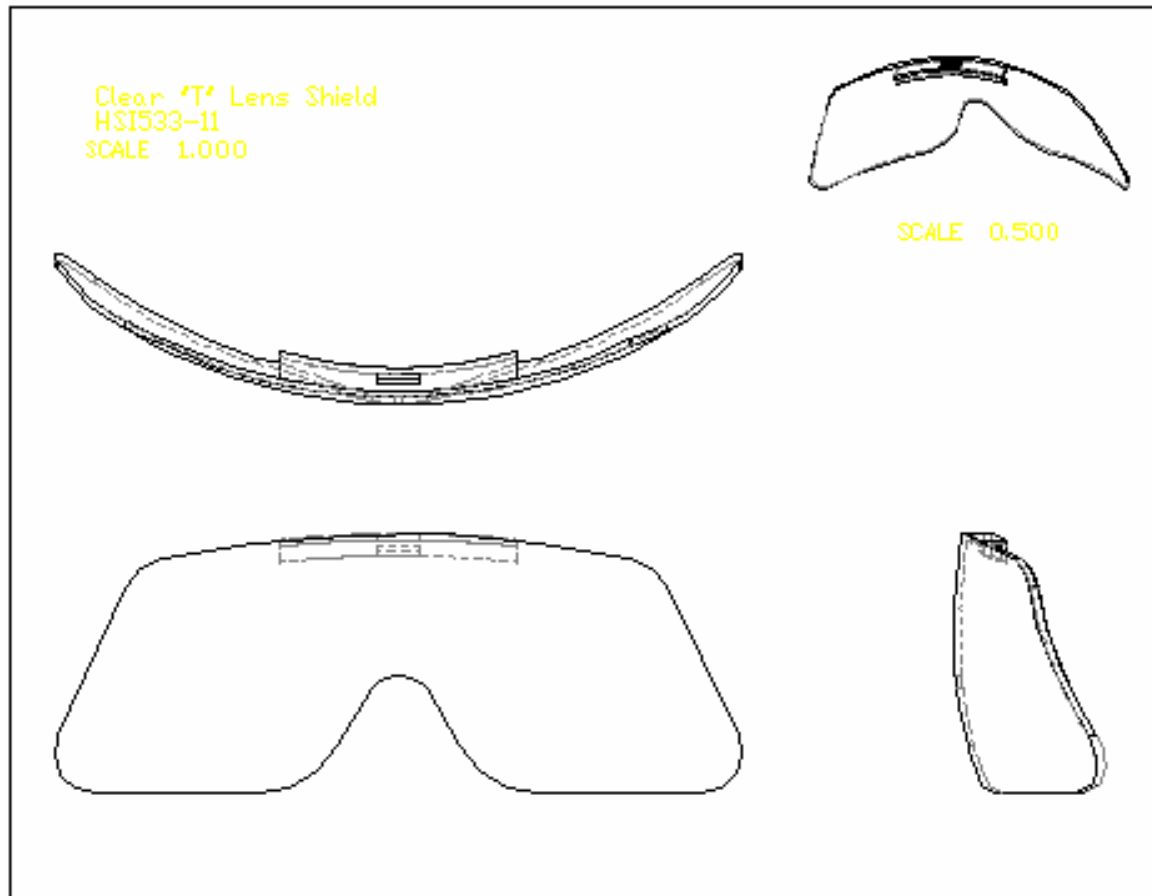


Figure 26: OPTICS Concept 2 lens shield

OPTICS

Appendix 3 to Annex A: OPTICS Concept 2 Drawings

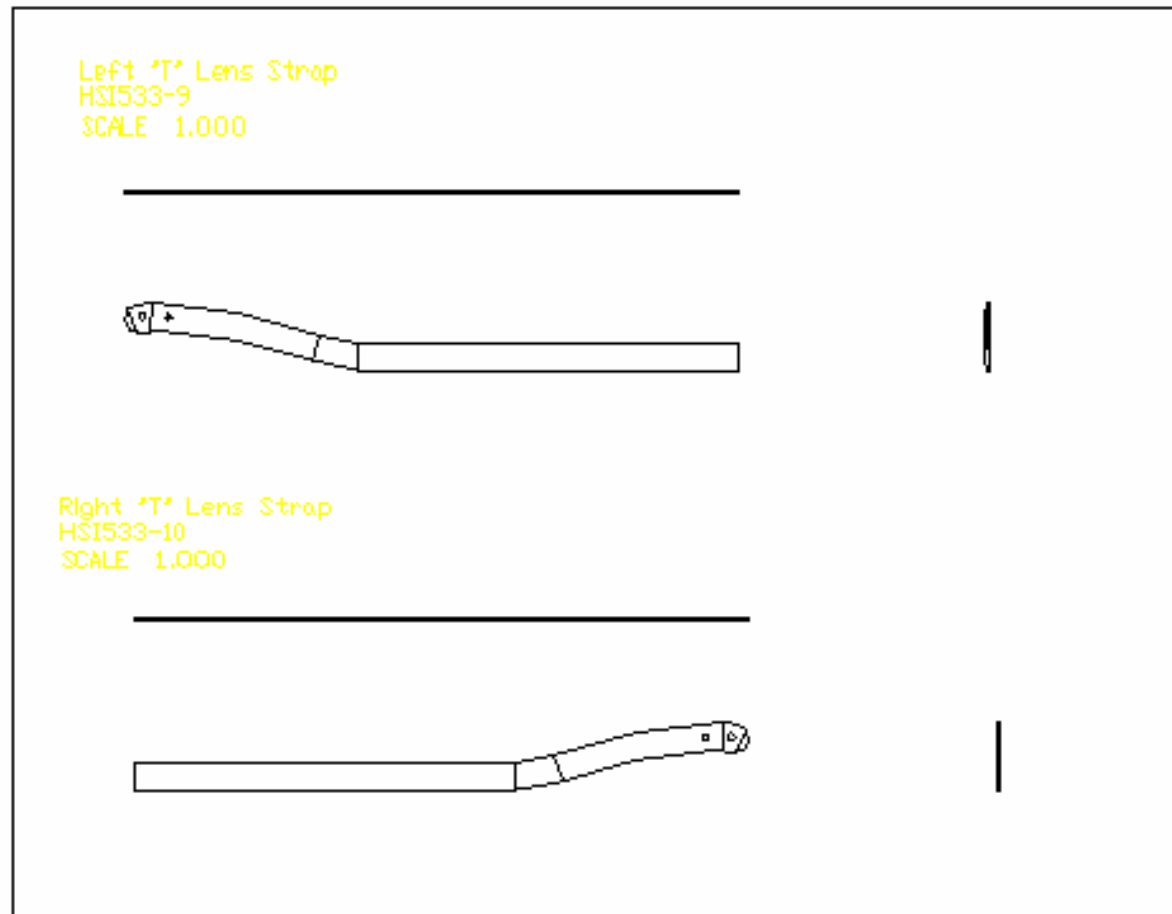


Figure 27: OPTICS Concept 2 temple arm

OPTICS

Appendix 3 to Annex A: OPTICS Concept 2 Drawings

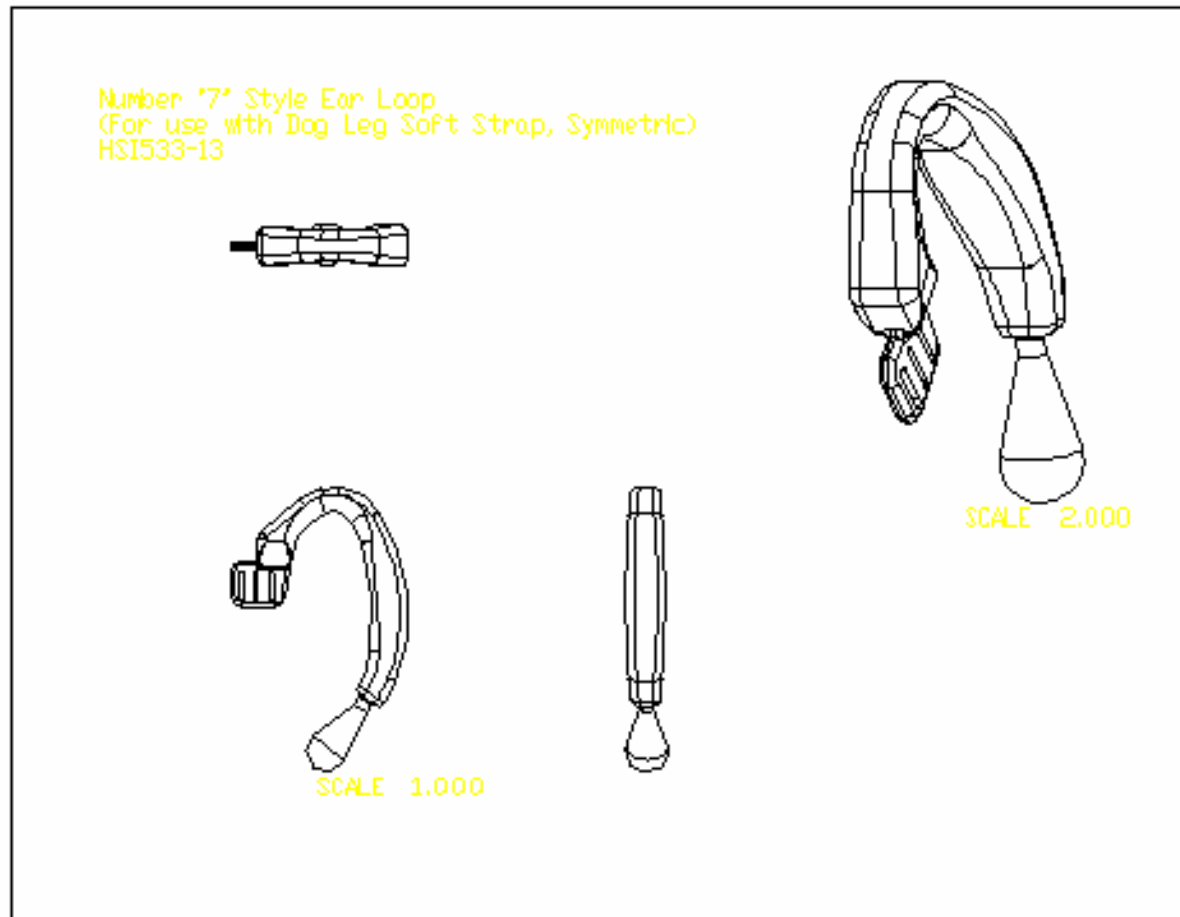


Figure 28: OPTICS Concept 2 ear hook

OPTICS

Appendix 3 to Annex A: OPTICS Concept 2 Drawings

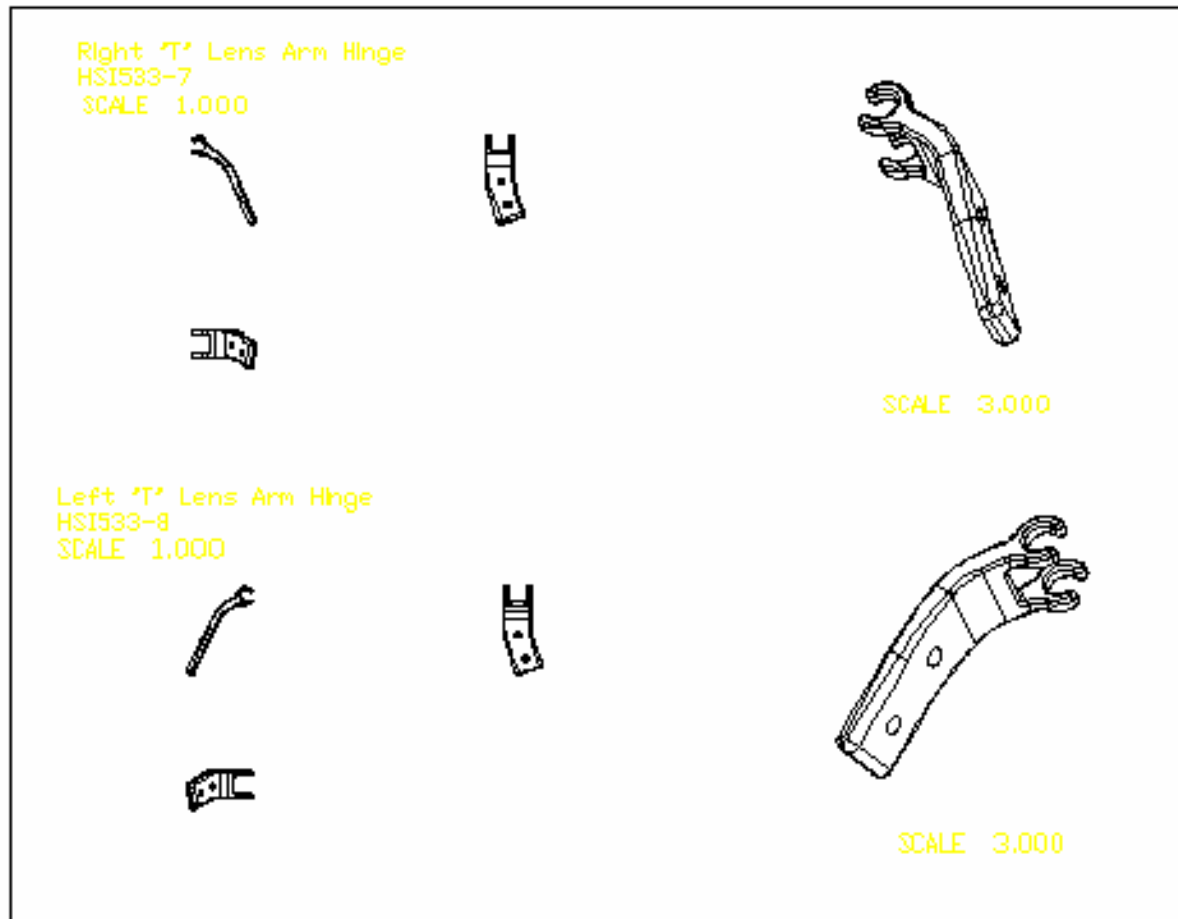


Figure 29: OPTICS Concept 2 temple arm hinge

OPTICS

Appendix 3 to Annex A: OPTICS Concept 2 Drawings

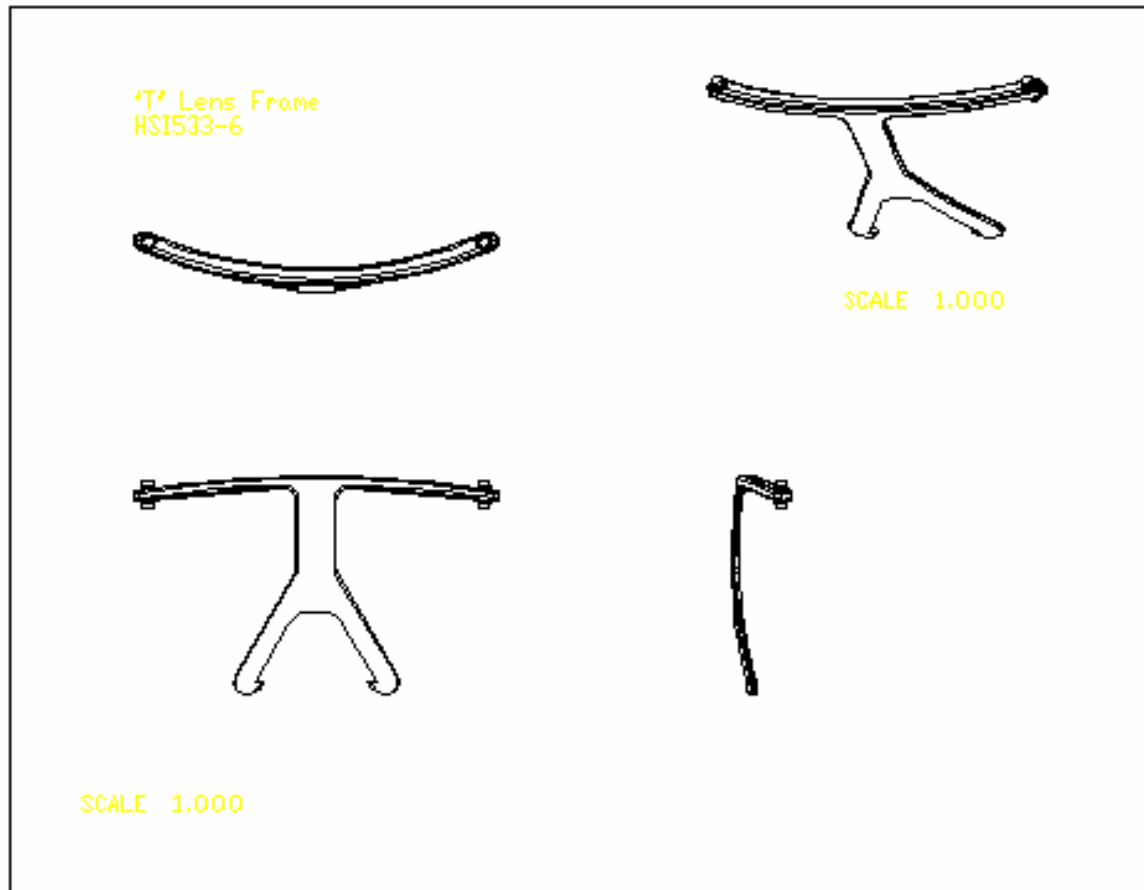


Figure 30: OPTICS Concept 2 T-frame

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|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1. ORIGINATOR (The name and address of the organization preparing the document, Organizations for whom the document was prepared, e.g. Centre sponsoring a contractor's document, or tasking agency, are entered in section 8.) Publishing: DRDC Toronto Performing: Humansystems, Incorporated, 111 Farquhar St., Guelph, ON N1H 3N4 Monitoring: Contracting: DRDC Toronto | | 2. SECURITY CLASSIFICATION <small>(Overall security classification of the document including special warning terms if applicable.)</small> UNCLASSIFIED |
| 3. TITLE (The complete document title as indicated on the title page. Its classification is indicated by the appropriate abbreviation (S, C, R, or U) in parenthesis at the end of the title) OPTICS (OPERATIONAL THREAT INTEGRATED CORRECTIVE SPECTACLES) PRODUCTION AND INITIAL HUMAN FACTORS TESTING (U) LUNETTES OPTICS (LUNETTES CORRECTRICES INTÉGRÉES À L'ÉQUIPEMENT DE PROTECTION CONTRE LES MENACES OPÉRATIONNELLES) – PRODUCTION ET ESSAIS INITIAUX RELATIFS AUX FACTEURS HUMAINS (U) | | |
| 4. AUTHORS (First name, middle initial and last name. If military, show rank, e.g. Maj. John E. Doe.) Harry Angel | | |
| 5. DATE OF PUBLICATION <small>(Month and year of publication of document.)</small> June 2006 | 6a NO. OF PAGES <small>(Total containing information, including Annexes, Appendices, etc.)</small> 50 | 6b. NO. OF REFS <small>(Total cited in document.)</small> 14 |
| 7. DESCRIPTIVE NOTES (The category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of document, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.) Contract Report | | |
| 8. SPONSORING ACTIVITY (The names of the department project office or laboratory sponsoring the research and development – include address.) Sponsoring: Tasking: | | |
| 9a. PROJECT OR GRANT NO. (If appropriate, the applicable research and development project or grant under which the document was written. Please specify whether project or grant.) | 9b. CONTRACT NO. (If appropriate, the applicable number under which the document was written.) W7711-7-7429/001-TOR | |
| 10a. ORIGINATOR'S DOCUMENT NUMBER (The official document number by which the document is identified by the originating activity. This number must be unique to this document) DRDC Toronto CR 2007-024 | 10b. OTHER DOCUMENT NO(S). (Any other numbers under which may be assigned this document either by the originator or by the sponsor.) | |
| 11. DOCUMENT AVAILABILITY (Any limitations on the dissemination of the document, other than those imposed by security classification.) Unlimited distribution | | |
| 12. DOCUMENT ANNOUNCEMENT (Any limitation to the bibliographic announcement of this document. This will normally correspond to the Document Availability (11). However, when further distribution (beyond the audience specified in (11) is possible, a wider announcement audience may be selected.)) Unlimited announcement | | |

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(U) This report details the design, development and preliminary testing of three different Operational Threat Integrated Corrective Spectacles (OPTICS) concepts. The aim of the OPTICS project is to develop an integrated set of corrective eyewear inserts that will be compatible with ballistic protective eyewear and will be compatible for use inside the in-service C-4 respirator. Over the course of 13 months, three different OPTICS concepts were designed, developed and delivered to DCIEM. An iterative design approach with user feedback was utilized. Each concept employed a different approach for meeting the aims of the device; Concept 0 utilized a Commercial Off the Shelf sports-style prescription insert as its starting point, Concept 1 used a previously developed NBC spectacle as its inspiration and finally Concept 2 used a unique carrier approach. The concept of fielding a system that could utilize a prescription insert with ballistic eyewear and with a C4 respirator was well received. The participants also identified the need to have a minimum of two sets of OPTICS inserts. Advantages and disadvantages with all of the concepts developed were noted. Overall the participants believed that Concept 0 and Concept 1 were the most promising for further development and testing. Proposed modifications to all concepts were noted. The participants believed that further development should only proceed after CTS has identified a winner in its ballistic eyewear program. Additional test requirements were also noted.

(U) Le présent rapport détaille la conception, la réalisation et les essais préliminaires de trois concepts différents de lunettes correctrices intégrées à l'équipement de protection contre les menaces opérationnelles (OPTICS). Le projet OPTICS a pour but de développer un jeu intégré de lentilles correctrices rapportées qui soient compatibles avec les lunettes de protection balistique et qui permettent l'utilisation à l'intérieur du respirateur C-4 en service. Sur une période de 13 mois, trois concepts OPTICS différents ont été conçus, réalisés et livrés à l'IMED. On a utilisé une méthode de conception itérative avec rétroaction des utilisateurs. Chaque concept faisait appel à une méthode différente pour atteindre les buts du dispositif; le concept 0 a pris pour point de départ des lentilles rapportées de prescription commerciales courantes de type sportif, le concept 1 s'est inspiré de lunettes NBC existantes et le concept 2 faisait appel à une méthode de support unique. Le concept de mettre en service un système pouvant utiliser des lentilles de prescription intégrées à des lunettes de protection balistique et à un respirateur C4 a été bien reçu. Les participants ont également identifié le besoin d'avoir un minimum de deux paires de lentilles OPTICS rapportées. Les avantages et les inconvénients de tous les concepts sont décrits. Somme toute, les participants étaient d'avis que le concept 0 et le concept 1 étaient les plus prometteurs aux fins de développement et d'essais ultérieurs. Des modifications ont été proposées pour tous les concepts. Les participants pensaient qu'on ne devrait pas procéder au développement ultérieur avant que les responsables du projet HLS aient déclaré le vainqueur dans son programme de lunettes de protection balistique. On mentionnait également d'autres exigences d'essai.

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(U) Operational Threat Integrated Corrective Spectacles; OPTICS; Corrective Spectacles; eyewear; ballistic protection; eyewear inserts; Clothe The Soldier; CTS