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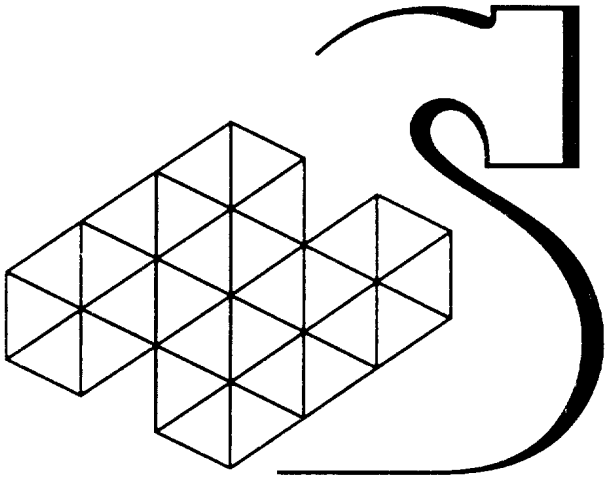

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Human Factors Review of Possible Approaches to the G2122 Fragmentation Vest Modification Programme

December 3, 1993

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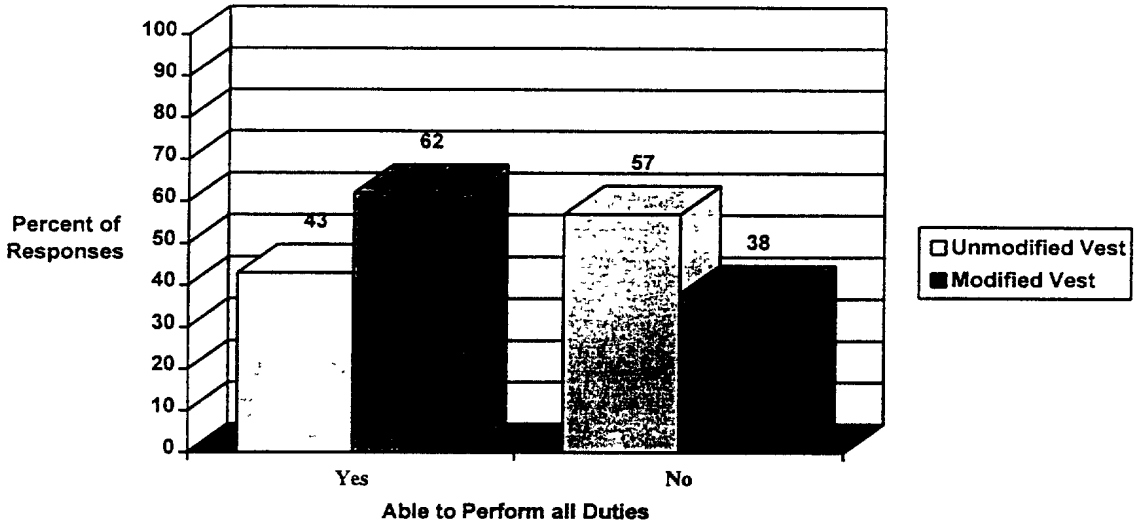
INTRODUCTION

As a result of operational feedback, numerous deficiencies have been reported with the current Canadian Forces fragmentation vest. Major deficiencies included the following.

- The vest collar is too stiff, restricting head and neck movement. During prone firing the collar restricts the head from adopting a normal sighting posture when wearing a helmet.
- The stiffness of the vest, restricts the amount of torso movment in many soldier tasks. Particular concerns have been raised with advance to contact and firing personal weapons.
- The long torso length of the vest is incompatible with seated and crouching tasks. When seated, the vest rides up the torso constricting the shoulders and neck. During vehicle operation, drivers reported difficulties with arm and shoulder carriage mobility which affected driver performance and comfort.
- Button fasteners are difficult to use and slow access to magazine pockets. Elastic straps wear too quickly.
- The small shoulder openings and large, heavily elasticized shoulder pads greatly restrict shoulder movement.
- Soldiers find their webbing to be incompatible when wearing a frag vest. Since webbing is not worn with the vest the webbing hooks provided have become an annoying snagging hazard.
- The two magazine pockets provided on the front panels of the vest are not considered adequate for replacing the storage capacity of their webbing.
- Both the shoulder pads and the top back panel (modified vest) are significant snagging hazards.

As a result, a restriction has been placed on live field firing when wearing the vest. To overcome some of these deficiencies, the back panel was modified on 4000 vests, from a total inventory of 33,000 vests. The modification included horizontally splitting the single back panel into two panels and attaching them with elastic straps.

To evaluate the effectiveness of this modification, DCIEM distributed a questionnaire to 300 soldiers on U.N. duty in the former Yugoslavia to determine if soldiers felt capable of performing their duties while wearing either vest. These results are summarized in the graph below.



Although the modified vest is an improvement, a significant proportion of respondents still had concerns with the modified vest. Wearing the unmodified vest, many soldiers (~60%) reported that they were unable to perform all duties. When wearing the modified vest, the back panel modification afforded some improvement, but a significant proportion of soldiers (~40%) still did not feel capable of performing all their duties. In an effort to correct the vest's operational deficiencies and enable the Land Force to remove the restriction on live field firing a new fragmentation vest modification programme (G2122) has been undertaken.

OBJECTIVE

As a first phase in the Fragmentation Vest Modification Programme, DCIEM requested that Humansystems Incorporated review the feasibility and economies associated with different approaches to the re-design of the current Army fragmentation vest. Three possible approaches are outlined below in order of increasing modification to the vest.

1. Retain the existing Kevlar panels and carrier. Undertake limited modifications to the existing vest such as shortening the length, removing the collars, altering pocket fasteners, etc.
2. Retain the existing Kevlar panels and design a new carrier based on human factors criteria.
3. Design a new carrier lined with new ballistic protection materials.

METHOD

To evaluate the suitability of each approach, Humansystems canvassed two Canadian body armour manufacturers (Pacific Body Armour and Canadian Body Armour) regarding the costs and feasibility of various frag vest modifications. These issues were also discussed with body armour researchers at the U.K. Stores and Clothing Research and Development Establishment and commercial body armour products were reviewed for state of the art developments.

RESULTS

Each body armour manufacturer was interviewed according to the same battery of questions. These questions and their respective answers are outlined in Appendix A. The suitability of each of the three approaches is summarized below.

1. **Retain Kevlar Panels and Carrier:** Several modifications to the existing carrier were proposed in the Statement of Work. These included re-designing and replacing pockets and fasteners, shortening the length of the vest, enlarging the shoulder area, modifying the collar, adding shock plates, shortening the protruding corners on the back panel, improving fit adjustment, reducing stiffness, and improving IR camouflage.

   Both manufacturers indicated that most of the proposed modifications were achievable but costly. Feasibility and costs were most affected by the current vest construction. The vest comprises several external panels. Changes to one panel will often require modifications to other related panels. The vest has also been assembled by sewing through the carrier and ballistic panels. As a result, most modifications require that the vest first be disassembled to separate the carrier from the ballistic panels.

   The easiest modifications include replacing pockets and fasteners, and removing the collar. Replacing the pockets, however, would require additional sewing through the ballistic material increasing vest stiffness. Shortening panels to reduce the length of the vest or to improve the range of shoulder movement would be time consuming and costly due to the extensive disassembly required. The following modifications are not feasible with the existing carrier.

   - **Stiffness:** The effect of vest stiffness on ease of movement and prone firing has been a major concern with the current vest. The current vest stiffness results from the sewn through construction, the heavy carrier fabric, and the dense waterproofing treatment used on the carrier. It is not practical to modify these features.
   - **Shock Plates:** Shock plates are becoming increasingly necessary due to the exposure of Canadian troops to high velocity sniper fire during U.N. peace keeping missions. Shock plate pockets cannot be easily added to the current vest design. This would necessitate that a separate shock plate carrier be developed and worn over the existing vest. The separate carrier is costly and could be impractical in wearability terms.

- **IR Camouflage:** Both manufacturers suggested a new carrier material be used with an IR absorption coating.
- **Fit Adjustment:** For a small amount of fit adjustment range the existing elasticized bands could be easily replaced with a strap and fastener mechanism. If a larger amount of adjustment is required then the size of the panels would need to be enlarged at the sides requiring considerable vest reconstruction.

2. Retain Kevlar Panels and Re-design Carrier: Both manufacturers recommended this option. It was generally felt that all the design objectives could be met most cost effectively with a new carrier. Ballistic material could be salvaged from the current vest, reshaped, and packaged in a waterproof pouch. These pouches would also protect the Kevlar panels from dirt, chemicals, abrasion, and U.V. light, are removable for easier carrier cleaning and repair, and offer a means of interchanging different carrier camouflages. The carrier itself would be constructed of a lighter fabric and coated for IR camouflage. Several improved fabric and materials options are now commercially available:

- High tensile, ripstop nylon and fire retardant materials (eg. Nomex) for the carrier fabric.
- Rugged nylon and polyester coil self-repairing zippers and snaps with low surface reflectance.
- A variety of load carriage options are available using combinations of heavy velcro, moveable pockets, and reinforcing fasteners for individually customized configurations.
- Durable, suede leather for collar comfort and for rifle butt securement on shoulder pads.
- "Wicking" fabrics are available as inner liners to vests to draw moisture away from the body.

Shock plate pockets would be integral to the carrier, fasteners would be improved, pockets re-designed and made adjustable to meet changing load carriage needs, and sufficient fit adjustment would be provided to allow wear over outer garments. Both manufacturers indicated that disassembly of the current vest and the construction of the new carrier and ballistic pouches could be achieved for a relatively low cost ($120.00 - $150.00).

3. New Ballistic Materials and Re-design Carrier: Several advantages could be realized by incorporating new ballistic materials into a new carrier design. There are two main players in the ballistic materials market: woven aramid fibers (Kevlar) and laminated polyethylene fibers (Spectra Shield). Since the construction of the current CF frag vest, several new Kevlar variants have been produced which have improved ballistic protection, flexibility, and reduced weight by volume. Spectra Shield is a relatively new ballistic material (introduced 1987) which reportedly offers the following advantages over aramid weaves.

- Stronger and lighter, providing more ballistic protection by weight.
- Much more resistive to chemical exposure.
- Ballistic performance is not affected by exposure to water.
- Improved blunt trauma protection.
- Ballistic performance unaffected by angled shots.

Proponents of Kevlar cite the following disadvantages.

- As a laminate, Spectra Shield tends to be quite stiff and could potentially reduce flexibility and user comfort.
- Spectra Shield's melting point (298^{o}F) is lower than Kevlar (428^{o}F).

The current state of the art in ballistic material combines layers of different ballistic fabrics (ie. hybrids). Hybrids balance the advantages of different fabrics to achieve a lighter, more flexible ballistic material which offers greater projectile protection. Vests manufacturered with Spectra Shield often incorporate layers of a Spectra woven fabric to overcome concerns with the laminate's stiffness. Future vest designs will likely include both Spectra Shield and Kevlar in a hybrid configuration to achieve the greatest balance of benefits to the user.

Fitting new carriers with new ballistic materials, however, can be quite costly. Commercially available tactical vests are priced between $1000.00 - $2000.00.

DISCUSSION

In assessing the best approach for the frag vest program two basic factors must be considered, the functional effectiveness of the resulting vest and the costs.

Common sense might suggest that keeping the existing carrier and ballistic materials with modifications would be the cheapest option. However, given the sewn through construction and the number of related panels, the disassembly costs associated with these modifications would be high. Even with these modifications, several important functional issues would remain unresolved. The vest would still be quite stiff, lack IR camouflage, be difficult to clean and repair, and would require an additional carrier for shock plates. On balance, modifying the existing carrier and ballistic materials would not seem prudent.

Designing a new carrier with new ballistic materials would satisfy the functional requirements of a vest while employing state of the art ballistic protection. The most expensive feature of this option, however, is the replacement of ballistic materials. If the Kevlar in the current vest satisfies the Army's ballistic protection requirement then replacing it with new materials may be an unnecessary cost. Although advantages could be realized with new hybrid materials, the significant additional costs likely outweigh the associated benefits at this time.

In sizing up the three approaches we feel that designing a new carrier and retaining the existing ballistic panels offers the most cost effective balance of solutions.

RECOMMENDATIONS

Following our review, we recommend the following approach to modifying the Army fragmentation vest.

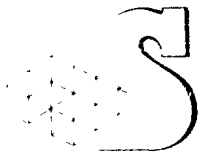
1. Design a new carrier and salvage the ballistic materials from the current frag vest.
2. Undertake the following Human Factors program to design the new carrier.
   - Establish carrier design criteria based on a review of soldier's needs: functionality, fit, load carriage, range of movement, thermal load, donning/doffing, maintainability, ease of adjustment, compatibility with other clothing, equipment, and weapons, etc.
   - Develop a prototype fragmentation vest according to identified user needs.
   - Trial the prototype vest among a representative cross-section of soldiers in the field and test whether minimum design criteria have been achieved.
   - Modify the prototype carrier design based on the user trial data.
   - Prepare a final set of manufacturers specifications for the procurement process.

APPENDIX A

INTERVIEW QUESTIONS	PACIFIC BODY ARMOUR	CANADIAN BODY ARMOUR
1. The pocket fasteners of the existing vest are unsatisfactory and the pocket sizes may need to be altered.		
Could the pocket buttons be replaced with an alternative fastener?	Several alternative fasteners could be used here.	Very difficult and costly to replace fasteners.
How difficult would it be to replace the existing pockets with a new pocket design?	Simple to do. Requires 7.0 minutes to perform. Drawback is increased stiffness if the pockets must be sewn through the Kevlar for attachment.	Very difficult and costly to replace pockets. Requires sewing through Kevlar making vest even stiffer. Best to replace carrier.
2. The construction of the collar is such that it interferes with head movement when wearing a helmet.		
Can the collar be removed?	Collar can be removed easily, only requires 2.2 minutes to perform.	Collar can be removed but it is a major step to take apart the whole vest.
Could it be modified to be less of an obstruction?	Modify the shape of the collar and do not sew the ballistic material directly to the Kevlar in the vest. This will leave a slight gap but this should be an acceptable tradeoff.	Collar can be modified to make it less stiff but this is best addressed with a new carrier.
3. The current vest cannot accommodate shock plates to defeat high velocity small arms projectiles.		
Can pockets for shock plates be added to the front and back of the existing vest?	Not unless the entire carrier is changed or an additional pouch is designed to be worn over the existing vest.	A separate carrier for the plates could be designed and worn over the existing vest. Cost about $45.00.
Could shock plates be accommodated with a front opening vest?	With a new carrier design, plate pockets could be added which would not affect performance or wearability.	Several possible front opening designs. May require an additional section of paneling.

What are the advantages and disadvantages to a side opening vest?	Advantages include improved ballistic integrity of the vest front and ease of access to plates. Side vests are more difficult to don and more awkward for securing the side closure.	Side opening vests allow easier plate access. No protective panel overlap so vest is lighter, more flexible, and single front panel has better ballistic integrity. Faster to don and doff. No disadvantages.
4. The protruding corners of the back panel often become snagged on other equipment, and when entering and exiting vehicles.		
How could snagging be eliminated?	Difficult to eliminate without designing a new carrier. New carrier design should have less segmentation.	Corners should be rounded. Best addressed by a new carrier design.
5. The length of the current vest obstructs leg and hip movement during seated, crouching, and bending tasks.		
Can the current vest be shortened?	The vest can be shortened with about 0.52 hours per vest production time.	Vest must be taken apart to shorten. A new carrier must be constructed to accept shorter panels.
6. The range of movement at the shoulders is limited by the size and stiffness of the shoulder pads.		
Can the shoulder opening be enlarged?	Enlarging the opening requires that several panels be cut back. This is difficult and time consuming (0.75 hours).	Shoulder stiffness can be relieved by removing a portion of the garment directly under the shoulder pad.
Are there other ways to reduce the current restriction to shoulder movement?	To reduce restriction of shoulder movement, trim front panels 1-2 cm, reduce the stitching attaching the shoulder pads to the collar and vest body, and reduce the stiffness of the carrier material.	New carrier design is required. The vest could be disassembled, and material and through stitching removed in the shoulder area. This would need to be tested for manufacturing practicality first.

7. The carrier of the existing vest is permanently sewn to the ballistic insert resulting in increased stiffness, difficulties for cleaning and repair, and provide only one colour of camouflage.		
Are there any shortcomings to a removable carrier?	Few if any. Problem only if panels are installed incorrectly by the user or if they are lost.	If the collar is retained, it may be difficult to provide a good, consistent overlap at the collar/vest junction.
What are the typical costs of a plain carrier without pockets versus a tactical carrier?	Plain carrier for this style of vest would be about $100.00. Tactical vest, which is more complex, would cost $150.00. These costs do not consider volume discounts and other applicable costs.	Cost depends on the number of extra pockets, the materials specified, etc. Estimated cost is about $65.00 plus $5.00 for plate pockets.
8. The current vest cannot be adjusted in size to accommodate the wearing of additional garment layers underneath the vest.		
How might the existing vest be modified for sizing adjustment?	Several adjusting mechanisms could be considered (buckles or Velcro). If a large amount of adjustment is needed then a new carrier design should be considered. This would include an additional overlap panel.	Extra adjustment could be added if elastic was replaced with elastic and hook & loop closures. Cost about $20.00.
9. To protect the Kevlar material from moisture, the existing carrier has been treated with a waterproof coating.		
What other means exist for achieving the same moisture protection?	With a removable carrier, the ballistic panels would float inside a light waterproof nylon pouch. This would include minimal stitching through the Kevlar.	Using the existing Kevlar, the armour panels could be removable in a ripstop nylon pouch. The new carrier material should also be coated in a light urethane on one side. For new aramid ballistic material, a water repellent treatment could be applied which does not increase stiffness.



10. The heavy carrier material and the waterproof coating combine to make the vest quite stiff, reducing ease of movement.		
How might this stiffness be reduced?	Best to replace the carrier material and have removable ballistic panels in waterproof pouches.	Eliminate the sewing through the vest and use a lightly coated new material for the carrier.
11. The carrier material does not reflect Infra-red radiation and offers little camouflage from night vision devices.		
How might IR camouflage be improved?	Acquire a new carrier material with IR absorption coating.	IR camouflage can be enhanced by controlling the finish on the carrier material.
Carrier Replacement Costs	Plain carrier is $100.00. Tactical carrier is $150.00.	Side opening carrier with plate pockets is $100.00. Front opening carrier **without** plate pockets is $100.00 Front opening carrier with plate pockets is $120.00.

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