ANNEX A

STATEMENT OF WORK

Personal Armour Plate: Alternative Exploration

1.0 OBJECTIVES:

This project includes two phases: Phase 1- development phase of three years which explore and develop advanced material concept armour for personnel and phase 2- procurement phase of one to five years maximum, which is optional and discretionary. Details objectives are:

1- To support Canadian industries that have capabilities of developing, manufacturing and integrating armours to improve processing and manufacturing techniques that will result in a better quality of armour (new technologies and/or material almost ready to be put in service and improve ceramic base for AP threats)
2- To increase the performance of armours for personal protection NIJ threat level III and IV
3- To optimize integration to reduce weight of armour
4- To answer punctual needs in armour plate supplies

2.0 BACKGROUND:

2.1 For NIJ Threat level III

A large variety of material can be used to defeat NIJ threat level III. Materials such as ultrahigh molecular weight polyethylene (UHMWPE), metal plate, ceramic plates are among the most commonly used. The preferred material of choice might depend on the nature of the mission, the weight or price, the threat definition, especially when it is more severe around than the one defined in NIJ for a level III (often referred to as level threat III+), but excluding AP rounds that correspond to a level IV, etc.

R&D is constantly contributing to material improvement. A good example is the integration of nanotubes with other materials that have the potential to change material property and influence the development of armour material in the near future. As such, recent experiments report a significant enhanced toughness in the UHMWPE films due to the addition of 1 wt% multiwalled carbon nanotubes (MWCNTs) (S. L. Ruan et al., Polymer, Vol 44, Issue 19, Sept. 2003). In comparison with the pure UHMWPE fiber at the same draw ratio, adding 5 wt% MWCNT has increased by 18.8% the tensile strength and by 15.4% the ductility. Also, a 44.2% increase in energy to fracture has been observed (S. L. Ruan et al., Polymer, Vol 47, Issue 5, Sept. 2006). Based on these results, it is expected that multiwalled carbon nanotubes might contribute to build a better protection in the near future, especially for threat level III.

Other options might also exist using other varieties of materials and are all of interest if they can contribute to improve performance or reduce weight burden of armour.

2.2 Threat level IV

Ceramics have been used in armour applications for more than half a century. They are attractive as armour materials for personal protection because compared with steel, they are capable of resisting the same armour piercing ammunitions with a significant lower mass. In fact, their low areal density but high compressive strength and hardness overmatch the loading produced by a penetrator at impact, which fractures and breaks on the surface of the ceramic. The advances in processing techniques of these materials over the past few decades have resulted in lower areal density and a variety of these types of materials is now available (Al203, SiC, B4C, TiB2, combining SiC and B4C, integrated nanofibers in ceramic, etc.). Many manufacturing processes exist (slip casting, reaction bonded, pressure casting, hot pressing, hot isostatic pressing (HIP), sintering, rapid carbothermal reduction process, etc.), but they are the major cause of internal defects (pores, inclusions, twin/grain boundary intersection, etc.) that influence significantly the performance of the armour because they are crack initiators during impact process. It is therefore of prime importance to continuously develop and improve manufacturing techniques that will result in improving quality and performance of ceramic armours.

The development of new ceramics for armours is limited by the understanding of the mechanisms involved in their ability to perform well under ballistic conditions. To date, armour performance has not been successfully correlated to a specific material characteristic or a static material property. Therefore, what the characteristics of an ideal ceramic should be is not clearly known. However, the positive influence of some of the ceramic properties in resisting ballistic impact has been established. Over such properties, the compressive strength of the ceramic affects the initial resistance to penetration. The bulk, shear and Young's moduli are responsible for resisting the deformation until failure. The yield stress is related to the failure resistance. The density defines the weight of the armour. The hardness influences the capability of destroying the projectile tip. The toughness is the resistance to fracture and defines the amount of energy per volume that material can absorb before rupturing. The foregoing key material properties that may be used to guide the development of new ceramics for light armours are density, hardness, and toughness. As a rule-of-thumb, hardness is higher than that of the projectile is desirable for armour ceramics. High fracture toughness is also desirable to minimize the shattering of the ceramic on impact which may improve the ability of the material to resist multiple hits. Unfortunately, hardness and toughness tend to follow an inverse relationship in most materials, which means that an increase in hardness is generally accompanied by a decrease in fracture toughness.

The armour backing material also has its importance in the global armour performance. Backing is usually made of rigid composite materials using different fibers such as Aramid and UHMWPE that is bounded to the ceramic layer. It supports the ceramic in preventing excessive local and global deformation and spreads the highly localized projectile/ceramic interaction over a wide area to limit loading on the person standing behind the armour. The backing also absorbs part of the residual projectile and ceramic debris energy through delamination and debris penetration processes. Material selection and integration process with the ceramic are key parameters in the quality of the armour.

3.0 APPROACH:

Following the development phase, presuming success has been achieved in developing a product, an optional one to five year supply for a small series (between few hundreds up to a thousand) could be considered acording to our disretion. Canada could decides to exercise and option if two or more amours meet the conditions in Section 5.0, the performance of candidate armours from each contractor would be rated using the ballistic tests results in Section 6.0. During this optional Supply and delivery phase, quality control tests made at DND ballistics laboratories would support the acquisition. Quality control tests would meet the conditions described in Subsection 6.1, below. A minimum of 20 armour systems would be required from each batch. This disclosure does not commit Canada to exercise an option.

Innovation should focus on maintaining existing level of protection while trading off technology advances for weight and burden reduction.

At any moment during the execution of the contract, should a situation develop that requires the protection to be adjusted to meet a different threat, this new threat will be disclosed to the contractor and the contract will be amended to meet the new needs.

4.0 PHASE I: ARMOUR DEVELOPMENT PHASE

In this phase, the contractors will execute the development plan proposed during the bidding and approved by DND. Two main improvement paths are available:

a) Improved ballistic performance.
b) Reduced weight.

Any approach or new concept that will improve one or both of the above is acceptable.

4.1 For NIJ threat level III / III+

4.1.1 Material performance improvement

- Any solution that has the potential to improve armour performance (new fiber/material for composite combination, new metal or metal matrix composite, integration of nanofibers with UHMWPE, new ceramic base material, etc.) is acceptable.
- For ceramic base armour, approach as per NIJ threat level IV is suggested (Section 4.2).
- If any material characterization is needed, it is the sole responsibility of the contractor.

4.1.2 Integration

- Depending on material use, integration might or might not be required. This is an important part because parameters such as transient deformation, rigidity, buckling, etc could be affected. The integration part is the sole responsibility of the contractor.
- To monitor the improvements of the armour, ballistic limit tests (V50) as per NIJ 0101.06 for threat level III can be used. Contractor has the option to use its 2 control ballistic tests at DRDC Valcartier ballistics laboratory allowed per year. However, only results from mandatory requirements as defined in Section 5.1 will be used to consider the supply option.
- The dimensions of the ballistic armour plate system shall not be smaller or bigger than the specified dimensions in drawing #1 (appendix 1). It should also be multicurved, as shown in picture #1 to better fit a typical human body.

4.2 For NIJ threat level IV

4.2.1 Ceramic material performance improvement

- Any solution that has potential to improve armour performance (new powder combination, integration of nanofibers in ceramic, for example) is acceptable.

- Improved ceramics can be compared with the reference ceramic material by using quasi-static tests, high strain rate or Depth of Penetration (DoP) tests. When significant improvement in performance (considering V50 vs Areal Density, for example) is achieved, full size plates could be manufactured and integration study could start.

4.2.2 Material characterization

- Different ceramic material characterization techniques exist. The following are possible ways to characterize these materials. More exotic techniques can be provided by DRDC Valcartier while others are more standard and will be done uniquely by the contractor.

a) Quasi-static (Contractor)
   - Material characterization using quasi-static tests (including measurements of fracture toughness, flexural strength, Vicker's hardness, Young's modulus, etc.) is the responsibility of the contractor.

b) High strain rate tests (DRDC Valcartier)

Compression and/or torsion (depending on personnel and laboratories availability)
   - DRDC Valcartier has the equipment to evaluate ceramic under high strain rate loading using Hopkinson test in shear or compression. During the armour development phase, these tests could be a key research tool to find a ceramic formula that will make a difference in ballistic performance. However, High Strain Rate specimens need to be manufactured to the final dimensions. If needed, the availability of the personnel and laboratories will be evaluated.

c) Depth of Penetration DoP Tests (Contractor and/or DRDC Valcartier)
   - The evaluation and comparison of ceramic materials performances for ballistic applications are performed using DoP tests. DoP test requires flat ceramic samples of 10 cm x 10 cm with a thickness roughly equal to the bullet diameter. For example, for the 7.62 calibre, the thickness would be rounded to 8 mm. The ceramic samples are fixed on a cylinder (aluminum 6061-T6 or clear polycarbonate). The reference DoP will be obtained using the ceramic material in which the armour plate given for qualification is made. If an aluminum cylinder is preferred, DoP is obtained by cutting the cylinder and measuring the inside crater depth or by using x-rays. The clear polycarbonate cylinder is more expensive but facilitates measurements by avoiding machine shop cutting time or x-ray requirements. The DND DoP ballistic tests contribution is cumulated with the two control ballistic tests offered per year/company.

   - For both types of cylinders (aluminum 6061-T6 or clear polycarbonate), minimum adjustment testing will be required to find the best approach to fix samples to the cylinder (type of glue, sample fixation on top of cylinder, in a cylinder hole or in a frame, etc.).

4.2.3 Integration

- When the ceramic development will be considered completed, the integration could begin. The weight of armour system is dependent of backing material. A full Polyethylene backing will produce a lighter armour than aramid, but parameters such as transient deformation, rigidity, buckling, etc. could be affected.
- Dimensions of the ballistic armour plate system shall not be smaller or bigger than the specified dimensions in drawing #1 (Appendix 1). It should also be multicurved, as shown in picture #1 to better fit a typical human body.
- During this process, a contractor can monitor the improvements by using ballistic limit tests (V50) as per NIJ 0101.06 for threat level 4. However, only results from mandatory requirements as defined in Section 5.1 will be used to consider the supply option.

5.0 FINAL ARMOUR SYSTEM TESTING

When material improvement and integration is completed (Section 4.0), final testing will be performed at DRDC Valcartier using the NIJ 0101.06 standard set-up with the block of plastilina calibrated as specified in the NIJ 010.06 standard. Only tests from requirements as defined in Section 5.1 will be performed. This will complete the armour development phase.

5.1 REQUIREMENTS

- If the candidate armour provided fails the requirements specified in this section, it will be disqualified from the five year supply contract

5.1.1 Threat definition:

- Threat definition is for a scenario based on NIJ 0101.06 threat level III/III+ or IV.
- Specific threat detailed charts including calibres, ammunition weights, weapons and impact velocities will be provided to the qualified contractor companies only.

5.1.2 Armour Drop Test:

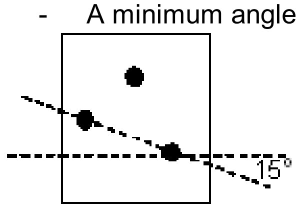
- Armour drop test will be performed on all armour plates before the penetration resistance tests, as defined in 5.1.3. Tests will be conducted as per NIJ 0101.06 using the proposed mechanical durability testing apparatus.

5.1.3 Required armour penetration resistance performance:

- Using a series of 20 armours, each one will need to sustain the impact of three shots. The following criteria will apply:
  1st shot stop 100% of the time,
  2nd shot stop 75% of the time,
  3rd shot stop 50% of the time.

5.1.4 Shot pattern definition:

- Minimum distance of 120 mm between shot with a three-shot displaced triangle.
- All shots will be at a minimum distance of 25 mm from any edges.
- For at least two samples taken randomly in the lot, 1st shot will be at 25 mm from one edge.
- A minimum angle of 15° between shot will be maintained.



6.0 PHASE 2: OPTIONAL ONE TO FIVE YEARS OF ARMOUR SUPPLIES

If Canada decides to exercise an option, DND will use the results of the final plate system testing (Section 5.0) to evaluate improvements on armours. For considering the one-to-five-year armour supply option, the requirements described in Section 5.1 must be achieved. Should a plate system be developed before the end of the three-year development phase, the procurement option could be exercised without prejudice to the completion of the development phase. If two or more developed armours meet the conditions as per Section 5.0, the performance of candidate armours from each contractor will be rated using the criteria described in Sections 6.1 and 6.2. However, the disclosure supplied does not commit Canada to exercice an option.

During this procurement phase, quality control tests made at DND ballistics laboratories will support the acquisition. Quality control tests should meet the conditions described in Sub-section 5.1. A minimum of 20 armour systems will be required from each batch.

At any moment during the execution of the contract, should a situation develop that requires the protection to be adjusted to meet a different threat, this new threat will be disclosed to the contractor and the contract will be amended to meet the new needs.

Note: armour system means the ceramic and backing package

6.1 Rating

6.1.2 For NIJ threat level III/III+

a) Stand-alone armour system weight
Maximum weight: 2.3 kg

2.0-2.3 kg	20 pts
1.7-2.0 kg	30 pts
≤1.7 kg	40 pts

b) Stand-alone armour system transient deformation
Maximum transient deformation: 40 mm

30-40 mm	15 pts
20-30 mm	25 pts
≤ 20 mm	35 pts

c) Stand-alone armour system thickness
Maximum thickness: 24 mm

22-24 mm	10 pts
20-22 mm	20pts
≤ 2 0 mm	25 pts

6.1.3 For NIJ threat level IV

a) Stand-alone armour system weight
Maximum weight: 2.7kg

2.5-2.7 kg	20 pts
2.3-2.5 kg	30 pts
≤ 2.3 kg	40 pts

b) Stand-alone armour system transient deformation
Maximum transient deformation: 40 mm

30-40 mm	15 pts
20-30 mm	25 pts
≤ 20 mm	35 pts

c) Stand-alone armour system thickness
Maximum thickness: 24 mm

22-24 mm	10 pts
20-22 mm	20pts
≤ 20 mm	25 pts

6.2 Rating priority order

- From 6.1, if an equal rating is obtained, the following priority order will apply

  a) lower weight (relative rating of 2)
  b) smallest transient backface deformation (relative rating of 1)
  c) smallest thickness (relative rating of 0.75)

- Based on this classification, for two equivalent weights, the smallest transient backface will win. For two equivalent weights with equivalent transient backface deformation, the smallest thickness will win.

At the end of the armour development phase (Section 4.0)

- if no armour system obtained the minimum requirement, as evaluated in Section 5.0, the supply option will not apply.

- based upon DND needs, the possibility of using or not using the supply option will be decided. DND has no obligation to use the optional supplies, even if all minimal requirements are achieved.

- If the supply option is used, quantity will be determined at the moment of the order and batches will be subjected to controlled tests at DRDC Valcartier.

7.0 SECURITY CLASSIFICATION

All information provided by contractors will be classified industry confidential. Information, data, test results obtained from a company or performed under this contract will circulate only between DND and the concerned company to whom it belongs.

8.0 MATERIAL/SUPPORT TO BE SUPPLIED BY DND PARTNERS

DND will provide control tests at DND ballistics laboratories. A maximum of two tests series per year will be allowed per company (DoP or Ballistic). The sender is responsible for all transportation fees.

Upon request and availability of personnel and equipment, access to High Strain Rate laboratories is possible. Sample preparation is the company's responsibility and has to be made in accordance with DRDC Valcartier sample design (given on request).

9.0 MEETINGS

Meetings will be held approximately every 6 months or as required to advance the work and to meet the schedule. Meetings will alternate between the contractor and DRDC Valcartier facilities. At DRDC Valcartier, visits will take place with escort. The meetings will be classified industry confidential.

10.0 DELIVERABLE:

10.1 Reports/deliverable -Development Phase

- All deliverable and/or material must be received through DRDC Valcartier supply section

10.1.1 Progress Report:

Short progress reports will be provided every three months for the full duration of the contract. The short progress report will describe the work accomplished during the two months and providing new results available. Sufficient sketches, diagrams, photographs, etc., shall be included if necessary to describe the progress accomplished.

10.1.2 Phase Report:

A report will be provided at the end of every year as a minimum frequency. The phase report will describe in detail the work accomplished during the full duration of the phase relative to the main objectives of the program. The technical specifications and technical data should be included as well as physical and performance characteristic. A meeting will be held at the end of every year to evaluate the pertinence of continuing the program based on the progress with respect to main objectives.

10.1.3Final Report:

a) At the end of the three-year contract and independently of the supply option, the contractor will provide DRDC Valcartier with 10 copies (printed and bound) of a detailed final report, which includes
   - Analysis and results from material characterization (point 4.1.1 of statement of work),
   - Integration process and mass efficiency compared with reference armour system (points 4.2 of statement of work).

b) A PDF version of the final report must also be provided. Reports must be formatted in accordance with DRDC standard. The standard can be obtained through the project's scientific authority.

10.1.4Publications:

All publications including manuscripts, presentation summaries or any other publications must be submitted to the scientific authority for revision and approbation 90 days before the due date. An explicit reference to financial support by the federal government must be included and must clearly state the sole responsibility of authors on the content. The scientific authority will provide a written jusification if the government’s interests are not well served, which will also be sent to the publication responsible (journal or conference).

10.2 Armour Plate -Procurement Phase

10.2.1 Control Plates sent to DRDC Valcartier

Quality control armour plates should meet the test conditions detailed in Section 5.0. The threat detail charts including caliber, ammunition weight, weapon and impact velocities is the same as per the development phase and will be provided to the qualified companies only. A minimum of 20 armour systems will be taken randomly from each batch and sent to DRDC Valcartier for testing.

10.2.2 Plates delivery to DND

After control tests will be completed and batches accepted, all plates of the batch will be sent to the user through DND supply system.

11.0 ACCEPTANCE PROCEDURE

11.1 Development Phase

- The development work will be completed to the satisfaction of the Director General, DRDC Valcartier. The contract is deemed completed upon acceptance of the final report by the Scientific Authority and reception of all deliverables.

11.2 Supply and Delivery Phase

- The procurement phase will be exercised by the DND procurement department. The contract is deemed completed upon reception of all armour units, as established at the beginning of the procurement phase.

DELIVERABLES

In addition to the disclosure obligation under Section 27 of the general conditions 2040, any Foreground Information must be fully disclosed and documented by the Contractor in the technical reports delivered by the Contractor to the Technical Authority under this Contract.

APPENDIX 1