DEFENCE R&D DÉFENSE

Requirements of Radiation Detection, Identification, and Dosimetry Equipment for the Canadian Forces

D.S. Haslip and T. Cousins

Defence Research Establishment Ottawa

DEFENCE RESEARCH ESTABLISHMENT OTTAWA

TECHNICAL MEMORANDUM
DREO TM 1999-079
April 1999

National Defence Défense nationale

Canada

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Project
DSP G2199

ABSTRACT

Technical Descriptions have been developed for equipment to be procured under Defence Services Procurement Project G2199 "Nuclear Detection, Identification and Dosimetry". These descriptions have been developed from NATO requirements, industry research, analysis of previous DREO tests, and extensive consultation with the project's operational sponsor in the Directorate of Nuclear, Biological, and Chemical Defence (DNBCD). They will form a useful starting point in the development of the project's Technical Statement of Requirements.

RÉSUMÉ

Les descriptions techniques ont été développés pour l'équipement qui sera obtenu pour le projet G2199, service de la défense pour la détection, l'indentification et les dosimètres nucléaires. Ces descriptions ont été développés des spécifications des besoins OTAN, recherches industrielle, l'analyse des tests présédents de CRDO et avec consultations extensives avec le parrain opérationel dans la direction générale de la défense nucléaire, biologique et chimique (DDNBC). Ils formeront un point de départ important dans le développement énoncé des besoins techniques.

EXECUTIVE SUMMARY

Background: As part of its commitment to provide technical expertise to Project G2199 "Nuclear Detection, Identification, and Dosimetry", DREO was tasked with developing a "comprehensive, defendable, statement of technical requirements" for the equipment systems to be procured by the project. This document provides these requirements, developed from NATO requirements, analysis of industry capabilities in radiation detection, and extensive consultation with the Directorate for Nuclear, Biological, and Chemical Defence (DNBCD).

Results: Many equipment systems are described in this report:

- Reconnaissance Detection Meter: a gamma-sensitive meter, intended for reconnaissance and sensitive to radiation levels down to the NATO limits.
- Advanced Survey Meter: a gamma-sensitive meter with alpha and beta probes. This meter satisfies the NATO requirements for alpha and beta detection, and exceeds them for gamma detection.
- Thermoluminescent Dosimeter: an excellent low-cost solution to providing low-level dosimetry to every soldier.
- Electronic Dosimeter: an electronic, direct-reading device that satisfies the NATO requirements for tactical dosimetry, while also allowing dose-rate measurement.
- Portable Beta-Gamma Spectroscopy System: the key to responding effectively to radiological hazards, this comprises a hand-carried and an airborne reconnaissance system.
- Air Sampler: a simple pump-and-filter arrangement for detecting airborne hazards.
- Alpha and Beta Air Monitors: more sophisticated, sensitive, and expensive devices for performing the same task.
- Non-Ionising Training Systems: an excellent way to provide realistic training to the CF without exposure to radiation.

Most of these systems can be procured through a Commercial-Off-The-Shelf (COTS) procurement, as desired by DND. Some equipment, such as spectroscopy and training systems, may require specialised development to meet the requirements of the Canadian Forces (CF). DREO can play an important role in this area.

Significance: These equipment descriptions form an important starting point in developing the requirements of this project. DREO's continued involvement in Project G2199 will ensure that technical issues are not forgotten during this process.

Haslip, D.S. and Cousins, T. Requirements of Radiation Detection Identification and Dosimetry Equipment for the Canadian Forces. Defence Research Establishment Ottawa, DREO TM 1999-079. April 1999.

SOMMAIRE

Étude Préliminaire: Dans le cadre de la promesse de fournir de l'expertise technique au projet G2199, détection indentification et dosimètrie nucléaire, CRDO à reçu la mission de développer une déclaration de besoins clair et distinct et défensive pour les systèmes d'équipements qui seront obtenu pour le projet. Ce document offre cette déclaration de besoins, qui a été développée de spécifications des besoins OTAN, l'analyse des capacitées des industries de détection nucléaire et de consultations extensives avec le parrain opérationel dans la direction générale de la défense nucléaire, biologique et chimique (DDNBC).

Résultats: Plusieurs systèmes d'équipement sont désignés dans ce rapport.

- Instrument de reconnaissance et détection: un instrument sensible à la radiation gamma à l'intention des reconnaissances radiologiques et sensible au niveau de radiation des limites de l'OTAN.
- Instrument de surveillance radiologique avancée: sensible à la radiation gamma avec une sonde alpha et bêta. Cet instrument contentera les spécifications de besoins OTAN pour le détection de la radiation alpha et bêta et dépasse les specifications pour la détection de la radiation gamma.
- Dosimètres Thermoluminescent: une excellente solution à peu de frais de procurer chaque soldat avec un dosimètre bas niveau.
- Dosimètre Électronique: un équipement électronique à lecture directe qui contentera les spécifications de besoins OTAN pour les dosimètres tactique en même temps que de mesurer les taux de dose.
- Le système de spectroscopie portatif bêta/gamma: l'instrument idéal pour répondre effectivement aux dangers de la radioactivitée, un instrument qui est portatif et qui peut être utilisé pour la reconnaissance radiologique aérienne.
- Échantillionneur d'air: une simple arrangement de pompe et filtre qui sert a détecter les dangers de radioactivitée dans l'air.
- Les moniteurs d'air alpha bêta: instrument de haute technicité sensible et dispendieux qui peut faire la meme tâche.
- Le système d'entraînement non-ionisant: une excellente façon de procurer un entraînement réel sans exposer le personnel des FC à la radiation.

La plupart des systèmes peuvent être achetés logiciel commercial (COTS) si désiré par MDN. Quelques équipements comme le système de spectroscopie et le système d'entrainement, devront avoir un développement spécialisé pour rencontrer les normes des forces canadiennes (FC). CRDO peut jouer un rôle important dans ce processus.

Signification: Ces descriptions formeront un point de départ important dans le développement énoncé des besoins techniques. La participation continuelle de CRDO au projet G2199, va assurer que les problèmes techniques ne seront pas oubliés durant ce processus

Haslip, D.S. et Cousins, T. Besoins d'Équipements pour la Détection, Indentification et Dosimètrie Nucleaire pour des Forces Canadiennes. Le Centre de recherches pour la défense Ottawa, DREO TM 1999-079. Avril 1999. (en anglais)

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1 INTRODUCTION

The radiological threat has evolved considerably since the end of the Cold War. Whereas the primary threat used to be a large-scale cataclysmic nuclear weapons exchange, the modern threat comprises a number of smaller-scale scenarios. These include:

(1) Radiological Dispersal Weapon – explosively dispersed medical or industrial radioisotope.
(2) Improvised Nuclear Device – a crude fission bomb, produced by a rogue nation or terrorist.
(3) Sabotaged or Damaged Nuclear Reactor – release of fission products from a reactor as a result of accidental or deliberate reactor damage.

As will be demonstrated in the following sections, these incidents can produce widespread contamination and expose personnel to significant levels of radiation.

NATO has recognised the importance of this new threat. Table 1 below shows clearly the Cold War and post-Cold War mentalities in NATO Standardisation Agreements (STANAGs) 2083 "Commanders' Guide on Nuclear Radiation Exposure of Groups" [1] and 2473 "Commanders' Guide on Low Level Radiation (LLR) Exposure in Military Operations" [2].

Table 1: NATO Radiation Exposure States

Reference	Radiation Exposure State	Dose (Gy)
STANAG 2083	3	> 1.50
	2	0.70 – 1.50
STANAG 2473	1E	0.25 – 0.70
	1D	0.10 – 0.25
	1C	0.05 – 0.10
	1B	0.005 – 0.05
	1A	0.0005 – 0.005

Whereas military doctrine used to regard radiation exposures of less than 0.7 Gy as one of negligible risk with respect to operations, today's military recognises the long-term health risks associated with much smaller levels of radiation exposure. This is reflected in the new guidance, which instructs commanders to monitor radiation exposure at levels 1400 times smaller than before. In addition, Allied Command Europe (ACE) Directive 80-63 [3] states that teams surveying a radiological hazard shall turn back when they detect a dose rate of 3 μGy/h, and identifies the radiological hazard as being all areas in which the dose rate exceeds 2 μGy/h. It should be noted that this hazard perimeter level of 2 μGy/h is about 30 times natural background levels, and that at this level, it would take 250 hours to reach exposure state 1A, defined above.

In order to operate in this new environment and under this new direction, the CF must be equipped to detect and analyse low-level radiation (LLR). To provide this capability, Project G2199 "Nuclear Detection, Identification, and Dosimetry" will procure a number of equipment systems. As part of its agreement to supply technical expertise to this project, DREO was tasked with outlining the technical requirements of this equipment. This document provides these requirements.

NATO LG.7 WG.2 "Low-Level Radiation in Military Operations" has recently produced a set of requirements for low-level radiation detection equipment, in the addendum to Triptych D/104 [4]. Many of the requirements in this report are based on those given in D/104. However, significant modifications and additions have been made related to the CF Concept of Operations [5], previous "buy and try" testing performed at DREO [6-8], and extensive consultations with the project's operational sponsor in DNBCD.

The rest of this document is divided into sections, each describing a different piece of equipment. Each section is divided into General Considerations, Performance Requirements, and Environmental Hardening Requirements. Justifications and comments on a given requirement are given in italics, as needed.

2 RECONNAISSANCE DETECTION METER

2.1 General Considerations

The Reconnaissance Detection Meters are intended to be compact, rugged, and simple to operate instruments. They will be used at the unit level to carry out the first gamma radiation reconnaissance of a potentially contaminated area.. They will be used to establish NATO hazard perimeters or turn-back points, and to permit limited operations in contaminated areas. More detailed gamma radiation surveys, and alpha and beta radiation surveys will be performed with the Advanced Survey Meter, described in Section 3.

Recce meters will be used in virtually all radiological scenarios. Consider the dispersion of a 3000 Curie source of ^{137}Cs (this is a reasonable activity for a medical radiotherapy source) by 100 pounds of TNT. Further, suppose that the explosion takes place in the heart of Ottawa, and that the local winds are from the north at 3.6 km/h (as on 22 April 1999). Figure 1 shows the total external dose (calculated with HPAC [9]) from material deposited on the ground, 24 hours after the incident (note that the doses are given in rads, where 100 rads = 1 Gray). One can expect that dose rates in the shaded hazard areas will be near the NATO hazard perimeter level of 2 μGy/h (0.0002 mrad/h). One can see that a significant fraction of the city is affected by this hazard. Recce meters could be used by military personnel to determine the extent of this hazard, or monitor dose rates inside the hazard, should the mission require this.

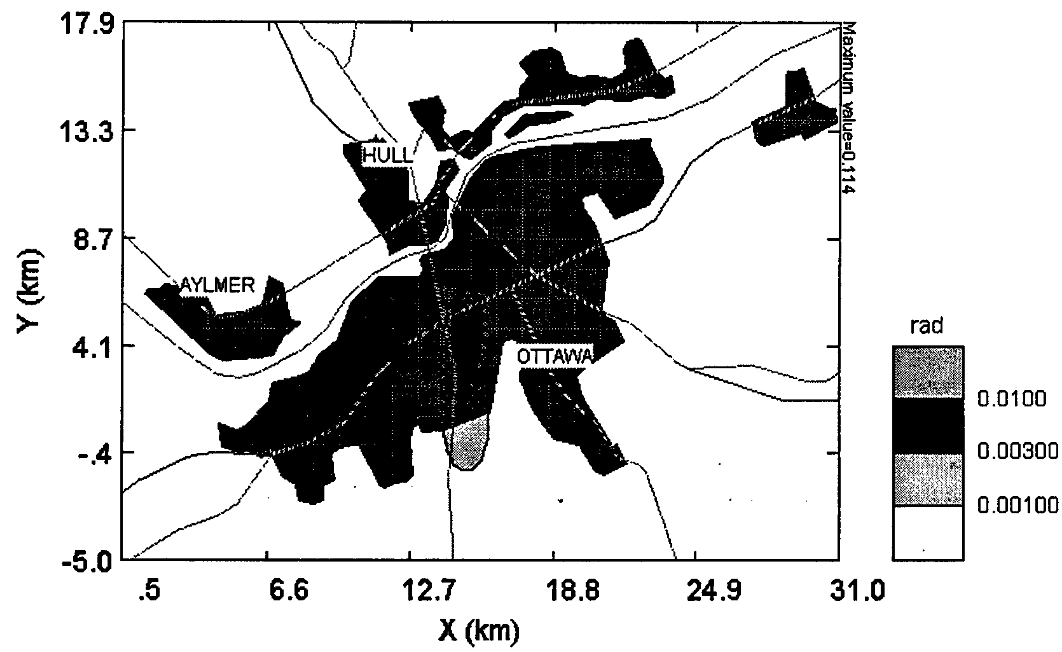

Figure 1: Total Dose, 24 hours after the dispersion of a 3000 Curie Cesium-137 source.

The Reconnaissance Detection Meters may also be used in vehicles to do reconnaissance. In such a role, the user will have to manually account for the shielding provided by the vehicle, unless it has an externally mounted probe.

The meters shall have adjustable and selectable audible and visual alarms. They shall also have a selectable function in which they emit an audible signal proportional to the measured radiation field, in a manner similar to the classic Geiger counters. This will allow the user to perform radiation surveys without constantly looking at the meter's display.

The output from the meters shall be capable of being integrated into a system for providing a real-time dose rate mapping capability to commanders.

2.2 Performance Requirements

2.2.1 TYPE OF RADIATION MEASURED AND RANGE:

2.2.1.1 It is essential that the Reconnaissance Detection Meters measure gamma radiation dose rates, from 1 μSv/h to 1 Sv/h. It is desirable that the meters read to levels as low as 0.05 μSv/h (that is, natural background levels) and to levels as large as 10 Sv/h. It is also desirable that the meters allow the Q-factor of the incident radiation to be set by the user, if they do not automatically determine the Q-factor.

The role of gamma reconnaissance requires only the ability to measure gamma radiation. Alpha and beta detection should be the responsibility of a survey team. The essential lower dose rate limit is derived from the NATO hazard perimeter dose rate. The desirable lower dose rate limit corresponds to the natural background rate; this capability is suggested by the LLR addendum to NATO Triptych D/104. For the upper limit, the sponsor is interested in as large a dose rate as is achievable, so that the device is of maximum utility in a nuclear weapons conflict. The essential characteristic is derived from what the manufacturers of military hardware routinely offer; the desirable characteristic is considerably more rare.

2.2.1.2 It is desirable that each meter measures the total gamma radiation dose to which it has been exposed during each mission. The meters shall allow the operator to reset this dose to zero.

Measuring gamma radiation dose could be useful to the operator. However, since the reconnaissance unit will likely be in possession of an Electronic Dosimeter (ED), the dose measuring capability is redundant. It should be noted that most meters in this class do provide this capability.

2.2.1.3 The meters shall include no more than one external probe to detect the full range of radiation required. If a probe is used, the meters shall sense all relevant properties of the probe when it is connected. Probes shall be interchangeable between meters without recalibration.

For maximum utility in the field, the ability to swap probes between meters is essential. Thus, the meter must be able to recognise probes and their calibration information automatically.

2.2.1.4 It is desirable that the meters take additional probes to be considered as an Advanced Survey Meter.

2.2.2 ENERGY RESPONSE: The Reconnaissance Detection Meters shall respond to gamma radiation with energies from 80 keV to 1.5 MeV. It is desirable that the meters respond to lower energies (down to 50 keV) and higher energies (up to 3 MeV).

The essential lower energy limit is determined by the fact that the biological importance of lower-energy radiation falls off quickly with energy. In fact, the detector case stops a significant proportion of the low-energy gamma rays. The desirable lower limit is set by the desire to detect Americium-241 (at 59 keV), a militarily significant isotope. However, detection efficiency typically falls off dramatically with decreasing energy at these energies, so a compromise may be required.

The essential upper energy limit is set by the requirement to detect Cobalt-60 (at 1332 keV), an isotope that may be very well be used in a radiological dispersal weapon. The desirable upper limit would allow virtually all isotopes with reasonable lifetimes to be detected. Again, however, many meters have trouble accurately measuring dose rates from the more energetic gamma rays and a compromise may be necessary.

2.2.3 ACCURACY: The Reconnaissance Detection Meters shall indicate gamma radiation dose rates with an overall accuracy of at 30%, over the entire operating range (gamma-ray energy and dose rate). It is desirable that the accuracy be 20%.

The figure of 30% is based on what the market can provide. It should be noted that since accuracy is more crucial as the energy of the radiation increases, accuracy requirements may be put on a sliding scale for evaluation purposes.

2.2.4 PRESENTATION:

2.2.4.1 All information presented on the Reconnaissance Detection Meters shall be in English and French. The language used on the display (English or French) shall be user-selectable.

2.2.4.2 The Reconnaissance Detection Meters shall be direct reading in Grays per hour or Sieverts per hour. They shall also use metric prefixes, as appropriate. Range switching shall be automatic.

The meters must use the metric units of dose (the Gray) or dose equivalent (the Sievert). The Gray has the advantage that it is in use by the U.S.A. (specifically, the centiGray).

However, since the CF nuclear training currently uses Sieverts, and since dose equivalent is the most relevant measure of radiation for determining effects on people, it *is felt that the Sievert is the most desirable unit. However, in order to make the Sievert more meaningful than the Gray, the quality factor should be user-programmable.*

2.2.4.3 The readings shall be presented digitally. It is desirable that the dose rate also be shown in an analog display as well. If such an analog display is not used, then it is desirable that the meters indicate whether the radiation field is increasing or decreasing. Such a trend indicator should not be continually changing in a constant field due to statistical fluctuations.

For ease of use, the display must be digital and autoranging. However, an analog counterpart or trend indicator can be useful in seeing trends in the radiation pattern.

2.2.4.4 The meters shall be readable by day and night without an external light source.

Because personnel performing reconnaissance may be required to carry both the meter and his or her weapon, it is felt that the display should be visible at night without using external sources. It should, however, not be so bright as to make the operator a target.

2.2.4.5 The display shall be refreshed at least once every two seconds, for temperatures above 0°C. At lower temperatures, the refresh rate may be decreased.

The display's refresh rate should be relatively rapid so that the reconnaissance role is not hampered. However, it is recognised that at low temperatures, the refresh rate may be decreased to make up for the degraded performance of the LCD display.

2.2.4.6 The meters shall have a selectable mode in which they emit a real-time audible signal (clicking or chirping) that is directly proportional to the radiation field. The meters shall include earphone jacks so that the user can hear this signal (and audio alarms). It is desirable that the meters have a volume control for this audio signal.

Reconnaissance will be made simpler if the unit creates an audible signal proportional to the radiation field. It will allow the user to spend less time looking at the unit display, and hence more time looking at his or her surroundings.

2.2.4.7 Each meter shall have a readily visible serial number. An electronically readable (bar code) serial number is also essential.

2.2.4.8 Each meter shall also have the provision to display the date of last calibration and the expiry date for this calibration.

2.2.5 ALARMS:

2.2.5.1 The Reconnaissance Detection Meters shall have visible and audible alarms that are triggered when dose rates are measured that exceed designated levels.

2.2.5.2 If the meters also measure total mission gamma radiation dose, then it is essential that alarms may also be triggered when the total dose exceeds designated levels.

2.2.5.3 The meters shall allow the user to set the alarm levels.
The meters must have alarms so that, for instance, hazard perimeters and turnback points can be quickly located, perhaps even while the device is not being watched. Continually evolving military roles require that the alarm levels be user-programmable.

2.2.5.4 The alarm shall take the form of both an audible and visual signal. The meters shall allow the user to deactivate the audible part of the alarm, both before and after an alarm level is reached.
The alarm should be audible and visible for maximum effect. However, the user must have the option of deactivating the audible portion of the alarm for roles in which the operator does not want to be detected by an opposing force.

2.2.6 COMMUNICATION:

2.2.6.1 It is desirable that the meters have the ability to download gamma radiation dose rates to a PC-based platform in real time.

2.2.6.2 If the meters also measure total mission dose, then it is also desirable that the total mission dose can be downloaded to a PC-based platform in real time.

2.2.7 CONTROLS:

2.2.7.1 The controls of the Reconnaissance Detection Meters shall be simple to operate and be clearly marked. To prevent damage to protective gloves or clothing, it is desirable that plastic-covered buttons be used in place of toggle switches.

2.2.7.2 The meters shall be practical to use with combat equipment, including any environmental or NBC protective equipment, combat gloves, an NBC protective mask, or dust goggles.

2.2.8 CALIBRATION: Under normal circumstances, the meters shall be capable of being used for at least one year without recalibration of the instruments or probes.

2.2.9 ANCILLARY EQUIPMENT:

2.2.9.1 The Reconnaissance Detection Meters shall include separate check sources containing less than scheduled quantities of radioactive material. These check sources shall contain sufficient material or have a sufficiently long lifetime that they will continue to be effective for calibration purposes over the lifetime of the meters (approximately 10-15 years).

2.2.9.2 The meters shall also include a cable to connect the probes to the meters (if applicable), any tools required to perform first-line maintenance on the meters, and any external power sources (if applicable).

2.2.9.3 The meters shall include a tactical carrying case with a carrying strap. It is essential that the meters can be used while in the carrying case. That is, it is essential that the carrying cases have a transparent window for viewing the meter displays, and that the meters' audible signals can be heard while they are in the carrying case. It is desirable that each meter includes a clip that allows it to be hung from a soldier's combat webbing.

2.2.10 POWER SUPPLY:

2.2.10.1 The meters shall be capable of at least 96 hours of continuous operation at any temperature in the operating regime with a compact and lightweight power source, which may consist of internal batteries or a battery pack kept close to the body.

Ninety-six hours of battery life gives the operator enough power for a typical mission duration (72 hours) plus some time in reserve.

2.2.10.2 The batteries used in the meter or the power source shall be readily available and conform to international standards.

2.2.10.3 Batteries shall be replaceable in the field by the operator.

2.2.10.4 International variations in the size or performance of batteries shall not cause the meters' performance to fail the requirement of paragraph 2.2.10.1.

These meters may be used in locations far from a maintenance depot. As a result, the unit must be fully functional using batteries from any part of the world. In addition, these batteries must be replaceable in the field by the operator.

2.2.10.5 It is essential that the meters warn the users of battery failure at least two hours before this occurs.

The low-battery warning is important so that the operator is not surprised by a sudden power failure. Industry cannot provide much more than about five hours of warning to battery failure. If the operator begins a mission without new batteries, therefore, then the operator will have to carry a spare set of batteries.

2.2.10.6 It is desirable that there be a provision to power the meter from 12-28 Volt DC Vehicle power. Given that this characteristic is at odds with the more important requirement of low mass, this provision may come in the form of an external adapter.

2.2.11 SHAPE SIZE AND WEIGHT: The Reconnaissance Detection Meters shall be as compact as possible, with a size and weight such that they can be comfortably carried in the hand while performing reconnaissance.

2.2.12 RESPONSE TIME: The Reconnaissance Detection Meters shall give immediate response to radiation. A brief self-test is essential.

2.3 Environmental Hardening Requirements

These meters may be used in front-line situations under potentially hostile circumstances. As such, it is felt that these meters should meet military specifications for hardening with respect to all environmental conditions.

2.3.1 PRESSURE:

2.3.1.1 The meters shall operate at pressures existing between sea level and 3048 metres.

2.3.1.2 The meters shall survive rapid decompression at 12200 metres without presenting a hazard to personnel or damaging the aircraft.

The meters must be capable of operation after transport in aircraft, and must not prevent a hazard should explosive decompression occur.

2.3.2 TEMPERATURE AND TEMPERATURE SHOCK:

2.3.2.1 The meters shall be capable of operation within the ambient temperature limits of –45°C to +45°C. Mean instrument response at any temperature in this range shall differ by no more than 20% from the mean response at 22°C.

2.3.2.2 Within five minutes of being taken from -45°C or +45°C to +22°C, mean instrument response shall not differ by more than 20% from reference readings taken at +22°C.

2.3.2.3 Within five minutes of being taken from +22°C to either -45°C or +45°C, mean instrument response shall not differ by more than 20% from reference readings taken at those temperatures.

The meters must be operable at all temperatures and humidities in which operations could occur. Changes in device temperature should not result in an appreciable loss in performance.

2.3.3 HUMIDITY AND WATER RESISTANCE:

2.3.3.1 The meters shall be capable of operation at relative humidities between 0 and 95% at all temperatures in the operation range.

2.3.3.2 The meters shall be water-resistant.

The meters should also be capable of operation after immersion in water.

2.3.4 VIBRATION AND SHOCK:

2.3.4.1 The meters shall be capable of operation after being transported on ground vehicles as unrestrained cargo.

2.3.4.2 The meters shall be capable of operation after three falls, from 1.2 metres, onto a flat concrete surface.

The meters should also be rugged enough to withstand the shocks associate with unrestrained ground transport, and the accidental falls which will inevitably occur.

2.3.5 STORAGE CONDITIONS:

2.3.5.1 The meters shall be capable of operation after having been stored at temperatures between -50°C and +70°C at relative humidities between 0 and 95%.

The meters must also be capable of operation following storage at a wide range of temperatures. The higher upper limit on temperature reflects the fact that storage temperatures may exceed the ambient air temperature.

2.3.5.2 The meters shall have a shelf life of at least 10 years.

2.3.6 NUCLEAR SURVIVABILITY:

2.3.6.1 The meters shall be hardened against the effects of nuclear weapons as outlined in NATO Allied Engineering Publications AEP-4 and AEP-25. This includes the effects of Electromagnetic Pulse (EMP).

2.3.6.2 The meters shall be hardened against the Transient Radiation Effects on Electronics (TREE) as outlined in NATO AEP-22.

2.3.6.3 The meters shall be designed to resist NBC contamination in accordance with NATO AEP-7.

Likewise, it is felt that these meters should be designed for nuclear survivability, resistance against NBC contamination, and be hardened against EMP and TREE. This is particularly relevant for these meters because their use would be necessary in a nuclear conflict.

2.3.7 ELECTROMAGNETIC COMPATIBILITY:

2.3.7.1 The meters shall be shielded from non-ionising radiation or microwaves up to at least 10 mW/cm^2.

2.3.7.2 The meters shall not radiate electromagnetic radiation that will interfere with other equipment.

These meters shall neither interfere with, or be affected by, nearby equipment.

3 ADVANCED SURVEY METER

3.1 General Considerations

The Advanced Survey Meters (ASMs) will be used at the unit level to carry out detailed surveys of gamma radiation hazards identified by a reconnaissance team. They will also be required to perform alpha and beta radiation surveys in areas potentially contaminated by alpha- and beta-emitting materials. In particular, they will be used to measure the extent of alpha and beta contamination on surfaces and on filter papers from air samplers.

While it is valuable for the ASM to be able to carry out gamma radiation surveys in support of the Recce Meter, it is its ability to detect alpha and beta radiation whose importance cannot be underestimated. This is illustrated in Figure 2, below. The figure shows the concentration of ^{239}Pu on the ground, twenty-four hours after a 620 Curie source was dispersed from downtown Toronto with 100 pounds of TNT, weather conditions as on 22 April 1999 (light rain, winds from the east-northeast at 9.4 km/h).

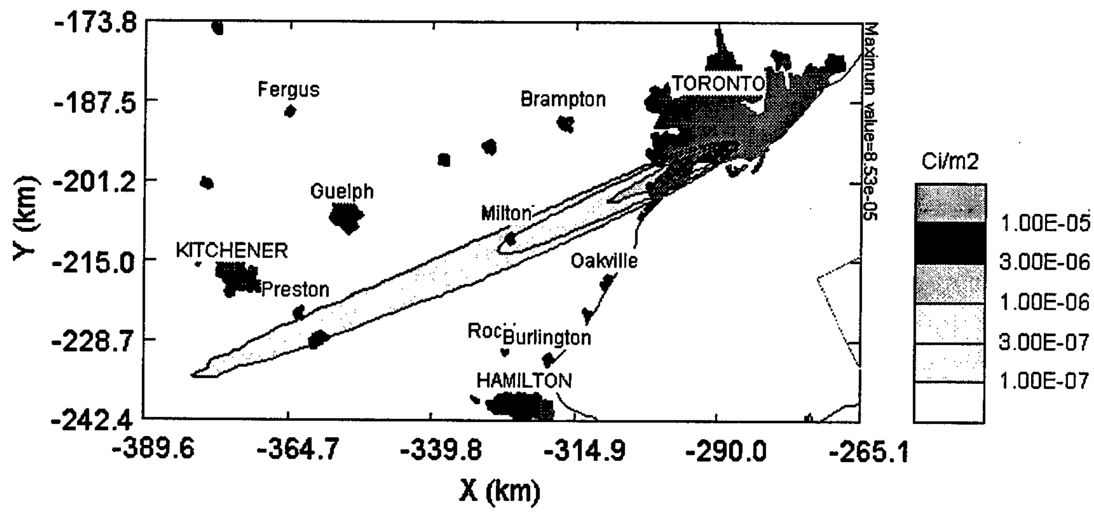

Figure 2: Deposition of Plutonium-239 on the ground, twenty-four hours after an explosive dispersal.

This amounts to 10 kg of ^{239}Pu, the approximate quantity required for the "Fat Man" plutonium weapon. This incident is analogous to the ^{137}Cs dispersal considered in the previous section, with one important difference. A ^{137}Cs source emits gamma rays, making it easy to detect with a Recce Meter; a ^{239}Pu source, on the other hand, emits mainly alpha radiation and low-energy X-rays, making it difficult if not impossible to detect with a Recce Meter. Proper detection requires an ASM. In addition, ^{239}Pu is highly radiotoxic when inhaled, 10000 times more damaging than ^{137}Cs. The depicted concentration of 0.1 μCi/m^2 (approximately 0.35 Bq/cm^2, detectable with the ASM) will result in enough resuspension of ^{239}Pu to commit unprotected personnel to internal dose rates of 37 μSv/h, more than ten times the NATO turnback dose rate. This, admittedly, is a worst-case scenario, since ^{239}Pu is the most highly radiotoxic material known, but it underscores the importance of the ASM and also of the Air Sampling capability, to be discussed later.

The Advanced Survey Meters shall consist of a unit with one or more external probes. Gamma detection may be performed with an external or internal detector. Alpha and beta detection shall be performed with a small probe capable of performing thorough checks of vehicle decontamination efficacy. A larger alpha probe may also be required for lower-level surveys.

Since these meters will be used by trained specialists under controlled conditions (that is, during daylight or lighted conditions), out of contact with the enemy they need to be rugged but not necessarily MIL-SPEC'd.

The ASMs will have selectable and adjustable audible and visual alarms, and shall emit a sound proportional to the measured radiation field, just like the Recce Meter.

There is obviously significant overlap between the Recce Meter and the ASM. An ASM is essentially a sensitive Recce Meter that is able to take alpha- and beta-sensitive probes. In fact, an ASM automatically satisfies all of the requirements of a Recce Meter, except for the environmental hardening characteristics. The project may want to consider purchasing hardened ASM kits as Recce Meters as well, or even relaxing the environmental characteristics of the Recce Meter so that other ASMs can meet the Recce Meter requirements. Using the same meter for the two groups could be extremely beneficial, allowing greater flexibility in the way these meters are deployed. It could also simplify the training requirements for the CF, even leading to cost savings in procuring training equipment. This must be weighed against the likely higher cost of procuring ASM-capable meters as Recce Meters.

3.2 Performance Requirements

3.2.1 TYPE OF RADIATION MEASURED AND RANGE:

3.2.1.1 It is essential that the Advanced Survey Meters measure gamma radiation dose rates, from 0.5 μSv/h to 1 Sv/h. It is desirable that the meter read to levels as low as 0.05 μSv/h (that is, natural background) and to levels as large as 10 Sv/h. It is also desirable that the meters allow the Q-factor of the incident radiation to be set by the user, if the meters do not automatically determine the Q-factor.

For an Advanced Survey Meter, the highest possible sensitivity to low-level gamma radiation is desirable (down to the natural background level). However, the essential sensitivity is based on what industry can provide. For the upper limit, the sponsor is interested in as large a dose rate as is achievable, so that the device is of maximum utility in a nuclear weapons conflict. The essential characteristic is derived from what the manufacturers of military hardware routinely offer; the desirable characteristic is considerably more rare.

3.2.1.2 The meters shall measure alpha radiation count rates in counts per second. When measuring alpha radiation (energies as described in paragraph 3.2.2.2) from a 100 cm^2 surface uniformly contaminated at 0.5 Bq/cm^2, the meter shall read at least four times the ambient background level. It is desirable that alpha-emitting surface contamination at levels as small as 0.1 Bq/cm^2 can be detected with this meter. The meters shall be capable of measuring and displaying alpha radiation count rates as high as 10000 counts per second.

3.2.1.3 The meters shall measure beta radiation count rates in counts per second. When measuring beta radiation (energies as described in paragraph 3.2.2.3) from a 100 cm^2 surface uniformly contaminated at 5 Bq/cm^2, the meter shall read at least four times the ambient background level. It is desirable that beta-emitting surface contamination at levels as small as 1 Bq/cm^2 can be detected with this meter. The meters shall be capable of measuring and displaying beta radiation count rates as high as 10000 counts per second.

The D/104 addendum suggests that alpha (beta) contamination should be detectable down to 0.25 (2.5) Bq/cm^2 (desirably 0.1 (1.0) Bq/cm^2, with a contamination of 0.5 (5.0) Bq/cm^2 giving a signal significantly above background. The requirement stated in this document will ensure both conditions above are satisfied. An upper limit is not defined in D/104. The stated goal of 10000 counts per second is routinely offered by industry and permits relatively high levels of contamination to be monitored.

3.2.1.4 It is essential that each meter measures the total gamma radiation dose to which it has been exposed. The meter must be capable of resetting this dose to zero.

Measuring gamma radiation dose could be useful to the operator. However, since the survey will likely be in possession of an Electronic Dosimeter (ED), the dose measuring capability is redundant. It should be noted that most meters in this class do provide this capability.

3.2.2 ENERGY RESPONSE:

3.2.2.1 The Advanced Survey Meters shall respond to gamma radiation with energies from 80 keV to 1.5 MeV. It is desirable that the meters respond to lower energies (down to 50 keV) and higher energies (up to 3 MeV).

The essential lower energy limit for gamma ray detection is determined by the fact that the biological importance of lower-energy radiation falls off quickly with decreasing energy. The desirable lower limit is set by the desire to detect Americium-241 (at 59 keV), a militarily significant isotope. However, detection efficiency typically falls off dramatically in this region (due in part to attenuation of the gamma rays by the detector case or window), so a compromise may be required.

The essential upper energy limit is determined by the requirement to detect Cobalt-60 (at 1332 keV), an isotope that is readily available in industry and could be used in a radiological dispersal weapon. The desirable upper limit would allow virtually all *isotopes with reasonable lifetimes to be detected. Again, however, many meters have trouble with the more energetic gamma rays and a compromise is necessary.*

3.2.2.2 The Advanced Survey Meters shall respond to alpha radiation with energies from 3 MeV to 6 MeV.

The LLR addendum to D/104 gives the stated energy limits for alpha radiation. This energy window permits detection of all alpha emitters of interest in a military context.

3.2.2.3 Table 1 below lists beta-emitters of military interest, as given in the addendum to NATO Triptych D/104. The Advanced Survey Meters shall respond to beta radiation from these elements and be able to measure surface contamination by these elements down to the limits specified in paragraph 3.2.1.3.

Nuclide	**Endpoint Energy (MeV)**
Phosphorus-32	1.710
Phosphorus-33	0.248
Chlorine-36	0.714
Calcium-45	0.252
Strontium-90 / Yttrium-90	0.546 / 2.27
Technetium-99	0.292
Promethium-147	0.224
Thallium-204	0.766

3.2.3 ACCURACY:

3.2.3.1 The Advanced Survey Meters shall indicate gamma radiation dose rates with an overall accuracy of at least 30%, over the entire operating range (gamma-ray energy and dose rate). It is desirable that the accuracy be 20%.

The figure of 30% is based on what the market has demonstrated that it can provide. It should be noted that since accuracy is more crucial as the energy of the radiation increases, accuracy requirements may be put on a sliding scale for evaluation purposes.

3.2.4 PRESENTATION:

3.2.4.1 All information presented on the Advanced Survey Meters shall be in English and French. The language used on the display (English or French) shall be user-selectable.

3.2.4.2 The Advanced Survey Meters shall be direct reading, with automatic range switching. When measuring gamma radiation dose rates, the unit shall display these rates in Grays per hour or Sieverts per hour, with metric prefixes, as appropriate. When measuring alpha or beta radiation count rates, the unit will display these rates in counts per second, with metrix prefixes, as appropriate.

It is essential that the meters use the metric units of dose (the Gray) or dose equivalent (the Sievert). The Gray has the advantage that it (specifically, the centiGray) is in use by the American Armed Forces.

However, since the International Radiation Safety Community currently uses Sieverts, and since dose equivalent is the most relevant measure of radiation for determining effects on people, it is felt that the Sievert is the most desirable unit. However, in order to make the Sievert more meaningful than the Gray, the quality factor should be user-programmable.

NATO Triptych D/104 suggests that alpha and beta contamination meters should use counts per minute or counts per second. This is the most versatile and practical solution given that these meters may be used in a variety of scenarios, where a meter reading in Bq/cm^2 would be misleading or incorrect.

3.2.4.3 The readings shall be presented digitally. It is desirable that the dose rate or count rate also be shown in an analog display as well. If such an analog display is not used, then it is desirable that the meters indicate whether the radiation field is increasing or decreasing. Such a trend indicator should not be continually changing in a constant field due to statistical fluctuations.

For ease of use, the display must be digital and autoranging. However, an additional analog counterpart or trend indicator can be useful in seeing trends in the radiation pattern.

3.2.4.4 The meters shall be readable by day and night without an external light source.

Because personnel performing a survey will probably be carrying both the meter and a probe, it is felt that the display should be visible at night without using external sources of light. It should, however, not be so bright as to make the operator a target.

3.2.4.5 The display must be refreshed at least once every two seconds, for temperatures above $0^{o}C$. Due to the tendency of liquid crystal viscosity to increase at lower temperatures, the refresh rate may be decreased to enhance the useful temperature range of the display.

The display's refresh rate should be relatively rapid so that the survey role is not hampered. However, it is recognised that at low temperatures, the refresh rate may be decreased to make up for the degraded performance of the LCD display.

3.2.4.6 The meters shall have a selectable mode in which they emit a real-time audible signal (clicking or chirping) that is directly proportional to the radiation field. The meters shall include earphone jacks so that the user can hear this signal (and audio alarms). It is desirable that the meters have a volume control for this audio signal.

Radiation surveys will be made simpler if the unit creates an audible signal proportional to the radiation field. It will allow the user to spend less time looking at the unit display, and hence more time looking at his or her surroundings. This is particularly true of contamination measurements where the probe must be held close to, but not touching, the surface of interest.

3.2.4.7 It is desirable that the meters have a selectable mode in which the ambient radioactive background can be subtracted from the count rate observed when doing alpha or beta surveys.

The capability to subtract background when doing alpha and beta contamination surveys is suggested in D/104. This should not be high on the list of priorities for this meter.

3.2.4.8 It is essential that the serial number of each meter be displayed on the outside of the case in both alpha-numeric and bar code formats.

3.2.4.9 Each meter shall also have the provision to externally display the date of last calibration and the expiry date for this calibration.

3.2.5 ALARMS:

3.2.5.1 The Advanced Survey Meters shall have visible and audible alarms that are triggered when dose rates are measured that exceed designated levels.

3.2.5.2 If the meters also measure total mission gamma radiation dose, then it is essential that alarms may also be triggered when the total dose exceeds designated levels.

3.2.5.3 The alarm threshold levels shall be user-programmable.

The meters must have alarms so that, for instance, contaminated surfaces can be quickly identified, even while the meter's display is not being watched. Continually evolving military exposure guidelines require that the alarm levels be user-programmable.

3.2.5.4 The alarm shall take the form of both an audible and visual signal. The meters shall allow the user to deactivate the audible part of the alarm, both before and after an alarm level is reached. By default, the alarms will be activated when the unit is powered on.

The alarm should be audible and visible for maximum effect. However, the user must have the option of deactivating the audible portion of the alarm for roles in which the operator does not want to be detected by an opposing force.

3.2.6 CONTROLS:

3.2.6.1 The controls shall be simple to operate and be clearly marked. To prevent damage to protective gloves or clothing, it is essential that plastic-covered buttons be used in place of toggle switches.

3.2.6.2 The meters shall be practical to use with combat equipment, including any environmental or NBC protective equipment, combat gloves, a mask, or dust goggles.

3.2.7 PROBES:

3.2.7.1 The Advanced Survey Meters shall have a probe that is small enough to monitor alpha and beta surface contamination in confined areas such as the treads of tanks. This probe shall be sensitive to alpha and beta radiation, and be able to detect beta contamination down to the limits outlined in paragraph 3.2.1.3. If this probe cannot measure alpha-emitting contamination down to the limits in paragraph 3.2.1.2, then the meters shall have a second, larger area probe that can detect these levels of alpha contamination.

Alpha and beta contamination surveys will likely be carried out with a versatile, small surface area probe. However, the small surface area of such a probe will likely make detection of low-level alpha contamination impossible. Thus, a larger area probe is probably also required for doing low-level alpha surveys.

3.2.7.2 If any of the probes contain gas-filled tubes, then these tubes shall not require regular or routine charging with a quench gas.

Some alpha and beta probes use a quench gas in their ionisation chambers. Such systems tend to leak, and require constant refilling. This additional form of maintenance is unacceptable in an operational scenario.

3.2.7.3 The probes shall include a type of "skid plate" to keep the active detection surface from making contact with the contaminated surface. It is desirable that the probes have additional provisions for preventing contact between the probes and the surfaces. This may take the form of an ultrasonic system that warns the operator when the probe is too close to the surface of interest. It may also take the form of a probe light to keep the contaminated surface lit when surveys are performed at night.

The paramount concern when doing alpha and beta contamination survey is the contamination of the probe. The measures outlined are intended to avoid such contamination.

3.2.7.4 When any external probes are connected to the meters, the meters shall sense all relevant properties of the probes. Probes shall be interchangeable between meters without recalibration.

For maximum utility in the field, the ability to swap probes between meters is essential. Thus, the meter must be able to recognise probes and their calibration information automatically.

3.2.8 CALIBRATION AND REPAIR:

3.2.8.1 Under normal circumstances, the meters shall be capable of being used for at least one year without recalibration of the instruments or probes.

3.2.8.2 Some probes may have fragile windows. The meters shall allow the repair or replacement of these parts by the user under controlled conditions such as under cover of a tent that is heated to a minimum of 10°C, or equivalent.

3.2.9 ANCILLARY EQUIPMENT:

3.2.9.1 The Advanced Survey Meters shall include separate check sources containing less than scheduled quantities of radioactive material. These check sources shall contain sufficient material or have a sufficiently long lifetime that they will continue to be effective for calibration purposes over the expected lifetime of the meters (approximately 10-15 years).

3.2.9.2 The meters shall also include cables to connect the probes to the meters (as applicable), any tools required to perform user maintenance on the meters, and any external power sources (if applicable).

3.2.9.3 The meters shall include a tactical carrying case with an adjustable carrying strap. These cases shall contain the meters and the gamma probe, if it is not internal to the meter.

3.2.9.4 A rugged carrying case for the other probes shall also be provided. It is desirable that this case also accommodates the meter itself.

The meter itself will be in a water resistant, durable carrying case that allows the user to read the meter during use. The probes will be carried separately in a case with a hardened outer shell. The interior of the case shall be designed so as to hold the individual probes firmly in place and so that they are protected against rough handling.

3.2.10 POWER SUPPLY:

3.2.10.1 The meters shall be capable of at least 12 hours of continuous operation at any temperature in the operating regime, with a compact and lightweight power source, which may consist of internal batteries or a battery pack kept close to the body.

Twelve hours of continuous operation is considered sufficient for a survey operation. It is assumed that the operator will carry extra batteries for the Advanced Survey Meter.

3.2.10.2 The batteries used in the meter or the power source shall be standard commercial off the shelf and conform to international standards.

3.2.10.3 Batteries must be replaceable in the field by the operator.

3.2.10.4 International variations in the size or performance of batteries should not cause the meters' performance to fail the requirement of paragraph 3.2.10.1.

These meters may be used in locations far from a maintenance depot. As a result, the unit must be fully functional using batteries from any part of the world. In addition, these batteries must be replaceable in the field by the operator.

3.2.10.5 It is desirable that the meters warn the users of imminent battery failure at least two hours before this occurs.

The low-battery warning is important so that the operator is not surprised by a sudden power failure. Industry cannot provide much more than about five hours of warning to battery failure.

3.2.11 SHAPE SIZE AND WEIGHT:

3.2.11.1 The Advanced Survey Meters shall be as compact as possible, with a size and weight such that they can be comfortably carried in the hand for up to six hours while performing surveys

The Advanced Survey Meter shall be no larger than and no heavier than those that are in service with our allies or in the CF Radiation Safety program.

3.2.12 RESPONSE TIME:

3.2.12.1 The Advanced Survey Meters shall give immediate response to radiation.

3.2.12.2 It is desirable for the unit to perform a brief self-test when it is turned on. The user should be able to bypass this test.

3.3 Environmental Hardening Requirements

These meters are designed to be used by NBC specialist trained personnel and will not generally undergo the rugged treatment of the Reconnaissance Detection Meter. Thus, while the meters will have to be more rugged than those used in an industrial, safety, or laboratory setting, it does not have to meet the stringent requirements set forth for the reconnaissance meter.

3.3.1 PRESSURE:

3.3.1.1 The meters shall operate at pressures existing between sea level and 3048 metres.

3.3.1.2 The meters shall survive rapid decompression at 12200 metres without presenting a hazard to personnel or damaging the aircraft.

These meters must be capable of operation after transport in aircraft, and must not present a hazard should explosive decompression occur.

3.3.2 TEMPERATURE AND TEMPERATURE SHOCK:

3.3.2.1 The meters shall be capable of operation within the ambient temperature limits of –20°C to +40°C. Mean instrument response at any temperature in this range shall differ by no more than 20% from the mean response at 22°C.

3.3.2.2 Within five minutes of being taken from -20°C or +40°C to +22°C, mean instrument response shall not differ by more than 20% from reference readings taken at +22°C.

3.3.2.3 Within five minutes of being taken from +22°C to either -20°C or +40°C, mean instrument response shall not differ by more than 20% from reference readings taken at those temperatures.

The given conditions can be satisfied by several available rugged but not MIL-SPEC'd meters.

3.3.3 HUMIDITY AND WATER RESISTANCE:

3.3.3.1 The meters shall be capable of operation at relative humidities between 0 and 95%.

3.3.3.2 The meters shall be designed to be water-resistant.

The meters must be able to operate in humid conditions and be water-resistant.

3.3.4 VIBRATION AND SHOCK:

3.3.4.1 The meters, in their transit cases, shall be capable of operation after being transported on ground vehicles as unrestrained cargo.

3.3.4.2 While outside of the transit cases, the meters, not including their probes, shall be capable of operation after a fall from 3.5 metres, on a flat wooden bench top at least 40 mm thick.

While in their travelling cases, these meters must be capable of withstanding the harsh treatment to be expected in a military scenario. However, when out of the case, the requirements are not as stringent as for the Reconnaissance Detection Meter.

3.3.5 STORAGE CONDITIONS:

3.3.5.1 The meters must be capable of operation after having been stored at temperatures between -40°C and +50°C at relative humidities between 0 and 95%.

The meters must be able to operate after storage under a wide range of conditions.

3.3.5.2 The metres shall have a shelf life of at least 10 years.

3.3.6 NUCLEAR SURVIVABILITY:

3.3.6.1 It is desirable that the meters be designed to resist the effects of nuclear weapons, including Electromagnetic Pulse (EMP), as outlined in NATO Allied Engineering Publications AEP-4 and AEP-25.

3.3.6.2 It is desirable that the meters be designed to resist the Transient Radiation Effects on Electronics (TREE) as outlined in NATO AEP-22.

3.3.6.3 It is desirable that the meters be designed to resist NBC contamination in accordance with NATO AEP-7.

It is not necessary for these meters to be able to withstand a nuclear blast. However, resistance to EMP, TREE, and NBC contamination is still very desirable.

3.3.7 ELECTROMAGNETIC COMPATIBILITY:

3.3.7.1 The meters shall be shielded from non-ionising radiation or microwaves up to at least 10 mW/cm^2.

3.3.7.2 The meters shall not radiate electromagnetic radiation that will interfere with other equipment.

These meters shall neither interfere with, or be affected by, nearby equipment.

4 THERMOLUMINESCENT DOSIMETER AND TLD PROVIDER

4.1 General Considerations

The previous two sections have demonstrated the kinds of radiological hazards that can be generated. CF personnel may be required to carry out operations in such radiologically contaminated areas. This implies the requirement for DND to measure and record the radiation dose to which each of its personnel is exposed, in accordance with national and international laws and agreements. DND has elected to measure the external gamma radiation dose with indirect-reading Thermoluminescent Dosimeters (TLDs). In this document, the acronym TLD will be used to denote the pieces of thermoluminescent material and the case in which they are carried.

Each individual participating in a mission for which there is a risk of radiological exposure will be required to wear a TLD. Each TLD will measure the total accumulated gamma radiation dose to which it is exposed.

The organisation providing the TLDs will issue freshly annealed TLDs to DND on an as-and-when-required basis. This organisation will read the TLDs after some prescribed time, or at the end of the mission. The organisation shall inform DND of the dose to which each TLD was exposed. This information will be used by DND in a dose management system. As required, the organisation may have to supply replacement TLDs when others are taken for reading. DND may also require TLDs to be read at short notice, in the event of an unexpected high-level exposure. DND has determined that a Canadian-based organisation shall provide and read the TLDs.

TLDs cannot be used to perform active (real-time) dose management. In the field, this role will be performed with Electronic Dosimeters, described in the next section.

4.2 Performance Requirements

4.2.1 TYPE OF RADIATION MEASURED AND RANGE:

4.2.1.1 The Thermoluminescent Dosimeters shall respond to gamma radiation. The organisation reading the TLDs shall provide accurate dose measurements over the range 10 μGy to 7 Gy.

A clothed soldier is essentially protected against alpha and low-energy beta radiation. Thus, it is primarily the gamma radiation dose that is of interest. TLDs can be used quite effectively to measure gamma radiation doses.

The essential lower dose limit is somewhat lower that the specification given in NATO Triptych D/104 for an Individual Gamma Dosimeter. However, the limit given here represents the abilities of a competent TLD system. Moreover, the limit given here is identical to that given in the specification for the Electronic Dosimeter.

The upper dose limit clearly classifies as Militarily Significant Level Radiation (MSLR). This limit, achievable by a competent TLD system, will make this dosimeter useful in all foreseeable circumstances.

4.2.1.2 The Thermoluminescent Dosimeters shall have negligible sensitivity to neutrons.

4.2.2 ENERGY RESPONSE:

4.2.2.1 The Thermoluminescent Dosimeters shall respond to gamma radiation with energies from 50 keV to 3 MeV.

The energy limits given in this document will provide a reliable dose measurement for the range of gamma radiations that could be expected in an operation. The limits are the same as the desirable characteristics given in D/104, and are achievable with TLDs.

4.2.3 ACCURACY AND FADING:

4.2.3.1 The organisation reading the Thermoluminescent Dosimeters shall provide measurements of gamma radiation doses with an accuracy of at least 30%, over the entire operating range (gamma-ray energy and dose). It is desirable that the accuracy be 20%.

An accuracy of 30% is achievable with a TLD system. Improved accuracy is desirable, but may not be achievable over the entire energy range.

4.2.3.2 Some thermoluminescent materials fade, meaning that the signal extractable from the TLD decreases as the time after exposure increases. The TLD provider shall ensure that fading contributes no more than a 10% uncertainty to the gamma radiation dose measurement.

The TLD provider should be able to reduce any effects of fading to 10% or smaller.

4.2.4 PACKAGING AND PRESENTATION:

4.2.4.1 Each TLD shall be equipped with a provision for securely fastening it to a soldier's clothing. If the TLD is lost, all TLDs in the group shall be immediately returned for reading. The group average dose shall be used to estimate the personal dose.

The TLDs will be worn under the outer layer of clothing. They must be securely fastened to prevent loss.

4.2.4.2 It is essential that the serial number of each TLD be displayed on the outside of the case in both alpha-numeric and bar code formats.

4.2.4.3 Each TLD shall also have the provision to externally display the date when it was last annealed (to reset the dose measurement).

4.2.5 SHAPE SIZE AND WEIGHT: The TLDs shall be as light and compact as possible.

4.2.6 SERVICE DETAILS:

4.2.6.1 On demand, the TLD provider will issue freshly annealed TLDs to DND. The quantity required shall not exceed 2500 in a 14-day period.

The TLD equipment group is distinct from the other equipment groups in that a TLD is not an item that is purchased and delivered to DND until it is needed. Since the TLD will accumulate background radiation dose while it is stored, it must be freshly annealed before issue so that a soldier's exposure can be properly determined. The TLD provider will, therefore, hold the stock and issue it is as-and-when-required.

4.2.6.2 The TLD provider shall read the TLDs as required by DND. This may be at the end of a mission, after a suspected high level dose, or after a predetermined time from issue.

4.2.6.3 The TLD provider shall provide DND with a document listing the radiation dose to which each TLD was exposed. This document shall be in an electronic format as specified by DND, and shall be provided within 48 hours of TLD delivery, with the proviso that no more than 1000 TLDs will be read in this period. This information shall be made available to both the operational and medical communities, and follow-up procedures established to track significant exposures.

4.2.6.4 If the TLDs are to be returned for reading prior to the end of a mission, immediate replacements shall be required. These will be supplied by the provider according to paragraph 4.2.6.1

4.3 Environmental Hardening Requirements

4.3.1 PRESSURE:

4.3.1.1 The TLDs shall be capable of use at pressures existing between sea level and 3048 metres.

4.3.1.2 The TLDs shall survive rapid decompression at 12200 metres without presenting a hazard to personnel or damaging the aircraft.

This equipment must be capable of operating in all conceivable theatres, after transport in aircraft, and should not present a hazard to air crews in the event of explosive decompression.

4.3.2 TEMPERATURE:

4.3.2.1 The TLDs shall be capable of use within the ambient temperature limits of – 50°C to +50°C. Mean response to radiation at any temperature in this range shall differ by no more than 20% from the mean response at 22°C.

The given temperature limits will allow the TLDs to be used effectively in any operational scenario.

4.3.3 HUMIDITY AND WATER RESISTANCE:

4.3.3.1 The TLDs shall be capable of use at relative humidities between 0 and 95%. Mean radiation response at any humidity in this range shall differ by no more than 20% from the mean response at a relative humidity of 50%.

4.3.3.2 The TLDs shall be capable of use following immersion in water.

TLDs are not affected by exposure to water.

4.3.4 VIBRATION AND SHOCK:

4.3.4.1 The TLDs shall be capable of use after being transported on ground vehicles as unrestrained cargo.

The TLDs will undergo some rough treatment, since they will be worn at all times. They will also be transported by air and ground, and must be able to withstand the rigours of such travel.

TLDs typically consist of thermoluminescent material, wrapped in foil and contained in a plastic case. The thermoluminescent material cannot be exposed to light without destroying the dose measurement. Should the plastic case be broken open, then it is possible that the TLD will be invalidated. It is felt that this situation can be avoided if the TLD is worn under the outer layer of clothing. If, however, the case is broken then group averaging should be applied, as specified in case of loss.

4.3.5 STORAGE CONDITIONS:

4.3.5.1 The TLDs must be capable of use after having been stored at temperatures between -50°C and +70°C at relative humidities between 0 and 95%. Storage under these conditions following exposure to radiation shall not influence the results of the subsequent reading by more than 20%.

The given storage conditions represent the extremes that can be expected. No problems are anticipated in meeting this requirement.

4.3.5.2 The TLDs shall have a shelf life of at least 10 years.

5 ELECTRONIC DOSIMETER

5.1 General Considerations

The previous section outlined the use of the TLD as DND's choice of a standard dosimeter. However, a TLD can only reveal the total dose to which it has been exposed when it is read, after it has left the field. In order for the commander to make informed decisions about troop deployment in radioactive areas, a direct-reading dosimeter is required. This role will be fulfilled by the Electronic Dosimeter (ED).

The Electronic Dosimeters are intended to be compact, rugged, and simple to operate instruments. They will be used at the unit level (usually with one or two EDs in a workgroup of 10-60 personnel) to actively monitor the gamma radiation dose rate, and the total gamma radiation dose to which the group is exposed. They will be used, often in concert with the Reconnaissance Detection Meter, to alert personnel when gamma radiation dose rates exceed certain thresholds, such as NATO hazard perimeters or turn-back points. They will also be used to alert workgroups when total dose thresholds are exceeded. For this purpose, the EDs will have user-adjustable and user-selectable audible and visual alarms

The ED Readers are also intended to be compact, robust, and simple to operate. They will be used at the unit level to download the total mission dose and, possibly, a dose-rate profile from the EDs. The readers will then be capable of transferring this information to a PC-based platform to enable the commander to conduct group dose management.

Two distinct types of ED are currently available from industry. The first may be described as a "miniature Recce meter"; it is compact and has good dose rate response down to 1 μSv/h. The second is a true dosimeter; it sacrifices dose-rate response at very low levels for what can be a substantial reduction in size. The project team should establish which of these options is desired, and thus refine the technical requirements given here.

Neither this device nor the TLDs described in the last section are specified to perform beta dosimetry. However, given that both Electronic and Thermoluminescent Dosimeters are available that measure beta radiation doses, it is worthwhile to ask whether beta dosimetry should be a requirement of this project.

External beta ray doses can be extremely important. Skin exposed to beta radiation can display severe burns and even necrosis, as observed in Chernobyl [10], and following the accidents with lost ^{137}Cs sources at Lilo, Georgia [11] and Goiania, Brazil [12]. One must not underestimate the risk of serious health risks from beta radiation. Beta contamination of clothing and equipment should be avoided whenever possible, and carefully monitored (with an ASM, for instance) if there is a chance that it has occurred.

However, beta dosimetry is notoriously unreliable. Due to the limited range of beta radiation, beta doses are strongly concentrated in the region of contamination. Therefore, unless the contamination on the soldier is uniform or localised near the beta dosimeter, the dose measured by the beta dosimeter will tend to be underestimated; a dosimeter hung at the waist will measure little dose when the soldier's shoulder is contaminated. Thus, beta dosimetry can give the wearer a false sense of security. It should also be noted that beta dosimeters are, by design, relatively fragile because of the thin window through which the betas are measured. These two factors suggest that beta dosimetry is not worth procuring.

5.2 Performance Requirements

5.2.1 TYPE OF RADIATION MEASURED AND RANGE:

5.2.1.1 The Electronic Dosimeters shall measure gamma radiation dose rates, from 1 μSv/h to 1 Sv/h. It is desirable that the dosimeter read to levels as low as 0.05 μSv/h and to levels as large as 10 Sv/h.

Since a clothed soldier is essentially protected against alpha and low-energy beta radiation, there is no need for the ED to measure the dose from these types of radiation.

The essential lower dose rate limit is half of the NATO hazard perimeter dose rate. This will allow the soldier to be aware of radiation in advance of crossing the hazard perimeter. The desirable lower dose rate limit is suggested by NATO Triptych D/104. For the upper limit, the sponsor is interested in as large a dose rate as is achievable, so that the device is of maximum utility if a nuclear weapons exchange takes place. The essential characteristic is derived from what the manufacturers of military hardware routinely offer; the desirable characteristic is the design point at which no further improvement in performance is either anticipated nor deemed to be cost effective.

5.2.1.2 Each ED shall also measure the total gamma radiation dose to which it has been exposed, from 10 μSv to 1 Sv. It is desirable that the dosimeter read doses as low as 1 μSv and as large as 100 Sv. The ED shall allow the user to reset this mission dose to zero.

The ED will be the primary means by which group exposure is known in real time. Dose measurement is, therefore, essential.

The essential lower dose limit is somewhat lower than the D/104 specification for a tactical dosimeter. However, the essential lower limit given in this document is definitely achievable by currently available dosimeters and could result in added flexibility in the way the EDs are deployed. The desirable lower limit is set by what industry can provide. The upper limits are intended so that the meters will be useful in a high-level radiation encounter.

5.2.2 ENERGY RESPONSE: The Electronic Dosimeters shall respond to gamma radiation with energies from 80 keV to 1.5 MeV. It is desirable that the meters respond to lower energies (down to 50 keV) and higher energies (up to 3 MeV).

The essential lower energy limit is set by the fact that the biological importance of lower-energy radiation falls off quickly. The desirable lower limit is set by the desire to detect Americium-241 (at 59 keV), a militarily significant isotope. However, detection *efficiency typically falls off dramatically in this region, so a compromise is likely required.*

The essential upper energy limit is set by the requirement to detect Cobalt-60 (at 1332 keV), an isotope that is readily available in industry and could be used in a radiological dispersal weapon. The desirable upper limit would allow virtually all isotopes with reasonable lifetimes to be detected. Again, however, many meters have trouble with the more energetic gamma rays and a compromise is necessary.

5.2.3 ACCURACY: The Electronic Dosimeters shall indicate gamma radiation dose rates and mission doses with an overall accuracy of at least 30%, over the entire operating range (gamma-ray energy, dose rate and dose). It is desirable that the accuracy be 20%.

The figure of 30% is based on what industry can provide.

5.2.4 PRESENTATION:

5.2.4.1 All information presented on the Electronic Dosimeters and on the ED Readers shall be in English and French. The user shall be able to select the language (English or French) to be used on displays of both the ED and the ED reader.

5.2.4.2 When displaying dose rates, the Electronic Dosimeters shall be direct reading in Grays per hour or Sieverts per hour, with metric prefixes as appropriate. When displaying doses, the Electronic Dosimeters shall be direct reading in Grays or Sieverts, with metric prefixes as appropriate. In both cases, range switching shall be automatic.

The meters must use the metric units of dose (the Gray) or dose equivalent (the Sievert). The Gray has the advantage that it is in use by the U.S.A. (specifically, the centiGray).

However, since the International Radiation Safety Community currently uses Sieverts, and since dose equivalent is the most relevant measure of radiation for determining effects on people, it is felt that the Sievert is the most desirable unit. However, in order to make the Sievert more meaningful than the Gray, the quality factor should be user-programmable.

5.2.4.3 The readings shall be presented digitally. It is desirable that the dose rate also be shown in an analog display. If such an analog display is not used, then it is desirable that the meters indicate whether the radiation field is increasing or decreasing. Such a trend indicator shall not be continually changing in a constant field due to statistical fluctuations.

For ease of use, the display must be digital and autoranging. However, an analog counterpart or trend indicator can be useful in seeing trends in the radiation pattern.

5.2.4.4 The meters shall be readable by day or night without an external light source.

An integral light source is essential to permit one-handed operation. This light should not be so bright as to compromise a soldier's position when it is used.

5.2.4.5 The ED display must be refreshed at least once every two seconds, for temperatures above 0°C. At lower temperatures, the refresh rate may be decreased.

The display's refresh rate should be relatively rapid for ease of reading. However, it is recognised that at low temperatures, the refresh rate may be decreased to make up for the degraded performance of the LCD display.

5.2.4.6 It is essential that the serial number of each meter and of each ED reader be displayed on the outside of the case in both alpha-numeric and bar code formats. It is essential that an ED's serial number can also be uploaded to and downloaded from the ED memory by the ED reader.

5.2.4.7 Each meter and reader shall also have the provision to externally display the date of last calibration and the expiry date for this calibration.

5.2.5 ALARMS:

5.2.5.1 The Electronic Dosimeters shall have visible and audible alarms that are triggered when dose rates are measured that exceed designated levels.

5.2.5.2 It is also essential that alarms be triggered when the total dose exceeds designated levels.

The dosimeters must have alarms corresponding to levels of total dose. This will allow commanders to know when workgroups have been exposed to certain levels of radiation.

5.2.5.3 The meters shall allow the user to set the alarm levels.

The dosimeters must have alarms so that, for instance, workgroups can be quickly alerted to radiation levels in excess of the NATO hazard perimeters and turnback point. Continually evolving military exposure guidelines require that the alarm levels be user-programmable.

5.2.5.4 The alarm shall take the form of both an audible and visual signal. The dosimeters shall allow the user to deactivate the audible part of the alarm, both before and after an alarm level is reached.

The alarm should be audible and visible for maximum effect. However, the user must have the option of deactivating the audible portion of the alarm for roles in which the operator does not want to be detected by an opposing force.

5.2.6 DOSE RATE PROFILE:

5.2.6.1 It is desirable that the ED record a dose rate profile for a mission. That is, the meter should store in memory the dose rates measured, at regular intervals, over the course of a mission.

Developments in our understanding of the health effects of radiation suggest that the rate at which radiation doses are administered is an important factor. Thus, a dose rate profile could be a very important component in dose management. This characteristic is highly desirable.

5.2.7 COMMUNICATION:

5.2.7.1 The ED reader shall download total mission dose from the EDs. If the ED records a dose rate profile, then it is essential that the reader be able to download this profile as well.

5.2.7.2 If the reader is not a PC-based platform, then it shall provide for its data to be downloaded to such a platform. This transfer should be accomplished via a cable or infrared interface.

Information stored in the ED should be downloadable to a reader and then to a PC so that it can be used effectively in a dose management system.

5.2.8 CONTROLS:

5.2.8.1 The controls of the Electronic Dosimeters and the dosimeter readers shall be simple to operate and be clearly marked.

5.2.8.2 To prevent damage to protective gloves or clothing, it is essential that plastic-covered buttons be used in place of toggle switches on the EDs.

5.2.8.3 The dosimeters must be practical to use with combat equipment, including any environmental or NBC protective equipment, combat gloves, a mask, or dust goggles.

It is assumed that the ED reader will be used in sheltered and clean conditions. Thus, it is not expected that the reader will be used while wearing NBC protective clothing.

5.2.9 CALIBRATION:

5.2.9.1 Under normal circumstances, the dosimeters shall be capable of being used for at least one year without recalibration.

5.2.9.2 Under normal circumstances, the dosimeter readers shall not require any form of calibration.

5.2.10 ANCILLARY EQUIPMENT:

5.2.10.1 The Electronic Dosimeters shall include separate check sources containing less than scheduled quantities of radioactive material. These check sources shall contain sufficient material or have a sufficiently long lifetime that they will continue to be effective for calibration purposes over the expected lifetime of the meters (approximately 10-15 years).

5.2.10.2 The dosimeters shall also include any tools required to perform user maintenance on the dosimeters, and any external power sources (if applicable).

5.2.10.3 The dosimeters shall include a clip that allows it to be hung from a soldier's combat webbing. A redundant method of attaching the ED to the soldier is desirable.

5.2.10.4 The readers shall include any equipment that is required for their data to be downloaded to a PC-based platform.

5.2.10.5 The dosimeter readers shall also include a transit case.

5.2.11 POWER SUPPLY:

5.2.11.1 The dosimeters shall be capable of at least 96 hours of continuous operation at any temperature in the operating regime, with a compact and lightweight power source, which may consist of internal batteries or a battery pack kept close to the body.

A typical mission will not exceed 96 hours. It is expected that the operator will carry spare batteries for the dosimeter, so that the ED will be useful throughout the mission that commences with used batteries in the dosimeter.

5.2.11.2 The batteries used in the meter or the power source shall be standard commerical off the shelf and conform to international standards.

5.2.11.3 Batteries shall be replaceable in the field by the operator.

5.2.11.4 International variations in the size or performance of batteries shall not cause the meters' performance to fail the requirement of paragraph 2.2.10.1.

These meters may be used in locations far from a maintenance depot. As a result, the unit must be fully functional using batteries from any part of the world. In addition, these batteries must be replaceable in the field by the operator.

5.2.11.5 The mission dose and dose rate profile shall not be lost if the ED loses power, including the time during battery replacement.

One of the primary uses of the ED is to measure total mission dose. Thus, if batteries fail or are replaced during a mission, this quantity.cannot be lost from the ED memory.

5.2.11.6 It is essential that the meters warn the users of battery failure at least two hours before this occurs.

5.2.11.7 The ED reader shall operate with 110 Volts / 60 Hertz or 220 Volts / 50 Hertz AC power sources.

It is assumed that the ED reader will be used in conditions where AC power is available.

5.2.12 SHAPE SIZE AND WEIGHT:

5.2.12.1 The Electronic Dosimeters and Dosimeter Readers shall be as compact as possible.

5.2.12.2 The EDs shall have a mass not exceeding 250 grams without batteries.

5.2.12.3 The EDs shall have a volume not exceeding 210 cm^3, with no dimension exceeding 10 cm.

5.2.13 RESPONSE TIME: The Electronic Dosimeters shall give immediate response to radiation. A brief self-test is permissible.

5.3 Environmental Hardening Requirements

5.3.1 PRESSURE:

5.3.1.1 The dosimeters and readers shall operate at all pressures existing between sea level and 3048 metres.

5.3.1.2 The dosimeters and readers shall survive rapid decompression at 12200 metres without presenting a hazard to personnel or damaging the aircraft.

This equipment must be capable of operation after transport in aircraft, and must not present a hazard should explosive decompression occur.

5.3.2 TEMPERATURE AND TEMPERATURE SHOCK:

5.3.2.1 The dosimeters and readers shall be capable of operation within the ambient temperature limits of –10°C to +40°C. Mean dosimeter response at any temperature in this range shall differ by no more than 20% from the mean response at 22°C. It is desirable that the operating temperature range be –45°C to +45°C.

5.3.2.2 Within five minutes of being taken from either temperature extreme of the operating range to +22°C, mean dosimeter response shall not differ by more than 20% from reference readings taken at +22°C.

5.3.2.3 Within five minutes of being taken from +22°C to either temperature extreme of the operating range, mean dosimeter response shall not differ by more than 20% from reference readings taken at those temperatures.

The given essential characteristics can be satisfied by several commercially available dosimeters. It is desirable that this equipment can be operated under the full range of temperatures in which an operation could occur.

5.3.3 HUMIDITY AND WATER RESISTANCE:

5.3.3.1 The dosimeters and readers shall be capable of operation at relative humidities between 0 and 90%.

5.3.3.2 The dosimeters shall be designed to be water-resistant.

5.3.3.3 The dosimeter readers shall be capable of reading a wet ED, and of operation afterward.

The given essential characteristics are derived from what industry can provide. The dosimeter readers will be used under cover, but must still be able to handle a wet dosimeter.

5.3.4 VIBRATION AND SHOCK:

5.3.4.1 The dosimeters shall be capable of operation after being transported on ground vehicles as unrestrained cargo.

5.3.4.2 The dosimeter readers shall be capable of operation after being transported, in their transit cases (if applicable), as unrestrained cargo.

5.3.4.3 The dosimeters shall be capable of operation after a fall, from 3.5 metres, onto a flat wooden bench top at least 40 mm thick.

The dosimeters and readers must both be designed for rough treatment. However, the readers will be used under much more controlled conditions, and do not need to meet the requirements of the EDs.

5.3.5 STORAGE CONDITIONS:

5.3.5.1 The dosimeters and readers must be capable of operation after having been stored at temperatures between -25°C and +70°C at relative humidities between 0 and 90%. It is desirable that the storage temperature range extend to –50°C.

The essential characteristics are defined by the limits of several commercially available dosimeters. It is desirable that the dosimeters withstand storage at colder temperatures.

5.3.5.2 The dosimeters and dosimeter readers shall have a shelf life of at least 10 years.

5.3.6 NUCLEAR SURVIVABILITY:

5.3.6.1 It is desirable that the dosimeters be designed to resist the effects of nuclear weapons, including Electromagnetic Pulse (EMP), as outlined in NATO Allied Engineering Publications AEP-4 and AEP-25.

5.3.6.2 It is desirable that the meters be designed to resist the Transient Radiation Effects on Electronics (TREE) as outlined in NATO AEP-22.

5.3.6.3 It is desirable that the dosimeters be designed to resist NBC contamination in accordance with NATO AEP-7.

Resistance to the effects of nuclear weapons is desirable.

5.3.7 ELECTROMAGNETIC COMPATIBILITY:

5.3.7.1 The dosimeters and their readers shall be shielded from non-ionising radiation or microwaves up to at least 10 mW/cm^2.

5.3.7.2 The dosimeters and their readers shall not radiate electromagnetic radiation that will interfere with other equipment.

These meters shall neither interfere with, or be affected by, nearby equipment.

6 PORTABLE BETA-GAMMA SPECTROSCOPY SYSTEM

6.1 General Considerations

The equipment described thus far will provide the CF with the capability to detect and delineate hazards, and to monitor the exposure of personnel performing tasks in these areas. However, the CF will not be adequately equipped to identify hazards without the ability to perform spectroscopy.

Beta-gamma spectroscopy can be used to identify the nature of many radiological hazards, such as the ^{137}Cs source described earlier. However, this capability becomes even more useful when the hazard is a mixed source, such as the plume from a reactor accident. Figure 3 shows the dose contours from exposure to the plume produced by a 35% inventory release from the 7-MegaWatt RA heavy water research reactor at the Vinca Institute in Belgrade [13], weather conditions as on 22 April 1999 (clear skies, winds from the south at 16 km/h). This severity of release is typical of a steam tube rupture.

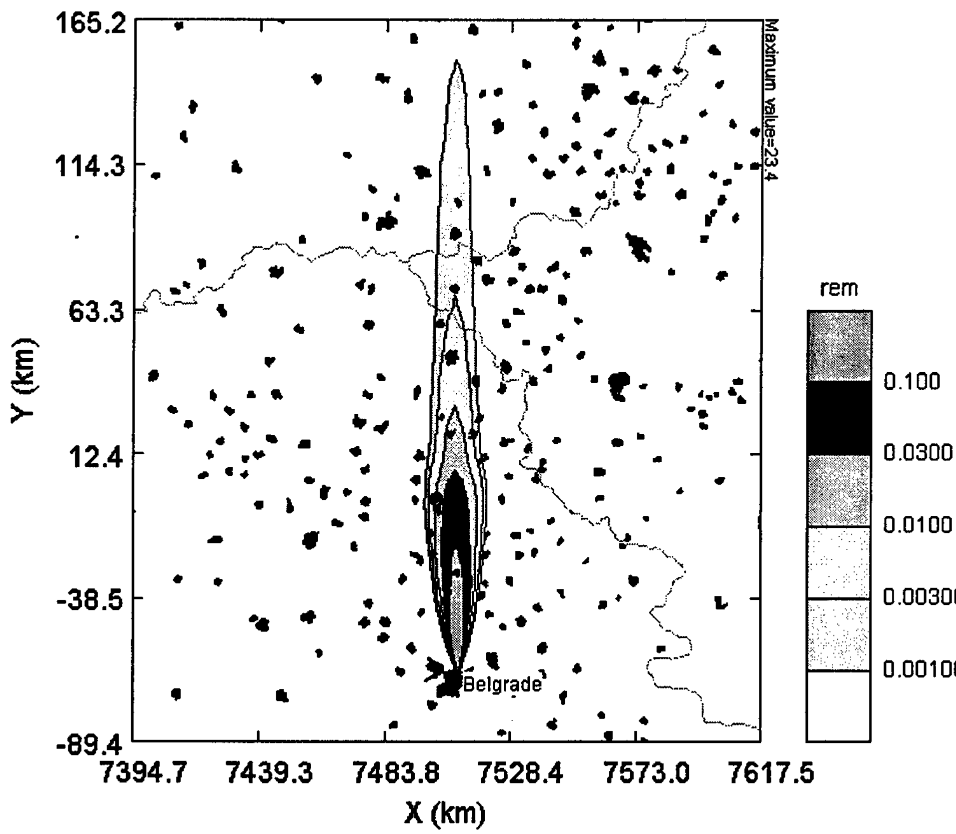

Figure 3: External dose rates from the radioactive plume following a reactor malfunction in Belgrade.

Clearly, the NATO hazard perimeter would extend at least 100 km downwind of the reactor, into Romania and perhaps even into Hungary. A spectroscopy system can help to identify what radioactive materials are being transported downwind, which in turn can be used to assess the 50-year committed dose to unprotected personnel in the plume.

NBC specialists will use the Portable Spectrometers. The Spectrometers shall perform two roles. The first role is to perform basic beta and gamma radiation spectroscopy on contaminated surfaces (including air filtration media) and in the air (gamma radiation only). This requires a man-portable device that can be carried for several hours.

The second role is to perform gamma radiation field mapping. This requires a device that can be mounted on military vehicles, including the LAV; helicopters; or, in a future application, RPVs. They will take input from a GPS device so that a map of the gamma radiation field can be produced. For airborne applications, they will also take input from an absolute reading altimeter and apply an altitude correction factor so that the radiation field at ground level can be obtained.

The Portable Spectrometers shall measure and display the energy spectrum of the incident radiation. They will use these spectra to perform isotopic identification. The Portable Spectrometer Systems shall also provide real-time dose equivalent rate measurements and integrated dose equivalents.

The Portable Spectrometers described in this report do not detect alpha radiation, although alpha radiation spectroscopy is required to perform sensitive air sampling. This requirement, if procured through this project, will be satisfied with another equipment group. If it is not procured through this project, then it could be provided through a radiological extension to the CIBADS system.

6.2 Performance Requirements

6.2.1 TYPE OF RADIATION MEASURED AND RANGE:

6.2.1.1 The Portable Spectrometers shall measure gamma radiation energy spectra. They shall operate in gamma radiation fields from background levels (approximately 0.05 μSv/h) to 1 mSv/h. It is desirable that the upper limit be 10 mSv/h.

6.2.1.2 When mounted in a helicopter flying at an altitude of 150 feet, the Portable Spectrometers shall, in a one-second sample, be able to detect large-area (infinite plane) gamma radiation sources on the ground producing fields between 1 μSv/h and 1 mSv/h at 1 metre above the ground. It is desirable for the operating range to be between background levels (approximately 0.05 μSv/h) and 10 mSv/h.

6.2.1.3 The Portable Spectrometers shall measure beta radiation energy spectra from natural background levels to 1 mSv/h. It is desirable for the upper limit to be 10 mSv/h.

6.2.1.4 The Portable Spectrometers shall use the spectral information collected to calculate radiation dose equivalents and dose equivalent rates in real time.
The operating ranges given here are taken from NATO Triptych D/104. These limits were based on commercially available systems.

6.2.2 ENERGY RESPONSE:

6.2.2.1 The Portable Spectrometers shall respond to gamma radiation with energies between 100 keV and 3 MeV. It is desirable for the response to extend down to 50 keV and up to 8 MeV.

6.2.2.2 The Portable Spectrometers shall respond to beta radiation with energies between 100 keV and 3 MeV. This will permit the isotopic identification of the elements in the table below.

Nuclide	**Endpoint Energy (MeV)**
Phosphorus-32	1.710
Phosphorus-33	0.248
Chlorine-36	0.714
Calcium-45	0.252
Strontium-90 / Yttrium-90	0.546 / 2.27
Technetium-99	0.292
Promethium-147	0.224
Thallium-204	0.766

The energy limits given here are based on the capabilities of commercially available systems. While spectroscopy at lower beta and gamma energies could be useful in operations, the windows on the probes required to do this work are very fragile. The desirable limits for the gamma-ray energies are taken from NATO Triptych D/104.

6.2.3 ACCURACY:

6.2.3.1 The Portable Spectrometers shall measure radiation dose equivalents and dose equivalent rates to with an accuracy of 5% over the entire operating range.
The accuracy given in this document is taken from NATO Triptych D/104, and is achievable by commercial systems.

6.2.4 PRESENTATION:

6.2.4.1 All information presented on the Portable Spectrometers shall be in English and French. Labelling, when required, shall be in both English and French. The displays shall either use both English and French simultaneously, or allow the user to select which of the two languages should be used.

6.2.4.2 The Portable Spectrometers shall use the SI unit of dose equivalent, the Sievert, when displaying radiation dose equivalents and dose equivalent rates.

In accordance with NATO guidelines and the international radiation safety community, Sieverts are the preferred units for measurements of dose equivalents. It is the long-term objective of NATO to use these units.

6.2.4.3 It is desirable for the Portable Spectrometer Systems to be readable by day and night without an external light source.

Since use of the Portable Spectrometers will likely require two hands, nighttime use will be difficult unless the display is lit in some way. However, since this feature is not available among commercial systems, it is not an essential requirement.

6.2.4.4 It is essential for the serial number of each spectrometer to be displayed on the outside of the case in both alphanumeric and bar code formats, and be electronically addressable if connected to a controller system such as envisioned in CIBADS.

6.2.5 ISOTOPIC IDENTIFICATION:

6.2.5.1 The Portable Spectrometers shall use the measured radiation spectra to perform isotopic identification of the radioactive material under consideration. This procedure shall require minimal user interaction. Controlling software shall perform the identification function.

Accurate isotopic identification is the most important capability of a spectroscopy system. Without isotopic identification, commanders cannot make informed decisions to avoid and / or limit internal or external doses, and calculation of (50-year) committed dose equivalents is not possible.

Since the Portable Spectrometers will be used by NBC specialists but not by highly-trained experts, the isotopic identification process should require little input from the user.

6.2.5.2 The Portable Spectrometers shall be able to identify, at a minimum, the gamma radiation emitting radionuclides in the table below. They should also be able to identify the presence of sources consisting of many radionuclides, such as fresh nuclear fuel, aged fuel, and Uranium-235 fission products.

Nuclide	Endpoint Energy (MeV)
Cobalt-60	1.17, 1.33
Cesium-134	0.569, 0.605, 0.796
Cesium-137 (Barium-137m)	0.662
Iridium-192	0.296, 0.308, 0.317, 0.468
Uranium-235	Several
Uranium-238	Several

The most desirable detection medium (that does not require cryogenic cooling) is sodium iodide. This material has a resolution sufficient for the identification of the individual *isotopes of interest to DND, and to classify collections of radiological agents, as described in this document.*

6.2.5.3 The Portable Spectrometers shall be able to identify, at a minimum, the beta radiation emitters in the table in paragraph 6.2.2.2.

6.2.6 DATA TRANSFER:

6.2.6.1 The Portable Spectrometers must be able to download data (defined below) to any PC-based platforms loaded with the appropriate software, including but not exclusively the PC-based platform running the Portable Spectrometer.

6.2.6.2 Downloadable data includes the spectra from mapping operations, radiological maps, and the raw data from which the maps are made. The user shall be able to selectively download any of these objects. Limits, quantities, and types of files will be specified later.

Spectra and raw data must both be downloadable from the Portable Spectrometer to a PC-based platform so that further analysis can be performed, if needed.

Radiological contour maps must be downloadable so that they can be overlaid on topographical maps for use by Command and Control structures.

6.2.6.3 It is desirable for the Portable Spectrometer to have the ability to store and compress its data for transmission to a ground station via the helicopter's own radio system.

Transmission from an airborne platform to a ground station is a desirable property of the Portable Spectrometer. However, to minimise radiofrequency conflicts, it is desirable for this communication to be performed with existing communications gear.

6.2.6.4 It is also desirable for data transmitted in this way to be encrypted.

6.2.7 MAPPING:

6.2.7.1 For mapping operations, the Portable Spectrometers shall have the provision for probes and other necessary hardware (eg: GPS antenna, altimeter) to be mounted on military vehicles, such as the LAV, a helicopter, or a RPV (for future applications).

For mapping operations, some hardware, such as the GPS antennae, will have to be mounted outside the vehicle, ship, or aircraft. The Portable Spectrometer must have the provision for doing this.

6.2.7.2 During mapping operations, the Portable Spectrometers shall be able to show a map of the measured radiation field in real time.

Real-time display of the radiological map is necessary for efficient operation. It could allow personnel to return to certain areas for more detailed surveys, or provide rapid warnings to personnel below.

6.2.7.3 The Portable Spectrometers shall be able to determine their position (for mapping purposes to an accuracy of at least 0.5 km. It is desirable for this accuracy to be 100 m.

In the airborne reconnaissance role, high-resolution mapping is not required. However, for other roles, resolution of a few metres is required. Whether this can be achieved in a commercial system is under investigation by DREO, and may become a subject of engineering studies.

6.2.7.4 If the map is produced from an airborne platform, then during post-mission processing, the Portable Spectrometers shall be capable of converting this map into a map of the radiation field at 1 metre above the ground. The computational process to do this should not exceed five minutes when performed by a 200 MHz Pentium II with 64 Mb RAM.

Improvement of the real-time display into a map of the field at 1metre above ground is also important for refining command decisions. However, this information must be available quickly to be useful. It should be noted that, even if it was possible for the system to give altitude-corrected dose rates in real time, personnel in the aircraft must still be able to see what the dose rate is in the aircraft.

6.2.7.5 The Portable Spectrometers shall be capable of recording and storing up to 3 hours (desirably 6 hours) of data from such a mapping operation.

A mapping mission should not exceed two hours in mapping time.

6.2.7.6 It is desirable for the mapping operation to be sufficiently automated such that an operator could start the procedure prior to take-off, and leave the Portable Spectrometer unattended until landing.

Completely unattended operation is desirable, so that the aircraft does not have to carry extra personnel to carry out a reconnaissance mission.

6.2.7.7 When passing over an area which is contaminated above some user-selected level, it is desirable for the Portable Spectrometer to emit an audible alarm (possibly through the helicopter's crew inter-communication system).

6.2.7.8 It is desirable for a downward-looking low-light digital camera to be activated when the above alarm level is reached. This will allow visual survey of a radiologically contaminated area at any time of day or night, without having to obtain pictures over the entire mission.

A digital camera could be very useful for reconnaissance missions. However, this camera should only be activated when passing over contaminated areas.

6.2.7.9 When passing over areas contaminated above the alarm level, the Portable Spectrometers shall store data with a one-second sampling interval. When passing over less contaminated areas, the Portable Spectrometers may store less data, possibly summing several time slices. In this way, less data is stored and transmitted concerning areas of lesser interest.

6.2.8 CONTROLS:

6.2.8.1 The controls of the Portable Spectrometers shall be simple to operate and be clearly marked.

6.2.8.2 The spectrometers shall be practical to use with combat equipment, including most environmental or NBC protective equipment, combat gloves, a mask, or dust goggles.

6.2.9 PROBES:

6.2.9.1 When any external probes are connected to the spectrometers, the spectrometers shall sense all relevant properties of the probes. Probes shall be interchangeable between spectrometers (it is understood that re-calibration will be necessary).

6.2.9.2 Connecting the probes to the spectrometers shall be easy for a user wearing protective gloves.

6.2.9.3 If any of the probes contain gas-filled tubes, then these tubes shall not require regular or routine re-charging with a quench gas.

6.2.10 CALIBRATION:

6.2.10.1 The Portable Spectrometers shall be self-calibrating using included calibrated radioactive sources of non-scheduled activities.

6.2.10.2 It is desirable for the Portable Spectrometer to have the ability to automatically adjust the calibration coefficients to compensate for gain shifts caused by, for instance, temperature changes.

The gain of a sodium iodide system will shift substantially when the temperature of the crystal is changed. In practice, this means that the device must be periodically re-calibrated when its temperature is changed. It is desirable for a system to be able to make automatic corrections for the gain shifts without re-calibration.

6.2.11 ANCILLARY EQUIPMENT:

6.2.11.1 The spectrometers shall include cables to connect the probes (as applicable), any tools required to perform user maintenance on the meters, and any external power sources (if applicable).

6.2.11.2 The spectrometers shall include a transit case to protect the spectrometer, probes, and other components of the system from mechanical shock and temperature shock.

6.2.11.3 The Portable Spectrometers shall include a GPS receiver (minimum 12 channel) and absolute altimeter for use during mapping operations. Differential GPS systems will be accepted, but they must be capable of operation in the absence of a beacon signal.

Aerial mapping operations will require the Portable Spectrometer to employ a GPS system and an absolute-reading altimeter. The spectrometer will provide its own such modular systems, and shall not rely on the aircraft's onboard systems.

6.2.12 POWER SUPPLY:

6.2.12.1 The Portable Spectrometers shall be capable of at least 3 hours (desirably 6 hours) of continuous operation at any temperature in the operating regime, with a compact and lightweight power source.

Three hours of continuous self-sufficient operation is sufficient since mapping operations shall not exceed two hours.

6.2.12.2 If the power source consists of non-rechargeable batteries, then they shall be standard commercial off the shelf and conform to international standards.

6.2.12.3 Non-rechargeable batteries shall be replaceable in the field by the operator.

6.2.12.4 International variations in the size or performance of non-rechargeable batteries should not cause the spectrometers' performance to fail the requirement of paragraph 6.2.12.1.

6.2.12.5 If the power source is rechargeable, then it shall be rechargeable with both 120 Volt, 60 Hertz, and 220 Volt, 50 Hertz power sources.

Rechargeable batteries must be rechargeable from both 120 V and 220 V power sources.

6.2.12.6 It is desirable for the spectrometers to warn the users of imminent battery failure at least thirty minutes before this occurs.

6.2.12.7 It is also desirable for the spectrometers to be operable with an external 6-32 V DC power source.

6.2.13 SHAPE SIZE AND WEIGHT:

6.2.13.1 The Portable Spectrometers shall be as compact as possible. The mass of the entire system, including all probes and the transit case, shall not exceed 15 kg.

6.2.13.2 The Portable Spectrometers shall have a size and weight such that they can be comfortably carried for up to 3 hours, in conjunction with protective clothing and equipment. A strap shall be provided for ease of carrying.

6.3 Environmental Hardening Requirements

The Portable Spectrometers will be used under controlled conditions. The probes are particularly susceptible to fracture from temperature shock and mechanical shock, and personnel using these devices will need to be particularly careful.

6.3.1 PRESSURE:

6.3.1.1 The spectrometers shall operate at atmospheric pressures existing between sea level and 3048 metres.

6.3.1.2 The spectrometers shall survive rapid decompression at 12200 metres without presenting a hazard to personnel or damaging the aircraft.

These devices must be capable of operation after transport in aircraft and should not present a hazard should explosive decompression occur.

6.3.2 TEMPERATURE AND TEMPERATURE SHOCK:

6.3.2.1 The spectrometers shall be capable of operation within the ambient temperature limits of -30°C to +40°C.

6.3.2.2 It is recognised that the crystals used in spectroscopy systems are susceptible to fracture from temperature shock. It is desirable for the transit case of the Portable Spectrometers to have temperature sensors inside and on the outside of the case and an indicator that uses the output of these sensors to indicate when it is safe to remove the probe from its case.

6.3.3 HUMIDITY AND WATER RESISTANCE:

6.3.3.1 The spectrometers shall be capable of operation at relative humidities between 0 and 95%.

6.3.3.2 The spectrometers, including ancillary equipment, shall be designed to be splash-resistant, if not immersion-proof.

6.3.4 VIBRATION AND SHOCK:

6.3.4.1 The spectrometers, in their transit cases, shall be capable of operation after being transported on ground vehicles as unrestrained cargo.

The transit case has an important role to fulfil since the crystal in the probe is susceptible to damage from mechanical shock.

6.3.5 STORAGE CONDITIONS:

6.3.5.1 The spectrometers must be capable of operation after having been stored at temperatures between –20°C and +40°C at relative humidities between 0 and 95%.

6.3.5.2 The spectrometers shall have a shelf life of at least 10 years.

6.3.6 NUCLEAR SURVIVABILITY:

6.3.6.1 It is essential for the spectrometers, in their transit cases, to be designed to resist the effects of Electromagnetic Pulse (EMP), as outlined in NATO Allied Engineering Publications AEP-4 and AEP-25.

6.3.6.2 It is essential for the spectrometers, in their transit cases, to be designed to resist the Transient Radiation Effects on Electronics (TREE) as outlined in NATO AEP-22.

6.3.6.3 It is desirable for the spectrometers to be designed to resist NBC contamination in accordance with NATO AEP-7.

It is not necessary for these devices to be able to withstand a nuclear blast. However, resistance to EMP, TREE, and NBC contamination are still desirable.

6.3.7 ELECTROMAGNETIC COMPATIBILITY:

6.3.7.1 The spectrometers shall be shielded from non-ionising radiation or microwaves up to at least 10 mW/cm^2.

6.3.7.2 While in use, the spectrometers shall not radiate electromagnetic radiation that will interfere with other equipment.

These meters shall neither interfere with, nor be affected by, nearby equipment.

7 AIR SAMPLER

7.1 General Considerations

Airborne contamination is an often neglected, but extremely important part of radiation protection. In the last section, Figure 3 showed the external dose to personnel as a result of exposure to the plume from a reactor accident. Figure 4 below shows the internal 50-year committed dose equivalent to unprotected personnel from the same incident, also at twenty-four hours following the release.

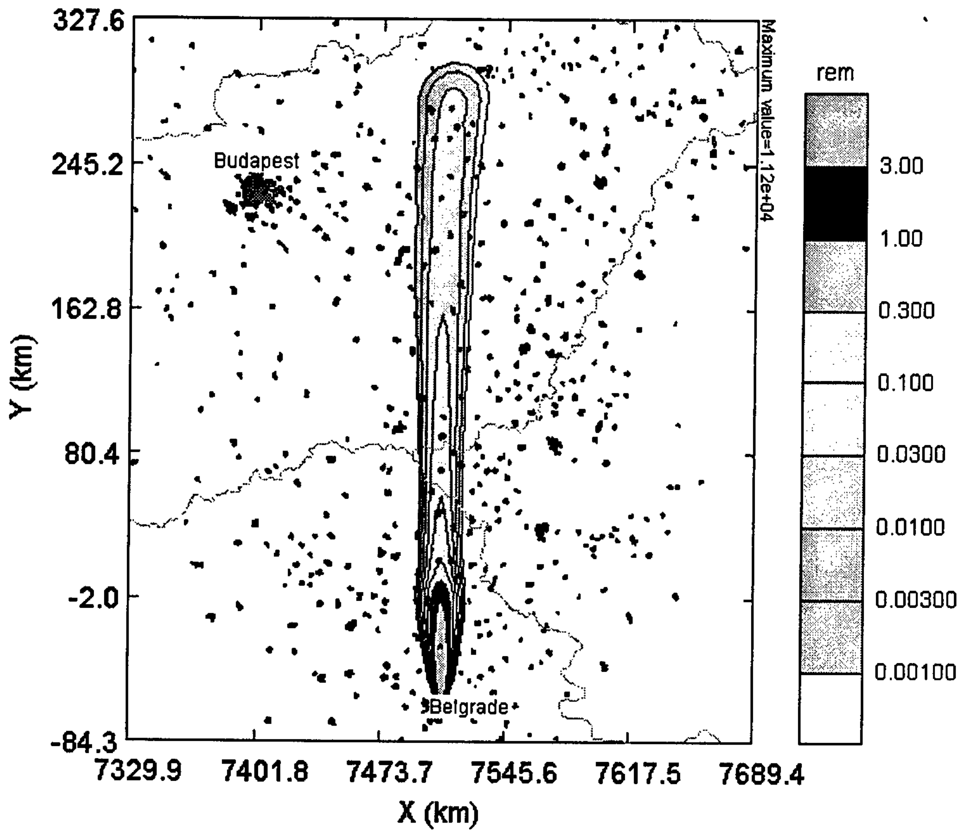

Figure 4: Internal 50-year committed dose equivalents from inhalation, twenty-four hours after the plume release.

Note that the internal doses are approximately ten times greater than the external doses received at the same position, and that the NATO hazard perimeter, taking the internal dose into account, would extend almost all of the way across Hungary into Slovakia. This emphasises the importance of accurate assessment of airborne hazards, which can only be done through air sampling or monitoring. The Air Samplers, together with the Advanced Survey Meters and the Portable Spectrometers, are intended to provide this capability with a 1-4 hour time frame required by commanders.

The Air Samplers are intended to be compact, rugged, and simple to operate instruments. They will employ filter papers to capture particulates, and a filter medium to collect vapours, such as radioiodines (charcoal canisters are suitable for this role). At the conclusion of a run, the filter media shall be examined with an Advanced Survey Meter (for alpha and beta detection) and/or a Portable Spectrometer (for beta and gamma isotopic identification).

In order to obtain greater sensitivity, or to provide a continuous air monitoring capability, the Air Samplers may be required to run on a continuous basis. It is desirable for the Air Sampler to have a timer that turns it on and off at pre-set times. Remote operation is also desirable.

The Air Samplers shall use either 120 V, 60 Hz or 220 V, 50 Hz AC power. It is desirable for the Air Samplers to be capable of operation with 6-32 V DC power supplies.

7.2 Performance Requirements

7.2.1 FILTER MEDIA:

7.2.1.1 The Air Samplers shall accommodate both particulate filter papers and filter media for vapours (such as charcoal canisters) at the same time.
Most of the conceivable airborne radiological hazards arising during operations will be in the form of particulates. A particulate filter is thus an essential component of the Air Samplers.

However, there is also a risk of exposure to gaseous radioiodines, for which a particulate filter is unsuitable. This risk is exacerbated by the inability of the NBC mask to prevent radioiodine inhalation.

7.2.1.2 The filter media shall have a minimum diameter of 47 mm.
Forty-seven millimetres is a commonly used diameter for particulate filters. Smaller filters may be difficult to use efficiently with the Advanced Survey Meter, particularly if the alpha probe is 100 mm on a side.

7.2.1.3 At a flow rate of 90 litres per minute, the particulate filters shall have a retention efficiency in excess of 98% for dioctyl phthalate (DOP) particles with a diameter of 0.3 μm.

7.2.1.4 At a flow rate of 90 litres per minute, the vapour-collecting medium shall have a methyl iodide (CH_3I) retention efficiency in excess of 90%.
The quoted retention efficiencies for the particulate and vapour filters are readily available from industry.

7.2.1.5 The particulate filters shall absorb no more than 30% of the alpha particles emitted by particulates captured in the filters.

The given alpha particle absorptivity is also achievable, and is important in attempting to determine the sensitivity of this system.

7.2.2 AIRFLOW:

7.2.2.1 If the particulate filter has a diameter of 47 mm, then the Air Samplers, with both filter media installed, shall have a maximum flow rate no less than 90 litres per minute. It is desirable that the flow rate be as large as 150 litres per minute.

The flow rate quoted is achievable by AC-powered high-volume air samplers. It is important that this airflow be achieved with both filter media installed, since this has a dramatic impact on the flow rate of these systems.

7.2.2.2 If the diameter of the particulate filter exceeds 47 mm, then the quantities stated in the paragraph above shall be scaled up proportional to the ratio of the area of the particulate filter to the area of a 47 mm-diameter filter.

If the particulate filter is larger but the airflow remains constant, then the resulting contamination per unit area on the filter paper will decrease. This undesirable outcome is mitigated by the requirements for larger airflows for larger filters.

7.2.2.3 In the absence of power fluctuations, the airflow meters shall be accurate to 20%, in terms of volume per unit time.

The stated requirement for airflow accuracy is achievable by the available devices.

7.2.2.4 The Air Samplers shall have a provision for the user to calibrate the airflow.

7.2.3 PRESENTATION:

7.2.3.1 All information presented on the Air Samplers shall be in English and French.

7.2.3.2 The Air Sampler shall show the current airflow rate, in litres per minute.

The power supply, if the voltage is unstable, may affect the airflow. Otherwise, factors such as level of contamination, air density, and temperature may also influence the actual volume that is sampled. As a result, the actual airflow must be displayed.

7.2.4 CONTROLS:

7.2.4.1 The controls of the Air Samplers shall be clearly marked and simple to operate.

7.2.4.2 The Air Samplers shall have a switch to turn the unit on and off.

7.2.4.3 The Air Samplers shall have a timer so that the unit can be set to run for a user-selectable length of time (up to 1 hour) and shut off. It is desirable that the timer accommodates longer time periods (up to 24 hours). It is desirable that the time remaining before shut-off be displayed on the unit. It is also desirable that the units have a user-selectable audible alarm that sounds prior to automatic shut-off. An electronically programmable timer is preferable to a mechanical time.

Timed operation is important for accurate determinations of radiological concentrations. The commercially available high-volume systems normally have one-hour timers.

7.2.4.4 It is also desirable that the Air Samplers be equipped to shut off after a user-selectable quantity of air (up to 10000 litres) has passed through the unit.

An even more valuable feature would be set-volume operation. This option is not available on any of the units we have seen.

7.2.5 EXTENDED OPERATION:

7.2.5.1 The Air Samplers shall be capable of at least 24 hours of continuous operation, aside from the time required to change filters. It is desirable for the Air Samplers to be capable of 4 days of continuous operation.

The stated requirement should not be a problem for the commercially available units, although the high-volume units are not normally used in this way.

7.2.6 SHAPE SIZE AND WEIGHT:

7.2.6.1 The Air Samplers shall be as compact as possible.

7.2.6.2 The mass of the Air Samplers shall not exceed 8 kilograms.

7.2.6.3 No dimension of the Air Samplers shall exceed 40 cm.

The stated size and weight are defined by the size of commercially available units.

7.2.7 ANCILLARY EQUIPMENT:

7.2.7.1 Each Air Sampler shall include a tripod capable of being erected on uneven ground and able to withstand winds of up to 50 km/h. The tripod shall keep the air sampler 1.5 m above the ground (the average intake level for a standing soldier).

The Air Sampler is intended to provide information on committed doses from inhalation. As a result, it should be operated at approximately head height.

7.2.7.2 Each Air Sampler shall include any packaging required to make it ready for air or ground transport.

7.2.8 POWER SOURCE:

7.2.8.1 The Air Samplers shall operate with either 120 Volt, 60 Hertz, or 220 Volt, 50 Hertz power.

The Air Sampler will usually be powered from the local power grid. It must therefore accommodate either 120 V or 220 V AC power sources. Commercially available systems *generally use one or the other, so a commercial transformer may be required. In circumstances where local power is not available, the Air Samplers may be run off of a generator; however, it is not envisioned that generators will be purchased for this purpose as part of this project.*

7.2.8.2 It is desirable for the Air Samplers to be capable of operation with 6-32 Volt DC power supplies as well.

Operation with DC power sources may also be required where AC power is not available.

7.3 Environmental Hardening Requirements

These devices will be used under controlled conditions, so while they must be rugged, they do not need to be MIL-SPEC'd.

7.3.1 PRESSURE:

7.3.1.1 The Air Samplers shall operate at all atmospheric pressures existing between sea level and 3048 metres.

7.3.1.2 The Air Samplers shall survive rapid decompression at 12200 metres without presenting a hazard to personnel or damaging the aircraft.

These devices must be capable of operation after transportation in aircraft, and must not prevent a hazard should explosive decompression occur.

7.3.2 TEMPERATURE:

7.3.2.1 The Air Samplers shall be capable of operation within the ambient temperature limits of –35°C to +50°C.

These devices must be capable of operation over a wide range of temperatures.

7.3.3 HUMIDITY AND WATER RESISTANCE:

7.3.3.1 The Air Samplers shall be capable of operation at relative humidities between 0 and 95%.

7.3.3.2 The Air Samplers shall be designed to operate in blowing rain.

The Air Samplers must be capable of operation in humid conditions, including rain. This condition also affects the particulate filter that can be used with this system, since glass-fibre filters are more effective than paper filters in damp conditions.

7.3.4 VIBRATION AND SHOCK:

7.3.4.1 The Air Samplers shall be capable of operation after being transported on ground vehicles as unrestrained cargo.

The Air Samplers must be capable of withstanding the shocks of military transport.

7.3.5 STORAGE CONDITIONS:

7.3.5.1 The Air Samplers shall be capable of operation after having been stored at temperatures between –50°C and +70°C at relative humidities between 0 and 95%.

The Air Samplers must be able to operate following storage under a wide range of conditions.

7.3.5.2 The Air Samplers shall have a shelf life of at least 10 years.

7.3.6 NUCLEAR SURVIVABILITY:

7.3.6.1 It is desirable that the Air Samplers be designed to resist NBC contamination in accordance with NATO AEP-7.

Resistance to NBC contamination is desirable for a device intended for use in a contaminated environment.

7.3.7 ELECTROMAGNETIC CAPABILITY:

7.3.7.1 The Air Samplers shall be shielded from non-ionising radiation or microwaves up to at least 10 mW/cm^2.

7.3.7.2 The Air Samplers shall not radiate electromagnetic radiation that will interfere with other equipment.

This condition is necessary, and not expected to create a problem for this type of device.

8 ALPHA AIR MONITOR

8.1 General Considerations

This project has identified a requirement for an Air Sampling capability, as described in Section 7. This is in accord with the requirement given in NATO D/104. However, this system is deficient in several areas, which can be ameliorated with the Alpha Air Monitor described in this section. A comparison of these systems follows. It concentrates on the ease of use of the system, and the protection afforded by the systems against committed doses from inhalation. Financial considerations will have to be weighed by the project team so that appropriate action can be taken.

As discussed in Section 3, the worst-case airborne hazard is ^{239}Pu, an alpha emitter. The Air Sampling system described in Section 7 has a limited sensitivity to this hazard. Assuming an ASM alpha sensitivity of 0.5 Bq/cm^2, a 4.7 cm diameter filter paper, 30% alpha absorption by the particulate filter, an airflow of 90 L/min, and a measurement time of one hour, this system is sensitive to 2.6 Bq/m^3 of ^{239}Pu. This results in a 50-year committed dose equivalent for unprotected personnel of 0.26 mSv/hr, approximately 90 times the NATO turnback level. Note that the external dose rate in this scenario is 10000 times smaller than the background rate, so that a dose-rate meter is completely unsuited to detecting this hazard.

The Alpha Air Monitor described in this report is capable of detecting 0.4 Bq/m^3 in one hour of counting. It is thus approximately six times more sensitive than the Air Sampler. It is also easier to use than the Air Sampler, leaving less opportunity for user error, and allowing for remote operation. Based on these criteria, the Alpha Air Monitor is highly recommended for this project.

8.2 Performance Requirements

8.2.1 FILTER MEDIA:

8.2.1.1 The Alpha Air Monitor shall accommodate particulate filters.

8.2.2 TYPE OF RADIATION MEASURED AND RANGE:

8.2.2.1 The Alpha Air Monitor shall detect alpha radiation emitted by particulates trapped in the filter.

8.2.2.2 The Alpha Air Monitor shall respond to alpha radiation with energies between 3 MeV and 6 MeV.

8.2.3 SENSITIVITY:

8.2.3.1 The Alpha Air Monitor shall detect the presence of alpha-emitting particulates in air to a level of at least 0.4 Bq/m^3 in one hour. For ^{239}Pu, this corresponds to approximately 4 DRAC-hours.

8.2.3.2 The Alpha Air Monitor shall detect and correct for the presence of radon and thoron backgrounds. This shall be done through alpha spectroscopy.

8.2.4 PRESENTATION:

8.2.4.1 All information presented on the Alpha Air Monitor shall be in English and French. The language used on the display (English or French) shall be user-selectable.

8.2.4.2 Readings shall be displayed digitally.

8.2.4.3 The level of airborne contamination shall be displayed in DRAC or in Bq/m^3.

8.2.4.4 The Alpha Air Monitor shall also be able to display airflow rates and alpha energy spectra.

8.2.4.5 Each Monitor shall have a readily visible serial number. An electronically readable (bar code) serial number is also essential.

8.2.4.6 Each monitor shall also have the provision to display the date of last calibration and the expiry date for this calibration.

8.2.5 ALARMS:

8.2.5.1 The Alpha Air Monitor shall have user-settable alarms for the levels of alpha-emitting contaminants. These alarms shall have an audible and a visual component.

8.2.6 COMMUNICATION:

8.2.6.1 The Alpha Air Monitor shall have the provision to communicate data to a PC-based platform via an RS-232 or RS-485 connection.

8.2.6.2 It is also desirable for the system to allow external operation through the PC. These properties will allow this system to be integrated into a system like CIBADS.

8.2.7 CONTROLS:

8.2.7.1 The controls of the Alpha Air Monitor shall be simple to operate and be clearly marked. To prevent damage to protective gloves or clothing, it is desirable for plastic-covered buttons to be used in place of toggle switches.

8.2.7.2 The monitors shall be practical to use with combat equipment, including any environmental or NBC protective equipment, combat gloves, an NBC protective mask, or dust goggles.

8.2.8 CALIBRATION:

8.2.8.1 Under normal circumstances, the monitors shall be capable of use for at least one year without recalibration.

8.2.9 POWER SUPPLY:

8.2.9.1 The Alpha Air Monitors shall operate with 120 Volt, 60 Hertz, or 220 Volt, 50 Hertz AC power.

8.2.10 SHAPE SIZE AND WEIGHT:

8.2.10.1 The Alpha Air Monitors shall be as compact as possible. Not including the pump, the unit shall not exceed 10 kg, with no dimension larger than 40 cm.

8.3 Environmental Hardening Requirements

8.3.1 PRESSURE:

8.3.1.1 The Alpha Air Monitors shall operate at all atmospheric pressures existing between sea level and 3048 metres.

8.3.1.2 The Alpha Air Monitors shall survive rapid decompression at 12200 metres without presenting a hazard to personnel or damaging the aircraft.

8.3.2 TEMPERATURE:

8.3.2.1 The Alpha Air Monitors shall be capable of operation within the ambient temperature limits of $-35^{o}C$ to $+50^{o}C$.

8.3.2.2 It is understood that the display of the monitor may not function at low temperatures. However, the function of the rest of the unit shall not be affected, and data shall still be downloadable to a PC.

8.3.3 HUMIDITY AND WATER RESISTANCE:

8.3.3.1 The Alpha Air Monitors shall be capable of operation at relative humidities between 0 and 95%.

8.3.3.2 The Alpha Air Monitors shall be designed to operate in blowing rain.

8.3.4 VIBRATION AND SHOCK:

8.3.4.1 The Alpha Air Monitors shall be capable of operation after being transported on ground vehicles as unrestrained cargo.

8.3.5 STORAGE CONDITIONS:

8.3.5.1 The Alpha Air Monitors shall be capable of operation after having been stored at temperatures between –50°C and +70°C at relative humidities between 0 and 95%.

8.3.5.2 The Alpha Air Monitors shall have a shelf life of at least 10 years.

8.3.6 NUCLEAR SURVIVABILITY:

8.3.6.1 It is desirable that the Alpha Air Monitors be designed to resist NBC contamination in accordance with NATO AEP-7.

8.3.7 ELECTROMAGNETIC CAPABILITY:

8.3.7.1 The Alpha Air Monitors shall be shielded from non-ionising radiation or microwaves up to at least 10 mW/cm^2.

8.3.7.2 The Alpha Air Monitors shall not radiate electromagnetic radiation that will interfere with other equipment.

9 BETA AIR MONITOR

9.1 General Considerations

The discussion at the outset of the previous section concentrated on the sampling of alpha-emitting particulates. This is the most important aspect of the airborne hazard, but not all of it. This section describes a Beta Air Monitor, an analogous unit to the Alpha Air Monitor, but designed to deal with beta- and gamma-emitting airborne hazards. The following discussion compares the merits of this system with that of the Air Sampler described in Section 7.

For beta-gamma radiation hazards, the worst-case airborne hazard is ^{90}Sr. Making the same assumptions as before, except for an ASM beta sensitivity of 5 Bq/cm^2 and no beta absorption in the filter, the Air Sampler can detect 18 Bq/m^3 of ^{90}Sr. The sensitivity of this system could be considerably worse, depending on the natural radon backgrounds and how well these can be eliminated. At 18 Bq/m^3, unprotected personnel would receive a 50-year committed dose of 7.6 μSv/hr, 2.5 times the NATO turnback level. Once again, it should be noted that the external dose rate in this case is 2000 times below background levels, so that dose-rate meters cannot help the situation.

The Beta Air Monitor described in this report can detect 1.5 Bq/m^3 in one hour. Commercial systems can achieve this, even in high gamma-ray fields, and irrespective of the radon background. It is thus at least 12 times more sensitive than the Air Sampler, bringing the sensitivity well below the NATO turnback point. It is also easier to use than the Air Sampler, leaving much less chance for systematic errors in use. Based on these criteria, the Beta Air Monitor is recommended for this project. The requirement for the Alpha Air Monitor is much more urgent, however, because of the highly radiotoxic nature of some alpha emitters.

9.2 Performance Requirements

9.2.1 FILTER MEDIA:

9.2.1.1 The Beta Air Monitor shall accommodate particulate filters or charcoal canisters for the capture of radioiodines.

9.2.2 TYPE OF RADIATION MEASURED AND RANGE:

9.2.2.1 The Beta Air Monitor shall detect beta radiation emitted by particulates trapped in the filter media.

9.2.2.2 The Beta Air Monitor shall respond to beta radiation with energies between 200 keV and 3 MeV.

9.2.3 SENSITIVITY:

9.2.3.1 The Beta Air Monitor shall detect the presence of beta-emitting particulates in air to a level of at least 3 Bq/m^3 in one hour. It is understood that sensitivities will depend on the isotope under consideration; for reference, the system sensitivity for $^{90}Sr/^{90}Y$ shall be 1.5 Bq/m^3 in one hour.

9.2.3.2 The Beta Air Monitor shall detect and correct for the presence of alpha emitters in the filter media.

9.2.4 PRESENTATION:

9.2.4.1 All information presented on the Beta Air Monitor shall be in English and French. The language used on the display (English or French) shall be user-selectable.

9.2.4.2 Readings shall be displayed digitally.

9.2.4.3 The level of airborne contamination shall be displayed in DRAC or in Bq/m^3.

9.2.4.4 The Beta Air Monitor shall also be able to display airflow rates.

9.2.4.5 Each Monitor shall have a readily visible serial number. An electronically readable (bar code) serial number is also essential.

9.2.4.6 Each monitor shall also have the provision to display the date of last calibration and the expiry date for this calibration.

9.2.5 ALARMS:

9.2.5.1 The Beta Air Monitor shall have user-settable alarms for the levels of beta-emitting contaminants. These alarms shall have an audible and a visual component.

9.2.6 COMMUNICATION:

9.2.6.1 The Beta Air Monitor shall have the provision to communicate data to a PC-based platform via an RS-232 or RS-485 connection.

9.2.6.2 It is also desirable for the system to allow external operation through the PC. These properties will allow this system to be integrated into a system like CIBADS.

9.2.7 CONTROLS:

9.2.7.1 The controls of the Beta Air Monitor shall be simple to operate and be clearly marked. To prevent damage to protective gloves or clothing, it is desirable for plastic-covered buttons to be used in place of toggle switches.

9.2.7.2 The monitors shall be practical to use with combat equipment, including any environmental or NBC protective equipment, combat gloves, an NBC protective mask, or dust goggles.

9.2.8 CALIBRATION:

9.2.8.1 Under normal circumstances, the monitors shall be capable of use for at least one year without recalibration.

9.2.9 POWER SUPPLY:

9.2.9.1 The Beta Air Monitors shall operate with 120 Volt, 60 Hertz, or 220 Volt, 50 Hertz AC power.

9.2.10 SHAPE SIZE AND WEIGHT:

9.2.10.1 The Beta Air Monitors shall be as compact as possible. Not including the pump, the unit shall not exceed 10 kg, with no dimension larger than 40 cm.

9.3 Environmental Hardening Requirements

9.3.1 PRESSURE:

9.3.1.1 The Beta Air Monitors shall operate at all atmospheric pressures existing between sea level and 3048 metres.

9.3.1.2 The Beta Air Monitors shall survive rapid decompression at 12200 metres without presenting a hazard to personnel or damaging the aircraft.

9.3.2 TEMPERATURE:

9.3.2.1 The Beta Air Monitors shall be capable of operation within the ambient temperature limits of –35°C to +50°C.

9.3.2.2 It is understood that the display of the monitor may not function at low temperatures. However, the function of the rest of the unit shall not be affected, and data shall still be downloadable to a PC.

9.3.3 HUMIDITY AND WATER RESISTANCE:

9.3.3.1 The Beta Air Monitors shall be capable of operation at relative humidities between 0 and 95%.

9.3.3.2 The Beta Air Monitors shall be designed to operate in blowing rain.

9.3.4 VIBRATION AND SHOCK:

9.3.4.1 The Beta Air Monitors shall be capable of operation after being transported on ground vehicles as unrestrained cargo.

9.3.5 STORAGE CONDITIONS:

9.3.5.1 The Beta Air Monitors shall be capable of operation after having been stored at temperatures between $-50^{o}C$ and $+70^{o}C$ at relative humidities between 0 and 95%.

9.3.5.2 The Beta Air Monitors shall have a shelf life of at least 10 years.

9.3.6 NUCLEAR SURVIVABILITY:

9.3.6.1 It is desirable that the Beta Air Monitors be designed to resist NBC contamination in accordance with NATO AEP-7.

9.3.7 ELECTROMAGNETIC CAPABILITY:

9.3.7.1 The Beta Air Monitors shall be shielded from non-ionising radiation or microwaves up to at least 10 mW/cm^2.

9.3.7.2 The Beta Air Monitors shall not radiate electromagnetic radiation that will interfere with other equipment.

10 "NON-IONISING" TRAINING SYSTEMS

10.1 General Considerations

DND has expressed a desire to perform training on the use of its radiation detection equipment without ionising sources. This will allow DND to reduce its inventory of radioactive materials. Several systems are currently available that use the Global Positioning System (GPS), chemical simulants, magnets, and radiofrequency (RF) transmitters to simulate the behaviour of radiation detection equipment in radioactive fields.

Training systems are required for the Reconnaissance Detection Meter, the Advanced Survey Meter, and the Portable Spectrometer. The operation of these systems must be as similar as possible to the operational system. Training Systems for Electronic Dosimeters are not currently available, and would be difficult to implement because of the small size of the dosimeters. Training for their use, and the use of the reader (if applicable), will likely have to be accomplished with check sources.

These systems will be used repeatedly by many personnel. They must, therefore, be rugged, although not necessarily MIL-SPEC'd. In addition, their environmental requirements are not as stringent as the operational systems.

10.2 Performance Requirements

10.2.1 GENERIC:

10.2.1.1 The operation of the Training Systems should be as similar to that of the operational system as is possible. This includes such elements as statistical fluctuations in the count rates and the ability to simulate the processor time in digital mode versus the real-time audio count rate.

10.2.1.2 The presentation of the Training Systems (including alarms) should be identical to that of the operational system. Additional output pertaining to the function of the Training System is permissible, as required.

In order for the Training Systems to be effective, their operation must be as similar to the operational systems as possible.

The only exception to this rule is for "status lights" for the Training Systems. For example, warnings for low batteries in the training probes or loss of GPS fix are imperative for the user, although they do not appear on the operational unit.

10.2.1.3 The Training Systems may require batteries other than those used by the meter itself. Such batteries should be compact and standard commercial off the shelf. They should permit operation of the Training System for 12 hours at 20°C.

Training exercises should not exceed 12 hours, so a 12-hour battery life is permissible.

10.2.1.4 These batteries should be replaceable in the field.

10.2.1.5 The Training System should have an indicator for battery failure.

10.2.1.6 Elements of the Training System shall have a readily visible serial number located on an externally mounted bar code label.

10.2.1.7 Provision shall be made for the soldier to carry any extra equipment associated with the training system, including extra batteries.

Some of the Training Systems may be implemented through the use of a "black box" external to the meter. Provision shall be made for the operator to transport and use this box in the field.

10.2.2 RECONNAISSANCE DETECTION METER TRAINING:

10.2.2.1 The Training System for the Reconnaissance Detection Meter (RDM) shall be implemented by the modification or addition of probes, as appropriate. The RDM shall not be modified.

By not modifying the meter itself, a larger quantity of operational units can be purchased.

10.2.2.2 The Training System for the RDM shall be used outdoors. It shall be capable of being used in wet conditions.

Although indoor training could potentially be useful, this would not be possible for a GPS-based system.

10.2.2.3 Due to radiofrequency (RF) licensing problems, Training Systems using RF signals shall not be considered.

10.2.2.4 The Training System shall simulate fixed contamination of the ground by a gamma-emitter, dispersed over a wide area (exact areas to be determined). It is desirable for the system to make allowances for the decay of radioactive materials, through a time-dependent simulation.

10.2.2.5 It is desirable for the Training System to be able to simulate wide-area airborne contamination as well, although not necessarily in the same scenario. Such a simulation must also provide for the changes in the contamination according to user-defined winds and radioactive decay rates.

Exercises with fixed, ground-based contamination are most relevant to the threats that could be encountered by the CF. Reconnaissance of airborne contamination provides additional challenges but is somewhat more difficult to implement.

10.2.2.6 For simulations involving contaminated ground, the Training System shall provide a resolution of 5 metres. That is, signals should be reproducible to a degree that personnel can locate features in the contaminated field to within 5 metres.

10.2.2.7 For simulations involving airborne contamination, the Training System shall provide a resolution of 50 metres.

The resolutions given are based on what is achievable with commercially available software.

10.2.2.8 The parameters of the scenarios shall be set with software that runs on a PC-based platform with at least a 200 MHz Pentium-II processor, 1 Gb hard drive and 32 Mb RAM. The software shall be based on software used elsewhere in the CF NBC community.

10.2.2.9 The display of the software shall be in English and French, allowing the user to select which one is used.

10.2.2.10 The scenario description software shall allow the instructor to set scenarios quickly. It must be capable of simulating radiation rate contours in contaminated areas with irregular (non-elliptical) shapes, possibly through the use of multiple release points.

The software that creates the training scenario should be relatively easy to operate. A high level of detail is not required for these training exercises, and the software must be relatively easy to use.

10.2.3 ADVANCED SURVEY METER TRAINING:

10.2.3.1 The Training System for the Advanced Survey Meter has two components: a gamma radiation simulation, and an alpha-beta radiation simulation.

10.2.3.2 The requirements for the gamma radiation simulation are exactly the same as those for the Reconnaissance Detection Meter specified in Section 10.2.2.

10.2.3.3 The alpha-beta simulation shall be implemented through modification of the alpha-beta probe. The Advanced Survey Meter shall not be modified.

A realistic simulation of an alpha-beta probe can't be implemented without modification of the alpha-beta probe. Modification of the meter is neither necessary nor desirable.

10.2.3.4 The Training System shall only allow detection of the contaminating agent when it is within a few centimetres of the contaminated surface, as for the detection of alpha contamination with a real alpha-beta probe.

10.2.3.5 The instructor should be able to set up scenarios in which, for example, parts of a vehicle are selectively contaminated. A GPS-based system will likely be insufficient for this task.

10.2.3.6 It is essential that the probe not be able to detect the simulated contamination if not properly positioned over the source, and it is desirable for the Training

System to simulate contamination of the probe when it touches the contaminated surface.

A realistic simulation of a alpha-beta probe must not allow detection of contamination until the probe is close to the surface and should simulate probe contamination.

10.2.4 SPECTROMETER TRAINING:

10.2.4.1 The Spectrometer Training Systems shall be required to provide training for the vehicle-mounted mapping operation.

Training on the basic functions of a Portable Spectrometer can be performed with check sources. Proper training on the mapping operation will require a simulation.

10.2.4.2 The training simulation shall be concerned with the reconnaissance of fixed sources of radiological contamination on the ground, as opposed to airborne contamination.

The Portable Spectrometer is intended for mapping fixed ground sources, so the simulation does not need to address airborne contamination.

10.2.4.3 The Training System shall provide a resolution of 5 metres. That is, signals should be reproducible to a degree that personnel can locate features in the contaminated field to within 5 metres.

10.2.4.4 The parameters of the scenarios shall be set with software that runs on a PC-based platform with at least a 200 MHz Pentium-II processor, 1 Gb hard drive and 32 Mb RAM.

10.2.4.5 The display of the software shall be in English and French, either using both languages simultaneously or by allowing the user to select which one is used.

10.2.4.6 The scenario description software shall allow the instructor to set scenarios quickly and with a minimum of training. It must be capable of simulating contaminated areas with irregular (non-elliptical) shapes, possibly through the use of multiple release points.

As stated above for the Reconnaissance Detection Meter Training System, a high degree of complexity is not required for these simulations. A simple scenario generator is preferred.

10.3 Environmental Hardening Requirements

10.3.1 GENERAL:

10.3.1.1 The Training Systems shall satisfy all of the environmental requirements of the operational systems, except as noted below.

10.3.2 VIBRATION AND SHOCK:

10.3.2.1 The Training Systems for the Reconnaissance Detection Meter need not satisfy the drop test requirement outlined in the Reconnaissance Detection Meter document. Instead, the Training Systems for the Reconnaissance Detection Meter shall be capable of operation after a fall from 3.5 metres, on a flat wooden bench top at least 40 mm thick.

The requirements for the Training System for the RDM have been relaxed from the operational system, since these units will not be used in operations.

10.3.3 TEMPERATURE:

10.3.3.1 The Training Systems for the Reconnaissance Detection Meter and Advanced Survey Meter shall be capable of operation within the ambient temperature limits of $-10^{\circ}C$ to $+45^{\circ}C$.

Training will not be performed in conditions of extreme cold. Thus, the Training Systems for the ASM and RDM do not have the same requirements as the operational systems.

10.3.4 NUCLEAR SURVIVABILITY:

10.3.4.1 The Training Systems need not be hardened against the effects of nuclear weapons, including EMP and TREE.

10.3.4.2 The Training Systems need not be designed to resist NBC contamination.

Resistance to EMP, TREE, and NBC contamination are not requirements of the Training Meters since they will not be used in nuclear conflicts or contaminated environments.

11 CONCLUSIONS

This document describes the technical requirements of a large suite of radiation sensors for use in the CF. Should the CF be supplied with this equipment, and properly trained in its use, it will be prepared to meet many of the radiological challenges of the modern battlefield. Most of these systems can be procured through a Commercial-Off-The-Shelf procurement, as desired by DND. However, some systems, such as the Spectroscopy and Training Systems may have requirements that are so specific to DND that specialised development is unavoidable.

It is worthwhile to note that this document is the first major deliverable required from DREO as part of its provision of technical expertise to G2199. The size and complexity of this document demonstrates the degree of complexity involved in procuring this equipment, and thus the value of having DREO participation in this process. This involvement will only become more important as these requirements are refined and product development is performed.

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DOCUMENT CONTROL DATA

(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

1. ORIGINATOR (the name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g. Establishment sponsoring a contractor's report, or tasking agency, are entered in section 8.) Defence Research Establishment Ottawa Ottawa, Ontario K1A 0Z4	2. SECURITY CLASSIFICATION (overall security classification of the document, including special warning terms if applicable) UNCLASSIFIED

3. TITLE (the complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S,C or U) in parentheses after the title.)

Requirements of Radiation Detection, Identification, and Dosimetry Equipment for the Canadian Forces (U)

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

D. S. Haslip and T. Cousins

5. DATE OF PUBLICATION (month and year of publication of document) April 1999	6a. NO. OF PAGES (total containing information. Include Annexes, Appendices, etc.) 64	6b. NO. OF REFS (total cited in document) 13

7. DESCRIPTIVE NOTES (the category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

DREO Technical Memorandum

8. SPONSORING ACTIVITY (the name of the department project office or laboratory sponsoring the research and development. Include the address.)

Defence Services Procurement Project G2199
Directorate of Soldier Systems Program Management (DSSPM)
National Defence Headquarters, Ottawa, Ontario, K1A 0K2

9a. PROJECT OR GRANT NO. (if appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant) DSP G2199 (FE W28476KR00E)	9b. CONTRACT NO. (if appropriate, the applicable number under which the document was written)
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.) DREO Technical Memorandum # 1999-079	10b. OTHER DOCUMENT NOS. (Any other numbers which may be assigned this document either by the originator or by the sponsor)

11. DOCUMENT AVAILABILITY (any limitations on further dissemination of the document, other than those imposed by security classification)

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

radiation, detection, survey, reconnaissance, thermoluminescent dosimeter, electronic dosimeter, air sampling, air monitoring, spectroscopy, training

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