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## **FIRST trial**

*Lemay park collection plan*

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DRDC Valcartier*

**Defence R&D Canada – Valcartier**

Technical Note

DRDC Valcartier TN 2007-435

December 2007

**Canada**



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# Abstract

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The company Telops has performed studies that indicate their FIRST system is capable of providing long-wave infrared (LWIR) airborne hyperspectral images. Defence R&D Canada – Valcartier (DRDC Valcartier), being interested in evaluating a possible Canadian high performance airborne hyperspectral imager, has started a collaborative effort with Telops with the goal to perform two field trials with the FIRST hyperspectral imaging system in airborne mode in order to determine its current capability as an airborne hyperspectral imager. The plan for the first trial is presented in this technical note. The trial will take place at Valcartier between December 3<sup>rd</sup> and 14<sup>th</sup>, 2007. During this trial, Telops FIRST hyperspectral long-wave infrared imager will be operated on an aircraft in a push-broom configuration to obtain hyperspectral imagery of the DRDC Valcartier Lemay park and a variety of installed targets. The ground experiments and ground truth are organized by DRDC Valcartier. Telops has the responsibility for the airborne instrumentation and the platform.

During this trial, DRDC Valcartier will setup four small experiments: a gas plume detection experiment, a plastic plume experiment, a powdered chemical sensing experiment and an unexploded ordnance detection experiment. The main objective of this trial is to investigate the possibilities of detection and identification by the FIRST hyperspectral imager.

# Résumé

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La compagnie Telops a effectué des études qui indiquent que son système FIRST est capable de fournir des images aériennes hyperspectrales dans l'infrarouge lointain. R & D pour la défense Canada – Valcartier (RDDC Valcartier), étant intéressé à l'évaluation d'un capteur imageur hyperspectral aéroporté canadien, a entrepris un effort de collaboration avec Telops avec le but d'accomplir deux essais sur le terrain avec le système imageur hyperspectral FIRST dans sa configuration aéroportée dans le but de déterminer sa capacité actuelle comme imageur hyperspectral aéroporté. Le plan de l'essai FIRST est présenté dans cette note technique. L'essai aura lieu à Valcartier entre le 3 et le 14 décembre 2007. Durant cet essai, l'imageur hyperspectral dans l'infrarouge thermique de Telops sera opéré dans un avion dans une configuration de capteur en peigne pour obtenir des images hyperspectrales du parc Lemay à RDDC Valcartier et d'une variété de cibles ajoutées. Les expériences au sol et les mesures témoins au sol sont organisées par RDDC Valcartier. Telops a la responsabilité de l'instrumentation aéroportée et de la plateforme.

Durant cet essai, RDDC Valcartier préparera quatre petites expériences : une expérience de détection de panache de gaz, une de plastique simulant un panache de gaz,

une de poudre chimique et une d'artilleries non explosées.

# Executive summary

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## FIRST trial: Lemay park collection plan

C. S. Turcotte, E. Puckrin, J. Lévesque; DRDC Valcartier TN 2007-435; Defence R&D Canada – Valcartier; December 2007.

**Background:** The company Telops has introduced and patented a ground-based Fourier-transform imager, called FIRST, for the hyperspectral (HS) long-wave infrared detection of chemical plumes and chemical powders. Telops has performed studies that indicate the FIRST system is capable of providing airborne HS images. Defence R&D Canada – Valcartier (DRDC Valcartier), being interested in evaluating a possible Canadian high performance airborne HS imager, has started a collaborative effort with Telops with the goal to perform two field trials with the FIRST HS imaging system in airborne mode in order to determine its current capability as an airborne HS imager.

**Experiment description:** The FIRST trial is the first field trial of this partnership. It will take place in the Valcartier region between December 3<sup>rd</sup> and 14<sup>th</sup>, 2007. During this trial, Telops FIRST HS longwave infrared imager will be operated on an aircraft in a push-broom configuration to obtain HS imagery of a variety of targets in Lemay park at DRDC Valcartier. The ground experiments and ground truth are organized by DRDC Valcartier. Telops has the responsibility for the airborne instrumentation and the platform.

During this trial, DRDC Valcartier will install four small experiments: a gas plume detection experiment, a plastic plume experiment, a powdered chemical sensing experiment and an unexploded ordnance detection experiment.

**Objectives:** Through this exercise, DRDC Valcartier will evaluate the possibilities of detection and identification using the FIRST. An evaluation of the FIRST performance will be undertaken to define what changes are necessary to further enhance the capability of the airborne FIRST sensor and to define if it has the potential to be a high performance HS airborne imager.

This field trial experiment is a collaboration between DRDC Valcartier and Telops through the W7701-72284 “FIRST airborne testing” contract.

The work is conducted as part of the DRDC Thrust 5e program.

# Sommaire

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## FIRST trial: Lemay park collection plan

C. S. Turcotte, E. Puckrin, J. Lévesque; DRDC Valcartier TN 2007-435; R & D pour la défense Canada – Valcartier; décembre 2007.

**Introduction :** La compagnie Telops a introduit et fait breveter un imageur au sol appelé FIRST pour la détection hyperspectrale (HS) dans l'infrarouge lointain pour des panaches de produits chimiques et des poudres chimiques. Telops a procédé à des études qui indiquent que son système FIRST est capable de fournir des images HS aériennes. R & D pour la défense Canada – Valcartier, étant intéressé à l'évaluation d'un imageur HS aéroporté canadien, a entrepris un effort de collaboration avec Telops dans le but d'accomplir deux essais sur le terrain avec le système imageur HS FIRST dans sa configuration aéroportée pour déterminer sa capacité actuelle comme imageur HS aéroporté.

**Description de l'expérience :** L'essai FIRST est le premier essai de terrain pour ce partenariat. Il aura lieu dans la région de Valcartier entre le 3 et le 14 décembre 2007. Durant cet essai, l'imageur HS dans l'infrarouge thermique de Telops sera opéré dans un avion dans une configuration de capteur en peigne pour obtenir des images HS d'une variété de cibles disposées dans le parc Lemay à R & D pour la défense Canada – Valcartier. Les expériences et les mesures témoins au sol sont organisées par RDDC Valcartier. Telops a la responsabilité de l'instrumentation aéroportée et de la plateforme.

Durant cet essai, RDDC Valcartier installera quatre petites expériences : une expérience de détection de panache de gaz, une de plastique simulant un panache de gaz, une de poudre chimique et une d'artilleries non explosées.

**Objectifs :** Par cet exercice, RDDC Valcartier évaluera les possibilités de détection et d'identification du FIRST. Une évaluation des performances du FIRST sera entreprise pour définir les changements nécessaires pour l'amélioration des capacités du senseur FIRST aéroporté et déterminer s'il a le potentiel de devenir un imageur HS aéroporté de haute performance.

Cet essai sur le terrain est une collaboration entre RDDC Valcartier et Telops avec le contrat W7701-72284 intitulé "FIRST airborne testing". Ce travail est réalisé dans le cadre du vecteur 5e de RDDC.



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# 1 Introduction

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Telops has introduced and patented a ground-based Fourier-transform imager, called FIRST, for hyperspectral (HS) long-wave infrared (LWIR, 8-12  $\mu\text{m}$ ) detection of chemical plumes and chemical powders. Telops has performed studies that indicate the FIRST system is capable of providing airborne HS images. Defence R&D Canada – Valcartier, being interested in high performance HS imager airborne solutions, has started a collaborative effort with Telops with the goal to perform two field trials with the FIRST HS imaging system in airborne mode in order to determine its current capability as an airborne HS imager.

The FIRST trial is the first field trial of the partnership. The objective of this trial is to investigate the possibilities of chemical detection and identification with the FIRST HS imager. For this purpose, the FIRST LWIR sensor will be installed and operated on an aircraft in a push-broom configuration to obtain HS imagery of targets on the ground. The FIRST trial will take place at various sites including in Defence R&D Canada – Valcartier between December 3<sup>rd</sup> and 14<sup>th</sup>, 2007.

This field trial experiment is a collaboration between Defence R&D Canada – Valcartier and Telops through the W7701-72284 “FIRST airborne testing” contract. Since the beginning of this contract, Telops has started to modify the FIRST for airborne measurement by making vibration tests, designing a new servo loop and adding a vibration-stabilization platform.

This document describes the field experiment that will be realized at the Lemay park (71°28'W/46°53N) inside the Defence R&D Canada – Valcartier grounds. The document is divided in two core chapters: chapter 2 describes the experimental setups and their objectives and chapter 3 presents the required instrumentation for the trial. Chapter 4 concludes the test plan description.

The work is performed under project 15ei. The preparation of the collection plan extended from September to November 2007.

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## 2 Experiments and objectives

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The Lemay park at Defence R&D Canada – Valcartier has been chosen for this trial because it has already been used in similar airborne sensing experiments and is easy to access. Figure 1 shows a Google aerial photo of the Lemay park. The red line shows the planned flight line which starts at latitude  $46^{\circ}53'14''$  and longitude  $71^{\circ}28'45''$  and stops at latitude  $46^{\circ}53'17''$  and longitude  $71^{\circ}29'2''$ . The flight altitude should be between 500 m to 1 km. A pixel size of around  $1\text{ m}^2$  is intended. The main objective of the FIRST trial is to acquire a FIRST hyperspectral dataset and compare its detection performance with well known instruments. The trial is planned to occur between December 3<sup>rd</sup> and December 14<sup>th</sup> 2007. To achieve good temperature contrast and good detection, nominal weather requirements should consist of clear skies. No collections will be made during periods of heavy cloud, precipitation or wind. The decision of the exact day of the trial will be taken with a 24-hour notice to account for the meteorological conditions.



**Figure 1:** *Lemay park and the flight line*

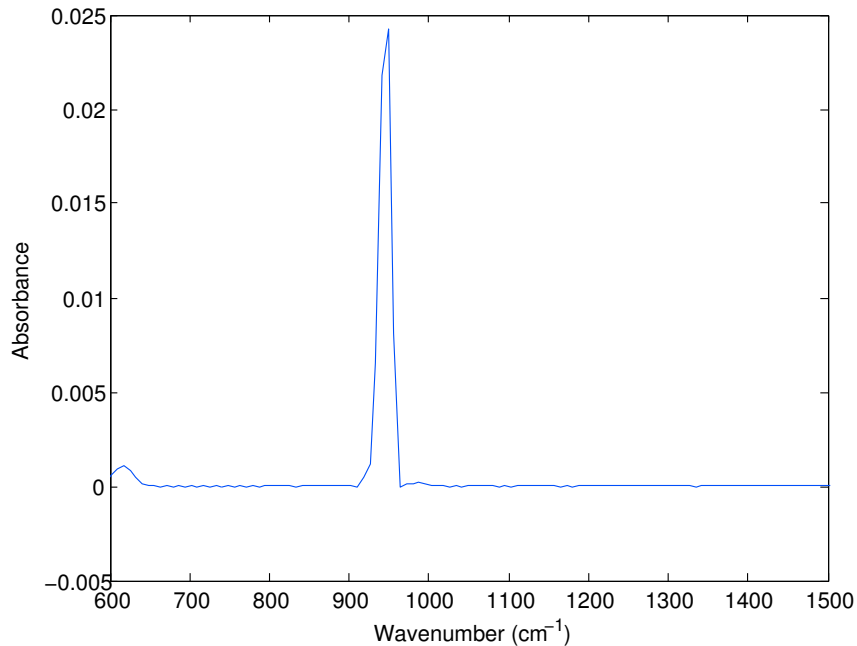
Four experiments are planned: a gas plume detection experiment, a plastic plume experiment, a powdered chemical sensing experiment and an unexploded ordnance detection experiment. The objectives of the different experimental components of the trial are detailed in the following subsections.

## 2.1 Gas plume sensing

SF<sub>6</sub> gas will be ejected from a 1.3 cm diameter pipe raised at approximately 3 meters above the ground. The flow rate will be 100, 50, 25 and, optionally, 10 liters/minute. A minimum of 6 passes are planned and 2 optional passes are possible. Table 1 summarizes the planned flow rate for each flight pass and Figure 2 presents the SF<sub>6</sub> absorbance signature. The objective of this experiment is to evaluate the capability of the FIRST imager for detecting gas plumes in the LWIR region for various flow rates and to compare with the ground based Bomem MR-300 measurements. The data will be exploited to detect and identify the chemical vapor amounts from the LWIR signature and evaluate the minimum detectable quantity.

Pass number	Flow rate (l/min)
1	100
2	50
3	25
4	25
5	50
6	100
7 (Optional)	10
8 (Optional)	10

**Table 1:** *Planned SF<sub>6</sub> Flow rate for each pass number*

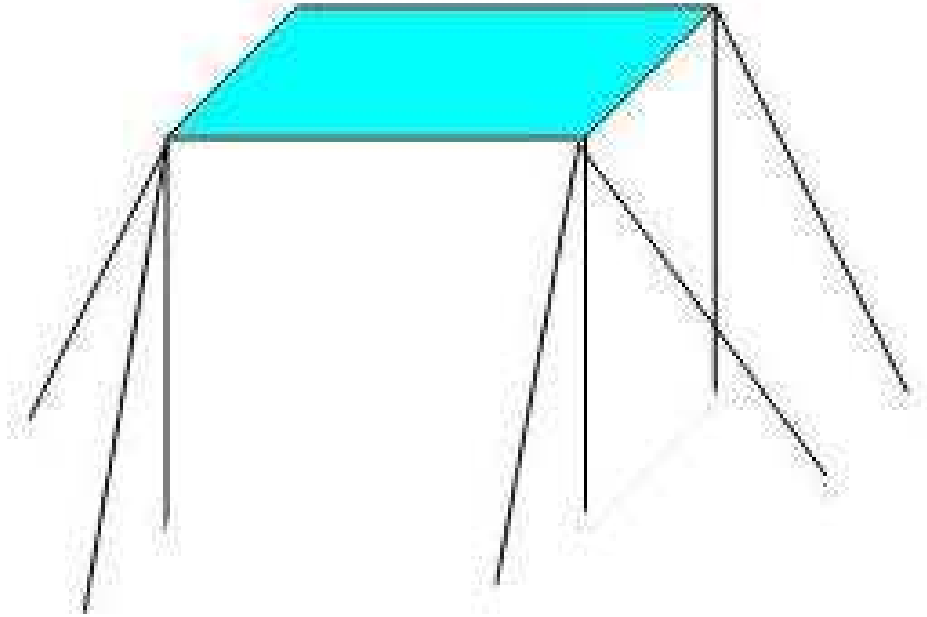


**Figure 2:** *SF<sub>6</sub> signature*



## 2.2 Plastic plume sensing

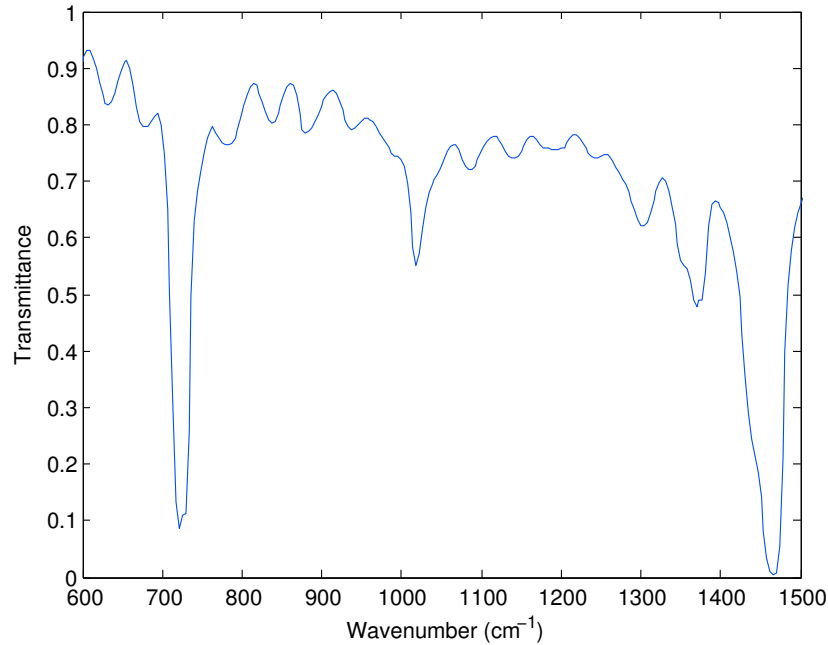
For this experiment, a polypropylene layer will be held at approximately 2.5 m above the ground. The plastic will be attached to a 2.5 by 2.5 m wood frame. This frame will be lifted and held horizontally above ground with wood posts and cords as shown in Figure 3. The purpose of this experiment is to simulate gas detection with a polypropylene layer.



**Figure 3:** *Plastic plume setup*

Figure 4 shows the LWIR signature of the polypropylene. The plastic plume has the advantage of testing the geo-localization of a pixel integrity over that of the fluctuating gas plume. The temperature of the plastic plume will be recorded every 10 minutes with a thermo-couple and a data logger. The LWIR signature of this polypropylene target is similar to some gas signatures and may be used as a gas simulant.

This simulated plume setup will be used for the first time by Defence R&D Canada – Valcartier. The objective of this experiment is to evaluate the capability of the FIRST airborne imager data to detect and identify the polypropylene layer and to compare with the ground based Bomem MR-300 measurements. The data will be exploited to verify the efficiency of such a gas simulant and compare with other gas simulant results.



**Figure 4:** *Polypropylene LWIR signature*

## 2.3 Powdered chemical sensing

For this experiment, a 2.5 by 2.5 m wooden tray placed on the ground will be covered with ammonium sulfate as shown in Figure 5.

The ammonium sulfate shall cover completely the surface and no wood will be exposed inside the frame. The LWIR signature of the ammonium sulfate is presented in Figure 6. It represents a good simulant for several explosives. The position of the wood section will be geo-localized. The objective of this experiment is to evaluate the capability of the FIRST imager to detect and identify the chemical powder (ammonium sulfate) and to compare with the ground based Bomem MR-300 measurements. The data will be exploited to detect and identify the powder product from the LWIR signature and evaluate the minimum detectable quantity.

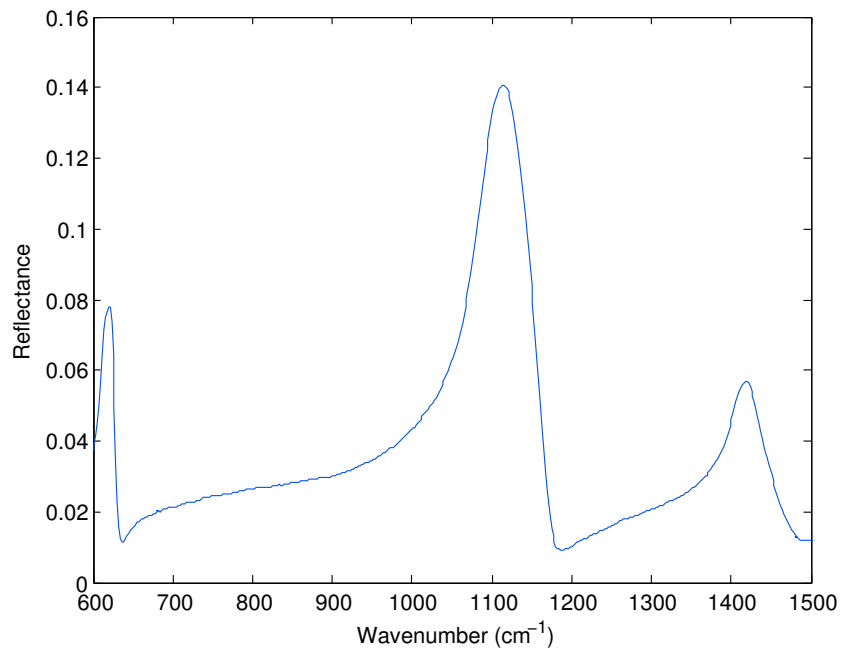
## 2.4 Unexploded ordnance simulants

A set of 60 target inert projectiles (TIP) will be placed on a referenced grid to simulate unexploded ordnance (UXO). This experiment will test:

- 3 orientations of UXO,
- 2 types of background (grass and soil),
- 3 degrees of vegetation cover,



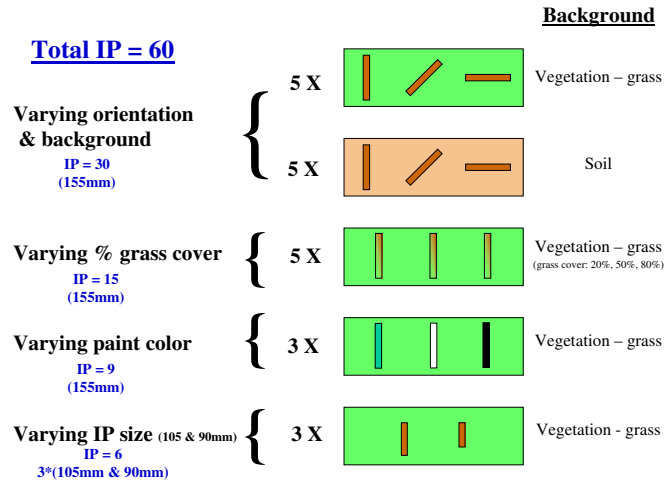
**Figure 5:** *Ammonium sulfate layout*



**Figure 6:** *Ammonium sulfate signature*

- 3 paint colors, and
- 4 projectile sizes.

*Inert projectile (IP) layout*



**Figure 7:** *Target inert projectile (TIP) layout*

Figure 7 presents the TIP layout. The position of each TIP will be geo-localized with the GPS. The objective of this experiment is to evaluate the capability of the FIRST imager to detect inert projectiles (unexploded ordnance simulants).

## 3 Instruments summary

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### 3.1 Airborne sensor

The FIRST hyperspectral imager (Figure 8) will be mounted in an airplane operated by Group Alta in a push-broom configuration using a linear array detector from its 320x256 pixels detector. Table 2 summaries the main instrument specifications.



**Figure 8:** *Photo of the FIRST imager*

### 3.2 Ground instruments

Table 3 provides a list of the ground instruments that will be deployed during the trial.

**Table 2:** *FIRST-LW Specifications for this trial*

Parameter	Unit	Min	Typical	Max	Comments
Spectral Range LWIR	$\mu\text{m}$	8		11	
	$\text{cm}^{-1}$	900		1250	
Spectral Resolution	$\text{cm}^{-1}$		16		
Number of pixels		320			
Single-pixel Field of View	mrad		1.75		
NESR ( $16\text{cm}^{-1}$ , single scan)	$\text{nW}/\text{cm}^2 \text{ sr cm}^{-1}$		65 at $10\mu\text{m}$		For a single-center pixel (other measurement schemes can improve NESR)
Digitization	bits		14		
Power Consumption	W		150		Depends on operating conditions
Weight	kg		29		Includes the calibration module does not include stabilized platform or additional pointing optics

**Table 3:** *Ground instrument list*

Quantity	Name	Description
1	ABB/Bomem MR254	FTIR spectroradiometer (MWIR-LWWIR) mounted on a platform for down-looking measurements
1	MPG	Mobile plume generator, for chemical detection experiment
1	Meteorological station	Automatic meteorological station with data logging capacity (air temperature, wind speed and direction)
1	Thermocouple with data logger	Record the plastic plume temperature
1	Truck with elevation platform	To lift the MR300 above the targets for down-looking measurements
2	Digital camera	
1	Video-camera	
1	GPS	

## 4 Conclusion

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This document presents the collection plan of the FIRST trial. During this trial, Telops' FIRST hyperspectral longwave infrared imager will be flown over the Lemay Park at DRDC - Valcartier. This trial was initiated with a Defence R&D Canada – Valcartier/Telops collaboration under the W7701-72284 “FIRST airborne testing” contract.

This trial consists of the installation of four small experiments: a gas plume detection experiment, a plastic plume experiment, a powdered chemical sensing experiment and finally an unexploded ordnance detection experiment. The objective of this trial is to investigate the possibilities of detection with the FIRST hyperspectral imager. Each experiment was designed to study the performance of the FIRST hyperspectral imager with a different type of target. The results will help to determine the necessary modifications to improve the sensor performances for future tests.

The ground truth for the FIRST trial will be compiled during the trial to characterize the exact target.



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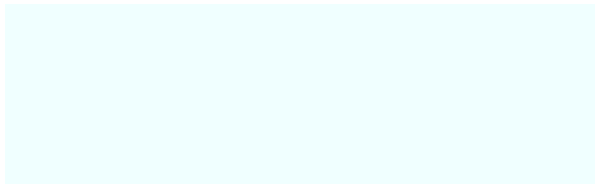
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During this trial, DRDC Valcartier will setup four small experiments: a gas plume detection experiment, a plastic plume experiment, a powdered chemical sensing experiment and an unexploded ordnance detection experiment. The main objective of this trial is to investigate the possibilities of detection and identification by the FIRST hyperspectral imager.

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Plastic plume  
Chemical powder  
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UXO





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