FOREWORD

This special journal issue contains select papers from the *2006 International Symposium on Spectral Sensing Research (2006 ISSSR)* that fall into the subject matter areas of Multispectral/Hyperspectral Techniques for Surface & Air Monitoring in Chemical, Biological and Radiological (CB&R) Defense Applications. The specific focus of the *2006 ISSSR* was on the creation of new technology-program oriented networks that will serve as a research and development foundation for the advancement of the state-of-the-art in spectroscopic-based early-warning sensor capabilities. In recent years, spectral sensing has experienced rapid technical advancement that has led to practical field sensors. Therefore spectral-based techniques exhibit the clear potential for providing more effective, economical and supportable (i.e., reagentless) solutions to military and homeland defense early-warning monitoring requirements for water, surface and air related sensing applications.

An increased emphasis on *reagentless* spectroscopy is motivated primarily by performance issues associated with traditional chemical and biological (CB) point and standoff techniques. In particular, sensors have been previously developed and fielded that rely heavily on reagents and/or burdensome support structures that are expensive and difficult to maintain and that have serious false alarm issues. Previously implemented technologies include biological assays, mass spectrometry and ion mobility. Other explored methodologies include novel materials (mips, smart ligands, amino acid sequences, aptamers, sol gel, aerogel, electro-conducting polymers, etc.) or bulk property interactions (electrochemistry, surface acoustic wave, surface plasmon resonance, thermal capacity) and combinations of the two.

At this time, extensive expertise exists in the multispectral/hyperspectral community for applications such as airborne and space-based sensing and imaging which has proved effective in monitoring weather, resource management (agriculture, forestry), oil/mineral deposits and CB detection in air releases. Hence, spectral-based techniques clearly have potential for providing near to mid-term solutions for many of the monitoring problems associated with CB&R contaminations of water, surfaces and air. However, the ultimate realization of such spectroscopic techniques will probably require the fusion of many types of spectral-sensing techniques and modality. Therefore, standoff and point interrogation sensors are now sought that can provide for extremely high confidence in CB&R detection and monitoring scenarios and the goal of the *2006 ISSSR* and this companion special issue is to organize and focus the science and technology base towards these important challenges.

This special issue begins with a collection of research and development papers on the subject of spectroscopic and lidar techniques for "Surface Sensing and Monitoring" that have relevance to a general array of CB&R defense and security applications. The first section of papers focuses on novel scientific techniques and phenomenology applications that offer the potential for enhancing the effectiveness of existing hyperspectral/multispectral surface sensing methodologies. Examples of these research and development efforts include: Creation of reference data for vapors and liquids infrared spectral signatures suitable for quantitative analyses in environment monitoring; Novel approach for passive standoff detection of surface contaminants by differential polarization FTIR spectrometry, which mitigates sky radiance drifts and favours unambiguous contaminant detections; Advances in principal components analysis for the detection and classification of organic and organophosphorus analytes on soil from reflection-absorption spectroscopy; Novel developments in the detection of invisible bacilli spores on surfaces using a portable surface-enhanced raman spectroscopy (SERS) analyzer, which provides identification of chemicals based on their unique spectrum; Novel concept and simulation of a multiple-field-of-view (mfov) lidar for the standoff determination of bioaerosol size based on double scattering measurements; Advances in infrared spectrometry and analysis for the detection and differentiation of spore and vegetative forms of *bacillus spp*; New application of passive standoff radiometry for the measurement of explosives with a field result at a standoff distances of 60 m; Investigation of signature and signal generation for explosive detection using thz time-domain spectroscopy which addresses the selectivity of thz spectra to distinguish the clutter from background spectra; Recent advances and results in differential passive Long Wave Infrared (LWIR) radiometry for the detection, identification and quantification of toxic chemical vapor clouds in an open-air environment; Comparative analyses of spectral background statistics in direct and differential Fourier Transform (LWIR) measurements, which serve to optimize spectral detection methods of atmospheric contaminants;

The second portion of the "Surface Sensing and Monitoring" section focuses on advanced sensing technology and algorithms developments that will impact spectroscopic-based sensing in the future. Some examples of these research and development efforts include: Overview of novel techniques under investigation by NVESD on active imaging of hard targets; Presentation of a high-resolution 2D imaging laser radar for occluded hard target viewing and identification with verification of system performance during a variety of operating conditions; Emerging technology of 3D flash Ladar focal planes and time dependent imaging that shows evidences and applications of this technology; Presentation of the design for the advanced responsive tactically-effective military imaging spectrometer (ARTEMIS); Assessment of the effects of image segmentation on subspace-based and covariance-based detection of anomalous sub-pixel materials in hyperspectral visible/near-IR/SWIR imagery; Advanced design of a spectral processing method for laser-induced fluorescence from threatening biological aerosols with simulations showing a good signal-to-background discrimination level;

Development of a processing method for improving pixel purity index for endmember extraction in hyperspectral imagery; Novel methodology of signal processing for multicomponent Raman spectra of particulates for improving identification of chemical fingerprints; Development of support vector classification method for land cover and benthic habitat from hyperspectral images; and, Construction of a compact high peak power eye-safe optical parametric oscillator obtained by pumping with a master oscillator power amplifier.

The second section of this special issue contains a collection of research and development papers on the subject of spectroscopic techniques for "Air Sensing and Monitoring". The goal of this portion of the special issue is to investigate technologies for early warning, detection, and identification of chemical and biological contaminants in the atmosphere. This part examines optically-based sensors that are capable of detecting and identifying contaminants in the air. This area is divided into two categories: (1) point technologies where the sensor is in physical contact with the threat, and (2) standoff technologies where a sensor is physically separated from the threat by some distance. Active standoff techniques require the propagation of a probe beam such as in LIDAR systems. Passive standoff techniques rely on ambient electromagnetic radiation for detection and do not utilize probe beams.

New and novel spectroscopic techniques for detection, identification, and quantification of contaminants are examined. All regions of the electromagnetic spectrum, from radio waves to x-rays, are considered to be of interest. New spectral methods for the discrimination of contaminants from atmospheric interferents are of interest. Methods that increase detection sensitivity while reducing false alarms are also examined. Fluorescence, Raman, infrared, and terahertz spectroscopy are possible detection techniques locating and quantifying airborne chemical and biological contaminants.

Wide area detection and surveillance involves the simultaneous monitoring of the atmosphere over large surface areas for a possible contaminant. Spectral imaging techniques provide continuous, real-time monitoring of large areas for pollutions or other contaminants. Hyperspectral and ultraspectral imaging systems allow passive spatial/spectral monitoring of large areas which contain a possible pollution source. Hyperspectral and ultraspectral imaging systems also allow point source detection of hazards and determination of the flux of pollutants at important temporal and spatial scales Airborne and ground-based sensors are possible platforms for deployment of sensor.

Remote sensing of atmospheric pollutants usually involves scenarios with low signal-to-noise. New and novel signal processing techniques are required in order to extract the pollutant's spectroscopic signatures. Radiometric models are very important in designing new sensors. Good models allow one to computationally prototype and test a sensor before actually building it.

New excitation sources for optical detection are examined. New laser sources for CB detection are relevant. Also better sources in other regions of the electromagnetic

spectrum, such as far infrared and millimeter wave regions, are also being sought. Recent developments in IR source technologies have expanded the possibilities for creating chemical and biological sensors which are compact, highly selective, and extremely sensitive. These IR source technologies are e.g. Quantum Cascade Lasers, Optical Parametric Oscillators, Difference Frequency Generation.

Finally, the organizing committee *2006 ISSSR* and the Editors of this special issue would like to recognize the following Best Paper Presentations that lead off this collection of technical papers:

Infrared Spectral Signatures: Creation of Reference Data for Vapors and Liquids
By Steven Sharpe, *Pacific Northwest National Laboratory*

Passive Standoff Detection of Surface Contaminants: A Novel Approach by Differential Polarization FTIR Spectrometry
By Jean-Marc Theriault, *DRDC-Valcartier, Canada*

Background Contributions in Direct and Differential Fourier Transform LWIR Measurements: A Comparative Analysis
By Francois Bouffard, *DRDC-Valcartier, Canada*

Signal Processing of Multi-Component Raman Spectra of Particulate Matter
By Javier Foshesatto, *University of Alaska, Fairbanks*

Computed Tomographic Imaging Spectrometer (CTIS) and a Snapshot Hyperspectral Imager and Polarimeter
By John Hartke, *United States Military Academy*

Wide Area Spectrometric Bioaerosol Monitoring in Canada: from SINBAHD to Biosense
By Jean-Robert Simard, *DRDC –Valcartier, Canada*

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