Rochester Institute of Technology

Digital Imaging and Remote Sensing Laboratory

Annual Report for the 2004 Academic Year
(July 1, 2003 – June 30, 2004)

of the
Frederick & Anna B. Wiedman Professor
on the
Activities of the Digital Imaging and Remote Sensing Laboratory

Prepared by Dr. John R. Schott

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1.0 Foreword

This year's annual report reflects a very healthy year for the DIRS group exemplified most strongly in the increased publication levels listed in Section 5. This is an area we had identified as needing more attention with many of the staff so busy with getting the work done we had neglected somewhat our responsibility to the broader scientific community to share our many technical contributions. The initial results of our renewed effort in this area are very encouraging and we expect to continue this trend. Also reflected in this year's report is the very large number of students at all levels linked to the DIRS activities. This year we once again involved students from high school interns to doctoral candidates with roughly equal numbers of undergraduates, Master's level and Doctoral level students. Education of students is the "cine qua non" of our research activities and I am very happy to report that these pages reflect a heavy involvement of students in all our activities. We are particularly pleased that we were all able to support a record year for students attending, presenting and publishing papers at scientific conferences.

The technical section presents brief summaries of the wide range of research taking place in the Lab. I'm happy to report that our Laboratory for Advanced Spectral Sensing (LASS) grew this year with the addition of the Los Alamos National Laboratory (LANL) as a LASS partner. Membership in LASS represents a major multiyear commitment by the sponsors to the students and research programs in the DIRS Laboratory. We welcome LANL to a program that already includes Eastman Kodak, NRO, Boeing, ITT and Lockheed Martin. We also want to acknowledge the support of our many mission oriented contract/grant sponsors listed in the descriptions of the technical programs. The ongoing support of these organizations has enabled DIRS to have another successful year producing research results and highly trained research specialists to support the needs of the remote sensing scientific community.

The Frederick and Anna B. Wiedman Professorship was endowed by Frederick Wiedman to honor his parents and encourage the role of faculty as scholars and mentors. I am honored to hold the Frederick and Anna B. Wiedman endowed professorship. The support for the chair provides enabled me personally to spend a great deal of effort this year initiating a major expansion of Remote Sensing: The Image Chain Approach (a.k.a. the book). In addition the Wiedman endowment supports a wide range of activities within the DIRS group by providing support to the many non contract funded activities that would often fall through the cracks in a soft money research group. This includes support for students to bridge between funded programs, internal research and development support to pay the foundation for future programs and administrative support particularly in the area of coordinating student activities. I am very grateful for the support of the Wiedman professorship in enhancing my ability to work with students.

As always the results reported here are the product of the dedicated effort of the faculty, staff and students who make up the Digital Imaging and remote Sensing (DIRS) Laboratory. I hope you find the brief accounts of our work intriguing and that you are motivated to contact us for more details.

John R. Schott

2.0 The DIRS Group

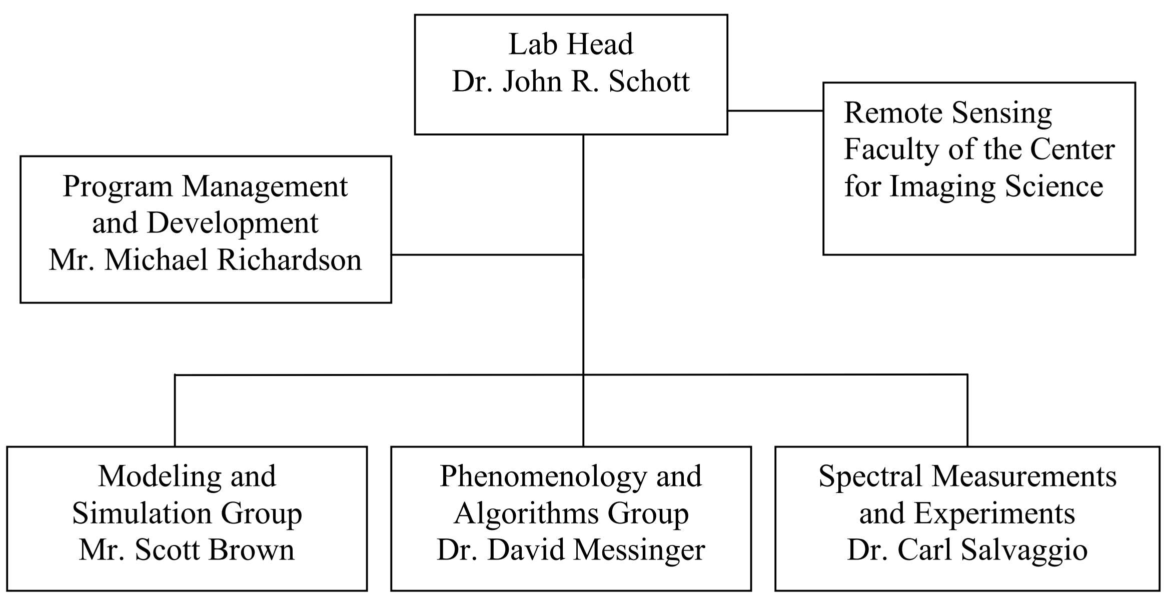
2.1 DIRS Background

The Digital Imaging and Remote Sensing (DIRS) Laboratory is a research group within the Chester F. Carlson Center for Imaging Science. Our work focuses on the development of hardware and software tools to facilitate the extraction of information from remotely sensed data of the earth and the education of students who will continue this work for government agencies and private industry.

The DIRS group is made up of faculty and research staff working with over 30 students ranging from the Baccalaureate through Doctoral level. Most students are degree candidates in Imaging Science, but students from other departments, such as Engineering and Physics are often part of the student population supporting our research initiatives. This year also saw the inclusion of several high school interns who were provided the opportunity to participate in research projects and learn more about imaging science.

2.2 DIRS Lab Organization

The DIRS Lab is managed using a matrix approach where faculty and senior research staff manage programs to generate research results, student thesis and meet sponsor requirements. The needs of the research programs are supported by the research staff who, are organized into three overlapping groups managed by group leaders.



2.3 DIRS Personnel

The DIRS group has built an impressive technical team that is driving the educational experience of our students and the research agenda for our research sponsors.

The Faculty Team

Dr. John R. Schott
Professor and DIRS Laboratory Head
Research Interests
-Hyperspectral data analysis and algorithm development
-Multi and hyperspectral instrument development and calibration
-Synthetic scene generation
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Dr. Anthony Vodacek
Associate Professor
Research Interests:
- Environmental applications of remote sensing
- Forest fire detection and monitoring
- Active and passive sensing of water quality

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Dr. Carl Salvaggio
Associate Professor
Research Interests:
- Novel techniques and devices for optical properties measurements
- Applied image processing algorithm development
- Image simulation and modeling

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Dr. John Kerekes – hired August 7, 2004
Associate Professor
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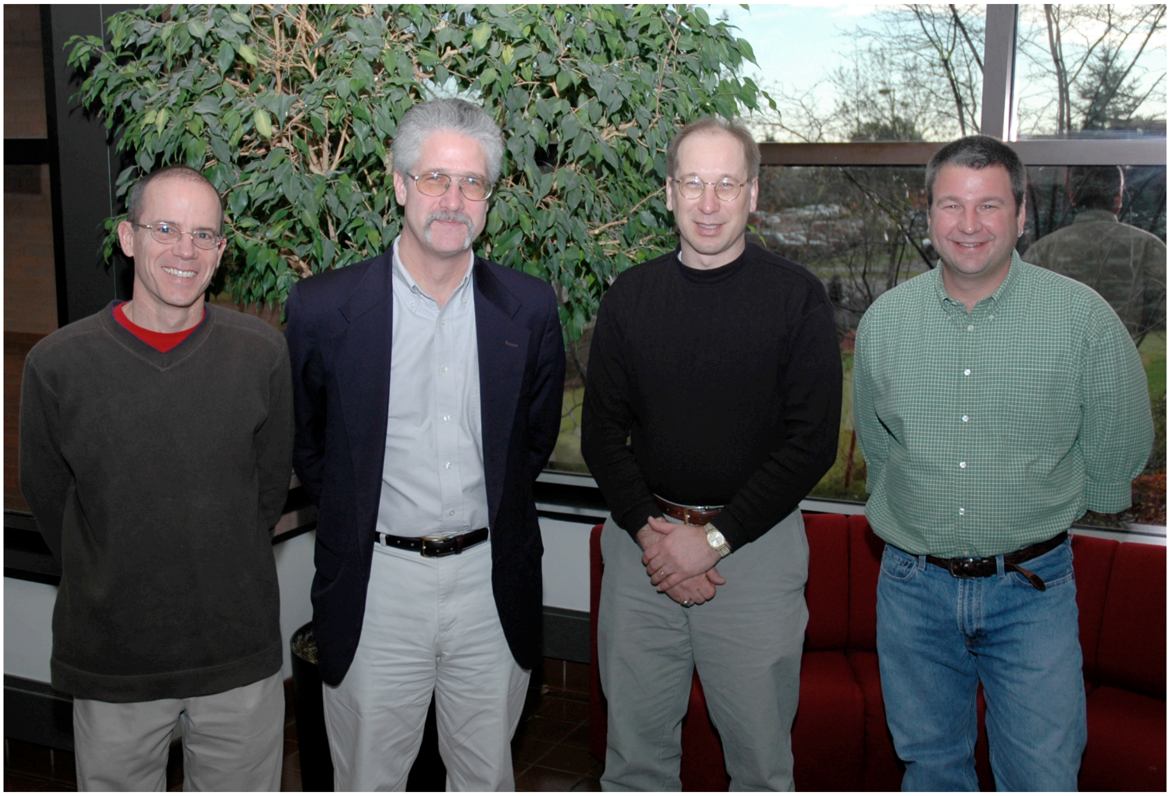

A. Vodacek, J. Schott, J. Kerekes, C. Salvaggio

The Research Team

Scott Brown Scientist	Group Lead, Modeling and Simulation	(585) 475-7194 brown@cis.rit.edu
Gary DiFrancesco Scientist	Spectral Measurements and Experiments	(585) 475-7094 difrancesco@cis.rit.edu
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Timothy Hattenberger Junior Scientist	Modeling and Simulation Applications	(585) 475-4567 hattenberger@cis.rit.edu
Emmett Ientilucci Associate Scientist	Advanced Algorithm Development	(585) 475-7778 ientilucci@cis.rit.edu
Dr. Robert Kremens Senior Scientist	System Development and Analysis	(585) 475-7286 kremens@cis.rit.edu
Paul Lee Assistant Software Dev.	Software Tool Development	(585) 475-4388 lee@cis.rit.edu

Dr. David Messinger Scientist	Group Lead, Algorithms and Phenomenology	(585) 475-4538 messinger@cis.rit.edu
Dr. Ambrose Ononye Post Doctoral Scientist	Wildland Fire Research and Data Processing	(585) 475-5037 ononye@cis.rit.edu
Nina Raqueño Assistant Scientist	GIS, Data Processing, and Database Devel.	(585) 475-7676 nina@cis.rit.edu
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Cindy Schultz Staff Assistant	Staff Support	(585) 475-5508 schultz@cis.rit.edu
Lon Smith Scientist	Spectral Measurements and Experiments	(585) 475-2521 smith@cis.rit.edu

P. Lee, R. Kremens, T. Hattenberger, E. Ientilucci, A. Ononye, N. Sanders, D. Messinger, N. Raqueño, M. Richardson, C. Schultz, D. Pogorzala, R. Raqueño, T. Gallagher

DIRS Students

May Arsenovic Nancy Baccheschi Kris Barcomb Amy Barriale Brent Bartlett Dan Blevins Noah Block Marvin Boonmee George Brown Joshua Caiazza Bethany Choate Adam Cisz Jessica D'Amico Brian Daniel Jeff Dank Jessica D'Amico Brian Dobbs Gabriel Dore Lomax Escarmant Jason Faulring Andrew Gallagher	Rachael Gold Adam Goodenough David Grimm Jason Hamel Gary Hoffmann Rob Introne Marek Jakubowski Scott Klempner Lydia Knurek Brian Leahy Yan Li Ying Li Domenic Luisi Jill Marcin Brian McMullen Matt Meyer Steve Mellen Amanda Merritt Danielle Merritt Ben Miller Mike Muldowney	Erin O'Donnell Erin Peterson Dave Pogorzala Becky Ruby Neil Scanlan Cindy Scigaj Jesse Schott Jim Shell Alvin Spivey Brian Staab Tom Schwarting Ken Smith Mahek Sujan Karl Walli Zhen Wang Matt Weinstock Jason West Seth Weith-Glushko Yonghui Zhao Yushan Zhu

3.0 Research Project Summaries

2004 was another active year for funded research activities. A wide range of government and commercial entities provided research support in a variety of areas related to the fundamental science and phenomenology of remote sensing. Spectral remote sensing continues to be an important and growing area of research with significant emphasis on the development of algorithms that can operate on data from the visible through thermal infrared. The following is a summary of the significant funded projects within the DIRS group.

3.1 ONR MURI

Sponsor(s): Office of Naval Research. RIT leads a team including Cornell University and the University of California at Irvine

Research Team: David Messinger, John Schott, Mike Richardson

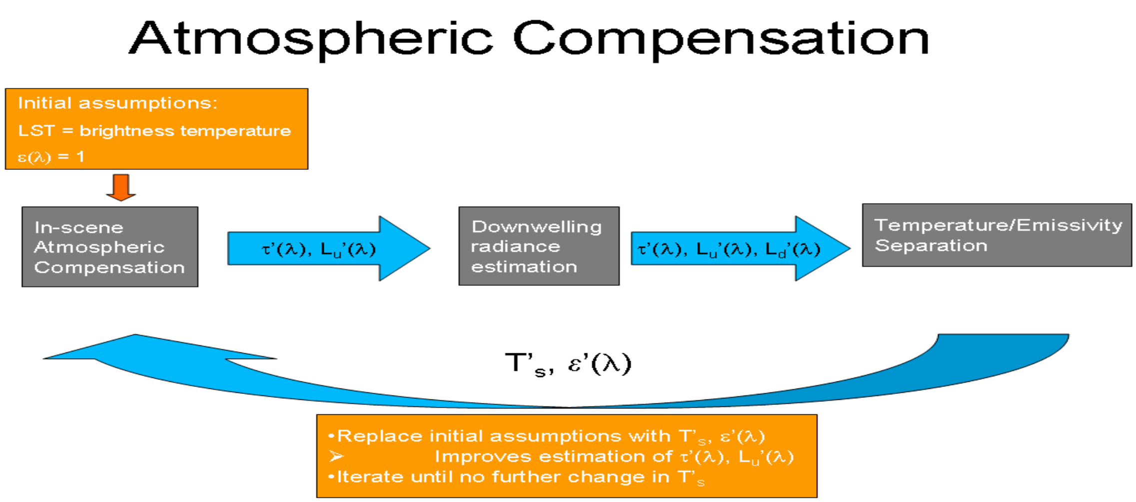
Project Scope: Development of exploitation algorithms for hyperspectral imagery based on physics based models. This effort involves the development of algorithms aimed at target detection, atmospheric correction, gaseous effluent detection and mapping of the littoral zone. All the approaches have in common an effort to incorporate physics based knowledge of the scene, the radiative transfer process and/or the sensor into the algorithmic processing chain. Conceptually the project makes the assumption that any given target may be manifest in sensor reaching spectral radiance space as a very wide range of spectral radiance vectors. By applying knowledge of the target, atmosphere, illumination, sensor and radiative transfer process we believe the spectral radiance space the target can be expected to occupy can be significantly reduced and its location constrained thus improving our ability to detect and quantify targets and reducing the likelihood of false alarms. The details of specific algorithmic approaches are discussed below.

Project Status: Completed years 1 – 3; 2 year follow-on contract awarded January 2004

3.1.1 Atmospheric Parameter Retrieval

Research Team: Marvin Boonmee (Ph.D. student)

Task Scope: This task seeks to develop algorithms to retrieve atmospheric parameters from Long Wave (Thermal) Infrared Imagery. These parameters are then used to compensate the imagery for the effects of the atmosphere as well as aid in the separation of temperature and emissivity effects. We are also performing an analysis of the effects of multiple existing atmospheric compensation routines on the signatures of gaseous plumes in LWIR imagery.



Task Status: A hybrid algorithm is under development merging aspects of in-scene methods (such as ISAC) and model-based methods as part of Marvin Boonmee's Ph.D. thesis. The atmospheric compensation method comparison study is being conducted by an undergraduate student, Ben Miller. His preliminary results will be presented at the 2004 Summer

Undergraduate Research Symposium at RIT. The project is expected to be completed in the fall of 2004.

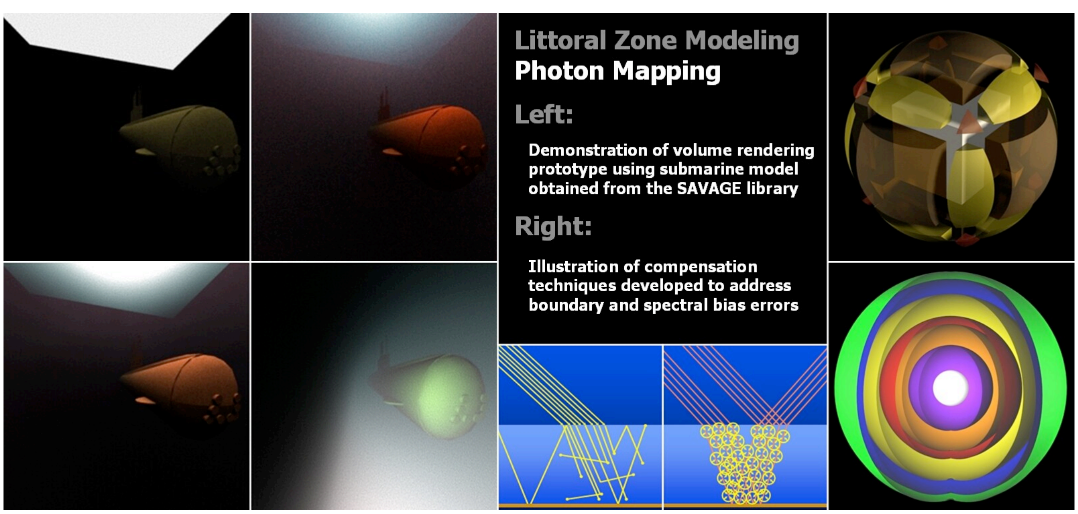
3.1.2 Littoral Zone Modeling – Photon Mapping

Research Team: Adam Goodenough (Ph.D. student), Rolando Raqueño

Task Scope: This task involves the development of accurate models of the in-water and water-leaving radiance fields. These physics-based models will be used to develop and train algorithms for the exploitation of real, littoral zone hyperspectral imagery.

Task Status: Methods have been developed utilizing the existing in-water radiation transfer model Hydrolight. These results demonstrated the need for a more accurate model, currently being developed. This model incorporates a technique called Photon Mapping to simulate the in-water scattering and absorption of incident light. This capability will be inherently tied to the existing radiative transfer simulation, DIRSIG. Initial simulations have been successfully conducted showing the correct spectral nature of the in-water effects. Larger simulations are currently being developed and tested.

To this end, a large experiment campaign during the summer of 2003 was conducted on Conesus Lake incorporating overhead sensors, controlled in-water targets, and simultaneous surface measurements. Collaboration with other institutions such as Cornell University and SUNY Geneseo provided other sources of surface measurements. These experiments will ultimately be used as a test of the Photon Mapping water-leaving radiance simulation.



3.1.3 Littoral Zone Mapping

Research Team: Jason Hamel (MS student), Rolando Raqueño

Task Scope: This task aims at developing accurate methods for extraction of in-water and benthic quantities of interest for the littoral zone.

Task Status: This task continues to rely heavily on the dataset collected during the LEO-15 experiment conducted by the ONR. Efforts continue to collect, collate, and analyze ground-truth data from the experiment to validate our algorithm development efforts. Our current exploitation algorithm involves a pre-computed Look Up Table (LUT) containing potential manifestations of the at-sensor radiance due to variable in-water conditions. Current work is aimed at extending this method to include variability due to atmospheric parameters in the LUT. This would allow simultaneous retrieval of both the in-water and atmospheric constituents.

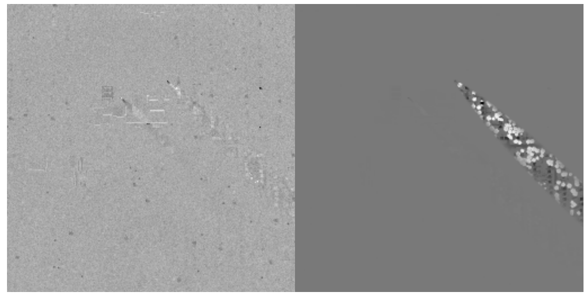
A parallel effort is being conducted to investigate the sensitivity of the at-sensor radiance on the physical and optical properties of the Total Suspended Sediment component of the in-water materials. Currently, it is unknown how accurate knowledge of the sediment material type, size, shape, etc., must be for sufficient retrieval. A Masters Thesis is in preparation addressing these issues through simulation. A test matrix containing a number of measurable parameters and their appropriate values has been created. The radiance from each test run will be simulated and the correlation in spectral variability to the input parameters will be derived.

3.1.4 Gaseous Effluent Detection

Research Team: David Messinger, David Pogorzala (MS student) Erin O'Donnell (MS student)

Task Scope: Under this task, algorithms are currently under development to detect, identify, and quantify gaseous effluents in overhead, LWIR hyperspectral imagery.

Task Status: An investigation comparing several existing methods of gas detection has been conducted addressing both "strong" (spatially large releases) and "weak" (spatially small releases) plumes using synthetic data. This work has shown that the presence of the gas in the scene has a large effect on scene-based statistical methods and must be accounted for in the calculation of the scene statistics.



Detection of Freon plume in synthetic imagery using a Clutter Matched Filter with a global covariance estimate (left) and using a local plume-free covariance estimate (right).

Two methods to identify the gas species with little or no *a priori* information have been developed. The first employs the Invariant Target Detection Method to consider multiple gas species of varying concentration and temperature in the target set. This method has been shown to accurately detect and identify both atmospheric native and non-native gases in synthetic imagery. The second method uses a stepwise regression analysis to find the best-fit model for a given pixel given a set of gas absorption spectra. The models account for both gas absorption and emission. This work has shown that spectral overlap between the features of the target gases significantly influences the identification problem when unconstrained regression is used. Various constraining methods are being considered to address this problem.

3.1.5 Material Identification

<u>Research Team</u>: Emmett Ientilucci

<u>Task Scope</u>: The detection and identification of materials and targets of interest in overhead hyperspectral imagery continues to be an area of great interest. Under this task, methods are being developed to study various representations (statistical, geometrical, etc.) of both target and background spaces to better exploit imagery. Existing methods are being examined as to their applicability to imagery acquired under various scenarios and different targets of interest. Additionally, the "algorithmic chain" required to ultimately perform target detection is being characterized.

Task Status: Various representations of target and background spaces have been used in the target detection process. Our work here seeks to better understand the advantages and disadvantages of each to improve our ability to detect and identify targets of interest. This involves not only large scale differences, such as geometric versus statistical representations, but also smaller variations such as the number of basis vectors required to accurately describe a particular scene. These investigations have shown that the methods used, and the particulars of how they are employed are scene-dependent. This work has led to the development of new target detection methods utilizing the statistics of target spaces based on physics-based models.

New work has been initiated to characterize several aspects of the algorithmic chain. Existing processing algorithms are being compared as to their ultimate affect on target detection algorithms. This work considers several data-collection scenarios and targets of interest. Both real and synthetic datasets will be used to make both qualitative and quantitative assessments of various processing algorithms.

3.2 ARO MURI

Sponsor(s): Army Research Office. RIT is on a team led by Georgia Tech.

Research Team: David Messinger, John Schott

Project Scope: RIT is providing synthetic data to be used by other team members in the development and testing of Automatic Target Recognition (ATR) Algorithms.

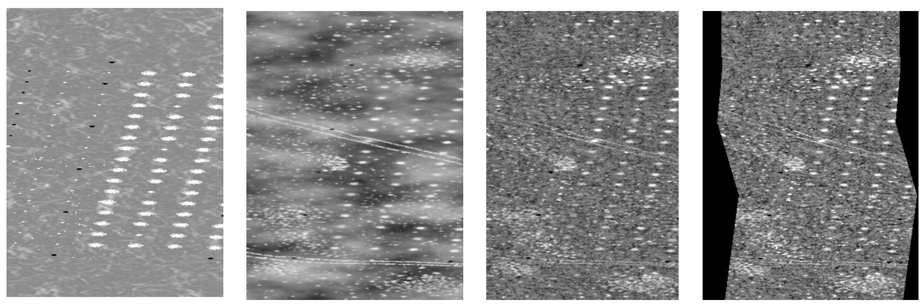
Project Status: This program is two and one half years through a three year grant which will be considered for a two year follow-on contract at the start of 2005.

3.2.1 Minefield DIRSIG Simulation

Research Team: Erin Peterson (MS student), Tim Hattenberger, Scott Brown, Lon Smith

Task Scope: RIT has created and delivered a synthetic scene representative of a surface and buried landmine field to be viewed in the Long Wave Infrared (LWIR). The scene is based on an actual test site and has been validated against an overhead LWIR hyperspectral dataset of the area. These data are to be used in algorithm development and testing studies and serves as a reliable method for creation of several representative datasets under a variety of viewing and target placement conditions.

Task Status: An initial version of the scene was completed as part of Erin Peterson's Masters Thesis and has been delivered to the team partners. It will continue to evolve as new phenomenology and simulation methods become available. Variations in the scene geometry, viewing conditions, and target layouts will be generated providing the team members with an extensive dataset under which they can develop and test automatic target recognition algorithms.



Cyclic progression of synthetic LWIR landmine scene showing improvements in spatial clutter, target modeling, and aircraft roll.

3.2.2 Concealed Target DIRSIG Simulation

Research Team: Kris Barcomb (MS student), Tim Hattenberger, Scott Brown, Lon Smith

Task Scope:
The second topic of interest under this program is the development automatic target recognition algorithms for concealed surface targets in Visible – Near Infrared hyperspectral imagery. RIT has developed techniques for the simulation of these targets within synthetic scenes, particularly under image-collection scenarios providing high-spatial resolution. These methods have been used to create and render a high-spatial resolution scene containing military vehicles under various levels of concealment (e.g., camouflage netting, tree canopy). This synthetic scene was validated against a collection using the DIRS MISI imaging spectrometer on the RIT campus. The techniques developed in this stage of the program will be applied to a scene (agreed to by the MURI team members) that will be developed and delivered to the team and community.

Task Status: The “MicroScene” has been developed for simulation within DIRSIG as part of Kris Barcomb’s Masters Thesis project. Innovative simulation techniques, such as partially transmissive materials and materials with holes in them, have been created and applied to successfully simulate a high-spatial resolution scene containing concealed targets. This scene was created to spatially match an experiment conducted on the RIT campus. Radiometric validation of the scene was accomplished through comparing the simulated radiance spectra against actual spectra collected using the RIT MISI imaging spectrometer.

Overhead rendering of the synthetic concealed target scene in DIRSIG showing the camouflaged and concealed vehicles.

3.3 NURI Algorithm

Sponsor(s): National Geospatial Intelligence Agency. RIT leads a team including Boeing and ITT – RSI (formerly Eastman Kodak Commercial and Government Systems).

Research Team: David Messinger, Harvey Rhody, Don McKeown

Project Scope: Under this program, the DIRS group is working with the Laboratory for Imaging Algorithms and Systems (LIAS) within the Center for Imaging Science. Algorithms developed within DIRS to analyze and exploit hyperspectral imagery are transitioned to LIAS for prototype-level implementation within the IDL-ENVI framework. Three tools have been identified for development under this program: invariant subpixel target detection, target detection of concealed and contaminated targets, and gaseous effluent detection and analysis.

Project Status: The first tool, the subpixel target detection algorithm has been developed, implemented, and delivered to the team members. The second tool, contaminated target detection, is currently under test and evaluation for delivery to the team members on Dec. 31, 2004. The third tool, gaseous effluent detection and analysis, is in the algorithm development phase and will be delivered to the LIAS team for implementation in the winter of 2003/2004.

3.3.1 Subpixel Invariant Algorithm

Research Team: Emmett Ientilucci

Task Scope: The tool developed under this task is focused on an implementation of a sub-pixel target detection algorithm based on the Invariant Method. This implementation utilizes the MaxD basis vector selection method to describe the target and background spaces. The target space is described through a physics-based model incorporating variability in the atmosphere through which the scene is viewed and the viewing geometry of the target. The tool is developed in IDL/ENVI with a full graphical user interface.

Task Status: This tool was delivered to NGA and the NURI team on January 1, 2004 in its completed form. Work is ongoing to streamline the creation of the Look Up Table (LUT) incorporating the atmospheric variability.

3.3.2 Contaminated Surface Detection Algorithm

Research Team: David Messinger

Task Scope: The second tool to be developed under this program is an extension of the initial sub-pixel target detection. Here, the goal is to detect resolved and sub-pixel targets with surface optical properties altered in some way. In particular, those surfaces that have been "contaminated" (e.g., have a coating of dust, or dirt, or have aged in the sun, etc.) and those targets that have been "concealed" (e.g., targets under camouflage netting or tree canopy). This variability in the target signature is incorporated into the physics-based model describing the target space (similarly to the atmospheric variability in the previous tool) in an effort to include these "altered" targets in the target detection scheme.

Task Status: An algorithm has been proposed to accomplish the goal of concealed and contaminated target detection and an initial implementation of the algorithm has been achieved. Testing of the algorithm against both synthetic (DIRSIG – MicroScene) and real data (DIRS – MegaCollect) has begun. It is anticipated that a cyclical test, evaluation, and development process will be required to fully explore the algorithm before final implementation is completed.

3.3.3 Gas Detection and Analysis

Research Team: David Messinger, Erin O'Donnell (MS student), David Pogorzala (MS Student)

Task Scope: The third tool to be developed under this program is for gaseous plume detection and analysis. Similar to the previous tools, the focus of the research in is Hyperspectral Imagery, however this application is different in that the spectral regime of interest in the Thermal Infrared.

Task Status: Several competing algorithms have been developed to address the detection and species identification problems. Aspects of the various methods will be presented to the NURI team for discussion of which tool should be implemented as the final deliverable. A method of quantifying the gas is also being developed for inclusion in the tool if desired by the team. Testing of the gas analysis algorithms will be performed against both real and synthetic data.

Detection of weak plume, identified as Freon in synthetic imagery using the Invariant Gas Detection and Identification Method, similar to that method delivered under Tool #1 of this program.

3.4 Forest Fire Imaging Experimental System (FIRES)

Sponsor(s): National Aeronautics and Space Administration (NASA)

Research Team: Anthony Vodacek, Ambrose Ononye, Robert Kremens, Zhen Wang (Ph.D. student) Ying Li (Ph.D. student) Yushan Zhu (Ph.D. student)

Project Scope: Basic research and development related to the remote imaging of wildland fires. Topics include physical measurements of fire properties, automatic analysis of fire images, and visualization of fire in DIRSIG.

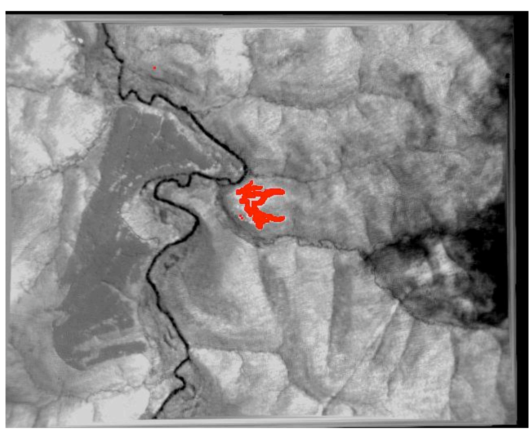
Project Status: Completed years 1 – 4; Award to end 2/28/05.

3.4.1 Fire Detection Algorithms

Research Team: Ying Li (Ph.D. student), Anthony Vodacek

Task Scope:
This task involves the development of automated algorithms for the detection of fire in multi- and hyperspectral satellite and airborne images.

Task Status:
A hybrid contextual algorithm has been developed that is useful for analysis of both satellite and airborne images. The hybrid algorithm can work with multi- or hyperspectral infrared data and is self-adapting to temperature variation in the background scene. The fire decision is made using the statistical properties of the spectral images.



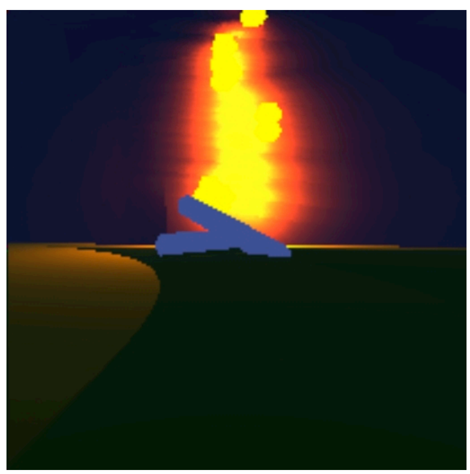
Long wave infrared image collected with the WASP sensor (see section 3.5) over a prescribed fire in southern Ohio. The red pixels denote detections of fire using the hybrid contextual algorithm working on the three WASP infrared bands.

3.4.2 Wildland Fire DIRSIG Modeling

Research Team: Zhen Wang (Ph.D. student), Anthony Vodacek

Task Scope:
This task is seeking an effective method for representing the three dimensional structure and the spectral characteristics of fire in RIT's DIRSIG model.

Task Status:
Good progress is being made on this complex task. The rendering of fire in DIRSIG is using input from laboratory measurements of fire spectra made in collaboration with US Forest Service researchers in Missoula, MT. Several methods for representing the physical structure of flame in three dimensions have been investigated including an image processing approach to characterize the spatial scale of fire. Depending on the application, a less complex rendering may be possible, but the ultimate rendering of fire in DIRSIG will borrow from the work on gas plumes that is described in Section 3.1.4.



A simple color visualization of a DIRSIG rendering of a small fire. In this case the fire is represented in three dimensions by using a set of emitting spheres that are glowing at the temperature of a wood fire.

3.4.3 Fire Characterization and Physical Properties Measurement

Research Team: Ambrose Ononye, Anthony Vodacek, Robert Kremens

Task Scope:
This task involves the analysis of multi- or hyperspectral images of fire in conjunction with ground sensor measurements such as temperature and wind direction, and the analysis of spectral measurements of controlled fires

Task Status:
A set of spectral measurements of controlled fires were made at the US Forest Service fire Science Laboratory in Missoula, MT. This particular set of experiments was designed to allow estimation of the transmission of light by fire. However, the measurements showed that there was little attenuation of light by fire up to 3 meters thick. Although it was not possible to calculate the transmission value of fire from the measurements, an upper bound for the value can be established. This information is useful for the DIRSIG rendering of fire. An interesting observation from these measurements is that the potassium emission line at 766 nm is independent of the flame thickness, indicating saturation of the emission. This may have implications for using the potassium emission for fire detection because the integrated signal strength in an image can be expected to be proportional to the area of the fire. Knowledge of fire area can be a very important for fire management.

3.4.4 Real-time Fire Modeling

Sponsor(s): National Science Foundation (NSF). RIT is on a team being led by the University of Colorado-Denver with Co-PIs at the National Center for Atmospheric Research, the University of Kentucky, and Texas A&M University.

Research Team: Robert Kremens, Ambrose Ononye, Zhen Wang (Ph.D. student)

Project Scope:
The RIT role in this large project is to provide fire images and ground sensor data to our collaborators for input to a real time fire propagation model. RIT will also be involved with visualization of the model results in near real time. The visualization work is based on the DIRSIG modeling of fire being done in the FIRES project.

Project Status:
WASP images and ground sensor data that will be used as test data for the model input are available from the WASP and FIRES projects (see Section 3.5). Working with our collaborators we are currently assessing

data format standards and data handling procedures so that the field data can be seamlessly inserted into the fire propagation model.

3.5 WASP

Sponsor(s): NASA-This effort is being led at RIT by the LIAS group with support from DIRS

Research Team: Harvey Rhody, Don McKeown, Jason Faulring, Juan Cockburn, Robert Kremens, Jangho Park, Daniel Fava, David Morse (MS student), Greg Semevaro and Don Light

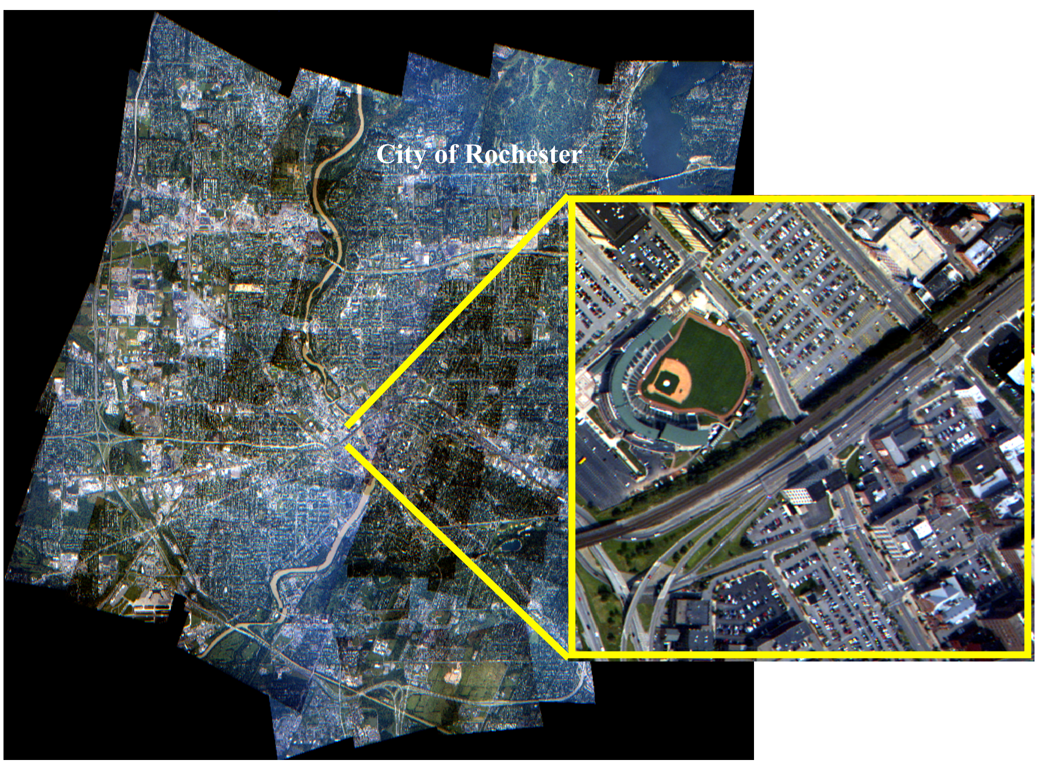
Project Scope:
The Wildfire Airborne Sensor Program (WASP) is a multi-band mapping camera system developed by RIT under a federal grant from NASA. The mission of WASP is to detect and monitor wildfires from a light manned aircraft and produce geo-referenced data products aboard the aircraft in near real time.

Project Status:
The WASP camera system consists of 4 high performance frame cameras mounted on a common structure that pivots about a single axis to image a 4 mile swath from 10,000 ft. AGL. The camera suite provides simultaneous coverage of the electromagnetic spectrum from 400 nm to 9200 nm. Table 1.0 summarizes the WASP camera capabilities. The three IR cameras provide high sensitivity detection and the capability to discriminate targets day and night on the basis of relative brightness in the different bands. The visible RGB camera provides a very high resolution literal image in the day for better interpretation and mapping. It is also notable that the IR cameras are capable of operating at full video rates for true motion imaging as well as still frame. The figure shows the WASP camera system installed in a light twin engine aircraft.

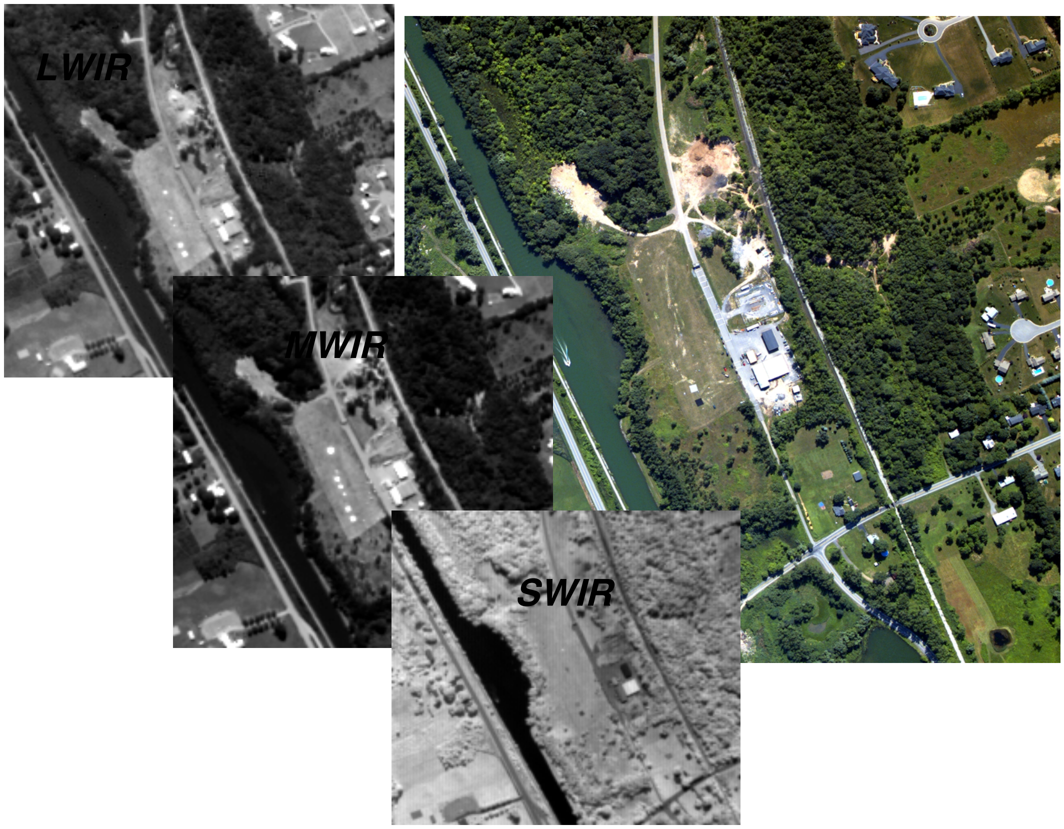
Table 1.0: WASP Camera Capabilities

Camera	Spectral Coverage	Frame Size (pixels)	IFOV (mrad)	FOV (deg)	Frame Rate (frames/sec)
Visible (RGB)	400 – 900 nm	4,000 x 4,000	0.16	37.5	0.25
SWIR	900 – 1700 nm	640 x 512	1.0	37.0	30 (max)
MWIR	3000 – 5000 nm	640 x 512	1.0	37.0	30 (max)
LWIR	8000 – 9200 nm	640 x 512	1.0	37.0	30 (max)

The WASP system is configured to operate all four cameras simultaneously or individually depending on the mission. Camera position and orientation data, used to geo-reference the imagery, is provided by a high performance inertial measurement unit (IMU) and GPS. The WASP camera system has been successfully flying since July 2003.



WASP Covers Large Areas at High Resolution (Example shows 64 sq. miles around Rochester NY)



Example of Simultaneous Multiband WASP Imagery from 10,000 ft AGL

3.6 The Laboratory for Advanced Spectral Sensing (LASS)

Sponsor(s): Eastman Kodak Company, ITT Industries, Boeing, National Reconnaissance Office (NRO), Lockheed-Martin, Los Alamos National Laboratory (LANL)

Management Team: John Schott, Mike Richardson

Project Scope: 2004 saw the addition of a new LASS partner, Los Alamos National Laboratory (LANL). LASS was established as a research incubator in the area of spectral remote sensing. The intent has been to have an entity for government agencies and industry partners to conduct pre-competitive research that benefits all the partners. Many projects are funded by more than one partner and research results are shared with all the partners. The focus of this year's research has been in three primary technical areas; modeling and simulation, algorithms and phenomenology, and measurements and experiments. Technical research areas (that will be further discussed in Section 3) included; completion of DIRSIG MegaScene 1 and planning activity for MegaScene 2, DIRSIG sensor model upgrade, sparse aperture telescope modeling and performance evaluation, an ENVI tool for multispectral haze removal, and a target detection algorithm survey and evaluation.

Project Status:
A number of these projects saw significant research progress in 2004. Some of the notable activities included the completion of MegaScene 1 and the spectral database going "on-line". More detailed status information is provided for each of the significant LASS research projects.

3.6.1 MegaScene 1

Research Team: Emmett Ientilucci

Task Scope: This task was aimed at construction of a synthetic scene covering several square miles to be used as a high fidelity clutter environment to support sensor design and algorithm development.

Task Status: Of interest to algorithm developers and sensor designers is the ability to test the performance of developed tools or models. Recently, this community has requested pre-developed wide-area synthetic scenes to use as a surrogate to real data, which may be difficult to collect in some circumstances. To aid in this effort, a project called MegaScene was formed. MegaScene is an attempt to create wide-area simulated scenes using RIT's DIRSIG model to generate synthetic scenes with spatial and spectral clutter similar to that found in real imagery.

To save on computation time, the MegaScene project was initially segmented into five independent regions or "tiles". Recently, however, the tiles have been concatenated. Figure 4 shows a color rendering of tiles 4 and 5, concatenated with a single terrain. These tiles contain thousands of trees as well as a water treatment plant and shore line. The geometric resolution of the material and texture maps is on the order of 0.15 meters (before sensor effects, such as PSF, are applied).

Concatenation of MegaScene tiles 4 and 5 only. Simulated nadar view at an elevation of 2,500 meters.

3.6.2 MegaScene 2

Research Team: Jeff Dank (MS student), Tim Hattenberger

Task Scope:
MegaScene 2 is the second large-scale scene development/building effort by the DIRS group at RIT. The motivations are similar to the first MegaScene effort. The MegaScene program demonstrates the scene simulation capabilities of DIRSIG, on a large scale. The size of MegaScene 1 is several square miles, which allows the simulation of long flight lines. MegaScene attempts to capture the spatial and spectral complexity of the real world.

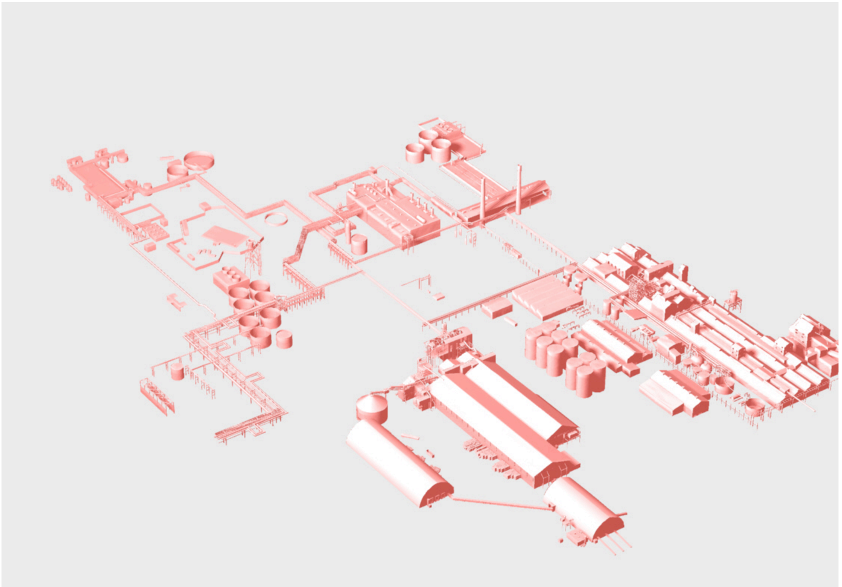
MegaScene 2 is an effort to; utilize the scene building techniques learned in the first effort, develop new techniques, as well as, use the scene to test and develop algorithms and phenomenology. The first MegaScene effort was a learning experience. New tools are currently under development to aid in the construction of such a scene. These tools are generally associated with the scene construction tool termed Bulldozer being developed to support DIRSIG. Other external software is being evaluated for enhanced modeling capabilities.

The novelties of MegaScene 2 are as follows. First, MegaScene 2 will encompass an arid, desert-type region. This also implies the vegetation, atmosphere and mountainous terrain is in accordance with that type of region. The spatial resolution will be on par with MegaScene 1 (~1m) with the exception of an industrial complex that will be on the order of ~0.5m. The overall ground coverage will be larger than MegaScene 1, allowing simulated flight lines covering mountainous transitioning to flat terrain. The industrial complex can be used as a surrogate chemical plant with factory stack plumes projecting over varying background, or a nuclear power plant. The mountainous terrain also affords the use of another new tool, which is to simulate an inhomogeneous atmosphere. The atmosphere can now be varied both vertically and horizontally.

<u>Task Status</u>:
Trona, CA has been selected as the location for MegaScene 2. Trona is located in Death Valley. It offers the desert vegetation and climate as well as the mountainous terrain. The expansive mountainous terrain can be augmented with UGF (underground facility) phenomenology. Additionally, several industrial (mining / chemical plants) sites have been identified as placeholders for the industrial component of the new scene. The site is being researched further in terms of accessibility. An initial site visit is set for August 13, 2004, with the data collect scheduled for October 20 thru November 3, 2004.

Geometric modeling of the structures in the town is well underway, and has been accomplished through the use of imagery and software provided by Pictometry. Measurements of the structures is made with this software, and in turn, used to model the objects in a CAD environment.

Oblique aerial photograph of Trona, CA courtesy of Pictometry



Simple rendering of structures modeled from Trona. Note the high level of geometric fidelity

3.6.3 Spectral Measurements

Research Team: Bethany Choate, Jessica D'Amico, Rachael Gold, Marek Jakubowski, Brian Leahy, Yan Li, Jesse Schott, Brian Staab, Tom Schwarting, Nina Raqueño, Lon Smith, Gary DiFrancesco

Task Scope:
The success of developed exploitation algorithms and simulation and modeling hinges on the data to which these efforts have access. The data collection carried out as part of the LASS effort directly supports these activities by identifying and measuring materials required under these efforts and requested by the cognizant researchers. Spectral signature measurements are carried out from 0.35 to 14 microns both in the laboratory and the field. An impressive instrumentation suite has been assembled for this purpose that includes a Varian-Cary 500 and a Surface Optics SOC-100 laboratory spectrometer as well as field spectrometers from Analytical Spectral Devices (FieldSpec), Surface Optics (Model 400T) and most recently from Designs and Prototypes (Model 102F)

Task Status:
To date this task has gathered over 2,000 spectral signatures. The majority of these data are currently undergoing quality checks and the associated metadata being vetted before they are incorporated in the RIT spectral database.

3.6.4 Spectral Database

Research Team: Ken Smith, Mahek Sujan, Nina Raqueño, Lon Smith, Carl Salvaggio

The RIT spectral database went online in June 2004 and can be found at:

http://chapman.cis.rit.edu/spectraldb

3.6.5 Sparse Aperture Modeling

Research Team: John Schott, Rob Introne (Ph.D. student), Noah Block (MS student)

Task Scope:
This project is studying improved ways to model sparse aperture telescope designs. These designs are intended to allow very high

resolution imaging by synthesizing large effective apertures from many sub aperture samples of the wave front which must be combined and phased to form an initial image. This poor quality image is restored with inverse filters that take advantage of knowledge of the instrument point spread function and phasing errors.

Task Status:
Efforts this year focused on the development of a sensor model that allows us to model various telescope designs with full spectral fidelity. This is a significant improvement over earlier approaches where an averaged "gray world" approximation was employed. The overall model approach is shown in the figure below illustrating the model inputs processes, raw image output and image restoration steps.

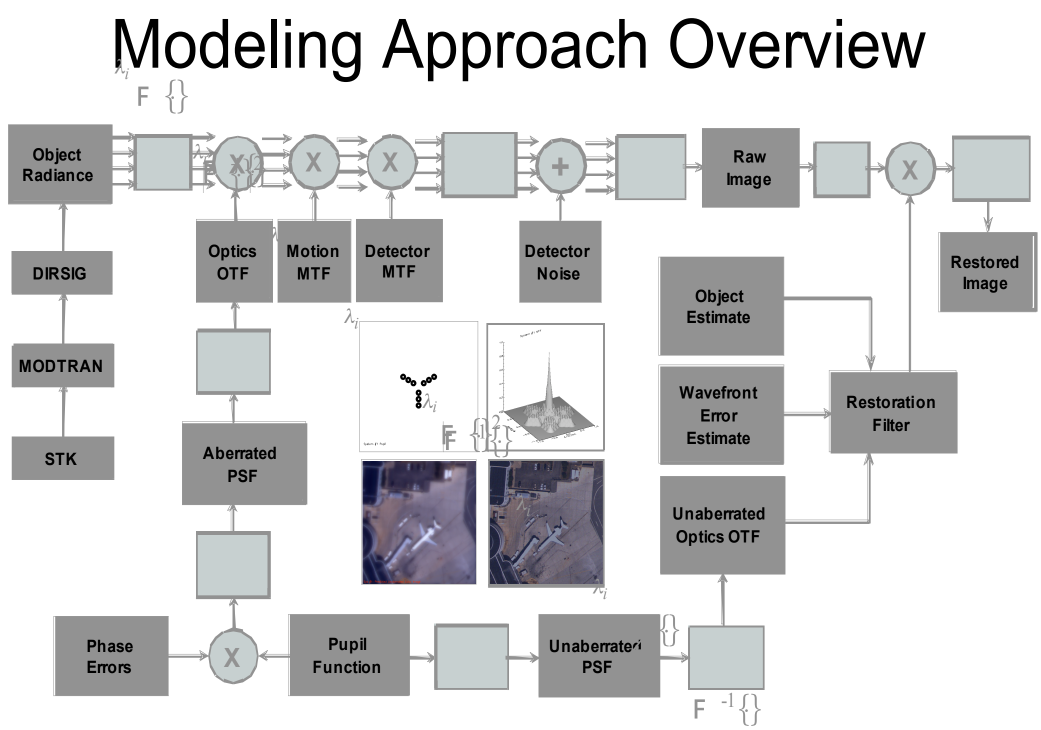


Illustration of the end to end processing chain for sparse aperture image simulation and restoration.

The importance of this improved approach is shown below where results of modeling the image process through to a fully restored image are shown for two levels of telescope quality. In one case, a RMS error in wave front control of 0.1 λ RMS is modeled and in the other a poorer control value of 0.25 RMS is modeled. In each case the improved polychromatic model is compared to the oversimplified gray world model. Note in the 0.1 λ case the two models perform very similarly visually although the numerical error (RMSE) is predicted to be slightly worse using the higher fidelity polychromatic approach. When the 0.25 λ RMS wave front error is modeled the "gray world" model and the polychromatic model differ significantly with the polychromatic model showing observations not apparent in the gray world. This points out the need for the higher level of fidelity model developed on this effort (i.e. the simplified model is too optimistic and could lead to inadequate image quality if used to control the instrumentation design.

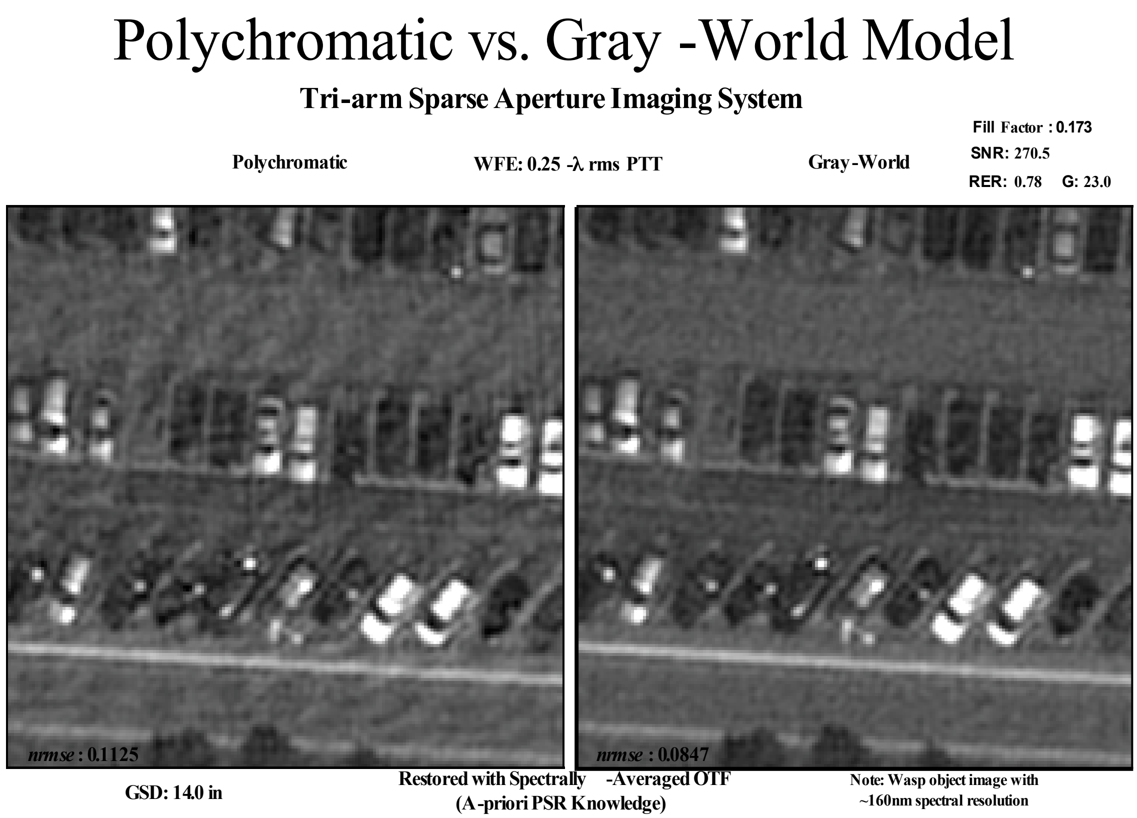


Illustration of restored images simulated with the improved polychromatic approach and the more traditional gray world approach.

3.6.6 DIRSIG Sensor Model Upgrade

<u>Research Team</u>: Cindy Scigaj (MS student), Scott Brown, Paul Lee

Task Scope:
One of the major improvements in the next generation of DIRSIG is with respect to the sensor modeling capabilities provided by the model. The existing sensor model in DIRSIG accounts for focal plane geometry effects including scanning mechanisms associated with line scanners and platform motion. The area that the existing sensor model could be improved is the treatment of the instrument focal plane.

The new DIRSIG sensor model will allow the user to specify the spectral response, spectral PSF and spectral noise on a *pixel-by-pixel* basis. This feature allows system modelers to provide this information at run-time rather than force a post processing procedure. The interface to this aspect of the model is intended to allow rigorous in-house focal plane models to drive the DIRSIG image formation process. In addition, the creation and distribution of basic system models for community accessible imaging assets such as AVIRIS, COMPASS, etc. will allow users without in-house focal plane modeling capabilities to produce more realistic image data.

Task Status:
The baseline components of the new DIRSIG sensor model have been developed and demonstrated separately. This includes new noise models that include support for spectrally correlated noise and a more rigorous treatment of the pixel point-spread functions.

At this time, the project is transitioning into the final phase where the software architecture will be finalized which integrates the components in a way that will allow the model to be configured to model a variety of sensor packages. This includes the design and definition of the user and database interfaces that will be used by both low-level instrument modelers and high-level instrument customers.

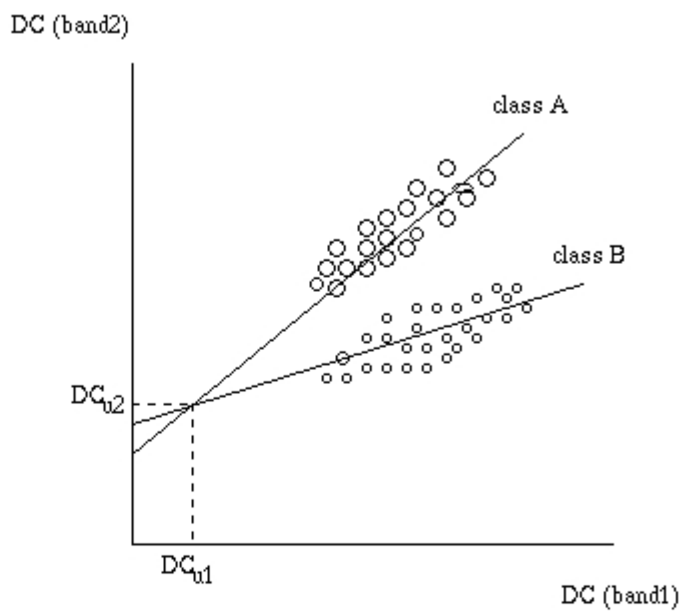
3.6.7 Multispectral Haze Removal

Research Team: Paul Lee

Task Scope:
Degradation of remotely sensed images can be significantly attributed to atmospheric effects. These include the absorption of photons otherwise destined for the sensor and the direct scattering of solar photons towards the sensor. They respectively make up the multiplicative and additive effects of the atmosphere on an

image. In particular, the additive component is the primary contributor to the non-image photons collected by the sensor. This feature reflects the haze that can be visually detected in remotely sensed images. The underlying premise of this task will be to apply a statistical technique to multi-spectral imagery that will provide us with the quantification of this additive effect of the atmosphere, also know as up-welled or path radiance. Once this is known for each of the spectral bands, we can then use an estimate of the surface phenomena of at least one target of interest to solve the governing radiation propagation equation for the scene.

The Regression Intersection Method is an algorithm [Crippen, 1987] that can be used to determine the up-welled spectral radiance. It is based on an assumption that the radiance arriving from a 0% reflector can be attributed to up-welled radiance and sensor bias. But instead of requiring the presence of near zero reflectance surfaces, it calls for various spectrally unique classes of materials within which there is a variation of irradiance. For each pixel, the digital count value in one image band is plotted against the value in a second band. After every pixel in a given class is plotted in this manner, the resulting distribution is fitted using a pair-wise regression. The figure below illustrates the manner of extrapolating two bi-spectral distributions towards an intersection.



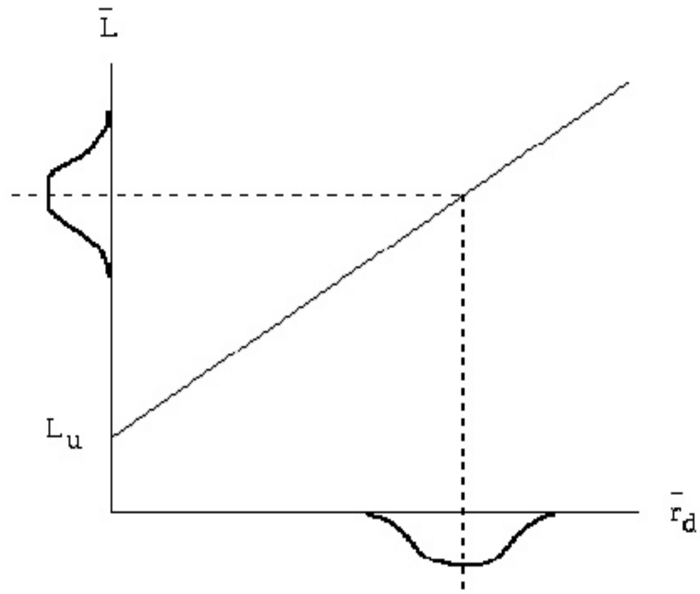
Regression Intersection Method: According to this diagram, DC_{u1} would be the estimated up-welled value for the band in the independent axis (Band 1).

The intersection of two class distributions is regarded as the zero reflectance point, and any radiance arriving from that point must be attributed to atmospheric scattering. This intersection is taken to be the up-welled radiance. To make the up-welled radiance estimation more robust, all possible class combinations are analyzed for a given band pair and the process is repeated for all possible band pairs.

Once the up-welled radiance is known, the Scene Color Standard Method completes the atmospheric correction. This approach suggests that, given an up-welled radiance, the total incident radiance term can be solved for using a statistical estimate of the mean observed radiance for a class of objects whose mean reflectance in the band-pass can be well estimated [Piech and Walker, 1971]. Assuming that the atmospheric transmission is constant over the entire scene, that both the background and cosine effects are negligible, and the thermal energy factors are omitted, the governing radiance equation takes on the form:

$$\overline{L} = \left[\frac{E_s}{\Pi}\tau_2 + L_d\tau_2\right]\overline{r}_d + L_u$$

Where $\overline{L}$ is the mean radiance observed for many samples of a standard material sampled in the scene, L_u is the estimated up-welled radiance value, and $\overline{r}_d$ is the mean reflectance based on numerous laboratory or field measurements of the standard material. The technique maps the mean of one or more reflectance distributions to the means of the corresponding radiance (digital count) distributions. This will yield a complete two-point solution to the radiance equation. The figure below illustrates this empirical straight-line solution for one band.



Scene Color Standard: Linear mapping from reflectance to radiance space

In many cases, the logistics associated with acquiring good ground truth data are impractical to meet. As a result, this method of *in-scene* calibration will require a best-guess estimation of the average reflectance of at least one surface feature. The average radiance distribution can be obtained directly from the image digital counts.

Task Status:
Completed. Software delivered.

References:

Crippen, R.E. (1987), "The Regression Intersection Method of Adjusting Image Data for Band Ratioing". International Journal of Remote Sensing, Vol.8, No. 2. pp. 137–155.

Piech,K.R. & Walker,J.E. (1971), "Aerial Color Analysis of Water Quality". Journal of Surveying & Mapping Division American Society of Civil Engineers, Vol.97, No.SU2, pp.185-197.

3.6.8 Target Detection Algorithm Survey

Research Team: Adam Cisz (MS student), David Messinger

Task Scope: Under this task, a comparison of several target detection algorithms is being conducted to better characterize their relative performance against a number of images. The target detection scenarios being considered vary in background complexity, target size and contrast, and collection geometries. Both synthetic and real imagery is being considered, the former allowing the use of metrics such as ROC curves through use of exact truth maps. Algorithms under consideration will be coded in the IDL/ENVI environment for a consistent user interface and portability.

Task Status: Several algorithms have been identified for this study. They include Spectral Angle Mapper (SAM), Orthogonal Subspace Projection (OSP), Adaptive Coherence Estimator (ACE), Constrained Energy Minimization (CEM), the Invariant Algorithm, Independent Components Analysis (ICA), and the Finite Target Matched Filter (FTMF). Several of these methods have been implemented in IDL. Datasets for testing and performance metrics have been identified.

3.7 Landsat 5, 7 Thermal IR Calibration Project

Sponsor(s): NASA

Research Team: Nina Raqueño, Tim Gallagher, Brian Staab

Project Scope:
Under this project, DIRS monitors the thermal calibration of both the Landsat ETM+ and TM satellites. This is performed by collecting surface water temperatures and MISI thermal imagery, propagating the surface radiances to the satellite using MODTRAN and an interpolated atmospheric profile, and comparing know surface radiances to sensor reaching radiances. This calibration is essential to users of this thermal data since the Landsat system of instruments is intended for long-term studies of the earth.

Project Status:
This Landsat calibration has been a multi-year monitoring project since 1995. Results and recommendations were presented to the Landsat Science Team in December 2003 and June 2004. DIRS results were comparable to an independent team's results. At this time Landsat ETM+ remains stable and no changes to the calibration coefficients are necessary. Both teams show a slight bias in Landsat TM but no action was warranted until a better understanding of how the TM instrument has performed historically. DIRS will continue to collect new ground truth to monitor Landsat ETM+ and further refine Landsat TM thermal calibration history into 2005.

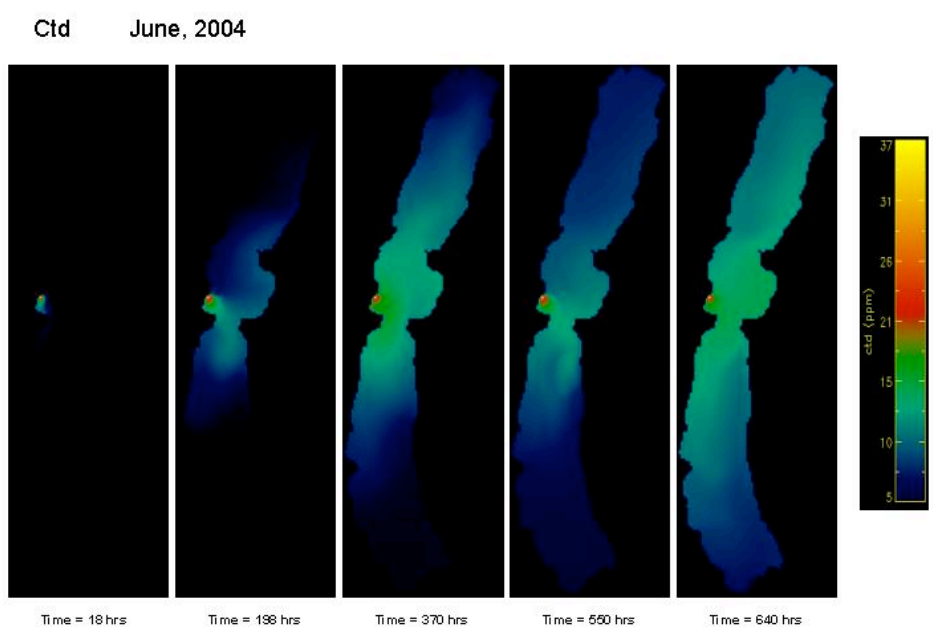
3.8 Conesus Watershed

Sponsor(s): : United States Department of Agriculture (USDA)

Research Team: Anthony Vodacek, Nina Raqueño, Yan Li, Marek Jakubowski

Project Scope:
In collaboration with the lead PI at SUNY-Brockport and Co-PIs at SUNY Brockport and SUNY Geneseo, we are studying the hypothesis that improved farming practices in the small watersheds of Conesus Lake can lessen algae and weed growth in the lake by reducing the amount of nutrients in stream water runoff. We are using the ALGE hydrodynamic model coupled with thermal images of stream plumes in the lake as a way to assess the fate of nutrients flowing into the lake.

Project Status:
The ALGE nutrient flow simulations shown below are consist with observations of the distribution of weed beds. The ALGE results are being compared to field data, including water temperature measurements at a series of depths from April to October and images from over flights by the WASP thermal sensors in the spring and fall.



An ALGE simulation of the fate of dissolved nutrients that are entering Conesus Lake from the small creek at Sandpoint. Nutrients from the stream distribute over most of the lake, but do tend to move in higher concentration to the north basin (top of image) where the outlet is located.

3.9 NAIC Spectral Library

Sponsor(s):
General Dynamics Corporation

Research Team: Lon Smith, Jessica D'Amico, Brian Leahy, Jesse Schott, Bethany Choate, Rachael Gold, Gary DiFrancesco, Carl Salvaggio

Project Scope:
The Wolfpack effort is an intelligence community effort to construct and populate a community accessible database of spectral signatures that is sponsored by the National Air & Space Intelligence Center at Wright Patterson Air Force Base. The effort includes the construction of the database schema and incorporation of existing data. RIT's involvement in this project is in the definition of field and laboratory protocols for measuring spectral reflectance, emissivity and radiance in the laboratory and the field to insure that data collected by RIT and other organizations can receive the highest possible data quality rating and prove useful to the community for years to come. The RIT team is also involved in field campaigns at which data for real-world targets in their natural environments are collected.

Project Status:
This initial phase of the project will be drawing to a close in September 2004. The effort to this point has produced a visible/near infrared/shortwave infrared reflectance measurement protocol for both the laboratory and the field, as well as a traceability protocol so that measurements made by the RIT team can be traced back to primary NIST standards. A protocol for field midwave and longwave infrared spectral emissivity measurements has also been delivered while the laboratory equivalent for this wavelength region is being authored. The RIT team has participated at and delivered data from several field collection campaigns at Eglin AFB.

3.10 DCI Post Doc

Sponsor(s): Director of Central Intelligence Postdoctoral Fellowship Program

Research Team: David Messinger, John Schott

Project Scope: This two-year program is a comparison of methods for detection and analysis of gas plumes. Methods under consideration are active sensing (LIDAR) and passive sensing (LWIR Hyperspectral). Existing algorithms are being studied while new algorithms are being developed. Trade studies between the two methodologies involving synthetic data will be conducted to better understand the limits of each technology and the applicability of each to a particular collection scenario.

Project Status: Initial results of this project revolve around the ability to detect gas plumes in LWIR hyperspectral imagery. Several existing methods were compared both qualitatively and quantitatively and where appropriate, enhanced to meet the challenges of the passive gas detection. In addition, a theoretical comparison between active and passive minimum detectable target concentrations was done demonstrating the differences in performance for the two methodologies as functions of overall system Signal-to-Noise Ratio (SNR). These results were initially presented at the DCI Postdoctoral Colloquium in April 2004 and have been submitted for publication in the Journal of the Intelligence Community Research and Development.

3.11 NYS Image Degradation

Sponsor(s):
New York State Office for Cyber Security and Critical Information Coordination

Research Team: May Arsenovic, Carl Salvaggio

Project Scope:
RIT will be providing a software tool that will allow the NYS OCSCIC to selectively degrade their online statewide library of aerial photographs to protect critical infrastructure information. As part of the Homeland Security initiative afoot in New York State, the OCSCIC desires a tool that would let them selectively degrade the resolution of their archives of air photos that are available to the public so that potential organizations that would aspire to do harm to these facilities do not have high quality data available to them, while maintaining the quality of the data in other regions for legitimate users. RIT will develop this software tool to key off of OSCCIC supplied shape files and apply the degradation to the library of imagery.

Project Status:
This effort has reached a close with the tool developed and delivered to NYS OCSCIC on 16 July 2004. The tool is currently under review at the sponsor office and is awaiting final acceptance. The RIT development team will be heading to Albany on 17 August to train the sponsor personnel on the theory and operation of the tool.

3.12 DIRSIG Texture Upgrade

Sponsor(s): SSI/ AFRL and Eastman Kodak Company

Research Team: Neil Scanlan (MS student), Scott Brown, John Schott

Project Scope:
Develop and test improved methods for incorporation of texture into DIRSIG VNIR and SWIR scenes.

Project Status:
Three methods of texture generation were developed and implemented into DIRSIG. Any texture method can be applied to any material so the most appropriate method can be used. Also as part of this study methods for assessment of texture were developed. The table shows how the simple band (SB), multiple band (MB), fractional mixture (FM) and stochastic texture synthesis (TS) methods ranked. This project is complete.

	WT	**1**	**2**	**3**	**4**
GLCM **Gray Level Co-Occurrence Matrix**	1	FM	MBP	SBP	TS
SCR **Signal to Clutter Ratio**	1	TS	MBP	FM	SBP
SCM **Spectral Co-Occurrence Matrix**	1 (0.5)	FM	MBP	TS	SBP

Illustration of the relative performance several texturing methods in reproducing the indicated image derived metrics. The individual performance metrics were then combined to generate an overall metric.

3.13 DIRSIG Users Guide

Sponsor(s): Eastman Kodak Company

Research Team: Scott Brown, Paul Lee, Niek Sanders, David Messinger, Tim Hattenberger

Project Scope:
The purpose of this project was to improve the user documentation available to users of the Digital Imaging and Remote Sensing Image Generator (DIRSIG) software simulation package. The primary goal was to make a document that could be used by users of the model at all levels of

experience. The new manual emphasizes both the practical and theoretical aspects of the model, including a new section on the fundamental theory incorporated into the model.

In addition to updated end-to-end modeling tutorials, the new manual was architected to provide the user with various types of information for a range of specific topic areas. Within each of these topic areas, the reader will find a technical discussion of the topic (including relevant theory and equations), a how-to section that describes the various modeling techniques that are relevant to the topic, a set of step-by-step tutorials on the subject and also a suite of troubleshooting tips for the topic. This updated manual represents an excellent foundation on which future documentation will be added as more features of the model reach maturity.

Project Status
This project is complete. Both hardcopy and an on-line version of the new manual were delivered to Kodak.

3.14 Pictometry Algorithms Study

Sponsor(s): Pictometry International, Inc.

Research Team: Seth Weith-Gluchko, Carl Salvaggio

Project Scope:
RIT is determining the feasibility of automated tie point identification on numerous oblique air photos collected with the Pictometry system. Once a feasible approach is identified, RIT will be developing prototype software to assist Pictometry in this now largely manual process. This research was funded in part by CEIS, a NYSTAR-designated Center for Advanced Technology.

Project Status:
An initial algorithm has been delivered to the sponsor that provided accuracy from subpixel to 2 pixels across a variety of imagery. Additional studies have been carried out to improve this accuracy by taking advantage of color information within the aerial images, but have only provided marginal improvements at the expense of increased computational cost. The final report is being delivered to Pictometry in late August 2004.

4.0 RIT Funded Core Research and Research Applications

The following projects represent internally funded research activities that occurred in 2004.

4.1 DIRSIG 4.0

Research Team: Scott Brown, Paul Lee, Niek Sanders

Project Scope:
Our core simulation and modeling effort is largely encompassed in a whole scene model called the Digital Imaging and Remote Sensing Image Generation (DIRSIG) model which has been developed and enhanced over the last 15 years. Due to the size and complexity of the model, it had become almost impossible for students without anything short of a MS in Computer Science and several years of experience to contribute to the model development.

To address proposed additions to the model and the inability for imaging science students to contribute to the model, an effort was begun to redesign and rewrite the model in a heavily modularized approach that would break the model up into logical elements that could be enhanced, modified and replaced with ease. This new design allows the staff and student developers to modify, test and evaluate the components of the model with limited or no impact on the rest of the model. The code rewrite effort includes the user of a software documentation model that mixes code and supporting documentation so that detailed explanations and illustrations are literally attached to the source code. This allows new people joining the project to learn about the model and how it works on their own. This major upgrade to the model is encompassed in what is referred to as DIRSIG Version 4.

The modular design of the model allows people working on the model to learn and understand the specific subsystem they are working on rather then the entire model. This modular design also allows algorithm developers to utilize a piece of the DIRSIG model where, in the past, the entire model would have to be run to extract a single calculation of interest. This design also allows for the basic components of the model to be easily assembled in a different fashion so that different "versions" of the model can be created to perform different tasks or to serve a different user community.

Project Status:
DIRSIG Version 4 has been beta released to the user community with the DIRSIG Version 3 updates over the past year. The new model is the software platform on which several operational capabilities (including the polarized image model, time-gated LIDAR model and enhanced sensor model) are built. During the fall of 2004, the new model will replace the currently distributed model.

4.2 MicroScene

Research Team: David Messinger, Erin Peterson, (MS student), Kris Barcomb (MS student), Tim Hattenberger, Lon Smith

Project Scope: In an effort to collect well ground-truthed data of a small area for simulation within DIRSIG, the DIRS group conducted an experiment on the RIT campus utilizing several sensors and ground targets of interest. Targets in the scene included three military vehicles, buried and surface land-mine simulants, and several calibration targets. The military vehicles were placed in the scene under varying levels of concealment: one was in the open, one was under the tree canopy, and the third was under camouflage netting. Data were collected with the DIRS imaging spectrometer MISI as well as the LIAS WASP camera system. This provided both Visible-Near IR spectrometer data as well as high-spatial resolution broadband Visible, SWIR, MWIR, and LWIR data. Images were taken once an hour for 26 hours to characterize signature variability within a full diurnal period. In-scene and laboratory characterization of materials in the scene provided the ability to simulate the scene within DIRSIG, thus validating our ability to simulate high-spatial resolution scenes containing targets under varying levels of concealment.

Project Status: The experiment was conducted in the late summer of 2003 and the data were successfully used as part of Kris Barcomb's Masters Thesis project. Further analysis of the broadband temporal data is required.

Images taken during the MicroScene Experiment showing the sensor setup, on the scissor truck and some of the embedded targets of interest.

4.3 MegaCollect Experiment

Research Team: The DIRS staff and students

Project Scope:
The MegaCollect Experiment was a collaborative collection campaign to spectrally image and measures a well characterized scene for hyperspectral algorithm development and validation/verification of scene simulation models (DIRSIG).

Project Status:
RIT's MegaScene, located in the northeast corner of Monroe County near Rochester, New York, has been modeled and characterized under the DIRSIG environment and has been simulated for various hyperspectral and multispectral systems (e.g., HYDICE, SEBASS, etc.). Until recently, most of the electro-optical imagery of this area has been limited to very high altitude airborne or orbital platforms with low spatial resolutions. MegaCollect 2004 addresses this shortcoming by bringing together, in June of 2004, a suite of airborne sensors to image this area in the VNIR, SWIR, MWIR, and LWIR regions. These include the COMPASS (hyperspectral VNIR, SWIR), SEBASS (hyperspectral LWIR), WASP (broadband VIS, SWIR, MWIR, LWIR) and MISI (hyperspectral VNIR, multispectral LWIR, broadband SWIR, MWIR, LWIR).

In conjunction with the airborne collections, an extensive ground truth measurement campaign was conducted to characterize atmospheric parameters, select targets, and backgrounds in the field. Laboratory measurements were also made on samples to confirm the field measurements. These spectral measurements spanned the visible and thermal region from 0.4 to 20 microns. These measurements will help identify imaging factors that affect algorithm robustness and areas of improvement in the physical modeling of scene/sensor phenomena. Reflectance panels have also been deployed as control targets to both quantify sensor characteristics and atmospheric effects. A subset of these targets has also been deployed as an independent test suite for target detection algorithms.

The MegaCollect Experiment proved to be a valuable exercise in planning, multi-agency coordination, protocol review, and execution. Post-collect collaboration will continue through data sharing in a centralized Geographic Information System.

Overview of MegaCollect Area showing planned flight lines and experimental locations

Main experiment location taken with RIT's WASP sensor June 7, 2004

Some of the ground team tour the COMPASS platform.

4.4 Spectral Measurement Equipment Upgrade

Research Team: Lon Smith, Carl Salvaggio, Gary DiFrancesco

Project Scope:
The Measurements Group of the DIRS laboratory is continually striving to improve both the quality and diversity of optical property measurements that can be made. The mainstay of this group is the measurement of full spectrum reflectance in both the laboratory and field environments. Certain materials cannot be removed from their natural environment without a significant change in their spectral behavior. As a result, the high quality measurement capabilities available in the laboratory combined with the unique field measurement equipment allow us to measure those hard to move targets and still maintain traceability to standards with NIST certifications.

Project Status:
In continuing to enhance the capability to measure spectral emissivity in the field, the Measurements Group recently received internal (DIRS) and external (RIT) funding to purchase a Designs & Prototypes Model 102F MicroFTIR. This instrument allows us to now measure, in a non-contact fashion, absolute radiance leaving any target. The instrument provides superior performance in the longwave infrared portion of the spectrum with a signal to noise ratio approaching 1000 at 10 microns. This enhances our field capability to natural, textured materials that we were not able to measure in-situ in the past.

WASP Imagery at 3000 ft over Camp Eastman during MegaCollect

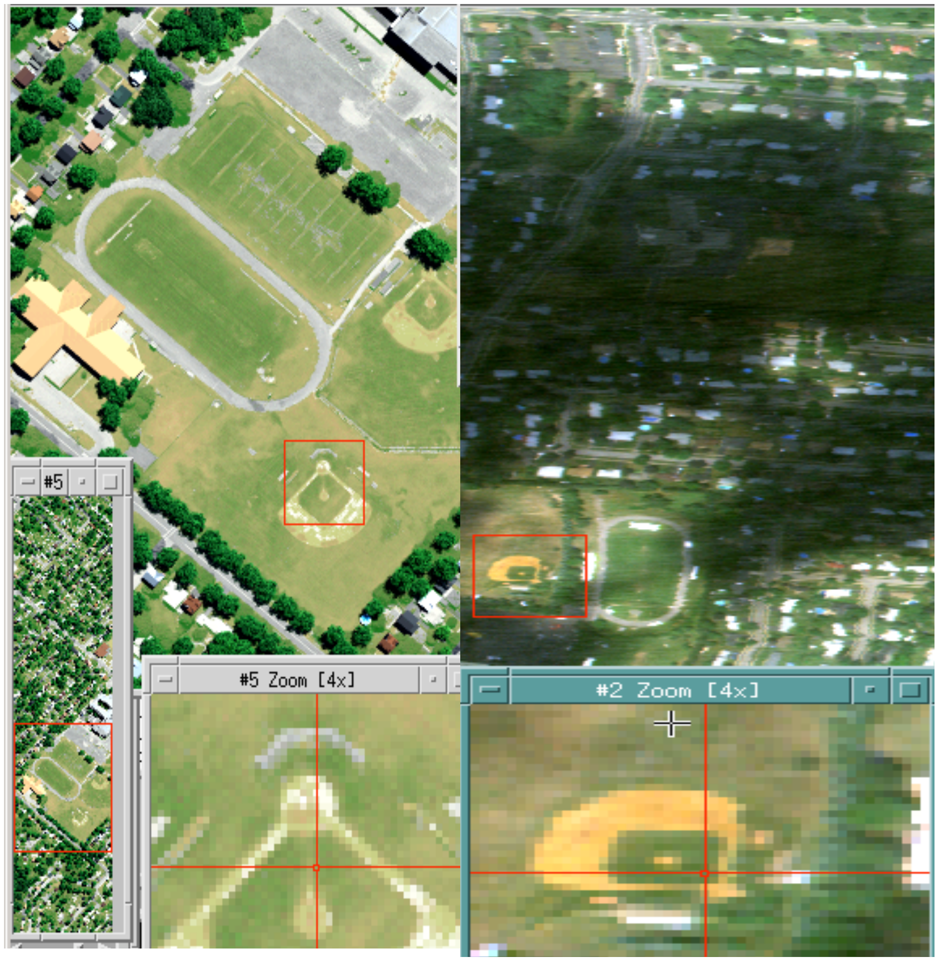
4.4 MISI Calibration and Hardware Upgrade

Research Team: Tim Gallagher, Rolando Raqueño, Bob Kremens, Jason Faulring, Lon Smith

Project Scope:
The DIRS Lab designed, built and operates an airborne imaging spectrometer with 64 bands in the visible and near infrared and multispectral bands in the shortwave through longwave infrared. As part of ongoing educational and engineering efforts the Modular Imaging Spectrometer Instrument (MISI) went through an extensive effort to design and implement calibration procedures for the reflective bands (note: the thermal calibration has been successfully implemented for several years).

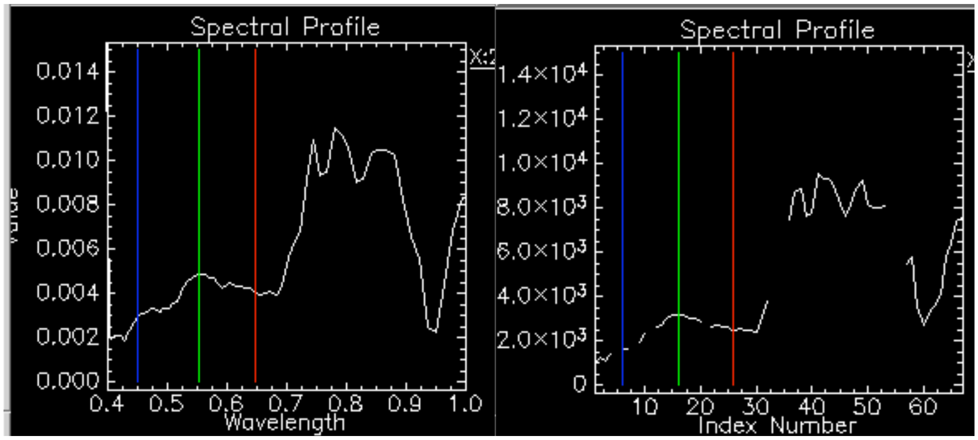
Project Status:
Spectrometer data from recent collections have been sufficiently calibrated to provide spectral radiance data that are similar to spectral shapes to those simulated by DIRSIG.

The illustration below shows a visual comparison of spectral data collected over the MegaScene by the MISI spectrometer and a similar region simulated by DIRSIG.



Visible color rendering of DIRSIG simulation of a section of MegaScene (left) and a MISI spectrometer image over another section of MegaScene (right). Both points highlight a corresponding grass pixel on a baseball diamond. Imaging parameters are slightly different and specified as follows (DIRSIG – HYDICE sensor; June 1, 2001; 1:00 PM local time; 2000 feet altitude; MLS atmosphere), (MISI – June 28, 2003; 12:35 PM local time; 3000 feet altitude; clouded atmosphere).

Although the DIRSIG simulation parameters were different from the MISI collection parameters, a comparison of the spectral data for the locations highlighted above show spectral plots of similar shapes as shown below.



Radiance spectral plot of baseball diamond grass pixel from DIRSIG simulation (left) compared with MISI radiance spectral plot of a similar pixel from the image data (right). Radiance levels between the DIRSIG and MISI plots are comparable [0.014 W/(m^2 sr um) = $1.4 \cdot 10^4$ uW/(cm^2 sr um)] and wavelength values and band numbers correspond to the appropriate wavelength centers. Uncalibrated bands are represented as blank gaps in the MISI spectrum.

While the radiance levels are slightly different between the DIRSIG simulation and the MISI imagery, it should be noted that the atmospheric conditions for MISI include clouds in the downwelling sky radiance field which was not simulated in the DIRSIG scene. Of particular interest are MISI's ability to resolve water absorption features in the 820 and 940 nm region. Resolution of these spectral features holds potential for using the MISI data for model-based atmospheric correction techniques and analysis.

This year's calibration activities have incited improvements in the calibration procedures and facilities as well as general MISI instrument infrastructure. Based on the success and lessons learned from the architecture of the WASP imaging sensor, computer and electronic upgrades are being implemented jointly by DIRS and LIAS to not only improve the signal-to-noise ratio (SNR) and electronic stability and reliability of the system, but also streamline the data processing flow. This will result in a turnkey hardware and software environment both from the instrument operator's and data user's perspective which will transition MISI from an experimental system to a more operational asset for the remote sensing community.

5.0 Publications

5.1 Books and Journal Articles

Schott, J.R., Brown, S.D., and Barsi, J.A., 2004. Calibration of Thermal Infrared (TIR) Sensors, In J. Luvall & D. Quattrochi (Eds), Thermal Remote Sensing in Land Surface Processes., United Kingdom: Taylor & Francis.

Mandel, J., M. Chen, J.L. Coen, C.C. Douglas, L.P. Franca, C. Johns, R. Kremens, A. Puhalskii, A. Vodacek, W. Zhao. (In press 2004). Dynamic Data Driven Wildfire Modeling. To appear in: Dynamic Data Driven Applications Systems, F. Darema (Ed.), Kluwer, Amsterdam.

5.2 Published Proceedings

Scanlan, N.W., Schott, J.R. Brown, S.D., "Performance analysis of improved methodology for incorporation of spatial/spectral variability in synthetic hyperspectral imagery," Proceedings of SPIE, Vol. 5159, pp 319-330, San Diego, August 2003.

Bajorski, P., Ientilucci, E.J., Schott, J.R., "Comparison of Basis-Vector Selection Methods for target and Background Subspace as Applied to Subpixel Target Detection", Proceedings of the SPIE conference. In Proc. of SPIE Algorithms and Technologies for Multispectral, Hyperspectral, and Ultraspectral Imagery X, April 2004.

Mandel, J., M. Chen, L. P. Franca, C. Johns, A. Puhalskii, J. L. Coen, C. C. Douglas, R. Kremens, A. Vodacek, W. Zhao., A Note on Dynamic Data Driven Wildfire Modeling. In: Computational Science - ICCS 2004: 4th International Conference, Kraków, Poland, Proceedings, Part III. Lecture Notes in Computer Science, Springer. Vol.3038. pp. 725-731, June 6-9, 2004

Wang, Z., and A. Vodacek., Modeling wildland fire with DIRSIG. Visual Information Processing XIII., Proc. SPIE Vol. 5438. pp. 290-296

Erin M. O'Donnell, David W. Messinger, Carl Salvaggio & John R. Schott, "Identification and Detection of Gaseous Effluents From Hyperspectral Imagery Using Invariant Algorithms", Algorithms and Technologies for Multispectral, Hyperspectral, and Ultraspectral Imagery X, Proceedings of SPIE Vol. 5425, April 2004

David Pogorzala, David W. Messinger, Carl Salvaggio & John R. Schott, "Gas Plume Species Identification by Regression Analyses", Algorithms and Technologies for Multispectral, Hyperspectral, and Ultraspectral Imagery X, Proceedings of SPIE vol. 5425, April 2004

David W. Messinger, "Gaseous Plume Detection in Hyperspectral Images: A Comparison of Methods", Algorithms and Technologies for Multispectral,

Hyperspectral, and Ultraspectral Imagery X" Proceedings of SPIE vol. 5425, April 2004

Peter Bajorski, Emmett J. Ientilucci, and John R. Schott, "Comparison of Basis-Vector Selection Methods for Target and Background Subspaces as Applied to Subpixel Target Detection", Algorithms and Technologies for Multispectral, Hyperspectral, and Ultraspectral Imagery X, Proceedings of SPIE vol. 5425, April 2004

Erin D. Peterson, Scott D. Brown, Timothy J. Hattenberger, and John R. Schott, "Surface and Buried Landmine Scene Generation and Validation Using the Digital Imaging and Remote Sensing Image Generation (DIRSIG) Model", "Imaging Spectrometry X", Proceedings of SPIE vol. 5546, August 2004

Kris Barcomb, John R. Schott, Scott D. Brown, and Timothy J. Hattenberger, "High Resolution, Slant Angle Scene Generation and Validation of Concealed Targets in DIRSIG", Imaging Spectrometry X, Proceedings of SPIE vol. 5546, August 2004

Vodacek, A., R. Kremens, A. Ononye, and J. Faulring. (In press 2004), Remote Image and Field Data Collection for a Dynamic Fire Modeling System. In: Remote Sensing for Field Users. Proc. 10th Biennial USDA Forest Service Remote Sensing Applications Conference. Salt Lake City, UT. CD-ROM. Am. Soc. Photogram. Remote Sens.

Ononye, A., Vodacek, A., and Kremens, R., (In press 2004), Improved fire temperature estimation using constrained spectral unmixing. In: Remote Sensing for Field Users. Proc. 10th Biennial USDA Forest Service Remote Sensing Applications Conference. Salt Lake City, UT. CD-ROM. Am. Soc. Photogram. Remote Sens.

Li, Y., Vodacek, A., Kremens, R., and Ononye, A., (In press 2004), A Hybrid contextual fire detection algorithm using MODIS Imagery. In: Remote Sensing for Field Users. Proc. 10th Biennial USDA Forest Service Remote Sensing Applications Conference. Salt Lake City, UT. CD-ROM. Am. Soc. Photogram. Remote Sens.

Wang, Z., Vodacek, A., Kremens, R., and Ononye, A., (In press 2004), Modeling wildland fire with DIRSIG. In: Remote Sensing for Field Users. Proc. 10th Biennial USDA Forest Service Remote Sensing Applications Conference. Salt Lake City, UT. CD-ROM. Am. Soc. Photogram. Remote Sens.

Vodacek, A., Ononye, A., Wang, Z., and Li, Y., (In press 2004), Automatic estimation of direction of propagation of fire from aerial imagery. In: Remote Sensing for Field Users. Proc. 10th Biennial USDA Forest Service Remote

Sensing Applications Conference. Salt Lake City, UT. CD-ROM. Am. Soc. Photogram. Remote Sens.

Ononye, A., A. Vodacek, Y. Li, and Z. Wang., (In press 2004), Mapping of active fire area by image gradient technique using multi-spectral imagery. In: Remote Sensing for Field Users. Proc.10th Biennial USDA Forest Service Remote Sensing Applications Conference. Salt Lake City, UT.CD-ROM. Am. Soc. Photogram. Remote Sens.

David W. Messinger and John R. Schott, (In press 2004), "Minimum Detectable Target Concentrations of Gaseous Plumes: A Comparison of Active and Passive Systems", submitted to the Journal of the Intelligence Community Research and Development

5.3 **Technical Reports**

DiFrancesco, A.G. and C. Salvaggio, *ASD High Intensity Reflectance Probe (HIRP) Lamp Voltage Reconfiguration*, June 2004.

DiFrancesco, A,G. and C. Salvaggio, *Spectra Collection Protocol Visible, Near Infrared, and Shortwave Infrared Using the Cary 500 Spectrometer*, June 2004.
Smith, L. and C. Salvaggio, *Infrared Reflectance Field Collection Protocol*, June 2004.

DiFrancesco, A.G. and C. Salvaggio, *Reflective Spectral Measurement Traceability Protocol*, June 2004.

DiFrancesco, A.G. and C. Salvaggio, *Visible, Near Infrared, and Short Wave Infrared Spectrum Collection Protocol*, June 2004.

Weith-Glushko, S.A. and C. Salvaggio, Automatic Tie-Point Generation for Oblique Aerial Imagery: An Algorithm, RIT DIRS Report Number 01-1963-166, August 2004.

5.4 **Presentations**

Schott, J.R., Combining Physics-Based Models and Imaging Spectroscopy to Study the Earth, AIAA Symposium, Dayton, OH July 2003

Li, Y., and A. Vodacek. Modeling stream plumes in Conesus Lake. Int. Assoc. Great Lakes Res., Waterloo, Ont. May 24-28, 2004.

Adam Goodenough "Simulated Spectral Light Transport in Coastal Waters Using Adaptive Photon Mapping", presented at the SIGGRAPH 2004 conference, Los Angeles, CA, August 2004

6.0 DIRS Student Capstone Projects

This section contains not only this year's projects but, as an ongoing tribute to our students, a listing of all the projects completed by DIRS students.

6.1 Ph.D. Dissertations

Snyder, W., *An in-scene parameter estimation method for quantitative image analysis.* Unpublished doctoral dissertation, Rochester Institute of Technology, New York, 1994.
Feng, X., *Design and performance evaluation of a modular imaging spectrometer instrument*. Unpublished doctoral dissertation, Rochester Institute of Technology, New York, 1995.
Gross, H., *An image fusion algorithm for spatially enhancing spectral mixture maps*. Unpublished doctoral dissertation, U.S. Air Force, Rochester Institute of Technology, New York, 1996.
Kuo, D., *Synthetic image generation of factory stack and cooling tower plumes*. Unpublished doctoral dissertation, U.S. Air Force, Rochester Institute of Technology, New York,1997.
Fairbanks, R., *A characterization of the impact of clouds on remotely sensed water quality.* Unpublished doctoral dissertation, U.S. Air Force, Rochester Institute of Technology, New York 1999.
Sanders, L., *An Atmospheric Correction Technique for Hyperspectral Imagery.* Unpublished doctoral dissertation, Rochester Institute of Technology, New York, 1999.
Hernandez-Baquero, E., *Characterization of the Earth's surface and atmosphere from multispectral and hyperspectral thermal imagery*. Unpublished doctoral dissertation, Rochester Institute of Technology, New York, 2000.
Bishop, J., *Modeling of Plume Dispersion and Interaction with the Surround of Synthetic Imaging Applications*. Unpublished doctoral dissertation, Rochester Institute of Technology, New York, 2001.
Burton, Robin, Elastic LADAR Modeling for Synthetic Imaging Applications. Unpublished doctoral dissertation, Rochester Institute of Technology, New York, 2002, US Air Force.
Meyers, Jason, Modeling Polarimetric Imaging using DIRSIG. Unpublished doctoral dissertation, Rochester Institute of Technology, New York, 2002, US Air Force.
Lee, Kyungsuk, A Subpixel Target Detection Algorithm for Hyperspectral Imagery, Unpublished doctoral dissertation, Rochester Institute of Technology, New York, 2004.

6.2 M.S. Theses

A.J. Sydlik, 1981, "A technique for calculating atmospheric scattering and attenuation effects of aerial photographic imagery from totally airborne acquired data" Canadian Forces
Dennis Weiss, 1982, "The Effects of Mechanical Stress on Photographic Emulsions" Canadian Forces
Arthur Byrnes, 1983, "A Comparison Study of Atmospheric Radiometric Calibration Methods for Aerial Thermgrams" Canadian Forces
Jean Claude Croteau, 1983, "Comparison of Methods of MTF/OTF Analysis for Optical Systems" Canadian Forces
Lawrence Maver, 1983, "The effects of shadow visibility on image interpretability"
George Grogan, 1983, "A model to predict the reflectance from a concrete surface as a function of the sun-object-image angular relationship"
Ian. Macleod, 1984, "An airborne thermal remote sensing calibration technique" Canadian Forces
William Volchok, 1985, "A study of multispectral temporal scene normalization using pseudo-invariant features, applied to Landsat TM imagery"
Joseph Biegel, 1986, "Evaluation of quantitative aerial thermography"
Tim Hawes, 1987, "Land cover classification of Landsat thematic mapper images using pseudoinvariant feature normalization applied to change detection" U.S. Air Force
Carl Salvaggio, 1987, "Automated segmentation of urban features from Landsat thematic mapper imagery for use in pseudoinvariant feature temporal image normalization"
Denis Daoust, 1987, "Development of a Photometric Primary Transfer Standard for Reflectance Goniospectrophotometry" Canadian Forces
Wayne Farrell, 1987, "Investigation of the Accuracy of Array Radiometry for Measuring Pulsed Radiation Sources" Canadian Forces

Myra Bennett Pelz, 1989, "A robotic vision system for identifying and grasping objects" (M.S. Computer Science)
John Francis, 1989, "Pixel-by-pixel reduction of atmospheric haze effects in multispectral digital imagery"
Denis Robert, 1989, "Textural features for classification of images" Canadian Forces
Jan North, 1989, "Fourier image synthesis and slope spectrum analysis"
Michael Davis, 1990, "Bidirectional spectral reflectance field instrument"
Wendy Rosenblum, 1990, "Optimal selection of textural and spectral features for scene segmentation"
Eric Shor, 1990, "Longwave infrared synthetic scene simulation"
James Warnick, 1990, "A quantitative analysis of a self-emitting thermal IR scene simulation system"
Curtis Munechika, 1990, "Merging panchromatic and multispectral images for enhanced image analysis" U.S. Air Force
Xiaofan Feng, 1990, "Comparison of methods for generation of absolute reflectance factor measurements for BRDF studies"
Rolando Raqueño, 1990, "Automated boundary detection of echocardiograms" (M.S. Computer Science)
Jonathan Wright, 1991, "Evaluation of LOWTRAN and MOTRAN for use over high zenith angle/long path length viewing" U.S. Air Force
Craig Eubanks, 1991, "Comparison of ellipso-polarimetry and dark field methods for determining of thickness variations in thin films"
Marc Lapointe, 1991, "Substitution of the Statistical Range for the Variance in Two Local Noise Smoothing Algorithms" Canadian Forces
Robert Mericsko, 1992, "Enhancements to atmospheric correction techniques for multiple thermal images"
Gustav Braun, 1992, "Quantitative evaluation of six multi-spectral, multi-resolution image merger routines"
Sharon Cady, 1992, "Multi-scene atmospheric normalization of airborne imagery: application to the remote measurement of lake acidification"
David Ehrhard, 1992, "Application of Fourier-based features for classification of synthetic aperture radar imagery" U.S. Air Force
Bernard Brower, 1992, "Evaluation of digital image compression algorithms for use on lap top computers"
Donna Rankin, 1992, "Validation of DIRSIG an infrared synthetic scene generation model"
Craig Laben, 1993, "A comparison of methods for forming multitemporal composites from NOAA advanced very high resolution radiometer data"
Tom Servoss, 1993, "Infrared symbolic scene comparator"
Richard Stark, 1993, "Synthetic image generator model: application of specular and diffuse reflectivity components and performance evaluation in the visible region" U.S. Air Force
Eleni Paliouras, 1994, "Characterization of spatial texture for use in segmentation of synthetic aperture radar imagery"
Robert Rose, 1994, "The generation and comparison of multispectral synthetic textures"
Joseph Sirianni, 1994, "Heat transfer in DIRSIG an infrared synthetic scene generation model"
Gary Ralph, 1994, "Characterization of the radiometric performance of an IR scene projector" Canadian Forces
Jim Salicain, 1995, "Simulation of camera model sensor geometry effects"
Steven Nessmiller, 1995, "A comparison of the performance of non-parametric classifiers with gaussian maximum likelihood for the classification of multispectral remotely sensed data" U.S. Air Force
Serge Dutremble, 1995, "Temporal sampling of forward looking infrared imagery for subresolution enhancement post processing" Canadian Forces
Alexander J. Granica, 1996, "Modeling of the radiometric characteristics of a simulated flourescent imager"
Todd A. Kraska, 1996, "Digital Imaging and Remote Sensing Image Generation Model: infrared airborne validation & input parameter analysis" U.S. Air Force

Frank J. Tantalo, 1996, "Modeling the MTF and noise characteristics of an image chain for a synthetic image generation system"
Russell A. White, 1996, "Validation of Rochester Institute of Technology's (RIT's) Digital Image and Remote Sensing Image Generation (DIRSIG) model-reflective region" U.S. Air Force
Jeffrey Allen, 1997, "Methods of digital classification accuracy assessment"
Paul Llewellyn Barnes, 1997, "In-scene atmospheric correction for multispectral imagery"
Todd Birdsall, 1997, "The development of an analytical model for the Kodak digital science color infrared cameras and its aerial imaging applications"
Phil Edwards, 1997, "A Canadian Resource Guide for a Water Quality Study of Lake Ontario" Canadian Forces
Gary Robinson, 1997, "Evaluation of two applications of spectral mixing models to image fusion" U.S. Air Force
David Schlingmeier, 1997, "Resolution enhancement of thermal infrared images via high resolution class-map and statistical methods" Canadian Forces
Tom Haake, 1998, "Modeling Topography Effects with DIRSIG
David Joseph, 1998, "DIRSIG: A broadband validation and evaluation of potential for infrared imaging spectroscopy"
Julia Laurenzano, 1998, "A comparative analysis of spectral band selection techniques" U.S. Air Force
Francois Alain, 1999, "Simulation of Imaging Fourier Transform Spectrometers Using DIRSIG" Canadian Forces
Dilkushi Anuja de Alwis, 1999, "Simulation of the formation and propagation of the thermal bar on Lake Ontario"
Daisei Konno, 1999, "Development and Testing of Improved Spectral Unmixing Techniques"
Emmett Ientilucci, 1999, "Synthetic simulation and modeling of image intensified CCDs (IICCD)"
Pete Arnold, 2000, "Modeling and Simulating Chemical Weapon Dispersal Patterns in DIRSIG"
Julia Barsi, 2000, "MISI and Landsat ETM+ : thermal calibration and atmospheric correction"
Robert Gray, 2000, "Modeling Forests for Synthetic Image Generation" Computer Science
Mary Ellen Miller, 2000, "An approach for assessment of Great Lakes Water Quality using Remote Sensing"
Nicole Wilson, 2000, "Hyperspectral Imaging for Bottom Type Classification and Water Depth Determination"
Kirk Knobelspeisse, 2000, "Atmospheric Compensation for SeaWiFS Images of Lake Superior Utilizing Spatial Information"
John Klatt, 2001, "Error Characterization of Spectral Products using a Factorial Designed Experiment"
Andrew Fordham, 2002, "Band Selection and Algorithm Development for Remote Sensing of Wildfires"
Hyeun-Gu Choi, 2002, "Spectral Misregistration Correction and Simulation for Hyperspectral Imagery"
Darien Hammett, 2002, "A Study of Clutter Reduction Techniques in Wide Bandwidth HF/VHF Deep Ground Penetrating Radar", US Air Force.
James Jeter, 2002, "A Three-Dimensional Ray Tracing Simulation of a Synthetic Aperture Ground Penetrating Radar System", US Air Force
Neil Scanlan, 2003, "Comparative Performance Analysis of Texture Characterization Models in DIRSIG" Canadian Forces
Karl Walli, 2003, "Multisensor Image Registration Utilizing the LoG Filter and FWT", US Air Force

6.3 B.S. Projects

Jeffrey Sefl, 1983, "Determination of the transformation relationship of pseudo-invariant features of two Landsat images"
Kirk Smedley, 1986, "Imaging land/water demarcation lines for coastal mapping"
David Sapone, 1988, "Verification of a thermal model through radiometric methods"
Joshua Colwell and Eric Higgins, 1988, "Determination of the modulation transfer function of a thermal infrared line scanner"

Donald Marsh, 1989, "Photometric processing and interpretation of ratioed imagery by multispectral discriminate analysis for separation of geologic types"
Fred Stellwagon, 1989, "Classification of mixed pixels"
Brian Jalet, 1991, "Evaluation of methods of cloud removal in multidate NOAA/AVHRR imaging and its application to vegetational growth monitoring"
Mike Heath, 1991, "Perspective scene generation employing real imagery"
Stephen Ranck, 1991, "Establishment of a simple geographic information system utilizing digital data"
James Schryver, 1991, "Topographical analysis of a raster geographic information system"
Robert Rose, 1992, "Design of the information dissemination technique for a heat loss study"
Joseph Sirianni, 1992, "Production of realistic-looking sky radiance in the SIG process"
Andy Martelli, 1992, "Color calibration of an Agfa matrix QCR camera for Ektar 100 and 125 color print films"
Mike Branciforte, 1993, "An automated video tracking unit based on a matched filter segmentation algorithm"
Brian Heath, 1993, "Use of a quad cell in tracking a unit"
Debbie Wexler, 1993, "Texture generation using a stochastic model"
Michael Platt, 1994, "Evaluation of the feasibility of using digital terrain elevation models for the generation of multispectral images at Landsat resolution"
Cory Mau, 1994, "Incorporation of wind effects in IR scene simulation"
Paul Barnes, 1995, "Introduction of vegetation canopy models into DIRSIG"
Jeff Ducharme, 1995, "Atmospheric downwelled radiance"
Chip Garnier, 1995, "Integrating sphere calibration"
Jeff Allen, 1996, "Comparison of modeled and real vegetation imagery"
Emmett Ientilucci, 1996, "Blackbody calibration of MISI"
Charles Farnung, 1997, "DIRSIG camouflage phenomenology"
Peter Arnold, 1997, "BRDF approximation using a mathematical cone function"
Julia Barsi, 1997, "The generation of a GIS database in support of Great Lakes Studies"
Jason Calus, 1997, "Modeling of focal plane geometry in DIRSIG"
Arnold Hunt, 1997, "Validation of BRDF model in DIRSIG"
Michael C. Baglivio, 1998, "Error Characterization of the Alpha Residuals Emissivity Extraction Technique"
Brian Bleeze, 1998, "Modeling the MTF and Noise Characteristics of Complex Image Formation Systems"
Chia Chang, 1998, "Evaluation of Inversion Algorithms on DIRSIG Generated Plume Model Simulations"
Peter Kopacz, 1998, "Simulation of Geometric Distortions in Line Scanner Imagery"
Jason Hamel, 1999, "Simulation of Spectra Signatures of Chemical Leachates from Landfills"
Daniel Newland, 1999, "Evaluation of Stepwise Spectral Unmixing with HYDICE Data"
J. Meghan Salmon, 2000, "Derivative Spectroscopy for Remote Sensing of Water Quality"
Janel Schubbuck, 2000, "Thermal Calibration of MISI"
Robert Light, 2001, "Hamamatsu R5900-01-L16 Photomultiplier Tube Spectral / Spatial Characterization"
Matt Banta, 2001, "Lunar Calibration Techniques"
Christy Burtner, 2001, "Texture Characterization in DIRSIG"
Adam Goodenough, 2001."Evaluating Water Quality Monitoring with Hyperspectral Imagery"
Erin O'Donnell, 2001, "Historical Radiometric Calibration of Landsat 5"
Nikolaus Schad, 2001, "Hyperspectral Classification with Atmospheric Correction"
Cindy Scigaj, 2001, "Design and Implementation of a LIDAR Imaging System"
Eric Sztanko, 2001. "Imaging Fourier Transform Spectrometer: Design, Construction, and Evaluation"
Eric Webber, 2001, "Sensitivity Analysis of Atmospheric Compensation Algorithms for Multispectral Systems Configuration"
Adam Cisz, 2002, "Multispectral Fire Detection: Thermal/IR, Potassium, and Visual"
Rose of Sharon Daly, 2002, "Polarimetric Imaging"
Matthew D. Egan, 2002, "Detection and Analysis of Industrial Gas Plumes"

Carolyn S. Kennedy, 2002, "The Testing and Assessment of Texturing Tools Used to Build Scenes in DIRSIG"
David Pogorzala, 2002, "Setting Fire to CIS, Small - Scale Combustion Chamber and Instrumentation"
Jonathan Antal, 2002, "Error Characterization of Hyperspectral Products with Emphasis on Atmospheric Correction Techniques"
Kenneth R. Ewald, 2002, "Creation of ISO Target 16067-1"
Jared Clock, 2003, "Inexpensive Color Infrared Camera"
Gary Hoffmann, 2003, "Visual Enhancement of the Archimedes Palimpsest Using a Target Detection Algorithm"
Jill Marcin, 2003, "Effects of Contamination on Spectral Signatures"
Brandon Migdal, 2004, Watermark Extraction Methods For Linearly Distorted Images to Maximize Signal-to-Noise Ratio
Alvin Spivey, 2004, An approach to synthetic scene completion and periodic noise removal by image inpainting and resynthesis.
Seth Weith-Glushko, 2004, Automatic Tie-Point Generation for Oblique Aerial Imagery: An Algorithm

7.0 Special Events

7.1 LASS Board of Advisors Meeting

The LASS Board of Advisors meeting for 2004 was held at RIT on June 10th. The purpose of this meeting is to provide an annual update to the government agencies and industry partners that financially support the LASS research agenda. This years' meeting was well attended with over thirty participants from all over the country, including ten individuals who are participating in the National Reconnaissance Office's Technical Fellows program.

A significant portion of the meeting was dedicated to technical presentations by RIT faculty, staff, and students. This provided opportunity for the partners to better understand the project scope and status, as well as, gaining a better appreciation for the research capabilities in the DIRS group. Key projects briefed included:

- DIRSIG Sensor Model Upgrades
- MegaScene 1 and 2
- Target Detection and Algorithm Survey
- Gas Detection and Quantification Algorithms
- Spectral Measurements Activity
- MegaCollect
- NURI Algorithm Implementation
- Wildfire Airborne Sensor Project (WASP)
- Sparse Aperture Modeling
- Distributed Sensors Initiative

The meeting concluded with two hours of open discussion. The purpose of this discussion is to solicit feedback from the partners and to enable an interactive discussion on technology trends that RIT should consider as it evolves its academic and research agenda.