Rochester Institute of Technology

Digital Imaging and Remote Sensing Laboratory

Annual Report for the 2005 Academic Year
(July 1, 2004 – June 30, 2005)

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

Prepared by Dr. John Schott

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1.0 Foreward

The DIRS Lab has had another year full of hard work, successful graduates and significant results on our research efforts. This report tries to capture some of the highlights of the research results over the last year in the research summaries. We also try to provide a glimpse at the cumulative history of the DIRS program by capturing at the end of the report a listing of student projects over the last 20+ years. As in all science we stand on the shoulders of those who have gone before us. In the classrooms and labs we teach the students to search out and build on the best ideas the world has to offer. The not-invented-here (NIH) syndrome is a virus that can cripple a research group. At the same time we recognize that both we and our collaborators/competitors are drawing heavily on the work of the students and research teams whose work is captured in the cumulative student projects section. I was vividly reminded of the role our graduates play in the remote sensing/image analysis community when I spoke this week with a graduate of many years ago. We hadn't talked in a while and in a few moments of catching up he reminded me of a half dozen of his classmates who were all still very active in the core remote sensing business supporting government and industry in research, development and production activities. It reminded me of the long term and far reaching impact the remote sensing and image science program at RIT has had and continues to have on the community.

With that in mind I'd like to acknowledge the confidence our sponsors show in the faculty, staff and students through their support of our research programs. This year 18 faculty and staff and approximately 45 students (Ph.D., Masters, Undergraduates, and High School interns) moved the research engine forward and produced the results reported here. Each project is the responsibility of a team of faculty, research staff and students. The contributions are listed individually in the personnel section and I want to thank them here collectively for their support in the past year.

I also want to acknowledge once again the support of Frederick Wiedman who endowed the chaired professorship I hold. Mr. Wiedman endowed the chair in the name of his parents, Frederick and Anna B. Wiedman to encourage and support the teaching and mentoring of students. Often, particularly as I walk up the main stair case on the Center past his portrait or search for a way to cover the expenses for a student when a grant ends and the thesis work hasn't, I am reminded how Fred's generosity and foresight have enabled much of what goes on in the research group.

2.0 The DIRS Group

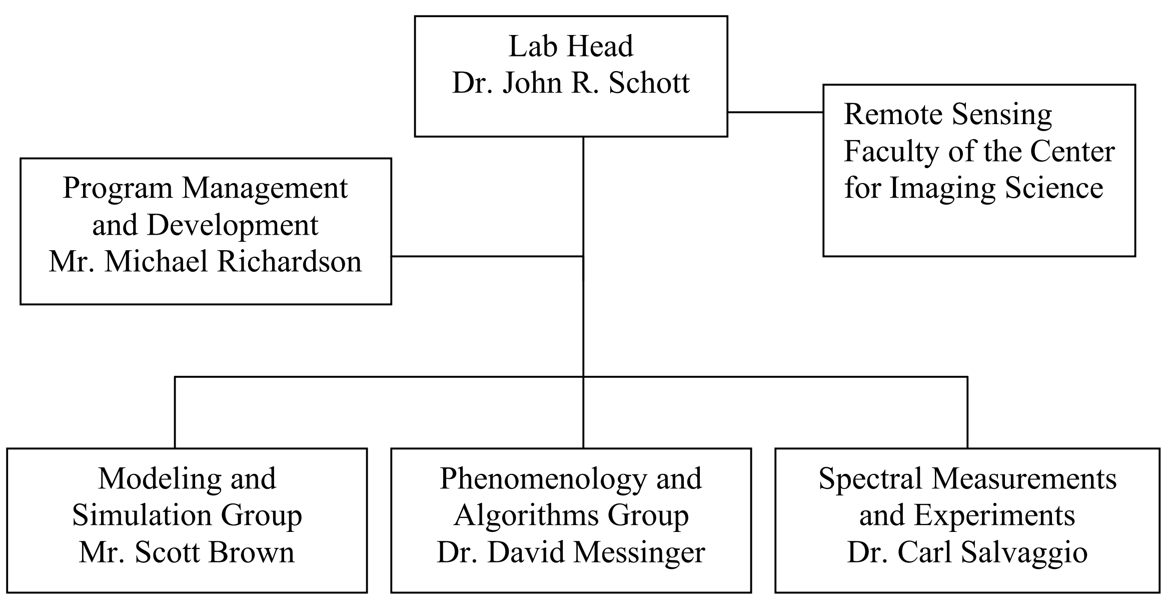
2.1 DIRS Background

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

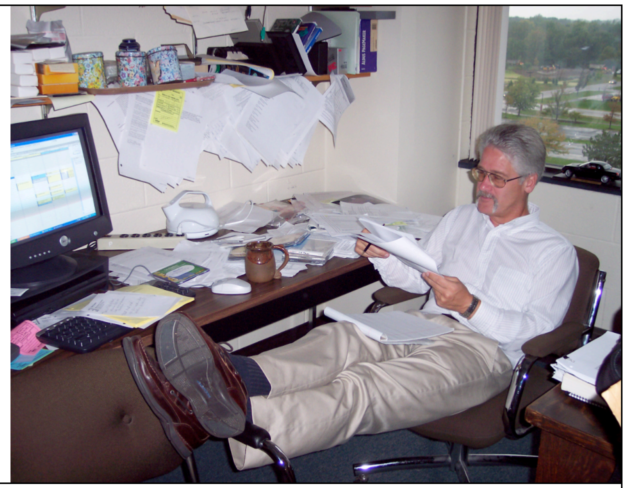
The DIRS Lab is managed using a matrix approach where faculty and senior research staff manage programs to generate research results, student thesis and meet sponsor requirements. The research staff, organized into three overlapping groups managed by group leaders, supports the needs of the research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



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 <u>Research Interests</u>: - Hyperspectral data analysis and algorithm development - Multi and hyperspectral instrument development - Synthetic scene generation <u>Contact Information</u>: 585-475-5508 schott@cis.rit.edu	
	**Dr. Anthony Vodacek** Associate Professor <u>Research Interests</u>: - Environmental applications of remote sensing - Forest fire detection and monitoring - Active and passive sensing of water quality <u>Contact Information</u>: 585-475-7816 vodacek@cis.rit.edu

Dr. Carl Salvaggio
Associate Professor

Research Interests:
- Novel techniques and devices for optical property measurement
- Applied image processing and algorithm development
- Image simulation and modeling

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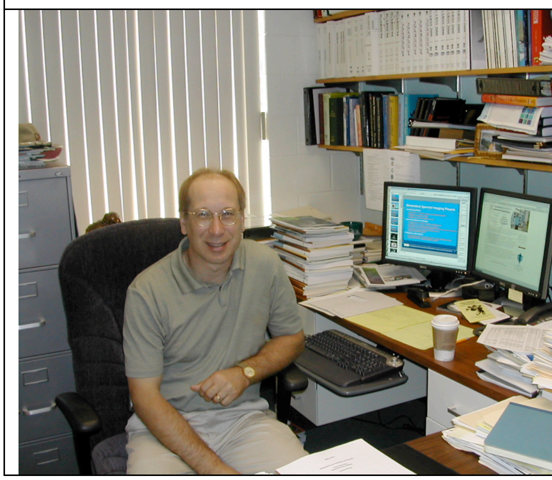
585-475-6380
salvaggio@cis.rit.edu



Dr. John Kerekes
Associate Professor

Research Interests :
- Image processing and algorithm research
- Image chain modeling and parametric analysis

Contact Information :
585-475-6996
kerekes@cis.rit.edu

The Research Team

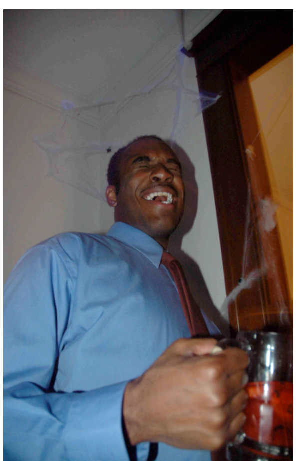
Scott Brown Scientist	Group Lead, Modeling and Simulation	(585) 475-7194 brown@cis.rit.edu
Timothy Gallagher Technical Associate	Instrument Development and Calibration	(585) 475-2781 gallagher@cis.rit.edu
Timothy Hattenberger Junior Scientist	Modeling and Simulation Applications	(585) 475-4567 hattenberger@cis.rit.edu
Dr. Emmett Ientilucci Associate Scientist	Advanced Algorithm Development	(585) 475-7778 ientilucci@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

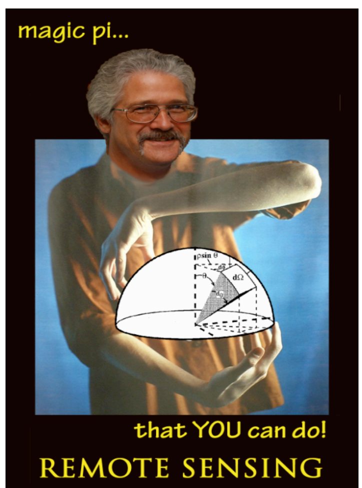
Dr. Ambrose Ononye Post Doctoral Scientist	Wild land Fire Research and Data Processing	(585) 475-5037 ononye@cis.rit.edu
David Pogorzala Assistant Scientist	Thermal Analysis and Modeling	(585) 475-5388 pogo@cis.rit.edu
Nina Raqueño Assistant Scientist	GIS, Data Processing, and Database Devel.	(585) 475-7676 nina@cis.rit.edu
Dr. Rolando Raqueño Scientist	Water Analysis and Modeling	(585) 475-6907 rolando@cis.rit.edu
Michael Richardson Distinguished Researcher	Project Management and Program Development	(585) 475-5294 richardson@cis.rit.edu
Niek Sanders Junior Software Dev.	Simulation Software Development	(585) 475-7371 sanders@cis.rit.edu
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

The Student Team

Andy Adams	Mike Foster	Dave Pogorzala
May Arsenovic	Adam Goodenough	Becky Ruby
Nancy Baccheschi	David Grimm	Cindy Scigaj
Kris Barcomb	Jason Hamel	Jesse Schott
Brent Bartlett	Rob Introne	Jim Shell
Dan Blevins	Marek Jakubowski	Alvin Spivey
Noah Block	Scott Klempner	Brian Staab
Marvin Boonmee	Steve Lach	Tom Schwarting
George Brown	Brian Leahy	Ken Smith
Pierre Chouinard	Yan Li	Kristen Strackerjan
Adam Cisz	Ying Li	Mahek Sujan
Brian Daniel	Domenic Luisi	Zhen Wang
Jeff Dank	Brian McMullen	Jason Ward
Chabitha Devaraj	Ben Miller	Matt Weinstock
Brian Dobbs	Erin O'Donnell	Jason West
Gabriel Dore	Erin Peterson	Seth Weith-Glushko
		Yushan Zhu

United States Air Force and Canadian Forces Officers
in our graduate program (record number) Fall 2004





Faculty, staff, students and alumni at SPIE Orlando, March 2005

3.0 Research Project Summaries

2005 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 Office of Naval Research (ONR) Multi-disciplinary University Research Initiative (MURI)

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

Project Scope: Development of exploitation algorithms for hyperspectral imagery using physics based models.

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), David Messinger

Task Scope: This task seeks to develop algorithms to retrieve atmospheric parameters from Longwave (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.

Task Status: An algorithm for the purpose of land surface temperature (LST) and emissivity retrieval from long wave infrared airborne hyperspectral imagery is described below. The algorithm consists of a preprocessing module, a near-blackbody pixels search loop, and a constrained optimization loop. The maximum brightness temperature per pixel is used for an initial estimate of LST. Estimates for atmospheric transmittance and upwelling radiance are determined by fitting a linear equation to the observed radiance versus blackbody radiance scatterplot for each band. A search for near-blackbody pixels, designed to improve the estimated atmospheric parameters, determines which pixels were under- or over-fitted by the linear regression. The downwelling radiance is estimated from the upwelling radiance by applying a LUT. The LUT coefficients are based on a polynomial regression of MODTRAN runs for the same sensor altitude. A constrained optimization of the atmospheric parameters using generalized reduced gradients allows the blackbody assumption to be removed and ensures physical results. The optimization maximizes the spectral smoothness of the retrieved emissivities. The LST and emissivity per pixel are retrieved simultaneously by compensating the observed radiance using the estimated atmospheric parameters and varying the surface temperature for the smoothest emissivity. The new algorithm can retrieve LST within ± 2.0 K, and emissivities within ± .02 based on numerical simulation of a wide range of targets including low emissivity targets.

3.1.2 Littoral Zone Modeling – Photon Mapping

Research Team: Adam Goodenough (Ph.D. student)

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 for water quality parameter retrieval 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 Suspended Sediment Modeling

Research Team: Jason Hamel (M.S. student), Rolando Raqueño

Task Scope: This task is focused on the analysis of remote sensing data to determine in-water constituents.

Task Status: While many studies have worked to identify correlations between water constituents and the radiance leaving the waters surface, little has been done to examine the effect of, and compensate for, the atmosphere between the water's surface and the sensor making the measurements. Typical atmospheric compensation algorithms over water assume there is zero radiance leaving the water in the 700-950 nm region due to the high absorption of water. This might be a valid assumption in clear ocean waters, but recent studies show that this does not hold true for waters containing suspended sediment as commonly found in coastal or river areas. To analyze the effect suspended sediments have on atmospheric compensation attempts, a spectral database of water reflectance curves associated with varying suspended mineral compositions, particle size distributions, and concentrations was generated using two modeling tools: Ocean Optical Plankton Simulator (OOPS) and Hydrolight. It is easy to see from Figure 3.1.3-1 that even for the most absorbing cases run, hypereutrophic waters will contain some significant water leaving radiance in the 700-950 nm region. Initial analysis of the database has also identified spectral vectors potentially allowing discrimination of spectra based on concentration (cf. Figure 3.1.3-2).

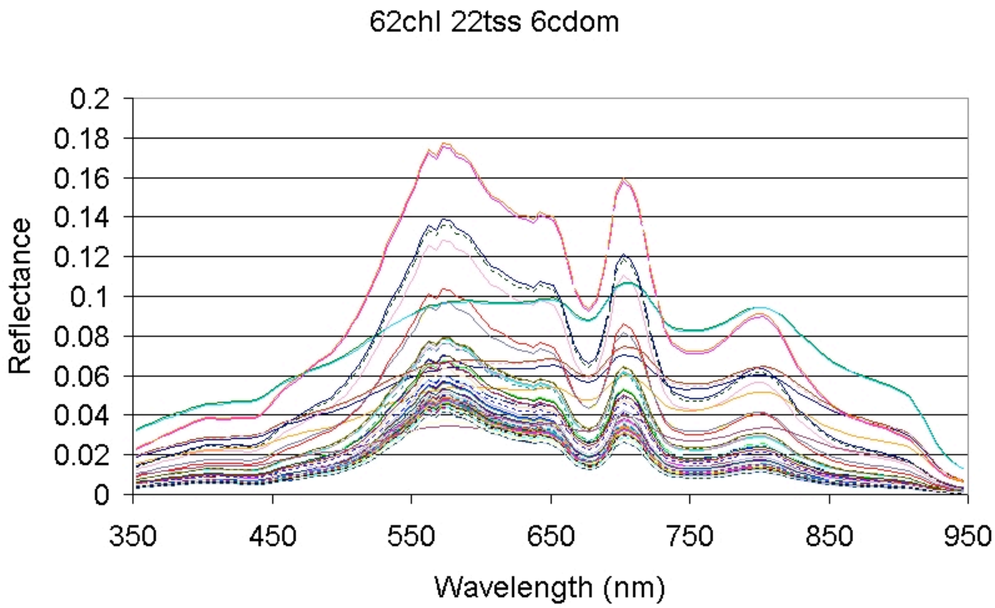
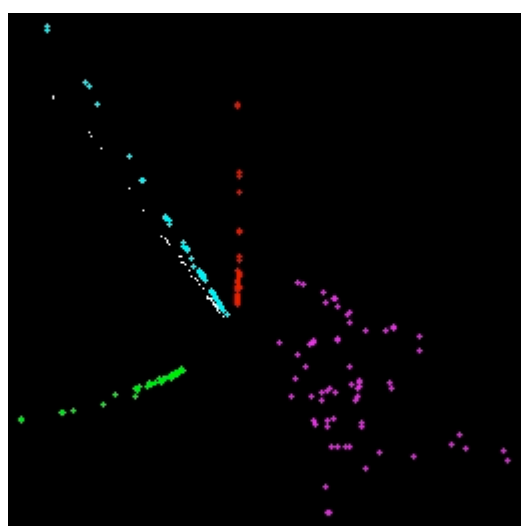


Figure 3.1.3-1: Example Reflectance Spectra of a Hypereutrophic Pond. This plot shows the effect of different compositions and particle size distributions but the same concentration of chlorophyll, suspended minerals, and colored dissolved organic matter

Figure 3.1.3-2: 3D Visualization of Spectral Space. This plot shows clear differentiation between the five concentrations used when building this database. The color key is for different concentration mixes within which only the suspended materials particle size distribution is varied



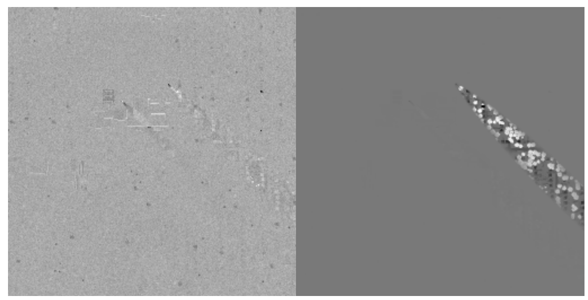
3.1.4 Gaseous Effluent Detection

Research Team: Erin O'Donnell (M.S. student), David Pogorzala (M.S. student), Carl Salvaggio, David Messinger

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.

Figure 3.1.4-1: Detection of a 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 (cf. Figure 3.1.4-1). 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 issue.

3.1.5 Material Identification

Research Team: Emmett Ientilucci (Ph.D. student), John Schott

Task Scope: 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 is the sponsor. RIT is on a team led by Georgia Tech.

Research Team: Tim Hattenberger, David Messinger

Project Scope: RIT is providing synthetic data to be used by other team members in the development and parametric testing of Automatic Target Recognition (ATR) Algorithms. Two scenes of interest have been identified by the MURI team: a Longwave Infrared scene containing a landmine field and a Visible – Near Infrared – Shortwave Infrared scene containing concealed targets.

Project Status: This program is three and one half years through a three year grant that has been extended for two years.

3.2.1 Minefield DIRSIG Simulation

Research Team: Erin Peterson (M.S. student), John Schott

Task Scope: RIT has created and delivered a synthetic scene representative of a surface and buried landmine field to be interrogated 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, serving as a reliable method for the creation of several representative datasets under a variety of viewing and target placement conditions.

Task Status: An original version of the scene was created as part of Erin Peterson's Master's thesis and delivered to the MURI team. Since then, several improvements to the scene have been made and a number of scene variants were created and delivered to the MURI team. These variations include:

- Inclusion of asymmetric targets (non-"circular" targets)
- Asymmetric target placement within the scene (non-uniform field)
- Several manifestations of the intervening atmosphere
- Several sensing altitudes providing various spatial resolutions
- Several different times of day

These variations were developed after consultation with the MURI team and were designed to further stress the ATR algorithms.

The figure below shows the comparison between the original (real) data set, the original scene simulating that data set, and the newest renderings building off the original scene. The original image and the simulation are of a 1400ft collect. The simulation on the right was for a sensor at 2000ft, has a different target map, a different spatial background clutter map, a different atmosphere, and was rendered at a different time than the original scene.

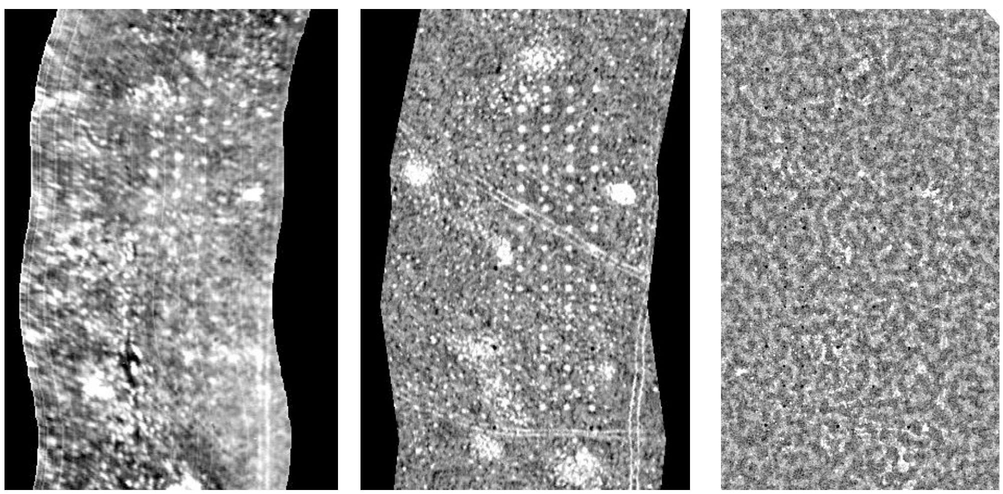


Figure 3.2.1-1: Left hand image is actual collected data. Center image is synthetic scene validated against real data. Right hand image is new rendering incorporating variations described in the text. Note that no sensor roll effects have been simulated in the image on the right. All images are in the LWIR portion of the spectrum.

3.2.2 Concealed Target DIRSIG Simulation

Research Team: Kris Barcomb (M.S. student), John Schott

Task Scope: The second topic of interest under this program is the development of automatic target recognition algorithms for concealed surface targets in Visible and Near Infrared (VNIR) 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). RIT is using this experience to develop and validate a high spatial resolution, hyperspectral synthetic scene containing concealed targets of military interest.

Task Status: The site of the concealed target scene has been selected and construction of the scene has begun. Several considerations were taken into account when choosing the site of the concealed target scene. The scene should be amenable to several types of concealment such as camouflage netting, tree canopies, and a mixture of the two. Additionally, the scene should provide an adequate setting for targets of interest such as Improvised Explosive Devices (IEDs) along roadsides. From a scene modeling perspective, the area should have a high fidelity data set collected over the area for validation studies. There should also be sufficient ground truth of the area and environment to enable accurate modeling.

The site for the concealed target scene is part of Northeast Rochester, NY (cf. Figure 3.2.2-1). In June 2004, RIT participated in a major collections experiment in this area involving several passive sensors, extensive ground truth, and relevant target placement for this program. Significant to this modeling effort, the area was imaged with the COMPASS sensor (hyperspectral, 256 spectral bands, Vis / NIR / SWIR, GSD = 1 m) and the RIT WASP sensor (multispectral, Vis / SWIR, GSD = 6 in). Targets were placed under camouflage netting and tree canopies. Additionally, the scene provides a tree line and a sparsely populated forest, ideal for the placement of concealed targets, and a dirt road along which IEDs may be placed if the relevant phenomenology becomes available. A high spatial resolution image of the target scene is shown in the figure below. Scene construction continues and will be completed in Fall/Winter of 2005 – 2006. The original version of the concealed target scene is due to be delivered to the MURI team in January 2006.

Figure 3.2.2-1: High spatial resolution overhead image of the site for the Concealed Target Scene to be developed under the ARO MURI program. Note the targets under camouflage netting and in the sparse trees.

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).

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 Nov 1, 2005. The third tool, gaseous effluent detection and analysis, has been implemented outside of the ENVI environment and final implementation and delivery will take place in the Fall / Winter of 2005 – 2006.

3.3.1 Subpixel Invariant Algorithm

Research Team: Emmett Ientilucci, Rolando Raqueño, David Messinger

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 the NGA and NURI team members on January 1, 2004 in its completed form. Work on the general method has continued as part of Emmett Ientilucci's Ph.D. project.

3.3.2 Contaminated Surface Detection Algorithm

Research Team: Emmett Ientilucci, 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 (in a similar manger as 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 developed to accomplish the goal of concealed and contaminated target detection and an initial implementation of the algorithm has been achieved. Testing of the algorithm has begun and will be completed by the end of the summer in 2005. It is anticipated that a cyclical test, evaluation, and development process will be required to fully explore the algorithm before final implementation is completed. Delivery is anticipated in November of 2005.

3.3.3 Gas Detection and Analysis

Research Team: Erin O'Donnell (M.S. student), David Pogorzala (M.S. student), David Messinger

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 is hyperspectral imagery however this application is different in that the spectral regime of interest is 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.

3.4 WASP Phase 2

Research Team: Harvey Rhody, Don McKeown, Mike Richardson, Jason Faulring, Bob Krzaczek, Scott Lawrence, Jangho Park (B.S. student), Shari McNamara (M.S. student), Xiaofeng Fan (student), Don Light (consultant)

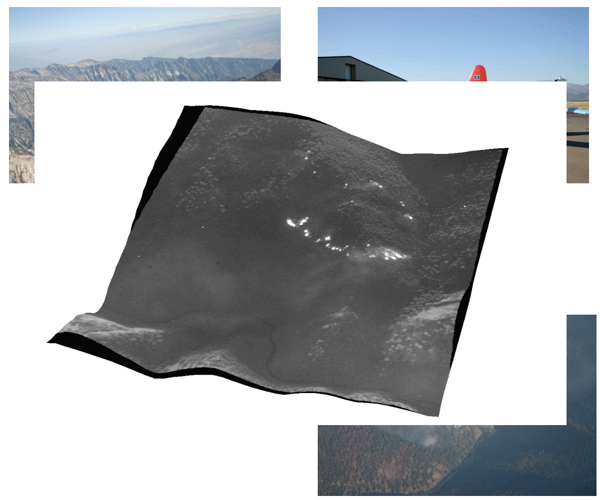
Sponsor(s): NASA

Project Scope: The project was a successful prototype deployment of a complete wildfire detection and mapping system.

Project Status: Appropriations garnered by Congressman Jim Walsh have been instrumental in establishing a research capability that directly supports NASA through the Ames Research Center in its mission to support Disaster Management. These activities have close alignment with NASA's Disaster Management Program Element of the Science Mission Directorate. This focus area for NASA is specifically called out on page 3 of the FY2005-2009 Plan for the Science Mission Directorate Applied Sciences

Program (10 Feb 2005 v1.5). As a result of our research activities, RIT is also an active participant on a national advisory committee, the Tactical Fire Remote Sensing Advisory Committee, chaired jointly by NASA Ames and the USFS Remote Sensing Applications Center (RSAC). The committee advises NASA and the USFS on the transfer of new technologies from NASA to USFS wildfire management programs. Over the last 3 years, work on the Wildfire Airborne Sensor Program (WASP) has led to the successful demonstration deployment of wildfire detection and mapping system over wildfires in Montana and Idaho. The deployment in August 2005 was conducted in collaboration with the USFS Missoula Fire Sciences Lab and the National Center for Landscape Fire Analysis at the University of Montana.

Figure 3.4-1 WASP Example Imagery. WASP has shown the ability to accurately map areas of fire. The figure at left shows imagery from Montana/Idaho including an infrared image (at center) of the SEEPAY II fire mapped onto a 3D terrain model.



RIT has reached out to the local emergency management community --the Monroe County Office of Emergency Preparedness (MC/OEP) to look for ways to employ NASA sponsored innovative sensor technology for local applications. The opportunities presented by new technologies and methods have been met with great enthusiasm by members of the MC/OEP which include the Rochester Fire Department, Rochester Police Department, Monroe County Sheriff's Department, as well as city and county SWAT teams.

The research has had benefits in environmental studies as well. The WASP sensor was recently flown in support of NYS DEC mapping of the Indian and Hudson Rivers. The object of the mission is to determine the impact of temperature changes on the river fisheries. The figure at right shows the relatively warm waters of the Indian River (seen as a lighter shade of gray) mixing with the Hudson River after a controlled release of water from the Lake Abanake Dam.

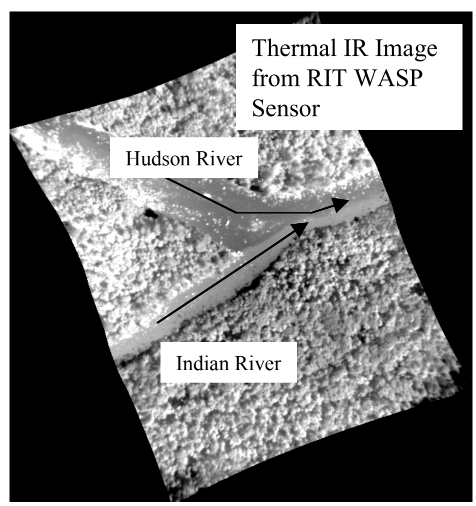


Figure 3.4-2 WASP Environmental Application Thermal mapping of the Indian and Hudson rivers.

3.5 The Laboratory for Advanced Spectral Sensing (LASS)

Research Team: Entire DIRS faculty, research staff, and students

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

Project Scope: LASS was founded in 2001 as a research incubator focused on pre-competitive research in the area of spectral remote sensing. The LASS partners commit to a multi-year funding commitment, backed by a detailed statement of work and project plan. A key element of the LASS philosophy has been that the research results are not only shared with the sponsor, but with all the LASS partners so that each member shares equally in the research results. Research focus areas mimic the key capabilities of the DIRS group that include: modeling and simulation, algorithms and phenomenology, and measurements and experiments. The funded support from the LASS partners has been critical to allow us to continue the development of our modeling and simulation software package, DIRSIG and enabled us to continue to expand our spectral material database.

3.5.1 MegaScene 2

Research Team: Jeff Dank (B.S. student), Tim Hattenberger

Task Scope: MegaScene 2 is the second large-scale scene development and 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 line scanners. MegaScene attempts to capture the spatial and spectral complexity of the real world.

The first MegaScene effort was a learning experience; Megascene 2 is an effort to utilize the scene building techniques learned in the first effort in addition to developing new methods. Additional 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. The details of the tool development are beyond the scope of this document. 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 are in accordance with that type of evironment. 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 for simulating an inhomogeneous atmosphere. The atmosphere can now be varied both vertically and horizontally.

Task Status: 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 plant) sites have been identified as placeholders for the industrial component of the new scene. The site is being researched further in terms of accessibility

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 are made with this software, and in turn, used to model the objects in a CAD environment.

Figure 3.5.1-1: Oblique aerial photograph of Trona, CA courtesy of Pictometry

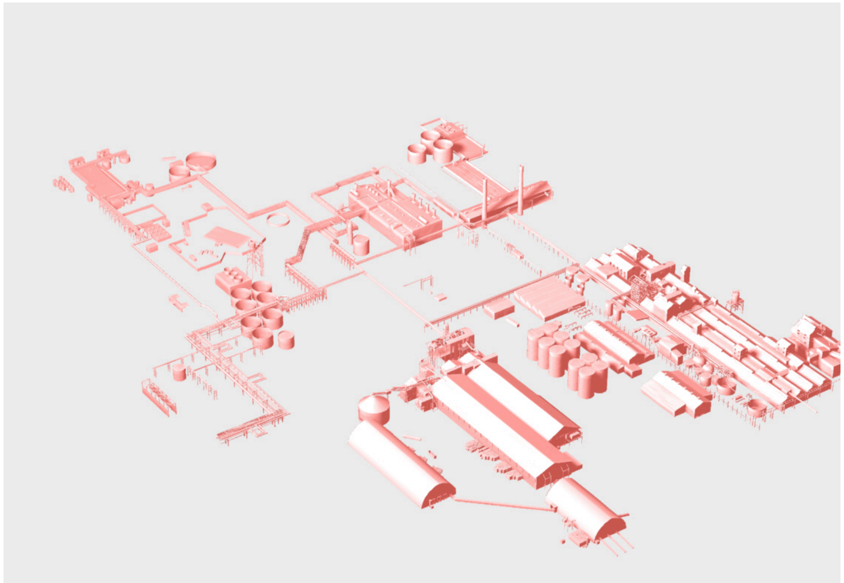


Figure 3.5.1-2: Simple rendering of structures modeled from Trona. Note the high level of geometric fidelity

3.5.2 Spectral Measurements

Research Team: Lon Smith, Emily Antoine (B.S student), Mike Fuller (B.S. student), Sarah Paul (B.S. student), Jesse Schott (B.S. student), Carl Salvaggio

Task Scope: The success of both exploitation algorithms and simulation and modeling hinges on the available data. The data collection carried out as part of the LASS effort directly supports these activities by identifying and measuring materials requested by 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, several thousand spectral measurements have been made. The most recent measurements made under this effort have been collected with a battery of instruments that allow near simultaneous collection across the full spectrum (0.4 to 14 microns). While only a limited number of these spectra currently exist in our publicly available, web-accessible database (see Figure 3.5.2-1), the remainder are poised for ingestion in the very near future. Most of these spectra contain multiple observations for use in deriving descriptive statistics for modeling and exploitation algorithms, along with full metadata records for every measurement taken.

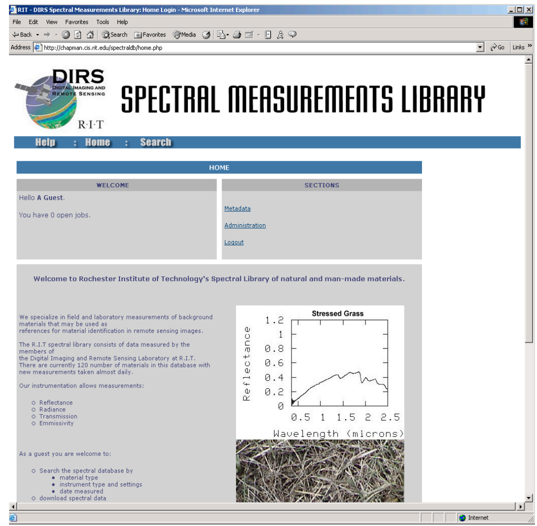


Figure 3.5.2-1: The Digital Imaging and Remote Sensing Laboratory online spectral database can be accessed from: http://www.cis.rit.edu/~cnspci/measurements/. A personalized login can be obtained from Nina Raqueño (nina@cis.rit.edu).

3.5.3 Sparse Aperture Modeling

<u>Research Team</u>: Noah Block (M.S. student), John Schott

<u>Task Scope</u>: Optical sparse-aperture telescopes represent a promising new technology to increase the effective diameter of an optical system while reducing its weight and stowable size. The sub-apertures of a sparse-aperture system are phased to synthesize a telescope system that has a larger effective aperture than any of the independent sub-apertures. Sparse-apertures have mostly been modeled to date using a “gray-world” approximation where the input is a grayscale image. The gray-world model makes use of a polychromatic” optical transfer function (OTF) where the spectral OTFs are averaged to form a single OTF. This OTF is then convolved with the grayscale image to create the resultant sparse-aperture image. The model utilized on this task uses a spectral image-cube as the input to create a panchromatic or multispectral result. These outputs better approximate an actual system because there is a higher spectral fidelity present than a gray-world model. Unlike its Cassegrain counterpart that has a well behaved OTF, the majority of sparse-aperture OTFs have very oscillatory and attenuated natures. When a spectral sparse-aperture model is used, spectral artifacts become apparent when the phasing errors increase beyond a certain threshold. This threshold can be based in part on the type of phasing error (i.e. piston, tip/tilt, and the amount present in each sub-aperture), as well as the collection conditions, including configuration, signal-to-noise ratio (SNR), and fill factor.

This research addresses whether integrating restored multispectral sparse-aperture images into a panchromatic image will decrease the amount of spectral artifacts present. The restored panchromatic image created from integrating multispectral images is compared to a conventional panchromatic sparse-aperture image. Conclusions are drawn through image quality analysis and the change in spectral artifacts.

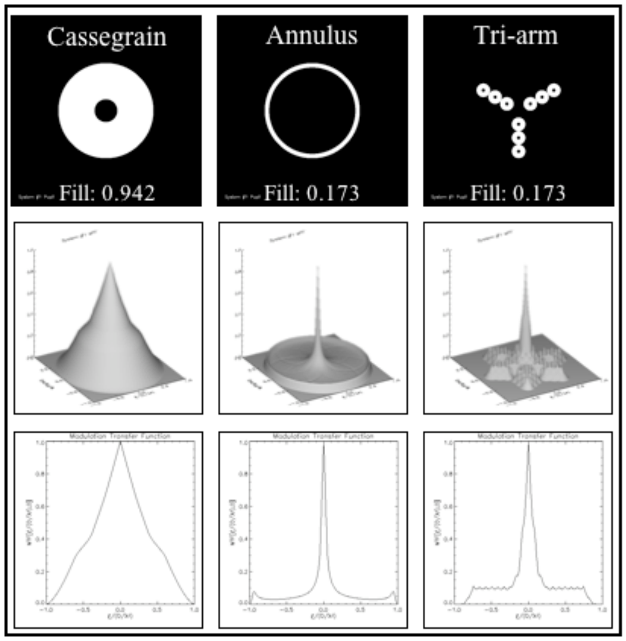


Figure3.5.3-1. The Cassegrain, annulus, and tri-arm telescope configurations. The Cassegrain is the standard telescope used, the annulus is a very sparse Cassegrain, and the tri-arm is a configuration of sub-apertures. The bottom row is their corresponding MTFs.

<u>Task Status</u>: Two examples of the type of sparse aperture system configurations studied are shown in Figure 3.5.3-1. The annulus in Figure 3.5.3-1 is included to show what happens as the central obscuration of the Cassegrain telescope increases, and its corresponding effect on the modulation transfer function (MTF).The MTF is the magnitude of the OTF. The tri-arm configuration is used for the simulations in this experiment.

It has been shown that spectral artifacts are not a noticeable problem with systems that have low amounts of phasing errors. Figure 3.5.3-2 shows the spectral curves for wavelengths 0.45m, 0.55m, and 0.65m. These curves are a representative sample of how much the MTF scan varies with respect to wavelength. Figure 3.5.3-2(a) shows that the spectral MTFs for unaberrated systems have oscillations, but the magnitude stays fairly constant across the mid to high-range frequencies and the oscillations are not very large. The amount of aberrations introduced in to the pupil is described as the λ rms-error, this is the mean phase error expressed as the average deviation in optical path distance (OPD) in multiples of λ.

When phasing-error is introduced as shown in Figure 3.5.3-2(b), the mid and high range frequencies are no longer fairly constant valued, but now oscillate wildly, with peaks of one spectral OTF correspond to the trough of another. The effect of the aberrated MTFs on a restored image is easier to understand if we consider the restoration filters. A restoration filter used to boost degraded but still significant frequencies in one spectral region will also end up boosting severely degraded frequencies in another band resulting in noise amplification and/or generation of image artifacts

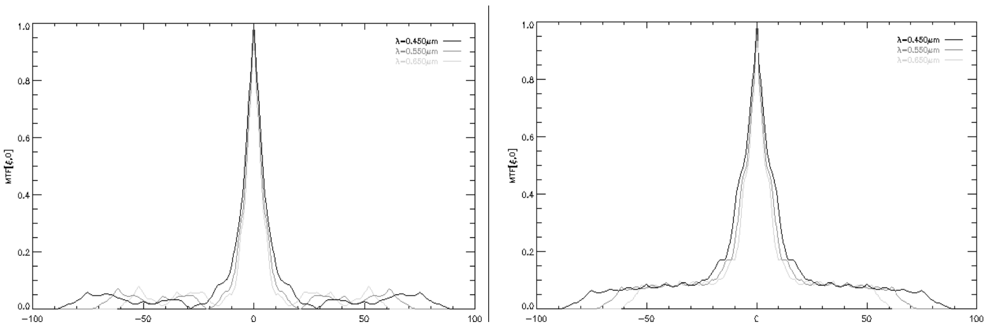
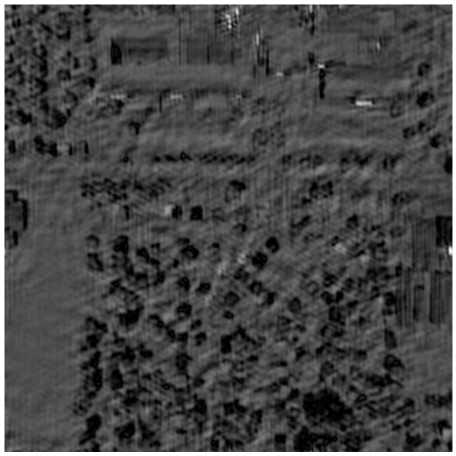


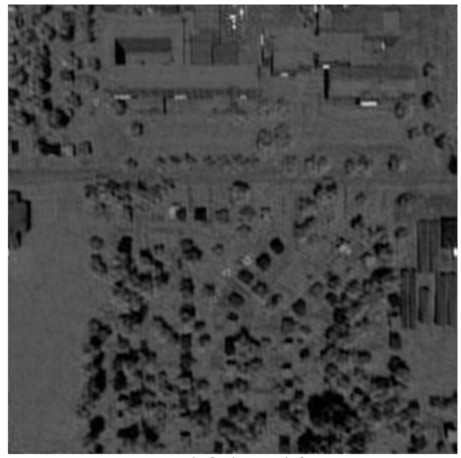
Figure 3.5.3-2. (a): A sampling of the red (0.65µm), green (0.55µm), and blue (0.45µm) unaberrated spectral OTFs for the tri-arm system in Figure 3.5.3-1. (b): The same MTFs in (a), except aberrated with ¼ λ rms-error phasing across the aperture.

The spectral sparse-aperture model developed at RIT operates on any image-cube of radiance values that has a spectral range, for example between 0.4 to 1.0m. It uses the header file of the image-cube to calculate how many, and which spectral OTFs to create for the simulation. The model normally creates a panchromatic image however it has the ability to create multispectral imagery of any number of bands not to exceed the number of bands in the original image-cube. The image-cube is a synthetically rendered image that has full spectral coverage from 0.4 to 0.9 μ m created using DIRSIG (Digital Image and Remote Sensing Image Generation). The image-cube rendered by DIRSIG is a section of Rochester, NY, with 51 bands, each having a 10nm bandpass. It has a ground sampled distance (GSD) of approximately one meter, with ground coverage of approximately 512m x 512m. The image was degraded assuming 0.15λ and 0.26λ RMS of phase error and then restored assuming a simple image was captured (panchromatic) and assuming the spectral Bandpass was sampled to form 3, 12, and 17 multispectral images that were individually restored and combined for form the final image. The results shown in Figure 3.5.3-3 shows that significant improvement can be obtained by processing sub-band images and combining to generate the final restored image. However the results also indicate that using more than a small number of bands does not significantly improve performance. This is very encouraging because it suggests that an operational solution in the form of acquiring 2 or 3 multispectral bands to be combined into a single panchromatic band may be possible. Ongoing work is investigating the robustness of the limited results described here.

Restored panchromatic and 3 band images with
0.26λ rms-error



restored panchromatic image
nrmse



restored 3 band image
nrmse

3.5.3 DIRSIG Sensor Model Upgrade

Research Team: Paul Lee, Scott Brown

Task Scope: The DIRSIG model has supported a variety of geometric sensor models since 1996, including traditional framing arrays, push-broom scanners, and line/whisk-broom scanners. However, the system restricted the user to modeling simple detector array geometries. It only supported uniform spectral response functions and it did not allow the user to directly introduce noise into the DIRSIG modeling chain (it had to be added in a post processing stage). Additionally, the existing model made it difficult for the user to model spectrally misregistered focal planes and multiple focal plane systems with different clock rates commonly used in high-altitude and space based imaging systems.
A new capability in DIRSIG4 allows the user to utilize the existing DIRSIG focal plane model (referred to as "structured" focal planes) and a new "tabulated" focal plane model that allows the user to specify the location and optical properties of individual detector elements. This provides system engineers with a powerful tool for modeling nearly any focal plane design and a means to incorporate common image system artifacts, including array misalignment, spectral smile/frown, etc. The rendering engine in DIRSIG4 is purely time-based, so the synchronization of focal plane clocking, instrument mount motion (instrument pointing), platform location and orientation and scene dynamics (e.g. moving objects) is vastly improved over DIRSIG3.

Task Status: This flexible instrument description capability has been in all of the official releases of DIRSIG4 since last spring 2005. At this time, we are preparing documentation and examples so that the user community can start to use this feature.

It is expected that as the user community starts to use this capability, that further improvements will be made.

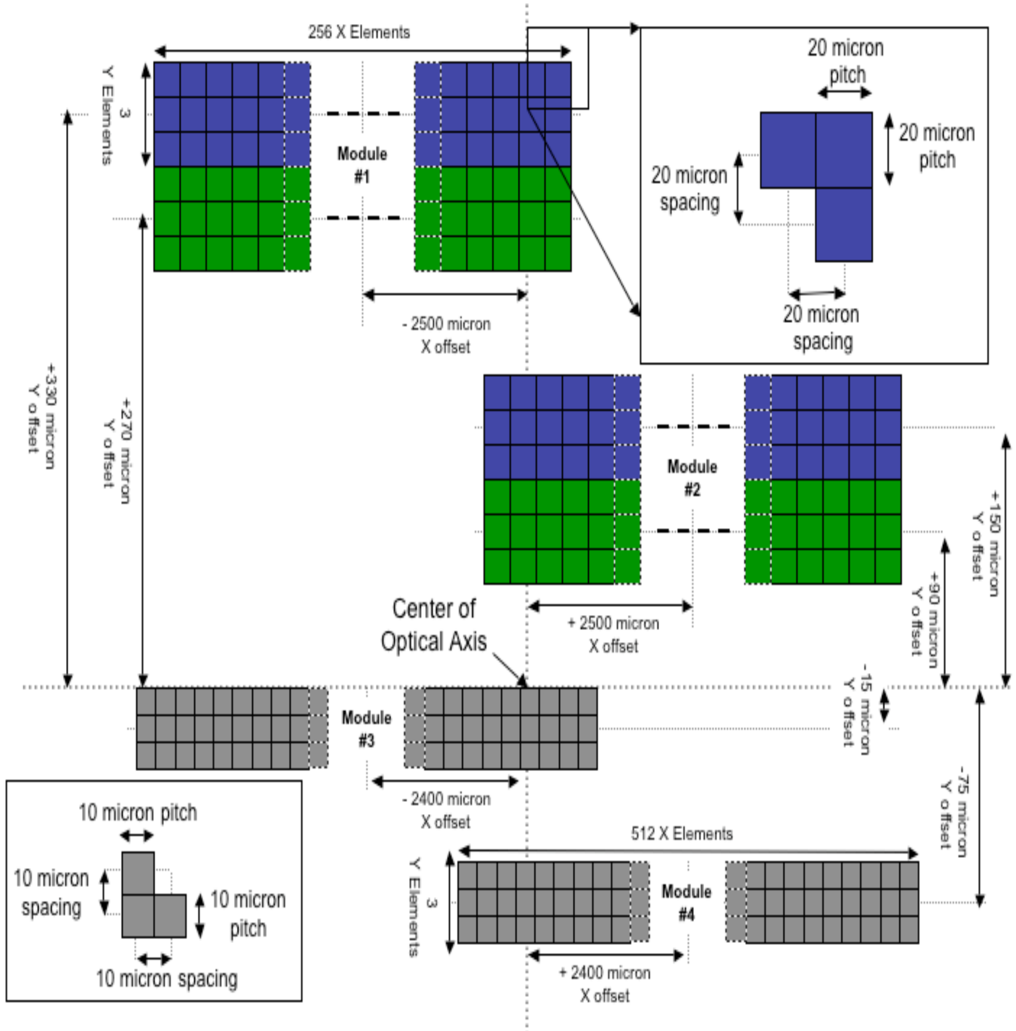


Figure 3.5.4-1: Arbitrary focal plane layouts are now possible in DIRSIG4.

3.5.4 Target Detection Algorithm Survey

Research Team: David Messinger, Emmett Ientilucci, Adam Cisz (M.S. student)

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 for portability.

Task Status: This project is nearing completion and is expected to finish in the fall of 2005. Several target detection algorithms have been developed and implemented into a common ENVI environment. The methods include both traditional statistical and geometrical matched filter detectors, as well as the newer class of forward-modeling algorithms (the Invariant Method). Application of the methodologies to two datasets (with different background characteristics but common target sets) has begun. Also, several qualitative and quantitative metrics for performance comparison have been developed and will be used in this work.

3.5.5 Hyperspectral Exploitation Algorithm Recipes

Research Team: David Grimm (M.S. student), David Messinger,

Task Scope: As hyperspectral imagery becomes more available, processes for exploitation of the imagery are becoming well entrenched but not necessarily well understood. In particular, the image must be processed through several steps before the final exploitation task can be completed. This task is designed to study these algorithm chains to understand which processing steps work well or poorly in relation to other steps, particularly aimed at the exploitation task of target detection.

Task Status: This task is expected to be completed in the fall of 2005. A dataset was selected with several targets covering a range of complexity. Algorithms have been identified and implemented (when necessary) for steps in the processing chain covering: atmospheric compensation; dimensionality reduction; noise reduction; background characterization; and target detection. Two or three choices are available for each step, providing several hundred possible "chains" of processing algorithms. Initial outputs indicate that performance is not predictable and results for different chains yield significantly different results.

3.5.6 Hyperspectral Imagery Background Characterization for Target Detection

Research Team: Jason West (M.S. student), David Messinger

Task Scope: Target detection is a common hyperspectral imagery exploitation task. The most popular methodology involves characterizing the scene background using statistical metrics. However, there are several ways to compute the background mean and covariance, each with a different effect on the target detection performance. This project seeks to understand the effects of several background characterization schemes as measured by target detection performance.

Task Status: Two datasets with differing scene backgrounds have been selected with common targets. Several background characterization schemes have been implemented and testing has begun on the identified targets of interest. Specific target masks will be used to accurately compute Receiver Operator Curves (ROC) as a metric of performance. This project is anticipated to be completed in the fall of 2005.

3.5.7 Simultaneous Scene Simulation of E-O and SAR Data

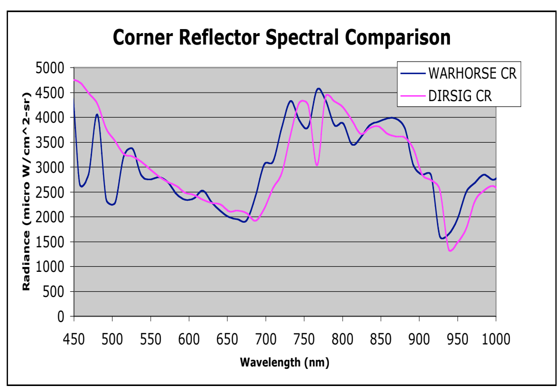
Research Team: Nancy Baccheschi (M.S. student), Scott Brown, John Kerekes

Task Scope: In order to improve understanding of the phenomenology and the design of fusion algorithms, it is desirable to have the capability of simulating a common scene as seen by both electro-optical and synthetic aperture radar imagers. The DIRS Lab has a long history in producing simulated optical scenes using the DIRSIG code, but very little experience in simulating SAR imagery. This project undertook the challenge of being able to simulate images in both modalities for a common scene.

Task Status: The project set as a goal the simulation of hyperspectral and SAR imagery over a common area for which both types of real data were readily available. The scene selected was from the Yellowstone Optical and SAR Ground Imaging (YOGI) collection that occurred in and around Cooke City, Montana in 2003. Hyperspectral imagery collected by the Naval Research Laboratory's WARHORSE sensor and radar imagery collected by Sandia National Labs Ka-band interferometric SAR were available and used for the study.

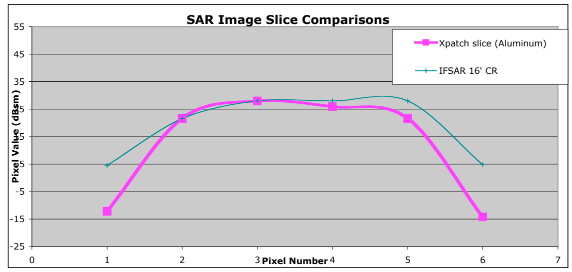
The hyperspectral simulation with DIRSIG went smoothly and an entire area of a grass pasture together with an aluminum corner reflector was simulated. Figure 3.5.8-1 shows a comparison of the spectrum from the real imagery together with the DIRSIG simulation. Except for a slight shift due to wavelength calibration errors in the WARHORSE sensor, the radiance curves match up quite well.

Figure 3.5.8-1: Spectral pixel comparison between the real (WARHORSE) and the simulated (DIRSIG) scene.



The SAR image simulation using XPATCH™, a SAIC product, did not proceed quite as smoothly. After much delay in receiving the software and getting it up and running, we were only able to simulate a corner reflector on a flat ground plane. Even for this simple scene, the run times were excessive. A more complex scene simulation was initiated, but was only 1% complete after 24 hours. However, the comparison shown in Figure 3.5.8-2 demonstrates that the simulation was able to produce a radar return signal with the proper shape and magnitude.

Figure 3.5.8-2: Comparison of the real and simulated radar backscatter for single slice through a SAR image of a corner reflector.



3.5.8 LADAR Modeling and Simulation

Research Team: Daniel Blevins (Ph.D. student), Scott Brown

Task Scope: Leveraging the photon mapping techniques utilized by the computer graphics community, a first principle based elastic LIDAR model was developed within the Digital and Remote Sensing Image Generation (DIRSIG) framework that calculates the time-gated radiance at a sensor for the atmospheric, topographic, and backscattered return. DIRSIG's active LIDAR module has been extended well beyond the initial proto-type development conducted by Burton in 2002. The LIDAR module now handles a wide variety of complicated scene geometries, diverse surface and participating media optical characteristics, multiple bounce and multiple scattering effects, and a variety of sensor models.

Task Status: During this year of this ongoing effort, we improved the modeling treatment for topographic LIDAR applications and produced a series of example, raw time-gated data cubes from topographic collection systems. ITT's Space Systems Division processed these data cubes using their in-house Gieger-mode detector model and geo-location algorithms into XYZ topographic point clouds for visualization (cf. Figure 3.5.9-1). We also expanded the modeling treatment of scattering within participating mediums. This allows the DIRSIG LIDAR model to be used to study the impact of scattering as a possible obscurant within factory gas plumes. Some initial demonstrations of the model for this purpose have been performed and reveal some interesting results.

During the upcoming year, the LIDAR modeling effort is expected to continue with a focus on topographic systems and foliage penetration problems.

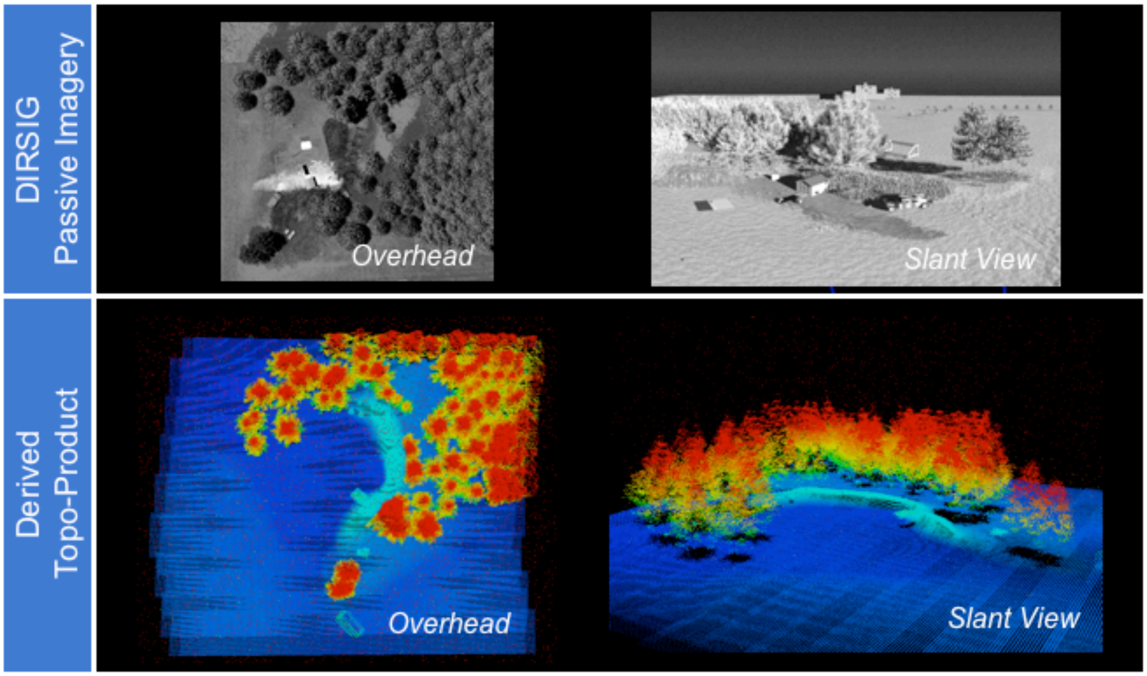


Figure 3.5.9-1: Sample output of DIRSIG's LIDAR and passive imaging models.

3.5.11 Polarimetric Image Modeling

Research Team: Jim Shell (Ph.D. student), John Schott

Task Scope: Polarization adds another dimension to the spatial intensity and spectral information typically acquired in remote sensing. Polarization imparted by surface reflections contains unique and discriminatory signatures which may augment spectral target-detection techniques. While efforts have been made toward quantifying the polarimetric bidirectional reflectance distribution function (pBRDF) responsible for target material polarimetric signatures, little has been done toward developing a description of the polarized background or scene clutter. Under this task an approach is developed for measuring the pBRDF of background materials such as vegetation. This included developing governing equation for polarized radiance reaching a sensor aperture which serves as a basis for understanding outdoor pBRDF measurements, as well as polarimetric remote sensing. A set of pBRDF measurements are acquired through an imaging technique, which enables derivation of the BRDF variability as a function of the ground separation distance (GSD).

Task Status: The initial step of defining a governing equation for the radiometric imaging process incorporating the polarimetric and BRDF behavior was completed and presented at the SPIE conference in Orlando.

A camera/filter combination and measurement procedures were assembled and implemented allowing measurements of pBRDF and BRDF spectral variability (c.f. Figures 3.5.11-1 and 3.5.11-2).

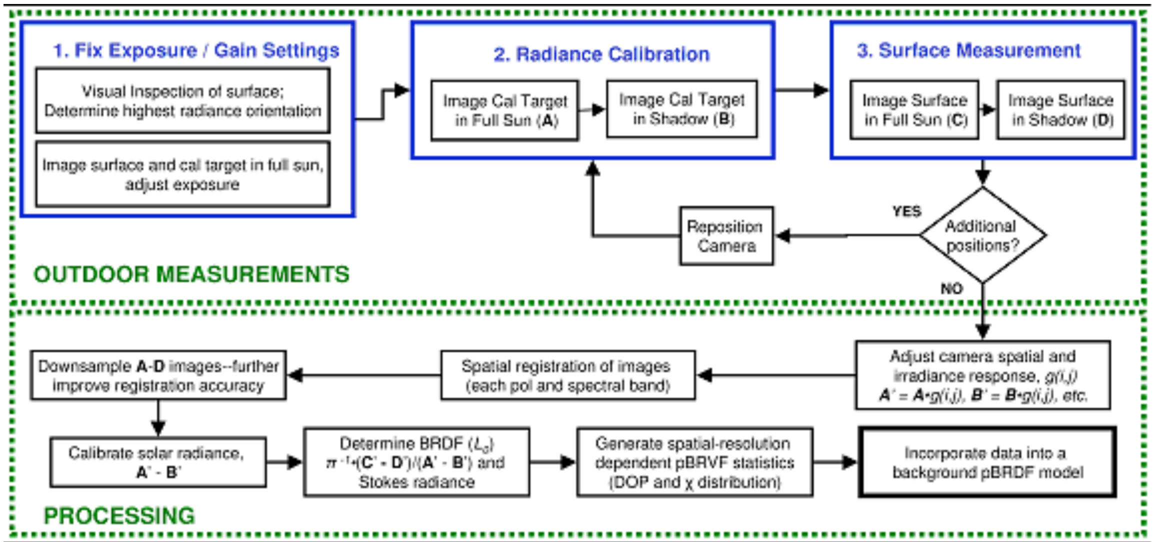


Figure 3.5.11-1. Measurement and process flow for making polarimetric BRDF and BRVF measurements with the camera system.

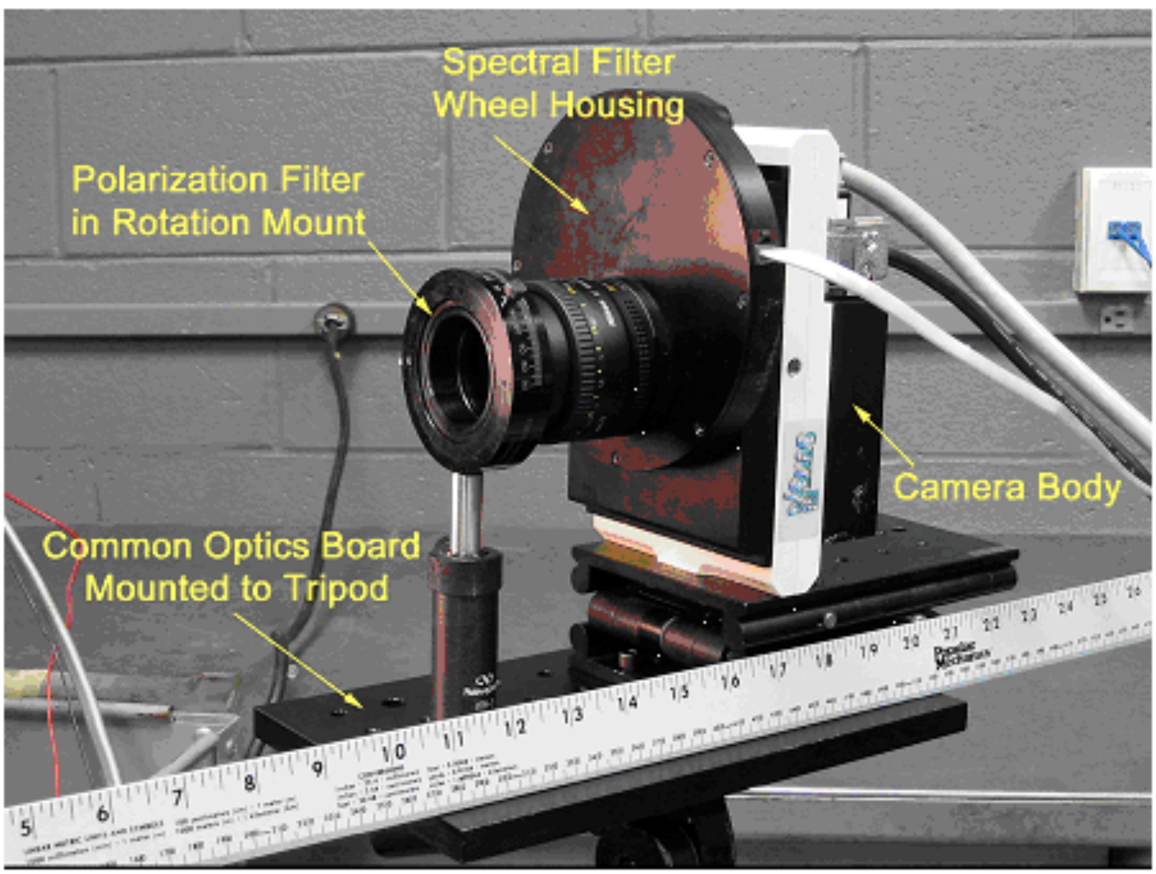


Figure 3.5.11-2. The assembled imaging system mounted on a tripod.

Indoor laboratory measurements of "pea gravel" at 550nm are presented to demonstrate the technique. A quartz-halogen lamp was used as a source which illuminated the gravel at an incident angle of $\theta_i \approx 37.5^\circ$. Polarimetric BRDF measurements were made in the forward ($\phi \approx 180^\circ$) and side ($\phi \approx 90^\circ$) scattering positions. The scattering zenith angle at the center of the images was $\theta_r \approx 30.3^\circ$ for the forward scattering case and $\theta_r \approx 29.1^\circ$ for the side scattering angle.

The standoff distance was such that the full FOV covered 26.7cm, resulting in a GIFOV of 174 µm. Bidirectional reflectance variability function (BRVF) statistics were calculated and are presented for GSD pixel sizes of 1, 13, 41 and 101 pixels or 0.017, 0.226, 0.713 and 1.757cm. Obviously these are not GSDs of interest for most overhead remote sensing applications, but serve to illustrate the technique which is easily scaled. Figure 3.5.11-3 presents the results. The polarization components of the BRVF may be presented as the distribution of Stokes components or by the degree of polarization (DOP). DOP is chosen here as it is insensitive to rotational alignment of the camera system about the optical axis.

Unlike outdoor conditions, the irradiance was not uniform across the entire FOV; therefore, the BRDF intensity measurement should only be considered an approximation. However, the DOP measurement is independent of irradiance uniformity. In the forward scattering case, the average BRDF is $0.0250\,\text{sr}^{-1}$. Similar results are obtained for the side scattering $\phi \approx 90^\circ$ sensor orientation where the average BRDF is $0.0291\,\text{sr}^{-1}$. In both cases the mean BRDF is independent of GSD due to linearity. The decreased radiance in the forward scattering direction is attributed to a higher fraction of the surface being shadowed, which is common with many natural materials.

There is a marked difference in the DOP between the forward and side viewing sensor orientations. For forward scattering, the mean DOP for the 1, 13, 41 and 101 averaging kernels is 0.1973, 0.1860, 0.1931 and 0.1929. The same results for the side scattering are 0.1300, 0.0976, 0.0922 and 0.0917, where the higher value for the 1× kernel is attributed to residual spatial misregistration of the raw images.

These initial studies have demonstrated the potential of the approach and ongoing efforts are focused on moving the instrumentation outdoors and continuing to refine models to estimate the pBRDF behavior from a limited number of measurements.

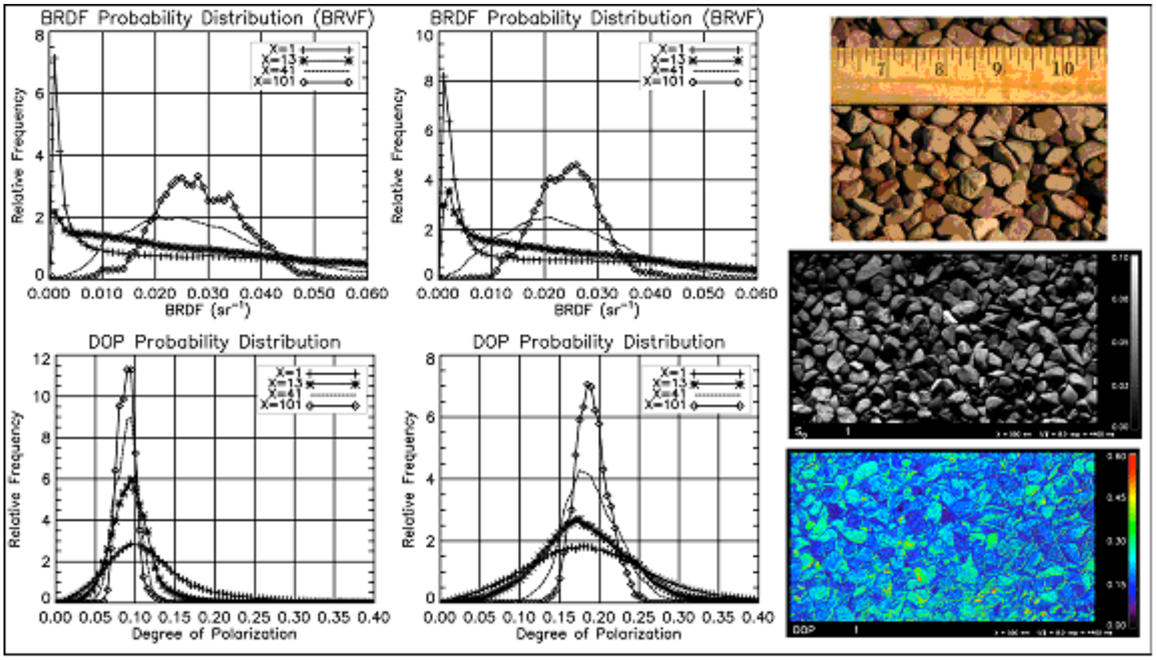


Figure 3.5.11-3. The BRDF and DOP probability distributions for the side (left column) and forward (middle column) scattering orientations. A color picture of the gravel is shown at top right with a ruler (in inches) along with the forward scattering images of the intensity S0 (middle right) and color-encoded DOP (bottom right) which is scaled from $0.0 \leq \text{DOP} \leq 0.6$**.**

3.5.12 DIRSIG Environmental Effects

<u>Research Team</u>: John Kerekes, Scott Brown, Kristin Strackerjan (M.S. student), Lon Smith, Mike Fuller (B.S. student)

<u>Task Scope</u>: The objectives of this task were to identify a limited number of environmental effects, collect field and laboratory data to characterize their phenomenology, and then implement modules within DIRSIG to model surfaces subjected to these effects.

<u>Task Status</u>: After initially developing taxonomy of environmental effects, the task first focused on making spectral reflectance and emissivity measurements of snow. Figure 3.5.12-1 show these data for three types of snow as measured on the RIT campus in January 2005.

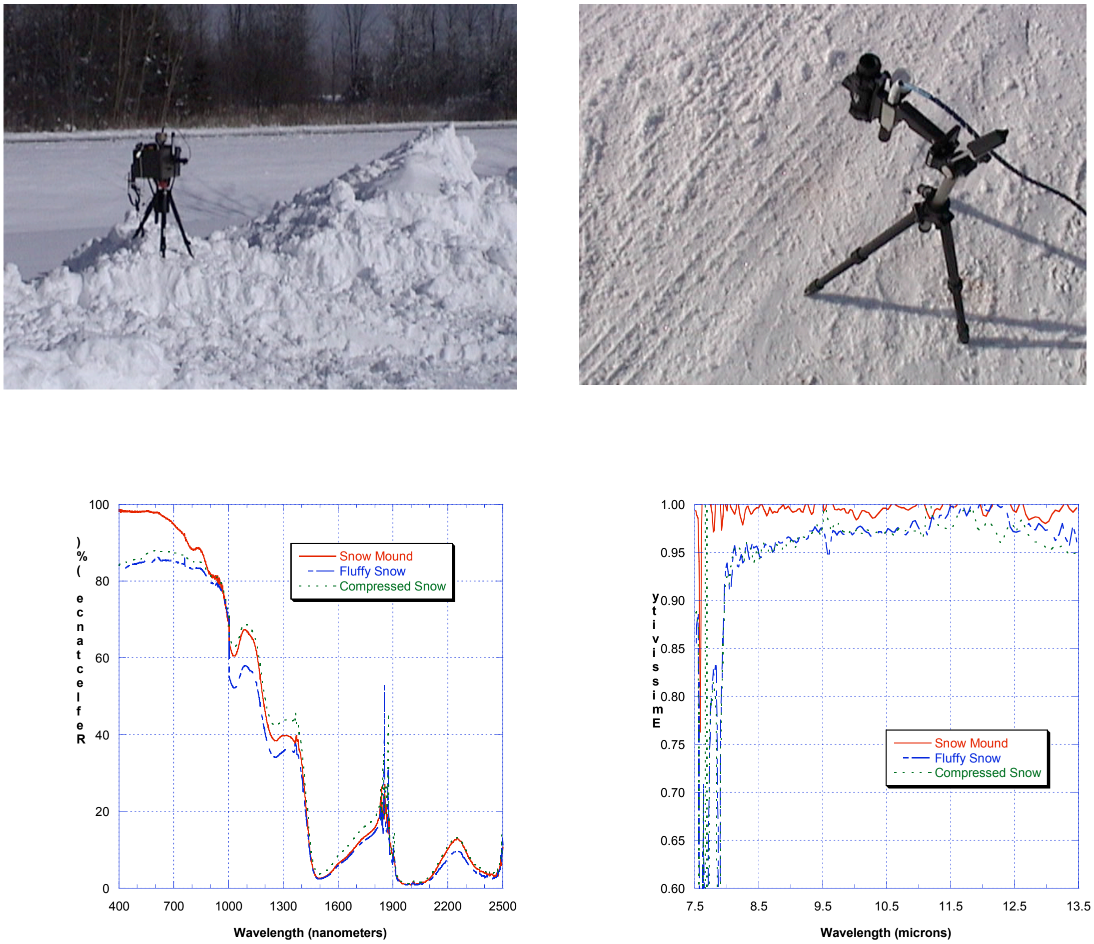


Figure 3.5.12-1: Experimental set-up and results of measuring snow reflectance and emissivity.

Subsequently, measurements of water and soil on man-made materials such as vehicles and roadways were conducted. Figure 3.5.12-2 shows results of reflectance measurements on vehicles under the four combinations of wet/dry and clean/dirty.

These measurements are being augmented with additional measurements in the laboratory along with theoretical models to be able to model the effects on spectral radiance of water and soil on surfaces within simulated DIRSIG scenes.

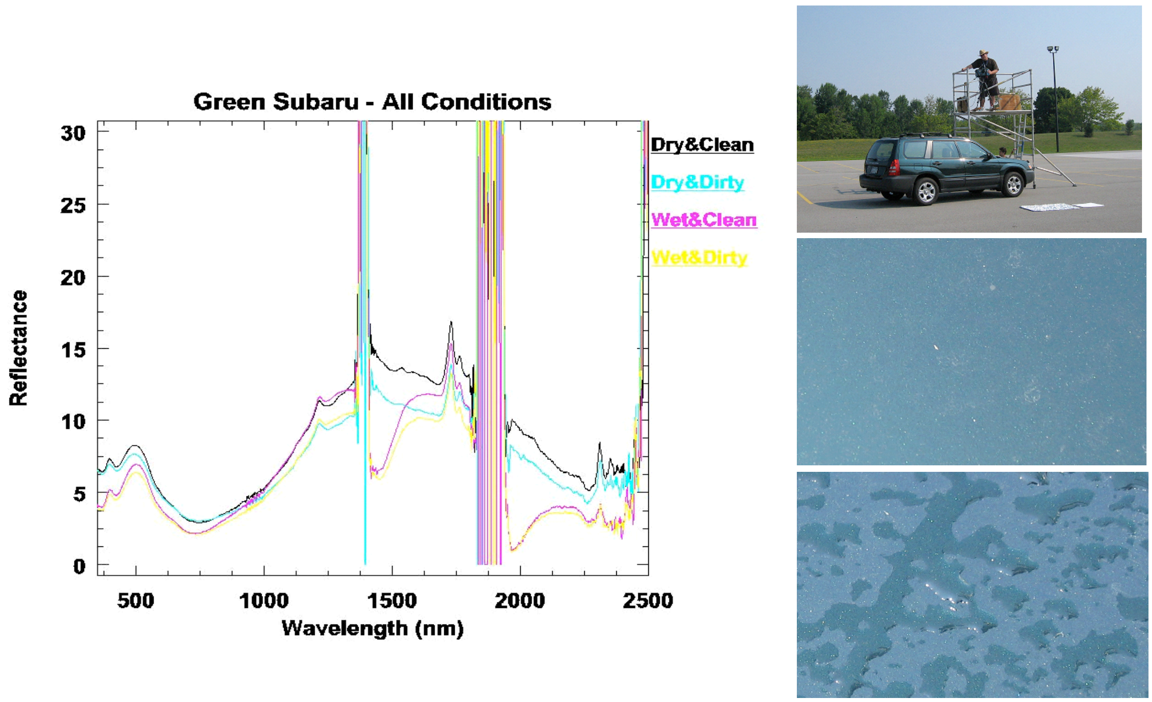


Figure 3.5.12-2: On the left are spectra of the same material under different contamination conditions. Right-top illustrates the measuring setup. Right-center shows the material contaminated by dirt. Right-bottom shows the same material when wet.

3.5.13 Improved VNIR Texture

Research Team: Jason Ward (Ph.D. Student) Scott Brown, John Schott

Task Scope: The purpose of this project was to improve some of the spatial-spectral modeling capabilities of the DIRSIG model. The performance of hyper-spectral algorithms (particularly target detection algorithms) is directly related to the ability of the algorithm to differentiate the background from the target. When synthetic imagery is used for testing these algorithms, it is important that the modeled data contain comparable spatial-spectral statistics to those found in real imagery. The DIRSIG model has supported a variety of methods for describing the spatial-spectral characteristics of a particular material.

Under this effort, the interfaces for some of these methodologies were improved and documented. In addition, guidelines for material optical property characterization techniques that capture the required spatial and spectral variability have been developed.

Task Status: The improved modeling techniques were documented in the new DIRSIG documentation project and the improved interfaces are part of the currently distributed version of the DIRSIG3 and DIRSIG4 model. Example scenes using the improved modeling tools are being produced for validation, testing and cyclic refinement.

3.6 RASER

Research Team: Jeff Dank (B.S. student), Brian Leahy (B.S. student), Mike Muldowney (B.S. student), John Kerekes

Sponsor(s): Air Force Research Laboratory Sensors Directorate (AFRL/SN)

Project Scope: The Revolutionary Automatic Target Recognition and Sensor Research (RASER) activity is a portfolio of programs sponsored by AFRL/SN to advance the state of the art of assisted and automated target recognition. In August of 2004, RIT was awarded a three-year grant to explore the use of mathematical modeling techniques to understand the parametric sensitivity of enhanced target detection using hyperspectral and synthetic aperture radar imagery. The project is being conducted in partnership with a small remote sensing business, HyPerspectives, Inc.

Project Status: The initial focus of the effort was to develop simulated scenes of a rural and an urban area for which multisensor remote sensing imagery was available. The particular area selected was in and adjacent to the small town of Cooke City, Montana, for which multisensor data were collected in 2003 as part of the multi-agency supported Yellowstone Optical and SAR Ground Imaging (YOGI) experiment. Hyperspectral imagery was simulated using the DIRSIG code, while SAR imagery was planned to be simulated using XPATCH™, a SAIC product. Excellent progress was made on the HSI simulation, but due to a variety of difficulties, only a small simulation of a corner reflector was completed for the SAR simulation. Figure 3.6-1 provides a graphical description of the results under this initial focus.

After the initial efforts, AFRL/SN asked RIT to refocus our efforts to be in support of research addressing the non-traditional threats now faced by our military. In particular, they were interested in technologies to monitor and/or defeat terrorist activity. In support of this revised objective, RIT refocused the effort to explore the ability of airborne hyperspectral imagers to monitor and track suspicious vehicles in a crowded urban area. As an initial experiment, RIT collected airborne hyperspectral imagery with its Modular Imaging Spectrometer Instrument (MISI) over the RIT campus with coordinated civilian vehicle movements between two sequential overflights. These data will be analyzed to determine the ability of the hyperspectral data to provide information to allow unique tracking of vehicles within the sequential images.

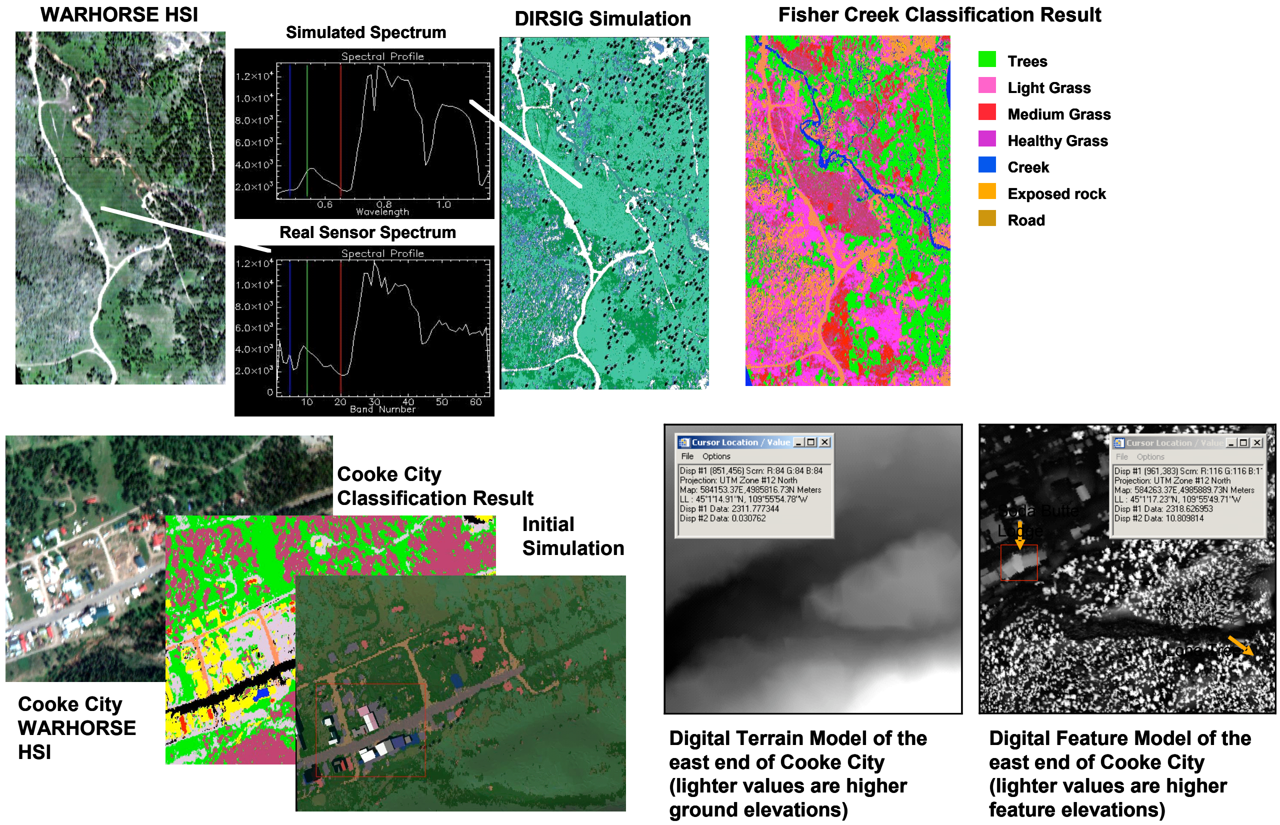


Figure 3.6-1: Initial results accomplished during the first phase of the AFRL/SN RASER program.

3.7 Spectral Quality Metrics

Research Team: Adam Cisz (M.S.student), John Kerekes

Sponsor(s): ITT Industries Space Systems Division

Project Scope: The quality and utility of a spectral image depends upon many factors including the technical characteristics (spatial and spectral resolution, noise level, number of spectral channels, etc.), but also the scene content, the desired task, and the algorithms used to analyze the data. This project is intended to explore the issues associated with such metrics and develop insight into plausible approaches to this complex problem.

Project Status: The effort focused on comparing several published spectral quality metrics to an empirical analysis of target detection performance in a hyperspectral image. Table 3.7-1 provides a summary of the findings showing the characteristics and sensitivity trends of the various metrics. A metric based on the sensor spatial resolution, number of spectral channels, signal-to-noise ratio and the target-to-clutter ratio (SQRS_SCR) was found to be most consistent with the observed empirical detection performance (Pd).

	SSV	SQRS	SQRS_SCR	Pd	Cspatial	Cspectral	Ctotal
Characteristics:							
Predictive		X		X	X		X
Function of image data	X		X			X	X
Function of sensor parameters		X	X	X	X		X
Task dependent		X	X	X		X	X
Incorporates analyst results						X	X
Parameter Sensitivity:							
Smaller GSD	↑	↑	↑	↑	↑	↓	↓
Higher SNR	-	↑	↑	↑	-	↑	↑
More Channels	↓	↑	↑	↑	-	↑	↑

Table 3.7-1. Comparative summary for spectral quality metric characteristics and parameter sensitivity. Algorithms are broadly categorized by the methods and input types. Also shown is how altering parameters increases or decreases sensitivity of the detection.

3.8 Landsat 5 and 7 Thermal IR Calibration Project

Research Team: John Schott, Nina Raqueño, Tim Gallagher, Brian Staab (B.S.student), Smita Gholkar (M.S. student)

Sponsor(s): NASA

Project Scope: The calibration of the Landsat TM and ETM+ sensors is essential for long-term global studies. DIRS monitors the thermal calibration of both the Landsat ETM+ and TM satellites to identify any sensor degradation (cf. Figure 3.8-1). The thermal calibration is verified by first collecting surface water temperatures of Lake Ontario and simultaneous thermal imagery with RIT's MISI airborne sensor. The specific atmospheric conditions are taken into account by implementing an interpolated atmospheric profile within MODTRAN. Final calibration results are reported as a comparison of sensor reaching radiances and known surface radiances propagated to sensor altitude (cf.Figure 3.8-2).

<u>Project Status</u>: This Landsat calibration has been a multi-year monitoring project since 1995. Results and recommendations were presented to the Landsat Science Team in December 2004 and May 2005. 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 is 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 throughout 2005.

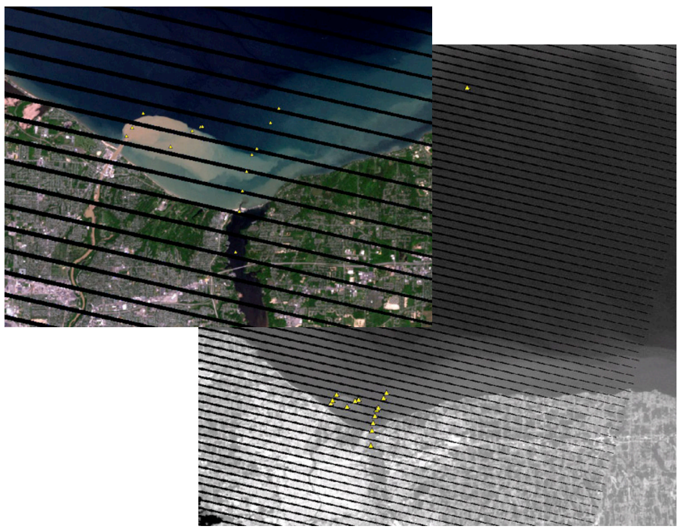


Figure 3.8-1: Example of Landsat RGB Composite and Thermal Imagery with corresponding stations where surface conditions were recorded.

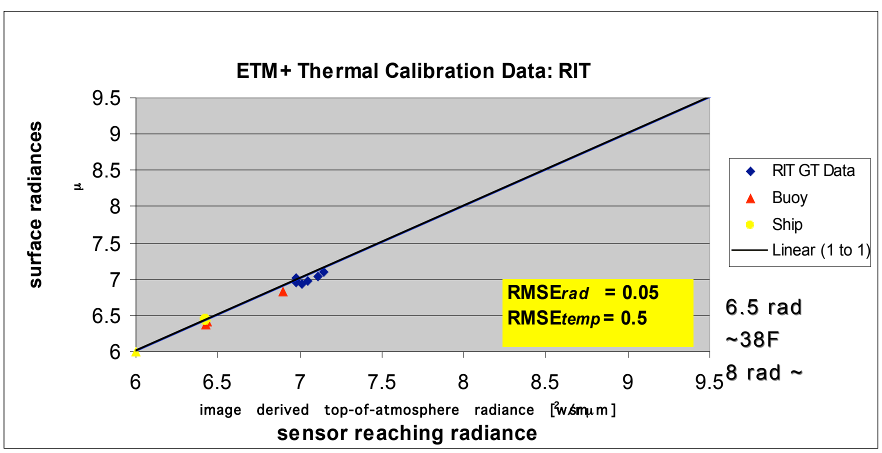


Figure 3.8-2: Results are reported as a comparison of sensor predicted radiances to ground based observations. A single collection date is shown here for simplification.

3.9 Conesus Lake Watershed

Research Team: Anthony Vodacek, Yan Li (Ph.D. student), Nina Raqueño, Robert Kremens (LIAS)

Sponsor(s): US Dept. of Agriculture. RIT is on a team being led by SUNY Brockport.

Project Scope: The goal of this three-year project is observing the effects of best management practices in the Conesus Lake watershed on stream runoff of sediment and nutrients to the lake. The RIT team used the ALGE hydrodynamic model to simulate the patterns of circulation in the whole lake as well as the patterns of stream plumes carrying sediment and nutrients into the lake. The simulations used hourly flow data provided by the SUNY Brockport researchers. This work was carried out in collaboration with the ALGE code author, Al Garrett of the DOE Savannah River plant. Thermal images collected with the MISI sensor in 2003 and 2005 were used as part of the validation of the hydrodynamic model results. A commercial fish finder and GPS unit were used with a data logging device built by Dr. Kremens to record high resolution bathymetric (water depth) data required for the stream plume simulations.

Project Status: RIT involvement in the project ended June 30, 2005. A final report in the form of a manuscript for submission to a journal is in preparation. A final presentation at a project meeting will occur in January 2006.

3.10 DCI Post Doc

Research Team: David Messinger, John Schott

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

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 were conducted to better understand the limits of each technology and the applicability of each to a particular collection scenario.

Project Status: This project was completed in June 2005. In the final year of this project, effort was focused on developing a method for quantifying gas concentration path lengths and temperatures from airborne hyperspectral imagery. Quantification in active LIDAR sensing is theoretically straightforward, but limited by implementation difficulties. In passive systems, the received signal is a non-linear combination of both the gas concentration path length and the gas – background temperature contrast. A method was developed to simultaneously solve for the gas temperature and concentration path length. Results showed that the space in which the solution lies is not unique and accurate estimate of the gas concentration path length is challenging.

3.11 Real-time Fire Modeling

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

Sponsor(s): National Science Foundation (NSF). RIT is on a team being led by the University of Colorado.

Project Scope: The goal of this project is to develop a dynamic data driven system for modeling the propagation of wild land fires. The end product will give wild land fire managers a tool for predicting the propagation of wild land fire with steering of the modeling results by data from ground sensors and remotely sensed data. RIT is developing the interface to use WASP or WASP-lite images as an airborne data source of fire location. Dr. Kremens is also continuing to develop ground sensor measurement capabilities and experimental data on the optical and thermal radiation emitted by fires. RIT is creating synthetic images from the model output for comparison to the ground sensor and airborne remote sensing data using DIRSIG as well as less rigorous models.

Project Status: There are two years left in this 4-year project. An interface for transferring WASP data to the propagation model is complete. The fire propagation model output and field data from sensors deployed by Dr. Kremens in the path of wild land fires are being used to help create fire scenes in DIRSIG (movies). Experimental data collected in Missoula, MT at the Fire Sciences Lab and at RIT has been analyzed to provide estimates of the spectral radiance from fires of different thickness, but more measurements are needed to better estimate the attenuation of fire through out the visible, and NIR through LWIR spectral regions. Work is also proceeding on the interface from the ground sensors to the propagation model.

3.12 Integrated Sensor System Initiative (ISSI)

Research Team: LIAS and DIRS Group

Sponsor(s): NASA

Project Scope: The Integrated Sensor System Initiative (ISSI) was initiated as a new start program in March 2004. ISSI involves the collection, processing, and fusion of remote sensing data, combined with information from other collateral sensors. The collateral sensors could be on the ground, in the water, or in the air and are collecting data that would be very difficult to collect solely from a remote sensing system or are collecting data that enhances the performance of a remote sensing system.

The research elements of this project involve:
*Systems Engineering: conducting a systems engineering analysis to determine the data that needs to be measured. Once the causes of error are understood, they become

opportunities to perform an in-situ measurement that can lead to an overall increase in system performance.
*Sensor Development: this involves the application or development of specialized sensors that will work in concert with the overhead remote sensors.
*System Integration: this involves the engineering required in networking overhead and collateral sensors into an integrated network. This includes digital communications, data storage, and data management.
*Data Fusion and Processing – this involves the post collection fusion of collected data. The focus will be on establishing geographic registration of collected data, processing and display to optimize interpretation.

<u>Project Status</u>: The project focus has been on preparing for two application areas that will be demonstrated under the ISSI program.
*Fire Demonstration – this involves an airborne sensor that operates in conjunction with ground-based meteorological stations that collect local weather information near fires. A new airborne sensor, called WASP-lite, was designed and reviewed. A communication architecture was developed that enables the ground sensors to communicate with the airborne sensor. A small scale demonstration is planned for November 2005 that will involve WASP-lite, several ground-based weather stations, and controlled fire (see Figure 3.12-2).

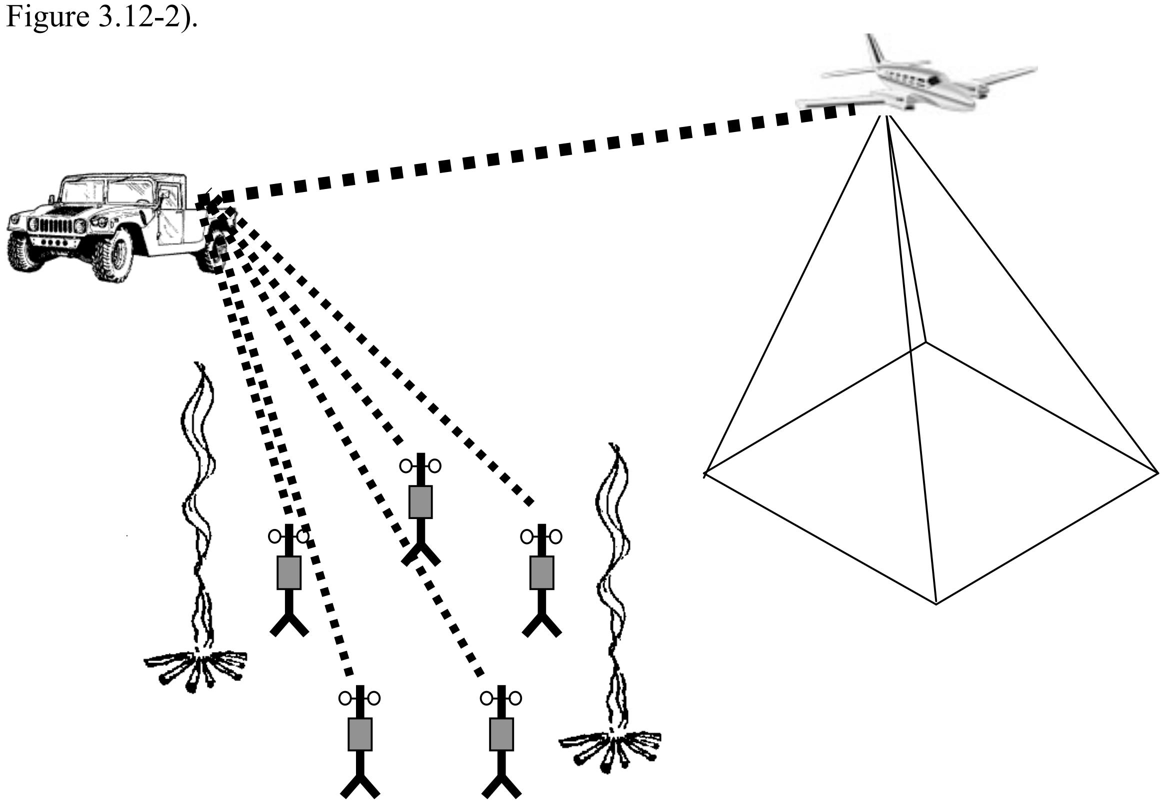


Figure 3.12-1: Fire Demonstration will include several meteorological stations combined with an overhead collection using WASP-lite

*Precision Radiometry – this demonstration involves the use of ground-based radiometric measurement instrument(s) to improve the accuracy of the MISI airborne spectrometer.

The overarching goal is to be able to convert MISI spectrometer output directly to accurate reflectance data. Two graduate students are currently working the details of this approach.

3.13 Sequential Frame Imaging (SFI)

Research Team: Tim Hattenberger, Paul Lee, Scott Brown

Sponsor(s): National Reconnaissance Office (NRO)

Project Scope: This goal of this project was to render a short animation in DIRSIG. In this first animation, the idea was to leverage existing geometric models, specifically MegaScene, while incorporating new tools and techniques for 3D animations.

Project Status: A twenty second movie at 20 frames per second was generated, resulting in 400 total frames. The movie is multispectral, with broadband coverage from the visible to near infrared portion of the electromagnetic spectrum. The moving objects include:
*A helicopter accelerating from the ground and hovering
*A jet at a constant speed
*A tank with articulating turret
*A convoy of two trucks and an articulating tractor-trailer decelerating and then accelerating through a turn.
*Several non-articulating humans and trucks throughout the scene

The movie project was divided into two parts. The first involved animating the various objects, and the second involved the actual rendering of the scene in DIRSIG. The project had a very short timeline, which did not allow a thorough investigation of animation tools and techniques. However, a pipeline was established where the objects were animated in a popular freeware software package called Blender, and the associated animation data was then imported into DIRSIG. Included in this pipeline were various scripts that formatted data and verified the average speeds of the moving objects.

The project was then passed off to DIRSIG for rendering. This was not a trivial step as DIRSIG is very computationally intensive. The condor distributed computing system was used to assist in the rendering, taking advantage of computers both in the Chester F. Carlson Center for Imaging Science, as well as in the Golisano College of Computing and Information Sciences. The project has been completed and delivered to the sponsor, who has since provided additional funding to continue research in this area.

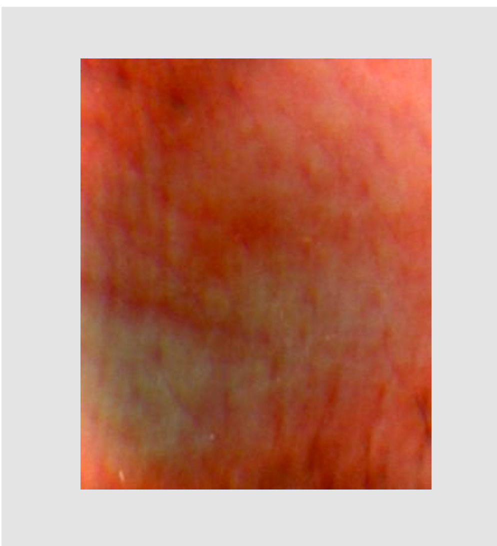
3.14 Biomedical Imaging

Research Team: John Kerekes, Nithya Subramania (B.S. student), Maria Helguera, Naval Rao, Maureen Ferran

Sponsor(s): Eastman Kodak Company

Project Scope: This project was initiated to study the feasibility of using imaging spectroscopy and associated processing algorithms for medical diagnostic applications.

Project Status: A survey of the literature found numerous applications of optical spectral imaging for medical applications including the mapping of blood oxygen saturation, cancer tumor detection, and the tracing of drugs with marker dyes in live subjects (mice) or in tissue samples. Our research group focused on the mapping of blood oxygen saturation and investigated algorithms applied to data sets obtained from Northeastern University and Geospatial Systems, Inc. These data were spectral images of human skin collected over the visible through near infrared spectral regions. A statistical-physical algorithm was adopted from the literature and used to retrieve the fraction of oxygenated hemoglobin visible in the near surface layer of the skin. Figure 3.14-1 shows an example of the natural color image of the skin sample and the resulting saturated oxygen map.



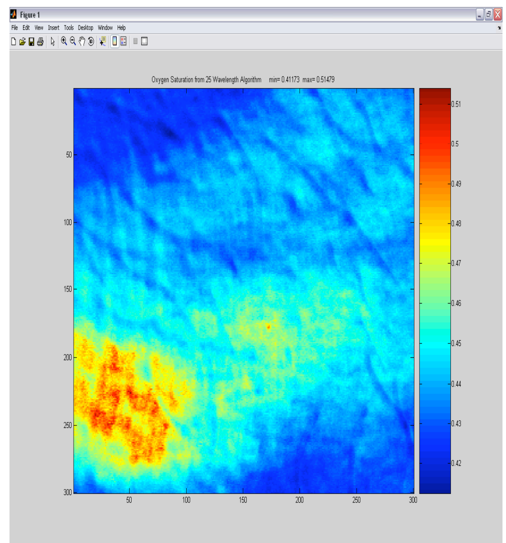


Figure 3.14-1: Three-color composite (natural color) of skin hyperspectral image (left) along with retrieved map of the fraction of oxygenated hemoglobin.

4.0 RIT Funded Core Research and Research Applications

The following projects represent internally funded research activities that occurred in 2005.

4.1 DIRSIG 4.0

Research Team: Scott Brown, Paul Lee, Niek Sanders, Adam Goodenough (Ph.D. student)

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, 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 use 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 DIRSIG Version 4 (usually referred to as simply “DIRSIG4”).

The modular design of the model allows people working on the model to learn and understand the specific subsystem they are working on rather than 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: DIRSIG4 was officially released to the user community in the spring of 2005. The new model is the software platform on which several operational capabilities are built, including the polarized imaging model, time-gated LIDAR model and enhanced sensor model. As some final features migrate from DIRSIG3 into DIRSIG4, we will have a period where both models are maintained. During the winter of 2005/2006 we expect to stop work on the DIRSIG3 code base and DIRSIG4 will take over as the primary model.

4.2 Spectral Measurement Equipment Upgrade

Research Team: Lon Smith, Tim Gallagher, Carl Salvaggio

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 causing 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 that make up the lab 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 long wave infrared portion of the spectrum with a signal to noise ratio approaching 1000-to-1 at 10 microns. This enhances our field capability to natural, textured materials that we were not able to measure in-situ in the past.

In a continuing effort to improve the quality of our visible, near infrared, and shortwave infrared spectral measurements in the field as well as extend the environmental conditions under which these measurements can be made, the group has undertaken the design, fabrication, characterization, and testing of a measurement probe for the ASD FieldSpec Pro spectroradiometer. ASD has provided, in the past, several probes such as the High Intensity Reflectance Probe (HIRP) and the High Intensity Contact Probe (HICP) that have each had there unique characteristics that limited their utility for making measurements of targets that exhibited any spatial heterogeneity. The Measurements Group has designed an instrumental probe that provides a uniform illumination field over the entire target area so that probe orientation will no longer influence the computed spectral reflectance signature.

The RAP (RIT/ASD Probe) makes use of a Flurion integrating sphere and light pipe to take the illumination provided by a typical quartz-halogen source and randomize the energy in such a way that the irradiance leaving the light pipe is uniform across the target with less than 1% variation. The probe will be fabricated, characterized and tested during the coming year.

4.3 MISI Hardware Upgrade

Research Team: Rolando Raqueño, Don McKeown (LIAS), Lon Smith, Robert Kremens (LIAS), Tim Gallagher

Project Scope: The scope of this project was to make design changes and improvements to the Modular Imaging Spectrometer Instrument (MISI) system in order to address performance and reliability issues.

Project Status: With the successes and learning experiences gained in the construction and operation of the WASP instrument, Robert Kremens and Jason Faulring of the LIAS group turned their attention to upgrading and improving the aging MISI instrument's hardware with advisement from the system's original designer, Tim Gallagher of the DIRS group. The MISI project developed an instrument capable of producing invaluable data for algorithm development, but was fragile in some aspects and required a special "touch" to keep running. The goal of the upgrade was to end up with a reliable instrument that was easily maintainable, upgradeable and addressed several known issues with the original design that resulted in poor noise rejection performance.

MISI's upgrade can be broken down into 3 basic sections: electronics, software and mechanical. The entire electronic acquisition system was redesigned and rebuilt from scratch. Following the distributed computing model employed by the WASP sensor, the task of handling the massive data stream during a collection was split amongst 3 computers: 2 performing high speed data capture and one cadencing the system's timing and providing a user interface and system synchronization. This configuration replaced the original, single, aging MISI computer that, while effective, required a highly customized operating system that was near impossible to maintain. The new computers are pretty much ordinary industrial PCs running a standard Windows XP operating system and utilize the same (6) 16 channel, 12 bit simultaneous sampling Analog to Digital converters as the old system for collection of the actual image data. In an effort to reduce noise in MISI's images from in system and external sources, signal conditioning was addressed from every level in the new design. New amplifier/filter boards were redesigned to provide more separation between high level output signals and the low level outputs from the spectrometer's linear array chips and the broad band SWIR, MWIR and LWIR channels. Clean power to the amplifiers comes from a new power supply system that provides 3 levels of isolation from the noisy power provided from the aircraft's 28V alternators. Other upgrades can be found in the black body controllers, motor controller, timing system, GPS and a new MEMs based IMU that replaces the previous power hungry system providing roll correction data. Everything was constructed using best engineering practices taking into consideration factors including ease of installation; wire routing, noise shielding and grounding systems.

MISI's acquisition software was rewritten to take advantage of the distributed computing environment. A new user interface was designed which provides the system operator many more features (and more that have yet to be implemented) all driven through a touch panel interface. The acquisition software also addresses the issue of mid-collect hard disk failures/hiccups that plagued the old system; all acquisition is now buffered into a total of 4GB of ram (capable of holding approx 12,000 scanlines) until the end of the flight line at which time the data is stored to disk. New post processing software is currently partially implemented to provide roll and over sample correction to the raw data; further code for the processing chain will be developed as the calibration process proceeds.

MISI sports substantial mechanical changes as well. All interface boxes are smaller, lighter and provide good EMI shielding for the noise sensitive amplifier circuits. The electronics rack is now much smaller and easier to integrate into the aircraft. The imaging head mounts were rebuilt to optimize space and weight, and shielding was added to help reduce issues with light-leaks. The black body mounts were redesigned for improved stability and safety.

5. Publications

5.1 Books and Journal Articles

Schott, J.R., Brown, S.D., and Barsi, J.A., Calibration of Thermal Infrared (TIR) Sensors. In D. Quattrochi &J. Luvall (Eds). *Thermal Remote Sensing in Land Surface Processes*. CRC, Boca Rutan, Fl., 2004.

Teillet, P.M.., Helder, D.L., Ruggles, T.A., Landry, R., Ahern, F.J., Higgs, N.J., Barsi, J., Chander, G., Markham, B.L., Barker, J.L., Thome, K.J., Schott, J.R., Palluconi, F.D., A definitive calibration record for the Landsat-5 thematic mapper anchored to the Landsat-7 radiometric scale, *Canadian Journal of Remote Sensing*, Vol. 30, No. 4, p 631-643, August, 2004

Schott, John R., "Imaging Spectroscopy," *Laser Focus World*, Vol. 40, no. 8, pp. 76-86, ISSN: 1043-8092, September 2004

J.P. Kerekes and J.E. Baum, "Full Spectrum Spectral Imaging System Analytical Model," IEEE Transactions on GeoScience and Remote Sensing, Vol. 43, No. 3, pp. 571-580, March 2005.

5.2 Published Proceedings

J. Kerekes and S. Hsu, "Spectral Quality Metrics for Terrain Classification," Proceedings of Imaging Spectrometry X, Vol. 5546, SPIE Annual Meeting, Denver, Colorado, 2-6 August 2004.

J. Kerekes and J. Baum, "Full Spectrum Modeling of At-Sensor Spectral Radiance Variability Due to Surface Variability," IEEE International GeoScience and Remote Sensing Symposium (IGARSS), Anchorage, Alaska, 20-24 September 2004.

J. Kerekes and D. Manolakis, "Improved Modeling of Background Distributions in an End-to-end Spectral Imaging System Model," IEEE International GeoScience and Remote Sensing Symposium (IGARSS), Anchorage, Alaska, 20-24 September 2004.

Shell, J.R., Salvaggio, C., Schott, J.R., "A novel BRDF measurement technique with spatial resolution-dependent spectral variance," Proceedings of IGARSS, IEEE International, Vol. 7, pp. 4754-4757, Anchorage, Alaska, September 2004

Introne, R.E.; Block, N.R.; Schott, J.R.; Comparison of Monochromatic and Polychromatic Modeling of Sparse-Aperture Image Quality, Aerospace, 2005 IEEE Conference, pp. 1-19, March 2005

Mandel, J., L.S. Bennethum, M. Chen, J.L. Coen, C.C. Douglas, L.P. Franca, C.J. Johns, M. Kim, A.V. Knyazev, R.Kremens, V.Kulkarni, G. Qin, A. Vodacek, J. Wu, W. Zhao, and A. Zornes. 2005. Towards a dynamic data driven application system for wildfire simulation. V.S. Sunderam et al. (Eds.): Computational Science - Proceedings ICCS 2005, Lecture Notes in Computer Science, Springer, Vol. 3515, p. 632-639.

Li, Y., A. Vodacek, R.L. Kremens, and A.E. Ononye. Double random field model

adaptive detection in remote sensing imagery. Proceedings 2005 Conference on Information Sciences and Systems, the Johns Hopkins University, March 16–18, 2005

N. Baccheschi, S. Brown, J. Kerekes, and J. Schott, "Generation of a combined dataset of simulated radar and EO/IR imagery," Proceedings of Algorithms and Technologies for Multispectral, Hyperspectral, and Ultraspectral Imagery XI, Vol. 5806, pp. 88-99, SPIE Defense & Security Symposium, Orlando, Florida, March 2005.

Noah R. Block, Robert E. Introne, John R. Schott, "Using multispectral information to decrease the spectral artifacts in sparse-aperture imagery," Proceedings of SPIE, Vol. 5798, p. 139-150, Orlando, March 2005

Scott D. Brown, Daniel D. Blevins, John R. Schott, "Time-gated topographic LIDAR scene simulation," Proceedings of SPIE, Vol. 5791, p. 342-353, Orlando, March 2005

Adam P Cisz, John R Schott, "Performance comparison of hyperspectral target detection algorithms in altitude varying scenes," Proceedings of SPIE, Vol. 5806, pp. 839-849, Orlando, March 2005

D. Grimm, D. Messinger, J. Kerekes, and J. Schott, "Hybridization of hyperspectral imagery target detection algorithm chains," Proceedings of Algorithms and Technologies for Multispectral, Hyperspectral, and Ultraspectral Imagery XI, Vol. 5806, pp. 753-763, SPIE Defense & Security Symposium, Orlando, Florida, March 2005.

Emmett J. Ientilucci, John R. Schott, "Target detection in a structured background environment using an infeasibility metric in an invariant space," Proceedings of SPIE, Vol. 5806, p. 491-502, Orlando, March 2005

J. Kerekes, A. Cisz and R. Simmons, "A comparative evaluation of spectral quality metrics for hyperspectral imagery," Proceedings of Algorithms and Technologies for Multispectral, Hyperspectral, and Ultraspectral Imagery XI, Vol.5806, pp. 469-480, SPIE Defense & Security Symposium, Orlando, Florida, March 2005.

Erin M. O'Donnell, David W. Messinger, Carl Salvaggio, John R. Schott, "The invariant algorithm for identification and detection of multiple gas plumes and weak releases," Proceedings of SPIE, Vol. 5806, p. 206-217, Orlando, March 2005

Ononye, A.E., A. Vodacek, and R.L. Kremens., Fire temperature retrieval using constrained spectral unmixing and emissivity estimation., Algorithms and Technologies for Multispectral, Hyperspectral, and Ultraspectral Imagery XI, S.S. Shen and P.E. Lewis, Eds. Proc. SPIE Vol. 5806, p. 352-360, March 2005

David Pogorzala, David Messinger, Carl Salvaggio, John Schott, "Gas plume species identification in airborne LWIR imagery using constrained stepwise regression analyses," Proceedings of SPIE, Vol. 5806, p. 194-205, Orlando, March 2005

Raqueño, N.G., Smith, L.E., Messinger, D.W., Salvaggio, C. Raqueño, R.V., Schott, J.R., MegaCollect 2004: Hyperspectral collection experiment of terrestrial targets and backgrounds of the RIT MegaScene and surrounding area (Rochester, New York), Proceedings of SPIE, Vol. 5806, p.554-565, March 2005

Raqueño, R.V., Raqueño , N.G., Weidemann, A.D., Effler, S.W., Perkins, M., Vodacek, A., Schott, J.R., Philpot, W.D., Kim, M. MegaCollect 2004: Hyperspectral collection experiment over the waters of the Rochester Embayment, Proceedings of SPIE, Vol. 5806, p.566-577, March 2005

James R. Shell II, John R. Schott, "A polarized clutter measurement technique based on the governing equation for polarimetric remote sensing in the visible to near infrared," Proceedings of SPIE, Vol. 5811, p. 34-45, Orlando, March 2005

J. West, D. Messinger, E. Ientilucci, J. Kerekes, and J. Schott, "Matched filter stochastic background characterization for hyperspectral target detection," Proceedings of Algorithms and Technologies for Multispectral, Hyperspectral, and Ultraspectral Imagery XI, Vol. 5806, pp. 1-12, SPIE Defense & Security Symposium, Orlando, Florida, March 2005.

5.3 Technical Reports

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.

Schott, J.R., Raqueño, N.G., Staab, B., Gholkar, S., and Parkes, J.D., "Landsat Radiometric Calibration: Towards a 20 Year Record of Calibrated Thematic Mapper Class Data," NASA Contract #NAG5-11298, 1 Report Covering Period: 9/04-8/05

5.4 Presentations

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

J. Kerekes, "Analytical Remote Sensing Imaging System Analysis," presented on January 26, 2005 at the CEIS Showcase, Rochester, New York.

Schott, J.R., "*The Evolution of Remote Sensing at RIT*" RIT Faculty Scholars Series, Wallace Memorial Library, February 8, 2005

Arsenocic, M.V., C. Salvaggio, T. Ruhren, "Selective Degradation Algorithm for Aerially Collected Image Archive Data", submitted to the ASPRS Annual Conference in Baltimore, MD, March 2005

Weith-Glushko, S.A. and C. Salvaggio, “Automatic Tie Point Generation for Oblique Aerial Imagery: An Algorithm”, submitted to the ASPRS Annual Conference in Baltimore, MD, March 2005.

Li, Y., Y. Zhu, and A. Vodacek., “An unsupervised statistical image segmentation algorithm for fire and smoke region extraction”. EastFIRE Conference, George Mason University, May 2005.

Ononye, A.E., A. Vodacek, and E. Saber. Extraction of active fire line and active fire map using AVIRIS imagery. EastFIRE Conference, George Mason University, May 2005.

Vodacek, A. The role of remote sensing in environmental forecasting systems. 4th Annual New York State Remote Sensing Symposium. Fulton Montgomery Community College, May 2005.

6. DIRS Student Capstone Projects

In this section we recognize the cumulative work of the students who have supported the DIRS group over the years.

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, 2003.

Lee, Seungsin, Models of Statistical Self-Similarity for Signal and Image Processing, Unpublished doctoral dissertation, Rochester Institute of Technology, New York, 2004.

Introne, Robert, Enhanced Spectral Modeling of Sparse Aperture Imaging Systems, Unpublished doctoral dissertation, Rochester Institute of Technology, New York, 2004.

6.2 M.S. Theses*

Mark Underhill, 1968, “Evaluation of an Alphanumeric Target as a means of Determining the “Resolution” of a Photographic Reconnaissance System” Canadian Forces
Edward MacMannus, 1971, “A Study of Latent Image Formation in Photographic Emulsions Subjected to a Combination of High and Low Intensity Exposures” Canadian Forces
Richard Young, 1975 “optimization of a Particular Aerial Photographic System by Simultaneous Intensification” Canadian Forces
David Dempster, 1978, Second Stage Autoradiographic Amplification of Developed Underexposed Tri X Emulsion Images” Canadian Forces
Amy Laitre, 1979, “Determination of the Chemical Spread Function of Kodak High Contrast Copy 5069 Emulsion” Canadian Forces
David Lyon, 1979, “The Effects of Sulphur Sensitization and Stabilization by 4-Hydroxy-6-Methol-1,3,3a,7-Tetraazaindene on Hydrogen Sensitization of a Photographic Emulsion” Canadian Forces
Harvey Smith, 1979, “Exposed Field Enhancement of Efficiency in Autoradiographic Exposures” Canadian Forces
Donald Vachon, 1979, The Effect of Photographic Reducers in Autoradiographic Intensification Method of Recovery of Incorrectly Exposed Radiographs” Canadian Forces
Larry Wheaton, 1980, “An Investigation of the Fog Problem in Autoradiographic Intensification Method” Canadian Forces
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 pseudo-invariant 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 pseudo-invariant 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"
John Klatt, 2001, "Error Characterization of Spectral Products using a Factorial Designed Experiment" Canadian Forces
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
Gabriel Dore, 2004, "Multiframe Super-Resolution of Color Image Sequences Using a Global Motion Model", Canadian Forces
Erin Peterson, 2004, "Synthetic Landmine Scene Development and Validation in DIRSIG", US Air Force
Kris Barcomb, 2004, "High Resolution, Slant Angle Scene Generation and Validation of Concealed Targets in DIRSIG", US Air Force
David Pogorzala, 2005, "Gas Plume Species Identification in LWIR Hyperspectral Imagery by Regression Analyses"
Erin O'Donnell, 2005, "Detection and Identification of Effluent Gases Using Invariant Hyperspectral Algorithms"
Gretchen Sprehe 2005 [M.S. Environmental Science, Remote Sensing Track] "Application of Phenology to Assist in Hyperspectral Species Classification in a Northern Hardwood Forest"

*Note the DIRS group was formed in 1981, however we have also captured here the M.S. thesis of the Canadian Forces officers that pre-date DIRS as they are part of our heritage.

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"
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”
Rachael Gold, 2005. “Performance Analysis of the Invariant Algorithm for Target Detection in Hyperspectral Imagery”
Michael Muldowney, 2005, “Time Series Analysis of Late Summer Microcystis Algae Blooms through Remote Sensing”
Brian Staab, 2005, “Investigation of Noise and Dimensionality Reduction Transforms on Hyperspectral Data as Applied to Target Detection”

7.0 Special Events

7.1 LASS Board of Advisors Meeting

The LASS Board of Advisors meeting for 2005 was held on May 17, 2005. The meeting was very well attended with representation from the LASS partners including ITT Industries, Lockheed Martin, Boeing, Los Alamos National Lab, and the National Reconnaissance Office. The purpose of this meeting was to focus on the research results funded by the LASS partners. Presentations included:
- DIRSIG 4.0 (What is it and when you can get it)-Scott Brown
- LADAR Modeling in DIRSIG-Dan Blevins
- Sequential Frame Imaging Simulations in DIRSIG-Paul Lee
- MegaScene 2-Tim Hattenberger
- Full Spectrum Polarimetric Image Analysis-Jim Shell
- NURI Algorithm Implementation in ENVI-Dave Messinger
- Target Detection Algorithm Trade Study-Adam Cisz
- Spectral Database and MegaCollect-Nina Raqueño
- RASER Project Overview-John Kerekes
- ISSI and WASP Project Overviews-Don McKeown
- Advanced Plume Model Integration-Scott Brown

An area of extensive discussion was the long term support and maintenance of DIRSIG, RIT’s modeling and simulation code. Some of the issues discussed involved supporting users (because there is no funding available for providing customer service) and funding sources for continued R&D. Several ideas were discussed including carving out part of the annual LASS support contract for general DIRSIG support and increasing the cost of training so that the funds raised could be used for DIRSIG support.