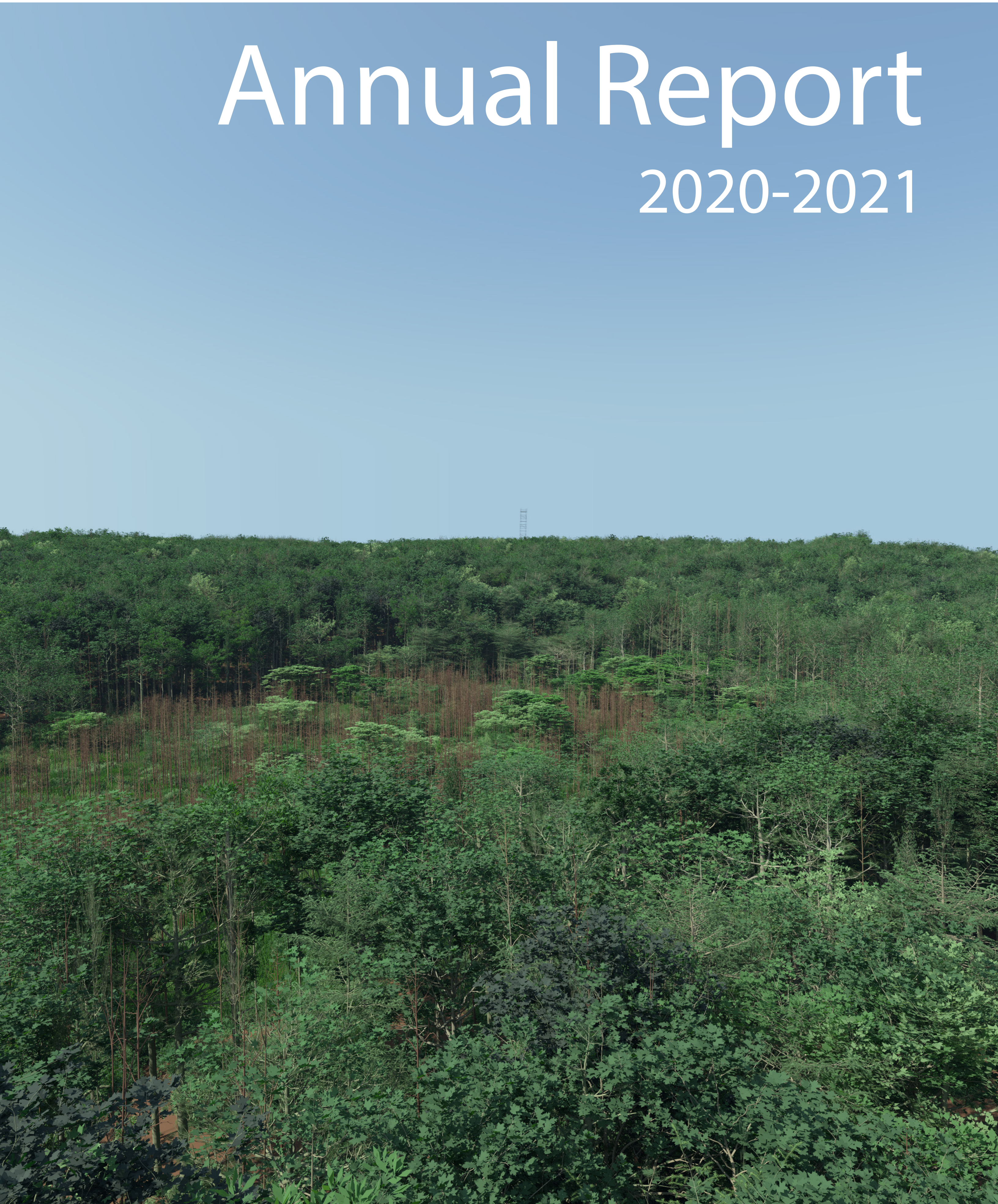
RIT | Chester F. Carlson Center for Imaging Science
Digital Imaging and Remote Sensing Laboratory

Annual Report
2020-2021



Cover Photo: A physically-simulated rendering produced by DIRSIG5, the Digital Imaging and Remote Sensing Image Generation software actively developed at the DIRS Lab. It displays a section of the Harvard Forest, an ecological research site in Massachusetts for which enough real-world data has been gathered to construct a high-fidelity computer model.

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Foreword

Carl Salvaggio

Foreword

The 2020-2021 fiscal year has come to an end, and while things aren't back to normal as we all had hoped they would be in our day-to-day lives, it sure seems like the Digital Imaging and Remote Sensing Laboratory is back to normal, continuing its world class research, and continuing to grow. This is all a reflection of the top-quality students, research staff, research faculty, tenure-track and tenured faculty that comprise this great organization.

We all pride ourselves on carrying out our mission with the great students in our undergraduate and graduate programs in Chester F. Carlson Center for Imaging Science. This year, our own Emmett Ientilucci was the recipient of the Richard and Virginia Eisenhart Provost's Award for Excellence in Teaching. This award recognizes RIT's best faculty for their teaching and dedication to our students over the course of their career. We could not be prouder of Emmett for the work that he does, year after year, to educate the next generation of Imaging Science graduates.

I want to thank the entire RIT community for supporting our laboratory so that we can continue to conduct our world-class research and continue to mentor our undergraduate and graduate student researchers in the manner that we have always prided ourselves on. Special thanks to the Center for Imaging Science director, David Messinger, the Dean of the College of Science, Sophia Maggelakis, our Vice President for Research, Ryne Raffaelle, and our director of Government and Community Affairs, Vanessa Herman for all that they do. We owe a large debt of gratitude to our administrators.

This year continued to be exciting as RIT remains on its' path to becoming a national research university. The past two decades have included dramatic growth in our laboratory to the point where we are now 9 tenured/tenured track faculty across multiple schools, 3 research faculty, 16 full-time research staff, 5 support and administrative staff, and over 40 undergraduate and graduate students supporting our vast research portfolio. We are currently looking to add an additional 3 researchers and support engineers at this writing. It is so exciting to see this growth.

We were joined this year by one new researcher, Jeffery Dank. This growth was enabled by exciting opportunities created by our DIRSIG researchers. Jeff has hit the ground running and is already making huge contributions to our laboratory's mission. We could not be happier to have him become part of the DIRS family. We are looking to grow even more by pushing into a new research thrust, synthetic aperture radar, and are in the search for researchers and faculty in this area.

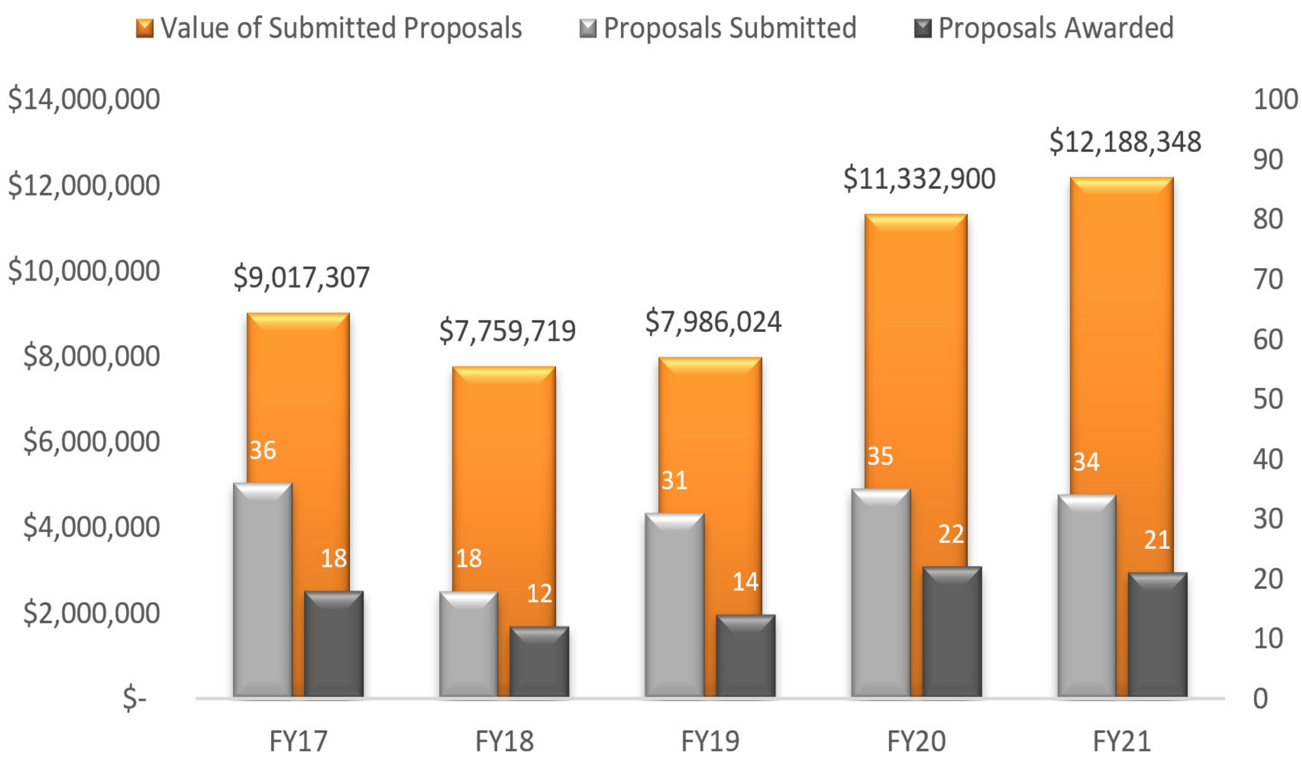
This year we have seen new work start with too many organizations to mention. The work is all described in this volume. We are excited to be working with some of these organizations for the first time and continuing our research relationships with many of our favorite long-term sponsors.

The newest facet to our laboratory, the DIRS Enterprise Center, has seen extraordinary growth this year. This fee-for-service organization with expedited contracting has enabled us to provide services to many organizations; providing our world-class data, skills, and expertise in support of their missions using the one-of-a-kind resources that we are so fortunate to have access to every day.

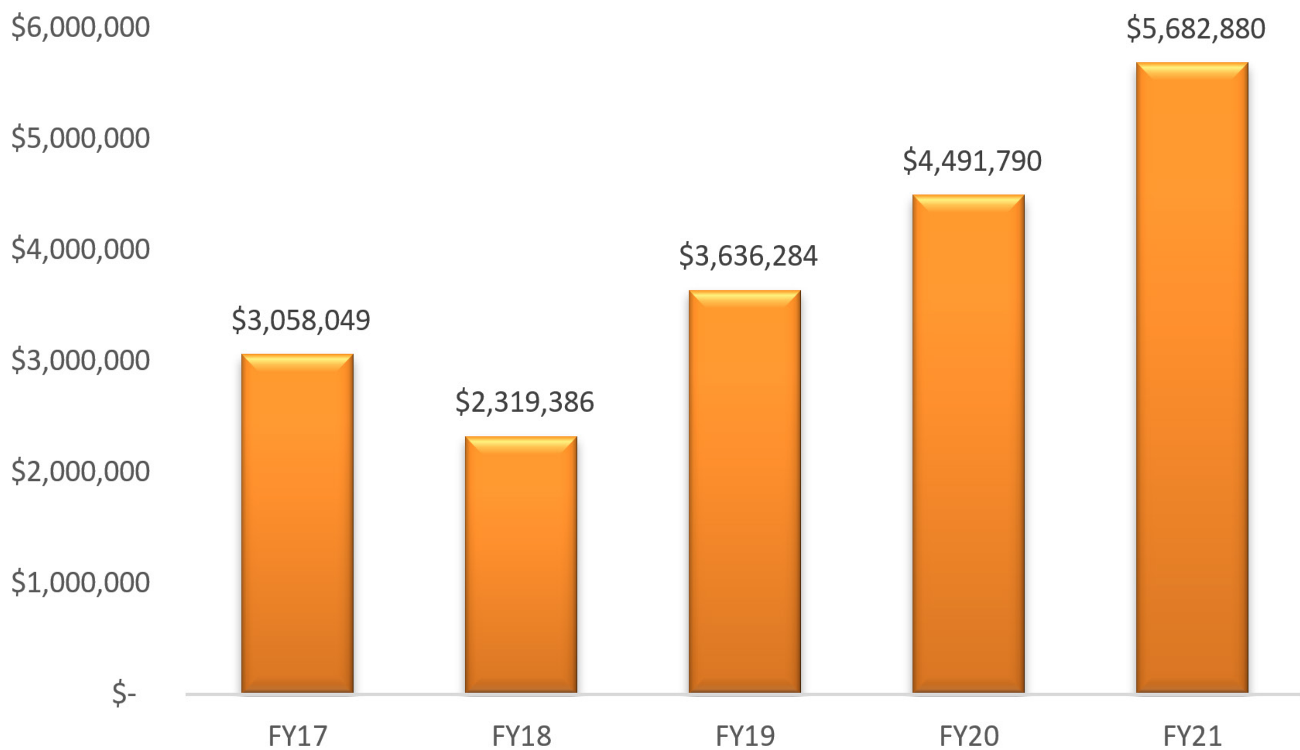
As I have said in the past, and continuing to feel more as every day passes, to be the Director of this laboratory is truly a gift. Having such a collection researchers, principal investigators, and faculty who all are all at the top of their disparate fields - all working together to share their kind of remote sensing science, elevates each of us to do things we could not do as individuals. We are all very lucky to be part of the DIRS family.

With my warmest regards,

Performance



Proposal activity by fiscal year for the principal investigators associated with the Digital Imaging and Remote Sensing Laboratory.



Fiscal year obligated funds for sponsored research projects for the Digital Imaging and Remote Sensing Laboratory.

Research

The following represents selected projects conducted by the students, research staff, and faculty of the Digital Imaging and Remote Sensing Laboratory during the 2020-2021 academic year. These projects are in various stages of their lifecycle and are representative of the widely varying interests and capabilities of our scientific researchers.

DIRSIG5 Development

Principal Investigator: Philip Salvaggio

Team: Scott Brown, Adam Goodenough, Grady Saunders, Jeff Dank, Byron Eng

Project Description

The DIRSIG model is used heavily by L3Harris internally in a number of workflows. This project serves as a collaboration to drive the development and refinement of the DIRSIG model from a number of requirements-driven angles. This project provides support for L3Harris in the form of software development, testing, bug fixes and consultations. In addition, L3Harris supports investigations into new areas for the DIRSIG model, whether those result in new features, new execution modes, improvements to existing features, optimizations or other outcomes. This project is part of a long-term effort and has resulted in a large number of improvements, specifically with respect to the maturation of the DIRSIG5 model.

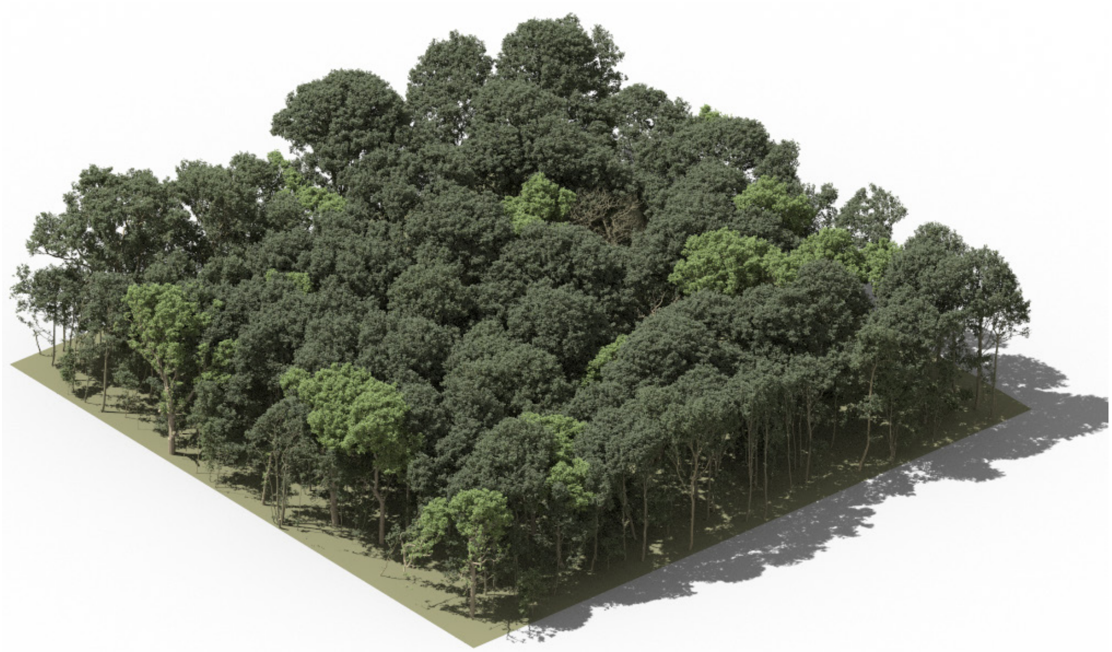


Figure 1: Example render of a radiation transfer model intercomparison (RAMI) test scene using DIRSIG5. RAMI simulations will serve to compare DIRSIG5 radiative transfer results with other models.

Project Status

This project has been ongoing for the last couple of years and has resulted in numerous outcomes. Recent advances have been made in a number of areas. DIRSIG5 has made significant strides in the past year with respect to thermal simulations. DIRSIG5 launched with support for thermal radiometry, but lacked the temperature prediction capability of DIRSIG4. Through this project, we have brought full thermal functionality to DIRSIG5 and we continue to expand functionality past that of DIRSIG4. Through collaboration and an exchange of knowledge, the DIRSIG team and L3Harris are working to streamline the process of DIRSIG scene construction, by expanding the DIRSIG distribution with more examples and scene components. L3Harris is also committed to supporting the testing of the DIRSIG model. One notable example is DIRSIG5's entry into the radiation transfer model intercomparison (RAMI) initiative this year. The DIRSIG team and L3Harris look forward to continued collaboration to expand the capabilities of DIRSIG while maintaining a focus on the quality of the model.

Figure 2: Render of a DIRSIG demonstration scene showing the library of bundled objects and materials that have been added to the DIRSIG distribution as a result of this project.

High-fidelity Scene Modeling and Vehicle Tracking Using Hyperspectral Video

Principal Investigator: Matthew Hoffman

Team: Anthony Vodacek, Chris Kanan, Tim Bauch, Don McKeown,
Aneesh Rangnekar, Zachary Mulhollan

Project Status

The ability to persistently track vehicles and pedestrians in complex environments is of crucial importance to increasing the autonomy of aerial surveillance. Non-visual surveillance is particularly beneficial when dealing with airborne collections, where the number of pixels on a target is relatively small and thus spatial features are not sufficient to identify a target. Spectral cameras have the ability to leverage additional phenomenological features to enhance robustness across varying environments. This project involves 1) collecting and annotating novel hyperspectral datasets of vehicle movement that will be released to the community, 2) developing a framework for efficiently extracting and exploiting spectral information from this large dataset using deep learning methods and 3) developing a new capacity for DIRSIG to support dynamic, online construction of physics-based scene models.

Figure. 1 A false color visualization of a hyperspectral frame of low-rate video of a highway scene. By flying along a highway, the vehicles moving in the same direction as the aircraft could be tracked for multiple frames. This oblique view provides tracking challenges due to shadows and obscurations.

Project Status

The Headwall visible and near-infrared (VNIR) E-Series micro-Hyperspec High-Efficiency (micro-HE) imager was adapted for use on a piloted aircraft to collect airborne hyperspectral low-rate video of vehicles on highways. Those data are being developed as a challenge data set for vehicle tracking using machine and deep learning methods. Analysis of the airborne data sets highlighted spectral misregistration artifacts. A procedure for compensating for spectral misregistration due to chromatic aberration was developed and testing of the procedure demonstrated considerable improvement in the spectral fidelity of the data collected by this hyperspectral camera.

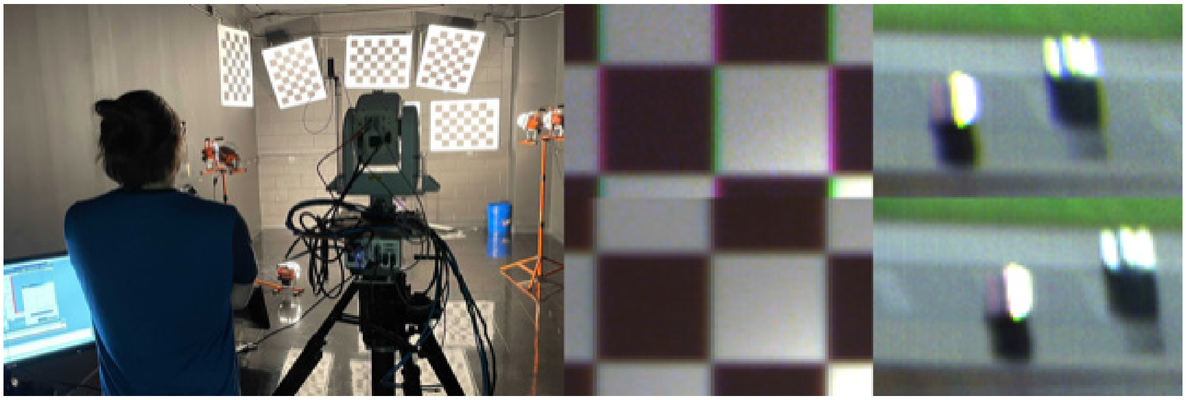


Figure. 2 Illustration of the spectral misregistration correction data collection procedure. The left side of the image shows the Headwall camera pointed toward a series of checkerboard targets. The top center and right images illustrate chromatic aberration at the edges of patterns, while the bottom center and right images demonstrates compensation for the chromatic aberration and thus much greater spectral fidelity.

Water Modeling

Principal Investigator: Adam Goodenough

Research Team: Adam Gooenough

Project Description

Continued work in collaboration with Areté has focused on the further development of DIRSIG 5's in-water radiative transfer capabilities in the context of submerged object identification. The work over the last year has been an effort to reasonably match real world imagery in the visible and NIR regions of the electromagnetic spectrum under a variety of atmospheric, surface, target, bottom and water composition conditions. Particular areas of development have been the accumulation and decay of white cap events, geometric and Mie models for the entrainment of clean and coated bubbles, and the spreading of source irradiance through an unresolved, roughened sea surface. A significant study was also undertaken to find and implement optimizations to the code to minimize noise in highly forward scattering waters.

Project Status

The water model has been successfully compared to collected data under clear sky conditions and we are currently investigating the impact of structured clouds in the red and near infrared to account for a small number of remaining discrepancies.

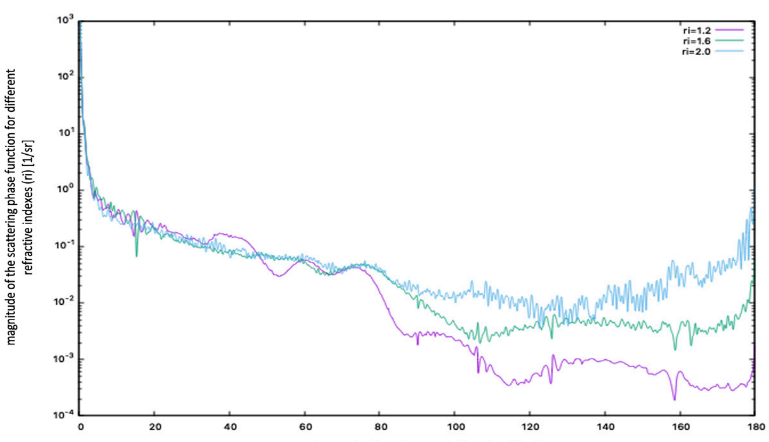


Figure 2: Results of an in-house model of scattering phase functions for bubble populations matching a Hall-Novarini [1989/1995] distribution for a 10 [m/s] wind speed and for different coating types (e.g. lipid, protein, etc..) of 1 [μm] thickness characterized by their real refractive index.

Figure. 1 A dynamic, SWASH-driven model of Egmond beach, Netherlands showing a new, stochastic white cap/foam accumulation and decay model that matches an Areté statistical model

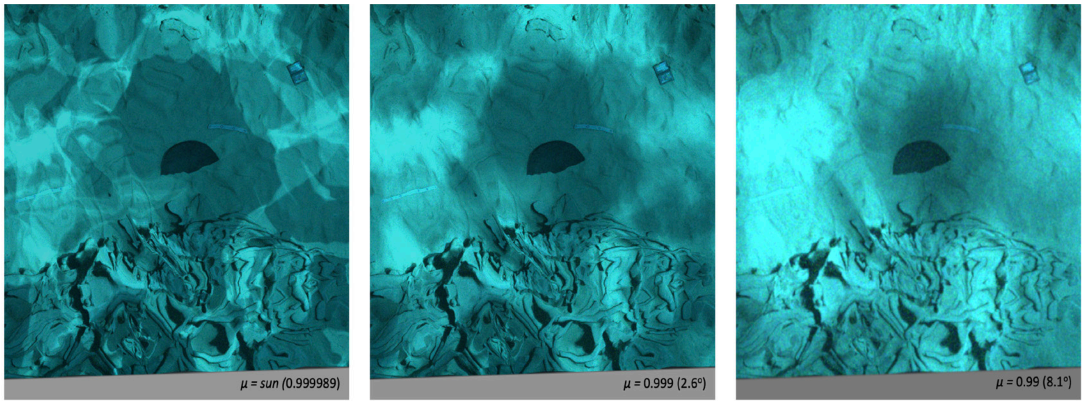


Figure 3: Generic demonstration of a new capability to model non-unidirectional sources (either by an extended source or through spreading due to a non-ideal transmittance distribution at the surface); Three examples are shown, characterized by the half angle subtended (both its cosine and measure in degrees)

Condensed Water Vapor Plume Volume Estimation

Principal Investigator: Carl Salvaggio

Team: Ryan Connal, Tim Bauch, Nina Raqueno, Imergen Rosario, Meg Borek

Project Description

The goal of this research is to develop a methodology for volume estimation of condensed water vapor plumes emanating from mechanical draft cooling towers for thermodynamic and hydrodynamic modeling purposes.

Modern 3D reconstruction is typically performed using techniques referred to as structure-from-motion, a process involving building the scene with correspondences found between multiple images. However, plumes are a dynamically changing physical form and the spatial features either within the plume, or forming the boundaries, are neither significant nor consistent.

Project Status

Current work involves adapting a space carving methodology towards the reconstruction of plumes with simultaneous captures. This requires knowledge of the position and orientation for each camera deployed around the cooling towers, as well as a segmentation mask of the plume from the background. This is currently being investigated with permanent ground stations deployed at a test site capturing data, as well as multiple small unmanned aircraft systems (sUAS) surrounding the cooling tower. One significant aspect of this research is to develop an automatic method for segmenting condensed plumes with a Mask R-CNN model to assist in the generation of 3D volumetric models. The ground-based stations maintain a high frequency of captures to span across various meteorological conditions and provide the ability to properly image the plumes to utilize for space carving and training data for the Mask R-CNN model to be robust.

Figure 1: Original RGB image of condensed water vapor plume.

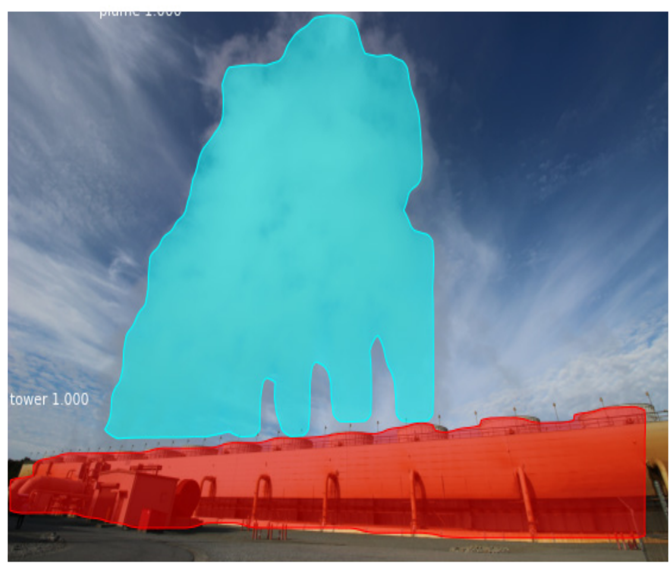


Figure 2: Mask R-CNN model segmentation result.

Characterization of the Computational Reconfigurable Imaging Spectrometer (CRISP) Instrument

Principal Investigator: Aaron Gerace

Team: Eon Rehman, Tania Rehman, Nina Raqueno

Project Description

The Computational Reconfigurable Imaging Spectrometer (CRISP) developed by MIT-LL represents an interesting technology that uses an encoding mask and along-track motion to acquire spectral thermal image data using a microbolometer. The as-built CRISP system was built as a demonstration unit with off-the-shelf components. The focus of this effort was to provide support to MIT to potentially characterize & calibrate the CRISP system and to provide suggestions for hardware solutions to motivate future modifications of the instrument.

Project Status

A ground campaign was conducted in the spring of 2021 in Lake Tahoe, California to support the characterization and potential calibration of the CRISP instrument. Several measurements of water (and other material) temperatures were acquired and used as reference for CRISP-performance characterization. Additionally, the RIT ground team acquired spectral measurements emitted from several materials (e.g., vegetation, sand water, asphalt) and used these data as reference for comparison to CRISP. Although this effort has been completed, potential future collaborations with MIT-LL are being investigated with an upgraded CRISP system.

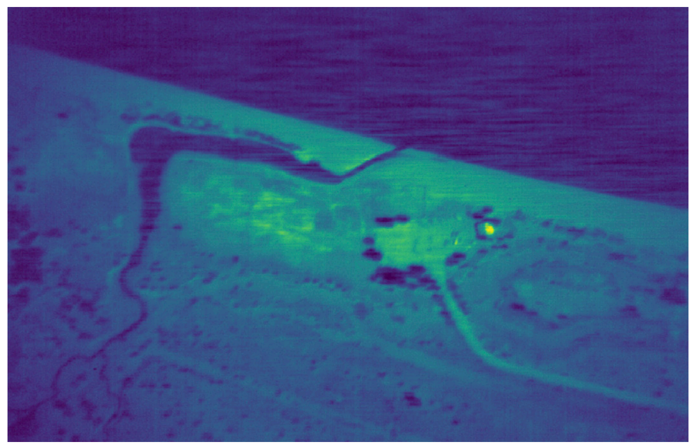


Figure 5: Raw CRISP image data acquired during a spring 2021 airborne campaign of Baldwin Beach in Lake Tahoe, California. To support the sponsor's goals, RIT conducted a coincident ground campaign to obtain reference measurements for CRISP characterization. Results of the studies conducted during this effort were used to inform future sensor modifications.

Hyperspectral Video Imaging and Mapping of Littoral Conditions

Principal Investigator: Charles Bachmann

Team: Rehman Eon, Christopher Lapszynski, Gregory Badura

Project Description

This project focused on the development of retrieval algorithms to map littoral conditions from short time-scale series of hyperspectral imagery. Critical underlying factors impacting littoral zone conditions include sediment density, moisture content, grain size distribution, material composition, and roughness. Our modeling efforts have considered radiative transfer models that incorporate hyperspectral time series and multi-view imagery to retrieve these critical geophysical variables. Hyperspectral imagery sources have included a state-of-the-art integrated mast-mounted hyperspectral imaging system developed by Dr. Bachmann, his students, and RIT staff as well as the DIRS UAS-based hyperspectral imaging systems. The mast-mounted hyperspectral system includes the Headwall visible and near-infrared (VNIR) E-Series micro-Hyperspec High-Efficiency (micro-HE) imager, a General Dynamics maritime-rated high-speed pan-tilt unit, and an onboard Applanix GPS-IMU system for pointing, georeferencing, and precision timestamps. At maximum operating rates, the system can produce a low-rate hyperspectral video imagery time series at about 1.5 Hz. Details of the system and purpose are further described in a recent journal article that was featured on the cover of the Journal of Imaging (https://www.mdpi.com/2313-433X/5/1/6).

Project Status

This past year, we published a validation study of a relatively new radiative transfer model for retrieving soil moisture content from hyperspectral imagery. This study considered both laboratory analysis of hyperspectral directional reflectance data from a hyperspectral goniometer system, the Goniometer of the Rochester Institute of Technology-Two (GRIT-T) (https://dx.doi.org/10.1117/1.JRS.11.046014), as well as the first known field validation of the approach using hyperspectral imagery from the DIRS UAS-based hyperspectral imaging systems acquired contemporaneously with ground truth data (see Eon and Bachmann, https://www.nature.com/articles/s41598-021-82783-3). The field validation campaign took place on a barrier island at the Virginia Coast Reserve LTER site (Figure 1).

Using both our mast-mounted hyperspectral system (https://www.mdpi.com/2313-433X/5/1/6) and our hyperspectral goniometer system GRIT-T, our team similarly has developed and validated other retrieval algorithms for sediment geophysical properties based on radiative transfer models in both laboratory and field settings. In these studies, we have used multi-view and multi-temporal hyperspectral imagery from our mast-mounted hyperspectral imaging system to directly estimate the sediment filling factor, which is directly related to sediment bulk density (https://doi.org/10.3390/rs10111758). The study described in this article documents a comprehensive field campaign to validate the methodology using multi-view and multi-temporal hyperspectral imagery of a tidal flat on a barrier island. This work builds on an earlier article (https://doi.org/10.3390/rs10111758) in which we adapted a radiative transfer model inversion approach that we originally developed and validated in our laboratory using our GRIT-T hyperspectral goniometer system. The extended method allows retrieval of the sediment filling factor from multi-view hyperspectral imagery in field settings. In this earlier article, we used both airborne hyperspectral imagery from the NASA G-LiHT sensor suite as well as multi-spectral satellite imagery from GOES-R.

Using our GRIT-T hyperspectral goniometer system, we have also published laboratory analyses quantifying the accuracy of a methodology that quantifies the degree of surface macroscopic roughness from spectral imagery and accounts for its impact on observed directional reflectance (https://dx.doi.org/10.1109/JSTARS.2019.2896592). This article quantified the limitations of a popular current approach to this problem, and for this work, our article received the prestigious IEEE Geoscience and Remote Sensing Society 2020 JSTARS Prize Paper Award. In related work, we have also developed a method to quantify the degree of surface roughness from a direct measure of the variability of spectral response with angle (https://dx.doi.org/10.1109/TGRS.2019.2908170). This work also used the GRIT-T hyperspectral goniometer system (https://dx.doi.org/10.1117/1.JRS.11.046014), a system which received the 2017 Best Paper Award, Photo-optical Instrumentation and Design, in the Journal of Applied Remote Sensing (https://spie.org/about-spie/press-room/press-releases/spie-journal-of-applied-remote-sensing-honors-three-with-best-paper-awards?SSO=1).

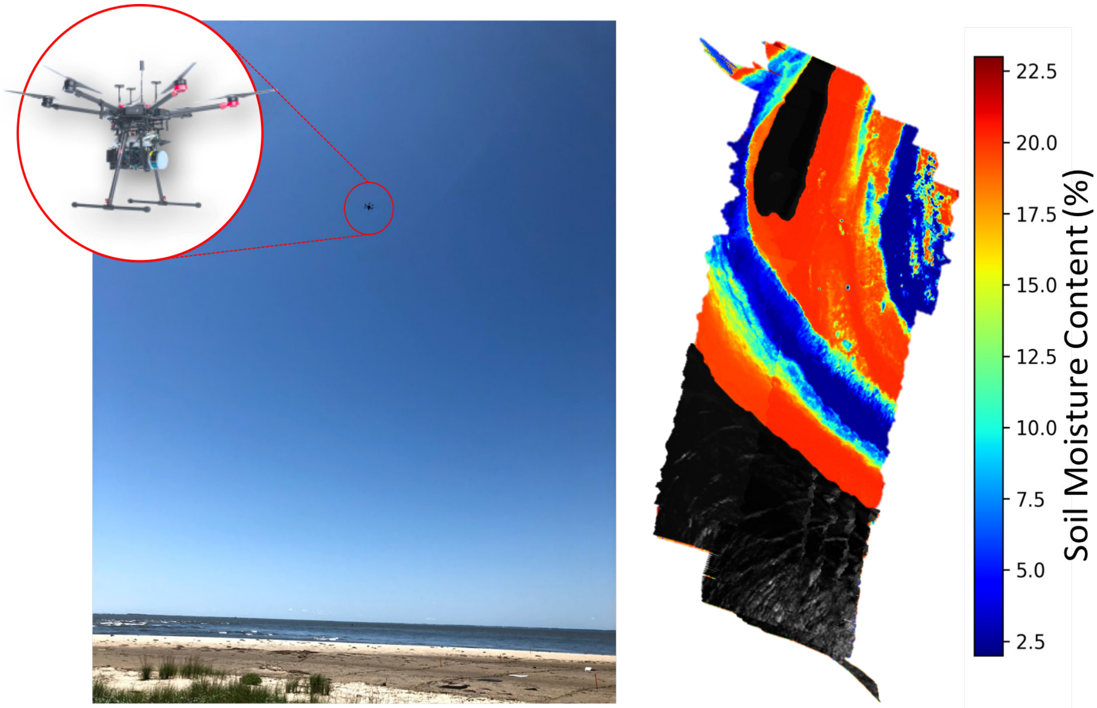


Figure 1 Caption: Hyperspectral retrieval of soil moisture content retrieval using a radiative transfer model of hyperspectral imagery from the DIRS UAS-based hyperspectral imaging systems described in our recent publication (Eon and Bachmann, https://www.nature.com/articles/s41598-021-82783-3). The field validation campaign was undertaken at the Virginia Coast Reserve LTER site.

Characterization of the Multi-Band Uncooled Radiometric Imager

Principal Investigator: Aaron Gerace

Team: Eon Rehman, Nina Raqueno, Tania Kleynhans, Chris Lapszynski, Cody Webber

Project Description

NASA's Earth Science and Technology Office (ESTO) encourages new technologies that can advance science from space. The Multiband Uncooled Radiometric Imager (MURI) developed by Leonardo DRS proposes a unique solution to acquire multispectral thermal data from an uncooled instrument. MURI was chosen by ESTO to be flight-tested with an airborne platform to demonstrate the potential image quality that can be achieved with this new technology. Future missions will test MURI's ability to survive launch and its potential in-orbit performance.

Project Status

Three ground campaigns were conducted over the course of this effort to characterize the fidelity of the image data acquired from the uncooled MURI instrument. Results of these ground campaigns indicate that the image data acquired from the MURI uncooled system exhibits a quality that is in-line with Landsat specifications and it's on-orbit performance. In addition to the characterization of MURI, image data acquired during the airborne campaign were processed to emissivity for comparison to ground reference measurements of several materials. The results shown here indicate that the image data acquired from MURI is of appropriate fidelity to support science applications and derivation of surface temperature products. These studies have concluded although RIT will continue to support MURI characterization & calibration once it achieves orbit.

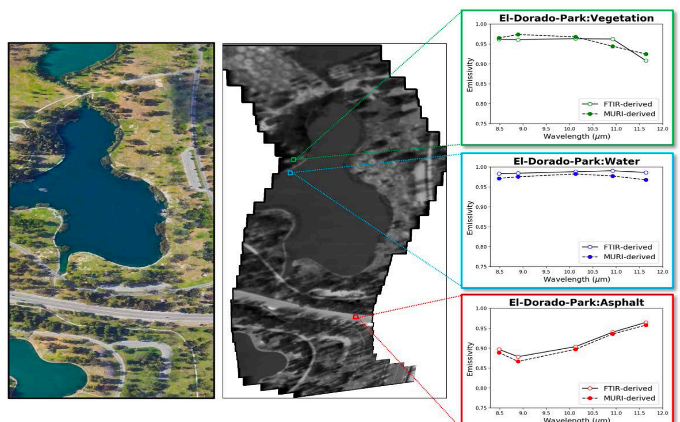


Figure 1: Reference image (left), MURI image data (center), and emissivity comparisons (right) of various materials at El Dorado Park in southern California. Note that RIT conducted a ground campaign to acquire reference measurements for comparison to the sponsor's multispectral thermal demonstration unit. Results of the studies conducted by RIT indicate that the MURI sensor developed by Leonardo DRS exhibits the sensor characteristics for its data to be used to conduct high-quality science.

Simulation & Modeling to Support Definition of Requirements for Landsat Next

Principal Investigator: Aaron Gerace

Team: Eon Rehman, Tania Kleynhans, Nina Raqueno, Lucy Falcon, Ethan Poole

Project Description

Landsat 9 was launched in the fall of 2021 and includes near carbon-copies of the instruments onboard Landsat 8. Requirements for the next Landsat (i.e., Landsat 10), however, are not yet well-defined and the instrumentation used for image acquisition may deviate significantly from the existing sensors. Several years of studies conducted by the USGS and NASA have helped define Landsat user needs. Based on results of these studies and sponsor feedback, RIT is conducting several modeling efforts to support the definition of requirements for Landsat 10's potential sensors.

Project Status

Several studies have been conducted in the first two years of this effort to support both thermal and reflective requirements for Landsat 10, including; assessing the impact of bit-depth on in-water parameter retrieval, determining thermal band-shape and/or band-combinations that enhance temperature and emissivity derivation, and assessing the impact of image compression on higher-level product fidelity. This project is entering its final year and will focus on the definition of requirements for a cross-calibrating transfer spectrometer that NASA is proposing to support the calibration of current and future fleets of small-satellites, which typically depend on vicarious sources of reference data.

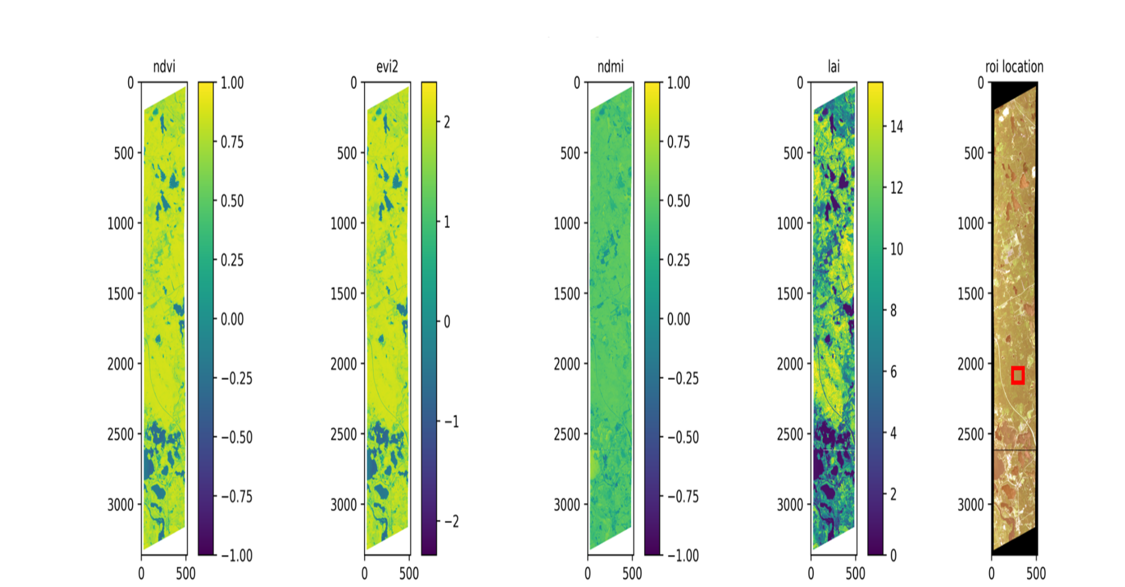


Figure 1: To assess the impact of compression on data quality, a simulated workflow was developed that leverages AVIRIS hyperspectral image data to simulate Landsat Next spectral bands. This figure shows the results of applying band-ratio science algorithms to the simulated & compressed Landsat image data. Note that results of this study will be weighed to determine an appropriate compression scheme that may be used by the next Landsat satellite to reduce the amount of data that is transmitted to ground stations.

Landsat Thermal Product Development and Validation

Principal Investigator: Aaron Gerace

Team: Tania Kleynhans

Project Description

With the release of its Collection 1 in 2017, the USGS has begun introducing higher-level data products to the Landsat user community. To support the development and verification of its potential thermal products (e.g., surface temperature), this five-year effort investigated suitable algorithms and conducted ancillary studies required to accurately derive surface temperature using Landsat 8's Thermal Infrared Sensor (TIRS). Results of this research, which concludes in January 2022, will be incorporated into EROS' Science Processing Architecture (ESPA) and released in Collection 2 reprocessing as a near real-time product to interested users.

Project Status

The generalized split window algorithm for deriving land surface temperature from space-based thermal platforms was researched and ultimately tailored specifically for Landsat 8's Thermal Infrared Sensor. Ancillary investigations were conducted with an emphasis on identifying and rectifying issues that may potentially impact the quality of the derived surface-temperature product. Comparisons of surface temperatures derived using split window to surface temperature reference measurements acquired from land-based equipment validate that the algorithm applied in this research is consistently more accurate than traditional radiative transfer single-band solutions. USGS has developed an implementation of the split window algorithm presented here and studies are being conducted to ensure that the algorithm is implemented as intended. A near real-time product based on this work-flow is anticipated to be released to users by the end of 2021.

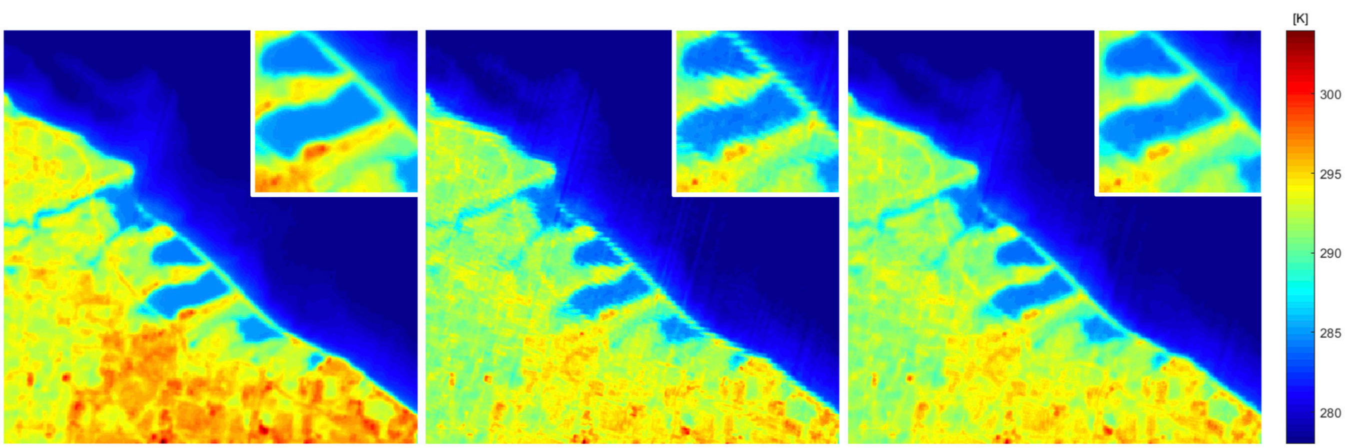


Figure 1: Illustration of the single channel (left), nominal split window (middle), and improved split window (right) surface temperature products developed at RIT. The algorithms developed here have been incorporated into the USGS EROS workflow and support the sponsor's goals of delivering science quality level-2 data to users.

Landsat Calibration & Validation Team Efforts

Principal Investigator: Aaron Gerace

Team: Rehman Eon, Tania Kleynhans, Nina Raqueno, Lucy Falcon, Ethan Poole

Project Description

Landsat 9 was launched on 27 September 2021 and carries near carbon-copies of OLI-1 and TIRS-1 onboard Landsat 8. With the launch of any new sensor, calibration techniques must be consistently applied to the image data to maintain high-quality, radiometry. A significant portion of this effort focuses on using traditional vicarious methodologies to leverage NOAA's buoy network to provide reference data for Landsat's thermal sensors. These methodologies are used to characterize thermal sensors throughout the lifetime of the mission and are particularly useful for identifying anomalies.

Considering the goals of the USGS, validation of their newly introduced higher-level products derived from Landsat data represents the primary focus of this effort. As such, significant research is being conducted to identify equipment, best-practices, and ancillary thermal phenomenology to characterize the fidelity of Landsat's higher-level products.

Project Status

This effort is currently in Year 3 (of 5). As they have done for over twenty-five years, the Landsat thermal group at RIT continues to provide calibration support for Landsat using the NOAA fleet of buoys and its forward modeling workflow. This methodology is particularly useful as it was used to show the impact of an anomaly that occurred with Landsat 8 on 1 November 2020. We continue to monitor TIRS-1 to support nominal calibration and to potentially identify and characterize future anomalies.

To support the goals of the USGS, RIT is developing multi-channel thermal radiometers that are intended to be used for accurately measuring surface temperature and band-effective emissivity at several locations across CONUS. Prototypes of these radiometers have been developed and are currently going through a lab-based characterization. Initial in-lab and in-field measurements verify previous observations that wind has a significant impact on measurement fidelity. A baffle design is being investigated to potentially mitigate the negative impact of wind. A final characterized prototype is anticipated by the end of 2021.

To support underflight activities during Landsat 9's commissioning phase, a ground campaign will be conducted by RIT in November 2021 where thermal measurements will be acquired and used as reference for validation and calibration efforts. It is anticipated that efforts conducted here will have a significant impact on the characterization of both TIRS-1 and TIRS-2 onboard Landsat's 8 & 9, respectively.

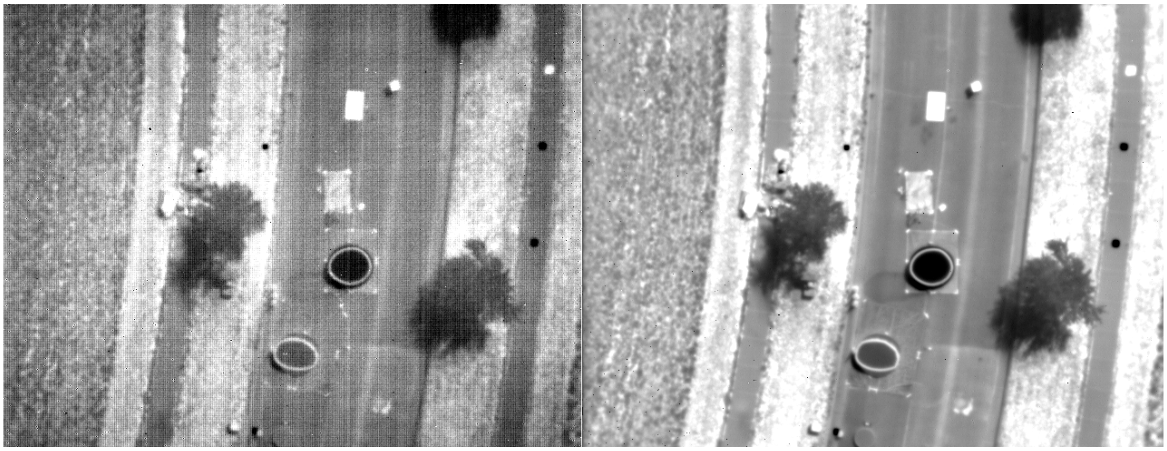


Figure 1: Uncalibrated cooled FLIR thermal data acquired during the Big Multi-Agency Collect (MAC) campaign, which was MX-2's maiden operational flight. (Right) Cooled FLIR image data after a lab-calibration is applied. Several water targets were placed in the study area to support the characterization of the UAS-based FLIR sensor. The Big MAC campaign was conducted to support the sponsor's goals of improving level-2 validation efforts.

L'Ralph Instrument Calibration Support

Principal Investigator: Matthew Montanaro

Project Description

This project provides support for the calibration and validation of the Lucy/Ralph (L'Ralph) payload for NASA. The dual instrument is both a visible/NIR multispectral imager and a short wave IR hyperspectral imager designed for rocky material identification for NASA's Lucy mission to visit multiple Jupiter Trojan asteroids (scheduled for launch in October 2021). The PI is involved in the development and execution of calibration test procedures and data processing and analyses during pre-flight instrument checkout at NASA Goddard Space Flight Center. These efforts support the spectral, geometric, and radiometric characterization of the instrument to ensure the primary and secondary science objections of the Lucy mission are met. The PI interfaces with the instrument engineering team, calibration team, and mission science team to convey instrument performance characteristics that may influence science results.

Project Status

Over the past year, the L'Ralph instrument has undergone an extensive series of pre-flight environmental tests at NASA Goddard including the spectral characterization test and three rounds of thermal-vacuum characterization tests (Focus, pre-vibe, post-vibe). The PI supported all of these campaigns by developing and executing test procedures, analyzing acquired data, reporting and documenting results, and providing processed datasets and figures for anomaly troubleshooting and resolution. Major efforts include troubleshooting the focal plane array output and the data stream playback issues, mapping focal plane and scan mirror geometry, providing processed focus results to Optical engineers, and characterizing stray light and scattering artifacts in the optical system. This work contributed to a successful pre-flight test campaign and subsequent successful pre-ship review for the instrument. L'Ralph has since been integrated with the Lucy spacecraft and completed observatory-level testing. It is currently in final launch preparations at Cape Canaveral Space Force Station.

Advanced Hyperspectral Exploitation Using 3D Spatial Information

Principal Investigator: Emmett Ientilucci

Team: Michael Gartley

Project Description

There is a need to advance hyperspectral exploitation algorithms by incorporating 3D spatial information for improved target detection and identification. Hyperspectral imaging (HSI) has demonstrated utility for material classification and target detection. Using HSI alone can produce false alarms and possible low confidence in detects for certain target classes. Additional 3D information can be used to help improve the separability of material and target classes, which can, ultimately, reduce the number of false alarms. The overall focus of the effort is to improve and expand upon previous work with emphasis on target detection, rather than material classification.

Project Status

RIT is working with SSI to choose target shapes and spectra of interest to the sponsor to be placed throughout DIRSIG Megascene1. Many instances of the target of interest are placed within the scene in locations ranging from wide open to the sun with minimal adjacent surfaces to hidden within a building courtyard and within the shadow of a treeline. Emphasis is placed on radiometric accuracy of the DIRSIG simulations and include radiometric effects of adjacent surfaces, partial transmission through tree leaves, and a MODTRAN derived skydome. Additionally, confuser targets are also being placed around the scene with similar spectra and 3D shape in order to test the robustness of detection algorithms. Hyperspectral (i.e., 0.5 to 2.5 um) simulations have been created for a variety of sun angles. Pixel geo-location truth (East-North-Up x,y,z coordinates) for each pixel have been provided to the sponsor for use in the detection algorithm.

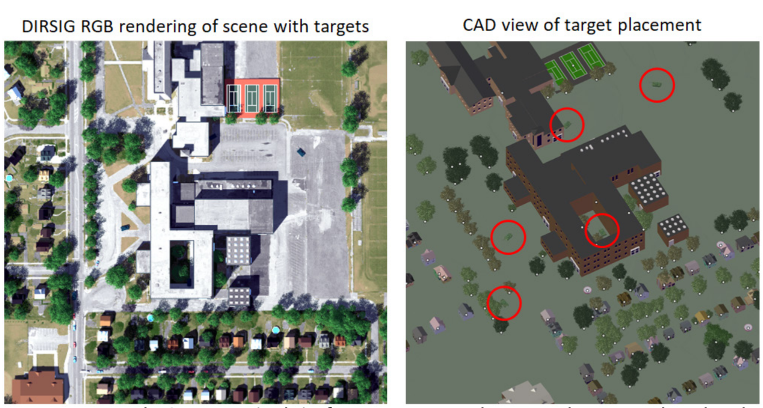


Figure 1: Example CAD view (right) of Megascene1 with T-72 tank targets placed in the open, along a tree-line, within an urban canyon, and next to a building side.

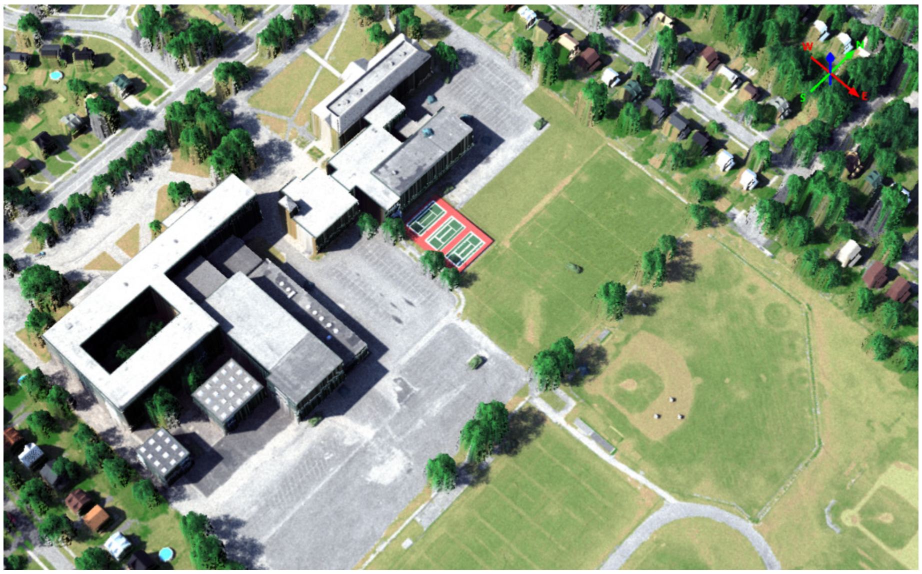


Figure 1: Example HSI image (RGB bands shown as texture to LiDAR base facetized image) of Megascene 1.

Analysis of NOx Blast Fumes with Drones

Principal Investigator: Emmett Ientilucci

Team: Bob Kremens, Nina Raqueno, Tim Bauch

Project Description

A private company who manufactures, distributes, and applies industrial explosives for industries including quarrying, mining, construction, and other applications. Although it's unusual, these massive explosions can release a foreboding yellowish-orange cloud that is often an indicator of nitrogen oxidecommonly abbreviated NOx. The company is seeking research into the ability to image these plumes so as to potentially estimate volume and concentration. The ultimate goal would be to image these plumes in the field with multiple drones.

Project Status

We have explored the usage of structure from motion to image 3D objects, run experiments to estimate volume of 3D solid objects, explored the usage of multiple cameras to capture images of still objects. We are currently working on utilization of a GPS mechanism for camera triggering along with video frame extraction towards modeling actual plumes. We have utilized smoke grenades as a surrogate for spatial imaging, designed and set up gas sampling devices to sample CO, near the detonation, as an intermediate surrogate for NOx.

Figure 1 : Synced video imagery (single frame shown here) from six camera positions. This data will inserted into the 3D-reconstructed background imagery, which has been geo-located.

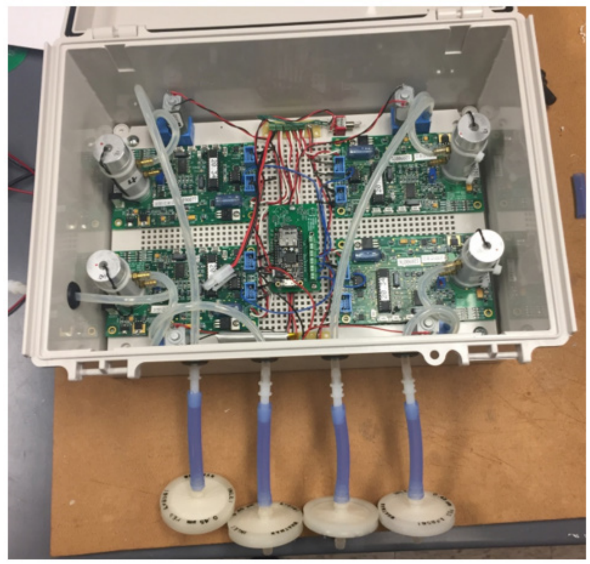


Figure 2 : CO air sampler. The sampler consists of 4 Val-Tronics CO samplers with a full scale range of 1% (10,000ppm) and a resolution of 1 ppm, 4 separate peristaltic pumps, input filters, a data logger sampling at 20Hz, battery power (up to 5 hours of battery life) and a port for the RAE systems NOx sampler.

Satellite Calibration with Flare

Principal Investigator: Emmett Ientilucci

Team: David Conran

Project Description

FLARE is a new capability for performing the vicarious radiometric calibration of high, medium, and low spatial resolution sensors. The SPecular Array Radiometric Calibration (SPARC) method employs convex mirrors to create two arrays of calibration targets for deriving absolute calibration coefficients of Earth remote sensing systems in the solar reflective spectrum. The first is an array of single mirrors used to oversample the sensor's point spread function (PSF) providing necessary spatial quality information needed to perform the radiometric calibration of a sensor when viewing small targets. The second is a set of panels consisting of multiple mirrors designed to stimulate detector response with known at-sensor irradiance traceable to the exo-atmospheric solar spectral constant. The combination of these arrays with a targeting station is the basis for a new, on-demand commercial calibration network called FLARE.

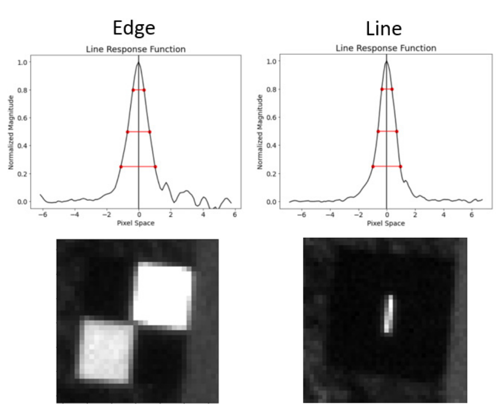


Figure 1: Investigating the spatial response of aerial imaging systems to standard targets can highlight major discrepancies between quasi-ideal (edge targets) and ideal (point or line sources) impulse responses. In this image a comparison study between edge and line targets was conducted with comparative results in favor of the line source. The line source has superior noise reduction and is not plagued by the numerical derivative used in the transformation of the edge response function into the line response function.

Project Status

We are currently working with the sponsor writing algorithms, as well as processing data, for the generation of PSF's and MTF's on imagery from the FLARE network.

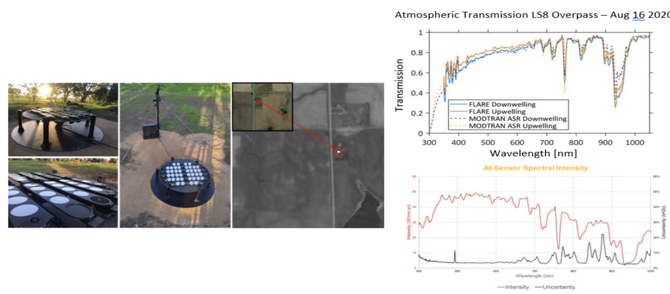


Figure 2: The FLARE Network Team has been validating the radiometric calibration procedure compared to standard practices performed by RadCalNet and Langley techniques. The current location of the FLARE station is on a farm in South Dakota in connection with the South Dakota State University. Current efforts are being conducted to install another FLARE system in Texas to provide more opportunities for calibration testing as the winter months approach South Dakota.

Shadow Mitigation

Principal Investigator: Emmett Ientilucci

Team: Michael Gartley, Scott Couwenhoven

Project Description

Shadows are present in a wide range of aerial images from forested scenes to urban environments. The presence of shadows degrades the performance of computer vision algorithms in a diverse set of applications, for example. Therefore, detection and mitigation of shadows is of paramount importance and can significantly improve the performance of computer vision algorithms. This work assumes as input a multispectral image and co-registered cloud shadow map which are used to calculate shadowed pixel spectral statistics and adjusting to match the statistics of spectrally similar sunlit pixels resulting in a shadow mitigated multispectral image.

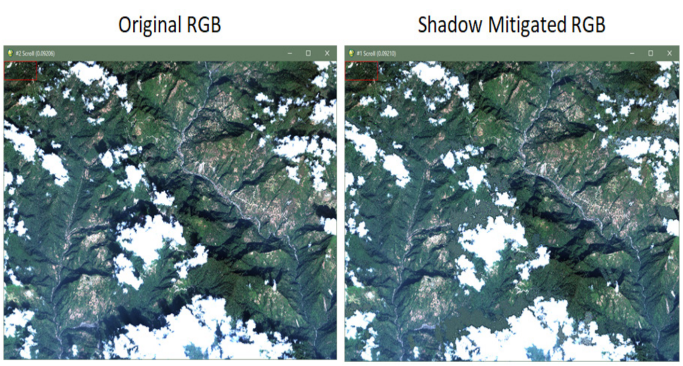


Figure 1: Thumbnail RGB images of a WV-2 image product before (left) and after (right) shadow mitigation is applied.

Project Status

RIT is developing a shadow mitigation algorithm which focuses on removing the appearance of shadows in high spatial resolution multispectral overhead collected imagery. The intent is for material spectral appearance to be constant regardless of the level of sun-light and shadow for use in sponsor algorithms. Our approach utilizes multispectral image data and a binary cloud shadow map as input and outputs a multispectral image with shadows removed. The removal of shadows is accomplished by determining spectral statistics of shadowed materials, comparing to spectral statistics of spectrally similar sunlit material surfaces and adjusting the shadowed pixels to match the brightness of the sunlit pixels. We have found good shadow mitigation results for vegetative scenes and moderate results for arid regions thus far. We are additionally researching methods for the incorporation of machine learning so as to help augment the physics-based process mentioned above.

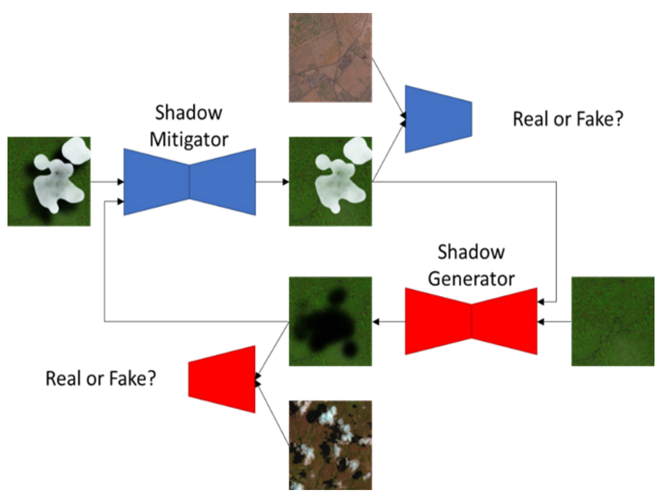


Figure 2: Demonstration of how the inability to remove clouds affects a CycleGAN based approach.

Unmanned Aerial System Data Collections

Principal Investigator: Emmett Ientilucci

Team: Nina Raqueno, Tim Bauch

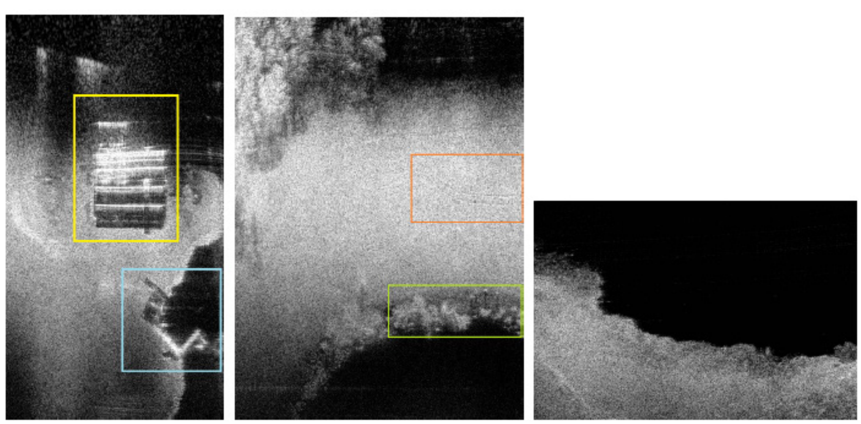
Project Description

RIT has been working work the sponsor to provide them with a variety of data sets with heavy focus on varying sensor modality, number of spectral bands (i.e., multi- and hyper-spectral), and imaging scenarios.

Project Status

We have been collecting and processing data related to a variety of scenarios that can be used for input to various algorithms. Recently, this includes shadowed targets, material types over a variety of backgrounds, RGB, VNIR hyperspectral, SWIR, thermal, LiDAR and more recently, SAR.

Figure 1: Late afternoon flight showing most targets in shadow mosaic from the RGB Mako sensor



a) b) c)

Figure 2: Example of SAR data collected of: a) hard structure with complicated roof line(yellow) and dock(blue); b) vehicle tracks(orange) and shoreline with vegetation(green); c) open shoreline with little vegetation.

Global Surveillance Augmentation

Principal Investigator: Emmett Ientilucci

Team: Scott Brown, Byron Eng, Grady Saunders, Phil Salvaggio

Project Description

This project is a multi-team effort to develop hardware and algorithms for target detection. In addition to providing general DIRSIG support, we are providing sensor models to simulate the hardware being developed. We will also be helping leverage DIRSIG's ChipMaker plugin to generate training data for target detection algorithms. To make the training data robust, we are developing procedural methods to generate urban/industrial DIRSIG scenes automatically. Such scenes are intended to serve as randomizable, high fidelity background environments with intuitive input parameters, so that end users can more easily introduce plausible variability into their training data.

Project Status

We are currently developing tools to generate DIRSIG scenes procedurally, with minimal effort from the end-user. Randomizable road networks, city block classifiers, and ground/roof clutter are being generated and cohesively assembled by a growing C++ codebase. The implemented algorithms have adjustable parameters to control, e.g., the density and width of roads, the placement of cars and trees, and the arrangement of platforms and ductwork on rooftops. Going forward, we would like to develop this codebase further, and to introduce a set of command tools and/or Python bindings to form a better asset creation and management workflow. Procedural techniques to generate textures have also been implemented using Python. These techniques sum octaves of elementary noise functions using configurable scaling and bias parameters to generate DIRSIG-compatible input images to mimic the appearance of, e.g., grass and cement, when used with an appropriate spectral database. We aim to better integrate our scene and texture generation techniques in the future to permit automated generation of spatially-aligned patterns on DIRSIG scene geometry, such as road markings and lawnmower lines.

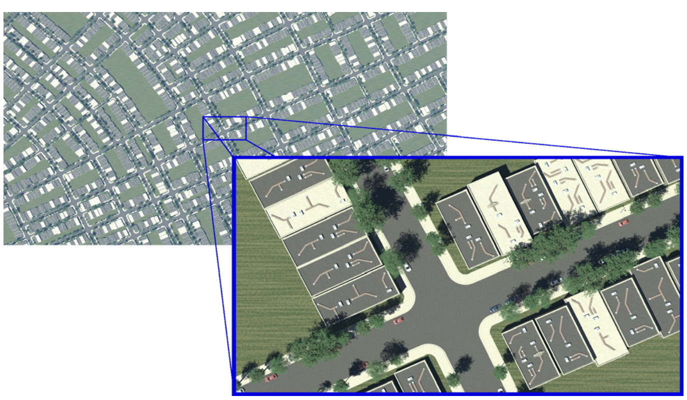


Figure 1: Miscellaneous asset geometry generated procedurally using our C++ codebase, as well as an example tree generated from the Sapling Blender plugin. All assets to be used to populate procedural scenes.

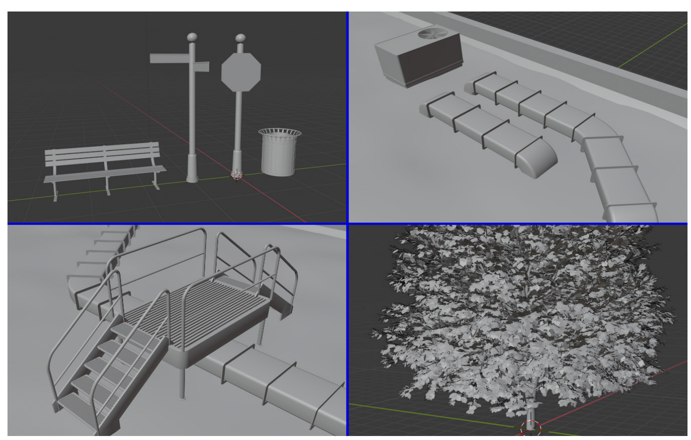


Figure 2: DIRSIG5 rendering of an example procedural urban residential environment, featuring roads, sidewalks, trees, cars, buildings, and rooftop assets, with procedural grass, cement, and asphalt textures.

Integrating TES and Modern Target Detection Capability into the FASSP Model

Prinicpal Investigator: Emmett Ientilucci

Team: Runchen Zhao

Project Description

A material's surface emissivity can be affected by many things including particle size, for example. Increasing or decreasing the particle size can vary the dominant scattering sources between surface scattering and volume scattering. Thus, how the particle size, e.g., a powder, impacts target detection performance is a valuable question, especially in the LWIR domain. To analyze this, parameter trade-off studies focusing on particle size can be studied using Forecasting and Analysis of Spectroradiometric System Performance (FASSP) model. FASSP is an end-to-end system performance forecasting analysis tool which uses first and second order statistics associated with targets and background. The current FASSP model does not have a temperature/emissivity separation (TES) algorithm which is needed to perform realistic analysis in the LWIR. In addition, a state-of-the-art and widely used detection algorithm called adaptive cosine estimator (ACE) is to be implemented. Due to the nature of FASSP (i.e., propagating statistics), ACE cannot be directly coded into the model. An alternative and equivalent algorithm called the cotangent detector will be utilized instead.

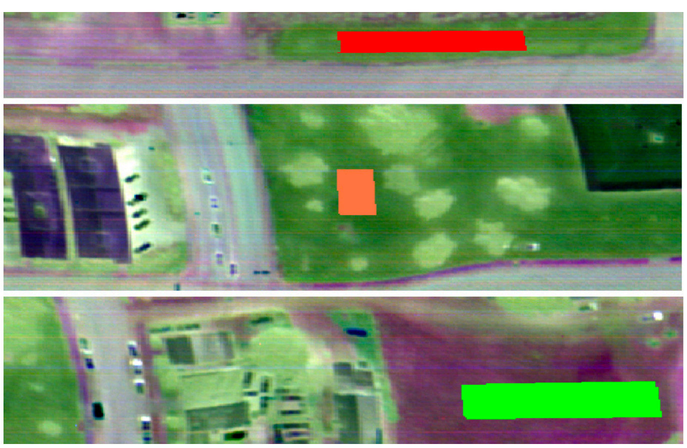


Figure 1: AHI LWIR data taken near the Yuma Proving ground in Yuma, AZ. False color images were generated using band 20 (8 um), band 96 (9.3 um) and band 176 (10.7 um). Shown are regions of interest (ROI) illustrated as a green region (4455 pixels), an orange region (2432 pixels) and a red region (1610 pixels). The overall mean and covariance were computed from these regions.

Project Status

We have already finished the development of a statistical TES algorithm (called S-ISSTES) and implemented it into FASSP as well as a cotangent detector which is equivalent to ACE. Comprehensive validations addressing both performance of S-ISSTES and the newly improved FASSP have been completed. Two real HSI datasets, HyTES and AHI, combined with simulated data were used in the validations. These results are to be assembled into two journal papers. Findings for the S-ISSTES algorithm are to be submitted to IEEE Geoscience and Remote Sensing Letters.

Figure 2: The HyTES data was captured from the Gallo Colony Vineyards in California. Regions of interest (ROI) were carefully selected (i.e., considering region uniformity and avoiding image artifacts) at different locations in the data. Mean spectrum of target and background used in our validation studies. The target spectrum mean was calculated from the green regions while the background mean spectrum was calculated from all five red regions.

HiRes Vineyard Nutrition

Principal Investigator: Jan van Aardt

Team: Rob Chancia, Tim Bauch, Nina Raqueno, Imergen Rosario, Mohammad Shahriar Saif, Terry Bates (Cornell U.), Justine Vanden Heuvel (Cornell U.), Manushi Trivedi (Cornell U.)

Project Description

The USA annual grape production value exceeds $6 billion across as many as 1 million acres (>400,000 ha). Grapevines require both macro- and micro-nutrients for growth and fruit production. Inappropriate application of fertilizers to meet these nutrient requirements could result in widespread eutrophication through excessive nitrogen and phosphorous runoff, while inadequate fertilization could lead to reduced grape quantity and quality. It is in this optimization context that unmanned aerial systems (UAS) have come to the fore as an efficient method to acquire and map field-level data for precision nutrient applications. We are working in coordination with viticulture and imaging teams across the country to develop new vineyard nutrition guidelines, sensor technology, and tools (see Figure 1) that will empower grape growers to make timely, data-driven management decisions that consider inherent vineyard variability and are tailored to the intended end-use of the grapes. Our primary goal on the sensors and engineering team is to develop non-destructive, near-real-time tools to measure grapevine nutrient status in vineyards. The RIT drone team is capturing hyper- and multispectral imagery over both concord (juice/jelly) and multiple wine variety vineyards in upstate New York.

Project Status

We published an article in Remote Sensing reporting our first wavelength selections for grapevine nutrient assessment using spectral imagery taken in September 2020. We acquired UAS-based hyperspectral (400-2500 nm, Headwall Nano & SWIR) and five-band VNIR (MicaSense) imagery at three sites in upstate NY, at bloom and veraison (fruit ripening) growth stages. Imagery was captured in coordination with field leaf sampling studies conducted by Terry Bates at Cornell Lake Erie Extension Laboratory (CLEREL) and Justine Vanden Heuvel at Cornell University:

- CLEREL Martin and Railroad Concord blocks – 06/10/2021 & 08/24/2021
- Cornell's Lansing Riesling block – 6/11/2021 & 08/09/2021
- Sheldrake Vineyard on Cayuga Lake – 06/17/2021 & 08/09/2021

We presented a comparison of two nitrogen status prediction models at the American Geophysical Union Fall Meeting in December 2021: One using five optimal bands chosen from hyperspectral imagery (Headwall Nano) and the other using five default multispectral bands (MicaSense), as shown in Figure 2. This report ncluded all spectral imagery and ground truth nutrients from both 2020 and 2021.

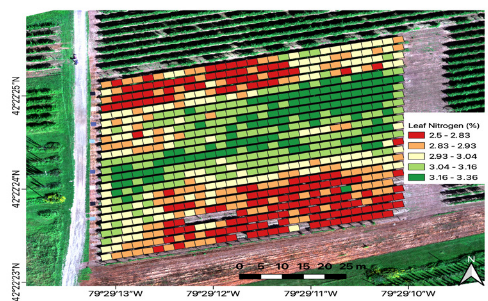


Figure 1. Grapevine nitrogen assessment based on 5-band MicaSense RedEdge-M imagery.

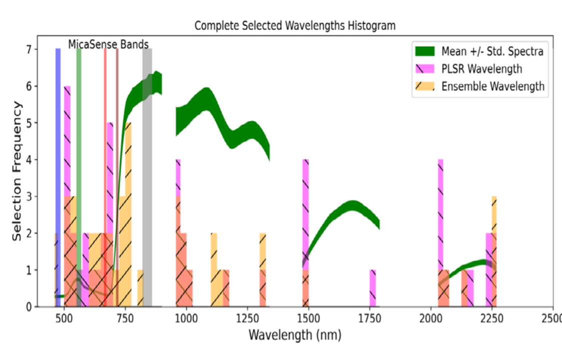


Figure 2. Wavelength selection histogram showing the frequency of selections throughout the VNIR and SWIR range for six different nutrient models. Blue-green, red, and red edge wavelengths were frequently selected outside the range of typical multispectral bandwidths (MicaSense RedEdge-M bands shown).

Fostering Agriculture Remote Sensing (FARMS) Alliance Part 1

Principal Investigator: Jan van Aardt

Team: Carl Savaggio, Sarah Pethybridge, Amir Hassanzadeh, Fei Zhang

Project Description

We established an academic/industrial innovation ecosystem, called the Fostering Agricultural ReMote Sensing Alliance, or FARMS Alliance, around the technology and data analytics of remote sensing from unmanned aircraft systems (UAS), with precision agriculture (PA) as the targeted application area. We focus on a proxy crop, snap bean, and three proxy applications prioritized by our industry partners as key to their commercial efforts, namely disease risk modeling, harvest timing/scheduling, and yield prediction to propel FARMS into a sustainable innovation ecosystem. This summary Part I, focuses on addressing the above-mentioned objectives via hyperspectral UAS-based sensing.

Over the past year we moved from a greenhouse experiment to a large field study in Geneva, NY, where we extensively studied how snap bean spectral response (UAS-based) could explain yield and harvest maturity. We conducted UAS flights that captured most important physiological stages of this broad-acre crop over the summer of 2019. We evaluated yield at two stages, namely early and late harvest. We also assessed crop pod maturity level for four different test sets (i.e., class combinations). For this study, we utilized a more robust approach for wavelength selection, which took into account not only correlation between spectral bands, but also the degree to which each is relevant to the objective. We used meta-heuristic optimization algorithms, such as Simulated Annealing (SA), Genetic Algorithm (GA), Particle Swarm Optimization (PSO), and plus-L minus-R Stepwise (LRS) approaches and compared the results.

Due to the nature of the hyperspectral sensor, atmospheric effects, UAS equipment influence, etc., we have also determined it is mandatory to remove the unwanted noise after the data are collected. We have been evaluating deep learning algorithms that can remove noise from the collected hyperspectral data rapidly using GPUs. Figure 1 shows the power of such algorithms in denoising hyperspectral data.

Project Status

Our team is continuing to collect data for the 2021 trial, which tie into current/past results, where we are i) extending results from a past greenhouse study and ii) validating UAS-based findings from 2019 with the aim to publish two more high quality articles based on the two different annual data sets. Finally, for the reported greenhouse study, we published an article in the Journal of Applied Remote Sensing (yield forecasting), as well as one ready-to-be submitted article (growth stage and maturity classification), aimed at the Remote Sensing Journal.

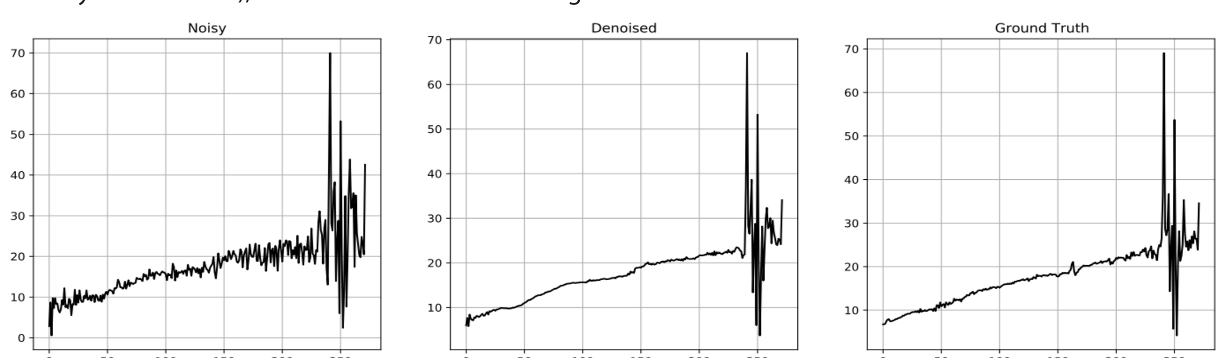


Figure 1: The hyperspectral denoising deep learning approach that is being developed in order to speed up the denoising process and improve performance on tasks such as classification and regression, for yield prediction and harvest maturity.

Fostering Agriculture Remote Sensing (FARMS) Alliance (Part 2)

Principal Investigator: Jan van Aardt

Team: Carl Savaggio, Sarah Pethybridge, Amir Hassanzadeh, Fei Zhang

Project Description

We established an academic/industrial innovation ecosystem, called the Fostering Agricultural ReMote Sensing Alliance, or FARMS Alliance, around the technology and data analytics of remote sensing from unmanned aircraft systems (UAS), with precision agriculture (PA) as the targeted application area. We focus on a proxy crop, snap bean, and three proxy applications prioritized by our industry partners as key to their commercial efforts, namely disease risk modeling, harvest timing/scheduling, and yield prediction to propel FARMS into a sustainable innovation ecosystem. This summary, Part II, focuses on addressing to above-mentioned topics via LiDAR and structure-from-motion (SfM) UAS-based 3D sensing.

Our premise is that UAS-based tools can be used to meet the farmers' need for enhancing crop productivity and yield. By utilizing imaging sensors carried by drone, we are extracting structure information of the crops from the 3D points cloud created by SfM of RGB images and by LiDAR, and then build up effective models to evaluate yield or the disease risk. Our objectives are to i) assess the utility of UAS-based LiDAR and SfM point clouds to accurately map digital elevation models and crop height models of snap bean; ii)) evaluate structural traits (e.g., leaf area index; LAI) of snap beans using the two types of point clouds; and iii) determine the efficacy of LiDAR and SfM-based point clouds and structural metrics to accurately model disease risk and crop yield for snap beans.

Project Status

We are comparing SfM and LiDAR point clouds across multiple evaluation criteria, evaluating LAI of snap beans using UAS-based LiDAR point clouds and multispectral imagery (see Figures 1-3), extracting key structural features of the snap beans for disease risk modelling and yield prediction, and building models to evaluate yield and disease risk of the snap beans.

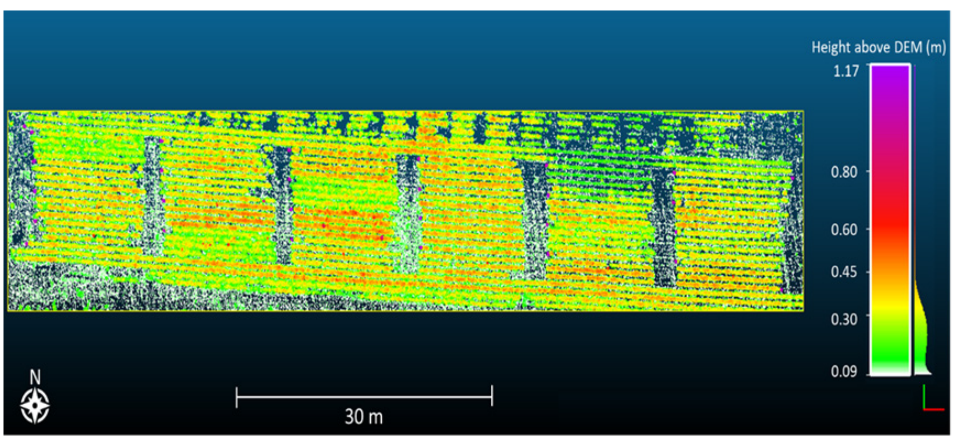


Figure 1. A crop height model generated from the LiDAR point cloud of a snap beans field.

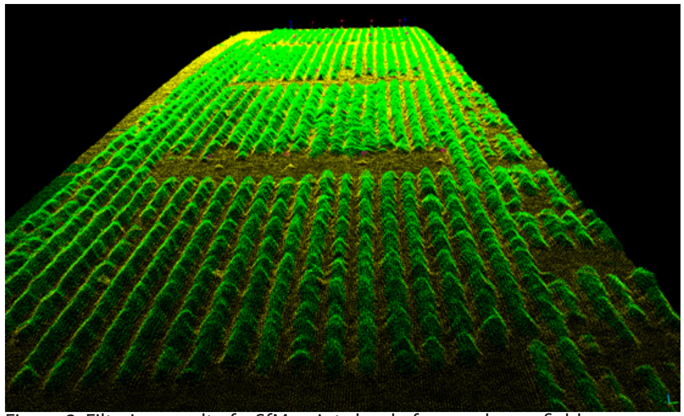


Figure 2. Filtering result of a SfM point cloud of a snap beans field.

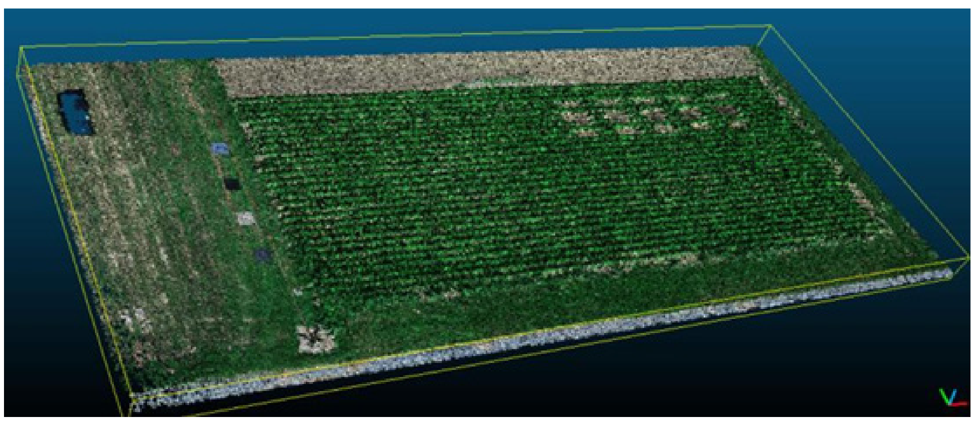


Figure 3. A SfM point cloud coloured by corresponding pixel values in mosaicked multispectral imagery.

The Influence of Forest Canopy Structure and Foliar Chemistry on Remote Sensing Observations

Principal Investigator: Jan van Aardt

Team: Kedar Patki, Rob Wible, Grady Saunders, Keith Krause (Battelle), Scott Ollinger (University of New Hampshire; UNH), Andrew Ouimette (UNH), and Jack Hastings (UNH)

Project Description

The objectives of this project are to i) better understand the correlations between spectral reflectance and LiDAR structural metrics and structure-trait cause-and-effect relationships; ii) propose a data fusion approach (LiDAR + Hyperspectral) to trait prediction; and iii) apply the fusion approach to mitigate scaling issues (leaf level, stand level, forest level). We are currently focusing our efforts towards understanding impact on spectral and structural metrics due to variation in leaf angle distributions (LAD). Leaf angle is a key factor in determining arrangement of leaves, and directly impacts forest structural metrics, such as leaf area index (LAI), which in turn is an important variable for a variety of ecological processes, such as photosynthesis and carbon cycling.

Project Status

Our approach is to use RIT's DIRSIG simulation package to simulate hyperspectral and LiDAR capture over a virtual forest scene, followed by derivation of various spectral indices and structural metrics for analysis. We have built a virtual replica of the Prospect Hill area of Harvard Forest, MA, using 3D models of trees from Onyxtree software suite. We have embedded optical properties (reflectance and transmittance curves), based on Ecosis and NEON vegetation spectra databases as well as data from our recent field collection to Harvard Forest in August 2021. Our simulations are based on the NEON AOP hyperspectral (NASA NIS Imager) and LiDAR (Optech Gemini) imaging instruments. We also have developed software (Python) to modify 3D models from Onyxtree to conform to desired leaf angle distributions (see Figure 1), as well as desired leaf size distributions. Finally, we are in the process of simulating different variants of our forest scene, each with a particular leaf angle distribution for deciduous broadleaf trees and obtained spectral imagery and lidar data.

We have been able to qualitatively show the change induced by varying leaf angle distributions in key vegetation indices (NDVI and PRI) and LiDAR penetration metrics and canopy height metrics for a sub-region of the forest area. Further quantitative analysis of change induced by varying leaf angle distributions in various spectral indices, LiDAR metrics and existing models for key biophysical traits (e.g., nitrogen %) will follow next, and we will introduce other structural parameters, e.g., leaf clumping, and analyze its impact in a similar way as done for leaf angle distribution variations.

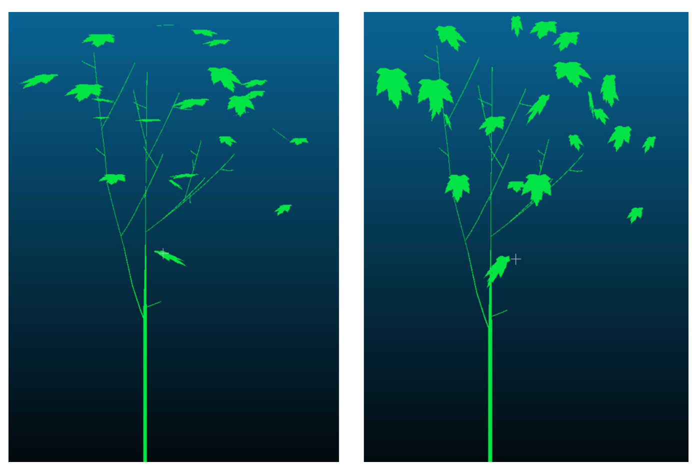


Figure 1. Examples of a peak 30 deg (left) and peak 60 deg (right) leaf angle distributions, for Acer rubrum sapling leaves as an example.

Enhanced 3D Sub-Canopy Mapping via Airborne/Spaceborne Full-Waveform LiDAR

Principal Investigator: Jan van Aardt

Team: Dr. Keith Krause, Kedar Patki, Grady Saunders

Project Description

This 3D modeling effort aims to better understand how light detection and ranging (LiDAR) laser light propagates through tree canopies. LiDAR has seen widespread use in measuring 3D vegetation structure, but it is not abundantly apparent how laser light propagates through a multi-layered forest canopy and, critically, which portions of the 3D space have been adequately sampled or remain unsampled. For the first phase of this project, a physics-based, first-principles radiometric model simulation tool (DIRSIG), combined with remote sensing data collected from Harvard Forest, MA, will be used to create a detailed virtual scene of a northeastern forest that accurately models reflectance, transmission, and absorption (380-2500nm) for multispectral, hyperspectral, and LiDAR sensing modalities. Here we highlight the methodology for creating and validating the virtual scene, which will be used to examine the effects of various LiDAR parameters, e.g., wavelength, beam geometry, etc., on sub-canopy detection.

Project Status

Building on the work accomplished by Dr. Ben Roth (RIT PhD 2020) on leaf bi-directional transmission distribution function (BTDF) modeling of northeastern trees, we have expanded and rebuilt an original 40 x 40m Harvard Forest scene. The new scene (see Figures 1 and 2) is a virtual representation of an actual 700 x 500m plot within Harvard Forest, dubbed the "mega plot". The mega plot is a long-term ecological research site established by Forest Global Earth Observatory (Forest GEO), containing three distinct ecological environments (wetlands, deciduous, and conifer-dominated forests). In August 2021, we conducted our own field research within the mega plot to gather structural and spectral information on the canopy and sub-canopy vegetation. UAS-based LiDAR, HSI, and MSI were collected over the entire mega plot with corresponding terrestrial LiDAR, photosynthetic active radiation (PAR), and hand-held spectral measurements, taken at 58 locations within the mega plot.

The mega plot scene was built from the ground up using the remote sensing data we collected during our site visit, as well as archived Harvard Forest data, containing over 110k geo-located tree and sub-canopy vegetation locations. Canopy height (CHM) and digital elevation models (DEM) were derived from the LiDAR point clouds and utilized in the scene to provide realistic elevation models. Valid tree heights were calculated via allometric equations. Certain shrubs and low-growing vegetation were given specific height ranges based on the local flora documentation. The 3D models used for each of the 64 species present in the mega plot were built using structural parameters derived from previous Harvard Forest field measurements, pictures, and information from a Harvard Forest flora paper, totaling 110 vegetation models. The models were assigned species-based reflectance spectra, taken from online databases and field measurements, processed in PROSPECT to derive transmittance. Objects such as towers, sheds and vehicles were placed using GPS data (see Figure 3).

Below are three simulated pictures of our mega plot scene. Next steps will involve extensive simulation to assess waveform LiDAR propagation through a complex forest, toward a better understanding of sub-canopy radiometric interactions.

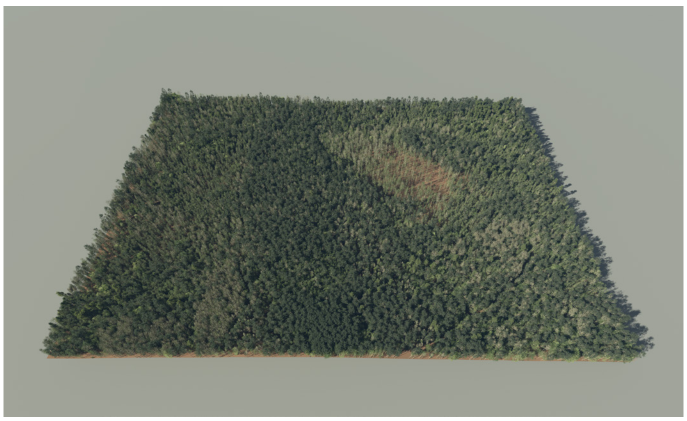


Figure 1. A simulated RGB image of the mega plot scene – oblique view. This scene contains >110,000 individual objects.

Figure 3. A simulated RGB image of a site within the mega plot scene, showing the inclusion of a vehicle object.

Figure 2. A simulated RGB image of the mega plot scene – side-view. Note the inclusion of even canopy competition in this scene.

On the Use of Terrestrial Laser Scanning for Structural Assessment of Complex Forest Environments

Principal Investigator: Jan van Aardt

Team: Richard MacKenzie, Rob Chancia, Ali Rouzbeh Kargar

Project Description

Mangrove forests respond to sea level rises by maintaining their forest floor elevation, and through root growth, sedimentation, resistance to soil compaction, and peat development. Human activities, such as altered hydrology, sedimentation rates, and deforestation, can hinder these natural processes. As a result, there have been increased efforts to monitor surface elevation change in mangrove forests. Terrestrial lidar system (TLS) data were collected from mangrove forests in Micronesia in 2017 and 2019, using the Compact Biomass Lidar (CBL). The sediment accretion was assessed in the lidar data, using the cloth simulation filtering (CSF), followed by filtering the points based on angular orientation, which improved the performance of the ground detection. The elevation change between the two years was found by subtracting the z (height) values of the nearest points found using nearest neighbor search. Extreme elevation changes, attributed to human interactions or fallen logs, were removed using interquartile range analysis. The consistency of TLS-measured elevation changes in comparison to the field-measured versions was found to be 72%, with standard error values being 10-70x lower.

Project Status

We are designing field sampling protocol and an open-source package to streamline TLS data collection, input, registration, DEM generation, and surface elevation change assessment. Whereas the previous implementation relied on various Matlab code segments and cumbersome manual manipulation of point clouds in Cloud Compare software, the new implementation utilizes open-source python libraries (open3d, pdal, laspy, etc.) to register point clouds and calculate surface elevation change, with no user interaction beyond pointing to the desired dataset. This will allow forest engineers to offload data from the TLS equipment, upload new data to a historical drive or cloud, and retrieve the desired surface elevation change output automatically. We are also prototyping algorithms to extract new forest inventory metrics and quantify water flow and obstruction (see Figure 1).

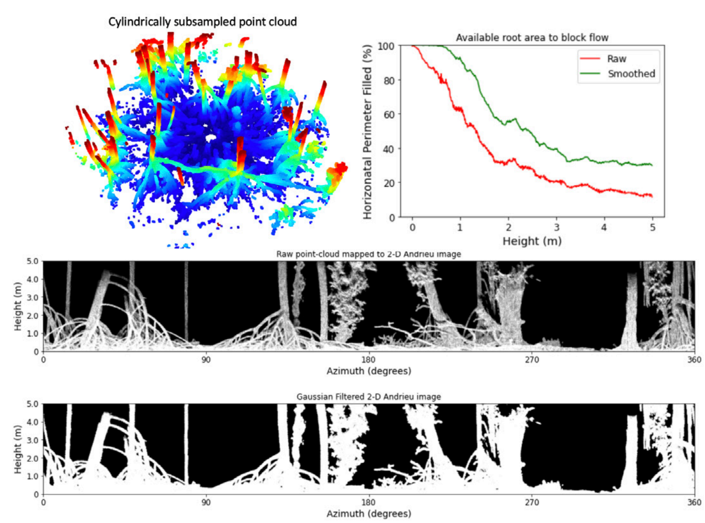


Figure 1. The quantification of root area that may hinder the flow of water at various elevations. Here we project a subsample of LiDAR returns onto a 2-D projection. The percentage of roots filling the available space can be quantified at a variety of radial ranges from the scan location and serve as inputs to existing mangrove sedimentation models.

Estimation of Beet Yield and Leaf Spot Disease Detection Using Unmanned Aerial Systems (UAS) Sensing

Principal Investigator: Jan van Aardt & Sarah Pethybridge

Team: Mohammad Shahriar Saif, Rob Chancia, Tim Bauch, Nina Raqueno, Imergen Rosario, Pratibha Sharma (Cornell U.), Sean Patrick Murphy (Cornell U.)

Project Description

The Rochester, NY area is home to a growing economy of table beet root growers and production facilities for various organic beet products, headed by Love Beets USA. Since 2018, a private company has been working with the RIT DIRS group and Cornell AgriTech to explore the application of UAS remote sensing imagery for yield estimation, plant count, and root size distribution forecasting. In the summer of 2021, in addition to the above-mentioned yield parameters, root weight, root number, and dry weight foliage were collected. The goal is to develop models based on the spectral signatures acquired from UAS. This will equip farmers with tools to forecast their harvest. Models developed from the previous season's data will be tested on the summer 2022 data in order to assess the robustness of models. Figure 1 shows ground image of a beet root field, while Figure 2 shows the entire study field plot two weeks and one month after the start of study. Both images were compiled from the blue, green and red channels taken from a MicaSense RedEdge-M five-band multispectral visible-near-infrared (VNIR) camera system mounted on a DJI Matrice 600.

Project Status

Rob Chancia published an article in Remote Sensing, reporting on the model developed for 2018 and 2019 seasons' imagery. We currently are working to determine which wavelengths can estimate specific growth stages to further enhance the original model. We are also exploring other methods to better model the yield parameters. A total of seven flights have been executed during summer 2021. Hyperspectral imagery, ranging from 400-2500 nm, were collected at seven different stages of plant growth. It is worth noting that select sections of the field were dedicated to a fungicide study, hence an additional model is being developed to determine the location of Cercospora leaf spot disease in table beets. Figure 3 shows an example of a diseased plant.

Figure 1. An example of a typical beet root crop, close to canopy closure

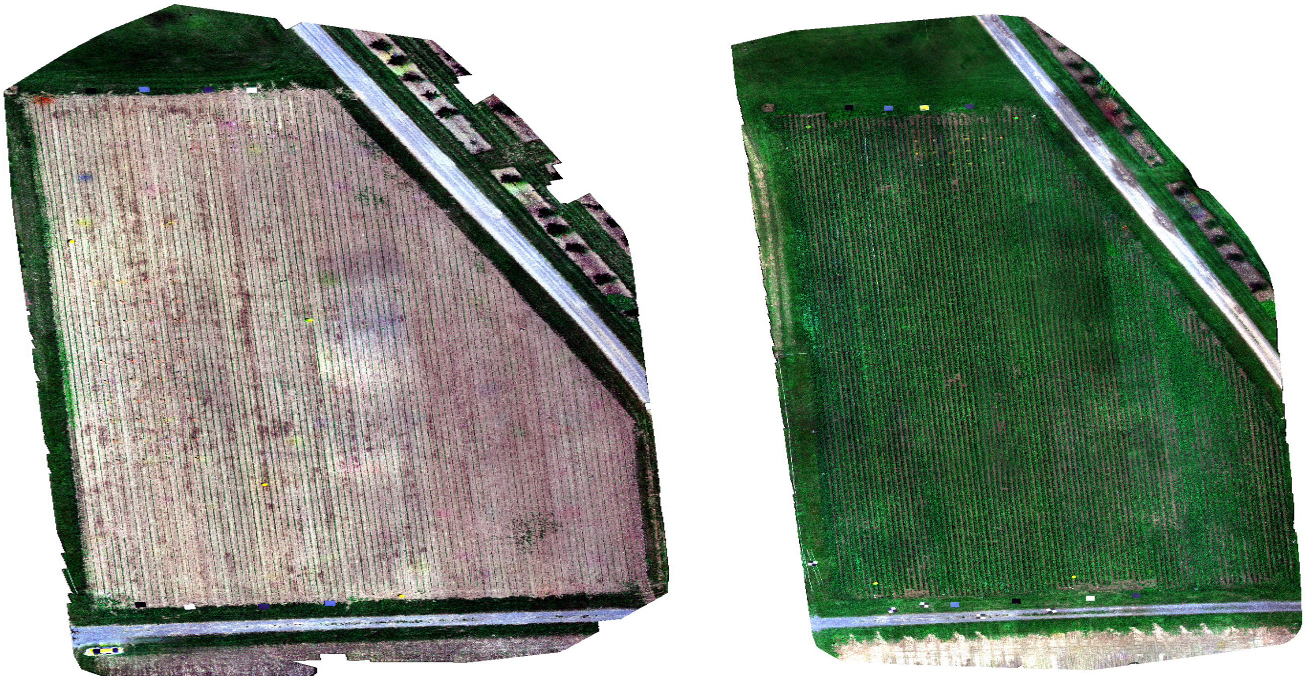


Figure 2. Imagery of the beet study site (Geneva, NY), at two weeks (left) and one month (right) after planting.

Figure 3. An example of a visibly diseased beet plant. Part of our efforts relate to early detection of Cercospora leaf spot disease in table beets.

Thermal Image Systems Engineering Support

Principal Investigator: Matthew Montanaro

Team: Tania Kleynhans

Project Description

This project provides general image calibration and systems support for the Landsat thermal band instruments for NASA. Specifically, this involves the continuing on-orbit characterization and calibration of the Landsat 8 / Thermal Infrared Sensor (TIRS) instrument and the pre-flight characterization of the TIRS-2 instrument for the upcoming Landsat 9 mission (scheduled for launch in September 2021). The PI serves as the Deputy Calibration Lead for the TIRS-2 project and is a member of the Calibration and Validation team for the Landsat program. Team members also provide technical expertise and guidance on Landsat thermal image products to the Landsat Science team and the US Geological Survey (USGS).

Project Status

Over the past year, the PI has been involved in the Landsat 9 observatory-level pre-flight environmental tests at the Northrop Grumman facility in Gilbert, AZ. The PI serves as the Science and Calibration representative for the TIRS-2 project for all observatory-level activities including the electrical integration of the TIRS-2 instrument to the spacecraft bus, comprehensive performance tests of the integrated observatory, electromagnetic interference/susceptibility evaluations, vibration trials, and thermal-vacuum test campaigns. Each activity involved writing and reviewing procedures, processing and evaluating image data files, documenting and reporting results for consent-to-proceed reviews, troubleshooting data stream issues with real-time analyses, and providing custom software tools and instructions to other team members. These efforts contributed to a successful observatory test campaign resulting in NASA's approval to ship the Landsat 9 observatory to Vandenberg Space Force Base to begin launch preparations. The PI is now involved in the final performance tests needed prior to launch and will lead the TIRS-2 instrument commissioning phase during the first 90 days on-orbit.

Additionally, team members contributed to the investigation and recovery of two safe-hold anomalies on the Landsat 8 observatory. The PI helped to coordinate TIRS instrument recovery operations between the instrument Systems engineers and the Flight Operations Team and planned and evaluated image data to assess the health of the instrument after the resumption of normal operations.

Finally, team members continued to support USGS efforts to field a Landsat land surface temperature product by providing USGS engineers with requested test data and algorithms. The team also continued to provide input for future Landsat thermal band architecture studies.

DIRS Enterprise Center

RIT's Digital Imaging and Remote Sensing Laboratory offers services to the public. The DIRS Enterprise Center provides data collection, calibration and other technical services. The DIRS laboratory, with deep expertise in drones, imaging and remote sensing technology has been offering its services to the public since late 2019. Through the Digital Imaging and Remote Sensing (DIRS) Enterprise Center, customers can now hire faculty and staff from our Lab to provide training, consulting, data collection, equipment calibration and more. The DIRS Enterprise Center is one of many RIT Enterprise Centers offering fee-for-service as a vendor.

We are excited to work with new collaborators outside of academia and expect to support a wide range of industries as we continue to attract new customers and provide high-quality data and services to our current Enterprise Center customers.

DIRS EC By the Numbers:

2019-2020 AY

16 Awards

$564K / $21K

Quoted Competitive / Quoted Sole Source

Quotes by Service

- DIRSIG 56%
- UAS 19%
- ICA 13%
- GRIT 12%

2020-2021 AY

26 Awards

$50K / $604K

Quoted Competitive / Quoted Sole Source

Quotes by Service

- DIRSIG 42%
- UAS 12%
- ICA 23%
- GRIT 23%

The full list of services the DIRS Enterprise Center offers includes:
DIRSIG Synthetic Image Generation Services

UAS / Drone Collection Services

GRIT - Material Directional Reflectance Measurement Services

Ground Reference - Field Material Measurement Services

Spectro-Radiometric Calibration Laboratory Services

Ground Based LiDAR Measurement Services

Geometric Calibration Laboratory Services

General Image Chain Analysis and Systems Engineering Services

People

The following represents and describes each of our talented list of faculty members, staff, and students. The time and effort from our members allows for the team to be sucessful in our research.

Faculty & Staff

Carl Salvaggio

Director of the Digital Imaging and Remote Sensing Laboratory and Full Professor of Imaging Science, Carl received his Bachelors and Masters degrees in Imaging Science from the Rochester Institute of Technology in 1987 and his Ph.D. in Environmental Resource Engineering from the SUNY College of Environmental Science and Forestry in 1994. Carl teaches and conducts research in image processing, computer vision, remote sensing, and programming. His research interests address the development of solutions to applied, real-world, problems utilizing the appropriate imaging modalities and algorithmic approaches. Carl's expertise are in thermal infrared phenomenology, exploitation, and simulation; design and implementation of novel imaging and ground-based measurement systems; three-dimensional geometry extraction from multi-view imagery; material optical properties measurement and modeling; radiometric and geometric calibration of imaging systems; and still and motion image processing for various applications.

Joesph Sirianni

Associate Director of the Digital Imaging and Remote Sensing Laboratory, Joe received his Bachelors (1992) and Masters (1994) degrees in Imaging Science from the Rochester Institute of Technology. During his 25-year career in the aerospace and defense industry Joe conducted research in image processing algorithms, software development and remote sensing and was a program and business development manager. Joe's continued interest in all-things imaging science, remote sensing and business development drive is a perfect combination for his current role with responsibilities in program management and business development for discovering new sponsored research opportunities for graduate students and research staff.

Charles Bachmann

He received the A.B. degree in Physics from Princeton University, in 1984, and the Sc.M. and Ph.D. degrees in Physics from Brown University in 1986 and 1990, respectively. After a 23-year career at the U.S. Naval Research Laboratory in Washington, DC, Chip joined the RIT Chester F. Carlson Center for Imaging Science faculty as the Frederick and Anna B. Wiedman Chair. Since 2016, he has also served as CIS Graduate Program Coordinator. He holds two U.S. Patents for methods of analysis related to hyperspectral remote sensing imagery. His research interests include hyperspectral and multi-sensor remote sensing applications in coastal and desert environments, BRDF and radiative transfer modeling for retrieval of geophysical and biophysical parameters, field calibration and validation, and the development of advanced instrumentation (goniometers and more recently a mast-mounted hyperspectral video system), as well as abstract models for interpreting hyperspectral and multi-sensor imagery based on manifold descriptions and graph theory.

Tim Bauch

Lab Engineer and sUAS Pilot for the Digital Imaging and Remote Sensing Laboratory, Tim received his Associates degree in Optical Systems Technology from Monroe Community College in 2015 and his Bachelors degree in Imaging Science from Rochester Institute of Technology in 2017. Tim received his Part 107 FAA Pilots license for sUAS Commercial Operations in January 2018. He has performed over 600 flights since that time for many different research projects. His research interests involve using drone technology to solve real world problems to areas such as precision agriculture, infrastructure, environmental science and remote sensing algorithm development. In addition, he has interests in system integration and design for both ground based and UAS Imaging systems. Tim also loves to help and instruct students and is teaching the Freshman Imaging Project in the Chester F. Carlson Center for Imaging Science.

Scott Brown

Head of the Modeling and Simulation group within the Digital Imaging and Remote Sensing Lab. This group focuses on the modeling of airborne and space-based passive and active EO/IR imaging systems. Scott's specific expertise is the mentoring of student and staff re-search projects and the implementation and integration of complex radiation propagation codes. Since 1994, he has been the lead for the physics-driven image and data simulation model called DIRSIG. This model is elaborate software architecture for radiation propagation across the EO/IR region. The capabilities of the model range from passive temperature calculations to active time-gated, LIDAR predictions. The model consists of nearly a million lines of C++ and is externally distributed to government organizations and contractors. Scott routinely conducts on- and off-site training courses that are attended by the professional community regarding the use of the remote sensing modeling and simulation tools developed at RIT and general remote sensing system design and phenomenology.

Jeff Dank

Jeff joined the Digital Imaging and Remote Sensing Laboratory as an Assistant Research Scientist in August 2021. He earned a Master's in Business Administration and Bachelor's degree in Imaging Science from The Rochester Institute of Technology, as well as a Bachelor's degree in Applied Computer Science from CU Boulder. He has 16 years of experience as a Research Scientist / Systems Engineering and Technical Advisor for both Lockheed Martin and Integrity Applications Incorporated. He is interested in real time rendering of synthetic images and sharing his experience with students and customers to enable them to be DIRSIG power users.

Byron Eng

Byron joined the Digital Imaging and Remote Sensing Laboratory as an Assistant Research Scientist in September 2019. He earned a Master's in Mechanical Engineering and Bachelor's degrees in Physics and Atmospheric Sciences from the University of Utah. His thesis work focused on improving temperature predictions of photovoltaic modules through improved convective cooling models. He is interested in applying his expertise in fluid mechanics and heat transfer in research topics such as atmospheric modeling, air quality, remote sensing, renewable energy, and land-air interactions. Byron is an experienced tutor, teaching assistant, and mentor and loves to help students succeed.

Michael Gartley

Assistant Research Professor in the Center for Imaging Science. Michael received his Bachelors degree in Physics from Binghamton University in 1995, his Masters degree in Materials Science and Engineering from Rochester Institute of Technology in 1997 and his PhD in Imaging Science from Rochester Institute of Technology in 2007. He teaches multiple graduate level courses, one of which he developed to teach practical approaches to system level design trades he learned from his 10 years in industry prior to entering academia. His research often focuses heavily on low level modeling and simulation of various remote sensing modalities such as panchromatic, polarimetric, spectral, and Synthetic Aperture Radar. Michael is also conducting research to improve detection, characterization and monitoring of resident space objects for improved Space Situational Awareness.

Aaron Gerace

Assistant Research Faculty in the Chester F. Carlson Center for Imaging Science. Aaron completed his Bachelors and Masters degree in Mathematics from Brockport College in 2002 and his Ph.D. in Imaging Science from the Rochester Institute of Technology in 2010. His research in the Digital Imaging and Remote Sensing laboratory focuses on calibration of spaceborne thermal sensors and validation of their corresponding higher level products. An upcoming award will enable him to investigate the impact of future Landsat sensor designs on science applications. He is motivated by challenging problems and the wise words of RATM.

Adam Goodenough

Senior Scientist with the Digital Imaging and Remote Sensing Laboratory and co-devel-oper of the Digital Imaging and Remote Sensing Image Generation (DIRSIG) tool. Adam received his B.S. and Ph.D. degrees in Imaging Science from the Rochester Institute of Technology (RIT) in 2001 and 2007, respectively. His contributions to the remote sensing community were recently recognized with the 2017 USGIF Achievement Award in Aca-demia. His research interests include modeling and simulation, water quality monitoring, and data visualization.

Emmett Ientilucci

Assistant Professor and Graduate Admissions Chair in the Chester F. Carlson Center for Imaging Science. Emmett has degrees in optics and imaging science. Prior to his faculty position, he was a Research Faculty and Postdoctoral Research Fellow for the Intelligence Community. His research interests include, spectral image analysis and variability, hyperspectral image processing, target and shadow detection, radiometric calibration, atmospheric compensation and algorithm development. He has taught courses and labs both at RIT and Monroe Community College. He has 70 publications and has served as referee on 14 journals including being an Associate Editor for a special issue of Optical Engineering and current Associate Editor for Geoscience Remote Sensing Letters. He has been a program reviewer for NASA, the Department of Defense, and is Chair for the SPIE Imaging Spectrometry Conference, the WNY Geoscience and Remote Sensing Society, and the UAS STRATUS Conference. He is currently working on a text book entitled, "Radiometry and Radiation Propagation" with Oxford University Press.

Daniel Kaputa

Director of Ravven Labs and Assistant Professor of Computer Engineering Technology, Dan received his Bachelors degree in Computer Engineering [2002] and Masters [2004] and PhD [2007] in Electrical Engineering from the State University of New York at Buffalo. Dan teaches and conducts research in FPGA programming, image processing, computer vision, deep learning, and UAVs. His research interests are broken into two distinct categories namely FPGA based on board video processing for GPS denied navigation and object classification and localization via quantized neural networks. His passion is to combine both domains to create a single FPGA based UAV capable of real time object detection for counter UAS applications.

John Kerekes

Professor of Imaging Science and served as past DIRS Director from 2016-2019. John received his BS, MS, and Ph.D. in Electrical Engineering from Purdue University in 1983, 1986, and 1989, respectively. John teaches courses related to probability, statistics, and system modeling in synergy with his research interests in remote sensing system analyses and performance sensitivity studies using simulation and modeling techniques. While his primary expertise is in the area of hyperspectral imaging systems, he has also worked with other remote sensing modalities including thermal imaging, lidar and synthetic aperture radar, with applications ranging from object detection and land cover classification to atmospheric sounding. John is also an active volunteer with the IEEE Geoscience and Remote Sensing Society. Prior to joining RIT, he was a staff member at the MIT Lincoln Laboratory for 15 years.

Tania Kleynhans

PhD. Researcher / Engineer II at the Chester F. Carlson Center for Imaging Science, Tania received a Bachelor's degree in Mathematics and Honors degree in Operational Research from the University of South Africa, and an M.S. and PhD. in Imaging Science at the Rochester Institute of Technology. She works on various research projects including algorithm development for calculating surface temperature from satellite imagery, thermal sensor calibration and band trade studies, pigment identification of hyperspectral data from paintings with machine learning and AI, and the development of a low cost multispectral imaging system and software for historical document discovery. Tania leads the Rochester Cultural Heritage Imaging, Visualization and Education (R-CHIVE) group that focus on using various imaging modalities to uncover faded, erased or damaged historical texts.

Robert Kremens

Dr. Kremens is an atomic physicist by education but has spent most of his career as an instrument physicist designer. In addition to a BS, MS and PhD in physics, he obtained a mid-career MS in Environmental Science. He has a strong history of designing and implementing complex experimental apparatus in government, industrial and academic settings. Bob has broad knowledge in measurement techniques including electronics design and fabrication, transducer interfacing, data acquisition and reduction, optical systems, lasers, pulsed power systems, vacuum systems and mechanical assemblies. Recently he has been engaged in designing and deploying portable, inexpensive, fireproof energy flux measurement for observation of wildland fires. Some of this unique equipment includes multi-pleband infrared radiometers, convective flow gauges that operate in high temperature environments, wide dynamic range data acquisition electronics and multiple band in fire camera systems. He has successfully deployed these sensors hundreds of times in the harsh environment of wildland fire.

Jennifer Lana

Senior Staff Accountant for Sponsored Programs Accounting. Jennifer provides accounting support for grants, gift, endowment, special projects, discretionary and operating accounts as it relates to the Digital Imaging and Remote Sensing faculty and staff. Jennifer received her Bachelor's degree in Business Management from Rochester Institute of Technology in 2010.

Elizabeth Lockwood

As Academic Coordinator for the Chester F. Carlson Center for Imaging Science, Beth's primary role is to assist the Graduate Program Coordinator and the CIS Director with the administration of the Imaging Science M.S. and Ph.D. programs, including scheduling of courses, processing of student actions, and tracking progress toward graduation.

Patricia Lamb

Staff Assistant for the Chester F. Carlson Center of Imaging and Science since 2018. Prior to coming to RIT, she worked for one of the world's largest distributors of electronic components and embedded solutions. With 30 years of experience in an administrative role at a corporate level. Patty supports faculty, staff, students and post-doctoral researchers. Patty husband is a proud alumnus of RIT.

Guoyu Lu

Assistant Professor at the Center for Imaging Science. Prior to joining RIT, Guoyu was a research scientist on autonomous driving at Ford Research and computer vision engineer at ESPN Advanced Technology Group. Guoyu finished his Ph.D. and M.S. in Computer Science at the University of Delaware, with the highest honor from the U. of Delaware (UD) Computer Science department. Before coming to UD, he was in European Master in Informatics (EuMI) Erasmus Mundus program. Guoyu obtained his Master degree in Computer Science at University of Trento and Master degree in Media Informatics at RWTH Aachen University. He finished his Bachelor degree in Software Engineering at Nanjing University of Posts & Telecommunications, with a minor in Business Administration and Management. Guoyu has board research interests spreading across computer vision, robotics, and machine learning and deep learning on the applications of computer vision.

Daniel Mancuso

Senior Financial Analyst for the departments of the Center for Imaging Science, Astrophys-ical Sciences & Technology, Color Science, and Integrated Sciences Academy. Daniel received his bachelor's degree in Accounting and American Politics from RIT, and is pursuing his master's degree in Accounting at RIT as well. Daniel aids the PIs, faculty, and staff in managing the many different sources of funding there are including federal, state, and private grants and contracts, operating funds, discretionary and designated accounts, gifts, endowments, capital, and cascade funds totaling in excess of $25M. He is responsible for providing analysis, projections, and financial, administrative, and policy counsel to the PIs and faculty, as well as senior management, to assist in decision making and strategy.

Donald McKeown

A Project Manager within the Digital Imaging and Remote Sensing Laboratory, Don received a Bachelor's degree in Aerospace Engineering from the State University of New York at Buffalo in 1982. He spent 20 years in industry at Eastman Kodak supporting operations and leading technology development programs for satellite remote sensing pay loads. Since 2001, Don has supported DIRS with program development, program management, and system engineering for a wide variety of projects with an emphasis on airborne (manned and drone) imaging systems.

Colleen McMahon

Research Program Coordinatorfor Digital Imaging and Remote Sensing Laboratory, with 10 years of experience in an administrative role, Colleen keeps our lab running with support in office management, event coordination, and logistics, to name a few. Colleen is pursuing a degree in Business Administration from Rochester Institute of Technology. When she is not putting up with our team's shenanigans, Colleen is an active member of the Seneca Siberian Husky Club..

David Messinger

Currently a Professor, the Xerox Chair in Imaging Science, and Director of the Chester F. Carlson Center for Imaging Science at the Rochester Institute of Technology. David received a BS in Physics from Clarkson University and a Ph.D. in Physics from Rensselaer Polytechnic Institute. He is an Associate Editor of the journal Optical Engineering and a Senior Member of SPIE. He has published over 150 scholarly articles. His research focuses on projects related to image system analysis and spectral image processing using advanced mathematical approaches with applications to remote sensing and cultural heritage imaging.

Matthew Montanaro

Matt holds degrees in Physics (BS, 2005) and Imaging Science (PhD, 2009) from the Rochester Institute of Technology. He is currently a Senior Research Scientist involved in the calibration of thermal infrared imaging instruments through close ties with NASA Goddard Space Flight Center and the US Geological Survey. He specialized in the calibration of the Thermal Infrared Sensor (TIRS) onboard Landsat 8 and was directly involved in the definition of the calibration methodologies, execution of characterization tests, and anal-yses of instrument performance data, both pre-flight and on orbit. He now serves as the Deputy Calibration Lead for the upcoming Landsat 9/TIRS-2 instrument. He has also sup-ported other NASA missions including the SOLARIS sensor and the New Horizons/LEISA instrument. Matt has a number of peer-reviewed scientific journal publications and confer-ence proceedings and has presented at various remote sensing-related conferences. Additionally, he has supported and advised a number of graduate and undergraduate students.

Nina Raqueño

Assistant Research Scientist for the Laboratory for the past 20 years. Nina received a Bachelors in Imaging Science from the Rochester Institute of Technology in the 1990s. Nina escaped for several years to SUNY College of Environmental Science and Forestry where she learned practical remote sensing tools, such as GIS, GPS, surveying, flight plan-ning, and many of the skills required for field work. During this period, Nina also served as a technical illustrator for "Remote Sensing: The Image Chain Approach". She was eventually lured back to RIT and DIRS by Dr. John Schott with the promise of spending cloud free days on Lake Ontario (which, by the way, is not quite the ocean but at least it's wet). The first project she was assigned to was Landsat 7 thermal calibration which she continues today as part of NASA/USGS's Landsat Calibration Team. Nina continues to coordinate remote sensing field campaigns of all sizes and for a variety of platforms, satellite, aircraft, rooftop, and now from sUAS. Basically, the only thing that has changed in 20 years is now with the advent of sUAS we can fly more often and under those pesky clouds.

Philip Salvaggio

One of our newest members, Philip joined the Digital Imaging and Remote Sensing Lab-oratory as a Senior Scientist in September 2019. He received dual Bachelor's degrees in Imaging Science and Computer Science from the Rochester Institute of Technology in 2012, as well as his Ph.D. in Imaging Science in 2016. His research involved imaging systems quality modeling, with a focus on systems with exotic apertures, such as sparse aperture telescopes. From 2016-2019, Philip was a Principal Engineer at EagleView, developing a scalable imaging processing workflow centered around the problem of dis-tributed aerial triangulation, as well as orthomosaic generation, dense 3D reconstruction and rolling shutter correction. He has also taught programming as an adjunct professor in the Imaging Science department. Philip is joining the Digital Imaging and Remote Sensing Laboratory as a Senior Imaging Scientist, where he will be continuing his research on imaging systems modeling as a member of the DIRSIG team. Philip is also an avid fan of ultimate frisbee, darts, and red pandas.

Jan van Aardt

Full Professor in the Chester F. Carlson Center for Imaging Science. Jan obtained a B.Sc. Forestry degree ("how to grow and cut down trees") from the University of Stellenbosch, South Africa in 1996. He completed M.S. and Ph.D. Forestry degrees, focused on remote sensing (imaging spectroscopy and light detection and ranging), at the Virginia Polytechnic Institute and State University, Blacksburg, Virginia in 2000 and 2004, respectively. This was followed by post-doctoral work at the Katholieke Universiteit Leuven, Belgium, and a stint as research group leader at the Council for Scientific and Industrial Research, South Africa. Imaging spectroscopy and structural (lidar) sensing of natural resources form the core of his efforts, which vary between vegetation structural and system state (physiology) assessment. Or stated differently, the interaction between photons and leaves is what really gets him going. He has received funding from NSF, NASA, Google, and USDA, among others, and he has published >70 peer-reviewed papers and >80 conference contributions… or rather, his students have.

Anthony Vodacek

Full Professor of Imaging Science. Vodacek received his B.S. (Chemistry) in 1981 from the University of Wisconsin Madison and his M.S. and Ph.D. (Environmental Engineering) in 1985 and 1990 from Cornell University. His areas of research lie broadly in multi-modal environmental remote sensing with a focus on the coupling of imaging with environmental modeling for application to monitoring both terrestrial and aquatic systems. His specific expertise is in spectral phenomenology, image interpretation, aquatic optics including fluorescence lidar, and wildland fire monitoring. He has extensive collaborations in Rwanda and elsewhere in Africa, where he has worked on various teaching and research projects for over ten years. Vodacek is on the Fulbright Specialist roster, is an Associate Editor for the Journal of Great Lakes Research, is a Senior Member of IEEE, and supports the IEEE Geoscience and Remote Sensing Society Global Activities Directorate as the regional liaison to Africa.

Melanie Warren

Since 2010, a Senior Staff Assistant for the Digital Imaging and Remote Sensing (DIRS) and the Multidisciplinary Vision Research (MVRL) Laboratories. Melanie received her Bachelors in Criminal Justice from Niagara University. This included a semester of study abroad at the University of Copenhagen. Melanie supports faculty, staff, and students with procurement purchases, travel arrangements, processing of reimbursements, lab support, special event coordination, and hospitality. She has served on the committee and chaired the College of Science Staff Advisory Council, COSSAC. Melanie is also the Department Captain for the annual RIT United Way campaign, Go Tigers! Hockey, Football, Rugby, Barrel Racing, are family favorites. As always GO BILLS!!!

Eon Rehman

Rehman Eon received a BSc. from Viterbo University in Mathematical Physics and Chemistry, and his Ph.D. in Imaging Science from the Rochester Institute of Technology (RIT). His research interests include the use of optical remote sensing for the assessment of earth sediments and vegetation, radiative transfer modeling, thermal calibration of air/space-borne imaging sensors, development of surface temperature algorithms, and defining requirements for future Earth Observing systems.

Michael Grady Saunders

Grady is a member of the Modeling and Simulation team in the Digital Imaging and Remote Sensing Lab. He received his Bachelor's degree with honors from East Tennessee State University in 2017, where he majored in Digital Media and minored in Mathematics. He earned a Master's in Imaging Science here at RIT in 2020. Following his graduation, Grady was happy to join the department as an Assistant Research Scientist. His primary role on the Modeling and Simulation team concerns the creation and management of high fidelity virtual environments to serve as inputs to the 5th edition of the Digital Imaging and Remote Sensing Image Generation model, or DIRSIG5. His scientific interests, revolve around stochastic light-transport simulation and procedural modeling techniques in the context of 3D computer graphics and computer generated environments. Prior to the pandemic, he also frequented nearby trampoline parks to hone his flipping skills.

Post-Doctoral Researcher

Rob Chancia

Rob is currently a Post Doctoral Researcher at the Center for Imaging Science. He received his PhD in Physics from the University of Idaho in 2019, for his work with outer planet imagery from NASA's Cassini, Voyager 2, and New Horizons spacecraft. He then completed a Master's degree in Imaging Science from RIT in 2021. His research with Dr. Jan van Aardt applies multiple imaging modalities to improve precision agriculture and forest inventory practices.

Graduate Students: PhD Candidates

Sarvani Bhamidi

Sarvani is a second year graduate student pursuing her doctorate degree at the Center for Imaging Science. She received her Bachelor's degree in Electronics and Communication Engineering from Manipal Institute of Technology, India in 2018. Her undergraduate and consequent research was focused on signal processing and computer vision: including fields such as astronomy and biomedical imaging. Her current research work and interests involve remote sensing, atmospheric compensation, spectral image analysis and image processing.

Chase Canas

Currently a second year Ph.D. student at the Center for Imaging Science. Chase received his B.S. in Physics at University of California, Santa Barbara and M.S. in Physics at California State University, Long Beach. His research interests are in remote sensing, with a focus in systems engineering, calibration, and hyperspectral imaging. Chase's current research at the CIS involves investigating fundamental limits of detection in spectral imaging systems.

Joe Carrock

Ryan Connal

Currently a Ph.D. candidate at the Center for Imaging Science. Ryan received his Bachelors degree in Imaging Science from RIT in 2018. In his undergraduate studies, he performed research with Drs. Aaron Gerace and Matthew Montanaro relating to Landsat 8 TIRS calibration. His current research interests involve remote sensing in the visible and thermal infrared, image processing, and computer vision.

David Conran

Received a B.S. in Astrophysics and Astronomy from the Pennsylvania State University in 2018. His research focus involves the spatial assessment of remote imaging sensors using convex mirrors producing ground-based point sources. In partnership with Labsphere, this technology and research is being brought to the satellite community for easy access to an ideal, stable calibration target, both spatially and radiometrically.

Rey Ducay

Lucy Falcon

Ph.D. candidate at the Center for Imaging Science. Lucy received her Bachelor's degree in Imaging Science from RIT in 2018. Her research is currently focused on calibrating ground based thermal instruments to support validation of Landsat TIRS.

Amirhossein Hassanzadeh

Sihan Huang

Peter Jackson

Currently a Ph.D. Candidate at the Center for Imaging Science and a bachelors in Physics, Peter is performing his research with Dr. Cristian Linte on image-guidance for medical procedures. His current research interests are in areas of medical imaging, registration, and augmented reality.

Ali Rouzbeh Kargar

Ali is a Ph.D. student at Chester F. Carlson Center for Imaging Science. He received his B.E. in Polymer Engineering and Color Science from Amirkabir University of Technology (Tehran Polytechnic) in 2015. Ali's research is focused on structural assessment of complex forest environments using terrestrial laser scanning data. The complexity in these forests introduce challenges to structural evaluation algorithms, thus Ali works on developing approaches to overcome these issues and improve the results acquired from forest inventories in the studied sites.

Vedant Anand Koranne

Currently pursuing MS in Electrical Engineering at the Kate Gleason College of Engineering, RIT. Vedant received his Bachelor's degree in Electronics and Telecommunication Engineering from Yeshwantrao Chavan College of Engineering, India in 2019. In his graduate studies, he performed research with Dr. Amlan Ganguly related to the detection of hardware trojan for multi-core chip processors and Dr. Emmett Ientilucci relating to Smoke Plume Segmentation using Superpixel based Fuzzy C-Mean Clustering. His current research interests involve image processing, image quality tuning, and computer vision.

Chris Lapszynski

Chris received his bachelors in Imaging Science from the Rochester Institute of Technology in 2013. Prior to returning to academia in 2016 Chris supported research and development efforts as an industry contractor engineering solutions to immediate world problems utilizing the appropriate sensor modalities and algorithmic approaches, while supporting multiple major field campaigns. His current research endeavors (soon to include polarization) seek to exploit hyper spectral data sets to derive geophysical parameters obtaining sediment strength and surface trafficability estimates of a scene. Chris' growing expertise are in visible and near infrared phenomenology; design and implementation of novel imaging and ground based systems; material optical properties measurement and radiative transfer modeling, and radiometric calibration.

Chris Lee

Chris is a Ph.D candidate at the Chester F. Carlson Center for Imaging Science since 2019 being advised by Dr. Charles M. Bachmann. He is working on hyperspectral and RGB video capture and analysis techniques for dynamic Earth remote sensing scenes and directional reflectance spectroscopy of artificial spacecraft materials in support of studying the impact of bright satellite constellations on the night sky for observational astronomy. He obtained a B.S. in Physics and a B.S. in Astronomy from the University of Michigan where he worked on space-related research ranging from galactic astronomy to Space Situational Awareness.

Jobin Mathew

A Ph.D. student at the Center for Imaging Science. Jobin received his Bachelor's degree from University of Kerala, India and his Master's degree in Electrical Engineering at Rochester Institute of Technology. His past research work includes fast text detection and document imaging/processing, spectral calibration of remote sensing data, human eye motion tracking, and forensic blood detection using hyperspectral imagery. He is currently working on change detection in multi/hyperspectral imagery using novel statistical and graph methods along with the application of machine learning techniques.

Zack Mulhollan

A PhD candidate in Imaging Science, Zack Mulhollan earned his Bachelors degree in Imaging Science from Rochester Institute of Technology in 2016. His research interests include multimodal data integration, estimating three-dimensional structures from two-dimensional images, real-world scene simulation, image segmentation, and dynamic object detection and movement prediction.

Cara Murphy

Currently a part-time Ph.D. candidate in the Chester F. Carlson Center for Imaging Science at RIT, Cara received her Bachelor's degree in Physics and Mathematics at Merrimack College and her Master's degree in Imaging Science from RIT. While working towards her Ph.D., she is also a Lead Engineer at Systems & Technology Research (STR) in the greater Boston area. At both RIT and STR, her interests include signal and image processing of hyperspectral reflectance datasets for material classification, image segmentation, and target detection and classification applications. Specifically, her thesis research investigates various methods for generating high-fidelity spectral libraries for trace chemical residue identification in active spectroscopic imagery.

Nayma Binte Nur

Currently enrolled in the third year of a Ph.D. program at the Center for Imaging Science. She earned a Bachelor of Science degree in Electrical and Electronic Engineering and a Master of Science degree in Mathematics. At the moment, she is collaborating with Dr. Charles M. Bachmann. Her current research focuses on hyperspectral remote sensing of coastal areas, as well as radiative transfer modeling for geophysical parameters retrieval.

Kedar Patki

Currently a Ph.D. candidate at the Center for Imaging Science. Kedar received his Master's in Electrical Engineering with a focus on Signal Processing from University of Rochester in 2014. His current research interests are in remote sensing for environmental applications.

Aneesh Rangnekar

A Ph.D. student at Chester F. Carlson Center for Imaging Science. He received his Masters in Electrical Engineering from RIT. His research revolves around dynamic data-driven application for hyperspectral imaging, with focus on aerial object tracking. His research goal is to create an adaptive tracker that can smartly shift between hundreds of spectral bands as required to track an object of specific color and material at real time speed.

Ryne Roady

Benjamin Roth

Mohammad Shahriar Saif

Currently, a second-year student seeking a Ph.D. in Imaging Science. Mohammad received a Bachelor of Science in Electrical and Electronic Engineering from Bangladesh University of Engineering and Technology in 2017. His current research interest lies in precision agriculture. Under the supervision of Dr Jan van Aardt, he is looking into the applicability of UAS to predict yield and detect disease in crops.

Dylan Shiltz

Dylan is a Ph.D. candidate at the Center for Imaging Science. He received his Bachelor's degree in Mechanical Engineering from Milwaukee School of Engineering in 2014 and his Master's degree in Mechanical Engineering from Massachusetts Institute of Technology in 2016. His previous research involved experimental fluid dynamics, design and modeling of net-zero energy buildings, and optimal control of electrical power systems. His current research focuses on the effects of surface roughness on remote sensing measurements in the VNIR/SWIR and X-band radar domains.

Jason Slover

Cody Webber

Cody is a Ph.D. candidate with the Digital Imaging and Remote Sensing Laboratory. Cody received his Bachelor of Arts in Physics from Skidmore College in 2016, and attended Dartmouth College where he studied engineering, as well as film and media. Currently, Cody is working on assessing environmental applications of a novel uncooled multispectral thermal remote sensing imager, focusing primarily on land surface temperature retrieval and detection of rogue methane emissions.

Robert Wible

Fei Zhang Ph.D

Fei Zhang received his B.S. degree in Optics from Wuhan University in 2015 and his M.S. degree in Optical Engineering from Zhejiang University in 2018. He is now a Ph.D. candidate at the Center for Imaging Science. His current research interests involve UAS-based 3D point clouds, multispectral imaging, vegetation phenotyping.

Runchen Zhao

Runchen Zhao received his B.S. in applied physics from Xidian University in 2011, and M.S. in material science from the Rochester Institute of Technology in 2014. He is currently a Ph.D. student working under Dr. Ientilucci in the Digital Imaging and Remote Sensing Laboratory, Chester F. Carlson Center for Imaging Science. His current research involves end-to-end LWIR simulations consisting of statistical atmospheric compensation and statistical detection algorithm development.

Yuwei Zhou

Graduate Students: MS Candidates

Scott Couwenhoven

A second year MS student in the Applied and Computational Mathematics program. Prior to graduate school, he obtained a BS in Mechanical Engineering from RIT. He is currently working on a machine learning approach to cloud shadow mitigation in overhead imagery under Dr. Emmett Ientilucci and has research interests in Deep Learning and Computer Vision.

Luke DeCoffe

Luke DeCoffe is an Aerospace Engineering Officer serving in the Royal Canadian Air Force and is currently working towards his MS in Imaging Science. After receiving his Bachelor's degree in Mathematics from Dalhousie University in 2016, he filled multiple engineering management roles surrounding avionics and defensive electronic warfare systems. The technical material encountered throughout his early career led him to pursue an MS here at the Center for Imaging Science. He is currently researching reflectance conversion techniques for hyperspectral remote sensing and developing a UAS-based spectral downwelling irradiance sensor with Dr. Carl Salvaggio.

Rachel Golding

MS student, graduated with a BS in Astronautical Engineering from the US Air Force Academy, current Air Force officer transferring to Space Force soon.

Jacob Osterberg

Jacob is currently a Master's student at the Center for Imaging Science. He received his Bachelor's degree in Electrical Science and Engineering from MIT in 2009. Before continuing his education at RIT, Jacob spent 9 years in industry as a systems engineer working on multiband and hyperspectral aerial remote sensing payloads. His current primary research interest is in automated no-reference image quality assessment. In his graduate studies with his advisor Dr. Carl Salvaggio, he tested and evaluated a machine learning based automated image sharpness assessment system from his company Aizo Systems utilizing a multiband sUAS payload.

Lucy Zimmerman

Lucy is currently a second year MS student at the Center for Imaging Science. She received her bachelor's degree in physics from the United States Air Force Academy in 2020; her undergraduate research topics included space domain awareness and atmospheric science. She is currently researching how to optimize hyperspectral imagery in order to detect methane emissions by comparing methane's detectability in the LWIR and the SWIR. Her research interests generally lie in remote sensing as it relates to climate change mitigation.

Undergraduate Students

Leanne Robinson

Currently a fifth-year undergraduate student receiving her Bachelor of Science degree in Motion Picture Science from the College of Art and Design at RIT this upcoming May. Leanne is performing research for her senior project with Dr. Emmett Ientilucci relating to spectral radiance calibration. Her current research interests involve radiometry, remote sensing, and computational photography.

Imergen Rosario

Currently a third-year undergraduate student, Imaging Science BS. Imergen graduated from the High School of Art and Design in Manhattan, NY, in 2019. Imergen is fascinated by image processing and the wide range of applications that arise from it.

Meg Borek

Meg is a senior undergraduate student at the Center for Imaging Science. She has previously conducted research with the DIRS drone lab, working with hyperspectral, multispectral, LIDAR, and thermal imagery for remote sensing applications under Dr. Carl Salvaggio and Timothy Bauch. Meg intends to pursue a graduate degree in Imaging Science with research relating to satellite remote sensing.

Publications

The following publications are from our hardworking staff members and required hours of dedication and commitment.

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