

The SHARE 2012 Data Campaign

AnneMarie Giannandrea^a, Nina Raqueno^a, David W. Messinger^a, Jason Faulring^a, John P. Kerekes^a, Jan van Aardt^a, Kelly Canham^a, Shea Hagstrom^a, Erin Ontiveros^a, Aaron Gerace^a, Jason Kaufman^b, Karmon M. Vongsy^b, Heather Griffith^c, Brent D. Bartlett^d, Emmett Ientilucci^a, Joesph Meola^b, Lawrence Scarff^c, Brian Daniels^e

^aRochester Institute of Technology, 1 Lomb Memorial Drive, NY, USA;

^bAir Force Research Lab, 2241 Avionics Circle, Wright-Patterson AFB, OH, USA;

^cUnited Technologies Aerospace Systems, 7 Technology Park Drive, MA, USA;

^dThe MITRE Corporation, 7515 Colshire Drive, VA USA;

^e U.S. Naval Research Lab. (United States);

ABSTRACT

A multi-modal (hyperspectral, multispectral, and LIDAR) imaging data collection campaign was conducted just south of Rochester New York in Avon, NY on September 20, 2012 by the Rochester Institute of Technology (RIT) in conjunction with SpecTIR, LLC, the Air Force Research Lab (AFRL), the Naval Research Lab (NRL), United Technologies Aerospace Systems (UTAS) and MITRE. The campaign was a follow on from the SpecTIR Hyperspectral Airborne Rochester Experiment (SHARE) from 2010. Data was collected in support of the eleven simultaneous experiments described here. The airborne imagery was collected over four different sites with hyperspectral, multispectral, and LIDAR sensors. The sites for data collection included Avon, NY, Conesus Lake, Hemlock Lake and forest, and a nearby quarry. Experiments included topics such as target unmixing, subpixel detection, material identification, impacts of illumination on materials, forest health, and in-water target detection. An extensive ground truthing effort was conducted in addition to collection of the airborne imagery. The ultimate goal of the data collection campaign is to provide the remote sensing community with a shareable resource to support future research. This paper details the experiments conducted and the data that was collected during this campaign.

Keywords: Data Collection, Hyperspectral, Ground Truth, HSI Dataset, HSI Signatures, LiDAR, Target Detection

1. INTRODUCTION

Multi-modal, coincident data with good ground truth is a desirable product for testing many types of algorithms and remote sensing products, yet few of these datasets exist due to budget or security concerns. The Rochester Institute of Technology Digital Image and Remote Sensing Laboratory has a history of collecting ground truthed datasets for public distribution. Previous experiments include the MegaCollect in 2004^{1,2} and this experiment's immediate predecessor, SHARE2010³ as well as a web distribution platform for Cañon City, NV ground truth and blind test data.⁴ This experiment draws on the ground truth and distribution experience gained during these past experiments.

The main ground truth experiment took place near Rochester, NY, near a small town called Avon, NY. The relation of that site to Rochester may be found in Fig. 1. This location was selected due to the active railroad corridor, providing a unique set of opportunity targets. In addition, the area selected is out of the immediate Rochester airport airspace, allowing for meteorological data to be taken. Within the selected area, a municipal park was selected for the main ground truth effort due to a variety of materials and large open spaces where

Further author information: (Send correspondence to A.M.G.)

A.M.G.: E-mail: amg4587@rit.edu, Telephone: 1 315 727 6375

N.R.: E-mail: nina@cis.rit.edu, Telephone: 1 585 475 7676

multiple experiments could be conducted. This park is shown in Fig 2. The opportunity targets, including the Barilla pasta plant, and a group of several circular grain silos (as in Figs. 3 and 4) had no official ground truth associated with them, and were primarily of interest for testing algorithms for the purpose of 3-D reconstruction from imagery. The secondary ground truth sites were located in a forest near Hemlock Lake and on Conesus Lake as in Figs. 5 and 6. The relation of the secondary sites to the main ground truth site are shown in Fig. 1. Three locations were selected for ground truth operations: the Avon Driving Park, Conesus Lake, and Hemlock Forest. In addition, a single large quarry North North East of the Hemlock Forest site was selected as an opportunity target due to its size, shape, and possibility for material identification in addition to 3D reconstruction. These four sites were covered by all of the sensors flown during the collect. In addition, a final site over Downtown Rochester was covered by the hyperspectral sensor only. This site has been covered in previous years with multispectral and LiDAR imaging sensors.



Figure 1. Location of the ground truth sites in relation to Rochester, NY.

2. SENSORS

Data was collected by airborne sensors in both the morning and afternoon. Several sensors made repeat passes over the main Avon ground truth site, in order to capture changes in ground truth target configurations.

2.1 ProSpecTIR - VS2

RIT contracted with SpecTIR to fly their ProSpecTIR sensor system. The system is a hyperspectral pushbroom spectrometer with 356 bands, covering the 400 - 2400 nm range.⁵ The sensor observes from a nadir geometry and has a 24 degree field of view. It flew all sites, and covered the Avon ground truth site in both the morning and afternoon. The flight altitude and gain varied only over the Conesus lake site; the altitude was lowered and the gain increased to increase the image fidelity over water. The quantization of this system varies according to the spectral range, with the VNIR having quantization of 12 bits and the SWIR having quantization of 14 bits. Figure 7 provides an example of the data collected by this sensor in the visible region over the main ground truth site.



Figure 2. WASP image of the main experimental ground truth site.



Figure 3. WASP image of the Barilla pasta plant in Avon, NY



Figure 4. WASP image of the grain silos of interest in Avon, NY

2.2 Wildfire Airborne Sensor Program

RIT's WASP instrument is comprised of 4 cameras: three Indigo Phoenix infrared imagers and one Geospatial Systems KCM-11 high-resolution visible camera. The IR images cover three bands in the infrared; short-, mid- and long-wave. They acquire 640x512 14 bit images. The KCM-11 acquires 11-megapixel color images over roughly the same space on the ground.⁶ This sensor also has positioning devices to determine the location of the aircraft and the look angle of the sensor for georectification purposes. WASP was able to collect images at near 80 percent forward overlap during this campaign. The images are associated to each other using positioning measurements taken from IMU and GPS sensors processed by an Applanix position and orientation system. Georectification software uses this data, along with a DEM of the local terrain, to correlate the imagery to precise locations on the ground.⁷

2.3 Leica ALS60 LiDAR System

Kucera International flew their Leica ALS60 LIDAR instrument. This sensor, pulsing at 1064 nm, was flown over all sites in the same aircraft as the WASP sensor. The ALS60 is a discrete LIDAR system using a pulsed oscillating mirror configuration. This system has 8 bit of quantization in the intensity channel. It was flown looking at nadir, and had a nominal field of view of 20 degrees, except at the Hemlock site, where high topology created a field of view of 12 degrees. This site also had a ground point density, with 12 points per meter squared, in contrast to the other sites, which had density of 8 points per meter squared.⁸ Figure 8 shows the flightlines flown during the morning image collection over the Avon ground truth site for both WASP and the LiDAR sensors. The lines were designed to provide high forward overlap for the WASP imagery and high overlap for LiDAR.



Figure 5. WASP image of a forest near Hemlock Lake. The forest had previously been extensively ground truthed with ground based LIDAR.



Figure 6. WASP image of the Conesus Lake ground truth site for testing in-water targets

2.4 MITRE Full Motion Polarimetric Imager

A highly experimental sensor, this was its first operational flight. The sensor did successfully collect oblique imagery in the afternoon, although there is no included geolocation information available for this data. The Polarimetric sensor was flown over the Avon site only and was flown from around 2-4 pm to capture polarimetric signatures from moving vehicles that typically manifest in higher sun angles. This system is a full motion, hyperspectral, polarimetric imager tested by the MITRE Corporation. The system was flown with a look angle of approximately 45 degrees and a field of view of 20 degrees. It was flown in a racetrack configuration over the site at both 2000 ft and 4000 feet above ground level. It has a quantization level of 8 bits, and its GSD was between 103 and 206 cm, depending on the portion of the frame. This sensor was flown later in the afternoon to maximize polarimetric signatures of interest, and to maintain flight safety.

2.5 Satellite Data

Three satellites collected images of at least the main target area during the day of the experiment. Most of these images were collected in the interim between the morning and afternoon flights in Avon. The data collected by these instruments has a much larger pixel size and generally has less bands than any of the airborne data. The WorldView2 Satellite was in an advantageous location on the day of the data collection and was tasked to collect an image over the main target site in Avon. This satellite has 8 color bands and one panchromatic band, with pixel sizes ranging from 50 cm in the panchromatic band to 200 cm otherwise. The data can be ordered directly from Digital Globe. GeoEye1, one of GeoEye’s (now Digital Globe) constellation of satellites was positioned such that it was able to be tasked to collect an image over the target site about midway through the data collection. The data exists in two smaller scenes which may be ordered from GeoEye (now Digital Globe). The GeoEye1 satellite has 4 color bands and one panchromatic band and pixels which range from 50 cm in the panchromatic band to 200 cm otherwise. Figure 9 shows the coverage available from this sensor. The two scenes cover most of the target area, missing only the Hemlock forest site. The Naval Research Lab was able to task the HICO sensor on the International Space Station to collect an image of the entire study area. This sensor has 124 bands and pixels with approximately 90 m spatial resolution on the ground.

Table 1. Airborne and space-based sensors involved in the SHARE 2012 collect and their related specifications.

| Sensors | GSD | Altitude (Feet AGL) | Bands | Look Angle | Polarized Bands | FOV (degrees) |
|---------------|-------------------------------|---------------------|---------|------------|-----------------|------------------------|
| WASP | 10.97 cm <i>60.96 cm (IR)</i> | 2000 | 6 | 0 | 0 | 36 |
| Leica ALS60 | 15 cm | 2000 | 1 | 0 | 0 | 20; <i>12(Hemlock)</i> |
| SpecTIR | 99 cm; <i>59 cm (Conesus)</i> | 2500 | 256 | 0 | 0 | 24 |
| MITRE FMV HSI | 103 - 206 cm | 2000 and 4000 | 24 | 45 (est.) | 4 | 20 |
| WorldView2 | 50 cm (Pan); 200 cm | 2,526,200 | Pan + 8 | 9 | 0 | 16.4 km |
| GeoEye1 | 50 cm (Pan); 200 cm | 2,244,094 | Pan + 4 | unknown | 0 | 15 km |
| HICO | 10,000 cm | 1,322,178 | 124 | unknown | 0 | 50 km by 200 km |

3. DESCRIPTION OF EXPERIMENTS

Subpixel Target Detection

In support of quantification of hyperspectral subpixel detection performance, an experiment was deployed in which a large number (~ 50 each) of two types of subpixel targets were deployed in two types of backgrounds. Both types of targets were blocks of wood approximately 20"x 12" in size, but were painted with different colors of paint: green and yellow. The green blocks were deployed in a grass area in the northern end of the Avon Driving Park test area, while the yellow blocks were deployed in the adjacent basketball court. The targets were deployed in a semi-random arrangement, spaced a minimum of 2 meters apart. Thus, given the approximate 1 m ground resolution of the SpecTIR airborne hyperspectral imager, the targets subtended an area subpixel fraction ranging from 5% to 20%, depending on how the pixels were aligned on the targets. Spectral reflectance ground truth measurements were made of both types of targets and the adjacent background areas.⁹



Figure 7. Mosaic of SpecTIR images in the visible spectrum for the morning pass over the main ground truth site.

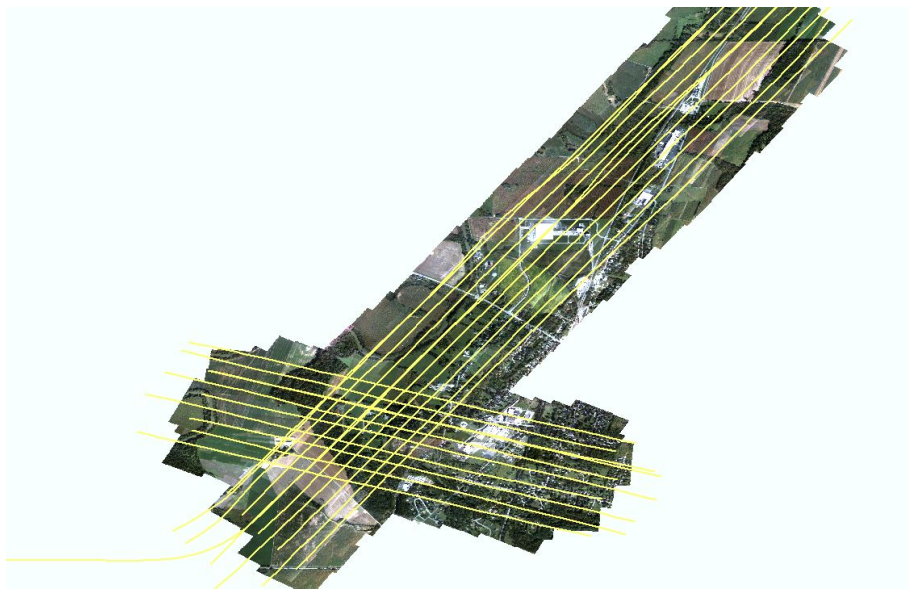


Figure 8. Morning WASP/LiDAR flightlines for the Avon ground truth site.

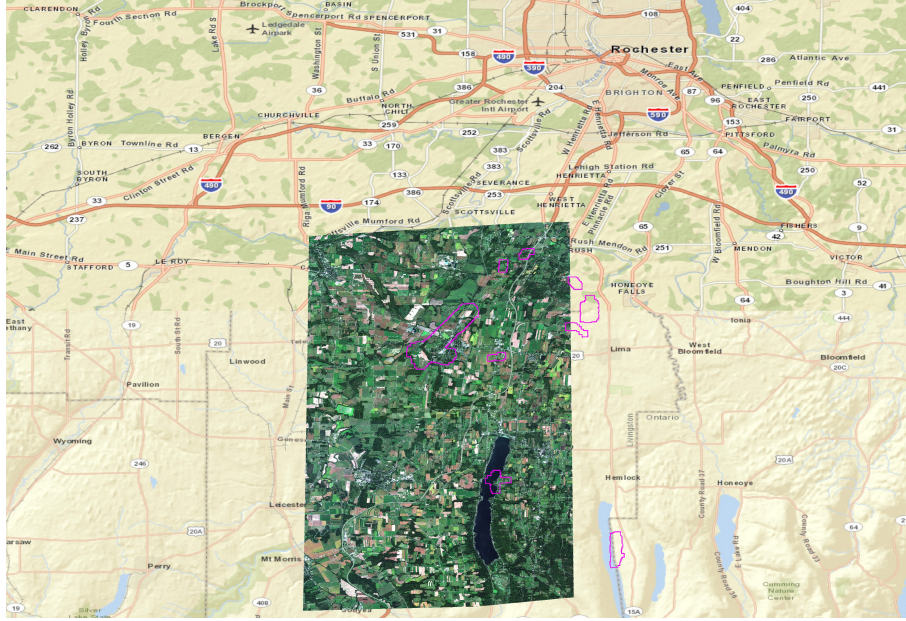


Figure 9. GeoEye1 coverage over the study area with respect to the city of Rochester.

Unmixing

Another experiment was included to enable quantification of hyperspectral unmixing accuracy. Accurate truth of material area fractions in real world hyperspectral imagery is often difficult to obtain. For this experiment a set of unique checkerboard targets were designed for which precise knowledge of the materials and their area fractions was known. Targets were constructed out of 12"x 12" squares of six different fabrics arranged in a repeating pattern. One target was 24' x 24' and made up of alternating blue cotton and blue felt squares, arranged as in a checkerboard fashion. Given the approximate 1 m ground resolution of the SpecTIR airborne hyperspectral imager, no matter how the pixels were aligned with the target pattern, this arrangement ensured each material occupied 50% of a pixel. An adjacent 16' x 16' panel was made with a 2' x 2' repeating pattern comprised of 3 gold felt squares and 1 yellow cotton square, thus achieving a 75%/25% area fraction per pixel. A second 16' x 16' panel was fabricated using a combination of squares in a repeating pattern, but with the exact materials and proportions not included in the ground truth with the goal of serving as a blind test target for unmixing algorithm assessment. The gold felt/yellow cotton target was deployed during the morning airborne collections and then was replaced for the afternoon collections by the unknown target panel, while the large blue 50/50 target was deployed throughout the day. To allow for in-scene endmember extraction, additional 10' x 10' whole panels of all six fabrics used in the unmixing targets were also fabricated and deployed adjacent to the unmixing targets. All panels were made large enough to ensure a good number of sample pixels would image the center of the targets avoiding edge effects, recognizing the ground area contributing to the radiance in a pixel is larger than the nominal 1 m due to optical and atmospheric point spread function effects. The unmixing experiment occupied a large asphalt court near the northern end of the Avon Driving Park test area. Spectral reflectance ground truth measurements were made of all fabric targets and the adjacent background areas.⁹

A second unmixing experiment was designed using a large high contrast edge oriented parallel to a planned flightline. These 30' by 30' targets were located in the volleyball courts at the main ground truth site. The size of these targets provided a better defined edge from which to estimate each pixel's area fraction, in addition to providing a few pure pixels in the center of the target for endmember selection.¹⁰

Spectral-Spatial Target Detection

This experiment was designed and executed by the Air Force Research Lab. Tarps were designed that were approximately one meter in size, but had varying shapes for algorithm testing. These tarps took several different shapes, and were arranged in a known grid. The shapes varied from square, triangular, and circular; some of the

square tarps also had smaller versions of the shapes attached to their edges. All of these targets were deployed in two colors configurations: the standard blue tarp, and a brown tarp.

Parallax Mitigation

This experiment was designed and executed by AFRL. This experiment was centered on the Barilla pasta plant to the North of the main Avon ground truth site. An observer collected photos of the plant during the hyperspectral overflights to document the ground condition of the plant in order to quantify the parallax effect observed in the hyperspectral imagery.

In-Water Target Detection

This effort was conducted at Conesus Lake as a preliminary study to identify phenomenology that impact the detection of submerged objects in a marine environment. The intended purpose of this dataset collected during the SHARE campaign was twofold: First, several targets with specific target spectra were developed and submerged in the lake to support a potential blind target detection test in which users could apply and assess the effectiveness of their algorithms. The targets were constructed by wrapping painted fabric around weighted 24-inch hanging plant baskets. They were submerged several hours before the overflight to minimize the suspension of bottom sediment and were placed at various depths and illumination scenarios (i.e., shade vs. no shade) in an attempt to disguise the targets. Secondly, a large edge target was constructed and submerged at depth to support a broader modelling effort. The edge target (or primary target) was developed to assist in identifying parameters that impact detectability of submerged objects, i.e., glint, caustics, target depth, etc. Furthermore, the image data collected from this target could be used to validate DIRSIG modelling efforts to enable the extension of submerged object detection to a much broader set of scenarios. The frame of the primary target was developed using 2 PVC and was 4m x 6m in dimension. Grommets were placed in black and white painted fabric that each measured 2m x 6m in size and fixed to the PVC-frame using nuts and bolts. Finally, holes were drilled in the frame to allow the target to submerge when placed in water and buoys attached at the corners to keep it suspended. The buoys were attached with rope that had a length of 2m for two corners and at the surface for the other two corners to enable the target to have a varying depth. Once the primary target was placed in the appropriate position, the four corners were anchored to prevent it from drifting in the current.

High Density LIDAR

The purpose of this high density LIDAR experiment is to collect a real-world dataset containing several known target objects under tree canopies, with the intention of examining their detectability. In addition, some targets were moved between the morning and afternoon overflights to provide support for change detection studies. Multiple overlapping flightlines were collected over the study area in Avon, NY, in order to achieve increased point density and greater angular diversity. Target objects consisted of several large cubes covered in various materials, a vehicle, and several panels of varying reflectances. Some of the panels were set apart from the target objects and unobscured, such that they may be used for calibration if desired. Spectra of the materials used and some of the surrounding environment were collected as well.

Forestry

An experiment was performed in order to assess the utility of airborne, small-footprint LiDAR to estimate forest structure in terms of height, volume, biomass, crown width and leaf area index (LAI). This data gives a useful perspective of sub-canopy structure, but introduce an interesting scaling consideration to the fusion with airborne data. Ground validation was performed by taking leaf area index estimates with an AccuPAR LP-80 3 days after the airborne campaign. Ground-based LiDAR scans were also taken periodically of the forest sites in the months preceding the SHARE 2012 campaign.

Search and Rescue

This experiment was designed and executed by RIT. This study involved placing human subjects in predetermined positions in a field and under significant tree coverage. These subjects were wearing common t-shirts and their spectral properties were measured on the subjects in the field. This was done in an attempt to better understand how find them using data from the various sensors.

Target Detection Under Varying Illumination Conditions

The objective of the “illumination” experiment was to place a common set of materials in locations where the illumination varied on the target either due to shadowing or some spectral illumination modification from background objects. An additional varying parameter was background type. The target objects consisted of red and blue felt material cut into two different sizes (*i.e.*, 3×3 and 2×2 meters). A colored pair (*i.e.*, red and blue) was used in all illumination situations. Specifically, target pairs were placed over backgrounds consisting of dirt/gravel and grass. Targets were also placed in the open (*i.e.*, full illumination and open sky), full shade (but still viewable by the airborne sensor), and partial obscuration (with full shade and some with no shade). In all, there were nine unique placements of the red and blue target pairs in various configurations of illumination loading, background type, and obscuration. The objective was to examine the impact shadow, background type, and adjacency has on the ground leaving and sensor reaching radiance spectra. Furthermore, these adverse changes can impact applications such as material detection, which is also examined in this paper.¹¹

Atmospheric Compensation

This experiment was designed and executed by RIT. In order to test the atmospheric compensation workflow, several types of meteorological data were collected over the course of the campaign day. Ground observations were collected by an on-site weather station tracking pressure, temperature, humidity, wind speed and direction, broad band visible irradiance, and broad band thermal irradiance throughout the day at five minute intervals. Upper air data was collected twice during the course of the campaign; launches were conducted in the morning before the sensors were airborne and again after they finished imaging the main ground truth site in the morning.

4. GROUND TRUTH

Guaranteeing that every required spectral measurement was taken before, during, and after the overflight was a challenge because of the number of requested measurements from the Principle Investigators (PIs) and because of the number of instruments available to take the measurements. MITRE, AFRL, RIT, and ITT Exelis all provided instruments for taking spectral measurements during the data collection. These instruments, 4 of which were ASD FieldSpecPro 3 models and one of which as a SVC HR 1024 hand held unit, were cross calibrated after the field collection to ensure that the data acquired was comparable in all cases. Of these instruments, the RIT ASD instrument was dedicated to obtaining the spectral downwelling irradiance during the entire period of data collection. The other sensors were used to collect ground truth data, both reflectance and radiance, from the targets and backgrounds in the scene. The ASD measurements and GPS coordinates were required for virtually every target in the field, along with the need for several duplicate radiance measurements.

Spectral Measurements

Four ASD instruments were operated during the experiment. The first, belonging to RIT, was dedicated to obtaining downwelling irradiance over the course of the day. This instrument was located in the large parking lot near the grey calibration target. Since the weather was extremely clear and dry over the entire course of the study period the variability in the instrument readings is primarily due to changes in sun angle over the course of the day. The second instrument was on loan from ITT Exelis for the course of the experiment. This ASD was used to collect some of the ground truth reflectance measurements and the morning radiance measurements. Figure 10 shows an example of a typical radiance measurement collected by this sensor. In this case, the sensor is sampling three different colored calibration targets using a 3 degree foreoptic. The HR 1024 radiometer was on loan from Spectra Vista Corp. for the duration of the experiment. The third instrument was loaned by MITRE. This instrument finished the radiance and ground truth collections assigned to the ITT ASD. The fourth ASD instrument was used by and belonged to AFRL. This sensor was used only to collect any and all spectra of interest to the AFRL team studying spatial/spectral identification. A partial list of materials which had spectra taken for this campaign are listed in Table 2. In addition, there was an ASD on loan from United Technologies Aerospace Systems located at the Conesus site collecting ground truth for experiments run by UTAS. Spectral data was collected at the Hemlock forest site using the RIT ASD several days before the experiment. These measurements were taken of tree components and background to support forestry experiments.

Location Measurements

GPS points were obtained in 3 ways during this experiment. The most accurate points were taken by the RIT owned Trimble XT differential GPS. These points, along with context imagery for North, South, East, West, Up, and Down directions were obtained by a full fish eye lens camera for all radiometer measurements taken, and for any background materials of interest at the Avon Driving Park. Each radiometer team was also issued a Garmin GPS receiver to take points as they obtained the measurements required by the PIs as a backup to the Trimble measurements. The PIs themselves also took many context images using cell phone cameras, many of which contained geotagged EXIF data, allowing for a third method of identifying target locations, as well as documenting conditions pre- and post-measurement.

Ground Based LiDAR

The Ground Based LIDAR instrument available for this experiment was assembled by RIT, and operated by members of the Hemlock Forest team with the most experience using the instrument. The instrument uses a commercially available sensor mounted on a rotating platform. The sensor assembles a full 360 degree view in approximately 60 seconds.¹² All scans were accompanied by context imagery to assist in interpretation of the returns. Figure 11 shows an example of the points generated by the RIT Ground Based LIDAR sensor.

Analytical Spectral Devices FieldSpec Pro Spectroradiometer

The Analytical Spectral Devices FieldSpec Pro has a spectral range of 350- 2500 nanometers with a sampling interval of 1.4 nanometer from 350 - 1000 nm and 2 nanometers from 1000 -2500 nm. The Full width, Half max (FWHM) varies over the range from 3 nanometers at 700 nm to 10 nm at 1400 nm to 12 nm at 2100 nm. The FieldSpec Pro contains 3 detectors. One is a 512 element VNIR silicon photodiode array covering the 350 - 1000 nm range. The other two are separate TE cooled, graded index SWIR InGaAs photodiodes with complete the 1000 to 2500 nm range. The input to this system is a 1.4 m fiber optic light guide upon which can be fastened a variety of foreoptics. This experiment made extensive use of the 3 degree foreoptic, as well as the cosine diffuser and the high intensity contact probe was utilized in the lab for post collect measurements. This instrument, under perfect lighting conditions was capable of taking a measurement in just under 3 seconds, and was run off of wall power or external NiMH rechargeable cells over the course of the data campaign.¹³

SpectraVista Corporation HR1024 Spectroradiometer

The HR-1024 from the Spectra Vista Corp. (SVC) is a high performance single-beam field spectroradiometer measuring the visible to short-wave infrared wavelength range (350-2500nm). The HR-1024 features include low noise indium gallium arsenide (InGaAs) photodiode arrays for the SWIR spectrum. The HR-1024 was operated through a netbook computer in the field. The included 4 degree lens was used for all measurements made by this sensor.¹⁴

Table 2. Material types used for targets in the field.

| | |
|-----------------|--------------------|
| Blue Felt | White Tyvek |
| Blue Cotton | Gray Mesh |
| Yellow Felt | Gray Canvas |
| Yellow Cotton | Camouflage Netting |
| Pink Felt | Blue Tarp |
| Gold Felt | Brown Tarp |
| Green Felt | Montmorillonite |
| Black Felt | Kaolite |
| Newsprint Paper | Magnetite |
| Calcite | Muscovite |
| Hematite | |

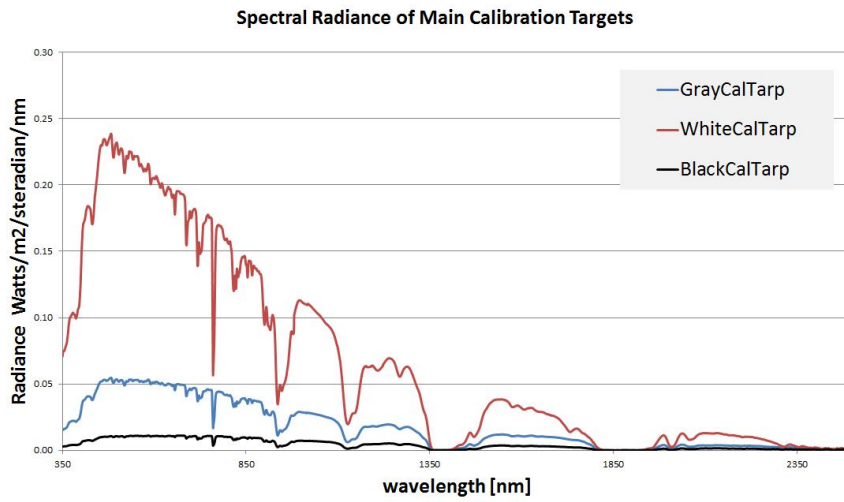


Figure 10. Sample radiance measurement taken of the calibration at the main ground truth site.

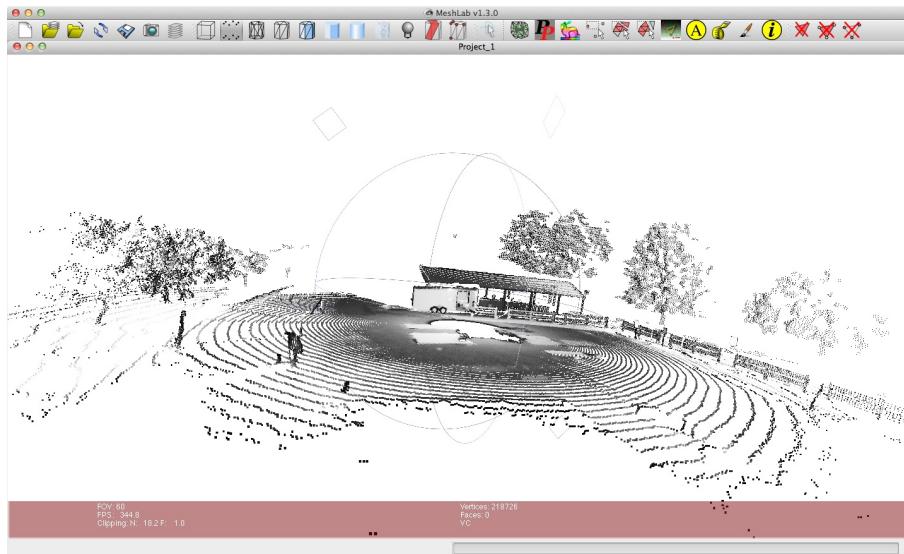


Figure 11. Sample Ground Based LIDAR scan

5. CONCLUSIONS

Care was taken during all steps of the experimental process to accurately document all decisions and logic, for the purpose of providing better documentation after the fact to the remote sensing community. This documentation was continuously compiled before, during, and after the experiment was carried out. The result of this documentation effort is the creation and curation of a website dedicated to the distribution of this dataset and all information related to it. This includes detailed descriptions of the instruments used in the data collection and experimental plans in addition to the data itself. Links to the data collected during this campaign will be made available at *dirs.cis.rit.edu*. In addition, a data download via map selection functionality is being tested and will be available at a later date through the same portal.

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