SpecTIR™

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SRS Project Report

1538 – R.I.T.

10/2/2012

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1.0 Overview

SpecTIR, LLC was contracted by R.I.T. under **Contract# 1538**, to acquire, process, and deliver hyperspectral imagery data utilizing the ProSpecTIR-VS sensor. This report describes the planning, collection, data processing, and final deliverables involved in the completion of this job.

The delivered data is provided in ENVI readable format, which is also directly accessible by other image processing packages such as Erdas Imagine. The associated ASCII *.hdr files provide all the necessary file format information which would be required to import the data into any other commercial or customized analysis platforms.

2.0 Acquisition Summary

2.1 Project Area and Flight Planning

All flight planning was accomplished using the program TOPOFLIGHT which incorporates Digital Elevation Models (DEMs) to ensure topographic compensation and pixel sampling uniformity.

R.I.T. provided shapefiles and coordinates outlining 5 sites near Rochester, NY. The identified sites and planning parameters were as follows:

Site	Spatial Resolution (GSD)	Sidelap	Total # Lines
Avon	1m	35.00%	4
Downtown	1m	35.00%	2
Conesus Lake	0.5m	35.00%	4
Hemlock Forest	1m	35.00%	2
Quarry	1m	35.00%	2

Plots of the resulting flight plan showing project area coverage for each site is included in Appendix A of this report. Full scale copies of these plots are also available in the "PROJECT OVERVIEW/DOCS" directory (JPG format). Also in this directory is an Excel spreadsheet showing the geographic start and stop coordinates for each line and calculated altitude.

2.2 Collection Specifications

Specific system settings such as integration time and frame-rate for each data file can be found in the associated ENVI *.HDR files within the DATA directory. These ASCII files also include other information such as the start and stop times and locations for each data file; the complete listing of center wavelengths, actual bandwidths and FWHM values.

For this data collection the general acquisition parameters were as follows:

Site: R.I.T.

Sensor System:	Prospectir-VS
Spectral Range:	~400nm to ~2450nm
Spectral Resolution:	5nm
Number of Bands:	360 bands
Ground Spatial Distance (GSD):	1m, 0.5m

2.3 Special Collection Requests

Client asked for two passes over line 4 in the Avon site. One line with high exposure time for strong vegetation signal and one line with low exposure time to not saturate the signal over bright calibration panels.

2.4 Acquisition Review

Data collection began on 9/20/2012 and was completed 9/20/2012. A copy of the collection flight log(s) can be found in the "PROJECT OVERVIEW/DOCS directory.

For ease of visualization, individual geocorrected, 3 band "quick look" images and a complete mosaic are provided in the "PROJECT OVERVIEW/QL" directory.

For ease of data navigation and assessment, an ENVI vector and ESRI Shapefile are provided in the "PROJECT OVERVIEW/INDEX MAP" directory. These polygons are attributed with their associated root filenames and can be used to spatially navigate the provided data files.

3.0 Data Processing Overview

3.1 Radiance

Radiometric and Spectral Calibration

SpecTIR's history in hyperspectral data collections and operations has led to a wealth of experience in radiometric and spectral calibration. SpecTIR's standard radiometric calibration is achieved through the use of a Labsphere USS-2000-V uniform source. This 20-inch diameter integrating sphere is equipped with three internal 45-watt and one 75 watt externally mounted halogen light sources. Each lamp is powered by separate DC regulated constant current power supplies and the addition of a variable attenuator, provides even more precise control of light levels. Luminance output is variable from 0 to 4000 foot-lamberts and measured uniformity is > 98% over the entire 8-inch exit port. This sphere carries a NIST traceable spectral radiance calibration from 400 nm to 2500 nm at a sampling interval of 5nm. The resultant calibration allows SpecTIR to provide data that is within +/- 5% of absolute radiance.

Wavelength calibration is generated through an Oriel Cornerstone 130 1/8m monochromator. This automated, computer controlled monochromator provides calibrated and repeatable wavelength outputs of 1nm channels in the VNIR and 3nm in the SWIR range. The central wavelength locations of this output is known and certified within 0.5nm accuracy. Additionally, data QA/QC processing routines utilize well-documented atmospheric features such as the Oxygen Fraunhoffer line at 760 nm to ensure that accurate wavelength mapping is maintained.

Radiance Processing

The following steps outline the generation of calibrated radiance from the raw imagery data.

Dark current measurements are included at the end of each flight line. The first step of processing is to remove the dark current "signal" from the imagery. If ProSpecTIR-VS data is being processed, then a bad element map is then applied to the SWIR utilizing a proprietary compensation algorithm to remove the spatial and spectral contribution of these elements in the array.

The calibration gain file is then applied to convert the raw data values to radiance units. Radiance data units and scaling factors are included in the header files for each processed flight line. Standard units are mW/(cm^2*steradian*µm) with a scaling factor of 1000. This setting means that for an image DN of 4500, the converted real world value is 4.5 mW/(cm^2*steradian*µm).

The final radiance output files follow a naming convention which starts with the line number followed by 4-digit Month and day, followed by 4 digit time stamp; e.g. 001_ 0719-1307_rad.dat.

3.2 Saturation Maps

An additional output of the radiance processing are associated "saturation maps" generated for every *_rad.dat file. Two different saturation maps are generated to provide the analyst with different tools for identifying, masking, and/or compensating for raw pixel saturations or scaling caused saturation.

The first file identified by the name *_saturation.map (with associated ENVI HDR file), is a

3 band ENVI file providing the end user with important pixel by pixel information related to either raw instrument saturation or subsequent "scaling saturation" which may occur in the conversion of floating point values to 16bit integers. The saturation maps provide analysts with information useful in masking out possible false endmember spectra which should not be identified as true target spectra.

The first band of the *_saturation.map file identifies those pixels that exhibit RAW at sensor saturation. A pixel in this band may have one of the following values and associated meaning:

0 = No RAW saturation
1 = Saturation in the RAW VNIR Imager
2 = Saturation in the RAW SWIR Imager
3 = Saturation in both RAW VNIR and SWIR

The second band is analogous to the first, however it identifies those pixels that may not have saturated during data acquisition, but during the course of radiometric processing and scaling to unsigned integer values, may have exceeded a 16bit value. Again, the values are 0-3, as in the RAW saturation band.

The last band is not of use to the end user, but is instead utilized by SpecTIR's data processing for internal checks and tracking of saturation scaling and darkcurrent underflow checks.

Whereas the provided *_saturation.map file is valuable, the provided information is not complete in that the saturation reported in this form is essentially binary but not qualitatively of use. It is feasible for a given pixel, saturation may have only occurred in only 1 spectral band and in a spectral region not of interest to the end user. Therefore, the user may not wish to exclude that pixel from processing.

In order to provide understanding of the amount of saturation in the spectral domain, a second type of saturation file is provided. This file is identified as *_FullSaturation.map (with associated ENVI HDR file).

The *_FullSaturation.map is a binary saturation map for every pixel in every band of the associated radiance image. In this file, no distinction is made as to whether the observed exceedence is RAW in nature or an artifact of the radiance scaling/gain factors.

3.3 Reflectance Processing

In order to convert the calibrated radiance data to surface reflectance values, SpecTIR employs a 3rd party implementation of the industry standard MODTRAN4 radiative transfer code. The software package ATCOR4 utilizes MODTRAN4 atmospheric lookup tables and proprietary techniques to correct for atmospheric absorption and scattering components. During processing, ATCOR4 generates log files for each flight line which provide information on all input parameters and program settings. These ASCII files are included in the data distribution directory

In handling atmospheric absorption features, ATCOR4 incorporates three possible interpolation schemes. In generating the final reflectance product, SpecTIR analysts select the best combination of interpolation options for the given data set. Linear interpolation is employed in the 760,725, and 825 nm regions. Non-linear interpolation is applied in the 940 and 1130 nm parts of the spectrum based on the function of the vegetation index to account for the leaf water content in plants. Lastly, non-linear interpolation is performed in the 1400 nm and 1900 nm water vapor absorption regions by fitting the curves with a hull of a template vegetation or soil spectrum. The interpolation parameter settings are identified in the associated log files and in addition all interpolated channels are marked with an "*" in the ENVI headers of the reflectance files.

The raw output reflectance data is evaluated for any model or sensor related artifacts which are then compensated for via library based spectra modifications and polishing. Polishing of the reflectance is achieved using a SpecTIR proprietary program based on a Savitsky-Golay algorithm with refined handling of atmospheric absorption features associated with CO2 and water.

3.4 Geocorrection Processing

Depending on the INS package coupled to the system, SpecTIR's instruments incorporate Inertial Navigation Systems (INS) with fiber optic gyros (FOG) or micro electrical mechanical systems (MEMS) based angular rate sensors and MEMS based accelerometers or servo/force-feedback accelerometers to provide for the accurate georeferencing of the data. The IMU is coupled with a 12-channel GPS system which utilizes Omnistar realtime differential corrections to feed the tightly coupled Kalman filter of the INS.

To ensure the optimal translation of the INS positional data to the image, the INS and camera must be boresighted. To achieve this, SpecTIR has established a boresight calibration site south of the Stead, NV airport. As control, 6 inch orthophotography and matching 2 foot contour data was obtained from Washoe County.

In order to provide ortho-corrected hyperspectral imagery, SpecTIR has the entire 10m resolution NED DEM database for the continental United States. If improved accuracies are required, client provided DEMs from such sources as Lidar can be incorporated into the processing stream. For international collections, SRTM DEMs are used if no higher resolution DEMs are made available. During processing, georeferencing performance is assessed based upon USGS 1m DOQQ imagery or for international locations, the highest resolution imagery made available.

The georeferencing process generates an Internal Geometry Map (IGM) file which is a 2 band pixel by pixel identification of easting (band 1) and northing (band 2) values of the unrectified imagery data. Also provided is the associated Geographic Lookup Table (GLT) which is a 1 band file, projected into map space. Either of these files can be used by image processing software to generate fully navigated imagery or subsequent analysis products.

The IGM and GLT data is provided in the following map projection and datum:

UTM Zone 18 / WGS-84

4.0 Delivery Media Directory Structure

```
BASIC Directory Structure:


>Job#-Client Name
      - PROJECT REPORT: This document

      >Project Overview

            >Job#-Client Name-Site Name

                  >Docs
                    - Flight plan
                    - Data collection log

                  >QL
                    - Individual 3-band georeferenced images
                    - 3-band mosaic of all data

                  >INDEX MAP
                    - Vector index map of collected flightlines for
                              ease of data navigation and file
identification


      >Data
            >Job#-Client Name-Site Name

                  >RAD
                     - processed radiance files
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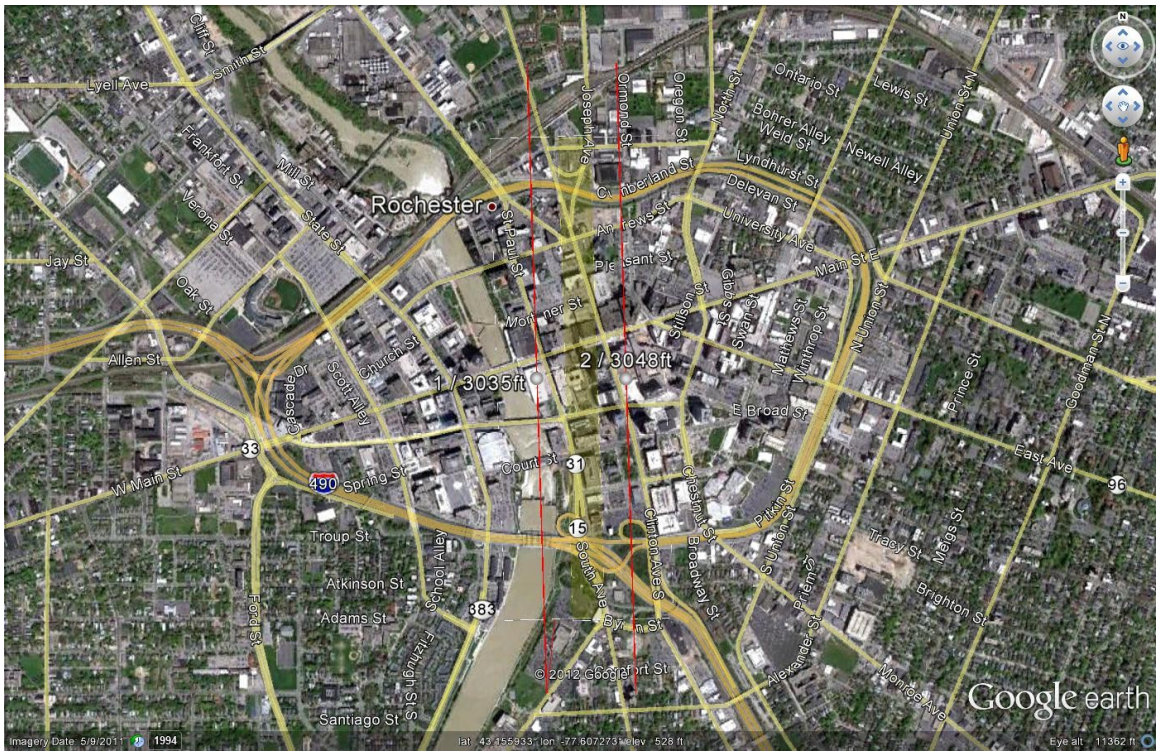
```
>Saturation Maps

>IGM_GLTS
   - associated IGM and GLT files

>REF
   - processed reflectance files
      >MODTRAN
```

Appendix A: Flight Maps

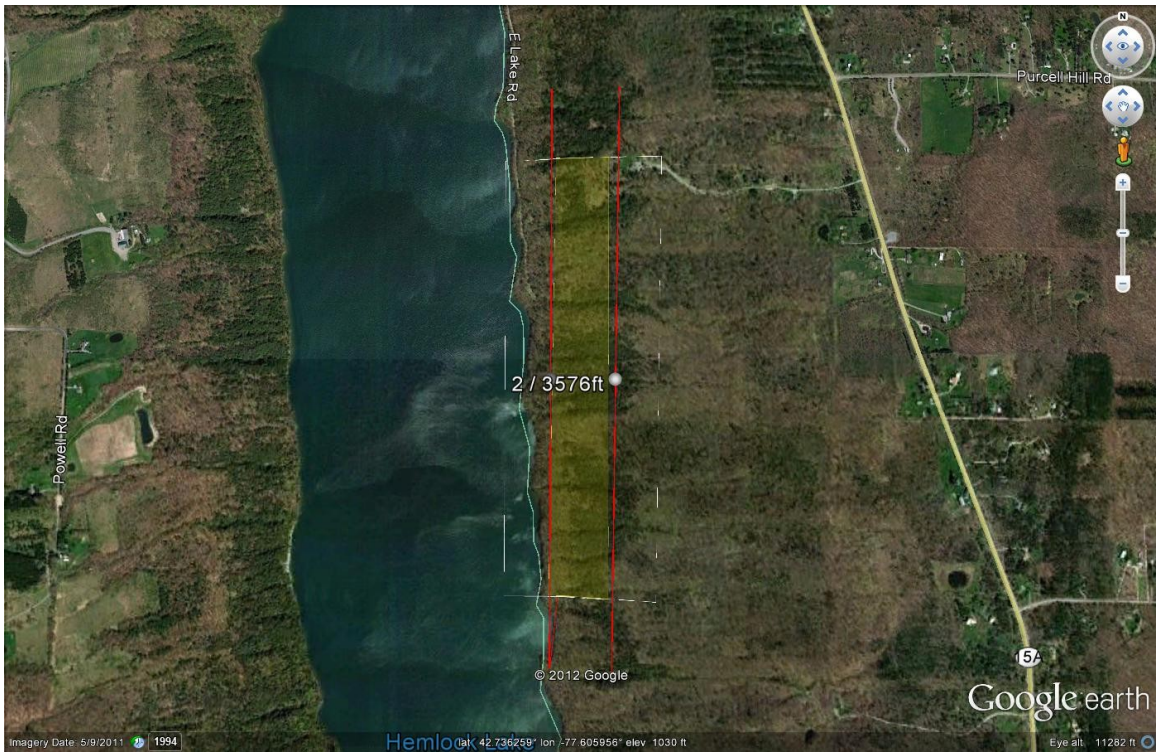
Downtown 1mGSD



Avon site 1mGSD

Conesus Lake 0.5mGSD

Hemlock Forest 1mGSD



Quarry 1mGSD