

ProSpecTIR Instrument Calibration and Data Processing Overview

Radiance Processing

The data as it is recorded during image acquisition is raw camera response values and must be corrected for such issues as electrical dark current, flat fielding, bad pixel mapping and calibration to real world radiance values. Only once this processing to radiance is complete, can the data be analyzed based on a given target's spectral response.

SpecTIR has incorporated all of these corrections into its first stage processing software which utilizes sensor specific files generated during the system's radiometric and wavelength calibration.

The first stage of processing the raw collected data is the removal of the "dark current", which is the underlying electrical noise that is present in any and all electrical systems and if unmeasured or uncorrected, prevents the accurate calibration of the data and possibly the subsequent detection of high fidelity spectral targets. The ProSpecTIR systems integrate "dark current" measurement into the data acquisition software such that these measurements are appended to each and every flight line of data. Essentially, the dark current is the measured signal the imaging array "sees" when no light is striking the array(s). This is accomplished on the ProSpecTIR systems through the use of an electro-mechanical shutter system.

The next step is the normalization of the array response. Each element on the VNIR and SWIR focal planes has slightly different responses to the amount of incoming light and so in order to convert these values to something meaningful, these response levels must be normalized in what is known as "flat fielding." SpecTIR has combined this flat fielding step with the actual calculation of radiance values utilizing the "calibration" file which is essentially a gain factor calculated for each and every detector on the imaging arrays.

As previously mentioned, the radiometric calibration file is generated during the system's pre and post mobilization calibration procedure.

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 is capable of outputting variable luminance from 0 to 4000 foot-lamberts with measured uniformity > 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 Fraunhofer line at 763 nm to ensure that accurate wavelength mapping is maintained.

Through the radiance calibration process, radiance data units and scaling factors are documented in the header files for each processed flight line. Standard units are $\text{mW}/(\text{cm}^2 \cdot \text{steradian} \cdot \mu\text{m})$ with a scaling factor of 1000. In analyzing the data then, an image value of 4500 with a scaling factor of 1000 would indicate a real world radiance value of $4.5 \text{ mW}/(\text{cm}^2 \cdot \text{steradian} \cdot \mu\text{m})$.

The final stage in the radiometric processing relates to the correction for bad and/or dead pixels on the imaging array. All CMOS based cameras suffer from these defects which include not just dead or nonresponsive pixels but also pixels which do not respond linearly or predictably to the amount of incoming light. If uncorrected, these pixels can lead to false spectral and or spatial anomalies. The identification of these elements generates what is known as a "bad pixel map." Spectir's radiance processing program incorporates these maps utilizing a proprietary compensation algorithm to remove the spatial and spectral contribution of these elements in the array.

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.

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 ATCOR-4 utilizes MODTRAN4 atmospheric lookup tables and proprietary techniques to correct for atmospheric absorption and scattering components. During processing, ATCOR-4 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, ATCOR-4 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.

Geocorrection Processing

Depending upon the survey requirements and/or location, the ProSpecTIR instrument can incorporate an ITAR unrestricted Fiber Optic Gyro/Mems-based or a restricted 3-ring Laser Gyro based Inertial Navigation Systems (INS) system to provide for the accurate georeferencing of data. In both systems, the IMU is coupled with a 12-channel GPS system which utilizes Omnistar real-time 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 utilizes an established boresight calibration site south of the Stead, NV airport. As control, 6 inch ortho-photography and matching 2 foot contour data provide for a highly accurate ortho-corrected boresight. While it is possible to generate a boresighting calibration in the field from the flown data itself, it is unlikely to be as accurate as that achieved when performed over a well characterized calibration site.

Provided that the INS and camera subsystems are not separated again, this boresight alignment is maintained and allows the system to be survey ready upon install in the survey aircraft platform. The only navigation related installation task is the determination of the positional relationship of the INS and GPS antenna, referred to as the "lever arm."

The georeferencing process generates an Internal Geometry Map (IGM) file which is a two-band, pixel-by-pixel identification of easting (band 1) and northing (band 2) values for the unrectified image. Also provided is the associated Geographic Lookup Table (GLT) file which is a two-band file of the unrectified pixel locations (x,y) projected into map space. These industry standard files are used by image processing software to generate fully navigated and georeferenced imagery of subsequent analysis products.