Automated airborne hyperspectral processing workflow

W. Oxford[1*], C. Barnes[1], P. Ventirozos[1], S. Case[1] and D. Mothersdill[1]

[1] 2Excel Aviation Ltd., Sywell Aerodrome, Sywell, Northamptonshire, NN6 0BN

(*email: william.oxford@2excel.uk)

I. INTRODUCTION

The 2Excel **geo** team within 2Excel Aviation Ltd. operates an airborne remote sensing platform equipped with a visible and near-infrared (VNIR) [1] and short-wave infrared (SWIR) [2] Norsk Elektro Optikk Hypsex (NEO) scientific grade hyperspectral cameras. These are accompanied by a Phase One Industries iXA180 [3] survey camera and Oxford Technical Solutions (OxTS) Ltd. Survey +2 [4] navigation unit (Fig. 1).

In order to exploit this data, requires the generation of 'analysis ready product' (ARP). However, hyperspectral data processing is complex and time consuming; this detracts from the time and effort spent on analysis. Challenging this paradigm motivated 2Excel to develop automated workflows to minimise the burden of processing so as to enable more time to be spent on data analysis.

This paper describes the current iteration of these automated workflows and comments on future enhancements.

II. REQUIREMENTS

In this context, ARP includes orthorectified apparent surface reflectance derived from the hyperspectral cameras, and orthomosaics and digital surface models (DSM) derived from the survey camera.

The characteristics of an automated workflow suitable to the generation of ARP include; reproducibility (the ability to reproduce processing steps); flexibility (the ability to start and stop processing at any point and run modules stand-alone); expandability (the ability to add modules); configurability (the ability to update parameters); traceability (the ability to log progress and errors).

In this initial development, speed was not a primary driver, since this is also a function of hardware performance.

III. ARCHITECTURE

At the outset, we chose to integrate existing third party software where possible. However, we have implemented some less familiar processes in order to improve data quality and consistency (e.g. statistical levelling, Section VII). The architecture is comprised of three major workflows;

- Photogrammetric processing;
- Navigation processing;
- Hyperspectral processing.

Fig.1 Piper PA-31 Navajo fitted with remote sensing payload

IV. PRE-REQUISITES

Prior to running the navigation and hyperspectral workflows, several elements must be in place, including;

- Files and folders adhering to the naming convention;
- KML file of the site boundaries;
- OS RINEX files (automatically downloaded from [5]);
- Hyspex boresight files generated using PARGE [6];
- Hyspex sensor model files generated during annual calibration by NEO;
- Hyspex sensor logs generated during collection;
- Digital terrain model (DTM) (e.g. OS 50m).

V. PHOTOGRAMMETRIC PROCESSING

Imagery collected by the Phase One survey camera is captured in GeoTIFF format, with the position and orientation of the frame centre embedded in the exif header. The photogrammetric workflow is comprised of a Python script that accomplishes the following;

- invokes Correlator 3D [7] to generate orthophotos, DSM and quality report;
- generates topographical features (e.g. surface roughness);
- generates virtual mosaics of the ortophotos and topographic features suitable for visualisation in QGIS [8].

VI. NAVIGATION PROCESSING

Navigation data generated by the OxTS Survey +2 box is post-processed using a Python script that accomplishes the following;

- invokes the OxTS *blended* software to process the navigation and RINEX data to generate a NCOM file;

- converts the NCOM file to position/orientation and trigger text files;
- invokes Hyspex NAV software to synchronise the Hyspex sensor logs and trigger files enabling the interpolation of the position/orientation data.

The output of this process is a navigation file for each raw hyperspectral image, containing the position and orientation of the sensor for each line.

VII. HYPERSPECTRAL PROCESSING

Hyperspectral processing is implemented in ENVI+IDL [9] and is comprised of a number of modules, some of which invoke scripts in C++ or Python. The choice to use IDL was initially motivated by the ease of integration of ReSe's orthorectification (PARGE) and atmospheric correction (ATCOR4 [13]) software. The design of the software exemplifies the characteristics described in Section II:

Expandability. The main program invokes modules in a pre-determined sequence. It is straightforward to modify or add modules.

Configurability. Prior to invoking a module, the program pre-populates a configuration (JSON) file. These parameters are drawn from an extensive default configuration file which may be overloaded using a user-specified configuration file or at the command line.

Reproducibility. Each module is invoked using the path to the configuration file. Thus the configuration file both records the parameters used in processing and enables the processing to be reproduced.

Flexibility. The user may choose to start and stop the workflow at specific modules; to include or exclude specific strips; to process VNIR only, SWIR only or both.

Traceability. The main program records a log detailing progress. Also, each time a module is invoked, a new log is generated.

The following modules may be familiar to those with experience in hyperspectral processing;

- Radiometric Correction. This uses Hyspex RAD software to convert raw counts to radiance. Includes water vapour band removal and optional spectral binning;
- Approximate Pixel Mapping. This uses PARGE to compute the approximate location of each pixel, based on the navigation file and DTM, in a map projection. This stage includes the generation of 3-band quicklooks, sensor footprints and additional inputs for ATCOR4;
- Clipping (optional). This sub-sets image and related files using a specified shape file and reduces the volume of data to be processed;

- Atmospheric Correction. This uses ENVI QUAC [11] and/or ATCOR4 and/or Empirical Line Method to convert radiance to apparent surface reflectance;
- Rectification. This process maps the previously generated images to a map projection using the approximate pixel mapping.
- Accurate Pixel Mapping. This process corrects for any residual rectification errors by mapping each pixel generated by the rectification [12] step to the orthomosaic described in Section V. This process is intended to mitigate, for example imprecise boresight correction and parallax, and includes the integration of VNIR and SWIR images into a single cube;
- Statistical levelling (optional). This process attempts to mitigate often observed strip-to-strip variance by applying a linear correction to adjacent strips on a band-by-band basis;
- Spectral Polishing. This process smooths pixel spectra using either Savitzky–Golay filters [13] or a derivative regularisation technique [14];
- Quality Layers. This computes various metrics to assist downstream processing including cast/cloud shadow indices and saturation;
- Spectral Math. This evaluates numerical expressions drawn from a database of over 100 vegetation, soil and other indices.

VIII. FUTURE ENHANCEMENTS

These automated workflows are under constant review and development. Future planned enhancements include automate notification of progress and completion, additional quality metrics (e.g. navigation solution) and automated cloud shadow mitigation. The author welcomes suggestions from the user community to improve the quality and consistency of the ARP.

REFENCES

1. https://www.hyspex.no/products/vnir_1800.php
2. https://www.hyspex.no/products/swir_384.php
3. https://industrial.phaseone.com/iXU_camera_system.aspx
4. https://www.oxts.com/products/surveyplus/
5. https://www.ordnancesurvey.co.uk/gps/os-net-rinex-data/
6. http://www.rese.ch/products/parge/
7. https://www.simactive.com/correlator3d-mapping-software-features.html
8. https://qgis.org/en/site/
9. https://www.harrisgeospatial.com/SoftwareTechnology/ENVI.aspx
10. http://www.rese.ch/products/atcor/atcor4/
11. https://www.harrisgeospatial.com/docs/BackgroundQUAC.html
12. http://w3.onera.fr/medusa/gefolki
13. C. Vaiphasa, "Consideration of smoothing techniques for hyperspectral remote sensing", *ISPRS Journal of Photogrammetry and Remote Sensing*, vol. 60, pp. 91-99, 2006
14. I. G. Roy, "On computing first and second order derivative spectra" *Journal of Computational Physics*, vol. 295, pp. 307-321, 2015