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MBASSS Landsat 8 Validation Project Detailed Project Planning Document

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FLIGHT RESEARCH LABORATORY

MBASSS Landsat 8 Validation Project Detailed Project Planning Document

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ABSTRACT

The objective of the "MBASSS Landsat 8 Validation Project" is to develop capability to validate Landsat 8 Operational Land Imager (OLI) land data products through the use of simulated Landsat 8 imagery. Satellite image simulations will be generated using techniques developed at the Canada Centre for Remote Sensing (CCRS) as implemented within their in-house image processing software package Imaging Spectrometry Data Analysis System (ISDASv2). Spectroradiometrically calibrated and atmospherically corrected airborne hyperspectral flight line mosaics of the Mer Bleue Peatland acquired with the National Research Council Canada (NRC) operated Compact Airborne Spectrographic Imager (CASI 1500) and Shortwave Infrared Airborne Spectrographic Imager (SASI 644) coincidentally with Landsat 8 overpasses of the site will serve as seed data for these simulations. Field acquired spectra of selected plant community groupings along with Unmanned Aerial Vehicle (UAV) derived high spatial resolution digital terrain models (DTM) and vegetation community segmentation maps will be acquired to assist in the segmentation of the airborne imagery in preparation for input into the simulation process. Ancillary field measurements available from the Mer Bleue Peatland Observatory (MBPO) will be assembled to support current and future analysis efforts. Additional field spectral measurements will be made of a calibration and validation site (Cal/Val site) in order to validate and, if necessary, vicariously calibrate the resultant airborne imagery.

This document, prepared upon the initiation of this project, provides a detailed plan for how this work is to be undertaken. Details are provided for each of the 12 work packages identified in the project contract with separate sections providing a project wide outline of issue related to internal project management, data management, project deliverables, risk management and a project web presence on the IDEAS+ web site.

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Abbreviations and Acronyms

APVE. *Arctic and High Latitude Product Validation and Evolution*

BRDF. B*idirectional Reflectance Distribution Function*

Cal/Val. *Calibration and Validation*

CASI. *Compact Airborne Spectrographic Imager*

CCRS. Canada Centre for Remote Sensing

DOC. *Dissolved Oxygen Content*

DPP. *Detailed Project Plan*

DTM. *Digital Terrain Model*

EVI. *Enhanced Vegetation Index*

FLAASH. *Fast Line-of-sight Atmospheric Analysis of Hypercubes*

FOV. *Field of View*

IMU. *Inertial Measurement Unit*

ISDASv2. *Imaging Spectrometry Data Analysis System*

LAI. *Leaf Area Index*

MBASSS. *Mer Bleue Arctic Surrogate Simulation Site*

MBPO. *Mer Bleue Peatland Observatory*

MSAVI. *Modified Soil Adjusted Vegetation Index*

MSL. *Mean Sea Level*

NBR. *Normalized Burn Ratio*

NBR2. *Normalized Burn Ratio 2*

NDMI. *Normalized Difference Moisture Index*

NDVI. *Normalized Difference Vegetation Index*

NIST. *National Institute of Standards and Technology*

NRC. *National Research Council of Canada*

NRCan. Natural Resources Canada

OLI. *Operational Land Imager*

QA. *Quality Assurance*

RSG. *Remote Sensing Group*

SAA. *Solar Azimuth Angle*

SASI. *Shortwave Airborne Spectrographic Imager*

SAVI. *Soil Adjusted Vegetation Index*

SWIR. *Short Wave Infrared*

SZA. *Solar Zenith Angle*

UAV. *Unmanned Aerial Vehicle*

VISNIR. *Visible Near Infrared*

WP. *Work Package*

1.0 Introduction

This document provides a Detailed Project Plan (DPP) for the Mer Bleue Arctic Surrogate Simulation Site (MBASSS) Landsat 8 Validation Project.

The project draws its focus from recommendations of the first Arctic and High Latitude Product Validation and Evolution (APVE I) workshop held in Ottawa Canada in November 2014 that highlighted the need for more robust 'best practices' for the validation of land parameters derived from high resolutions satellite sensors such as Landsat-8 and Sentinel-2. Even though these recommendations were made in the context of arctic and high-latitude applications, this project is looking at the validation of land data products derived from Landsat 8 in general as they apply to the specific target of interest central to this project, an easily accessible and well understood peatland site known as the Mer Bleue Arctic Surrogate Simulation Site located in the proximity of Ottawa, Canada (
Figure 1).

This project represents a first step in developing a systematic validation approach that will provide a robust basis for ongoing assessment and validation of satellite based land information products. The project concept entails incorporation of high resolution airborne hyperspectral imaging supported by ground-based field measurements and simulation tools to scale to satellite image sensor and mission parameters to validate land data products. Mer Bleue, a protected ombrotrophic bog located at the eastern boundary of the City of Ottawa, represents an ideal test site for the project in that, 1) access and development on the site is restricted and controlled by the National Capital Commission, 2) it has a long and ongoing history of systematic field data collection as a scientific environment of interest, and 3) it is logistically convenient for deployment of airborne imaging assets and field teams. An additional benefit, not directly related to the objectives of this project, but of significant interest to all parties involved and the reason that the site was initially identified for consideration as a validation site for satellite imagery data products, is that Mer Bleue can serve as a realistic surrogate site for high latitude wetland ecosystems.

The project is led by the Flight Research Laboratory at the National Research Council of Canada (NRC), in collaboration with the Canada Centre for Remote Sensing (CCRS), a division of Natural Resources Canada (NRCan), Department of Geography at McGill University, and LOOKNorth, a centre of excellence for commercialization and research operated by C-CORE.

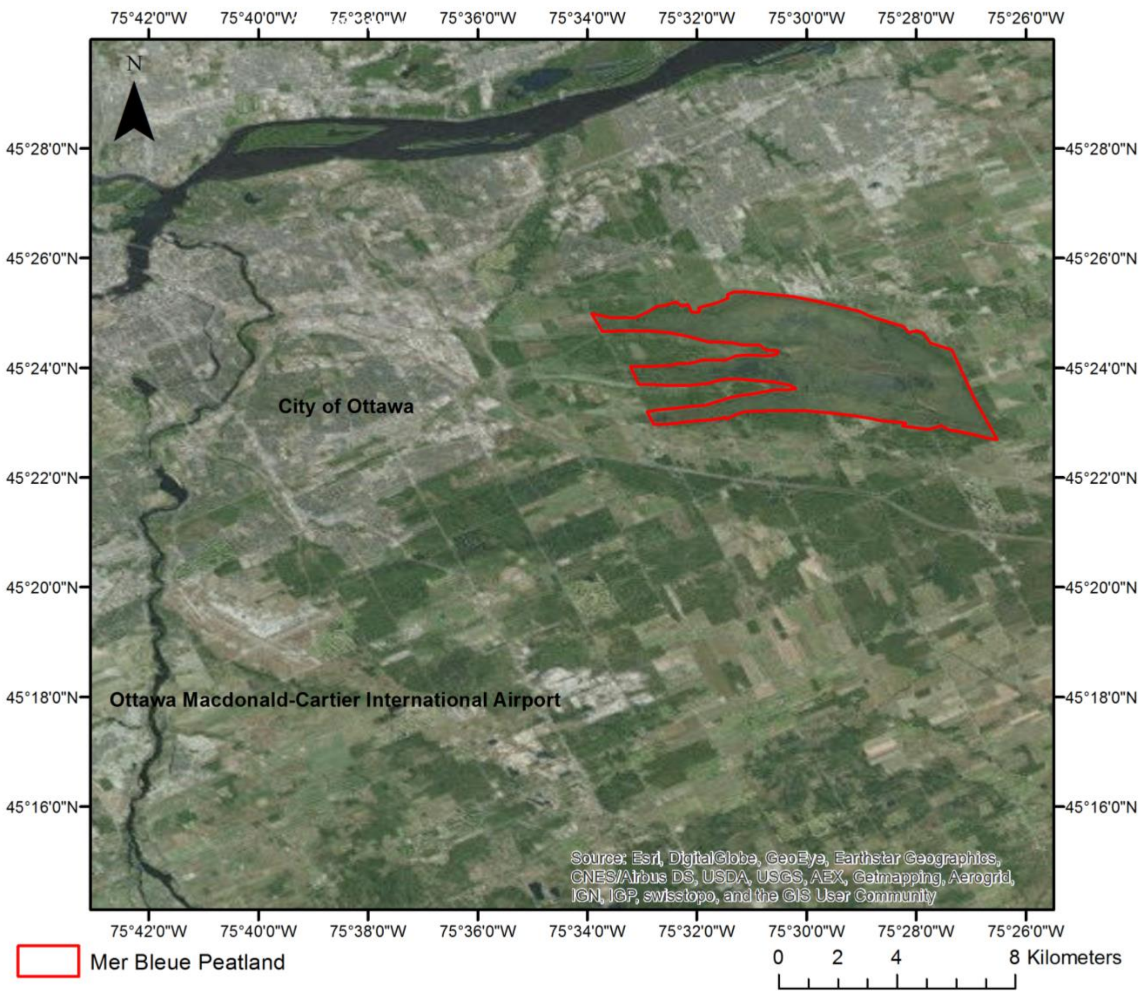

Figure 1: Location of the 25 km² Mer Bleue Peatland on the eastern outskirts of the City of Ottawa shown on a GeoEye image. The NRC Flight Research Laboratory hangar facilities are located at the McDonald Cartier International Airport.

2.0 Project Structure

Figure 2 illustrated the Work Package structure where the manager in-charge of each WP is noted.

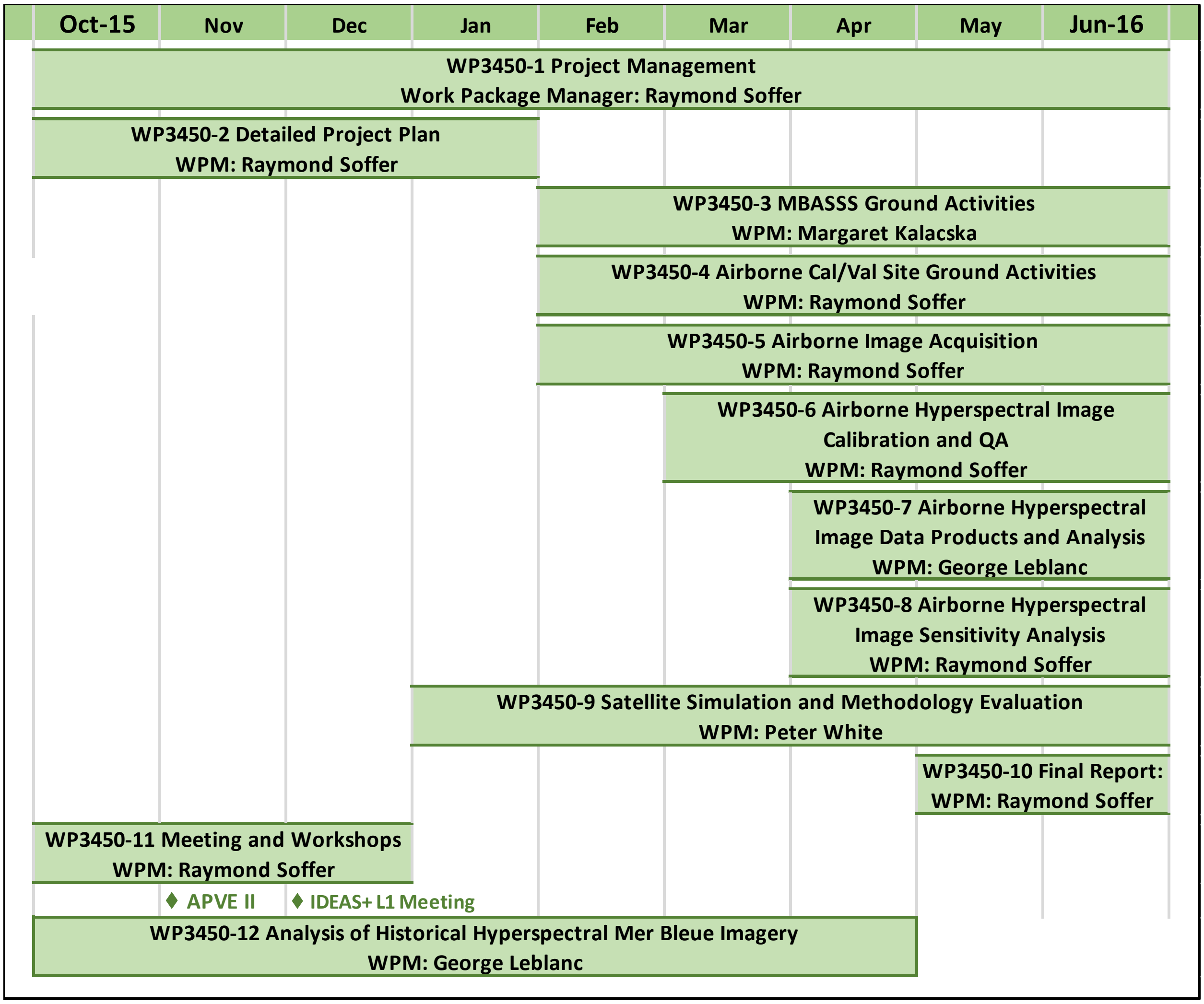

Figure 2: Work Package Structure of the MBASSS Landsat 8 Validation Project outlining the different work packages and their in-charge managers.

3.0 Work Package Plans

Each of the Work Packages (WP) identified in the contract are elaborated in this section of the report. The descriptions for each WP includes a general description, key tasks, inputs, start and end dates, followed by a detailed description of the work.

3.1 3450-1 Project Management

3.1.1 WP Summary

For the duration of the project, all project management activities will be undertaken as part of this work package.

3.1.2 WP Manager

- This WP is to be managed by Raymond Soffer.

3.1.3 WP Dates

- Start Date: Project start date (October. 1, 2015)
- End Date: Project completion data (June 30, 2016)

3.1.4 WP Inputs

- Work Package Description
- ESA Project management requirements
- Detailed Campaign Plan (once available)

3.1.5 WP Tasks

- Internal project management
- Interfacing with ESA and handling ESA requirements

3.1.6 WP Outputs

- Sub-contract with McGill University
- Sub-contract with NRCan
- Sub-Contract with LOOKNorth
- Sub-Contract with University of Arizona
- Weekly campaign project reports
- Monthly project progress reports to ESA

3.1.7 WP Details

General oversight of the project will be undertaken within this work package. In addition, the specific items identified above will be addressed.

3.2 3450-2 Detailed Project Plan

3.2.1 WP Summary

Upon contract start, a Detailed Project Plan (DPP) is to be generated describing the technical tasks to be addressed in this project.

3.2.2 WP Manager

- This WP is to be managed by Raymond Soffer.

3.2.3 WP Dates

- Start Date: Project start date (October. 1, 2015)
- Detailed draft is to be submitted to Serco by December 31, 2015 (a delay was agreed upon with Serco to January 31st for delivery of final version)
- Final version to be prepared and submitted upon receipt of comments on the draft version from Serco

3.2.4 WP Inputs

- The WP manager for each work package is responsible to submit a detailed plan for each work package
- Meeting notes from Kick Off meeting on Dec 15, 2015

3.2.5 WP Tasks

- Collect the technical and logistical details for each of the work packages
- Consolidate the WP inputs into a DPP (current document)
- Submit a draft DPP to Serco for comments and feedback
- Finalize the DPP and submit to Serco

3.2.6 WP Outputs

- Detailed Project Plan (current document)

3.2.7 WP Details

The details of the work to be carried out within this project have been under discussion for some time. With the official kick-off of the project with the project dates and budgets fixed, the technical and logistical details of the project are to be consolidated for each of the project WPs and to be submitted to Serco for comment by December 31, 2015 (project kick off + 3 months). A delay in the submission of the final DPP to the end of January 2016 was agreed to with Serco.

3.3 3450-3 MBASSS Ground Activities

3.3.1 WP Summary

Fieldwork will be undertaken at two readily accessible areas of Mer Bleue, the research area and public boardwalk. The data to be acquired at these locations will be used to supplement and validate the airborne hyperspectral data used in the Landsat 8 image simulations. Two field teams, one from McGill and one from NRCan, will deploy to Mer Bleue on Landsat 8 overpass days with suitable atmospheric conditions (days in which useable Landsat 8 imagery of Mer Bleue is expected) as well as on any other days on which airborne hyperspectral acquisition of the site is being acquired (i.e. sensitivity analysis data acquisitions – see Section 3.8). The teams' primary objectives on those days will be the acquisition of field spectra needed to complete the objectives detailed in Sections 3.3 and 3.9. Other supplemental measurements such as detailed microtopography measurements, tree height estimation, will be supported to validate the aerial DTM extraction.

3.3.2 WP Manager

- This WP is to be managed by Margaret Kalacska.

3.3.3 WP Dates

- Start Date: Project start date (February 1, 2016)
- End Date: Project End Date (June 30, 2016)

3.3.4 WP Inputs

- Project objectives and schedule
- Airborne imagery from 2015
- Ground data acquired in 2015

3.3.5 WP Tasks

- Create plant physiognomy maps necessary for calculation of spectral variability
- Determine location and number of field plots
    - Determination of optimal number of field plot
    - Supplement or reduce number of field plots to a maximum of 25 at each of the research and public boardwalks
- Collect field spectra at the two locations (research and public boardwalks) on dates airborne image acquisition dates
- Process field data to reflectance via methodology described in section 3.4.7
- UAV acquisitions of high resolution RGB imagery capturing seasonal phonological dynamics
- Deployment and acquisition of time lapse cameras on flux tower (TBC)

3.3.6 WP Outputs

- Field spectra of predetermined plots collected on airborne acquisition dates
- Processed field spectra (to reflectance) with links to ancillary data
- Vegetation classes and physiognomy maps
- Segmentation maps derived from UAV RGB imagery for each phonological period
- DTMs derived from imagery for each UAV RGB image set
- Microtops II Sunphotometer data on field days
- Research boardwalk site time lapse imagery

3.3.7 WP Details

The fieldwork being undertaken at Mer Bleue is centred on field spectrometry measurements that are to be acquired, as close as possible, coincidental with hyperspectral airborne image acquisition. Two field teams, one from McGill and one from NRCan will be deployed on suitable Landsat 8 overpass days as well as additional days on which airborne hyperspectral data of Mer Bleue is being acquired.

The McGill team will focus on field plots in the vicinity of the research boardwalk located at the Mer Bleue Peatland Observatory (MBPO) (Figure 3). The McGill team will also be in charge of ensuring supplemental data acquisitions that are available from the MBPO are operational and made available to the project database. The field spectrometer measurements will be made using the McGill owned ASD FieldSpec3 (SN: 16478) and a 10” Spectralon panel that has been cross calibrated to the project/lab reflectance standard as described in subsection 3.4.7.2. The specific ground targets of interest are described in subsection 3.3.7.13.3.7.1.

The NRCan team will focus on a secondary set of target locations adjacent to the public boardwalk (Figure 4). The specific location of these targets will be determined after the snow cover recedes this coming spring of 2016. The spectral measurements acquired by this team will be made using the Natural Resources Canada SVC 1024i (SN:2048) and a 12 inch Spectralon panel that has also been cross calibrated to the project/lab standard.

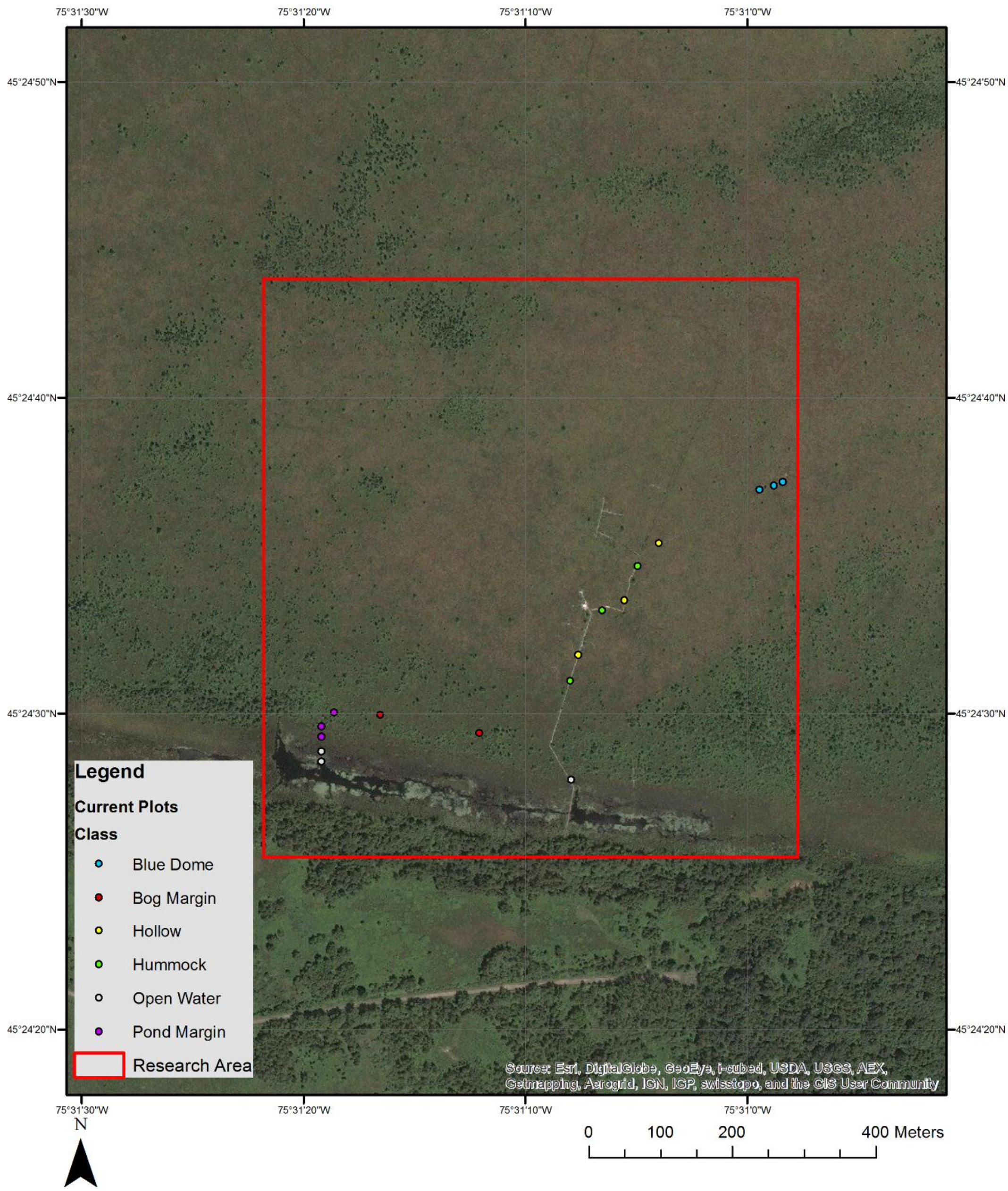

Figure 3: Mer Bleue research boardwalk (also known as Mer Bleue Peatland Observatory) with the locations of the 17 established field plots determined from 2015 field work as categorized by physiognomic class. The red perimeter represents the extended research boardwalk area (800 m x 800 m) at MBPO that will be target region for the UAV flights that corresponds to the Airborne field of view of a single airborne flight line.

Figure 4: The Mer Bleue public boardwalk. Field plots adjacent to the boardwalk will be established immediately following snow melt in the spring of 2016.

Both McGill and NRCan groups will also be involved in the acquisition of high resolution RGB images from UAV platforms. McGill will be using the imagery they collect to produce maps of the vegetation physiognomic and spectral classes as described in Sections 3.3.7.4. NRCan will use their imagery to produce DTMs and segmentation maps as described in Section 3.9.7 as part of the integrated Satellite Simulation WP description.

3.3.7.1 Fields Spectrometry Methodology

The plot reflectance spectra will be obtained using the panel substitution methodology as described in section 2.4. Each spectral measurement will be supplemented with:

- Spot-photo
    - The SVC 1024i system includes a camera co-aligned with the spectral Field of View (FOV) that takes a spot-photo coincidentally with each spectral measurement
    - The ASD FieldSpec 3 setup will include a digital camera co-aligned with the spectral FOV using an operator controlled remote control to acquire near coincidental spot-photos
- Sky-photo
    - An upward looking near-coincidental hemispherical photo of the sky
- Field-photos
    - General photos illustrating each measurement setup - not necessarily coincidental
- Microtops II sunphotometer measurement

3.3.7.2 Ancillary MBPO data

Ancillary data of interest to this project acquired at the MBPO, either for analysis undertaken as part of this project or for potential future work, includes the following:

- Time-lapse photography of the peatland target in the vicinity of the MBPO flux tower
- Cotton-grass distribution during flowering (peak)
- Standard data sets acquired at MPBO
    - Temperature
    - Precipitation
    - Beaverpond dissolved oxygen content (DOC)
    - Water table depth
    - Carbon dioxide (CO_2) gas flux
    - Methane (CH_4) gas flux
- Previously collected data sets
    - Peat profiles
    - Vegetation, chlorophyll, and nitrogen concentration (destructive sampling) (2009, 2011, 2013)
    - Leaf area index (LAI)
    - Vegetation carbon (2003, 2013)
    - Root profiles

3.3.7.3 Timing considerations

The primary days on which the fieldwork will occur will be the Landsat 8 overpass days (as identified in section 2.5) and additional days on which airborne hyperspectral imagery of Mer Bleue is to occur. Atmospheric conditions on these days must be suitably cloud free so that the Mer Bleue peatland is observable in the Landsat 8 imagery. The non-Landsat 8 days will likely occur in support of the sensitivity analysis airborne image acquisitions; although if suitable conditions prevail on the overpass days (clear and extremely stable), it is possible that those data sets could be acquired on those days.

There is no requirement for the UAV flights to occur on days of Landsat 8 or airborne hyperspectral acquisitions although they should take place within a few days of those data acquisitions. Bright overcast conditions are the most favourable for collected UAV data with minimal impact of viewing and illumination angles. The Mer Bleue area lays outside the 4 Control Zone Extensions impacting our work (Ottawa ON, Gatineau QC, Rockcliffe ON and the Ottawa/Macdonald-Cartier International Airport) as well as the 7 and 3-mile Control Zones around the 2 local airports (Ottawa/Macdonald-Cartier Intl and Rockcliffe ON). The proposed UAV flight altitudes are below the 1500-foot Terminal Control Area of the Ottawa/Macdonald-Cartier International Airport. Mer Bleue is also outside the two local Transport Canada Advisory Areas (Kemptville ON and Hawksbury ON) therefore simplifying the process of obtaining permission from Transport Canada for low altitude (i.e. < 300 ft AGL) UAV research (Figure 5).

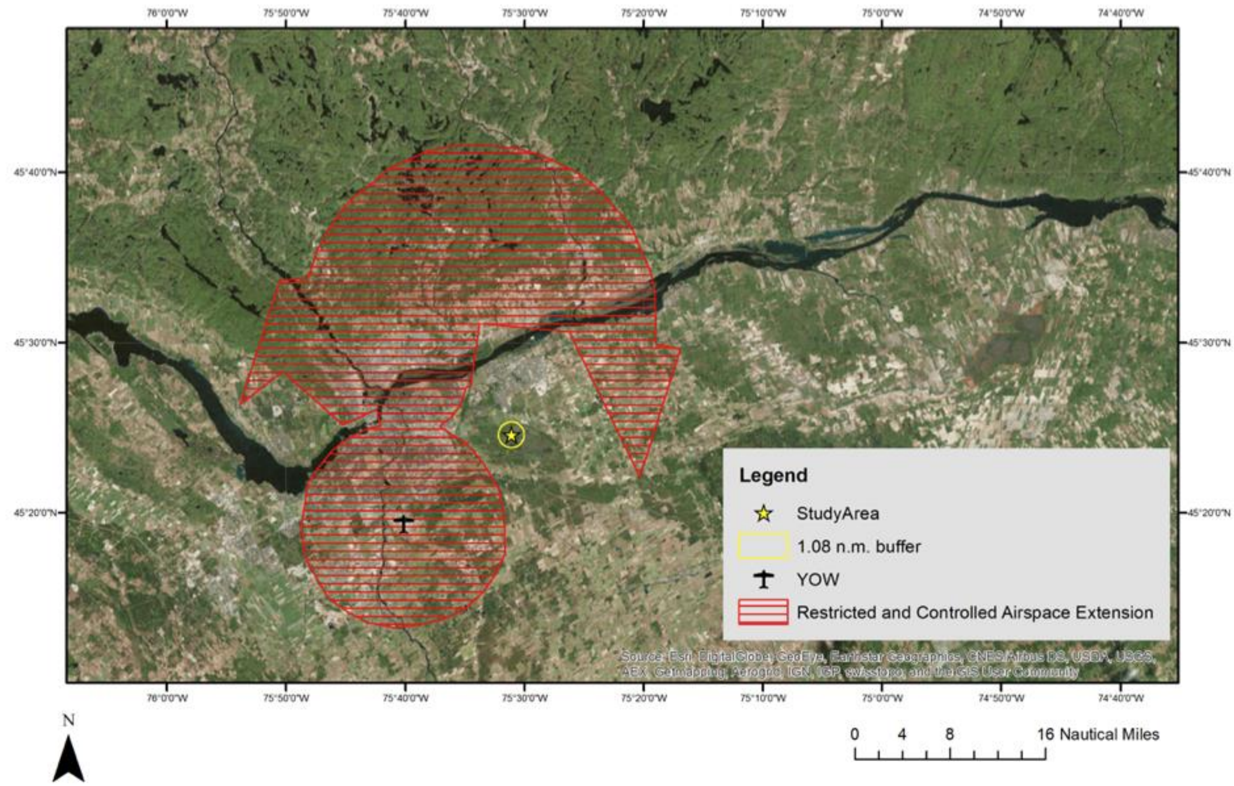

Figure 5: Location of the study area in relation to the Control Zones and Control Zone Extensions. The 1.08 nautical mile (2 km) buffer indicates maximum range of the project UAVs with a single battery.

During the growing season, six clearly identifiable phenological events have been identified (described in the field work general discussion below in subsection 3.3.7.4). If atmospheric conditions do not coincide with the Landsat 8 overpass days within one of these windows, consideration will be given to deploy the field and airborne teams on a non-Landsat 8 day with clear skies. The intention is also to deploy the airborne and ground teams at least one time during a Landsat 8 day on which the ground is covered with uniform snow conditions.

The Landsat 8 satellite is schedule to pass over Mer Bleue at approximately 15:45 ± 10 minutes GMT or 11:45 local time in the summer and 10:45 in the winter (solar noon is near 13:00 in the summer, 12:00 noon in the winter). The process of collecting the necessary spectra will take substantially longer than the brief period in which the Landsat 8 imagery is acquired. Measurement of the 17 extant plots (Figure 3) required approximately 2 hours during the 2015 field work. As the region tends to be subject to the development of convective cloud build-up due to daytime heating as the day progresses, the field measurement process will normally be initiated substantially in advance of the overpass time. Measurements will continue through solar noon on days in which suitable atmospheric conditions remain.

3.3.7.4 General discussion - Field Measurement Approach

The optimal number of field plots per physiognomic class (i.e. open water, bog margin, pond margin, hummock, hollow, blue dome) (Table 1, Figure 6) will be determined through a hierarchical process, which includes integration of microtopography data and the spectral characteristics of the peatland over time. *Physiognomic class* is defined here as the external morphological characteristics of the vegetation; the horizontal and vertical vegetation structure and species composition at a scale of 1 m. The primary microtopographic classes are hummocks and hollows with a mean relief difference of 25 cm.

Table 1 Current physiognomic classes established from the 2015 field work for ground spectral data collection.

Class	Description
Open Water	Exposed water in the beaver pond. Main species include *Sphagnum majus* and *Typha latifolia*.
Bog Margin	This represents the transitional area from the Open Water and pond margin, to the edge of the bog. In the bog margin, the deciduous herbs *T. latifolia*, *Calla pallustris* and *Eleocharis smallii* are especially common.
Pond Margin	This represents the transitional area from Open Water into grasses at the edge. *S. fallax* is a common species.
Hummock	Hummocks account for approximately 70% of the peatland, and are primarily composed of *Sphagnum* sp. mosses, with shrubs up to 30 cm tall growing above the moss. In these areas *S. capillifolium* is most common, however very little moss is exposed.
Hollow	Hollows are composed of different types of *Sphagnum* sp. mosses, and are where most of the *Eriophorum vaginatum* (cotton grass) and other herbs primarily grow. In these areas the mosses *S. angustifolium*, and *S. fallax* are most common.
Blue Dome	This area is of interest because on Landsat imagery it appears to have a blue hue. This area contains mainly *S. magellanicum*.

Mer Bleue also contains a sparse number of trees, *Betula populifolia*, *Larix laricina*, *Picea mariana* and *Pinus strobus*. Common shrubs at Mer Bleue can be found of either the evergreen (*Chamaedaphne calyculata*, *Kalmia angustifolia* and *Rhododendron groenlandicum*) or the deciduous (*Vaccinium myrtilloides*) variety. There are also a number of common deciduous herbs, such as *E. vaginatum* and *Maianthemum trifolium*. The moss *Polytrichum strictum* can be found throughout the bog. Plots and classes are primarily defined on structure and secondarily on species composition. Based on a rarefaction curve analysis of the primary species (not including trees) growing outside the lagg areas, within an area of 1.5 m^2 (95% confidence intervals: 0.77–2.5 m^2) a population of 13 sampled vascular plant and moss species can be found. Currently there are 17 field plots established in the research area of Mer Bleue (Figure 3, Figure 6). Their location was determined primarily by accessibility from the boardwalks in the research area.

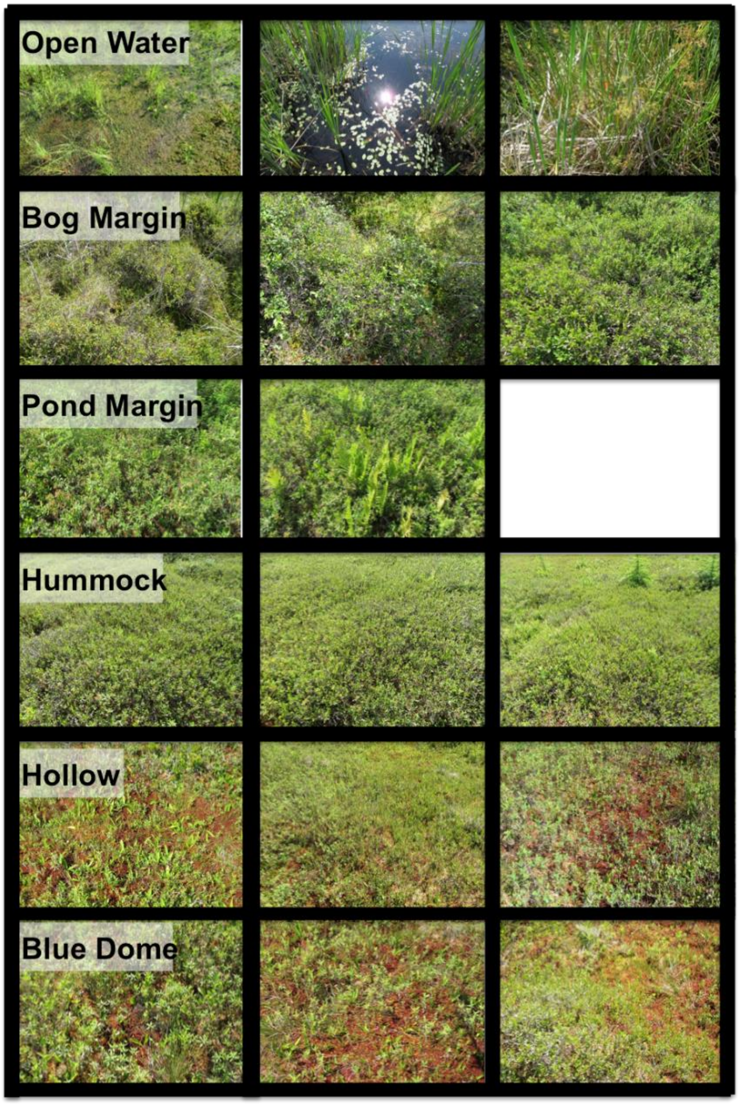

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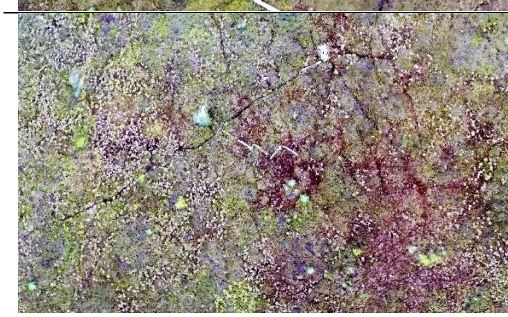
Figure 6: Photographs of the 17 established field plots in the six physiognomic classes. Each row represents a class. Photographs illustrate the plots in July 2015.

The first step in the determination of the optimal number of plots for 2016 will be the location of the areas that are primarily exposed mosses and the creation of a fine spatial resolution (< 5 cm) microtopography map for the research area illustrated in Figure 3. Low altitude (45 m (148 ft) AGL) UAV videography/photography immediately after the snow melt (approx. March/April) will be used to calculate the area of the exposed mosses. Very early in the growing season, prior to the development of the new leaves on the vascular plants, the mosses can be readily differentiated from areas with vascular plant cover (Table 2). Overall vegetation height and microtopography will be extracted from low altitude UAV videography/photography following the initial period new leaf period (approx. early May).

Table 2: Examples of early and late growing season data from low altitude UAV videography/photography collected during the 2015 field work over the MEr Bleue research area.

UAV Example	Significance of time Period
	Following snow melt prior to new leaf development in the vascular plants. Frame collected at the end of April 2015 illustrates the differentiation between mosses, vascular plants and location of *E. vaginatum* tufts.
	Early May 2015 image illustrating the difference mosses and vascular plants with new leaves.
	Early May 2015 image illustrating the different mosses and vascular plants with new leaves. Microtopography can be clearly differentiated during this window of time when new leaves on the vascular plants are just beginning to form.
	End of growing season (early November 2015) image illustrating clear microtopography and differentiation of *L. laricina* from other species.

Based on the two UAV datasets a final composite DTM of vegetation height will be used to stratify the research area into hummock and hollow classes. The Open Water, Bog Margin and Pond Margin classes will be determined from the earliest snow clear dataset (approx. late March/early April).

Once the extent of the classes within the research area have been determined from the UAV data, the spectral variability of the classes that can be captured by the ground data will be calculated from the airborne imagery collected in 2015 (Figure 7).

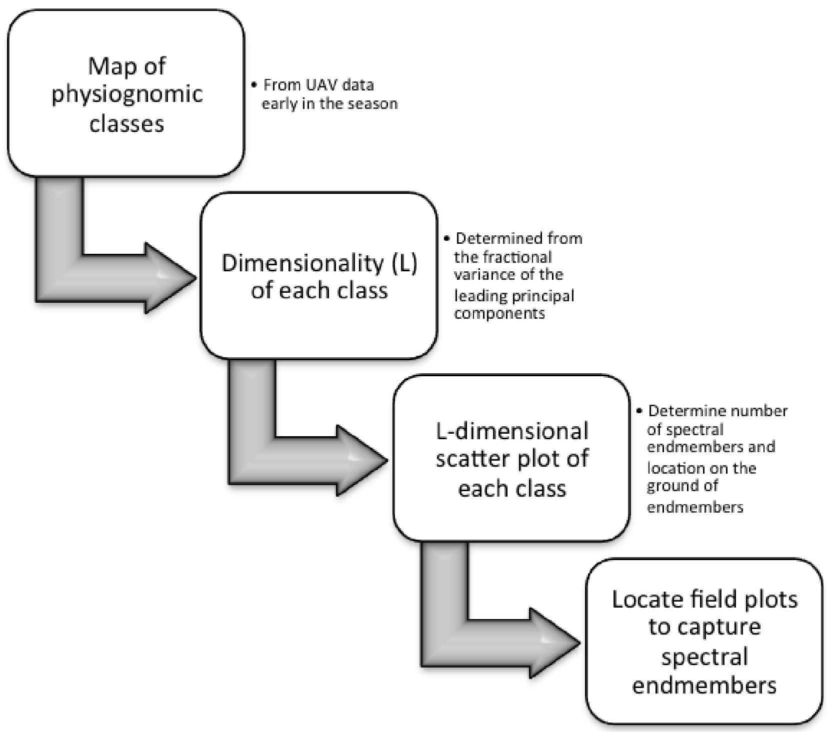


Figure 7: Primary steps in determination of field plot locations.

For the pixels that encompass the area within each class from the Compact Airborne Spectrographic Imager (CASI 1500) and Shortwave Airborne Spectrographic Imager (SASI 644), the image eigenvalue distribution will be ordered with the leading principal components with respect to variance. While determining the cut-off point for the leading subspace dimensionality is not straightforward, a decision will be made based on the cut-off point encompassing a large portion of class variance. We make the assumption through the determination of the cut-off point that the spectral content of the subspace will capture the spectral variability of the class. The eigenvector matrix can be decomposed by Eqn. 1:

$$V = [S\, S^{\perp}] \qquad \text{Eqn. 1}$$

where S is the matrix of size K x L of the top ranked eigenvectors (L) and $S^{\perp}$ are the remaining eigenvectors below the cut-off of size K x (K-L). We hypothesize the eigenvalue distribution from the CASI and SASI imagery will not follow the theoretical simple white noise distribution model where a plot of principal component versus variance would show the distribution flattening out to a constant value indicating the inherent dimensionality because the noise component will likely vary between bands and there may also be band-to band correlation. Therefore, L will be estimated from Eqn. 2 as the fractional variance which aims to calculate a subspace with a high fraction of the total variance in the leading principal components where $(\sigma_Z^2)_k$ are the eigenvalues:

$$F = \frac{\sum_{k=1}^{L}(\sigma_Z^2)_k}{\sum_{k=1}^{K}(\sigma_Z^2)_k} \qquad \text{Eqn. 2}$$

The result is expected to be a curve of dimensionality versus fraction of total variance with a shape resembling a cumulative distribution function curve. The value of L will be determined as the inflection point of the curve. Equation 2 is founded on the premise that the spectrum in a given pixel is the linear combination of signal and noise, which are assumed to be uncorrelated. The covariance matrix for the data in a given pixel is therefore expressed as the sum of the signal and noise.

The data encompassed by the subspace of eigenvalues (L), will be mapped in an L- dimensional scatter plot to determine the number of endmembers represented as the vertices. The distance (i.e. similarity) between the endmembers can be calculated as the multidimensional spectral angle. The location of the endmembers can subsequently be readily mapped in space (i.e. on the actual image). Those endmembers that fall within a 2 m buffer of the boardwalks will be retained as candidates.

The analyses, beginning with the subspace determination will be repeated for each airborne dataset acquired in 2015 because it is expected that the number of endmembers within a class will not be constant within space or time. The candidate endmembers that are repeated in several data collections will be ordered as high priority ground targets with others that are only found in one or two data sets as lower priority. It is estimated that one ground crew can collect spectra from 25 plots per day using the protocols created in 2015 (Figure 8). Therefore, if more than 25 high priority endmembers (across all classes combined) are found they will be ordered by importance of the physiognomic class with hummock and hollow having the highest importance due to their predominance across the bog, followed by Bog Margin, Pond Margin and Open Water respectively. It is expected that the Blue Dome area will be dissolved as endmembers within the hummock hollow classes.

During key phenological events such as the flowering of the cotton grass, additional plots may be established for the explicit purpose of capturing those endmembers at one point in time. The location of the current 17 field plots will be compared to the location of the priority targets to determine which can be kept and which ones need to be moved or replaced altogether. The entire methodology will be repeated for locating the field plots along the public boardwalk.

In order to capture the spatial dynamics of the growing season, a time lapse panoramic camera (Brinno TLC200 Pro with an ART 100 rotational platform) (TBC) will be set up to record the bog at set intervals across the growing season. The use of the time lapse data are proposed to compensate for the bi-weekly spectral sampling. Therefore, if important phenological events occur between sampling dates they would be captured by the time lapse data.

Figure 8: Field photographs from 2015 of the field team collecting ground spectra of the 17 established plots.

3.4 3450-4 Airborne Cal/Val Site Ground Activities

3.4.1 WP Summary

In support of validation activities of the airborne hyperspectral imagery, a calibration and validation test will be identified and monitored throughout the project in support of the airborne campaign through the use of field spectrometry. At the beginning and end of each Mer Bleue data acquisition flight, airborne hyperspectral imagery of the Cal\Cal site will be acquired from a similar altitude above ground level to that used in the acquisition of the Mer Bleue site imagery. A field team will be deployed to acquire near-coincidental ground spectral measurements using panel substitution methodology of a number of identified cal/val ground targets. Efforts will be made to optimize the panel substitution methodology cross calibration of the field panels to a lab standard. The lab standard will in turn be cross calibrated to the University of Arizona reflectance standard which is tied to the NIST standard. The Cal/Val target reflectance's will then be used to validate and, if necessary, to vicariously calibrate the airborne hyperspectral imagery.

3.4.2 WP Manager

- This WP is to be managed by Raymond Soffer

3.4.3 WP Dates

- Start Date: Project start date (retroactive start date of October 1, 2015)
- End Date: Completion of the Airborne Data Acquisition Phase (nominal end date of June 30, 2016)

3.4.4 WP Inputs

- Preliminary project objectives and schedule
- Completed Detailed Campaign Plan (once available)
- Calibrated field panel reflectance factors (once available)

3.4.5 WP Tasks

- Develop Test Site Ground Support Plan
- Oversee and undertake the test site data acquisition activities
- Data processing, validation, archival and project delivery of the test site ground data.

3.4.6 WP Outputs

- Detailed Test Site Ground support plan (this section)
- Ground spectral and ancillary metadata database (raw and processed) and summary table

3.4.7 WP Details

Whenever possible over the past several years, NRC has used the airport apron located just outside their hanger (NRC building U61) as a Cal/Val target to support local hyperspectral imaging deployments. The apron currently is composed of a 60 m x 24 m concrete pad and a much broader asphalt apron that were deemed suitable for this work (Figure 9). In addition, 8 m x 8 m grey and black canvas calibration tarps will also be deployed (given acceptable wind conditions) as two additional Cal/Val targets (Figure 10). These four target are deemed suitable as Cal/Val target for the airborne hyperspectral imagery as they are adequately large, relatively uniform, and are spectrally smooth. When time permits, field spectrometer measurements will also be made of adjacent vegetation (grass) plot.

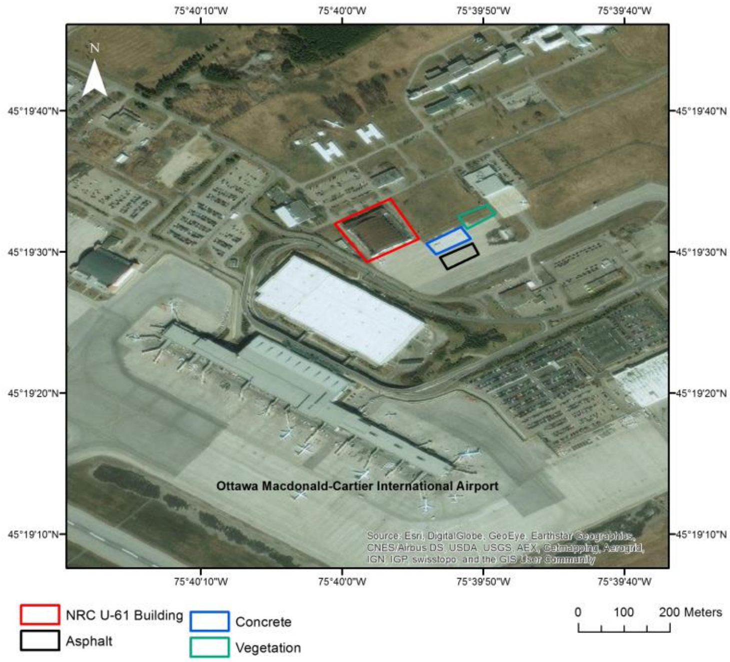


Figure 9: GeoEye image of NRC Building U-61 site showing concrete asphalt, and vegetation to be used as Cal/Val targets.

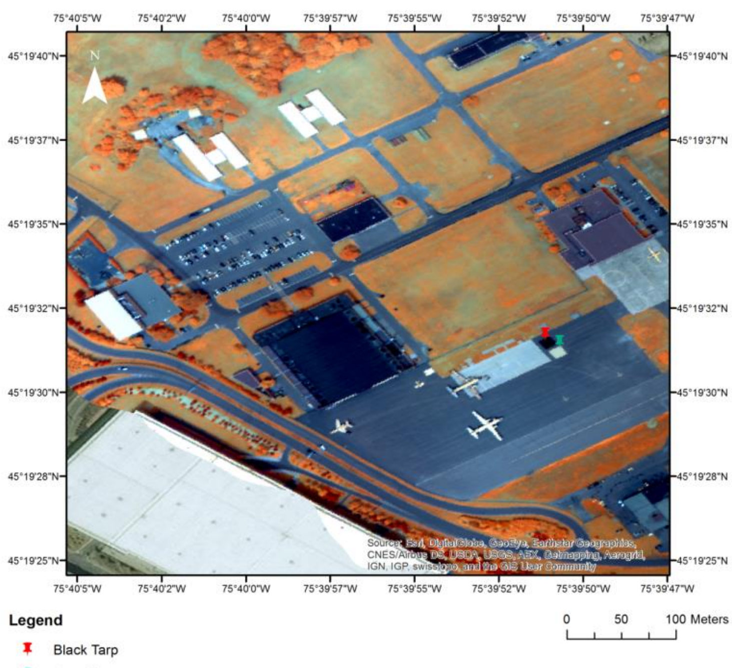


Figure 10: GeoEye image of NRC Building U61 site with SASI (R: 1052 nm, G: 1624 nm, B: 2122 nm) overlay collected on June 17th, 2015. The black and grey Cal/Val tarps are shown as typically deployed in this hyperspectral image.

3.4.7.1 Field Spectrometry Measurements

The field spectrometry measurements of the Cal/Val site will be carried out by a NRC lead team using their SVC1024i instrument (SN: 2047). During each deployment of the airborne hyperspectral equipment to Mer Bleue, a number of quick measurements will be made of the 5 targets at specific locations. These measurements are to be made as close as possible to the time aircraft overpass of the U61 Cal/Val site. In addition, a set of measurements will also be acquired of each of the various Cal/Val targets to determine the variability of the extended targets. These measurements do not need to be performed coincidental to the airborne hyperspectral overpass. These variability measurements will need to be acquired under clear/stable atmospheric conditions and, for each target, as quickly as possible. As described in Section 3.3.7.1, spot-, field-, and sky-photos as well as a Microtops sunphotometer measurement will be made with each field spectra acquisition.

3.4.7.2 Reference Panel

The basic equation used to calculate the ground reflectance is:

$$R_T(\theta_i : \theta_v) = R_R(\theta_i : \theta_v) \times {}^{S_T}/_{S_R} \qquad \text{Eqn. 3}$$

where $R(\theta_{i:}\ \theta_v)$ is the reflectance of the target (T) or reference panel (R) for a specific illumination and view angle, θ_i and θ_v respectively, and S is the offset corrected signal for the target and Spectralon reference panel. The accuracy of this approach is dependent on a number of issues:

- The two measurements must be acquired under identical illumination conditions
- The field spectrometer must have a stable response
- The field spectrometer must have a linear response
- The reflectance of the reference panel is accurately known for the given illumination conditions

Although all of these issues will be considered and efforts made to minimize and characterize the impact of any of them may have on the results, knowledge of the panel reflectance must be specifically addressed. As there will be at least three separate teams making field spectrometry measurements and each of those teams will be using a separate panel, each of these panels must be tied to a common standard. Therefore, those panels will be cross calibrated to a laboratory reflectance standard. Furthermore, the lab standard will be tied to a national standard so that each ground measurement can be stated in absolute terms with respect to the National Institute of Standards and Technology (NIST) reflectance standard.

The cross calibration of the field panels to the lab standard will be accomplished in-house at NRC using a dark lab setup making use of a stabilized illumination system, and an xy-translation stage. The NRC SVC1024i will be used to transfer the reflectance standard from the centre point on the lab standard to the centre point of each of the field panels using the panel substitution methodology. The spatial variability of each of the panels will also be determined allowing the uncertainty of the transferred reflectance values to be estimated. This process will be performed at a minimum once before and once following the field season. The approach at this time is performed only a single illumination angle of 45° with the view angle set at nadir.

Tying of the lab standard to the NIST national reflectance standard will be performed by the Remote Sensing Group (RSG) at the University of Arizona. This group is world leader in performing field spectrometry measurements in support of satellite validation operations and their dark lab approach to panel calibration is fundamental to their methodology and uncertainty estimates. Their approach makes measurements on illumination angle increments of 5° (view angle set to nadir) at 10 spectral point in the visible and near infrared region (i.e. 400 nm – 1061 nm) and 9 spectral points in the shortwave infrared region (i.e. 1243 nm – 2403 nm). The methodology used by the RSG to interpolate spectrally and to various illumination angles will be made available to us and implemented. In addition to sending our lab standard for characterization at RSG, a used field panels will also be sent. This will be done in order to allow us to validate our in-house cross calibration approach by attempting to duplicate the RSG results of this second panel which will show some effects of degradation, with respect to our lab standard.

3.5 3450-5 Airborne Image Acquisition

3.5.1 WP Summary

This work package addresses all aspects of airborne hyperspectral image acquisition, identification and acquisition of any ancillary data requirements, as well as the data archival and initial quality assessment of the imagery and ancillary data.

3.5.2 WP Manager

- This WP is to be managed by Raymond Soffer.

3.5.3 WP Dates

- Start Date: Project start date (retroactive start date of October 1, 2015)
- End Date: Completion of the Airborne Data Acquisition Phase (nominal end date of June 30, 2016)

3.5.4 WP Inputs

- Preliminary project objectives and schedule
- Completed Detailed Campaign Plan (once available)
- Mer Bleue Region of Interest for Mosaic
- Landsat 8 overpass of Mer Bleue Schedule

3.5.5 WP Tasks

- Airborne Hyperspectral Image Acquisition Plan
- Airborne Hyperspectral Image Acquisition
- Airborne Hyperspectral Image Acquisition Archival and QA

3.5.6 WP Outputs

- Raw CASI/SASI Imagery Library(Raw CASI/SASI files) and summary table
- Inertial Measurement Unit (IMU) data files

3.5.7 WP Details

The airborne hyperspectral image acquisitions can be broken down into two sets:

1) Mer Bleue Landsat 8 flight mosaics and
2) Mer Bleue Sensitivity Analysis flight lines

For all flight lines in both image sets, in addition to the CASI and SASI hyperspectral imagery, the following data sets will also be acquired:

- Inertial Measurement Unit (IMU) data
- Mer Bleue ground spectrometer and ancillary measurements (described in Section 3.3.7.1)
- Mer Bleue sun photometer measurements (described in Section 3.3.7.1)
- U61 Cal/Val site ground spectrometer and ancillary measurements (described in Section 3.4.7.1)

- U61 Cal/Val site sun photometer measurements (described in Section 3.4.7.1)

3.5.7.1 Mer Bleue Landsat 8 Underflight Airborne Mosaics

3.5.7.1.1 Schedule

The airborne crew, supported by the field teams (Mer Bleue and U61), will be prepared for deployment to collect a Mer Bleue mosaic on days of Landsat 8 overpasses of the Mer Bleue site when the sky conditions are considered sufficiently clear to produce Landsat 8 imagery of usable quality of the peatland. Attempts will be made to acquire one winter data set with snow covered ground conditions between Feb.1st and March 19th, 2016 (6 opportunities, the earlier the better). Once clear of snow, as many mosaics as possible of Mer Bleue corresponding to Landsat 8 overpasses will be acquired. Although the budget will not allow for airborne and ground campaign on all identified dates, the probability of clear skies will limit the number of suitable opportunities. Over the past 3 years (2013, 2014, 2015), the number of clear sky Landsat 8 images of Mer Bleue between April 1st and October 31st has been 40% (10 of 25), 22% (6 of 27) and 32% (9 of 28) respectively. Of the 27 coordinated opportunities in the projects's time frame, three Landsat 8 image acquisitions fall on Canadian statutory holiday weekends. Although deployments are possible on those days, ground and airborne work will not be planned unless clear sky opportunities to date have been limited. 3 additional days fall on weekends which have been budgeted for. The Landsat 8 data acquisition days of Mer Bleue are shown in Table 3.

Table 3 The Landsat 8 data acquisition opportunities of Mer Bleue

Landsat 8 Overpass (Mer Bleue)	Path	Comment	Landsat 8 Overpass (Mer Bleue)	Pat h	Comment
Tuesday, February 09, 2016	15	Snow cover opportunity	Thursday, June 23, 2016	16	
Tuesday, February 16, 2016	16	Snow cover opportunity	Saturday, July 02, 2016	15	Statutory Holiday Weekend
Thursday, February 25, 2016	15	Snow cover opportunity	Saturday, July 09, 2016	16	Saturday
Thursday, March 03, 2016	16	Snow cover opportunity	Monday, July 18, 2016	15	
Saturday, March 12, 2016	15	Snow cover opportunity	Monday, July 25, 2016	16	
Saturday, March 19, 2016	16	Snow cover opportunity	Wednesday, August 03, 2016	15	
Monday, March 28, 2016	15	Statutory Holiday	Wednesday, August 10, 2016	16	
Monday, April 04, 2016	16	Anticipated first snow clear opportunity	Friday, August 19, 2016	15	
Wednesday, April 13, 2016	15		Friday, August 26, 2016	16	
Wednesday, April 20, 2016	16		Sunday, September 04, 2016	15	Statutory Holiday Weekend
Friday, April 29, 2016	15		Sunday, September 11, 2016	16	Sunday
Friday, May 06, 2016	16		Tuesday, September 20, 2016	15	
Sunday, May 15, 2016	15	Statutory Holiday Weekend	Tuesday, September 27, 2016	16	
Sunday, May 22, 2016	16	Sunday	Thursday, October 06, 2016	15	
Tuesday, May 31, 2016	15		Thursday, October 13, 2016	16	
Tuesday, June 07, 2016	16		Saturday, October 22, 2016	15	
Thursday, June 16, 2016	15		Saturday, October 29, 2016	16	

3.5.7.1.2 Mer Bleue coverage

The Mer Bleue Peatland is located on the eastern outskirts of Ottawa. Figure 11 identifies the key elements of the Mer Bleue Peatland.
Figure 12. Mer Bleue extents identified for this project with the 12 mosaic flight lines (MB-A through MB-L) shown. Flight Line MB-E is the primary flight line that runs through the scientific and public boardwalk areas. illustrates the extent of the peatland and the 12 proposed flight lines, identified as flight lines MB-A through MB-L, required to create a complete airborne hyperspectral mosaic of that area. Both the CASI and SAASI instruments have FOVs close to ±20°. An altitude of 1108 m AGL will provide coverage of 800 m. If 20% overlap is planned to accommodate distortions in the imagery due to variations in the aircraft -altitude, a flight line spacing of 640 m results as is depicted in
Figure 12. Mer Bleue extents identified for this project with the 12 mosaic flight lines (MB-A through MB-L) shown. Flight Line MB-E is the primary flight line that runs through the scientific and public boardwalk areas.. The ground level of the peatland is relatively flat between 64 and 71 m mean sea level (MSL). A nominal ground level altitude of 70 m MSL (32 m HAE) will be used for planning purposes. A flight line heading of at 162° TN allows for the two boardwalk areas to be imaged within a single flight line and provides a heading that is close to the solar azimuth shortly before solar noon. The anticipated airborne spatial resolutions and spacings for the CASI and SASI imagery given the above noted parameters are shown in Figure 13.

3.5.7.1.3 Mer Bleue Mosaic Imagery Time of Day Considerations

Ideally the acquisition of the mosaic flight line imagery would occur instantaneously with the Landsat tile acquisition which occurs at 15:45 GMT (11:45 local time in the summer) ± 10 minutes. In reality the process of acquiring the 12 identified airborne flight lines will take between 2.0 and 2.5 hours assuming that the process occurs smoothly and without interruption. Taking these factors into consideration, a typical deployment plan would have the image acquisition start 1 to 1.5 hours prior to the satellite overpass. If convective cloud build-up is anticipated, then pushing the start time forward should be considered so that bulk of the flight lines would occur prior to the Landsat 8 overpass. Ideally flight line MB-E, which includes the ground sampling sites centred at both the research and public boardwalks, should be acquired as near as possible in time to the Landsat 8 image.

3.5.7.1.1 Other Considerations

Even a slight head/tail wind will produce a significant change in ground speed as well as the pitch of the aircraft. Target ground speeds of 80 knots are obtainable in the Twin Otter aircraft but often only in one flight direction. For this reason, acquiring the flights at a slightly higher speed (90 knots) or approaching all flight lines in the same direction, must be considered.

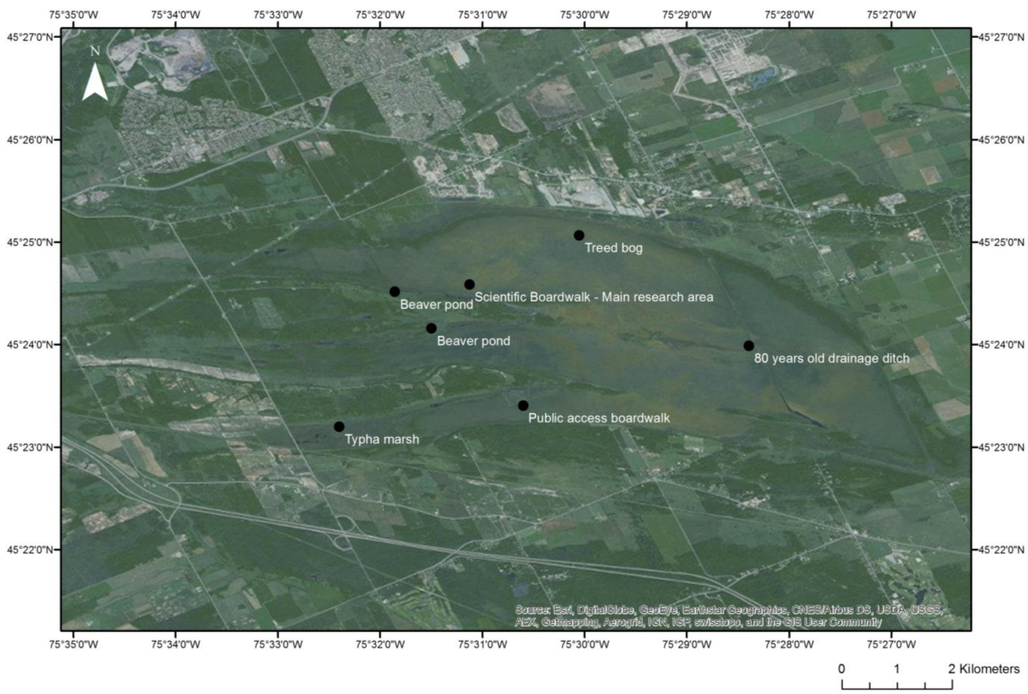


Figure 11: Mer Bleue GeoEye image with the primary targets of interest identified.

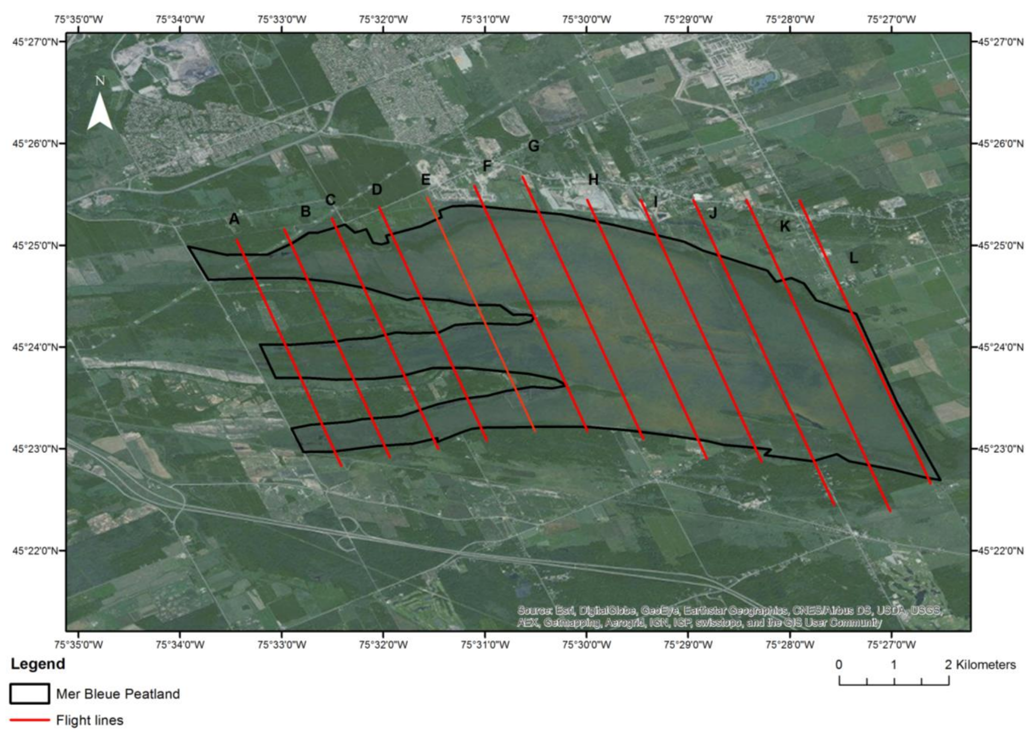


Figure 12. Mer Bleue extents identified for this project with the 12 mosaic flight lines (MB-A through MB-L) shown. Flight Line MB-E is the primary flight line that runs through the scientific and public boardwalk areas.

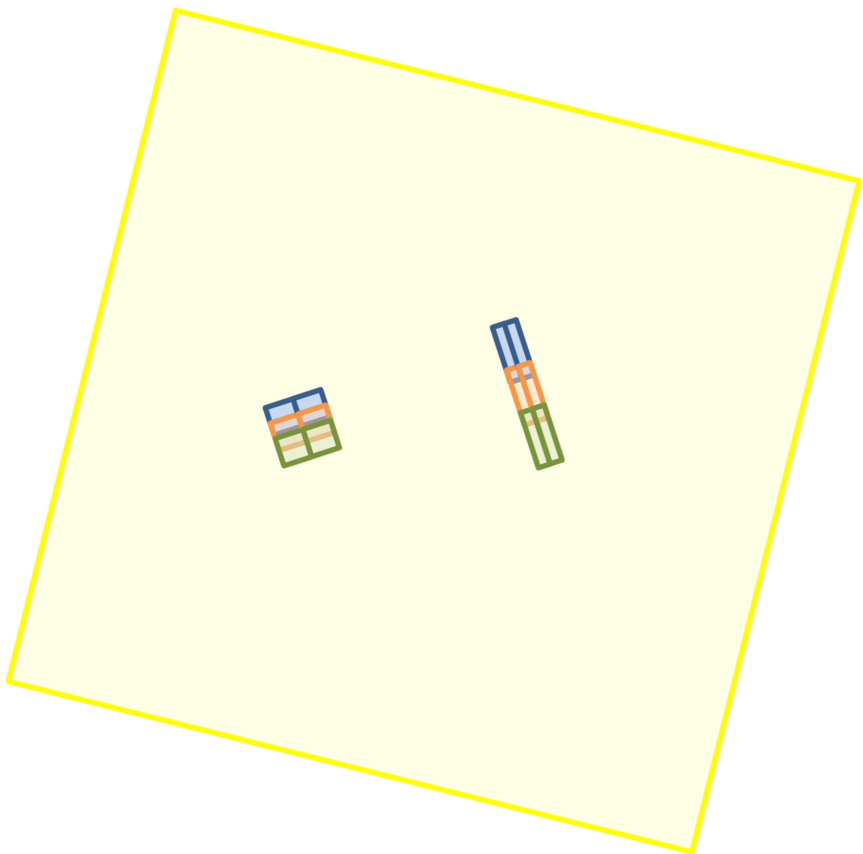


Figure 13: CASI and SASI pixels in comparison to Landsat 8 pixel are illustrated above. The 30 m x 30 m Landsat 8 pixel (yellow) is orientated at approximately 194° TN. 2 cross track by 3 along track SASI pixels are shown on the LHS for the SASI and on the RHS for the CASI which will be acquired on flight lines 18° off true north. The first pixel is shown in blue, second pixel in orange and third in green where the overlap is due to the difference in the along-track spacing versus resolution. The SASI resolution and spacing for the target altitude (1108 m) and ground speed (80 knots) will be 1.25m (cross and along-track) and 0.69 m (spacing). For the CASI the corresponding values are 0.54 m for the cross track resolution, 2.51 for the along-track resolution and an along track spacing of 1.98 m.

3.5.7.2 Sensitivity Analysis Flight Lines

Imagery will be acquired to perform at least four different sensitivity analyses related to understanding how to optimize image acquisition of a ground target and its impact on the various analyses, including the satellite simulation. Those four data sets will address the following issues:

1) Solar and view azimuthal issues
2) Solar zenith angle issues
3) CASI configuration (spectral resolution) issues
4) Sensor altitude (spatial resolution) issues

In order to optimize these data sets for the sensitivity analysis, image acquisition will only be undertaken on days with clear, stable atmospheric conditions. Although there is no requirement that this imagery be performed on Landsat 8 days, should the conditions cooperate, they could be acquired before or after the Mer Bleue mosaic thereby optimizing the ground support operations. The primary flight line of interest will be MB-E as defined in Figure 12

Figure 12. Mer Bleue extents identified for this project with the 12 mosaic flight lines (MB-A through MB-L) shown. Flight Line MB-E is the primary flight line that runs through the scientific and public boardwalk areas. as it will cover both the research and public boardwalk which represents the focal point of any ground sampling. For the azimuth angle data set, the area around the research boardwalk will be the target of interest. All the sensitivity analysis data sets potentially could be acquired on the same day.

3.5.7.2.1 Solar and View Azimuth Sensitivity Image Set

For this data set, a number of flight lines acquired at various headings centred over the research boardwalk are to be collected in as short a time frame as possible (Figure 14). The flight altitude will be the same as for the mosaics at 1080 m AGL. If time permits, 9 flight angles with heading offsets of 20° starting with the MB-E flight line will be acquired. This could be reduced to 6 flights with offset of 30° if needed. Ideally this would be performed twice on the same day at significantly different solar Zenith Angles (SZA), one relatively low (SZA = 60° (TBC)) and one relatively high (SZA = 30° (TBC)) respectively. The high SZA implies that this data set would have to be acquired in the June/July time frame.

3.5.7.2.2 Solar Zenith Angle Sensitivity Image Set

If successful in acquiring the azimuth angle image set at two substantially different SZA, then flight lines at 2 SZA will have already been acquired that are suitable for the SZA sensitivity analysis. Ideally a third image with an intermediate SZA would be acquired as well. The focus of this data set will be the MB-E flight line once again.

3.5.7.2.3 CASI Configuration Sensitivity Image Set

For this data set, the same flight line (MB-E) will repeatedly be acquired as quickly as possible with multiple CASI configurations. The configuration of interest would be:

- 288 channels (full spectral resolution)
- 144 channels (sum by 2)
- 96 channels (sum by 3)
- 72 channels (sum by 4)
- a Landsat 8 band simulation
- a Sentinel 2 band simulation

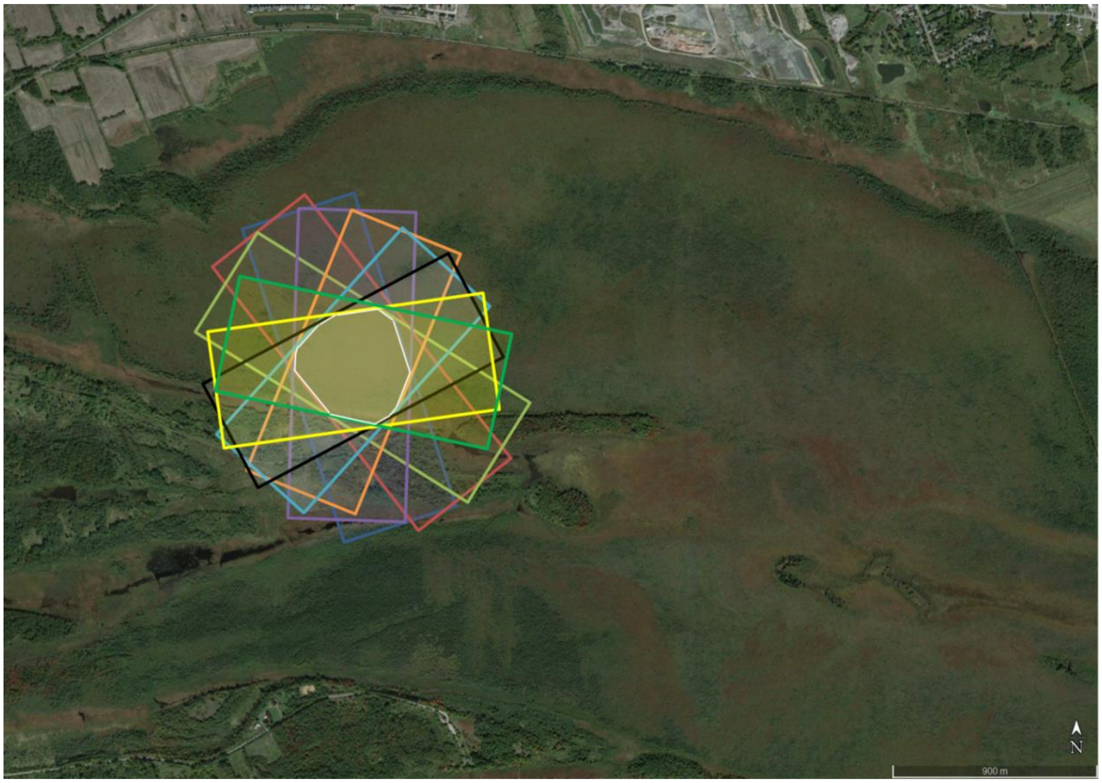


Figure 14: Azimuthal sensitivity analysis flight lines. 9 flight lines at 20° heading intervals over a centre point will be acquired starting with flight line MB-E at a heading of 162° TN. If required the number will be reduced to 6 flight lines at 30° intervals.

3.5.7.2.4 Sensor Altitude Sensitivity Image Set

For this data set flight line MB-E will be repeatedly acquired as quickly as possible at a number of different altitudes with corresponding adjustments to the ground speed. The various planned altitudes and ground speeds will be:

- 640 m AGL at 80 knots (minimum ground speed while stable)
  - CASI – XTR = 0.31 m, ATR = 2.29 m, ATS = 1.98 m
  - SASI – XTR = 0.72 m, ATR = 0.72 m, ATS = 0.69 m
- 1108 m AGL at 90 knots
  - CASI – XTR = 0.54 m, ATR = 2.22 m, ATS = 2.76 m
  - SASI – XTR = 1.25 m, ATR = 1.25 m, ATS = 0.77 m
- 2216 m AGL at 120 knots
  - CASI – XTR = 1.07 m, ATR = 4.04 m, ATS = 2.96 m
  - SASI – XTR = 2.50 m, ATR = 2.50 m, ATS = 1.03 m
- 9600 ft AGL at 120 knots (maximum ground speed)
  - CASI – XTR = 1.46 m, ATR = 4.42 m, ATS = 2.96 m
  - SASI – XTR = 3.40 m, ATR = 3.40 m, ATS = 1.03 m

XTR = Cross Track Resolution/Spacing, ATR = Along Track Resolution, ATS = Along Track Spacing

3.5.7.3 Airborne Imagery Data Handling

All airborne hyperspectral raw imagery, both CASI and SASI, will be transferred from the imager hard drives to NRC's primary Image Analysis Workstation immediately upon completion of the flight deployment. This workstation will subsequently be backed up to external hard drives and following that, to a project dedicated McGill SFTP server. All raw imagery will be subsequently be transferred onto ESA servers. In addition to the raw hyperspectral imagery, the raw C-MIGITS III IMU (and Honeywell 1700 IMU data if the enhanced geocorrection process be adopted) data files will be handled in an identical manner. NRC is also currently testing a higher accuracy Honeywell HG1700 IMU. This Honeywell IMU data file will also be stored both as a raw file and following differential GPS post processing. Flight log sheets for both the CASI and SASI will be scanned and stored with the raw data as well.

Parameters related to each acquired flight line of hyperspectral imagery will be inputted into the NRC Hyperspectral Database which is used for tracking data acquisition and automating the image calibration processing.

3.5.7.4 Airborne Imagery Initial Quality Assessment

A quicklook of the data files will be performed as soon as possible following the flight to ensure the basic integrity of the data files. As well, one CASI and one SASI file will be processed shortly after the flight to ensure that the data used in the geocorrection process was correctly recorded. This will be accomplished by 1) viewing the geocorrected file and 2) viewing the flight track produced as a KML file by the standard processing process.

3.6 3450-6 Airborne Hyperspectral Image Calibration and QA

3.6.1 WP Summary

This work package addresses the calibration of the airborne hyperspectral imagery and the quality assurance that will be applied to the resulting data sets. The data products to be addressed within this WP include spectral radiance and spectral reflectance as well as the geometric correction.

3.6.2 WP Manager

- This WP is to be managed by Raymond Soffer.

3.6.3 WP Dates

- Start Date: Project start date (October. 1, 2015)
- End Date: End of Contract (June 30, 2016)

3.6.4 WP Inputs

- Preliminary project objectives and schedule
- Completed Detailed Campaign Plan (once available)
- Raw CASI/SASI Imagery and associated IMU data files
- CASI/SASI Spectroradiometric Calibrations
- CASI/SASI bundling (geocorrection) solution
- Sunphotometer Measurements

3.6.5 WP Tasks

- Create Airborne Hyperspectral Image Calibration Plan
- Spectroradiometric Calibration of Airborne Hyperspectral Imagery

- Geocorrection of Airborne Hyperspectral Imagery
- Atmospheric Correction of Airborne Hyperspectral Imagery (project acquired flight lines as well as identified historical Mer Bleue flight lines)
- Spectral fidelity check of radiance imagery
- Bidirectional Reflectance Distribution Function (BRDF) Correction of Airborne Hyperspectral Reflectance Imagery
- Validation/QA of reflectance imagery
- Mosaic Landsat 8 underflight Airborne Hyperspectral Imagery
- Archival and QA Airborne Hyperspectral Image Acquisition

3.6.6 WP Outputs

- Airborne Imagery Calibration Plan
- Radiance and Geocorrected Radiance CASI/SASI Imagery and associated metadata
- Radiance and Geocorrected Reflectance CASI/SASI Imagery and associated metadata
- Summary table of resultant imagery
- Mer Bleue Image Mosaics
- WP summary report

3.6.7 WP Details

The spectroradiometric and geometric calibration performed by NRC on its hyperspectral data sets makes use of calibration procedures developed and made available by the instrument manufacturer, ITRES Research Ltd. These routines include:

- Spectral alignment (re-alignment of spectral registration - SASI only)
- Radiometric calibration
- Spectral registration for raster image file (resampling for removal spectral curvature issues to a common spectral grid)
- Geocorrection
- Mosaicking

The atmospheric correction to ground reflectance levels will be undertaken at this time with FLAASH (Fast Line-of-sight Atmospheric Analysis of Hypercubes) as implemented in ENVI v5.3 (important FLAASH bug fixes, including incorporation of correct Landsat 8 spectral response, are implemented in version 5.3 of the image processing system). The processing steps through the geocorrection of the radiance files are automated through the NRC Hyperspectral Database. The FLAASH atmospheric correction must be performed manually within ENVI. Geocorrection of the resulting reflectance files or any subsequent data processing that occurs on non-geocorrected imagery will be rerun through the ITRES geocorrection process. Mosaicking of geocorrected files will then be performed using ITRES provided routines (TBC).

It is not the intention to provide a full description of the individual routines within this document, rather just an overview of the steps involved in the image calibration.

Spectral fidelity of the radiance data product will be undertaken as an initial QA check. Once the atmospheric correction has been applied, the geocorrected reflectance data set will be compared with the field spectral results of the 4 Cal/Val targets (i.e. asphalt, concrete, grey and black tarps).

3.7 3450-7 Airborne Hyperspectral Image Data Products and Analysis

3.7.1 WP Summary

In this work package, typical land data products derived from Landsat 8 data will be determined directly from the Mer Bleue airborne hyperspectral imagery. The results will be compared with those derived from Landsat 8, and if time permits, the Landsat 8 simulation results generated in WP 3450-9 (section 3.9).

3.7.2 WP Manager

This WP is to be managed by George Leblanc.

3.7.3 WP Dates

- Start Date: April 1, 2016
- End Date: Project end date (June 30, 2016)

3.7.4 WP Inputs

- Preliminary project objectives and schedule
- Completed Detailed Campaign Plan (once available)
- CASI and SASI Mer Bleue Non- Geocorrected Radiance Imagery
- CASI and SASI Mer Bleue Non- Geocorrected Reflectance Imagery
- CASI and SASI Mer Bleue Geocorrected Radiance Imagery
- CASI and SASI Mer Bleue Geocorrected Reflectance Imagery
- CASI and SASI Mer Bleue Mosaic Reflectance Imagery

3.7.5 WP Tasks

- Generate Data Products and Analysis plan for DPP
- Generate Data Products and Analysis contribution for final report

3.7.6 WP Outputs

- Airborne Hyperspectral Image Data Products and Analysis Plan (contribution to DPP - current section)
- Airborne Hyperspectral Image Data Products and Analysis Report (contribution to final report)

3.7.7 WP Details

In this WP, the fundamental objective is to calculate, determine and provide data products from the data acquired over Mer Bleue by the NRC team as they relate to the Landsat 8 mission. Using airborne Visible Near Infrared (VISNIR) and Short Wave Infrared (SWIR) data, ground spectrometer data and simulation data derived from the airborne and ground spectral data, a direct comparison to products produced by the Landsat 8 process will be developed.

For the specific products generated within this WP, we will produce the same products as is available in the USGS Landsat 8 product guide (as referenced in http://landsat.usgs.gov/l8handbook_section1.php).

These products are as follows:

- Radiance
- Terrain Corrected Ground Reflectance
- Classification of pixels

- Red brightness threshold
- Normalized difference snow index
- Snow/ice threshold
- NIR/RED ratio for growing vegetation
- NIR/GREEN ratio for sensing vegetation
- NIR/SWIR ratio for soil

Furthermore, this WP will also include the products outlined in the USGS Provisional Landsat 8 Product Guide (http://landsat.usgs.gov//documents/provisional_l8sr_product_guide.pdf)
These include:

- Normalized Difference Vegetation Index (NDVI)
- Enhanced Vegetation Index (EVI)
- Soil Adjusted Vegetation Index (SAVI)
- Modified Soil Adjusted Vegetation Index (MSAVI)
- Normalized Difference Moisture Index (NDMI)
- Normalized Burn Ratio (NBR)
- Normalized Burn Ratio 2 (NBR2)

The other fundamental output of this WP will be an analysis of the geocorrection of the airborne radiance and reflectance products and the potential impact of the data at the level of Landsat 8. Furthermore, a detailed analysis of the proper geocorrection entry point in the data work flow will be assessed (e.g. before conversion of radiance to reflectance or after reflectance). Currently there exists only ad-hoc support for one method over the other.

In the end, the products of this WP will be fully compared to those derived for Landsat 8 missions over MB on the same day and will provide strong quantitative analyses of the information being supplied by the Landsat 8 mission.

3.8 3450-8 Airborne Hyperspectral Image Sensitivity Analysis

3.8.1 WP Summary

In order to understand the impact on the data products under investigation, the sensitivity of the data product to certain acquisition parameters must be evaluated. Although these parameters are fixed for a given Landsat 8 image acquired on a given day of a given location, acquisition on different dates or at different locations will result in different configurations. In contrast, the airborne imagery has many parameters that are variable and must be planned for. This flexibility in the acquisition of the airborne imagery results in potential complications within the acquired imagery that must be considered in the flight planning and image analysis. Alternatively, the flexibility can also be used as a tool to acquire data sets to undertake sensitivity analysis of these variables with carefully planned and acquired image sets. Such image sets have been planned for as discussed in Section 3.8. This WP will address the sensitivity analysis to be undertaken with those data sets.

3.8.2 WP Manager

- This WP is to be managed by Raymond Soffer

3.8.3 WP Dates

- Start Date: Project start date (October 1st, 2015)

- End Date: Project end date (June 30th,2016)

3.8.4 WP Inputs

- Preliminary project objectives and schedule
- Completed Detailed Campaign Plan (once available)
- CASI and SASI Mer Bleue Sensitivity Flight Line Non - Geocorrected Radiance Imagery
- CASI and SASI Mer Bleue Sensitivity Flight Line Non - Geocorrected Reflectance Imagery
- CASI and SASI Mer Bleue Sensitivity Flight Line Geocorrected Radiance Imagery
- CASI and SASI Mer Bleue Sensitivity Flight Line Geocorrected Reflectance Imagery

3.8.5 WP Tasks

- Generate Airborne Hyperspectral Image Sensitivity Analysis Plan
- Investigate airborne data product sensitivity to
  - Solar Zenith Angle
  - Solar Azimuth Angle
  - Pixel Resolution (aircraft altitude, ground speed, and integration time)
  - Spectral resolutions (number of acquired spectral channels)
- Contribution to final report

3.8.6 WP Outputs

- Airborne Hyperspectral Image Sensitivity Analysis Plan (current section)
- Airborne Hyperspectral Image Sensitivity Analysis Plan (contribution to final report)

3.8.7 WP Details

Essential to the successfully evaluation of the identified sensitivity analysis is the careful planning and execution of the airborne data acquisition plan. As already described in Section 3.5, flight lines will be acquired to evaluate the sensitivity of the resulting data products to the following four variables:

- Combined SZA and SAA
- Aircraft Heading
- Pixel Resolution (aircraft altitude, ground speed, and integration time)
- Spectral resolutions (number of acquired spectral channels)

As many complicating factors as possible must be appropriately dealt with. Perhaps most critical is the stability of the sky conditions over the period of each image set acquisition. For the aircraft heading, pixel resolution, and spectral resolution image sets, the multiple flight lines should be flown as quickly as possible in order to minimize changes in the atmospheric conditions. For the image set, quick acquisition is also important so as to minimize the changes in the SAA. This is not possible in the acquisition of the SZA/SAA image set as time must be allowed to pass in order to achieve variable solar angles. For this image set, the stability of the atmosphere over the extended acquisition period is therefore of extra importance.

For each of the proposed sensitivity analysis, distributions of the data products for a common area within Mer Bleue will be compared for the multiple flight lines and accessed for systematic changes. This will be performed first on the reflectance data product and then of a sample of the data products identified in Section 3.7 e.g. NDVI. These data sets will also be important in the assessment of the BRDF or cross track illumination impact and its correction.

3.9 3450-9 Satellite Simulation and Methodology Evaluation

3.9.1 WP Summary

To evaluate space borne spectral imagery as delivered by Landsat 8, the Imaging Spectrometry Data Analysis System will be used. ISDASv2 includes a broad range of image pre-processing, data quality, imagery simulation and information extraction tools designed in-house at the CCRS NRCan, to provide a robust system allowing for the simulation of space borne optical imagery from airborne or field data. This includes simulating effects of known sensor characteristics (spectral/spatial resolutions, spectral curvature, noise, etc.) and atmospheric influences to the recorded signal. Once derived, simulated imagery can be compared to actual acquisitions and further independently processed to at-surface reflectance. This allows for the evaluation of methodologies for information processing and their sensitivities to sensor design and acquisition viewing and illumination geometries. In this demonstration study, Landsat 8 scenes will be simulated for Mer Bleue to examine the efficacy of Landsat 8 data products for known and proposed acquisitions. The potential then exists to simulate wetland scenes at other locations (other geometries and orientations).

3.9.2 WP Manager

- This WP is to be managed by Peter White.

3.9.3 WP Dates

- Start Date: Project start date (October. 1, 2015)
- End Date: Project end date (June 30, 2016)

3.9.4 WP Inputs

- Preliminary project objectives and schedule
- Completed Detailed Campaign Plan (once available)
- CASI/SASI Geocorrected Reflectance Imagery
- Processed Test Site Ground Spectra and associated metadata
- Ancillary Data (details TBD)

3.9.5 WP Tasks

- Generate Satellite Simulation and Methodology Evaluation Plan
- Develop and validate methodology on test imagery
- Apply simulation methodology to airborne Mer Bleue imagery
- Generate identified data products from simulated Operational Land Imager (OLI) imagery
- Obtain relevant Landsat 8 data products and produce OLI data product of interest
- Comparison of simulated data product with OLI derived data products.

3.9.6 WP Outputs

- Satellite Simulation and Methodology Procedure
- Data product image files produced from Landsat 8 simulations
- Data product image files produced from Landsat 8 imagery
- Methodology and Evaluation Report

3.9.7 WP Details

- Summarize data acquired for testing simulations (acquired via other work plans)
    - Field (ground) Spectrometer data (Spectral library)
    - Field photography for ground vegetation community classification guide

    - UAV imagery (RGB) and derived DTM
    - Airborne CASI/SASI hyperspectral imagery
    - Atmospheric characterization
    - Landsat 8
- Step 1 – Evaluate the usefulness of using the UAV to determine a high spatial resolution DTM and high resolution segmentation map of vegetation communities to match with the spectral library.
    - UAV aerial photography, acquired at ~50m altitude, will provide approximately 800 nadir-viewing RGB photos with 80% overlap, covering an 800 m^2 area around the MBPO research boardwalk as shown in Figure 3. These acquisitions will be coordinated with the Ground Activities outlined in WP3450-3.
    - To provide at-surface spatial tie-ins, 5 semi-permanent targets are distributed on "stable" platforms over the peatland, with pre and post season geodetic 3D GPS (measured for 24 hours) at 1-5 cm accuracy.
    - 3D structures (i.e. of trees) and microtopography will be estimated from the 2D image sequences using scale invariant feature detection. This will provide a site ortho-mosiac, scene point cloud (average point cloud density of 500/m^2), and DTM (<6 cm estimated accuracy).
    - Image segmentation and DTM will be examined with respect to vegetation community classification, and related spectral characterization of these communities (from WP 3450-3). These results will be evaluated for use in end-member vegetation community definition for use in simulations.
- Step 2 – Define the airborne data to examine usefulness of UAV results for fraction designation of airborne pixels for extrapolation of fractions to complete image. Compare to creating airborne fraction map with matches to spectral library and compare ability to define vegetation community distribution via both techniques.
    - In conjunction with WP3450-3 and WP3450-6, examine the airborne at-surface reflectance imagery, examining the efficacy of using the UAV results tied with the field spectrometry to further improve surficial material fraction maps derived from the airborne imagery.
    - Using the airborne imagery (either as independent strips or as mosaics, depending on availability of data), define surficial fraction maps for the peatland area. This may involve scaling the UAV results to the airborne coverage, relying on the airborne imagery and the field spectrometry alone to create vegetation community fraction maps, or some combination of methodologies.
- Step 3 – Use results of Step 2 to create a fraction map with spectral library of the airborne imagery.
    - With the Step 2 derived end-member fraction spectral library, compare to the field spectrometry to examine commission and omission between the two. Identify if surficial communities have not been sufficiently captured by the field spectrometry, or of airborne derived fractions are capturing different community associations. If identified early enough in the process, this could be used to help guide adjustments in 3450-3 planning.
- Step 4 – Use results of Step 3, simulate atmospheric contribution to signal, and convolve to space borne sensor characteristics. Compare to Landsat 8 acquisition.
    - Given results of Step 3, an end-member map with assigned spectral fraction map, will provide an at-surface spectral reflectance map at a finer spectral and spatial resolution than the space borne sensor.

  - Atmospheric contributions to the upwelling radiance from this at-surface simulation will be derived.
  - The simulated observed signal will be adjusted to meet the characteristics of the space borne sensor (in this case Landsat 8)
  - Where the simulation is derived based on actual view and illumination geometries of an acquisition take the simulated at-sensor reported radiance imagery and compare to a Landsat 8 acquisition.
- Step 5 – Examine distribution of at-surface reflectance results of airborne defined scale and simulated space borne defined scale and evaluate impact of "scaling-up" with respect to Landsat 8 spectral indices.
  - Using a selection of vegetation indices (as defined and provided in WP3450-7), evaluate the range and distribution of index values for both the airborne and space borne imagery. Examine how spatial scaling has impacted (or not) these products.
- Step 6 – Use results of Test 3 to simulate other view/illumination geometries to examine impacts on the resulting Landsat 8 data products. Take result and independently produce at-surface reflectance.
  - Given successful airborne flights (WP3450-5) at view azimuth and illumination conditions that would match more northerly sites (and thus that do not match those acquired by space borne systems over this study area), produce at-sensor simulations following the Step 4 outline.
  - Produce independently derived at-surface reflectance product, and evaluate the results with respect to the changes in view and illumination geometries.

3.10 3450-10 Final Report

3.10.1 WP Summary

This WP will collect the outputs of the various work packages and collate them into a cohesive final report.

3.10.2 WP Manager

- This WP is to be managed by Raymond Soffer.

3.10.3 WP Dates

- Start Date: Project start date (October. 1, 2015)
- End Date: Project completion date (June 30, 2016)

3.10.4 WP Inputs

- Preliminary project objectives and schedule
- Completed Detailed Campaign Plan (once available)
- Summary report from WP:3450-2 to 3450-9 and 3450-12

3.10.5 WP Tasks

- Generate final report summarizing
  - Data acquisition and validation
  - Airborne imagery data products analysis
  - Airborne imagery sensitivity analysis
  - Satellite simulation methodology
  - Comparison of simulation with satellite derived data products

3.10.6 WP Outputs

- Final Report

3.10.7 WP Details

This WP will oversee the collation of the results from the various other WPs into a cohesive report.

3.11 3450-11 Meetings and Workshops

3.11.1 WP Summary

Key meetings and workshops undertaken within this project are identified and covered within this work package. Identified presentation to be made at these meetings and workshops will also be prepared within this work package. Internal project meetings are not considered as part of this work package.

3.11.2 WP Manager

- This WP is to be managed by Raymond Soffer.

3.11.3 WP Dates

- Start Date: Project start date (October. 1, 2015)
- End Date: December 31, 2015

3.11.4 WP Inputs

- Identification of key meetings and workshops

3.11.5 WP Tasks

- Attendance by the specified people at the identified meetings and workshops
- Preparation of required presentations

3.11.6 WP Outputs

- APVE II Presentations
- IDEAS+ L1 Meeting Presentations

3.11.7 WP Details

At the onset of the project two meetings and workshops had been identified that project personnel have been requested to attend and present at:

- The Arctic and High Latitude Product Validation and Evolution Workshop
    - Norrköping, Sweden, 27-28 October 2015
    - Attendance by Raymond Soffer, George Leblanc, Dennis Nazarenko and Peter White
- IDEAS+ L1 Meeting
    - Davos, Switzerland, December 7 and 8, 2015
    - Attendance by Raymond Soffer

3.12 3450-12 Analysis of Historical Hyperspectral Mer Bleue Imagery

3.12.1 WP Summary

Within this WP, airborne hyperspectral imagery of Mer Bleue and the Cal/Val site acquired in advance of this project (Spring/summer 2015) along with supporting field data will be analysed in advance of the 2016 project data acquisitions in order to prepare and better plan for the project data acquisitions. This effort will also allow the analysis approach to be developed in advance of the availability of the actual project data sets.

3.12.2 WP Manager

- This WP is to be managed by George Leblanc.

3.12.3 WP Dates

- Start Date: Oct 1, 2016
- End Date: April 31, 2016

3.12.4 WP Inputs

- Preliminary project objectives and schedule
- Completed Detailed Campaign Plan (once available)
- CASI and SASI Historical Mer Bleue Non- Geocorrected Radiance Imagery
- CASI and SASI Historical Mer Bleue Non- Geocorrected Reflectance Imagery
- CASI and SASI Historical Mer Bleue Geocorrected Radiance Imagery
- CASI and SASI Historical Mer Bleue Non- Geocorrected Radiance Imagery
- CASI and SASI Historical Mer Bleue Geocorrected Reflectance Imagery
- CASI and SASI Historical Mer Bleue Mosaic Imagery

3.12.5 WP Tasks

- Generate Data Products and Analysis plan for DPP
- Generate Data Products and Analysis contribution for final report

3.12.6 WP Details

The primary aim of the work package is to analyse airborne hyperspectral data from other projects that were collected in 2015 over the Mer Bleue site. Field work supporting these image acquisitions was performed consistent with the methods being developed for the work outlined in Sections 3.3 and 3.4. The data that were collected are to be used as a number of trainer data sets to allow the team to develop a more in-depth understanding of the specific responses, outcomes, performance and data products from this site. While the data were not specifically collected for this project, they are well-suited for analysis and application to the objectives of this work and will assists in many ways in preparing for the project field work such as the determination of the field plots.

The data consists of nearly 1TB of raw VISNIR and SWIR hyperspectral airborne data collected by the CASI and SASI systems installed aboard NRC's twin otter aircraft, along with some associated ground spectrometer data from McGill University's ASD FieldSpec 3 system. The ground data are not fully co-temporally collected with the airborne data, however they do offer a great deal of ground validation and are therefore useful in selection of end-member spectra and spectral combinations that are to be used in the airborne analysis. On two separate occasions, the data collected are somewhat coincident with the overflight of Landsat 8 and therefore, these will be the primary data sets to be developed. The airborne data coincident with the overflights will be developed, analysed and then used as the input data for the simulation work of the Landsat 8 scene.

For the specific products generated within this work package, we will be concerned primarily with the data products that are made available in the USGS Landsat 8 product guide (as referenced in http://landsat.usgs.gov/l8handbook_section1.php).

These products are as follows:

- Radiance
- Terrain Corrected Ground Reflectance
- Classification of pixels
    - Red brightness threshold
    - Normalized difference snow index
    - Snow/ice threshold
    - NIR/RED ratio for growing vegetation
    - NIR/GREEN ratio for Senescing Vegetation
    - NIR/SWIR ratio for soil

Furthermore, this work package will also include, where supported by appropriate data, the products outlined in the USGS Provisional Landsat 8 Product Guide (http://landsat.usgs.gov//documents/provisional_l8sr_product_guide.pdf)

These include:

- Normalized Difference Vegetation Index (NDVI)
- Enhanced Vegetation Index (EVI)
- Soil Adjusted Vegetation Index (SAVI)
- Modified Soil Adjusted Vegetation Index (MSAVI)
- Normalized Difference Moisture Index (NDMI)
- Normalized Burn Ratio (NBR)
- Normalized Burn Ratio 2 (NBR2)

The Historical MB work package will provide a very advantageous scenario to the project where we will have a good understanding of the behaviour and primary issues of the spectral data from Mer Bleue. This is advantageous as we will be able to more accurately develop specific scenarios, hyperspectral imagery band sets and data analysis work-flow to maximize information extraction during the campaign in 2016.

4.0 Internal Project Management

Overall, project management at both technical and logistical levels will be handled by Raymond Soffer. Initially, the primary method of project wide communication, which will include the external service providers NRCan, McGill, and LOOKNorth, will be twice a month WebEx meetings to be held on the second and last Wednesday of each month. In addition to sharing task progress and results, an Action Item list will be generated and shared in order to track project requirements and progress in an ongoing fashion. As the data acquisition tasks become a regular occurrence starting in April 2016, the meeting schedule will change to coincide with the deployment opportunities in order to coordinate airborne and ground data acquisition activities and to review acquisition activity results.

5.0 Data Management

All relevant information will be handled as one of three types of data files: 1) raw data, 2) processed data, and 3) reports and contributions to project web pages. In each case, the data will be archived in a minimum of three locations: 1) server of the primary file generator (Primary Server), 2) a project FTP server operated by McGill (McGill FTP Server), and 3) the ESA Cal/Val portal (ESA Portal). The primary file generator in this case refers to not only NRC, but to NRCan and McGill as well. An Excel spreadsheet database will be used to track acquired data sets and their entree on to the three servers. The McGill FTP server will serve as the primary method in which data files, raw and processed, and reports are shared between the project collaborators with the ESA Cal/Val portal acting as a backup system.

6.0 Project Deliverables

The project deliverables are identified as:

- Detailed Project Plan(current document) – 31/12/2015
- Weekly Campaign Progress Reports – ongoing starting with the winter campaign
- Monthly progress reports – ongoing starting with October to December 2015 report
- Project Data – 31/6/2015
- Project Report – 31/6/2015
- Contributions to project web pages

Key internal project deliverables include:

- Processed[1] historical airborne hyperspectral imagery - February 29, 2016
- Processed[2] historical ground support data - February 29, 2016
- Processed[1] airborne hyperspectral imagery - within 3 weeks of acquisition
- Processed[2] ground support data - February 29, 2016
- Field reference panels X-calibrated with respect to Project Lab Reference Panel (prior to University of Arizona calibration) – Feb 15, 2016
- Project Lab reference panel X-calibrated with respect to NIST reflectance Standard via University of Arizona standard - April 15, 2016
- Field reference panels X-calibrated with respect to Project Lab Reference Panel (post University of A calibration) – April 30, 2016

[1.] Spectroradiometrically, geometrically, atmospherically corrected, and (if necessary) vicariously calibrated – individual flight lines and, where appropriate, mosaic images.

[2.] In the case of the field spectrometry data, processed data refers to ground measurements converted to reflectance spectra.

7.0 Risk Management

The following list outlines the primary risks that have been identified to the successful completion of this project along with steps that will be taken to mitigate the issue:

- Optically clear, stable skies on Landsat 8 overpass days
    - Inherent in the selection of the MBASSS site is the fact that it is imaged 2 times per 16 days Landsat 8 repeat cycle providing multiple acquisition alternatives
- Equipment failure of Airborne Hyperspectral equipment (CASI/SASI) – May be difficult or impossible to replace the primary equipment
    - Given the short timeline of this project, there is no foreseeable corrective action that could be taken should one the primary hyperspectral instruments fail
- Aircraft (NRC Twin Otter) serviceability
    - A major aircraft maintenance service will have just been completed prior to the winter data acquisition reducing the probability of this becoming an issue. In addition, a number of annual maintenance items are being performed ahead of schedule to ensure the serviceability of the Twin Otter over the project period
    - NRC Flight Research Lab employs its own Aircraft Mechanics, Flight Worthiness Engineers, and instrumentation team that will be available to undertake any corrective action should an aircraft structural, mechanical or on-board project system problem arise
- Extreme weather events compromising the test site conditions and its accessibility
    - Given multiple satellite image acquisition dates, extreme weather events can be avoided by rescheduling field activities
- Processing and analysis of data acquired late in the project (May and June 2016) may not be completed prior to project close out date
    - Project end date extension is under discussion

8.0 Web Presence

In consultation with the Serco IDEAS+ team, the MBASSS Landsat 8 Validation Project will assist in the development of a web page to promote the project objectives and results as they become available. As this task is to be managed by Serco, the details of this effort are yet to be determined.

9.0 Summary

This detailed project plan provides the rationale for a systematic approach to validating Landsat 8 land information products. The project draws on a precisely planned set of integrated data sets including airborne hyperspectral imagery and satellite data, and supporting field measurements. Novell techniques to characterize the surface structure using UAV acquired data will be assessed and, if successful, incorporated in the approach of producing the simulated satellite imagery.

Mer Bleue, a wetland area near the city of Ottawa, Canada has been selected as the test site. It offers many advantages not the least of which is its near pristine condition with a long history of scientific evaluation. Near-simultaneous acquisition of the airborne hyperspectral imagery and field support data is a key element of the project. Mer Bleue's proximity to the science team and airborne data acquisition systems will maximize the likelihood of data collection coincident with Landsat 8 overpasses while minimizing the costs associated with their acquisition.

The project will draw on scientific understanding of the test site based on many years of observation. A series of airborne hyperspectral overflights will be undertaken, imaging the wetlands at various geometric and illumination angles. During the airborne overflights and satellite overpasses field teams will collect calibrated spectral, structural, and bio-physiological data.

Calibrated airborne and field data will then be processed and used to simulate Landsat 8 imagery using ISDASv2, a simulation toolset. The simulation process will be used to incorporate both sensor characteristics and atmospheric influences on image qualities allowing for comparison of data processing methodologies, and the impacts of acquisition viewing and illumination properties on output product characteristics.

Successful completion of this project will provide a robust methodology for validation of Landsat 8 image products under various conditions and various imaging geometries.