

FIELD SPECTROMETER & RADIOMETER GUIDE
REMOTE SENSING PROGRAM
Department of Geographical Sciences & Planning
The University of Queensland

Version 1.2

(Any comments /corrections welcomed !)

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February 2004

Purpose:

To establish guidelines for the safe and efficient use the Exotech 100C radiometer and the Analytical Spectral Devices (ASD) FieldSpec UV-VNIR CCD spectrometer for field based remote sensing studies

Who should read this?

Anyone planning or conducting field based remote sensing for image calibration or empirical investigations.

Essential Readings:

Milton, E.J. (1987) Principles of field spectroscopy, International Journal of Remote Sensing, 8(12):1807-1827

Goetz, A. F. H. 1992. Imaging spectrometry for earth remote sensing. In Imaging spectroscopy: Fundamentals and applications. ed. Toselli, F. and J.Bodechtel, 1-19.

Curtiss, B. and Goetz, A.F.H. (1994) Field spectrometry: techniques and instrumentation, In Proceedings of the International Symposium on Spectral Sensing Research, San Diego, July 10-15, pp, 195-203.

Contents:

1. Field radiometry and spectrometry
2. Project Planning
3. Pre-field work preparations
4. Equipment set-up
5. Equipment operation
 - 5.1 Radiometer Operation
 - 5.2 Spectrometer Operation
6. Data processing, quality checking and storage
7. UQ Remote Sensing Program Spectral Library
 - 7.1 Why maintain a spectral library ?
 - 7.2 Format of data for submission
8. Special consideration for Marine Measurements
9. Appendices and Contacts

1. Field radiometry and spectrometry at the University of Queensland

The goal of radiometry and spectrometry is to measure both incident light (irradiance) on target features and reflected light (radiance) from the features and relate these data to the biological, chemical and physical attributes of the target feature (e.g. vegetation chlorophyll content, organic matter content of water).

Radiometers are typically broad band multi-spectral systems with large spectral sampling interval (50nm) and producing a broad or low spectral resolution (i.e. Full –Width at Half Maximum response).

Spectrometers are narrow band hyper-spectral systems with very small spectral sampling interval (< 1nm), resulting in a very high spectral resolution, allowing discrimination of narrow band absorption troughs and reflectance peaks.

The Remote Sensing Program at the University of Queensland maintains both radiometer and spectrometer systems to support calibration of multi- and hyper-spectral airborne and satellite imaging sensors and terrestrial or aquatic/marine field spectrometry. These systems also form the ground calibration system for the ADAR-1000 airborne multi-spectral imaging system that is operated in cooperation with Northern Territory University and Airesearch. Pty. Ltd.

Both the radiometer and spectrometer are extremely high quality scientific instruments and should be treated with an according level of care. The purpose of this document is to present and explain safe operating conditions and sequences to maximise your ability to use the equipment effectively. There are only two other sensors similar to ours in use in Australia and as a result our systems are often off campus for research and consultancy work, so it is wise to book ahead.

SYSTEM SPECIFICS FOR UQ RADIOMETER & SPECTROMETER:

Exotech 100C Radiometer #3670

A four-band sensor in which different filters and field of view attachments can be attached to measure radiance and irradiance:

Output: Voltage (analog) signal with 0-5volts range

Converted to a digital signal (16 bit) using the National Instruments Data Card

Analog/Digital converter attached to a Toshiba Libretto palmtop PC

Band filters: Landsat Thematic Mapper 5 (blue, green, red and near-infrared)

Landsat Multispectral Scanner 5 (green, red and near-infrared)

SPOT (HRV) Multispectral 3 (green, red and near-infrared)

Field of View: 1 °

15 °

Cosine response (hemispheric) for irradiance

Refer to Exotech manual and Dr Phinn if you need to change filters or FOV

Power: 2 x 9V batteries

Waterproof: NO

Data logger: Toshiba Libretto 100CT attached via a National Instruments A/D card running a

Visual basic program (DataAcquire©) to collect and process data.

Output file: ASCII file containing individual records for each sample
(date, time, radiance, gain, notes, sample type)

ASD-Fieldspec UV-VNIR Field Spectrometer #805

A 1024 band sensor which collects data between 350nm and 1050nm with a 0.7nm interval between spectral samples (FWHM = 3nm).

Output: raw DN (12 bit), reflectance or radiance values in a binary and ascii file

Terrestrial FOV: 25 °

1 °

Cosine response (hemispheric) for irradiance

Underwater FOV: 6 °

Cosine response (hemispheric) for upwelling or downwelling radiance

10m of underwater fibreoptic cable

Calibration Panels (Lambertian/diffuse reflectance surface)

Fully calibrated spectralon® panels (50cm x 50cm and 5cm x 5cm)

DO NOT TOUCH THE SURFACE OF THESE PANELS !!!!!

(even the slightest oil or dirt from your hands will alter their reflectance properties)

2. Project Planning

2.1 Site selection

Determine the location of targets to be measured using the radiometer or spectrometer and what particular target needs to be sampled, e.g. individual leaves, canopies, soil types etc. In some cases lab-based sampling is required and both the radiometer and spectrometer can be set up in tripods and a standard diffuse illumination lamp used as a light source. **To collect accurate indoor samples ensure all fluorescent lamps and lights are turned off and only the standard illumination source is used.**

2.2 Instrument selection multi- or hyper-spectral

What type of information does your study require, are you developing an application or performing field calibration for broad-band multi-spectral sensors such as Landsat TM/ETM or SPOT? Are you conducting exploratory analysis of the spectral signature of a target to determine the biological, physical or chemical properties controlling reflectance and absorption? Are you conducting field calibration for an airborne hyper-spectral overflight? If you only require a multi-spectral system or broad band approach use the radiometer, otherwise use the spectrometer. In some cases, especially for underwater work, the spectrometer may be the only suitable system.

2.3 Terrestrial or aquatic

Determining the target you will be measuring and the sampling environment determines the type of system selected and the sampling approach utilised. Neither of the systems are waterproof and only the optics of the spectrometer with correct Fibre-optic cable and FOV should be used in water bodies. Prior to any water-based samples check with Dr Phinn that your sampling approach is safe and viable.

2.4 Additional measurements (GPS, meteorological, biological, chemical, physical)

Ensure you have established all other field based measurements that need to be made in association with your spectrometer or radiometer samples prior to designing your field sampling scheme and data collection protocol. For example, any ground based assessment to “scale-up” or calibrate satellite or airborne image data must be accompanied by a GPS reading of suitable precision. If you are examining foliar chemical properties of a specific type of vegetation you need to establish how you are going to make these measurements and record data to analyse with your radiometer samples.

2.5 Field data collection protocol and sampling sheets

Having determined the non-spectral data you are going to collect it is essential you spend time to consult related studies to determine a statistically and logistically appropriate sampling scheme. This will include the spatial arrangement of your sampling scheme, e.g. systematic quadrats or transects, how many samples you need to take, how to stratify your samples and what your actual sampling unit is (for both the radiometer/spectrometer and the biological/physical/chemical variables being measured). In addition, the solar geometry and data collection geometry (sensor height, FOV and ground resolution element, view angle and sensor distance above target) must also be clearly established for the project. **All persons developing field sampling schemes using the radiometer and spectrometer must submit a field plan outlining the planned dates, locations, sampling procedure, potential risks and sample data sheets, to Dr Phinn before finalising field work arrangements.** This is also meets our obligations under the University's new field trip guidelines.

2.6 Field data checking

A procedure for checking all radiometer/spectrometer data and field data prior to analysis should also be established to check data consistency and links to field data sheets.

2.7 Post-field data storage, processing, analysis and output

All radiometer and spectrometer data collected are to be processed in a common format and submitted to Dr Phinn for inclusion in a spectral library for use by other students and researchers. The standard format for radiometer data is provided in the output ASCII file, while the standard for field spectrometer data is an ASCII file with the first column being band centres and following columns being headed by an observation number and radiance or reflectance values. Both files should be accompanied by a meta-data file indicating the responsible researcher, date and location of data collection, fore-optic used and listing of data samples.

2.8 Instrument booking

Due to the high demand for use of the radiometer and spectrometer systems it is essential to establish a suitable field time for your project work and book that time with DR Phinn as soon as your field-plan has been approved. A listing of planned project work for the radiometer and spectrometer will be kept at <http://www.geosp.uq.edu.au> or contact **PETER SCARTH**

3. Pre-field work preparations

3.1 Instrument selection

Ensure you have selected the appropriate instrument, data collection system, fore-optics and calibration panels for your project before proceeding with field-work preparations. All of the equipment items must be booked ahead of time. Check with the equipment use log in both systems and Dr Phinn prior to changing any of the fore-optics and record any changes you make in the equipment use log kept with each instrument.

3.2 Power supply issues

Both the radiometer and spectrometer and their data collection PC's can be operated from direct power supply in a laboratory or from internal battery supplies in the field. Battery life times vary both systems and you must take these into account when designing your field sampling scheme.

The radiometer operates on two 9V batteries with a life of 8 hours maximum. It is advisable to carry at least two extra sets of batteries on field trips and regularly monitor battery levels when using the system. Always remember to turn off the system after fieldwork and prior to transport. The Libretto PC has a battery life of two hours fully charged and using a low power usage mode. Check battery levels and power usage mode prior to and during fieldwork.

The spectrometer system operates on a series of NiCad batteries carried in the waist-pack which have an operating duration of four and a half hours. The Libretto PC has a battery life of two hours fully charged and using a low power usage mode. Check battery levels and power usage mode prior to and during fieldwork. Make a note of checking the Libretto power usage levels as they will often be set to a maximum power usage option. It is also recommended that the Libretto is powered off its internal batteries while using the Fieldspec system in the field, and only connected to the portable battery when required.

3.3 Personnel selection and training

Due to the sensitive nature and value of the equipment operation of both the radiometer and spectrometer system will only be undertaken by students who have completed background training in field spectrometry and remote sensing. Use of the spectrometer system will always require participation of one of the members of the Remote Sensing Program (Phinn, Stanford, Roelfsema or Scarth), while use of the radiometer system will be less restricted.

3.4 Testing of data collection approach and in-field communication

It is essential prior to any detailed field data collection effort that a pilot or test run be conducted to assess the sampling protocol, data collection techniques and communication between the field crew. Communication between the field crew is essential especially for work in aquatic/marine environments and proper use of the system must be clearly demonstrated.

3.5 Transport of equipment

Although all the field sampling equipment is insured care should be taken in transporting all the systems. The radiometer and calibration panels should be transported in their respective water-proof Pelican cases. The spectrometer should be packed and stored in its own transport case (which is not waterproof!). Ensure all equipment is dry and turned off before packing. **Optical fibre cables must be kept rolled loosely to avoid any slight or permanent bends or kinks which would render them useless. Please check with Dr Phinn prior to arranging transport of systems and ensure this is also addressed in your field plan.**

4. Equipment set-up

4.1 Field station for set-up and charging

Equipment set up should always be undertaken slowly and in a sheltered, dry, dust and salt-free environment as possible. All equipment should be checked for any damage that may have occurred during transport. All battery levels should be checked (except Libretto on FieldSpec) and all batteries charged as required.

For lab based experiments both the radiometer and the spectrometer can be set up on benches, without using the field collection carrying cases. Standard tripod mounts can be used for the radiometer and spectrometer fore-optics. The Libretto's may be connected to power outlets and calibration panels set up at appropriate viewing locations along with target sample plates. For indoor measurements ensure the standard lamp is used and no fluorescent lights are turned on. There should also be no other sources of direct and diffuse light in the sampling room.

Set-up of the calibration panels should ensure they can be viewed at an appropriate angle by either sensor and that they are only illuminated by the standard lamp for an indoor measurement and direct sunlight and diffuse skylight when outside. Refer to Milton (1987) for further sampling details. **When handling the calibration panels never touch the surface of the panel, always handle the lower surface or use a clean cloth.** For cleaning

instructions refer to the Labsphere Calibration booklet. Any oil or dust on the spectralon panel significantly reduces the close to perfect diffuse reflectance characteristics.

Use of the radiometer and spectrometer in the field requires the systems to be placed in waste-belts able to be worn in the field and allowing significant mobility. These systems are described below and users should become familiar with how the instruments are placed in these and worn correctly. Collection of spectra requires particular attention be paid to the geometry of the sun and the direction, angle and height at which the fore-optics are held in relation to the target feature. All of the data collection parameters including solar and viewing parameters should be set out in the field sampling protocol.

5. Equipment operation

5.1 Radiometer Operation

“Wearing” the equipment correctly and in a manner that enables you to walk comfortably in the environment you are operating in and to collect data. Remember to ensure you are as comfortable as possible as you may be wearing the equipment for up to two hours. For the radiometer you may operate it in a manual mode as described in 5.1.1 to manually record voltage data from the Voltmeter on the sensor, or in an automated mode, using the Libretto PC and A/D conversion card as described in 5.1.2. For the latter option the Libretto and A/D card are strapped into a waste-pack allowing the instrument to be held over a target by the operator or another person and the PC used to acquire and process data for each sample.

5.1.1 MANUAL OPERATION OF THE RADIOMETER

The Exotech-100 is one of the most commonly used hand-held instruments for collecting spectral signatures to validate airborne and satellite images and to establish relationships between a feature's spectral reflectance properties and its controlling factors. As a measurement instrument the radiometer is simple and compact, containing four detector elements, internal filters to select specific wavebands, external lens to control the field of view, gain settings to increase the signal in each detector and a measurement scale for the output of each detector. Each detector element functions as a photon counter, to measure the strength of incident electromagnetic radiation (EMR). The amount and type of EMR incident on each detector is controlled by two factors, (1) the field of view of the lens; and (2) the type of filter used. Each of these factors is explained below in relation to the use of the radiometer to obtain measurements from targets in the field.

The area of ground from which reflected light is recorded by the radiometer is controlled by the angular FOV (α) of the lens attached to each detector and the height (H) that the instrument is held above the target. The equation used to estimate the area covered from a certain height, or conversely, the height at which to cover a specified target area is given by:

$$r = (\tan(\alpha/2) \times H)$$

where, r = radius of the circular FOV with area A

H = height the radiometer is held above the target surface

α = angular FOV for radiometer

Worked example to establish the area (A) sampled with $\alpha = 15^\circ$ and $H = 1.14\text{m}$

$$\begin{aligned} r &= (\tan(15/2) \times 1.14) \\ &= 0.15\text{m} \end{aligned}$$

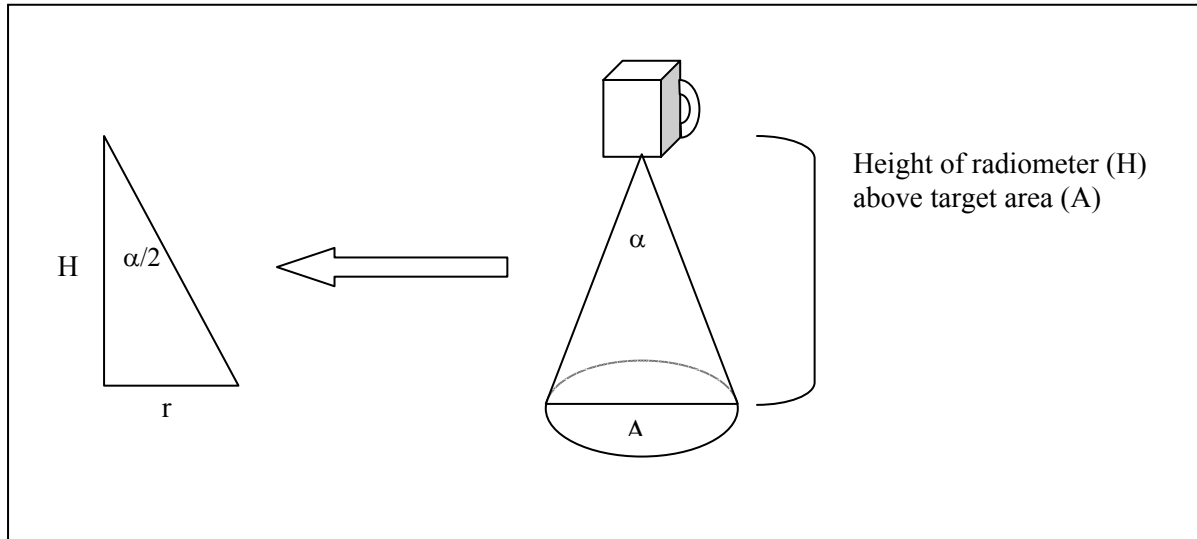
$$\text{area} = \pi r^2$$

$$= \pi (0.15\text{m})^2$$

$$= 0.07\text{m}^2$$

The area (A) sampled from a height of 1.14m is 0.07m^2

Instrument Field of View (FOV):



Worked example to establish sample height for a 1.0m^2 target area (A)

$$r = (\text{area} / \pi)^{0.5}$$

$$= (1.0\text{m}^2 / \pi)^{0.5}$$

$$= 0.56\text{m}$$

$$H = r / (\tan(\alpha/2))$$

$$= 0.56\text{m} / (\tan(15/2))$$

$$= 4.25\text{m}$$

By holding the radiometer 4.25m above a target a 1.0m^2 area is sampled on the ground

Measurement of Spectral Radiance:

To measure reflected spectral radiance in specific regions of the electromagnetic spectrum (e.g. red and near-infrared), filters are placed over each detector element to restrict the wavelengths of EMR recorded. For our purposes we have loaded filters that match the first four bands of the Landsat 5 Thematic Mapper instrument (for UQ sensor, serial no. 3670):

Radiometer band	Spectral range(μm)	Landsat TM band
A	0.45 - 0.52 blue	1
B	0.52 - 0.6 green	2
C	0.63 - 0.69 red	3
D	0.76 - 0.9 NIR	4

To measure the strength of reflected EMR in each of these bands, remove the lens covers from the radiometer and switch the central dial to the band you wish to record. Set the gain level on the band to an appropriate level. Read off the strength of EMR (0 - 1 volt) from the display dial and record it in a data sheet. The suggested column headings for a radiometer data sheet are given below:

1. Observation number
2. Plot number
3. Sky condition
4. Ground condition/photograph
5. Field measurement for blue, green, red and NIR voltage
6. Calibrated blue, green, red and NIR measurements

To convert from voltage values recorded in the field to appropriate physical units (m.watts/cm²), the following multiplicative constants should be applied to measurements made with a 15° FOV and a gain setting of 5. Refer to the calibration sheet provided for additional gain and FOV settings.

Band A = 2.32 m.watts/cm²volts
 Band B = 0.927 m.watts/cm²volts
 Band C = 1.01 m.watts/cm²volts
 Band D = 0.85 m.watts/cm²volts

Worked example for a sample from a grass plot

	Voltage	Coefficient	Spectral radiance (m.watts/cm²)
Band A	0.01	2.32	0.0232
Band B	0.12	0.927	0.1124
Band C	0.04	1.01	0.0404
Band D	0.2	0.85	0.1700

5.1.2 AUTOMATED OPERATION OF THE RADIOMETER **DataAcquire Version 1.0**

This help file describes the ‘user level’ aspects of connection and operation of the Exotech Model 100BX Handheld radiometer and Libretto palmtop computer with DataAcquire version 1.0.

DataAcquire is data acquisition software written in Visual Basic (5.0) to capture data from an Exotech Model 100BX Hand Held Radiometer. The capture calls NI-DAQ functions and library's and writes results to a text file for post-processing.

The DAQCard-500 is an analog input board for computers equipped with a PCMCIA socket and NI-DAQ software and documentation comes bundled with National Instruments products.

The procedure for use is quite simple.

STEP 1

Before a field trip ‘set up’ the data labels you will need, for example, a recent trip to Heron Island labels were:

- Dark
- Panel
- Substrate
- Water
- Live Coral
- Dead Coral
- Beach rock

This should be set up in notepad (or similar) beforehand, any number of labels may be included (within reason). You may also create a series of empty data files with file names pertaining to sites, transects or plots. To have these set up beforehand will save time (and eyestrain) in the field.

STEP 2

Before going into the field check you have all the equipment and it's in working order.

- **fully charged** Libretto Windows 95/98
- National Instruments DAQCard-500 analog input board with NI-DAQ software for PC compatibles
- PR27-30F I/O connector with cable
- also Libretto power cable for recharging if you're going for longer than an afternoon.

NOTE: **Start..Control Panel..Power** shows the battery meter for the Libretto. Otherwise, simply mouse over the small cord icon in the bottom right of the screen for current power.

STEP 3 In the field

Opening files -

Run the software, and open one of the recently created EMPTY data files – Ctrl + A opens the AppendFile dialog box. You may also type in a filename here and it will be created for you. The current filename will appear in the top right hand corner of the form. The current time and date should appear to its right.

Calibration settings -

The calibration settings in the bottom right will default to TM with a 15 degree Field of view and gain of one. These may need to be changed according to the lenses and gain settings on the radiometer itself. The Libretto *does not know* when the gain has been changed on the radiometer. Alt + S sets the gain according to the sensor selected and radio buttons checked. This will allow the appropriate gain to be written to the file you are appending.

Type of data

Once the calibration information is set focus shifts to the Type of Data frame. This is where the you will use the up/down arrow buttons to select the 'tag' you want for the type of data collected for later processing.

Data Acquisition

Any brief notes may be entered into the notes section although it is advisable to have pencil and paper on hand for details of conditions etc. To save data to file simply press Acquire data or Alt + A. The file written to disk has a format as follows: radiance1, radiance2, radiance3, radiance4, gain1, gain2, gain3, gain4,time of acquisition, current date, data label, notes

This file can be opened in Excel using the comma delimited option.

Step 4 Closing down

It is advisable to leave the software running between data capture sessions unless it is some distance between sites. To end a session, press END or Alt + E. Remove the DAQCard as described below.

Please note

Under **Start..Control Panel..PC Card** press STOP before removing the PCMCIA Card.

To remove data files from the Libretto there are two options:

- 1) use the a: drive attachment (RECOMMENDED)
- 2) use the network card and plug directly into the network in the labs and logging on normally.

For feedback I can be reached on the following email address.

Michael Stanford

michaels@cmlr.uq.edu.au

5.2 Spectrometer Operation

The spectrometer can either be operated in a stable or static mode at a fixed sampling point indoors, or outside on the ground or in a boat. In these situations the spectrometer should be laced on a level, stable and splash-proof surface. The system may also be used in a portable mode, by first fitting the battery waste-pack and shoulder harness. Prior to attaching the spectrometer its top cover should be removed after opening and sliding it to one side. To attach the system to the waist and shoulder harness place it on a desk or waist level surface and attach all of the clips (waist and shoulder). Adjust the straps and ensure the system is secure and comfortable.

Fore-Optics

You will have selected the appropriate fore-optics to use based on your field plan. These should be attached prior to commencing fieldwork and all connections (especially for water measurements) checked to ensure they are tight. In each case you will be attaching the fibre optic cable to one of the fore-optics. **IT IS ESSENTIAL THAT THE FIBRE-OPTIC CABLE IS NOT BENT OR CRIMPED IN ANY WAY AS THIS WILL DISTORT THE LIGHT FIELD REACHING THE SPECTROMETER.** When storing the cable after use ensure it is coiled loosely and placed in its pouch in the top of the spectrometer case – **all fore-optics are to be removed and the cable capped before it is stored.**

Hand-held measurements will require attachment of the pistol grip (25deg. FOV) and the 1deg FOV attachment. A cosine response corrected detector can also be mounted and levelled on a tripod to measure irradiance.

In-water measurements require extreme care in operation and establishing connection of the spectrometer with the 10m underwater fibre-optic cable and its fore-optics (6deg FOV and cosine response corrected detector for upwelling and downwelling radiance).

Connection of Fore-optics:

- Pistol-grip: Remove and store fibre-optic red cap, unscrew the crimp on the pistol grip and insert the end of the cable through the crimp and all the way into the grip until it protrudes from the front of the system. To secure the cable in place tighten the crimp so that the cable is held in place. **DO NOT OVERTIGHTEN** as this will damage the fibre-optic cable. **DO NOT PULL THE CABLE FROM SPECTROMETER** and avoid becoming tangled as this may disconnect the cable from the spectrometer. The system is now set up with a 25deg FOV. To reduce the FOV to 1deg, attach the 1deg FOV attachment.
- Cosine response corrected irradiance fore-optic: Connect to fibre-optic cable using the same approach as the pistol grip. This unit must then be mounted and levelled on a tripod to record irradiance.
- Underwater cable and 6deg and cosine response fore-optics: To attach the spectrometer fibre-optic to the underwater cable a connection jack must be used to link the two fibre optic cables. When using the spectrometer in this mode the area the spectrometer and cable connections are kept should be isolated from persons walking around the deck or platform. The underwater cable should also be kept loosely coiled in an easily deployable position. The cable is marked with black (0.5m) and red tape strips (1.0m) at set intervals for estimation of depth from the surface. Each of the underwater fore-optics connects to the underwater cables using 4 screws and maintains a waterproof seal by use of an O-ring. Always check the O-ring has not worn away and is sitting correctly in its groove on the fore-optic. All fore-optics and cable should be dried thoroughly prior to disconnection and packing for transport.

Sequence for turning on the system:

Check all direct connections and battery connections are solid

(1) Turn on the spectrometer first

(2) Turn on the PC second

NEVER TURN ON THE PC FIRST AS THE CURRENT THIS GENERATES WILL DAMAGE THE SPECTROMETER.

Data collection program

Once the system has been turned on it usually takes up to 30 minutes for the detector elements to become fully “warmed-up”, although after 10 minutes there is little fluctuation in measurements.

Remember to alter the power settings to a minimum use and maximum conservation mode prior to data collection if working remotely in the field.

To collect and process data from the spectrometer you need to run the “VNIR” program By clicking on the VNIR icon on the desktop.

The VNIR screen/user interface should appear. All of the functions can be run either through pull down menus or hotkeys (as the screen is difficult to see in the sun).

A number of equipment settings must be optimised for the incident light conditions prior to collecting spectra, these include:

Integration time (syn. with exposure time) is the time the sensor takes to acquire a single sample and is displayed in the third text box from the left (e.g. 17ms, milliseconds). The longer the integration time, the more EMR is recorded. For bright sunlit conditions the optimum setting is 17 – 34ms. However, you may wish to optimise this by taking samples over a calibration panel and selecting the time just below that when the response curve is saturated (exceeds maximum DN, flattens out at the top).

Spectrum Averaging is the number of samples taken per observation, the more sample taken, the higher your signal:noise ratio and greater probability of obtaining clean spectra. Using 25 samples produces a 5-fold increase in signal:noise ratio. This parameter is set by going to the top menu list, selecting Control and then Instrument configuration. The next step is to set the number of samples for a sample spectrum, dark current and white reference panel. Ideally these should all be at least 10.

Fore-Optics Selection should be specified in the pull-down menu box next to the integration time. It is essential to set this correctly to ensure that appropriate calibration equations are applied when calculating radiance and reflectance spectra.

Output Spectrum Type is defined in the pull-down menu box next to the Fore-optics selection and can be set to raw DN, reflectance (requires white panel measurement and only for terrestrial) and radiance.

Spectrum (File) Save options control the destination and names applied to spectrum saved from the VNIR window. By pressing the space bar at any stage the spectrum acquired will be saved into a binary file on the PC. The path name and base file name can be established by going to the top pull down menu and selecting Spectrum Save and entering appropriate information. This command may also be used to automate collection of spectra, e.g. for collecting irradiance data during an overflight.

There are two types of reading that are critical for effective spectrometry and these should be completed as often as possible:

Dark Current measurements are made by clicking on the DC pull down menu button. This operation closes a shutter on the spectrometer entrance aperture and measures the response of the system to no external input, i.e. noise due to internal electrical current. This reading is then subtracted from all subsequent readings until another dark current measurement is made.

White Reference measurements should be made over Lambertian reflecting surfaces, such as Spectralon field calibration panels to provide an estimate of irradiance that can be used in calculation of spectral reflectance. When the WR pull down menu button is selected a dark current measurement is also made prior to the measurement over a panel. The orientation of the fore-optics over the calibration panel should match that used for the field samples.

NOTE: Dark current and white references measurements should be made at regular intervals under constant illumination/clear skies and should be made with every target spectra obtained under variable illumination conditions

Spectral Data Collection

Now that you have set up the system to make measurements you should be at the start of transect or sampling operation, ready to acquire spectra. When using the hand-held pistol grip with 25deg or 1deg FOV you must carefully replicate the illumination and sampling geometry at each data sampling point. This involves a collection procedure in which you should be standing opposite to the plane of the sun and using a viewing elevation of 57deg. at a height where the resultant GRE only includes the feature(s) you are measuring.

CSIRO guidelines for sample position in relation to solar azimuth and zenith:

Elevation angle of fore-optics = 58 deg. from the horizontal plane

Azimuth angle = 90 deg. to the plane of the sun

Measurements of irradiance using the cosine corrected fore-optics and underwater sampling requires specific attention be paid to minimising indirect sources of radiance from buildings, field vehicles, field personnel and boats. Keep in mind the bi-directional reflectance distribution of the target you are measuring and how the variations in incident sunlight will affect reflectance throughout the day.

Prior to saving a data set ensure you have all the data collection settings optimised (integration time and sampling interval) and have selected the correct fore-optic and measurement level. After depressing the space-bar, the next spectra acquired will be placed in an output binary file as indicated in the Spectrum Save window. The Spectrum Avg window presents a graphic depiction of how many of the samples have been completed for a specific observation – **DON' MOVE THE SENSOR DURING THIS TIME !** At this stage it is important to link your field records (written) with the name of the spectrum-file you have just saved. This may also include notes of field conditions along with other sampled variables and location of the site.

Continue with your spectrum and field data collection as planned, keeping watch on the time you have spent and the battery levels of the spectrometer and PC. Always cross check you field sheets with the spectrum file names/numbers to ensure there are no mismatches. The number shown on the menu is the number which belongs the first spectra which will be measured after touching the space bar.

Finishing a Data Collection Program

To finish a data collection session Quit from the VNIR program and then check the files you have created during the sampling run are all present in your data directory and are all the same size. Connect the 3.5" disk-drive to the Libretto and download all of the files to

at least one diskette. Do not erase data from the Libretto until you have safely processed all of your data into the UQ spectral library format.

You may now switch off the PC and then the Spectrometer. ALWAYS SWITCH OFF THE PC FIRST !

All fore-optics should be disconnected and storage caps laced on the fibre-optic cables, which should then be coiled loosely and stored. All fore-optics should be wiped dry with a clean cloth and placed back in their pouches.

Update the equipment use log for the spectrometer, filling in the dates and times of use, fore-optics used and data sets produce and any problems encountered.

ANY PROBLEMS ENCOUNTERED SHOULD BE REPORTED IMMEDIATELY TO DR PHINN, PETER SCARTH CHRIS ROELFSEMA OR MICHAEL STANFORD.

6. Data processing, quality checking and storage

6.1 Data downloading to PC and Quality Checking (QC) procedure

Data collected from the radiometer using the manual approach should be checked to ensure all Voltage, and gain values were recorded along with all dark current and calibration panel measurements.

Data collected from the radiometer using the Libretto and A/D card should be checked by first matching the entries in the output file to the field data sheet and adding comments where necessary. In addition the magnitude of all radiance values should be scrutinised to determine that they were in a suitable range. If reflectance data are required all measurements should be linked to their closed dark current and calibration panel measurement.

Data collected from the spectrometer using a progressive series of binary files e.g. sample001 to sample100 should be downloaded from the Libretto and run through the program STable as follows: STable -xw -f -cc sample* > date_sample.txt

This runs on files sample001 to sample100 and creates an output ASCII file where the first column (-xw) contains wavelength values, and successive columns are separated by commas (-cc) and have their filename (-f) on the top row.

Once this is complete it is essential that you check your field data sheets against each column entry and add the appropriate descriptor data.

All field data (e.g. GPS, biomass, water depth) should also be checked for consistency and links to radiometer data at this stage prior to being entered into an appropriate spreadsheet or database.

Each data set should also have an accompanying Meta-data file that identifies: the responsible researcher, date and location of data collection, sky conditions, fore-optics used and listing of data samples and the file names of radiometer/spectrometer and field data.

Both radiometer and spectrometer data sets are now in an ASCII text format able to be imported directly into a spreadsheet (e.g. Excel) or ENVI's spectral library for graphical, statistical and numerical analysis.

6.2 Processing data sets to standard spectral libraries for statistical, numeric and graphic analyses

Processing of data sets can progress in a number of ways, the following are some suggested approaches:

Radiometer data:

- Graphic assessment of spectral signatures and their variability
- Correlation or regression analysis with biological, physical or

- Spectrometer data:
- chemical field data sets
 - Graphic assessment of spectral signatures and their variability
 - Correlation or regression analysis with biological, physical or chemical field data sets
 - Derivative analysis to examine spectral peaks, troughs and inflection points
 - Band re-sampling or convolution to match broad band sensors
 - Spectral curve matching within a library

7. The Remote Sensing Program Spectral Library

7.1 Why maintain a spectral library ?

To provide a resource for use by students and researchers for interpreting the results of their analyses and to develop a quantitative and accurate means of discriminating features in the next generation of airborne and satellite imaging systems. Most existing spectral libraries are based on North American or European environments and lack a variety of features from Australian forests, soils, minerals, water-bodies, submerged aquatic/marine vegetation and coral reefs.

7.2 Format of data for submission:

Meta Data file containing: the responsible researcher, date and location of data collection, sky conditions, fore-optics used and listing of data samples and the file names of radiometer/spectrometer and field data. This file must enable a link between spectral data and ground sample points and related information.

Excel, ENVI spectral library or ASCII comma/space delimited text file organised in columns with the first column containing band centre wavelengths and following columns radiance or reflectance values for specific samples.

8. Appendices and Contacts

ASD web page:

<http://www.asdi.com/>

USGS spectral libraries

<http://speclab.cr.usgs.gov/index.html>

NASA/ASTER spectral libraries:

<http://asterweb.jpl.nasa.gov/>

8.1 Special consideration for Marine Measurements

Field teams should be instructed to watch splashing of:

- people who move out and in the boat
- snorkelers/divers who e.g. clearing water out of snorkel or move of fins
- wet hair or cloth of the field team
- samples, instruments which go out or in the water
- things which are thrown in or out of the boat (e.g. boots, ropes)

How to protect the Spectrometer:

- from splashing water splashing
 - instructed the field team
 - keep the spectrometer in the special designated nelly bin
 - keep a towel over spectrometer and computers
 - place it in an area on the boat which can be separated as being the dry area
 - while the boat is moving close the nelly bin
 - have a dry cloth handy to dry of water
- keep it in the nelly bin on a location where it cannot move or where it is not shaken to much while sailing
- instructed the field team of the small area in the boat and the high expense of the instrument
- take time for installing it

How to protect the optical cable

- while moving have it on top of the nelly bin lit
- while using it have the part closest to the boat connected to the boat
- have somebody watch to cable in the boat
- give to much slack so that the optics operator (e.g. diver, snorkeler) in the water will not have to pull on the cable
- let the optics operator (e.g. diver / snorkeler) know that there is not much slack left
- do not pull on the cable
- look out that the cable those not get entangled
- never have the cable in the water when the boat is still moving on its engine

How to protect the fore-optics

- check to o ring before connecting the underwater optics
- test the o ring connection in fresh water before placing in salt water
- attach optics before going into the marine environment
- while not using it leaf it in fresh water or a wet towel this will stop dirt or salt cristals forming on the optics

How to protect the U/W spectralon

- keep it on wrist while in the water
- keep protection cap on while not using
- take time when using it

Consideration when collecting optical measurements

- wind forces 15 kn or higher waves will have such an effect on movement of water surface and therefore also movement of boat that this will influence the results considerably.
- plan the measurements with the optics operator who is going in and under water since communication will not be as effective
 - how to communicate (e.g. hand or line signals or buddyphone system)
 - communicate a minimum (e.g. only name what is been done)

- do not change plan when optics operator is in water
- dive/snorkeling safety and u/w spectrometry
 - stick to plan
 - diver cannot go up and down (bounce diving) this can cause serious injuries
 - diver has to stick to diving limits
 - limited factors in time spend u/w can be air, temperature, currents or diving tables
 - snorkeler had limited air u/w
- since the boat is on an anchor it will move around there fore it can be a disturbing shade for underwater measurements and above water the position of the optics operator relative to the sun will change ass well
- when measurements are taken above water with a wet optics, water on the optics can interfere with the result
- wet spectralon can interfere the result when used above water
- optics operator has to take care that he those not disturb the sediment since this will influence the u/w light climate
- higher integration time are necessary in underwater environment because of amount of light
- more samples have to be collected to calculate the spectrum average this because of movement of boat (for measurements on boat) which changes the angle of the light on the subject or movement of water surface which causes a change in light going through the water column
- be aware of reflecting effects of wet samples which are taken out of the water
- notes the depth were spectra was taken
- place samples on area with black cloth as background (e.g. shade cloth) to minimize reflectance surrounding environment (e.g. aluminum boat)
- reflectance measurement can have such low values underwater that in most cases it is advised to measure radiance of spectralon and then of subject and calculate reflectance values in the lab
- the constant change of the water surface and column will influence the underwater light climate so much that it is advised to measure before each subject the spectralon

When finished with marine measurements

- check for any water damage
- rinse optical cable and optics with fresh water are preferable leave them in fresh water for 15 minutes or more
- store the spectrometer open so that water vapor on it, can dry and those not settle down in electronic part of instrument
- take a wet cloth and rinse nelly bin in and outside

When suspected flooding toke place of spectrometer

- take all power off
- remove batteries (also internal) and other power sources
- disconnect lep top from spectrometer
- do not leave it in a wet environment
- contact Stuart