

FieldSpec® 3 User Manual



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Trademark Information

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Declaration of Conformity

According to IEC guide 22 and EN45014

Manufacturers Name: Analytical Spectral Devices, Incorporated.
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 Boulder, CO 80301
 Phone: (303) 444 6522
European Contact: Your local Analytical Spectral Devices Representative.

Declares that the product(s)

Product Name:	FieldSpec® 3	
Product Numbers	Description	Range (nm)
A100500	VNIR	350-1050
A100510	VNIR Desk Top	350-1050
A100520	Dual VNIR	350-1050
A100530	SWIR1	1000-1800
A100540	SWIR2	1800-2500
A100550	SWIR1 & SWIR2	1000-2500
A100560	NIR Junior	1000-2500
A100570	VNIR & SWIR1	350-1800
A100580	Full Range Desktop (VNIR, SWIR1, & SWIR2)	350-2500
A100590	Full Range (VNIR, SWIR1, & SWIR2)	350-2500
A100600	Full Range Junior	350-2500

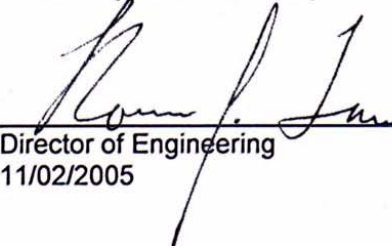
Conforms to the following EU Directives:

Safety: Low Voltage Directive, 72/23/EEC, as amended by 93/68/EEC
EMC: Electromagnetic Compatibility Directive, 89/336/EEC, as amended by 93/68/EEC

Supplementary Information:

The product complies with the requirements of the following Harmonized Product Standards and carries the CE-Marking accordingly:

- EN 61010-1: 2001** Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory use
- EN 61326-1: 2002** Class A, Electrical Equipment for Measurement, control and Laboratory use – EMC requirements

Signature: 
Title: Director of Engineering
Date: 11/02/2005



Notes:

Chapter 1 Introduction

The FieldSpec® 3 Spectroradiometer is a general-purpose instrument useful in many application areas requiring the measurement of reflectance, transmittance, radiance, or irradiance.

The FieldSpec spectroradiometer is specifically designed for field environmental remote sensing to acquire visible near-infrared (VNIR) and short-wave infrared (SWIR) spectra. *Remote sensing* is defined as the art and science of obtaining information about an object without being in direct physical contact with the object.

The FieldSpec spectroradiometer is a compact, field portable, and precision instrument with a spectral range of 350-2500 nm and a rapid data collection time of 0.1 second per spectrum. The FieldSpec spectroradiometer is also offered in various subsections of the spectral range.

While its most highly regarded features are performance and field-portability, this instrument also performs well in the laboratory.

Features and Advantages

Accurate and Precise - High signal-to-noise ratio and superior repeatability of results for better identification and analysis of materials.

Rugged and Transportable - Resistant to vibration and changes in temperature or humidity.

Fast - 10 spectra per second data collection for the entire 350-2500 nm range.

- » 0.1 second scanning time provides an accurate average every second.
- » Users can quickly scan several areas when analyzing bulk samples.
- » Rapid analysis allows screening all or most samples instead of spot checking.

Compatible - Works with off-the-shelf chemometrics software (Grams™ PLS plus/IQ and Unscrambler®).



1.1 Hardware Specifications

This section contains details about the FieldSpec spectroradiometer.

1.1.1 Physical Specifications

Height	12.7 cm	5 inches
Width	35.6 cm	14.5 inches
Depth	29.2 cm	11.5 inches
Weight	5.6 kg	12 lbs

- Durable satin powder coat finish with teal urethane end-caps and handles
- All vital components are in a dust-proof enclosure and EMI sealed
- Fiber optic inputs directly to each spectrometer

1.1.2 Power Input and Output

AC Power Supply Type	Auto ranging, Switching, SELV
AC Input	90-240 VAC, 50/60 Hz
DC Input	+12 VDC, 50 W
Accessory Power Port (front of instrument)	Output, +12 VDC, 19.2 W (max).



1.1.3 FieldSpec® 3 Spectroradiometer Wavelength Configuration

Product	Wavelength Name	Wavelength Range
A100590, A100600 (JR), A100580 (DeskTop)	VNIR-SWIR1-SWIR2	350 - 2500 nm
A100500, A100510 (DeskTop), A100520 (Dual)	VNIR-only	350 - 1050 nm
A100530	SWIR1-only	1000 - 1800 nm
A100540	SWIR2-only	1800 - 2500 nm
A100570	VNIR & SWIR1	350 - 1800 nm
A100550	SWIR1 & SWIR2	1000 - 2500 nm
	VNIR & SWIR2	350 - 1050 nm and 1800 - 2500 nm

The spectral resolution is:

- 3 nm (Full-Width-Half-Maximum) at 700 nm.
- 10 nm (Full-Width-Half-Maximum) at 1400 nm.
- 10 nm (Full-Width-Half-Maximum) at 2100 nm.

The sampling interval is:

- 1.4 nm for the spectral region 350-1000 nm.
- 2 nm for the spectral region 1000-2500 nm.

The FieldSpec spectroradiometer may be configured to have three separate holographic diffraction gratings with three separate detectors. Each detector is also covered with the appropriate order separation filters.

- VNIR: 512 element silicon photo-diode array for 350-1000 nm.
- SWIR1: “graded index” TE-cooled InGaAs photo-diodes for 1000 nm to 1830 nm.
- SWIR2: “graded index” TE-cooled InGaAs photo-diodes for 1830 nm to 2500 nm.



1.1.4 Interface Requirement

The FieldSpec spectroradiometer communicates using a 10/100 Base T Ethernet card. The FieldSpec spectroradiometer works fine with the Ethernet connection provided on many laptop computers.

The 802.11b wireless Ethernet cards within the FieldSpec spectroradiometer and instrument controller can allow communication distances of 30-40 m (100-150 ft). ASD tests the wireless communication up to 30 m (100 ft). However, obstructions or radio frequency interference in close proximity can cause loss of communication or significantly shorten the communication range.

Note: For information about configuration of the Ethernet card and cable, please refer to the *Installation Manual*.

1.1.5 Standard Accessories

- FieldSpec Instrument
- FieldSpec® 3 User Manual (PDF on Flash Drive)
- Auxilliary Power Supply 18 V.
- NiMh Battery (12 V, 9000 mA hour)
- Battery charger
- Power adapter with 6 m (20 ft) cord for automobile cigarette lighter. When using this adapter, the vehicle's engine should be turned off, because electromagnetic fields from the engine can generate noise in the acquired signals.
- RJ45 CAT 5e UTP Ethernet, Shielded, Crossover Cable 1.4 m (5 ft)
- Instrument Controller: ASD-approved laptop computer (not included with desktop instruments)
- RS³ Software Pack
- 64 MB (min.) Flash Drive Memory USB Flash Drive
- FieldSpec Pistol Grip
- Remote trigger with LED indications and velcro pads.
- Pro Laptop Carrier
- Mylar Reference
- Fiber optic inspection magnifier
- Ergonomic Pro-Pack with built-in rain protector, sample storage compartment, instrument controller (laptop) compartment, snap-on belly board for laptop, and two battery pouches designed for the hip belt.



- Shipping Trunk: Durable, air tight, wheeled, fold down handle, and foam filled with cutouts to protect the instrument and many accessories.

1.2 Computer Requirements

The *instrument controller* is a computer which manages the FieldSpec spectroradiometer, stores data, and processes the results.

The standard FieldSpec spectroradiometer includes a laptop computer, or the *instrument controller*. The desktop FieldSpec spectroradiometer does *not* include the instrument controller.

The minimum set of requirements for the instrument controller are:

- 1.2 GHz Pentium or better notebook or PC-w/monitor
- 256 MB RAM or more
- 20 GB of free disk space
- Microsoft Windows® (95,98,ME,NT,2000,XP)
- 1024 x 768 or better graphics resolution
- 24-bit color or better - 32-bit recommended
- Internet Explorer 6.0 or better
- Ethernet port: 10/100 Base T Ethernet interface
- (Optional) Ethernet wireless (Wi-Fi) adaptor: PCMCIA, USB, or built-in that is compatible with the 802.11b standard
- (Optional) Serial communications port (or USB port) for GPS receiver. Only needed if you want to use GPS.
- (Optional) NMEA compatible GPS receiver

1.3 Software Requirement

The instrument controller requires the following software:

- RS³ Software from ASD.
- Microsoft Windows® 95/98/NT/2000/ME/XP Operating System.

Users need a basic understanding of the Microsoft Windows operating system including software installation.



International customers using non-English versions of Windows® must alter the **Regional Settings** under **Start>Settings>Control Panel**. The default language must be set to English (United States) in order for the software to be registered and operate correctly. The numbering format must also be set to English.

1.4 Theory of Operation

The FieldSpec spectroradiometer measures the optical energy which is reflected from, absorbed into, or transmitted through a sample. *Optical energy* refers to a wavelength range that is greater than just the visible wavelengths, and is sometimes called *electromagnetic radiation* or *optical radiation*.

In its most basic configuration, the spectroradiometer views and detects the form of radiant energy defined as *radiance*. With accessories, various set-ups, and built-in processing of the radiance signal, the FieldSpec spectroradiometer can measure:

- spectral reflectance,
- spectral transmittance,
- spectral absorbance,
- spectral radiance, and
- spectral irradiance.

Fiber Optic Collection of Reflected/Transmitted Light

Optical energy is collected through a bundle of specially formulated optical fibers, precisely cut, polished, and sealed, for extremely efficient energy collection. The fibers themselves are of low OH composition providing the maximum transmission available across the instrument's wavelength range.

Inside the FieldSpec® 3 Spectroradiometer

The fiber cable sends the spectral radiance into the instrument, where it is projected onto a holographic diffraction grating. The grating separates and reflects the wavelength components for independent measurement by the detectors.

Visible/Near-Infrared (VNIR)

Note: This discussion assumes that the FieldSpec spectroradiometer has the hardware to perform a full-range spectrum analysis: VNIR, SWIR1, and SWIR2.



The Visible/Near-Infrared (VNIR: 350-1000 nm wavelength) portion of the spectrum is measured by a 512-channel silicon photodiode array overlaid with an order separation filter. Each channel (or detector) is geometrically positioned to receive light within a narrow (1.4 nm) range. The VNIR spectrometer has a spectral resolution (full-width half maximum of a single emission line) of approximately 3 nm at around 700 nm.

Each detector converts incident photons into electrons that are stored. At readout time, the photoelectric charge stored at each detector is converted to a voltage and digitized by a 16-bit analog-to-digital (A/D) converter. This digitized spectral data is then transmitted to the instrument controller for further processing and analysis by the controlling software.

The 512-channel array permits the entire VNIR spectrum to be scanned in parallel in 1.4 nm wavelength intervals. A single sample can be acquired in as little as 17 ms.

Short-Wave Infrared (SWIR)

Note: This discussion assumes that the FieldSpec spectroradiometer has the hardware to perform a full-range spectrum analysis: VNIR, SWIR1, and SWIR2.

The Near-Infrared (NIR), also called Short-Wave Infrared (SWIR), portion of the spectrum is acquired with two scanning spectrometers:

- SWIR1 for the wavelength range of 1000 nm to 1830 nm.
- SWIR2 for the wavelength range of 1830 nm to 2500 nm.

SWIR differs from the VNIR in that they only have one detector for SWIR1 and another for SWIR2, rather than an array of 512 detectors. Thus, SWIR spectrometers collect wavelength information sequentially rather than in parallel.

Each SWIR spectrometer consists of a concave holographic grating and a single thermo-electrically cooled Indium Gallium Arsenide (InGaAs) detector. The gratings are mounted about a common shaft which oscillates back and forth through a 15 degree swing. As the grating moves, it exposes the SWIR1 and SWIR2 detectors to different wavelengths of optical energy. Each SWIR spectrometer has ~600 channels, or a ~2 nm sampling interval per SWIR channel.

Like the VNIR detectors, the SWIR1 and SWIR2 detectors convert incident photons into electrons that are stored. This photocurrent is continually converted to a voltage and is then periodically digitized by a 16-bit analog-to-digital (A/D) converter. This digitized spectral data is then transmitted to the instrument controller for further processing and analysis by the controlling software.

The grating is physically oscillating with a period of 200 ms. It performs a forward scan (A) and a backward scan (B), resulting in 100 ms/scan. Thus, this is the minimum time required for any SWIR samples, or full-range samples.



The spectroradiometer firmware automatically accounts for the overlap in wavelength intervals by using a preset wavelength within the common subset at which to place a “splice”.

Communicating with the Instrument Controller

The FieldSpec spectroradiometer communicates with the instrument controller using an Ethernet cable or Wireless Ethernet (WiFi) interface. The amount of data that is sent depends on the configuration of the spectroradiometer.

- A single sample of VNIR is ~1024 bytes.
- A single sample of SWIR1 is ~2400 bytes.
- A single sample of SWIR2 is ~2400 bytes.

A full-range FieldSpec spectroradiometer can create packet data sizes over 5 KB. Other single or dual range configurations of the spectroradiometer could create smaller data packets (adding the packet sizes as above.)

When spectrum averaging features are turned on at the instrument controller within the application software, the averaging and consolidation of samples happens within the spectroradiometer.

Dark Current Measurement

Dark Current (DC) refers to current generated within a detector in the absence of any external photons. DC is the amount of electrical current that is inherent in the spectrometer’s detectors and other electrical components and is additive to the signal generated by the measured external optical radiation.

This manual uses DC to refer to all systematic contributions to the detector’s signal. DC is a property of the detector and the associated electronics (not the light source). DC varies with temperature. In the VNIR region, DC can also vary with integration time.

Whenever DC is taken, a mechanical shutter is used to block off the entrance slit of the VNIR spectrometer so the signal can be measured. This signal is subtracted from each subsequent spectrum until another DC is taken. The SWIR spectrometers take a DC on every scan.

The DC measurement can be updated at any time, but should be updated more frequently in the beginning of a given session while the instrument warms up.

Noise is the uncertainty in a given measurement, one channel at a time. Noise can be reduced by using more samples and averaging the signal.

Note: Dark Current is different from Noise. Noise by definition is random and its source is indeterminate. Dark Current is relatively stable and it can be characterized.

The DC shutter is an electro-mechanical device, so there is another level of DC created by the simple electronics that hold it closed. ASD measures this offset and stores it in the DCC (Dark Current Correction) entry in the



instrument's initialization file, `asdcfg.ini`. The controlling software automatically corrects all spectra taken with the shutter closed to account for this minor complication.

The VNIR spectrometer is fitted with a unique software and hardware combination feature called *Driftlock*. Driftlock deals with DC changes over long periods of time. It automatically updates DC for every measurement by looking at a series of masked pixels at the front portion of the VNIR array. The Driftlock feature corrects for the majority of DC variation over time.

White Reference

A material with approximately 100% reflectance across the entire spectrum is called a *white reference panel* or *white reference standard*.

Because the internal spectrometers only measure the intensity of a light field through a given point in space, a white reference is one method to correlate that measurement with the physical properties of the sample.

Reflectance and transmittance are inherent properties of all materials and are independent of the light source.

Reflectance is the ratio of energy reflected from a sample to the energy incident on the sample. *Spectral Reflectance* is the reflectance at a given wavelength.

Transmittance is the ratio of the radiant energy transmitted through a sample to the radiant energy incident on the surface of the sample. *Spectral Transmittance* is the transmittance at a given wavelength.

Relative reflectance is computed by dividing the energy reflected from the sample by that reflected off a white reference panel or standard. *Absolute reflectance* is computed by multiplying the relative reflectance by the known reflectance of the white reference panel.

With the reflectance of the reference standard available and known, RS^3 can compute the absolute reflectance or transmittance for the material being sampled.

Accessories for Light Sources and Probes

ASD offers several accessories for:

- Delivering illumination to the sample.
- Collecting reflected or transmitted radiance and irradiance from the sample (where solar light is the primary source of illumination).
- Transmitting the collected light to the spectrometer.

Some accessories, such as many of the optional foreoptic probes, rely on other illumination sources, and even solar light.



Notes:

Chapter 2 Setup

Inspect the shipping container and take careful notes regarding any damage to it and its contents that might have occurred during shipping.

Note: Save all packing materials, foam spacers, and paperwork for possible future use.

Figure 2-1 FieldSpec spectroradiometer carrying case and foam inserts.



Prepare a clear space on a sturdy bench or counter, ideally, a space near a wall-current receptacle and the controlling computer.

Carefully open the shipping container following all instructions and orientation labels on the container.

2.1 Unpacking the Instrument

Step 1 Carefully remove the instrument from its shipping case. Use the nylon straps at the top of the Ergonomic Pro-Pack and the hip belt at the bottom.



Figure 2-2 The spectroradiometer being removed from the carrying case.

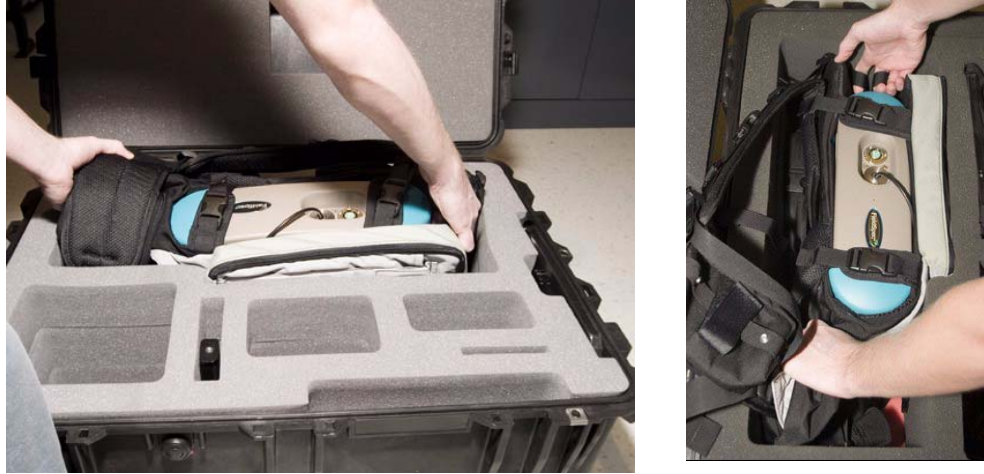


Figure 2-3 Ergonomic Pro-Pack on a flat surface with shoulder straps to floor and carrying the FieldSpec spectroradiometer and instrument controller.



Step 2 Place the Ergonomic Pro-Pack on a flat surface with the shoulder straps towards the floor.



Figure 2-4 Removing the instrument controller from the pack.



Step 3 Remove the instrument controller from its compartment on the outside of the Ergonomic Pro-Pack.

Figure 2-5 Removing the FieldSpec spectroradiometer from the Ergonomic Pro-Pack.



Step 4 Undo the five (5) plastic connectors which hold the FieldSpec spectroradiometer in the Ergonomic Pro-Pack.



Figure 2-6 FieldSpec spectroradiometer front-view showing fiber connection and power output.



The remaining portion of the shipping case is designed to hold the various accessories you may have purchased with your instrument. There are specific locations for the contact probe, mug light, Spectralon, battery pack, and miscellaneous power cables.

WARNING! The fiber cable should never be stored with a bend of less than a 5" diameter for long periods of time, because the cable can be damaged with undetectable longitudinal fractures that can cause light leakage and weaker signals.

2.2 Power Supply

The FieldSpec spectroradiometer requires input power to be 12 VDC (50 W). It does not contain an internal power supply to convert AC voltage to DC, nor does it have internal batteries.

The three options for providing the spectroradiometer with the appropriate DC voltage are:

- An external power supply which converts 90-240 VAC, 50/60 Hz to 12 VDC (shown in [Figure 2-7](#)).
- An external battery pack which delivers 12 VDC (shown in [Figure 2-8](#)).
- An external adapter for vehicle cigarette lighters (sold separately and should not be used with vehicle engine running).

Caution! Do not attempt to use non-ASD power supplies or connectors to power in the instrument.



Figure 2-7 FieldSpec spectroradiometer power supply and cables.



Figure 2-8 Portable battery packs (one on each side of hip belt).



The Ergonomic Pro-Pack has two pouches on the hip belt, either of which can be used to hold the battery. However, the battery should be on the opposite side from where the fiber optic cable will be.

Both the external AC power supply and the DC battery pack have the appropriate power connector (Figure 2-9) to connect to the FieldSpec spectroradiometer on the back panel (Figure 2-10).



Figure 2-9 FieldSpec spectroradiometer power connector which plugs into the instrument.



Insert power (battery or power supply) into the receptacle on the back panel labeled “**INPUT 12 VDC 50 WATT**”. Lock the connector in place by twisting the barrel end of the connector clockwise.

Figure 2-10 FieldSpec spectroradiometer back panel showing Ethernet connection, power switch, and power input jack.



2.3 Ethernet Cables

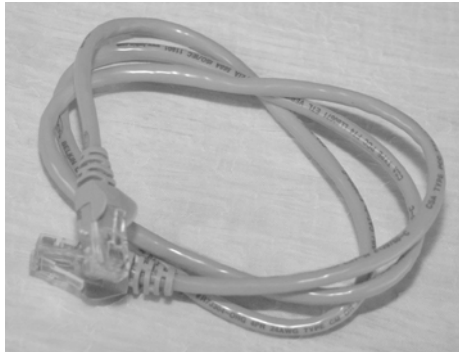
For Information about configuration of the Ethernet card and cable please refer to the *Installation Guide*.



Note the location of the computer interface connection. [Figure 2-10](#) shows the back panel containing the Ethernet port, which is labeled “RJ45/ETHERNET”.

With the FieldSpec spectroradiometer and the instrument controller fully powered-down and turned-off, plug the Ethernet (cross-over) computer cable into the Ethernet ports of the spectroradiometer and your instrument controller.

Figure 2-11 Standard Ethernet Cross-Over cable (shielded).



2.4 Accessory Power Port

The accessory power port is located on the front of the unit, as is shown in [Figure 2-12](#). This port is where external accessories, such as the Contact Probe or Source Probe (mug light), attach to receive power from the spectrometer.

Figure 2-12 Enhanced view of the front panel with the fiber cable connector and accessory power port.





The accessory power port is provided for optional ASD approved accessories. Attach the large connector end of the cable into the accessory power port of the front panel. Attach the other end of the power cable into the contact probe, mug light, or other ASD approved accessory.

- PIN-1 provides 12 VDC @ 1.6 A max Watts.
- PIN-2 is ground.

Please contact ASD for information about these accessories.

WARNING! Never attempt to use unauthorized accessories on the accessory power port

Figure 2-13 Cable (sold separately) for the FieldSpec spectroradiometer's accessory power port.



2.5 Pistol Grip

The pistol grip is standard with the FieldSpec spectroradiometer, as is shown in [Figure 2-14](#). The pistol grip has a 25 degree field of view, full conical angle.

The fiber optic cable feeds into the rear of the pistol grip.

The red-dot scope (sold separately) has a battery compartment is on the top of the pistol grip.



Figure 2-14 Pistol grip with red-dot scope (sold separately), one degree field of view (sold separately), and trigger (standard) attached.



2.6 External Trigger

An external trigger is standard with the FieldSpec spectroradiometer. The trigger plugs into the spectroradiometer near the fiber optic cable, as is shown in [Figure 2-15](#).

The LEDs on the trigger are bright enough to be seen even on a sunny day. The LEDs are light up when the trigger is pushed (briefly) and turn off when the capture is complete. [Figure 2-14](#) shows the pistol grip with the trigger activated.

Figure 2-15 External trigger and the FieldSpec spectroradiometer.





The trigger comes with several pieces of mated velcro, which are intended for use with several accessories. Place a piece of hook velcro onto the trigger; place pieces of mesh velcro onto the accessories, as shown in [Figure 2-16](#).

Figure 2-16 The trigger and the Pistol Grip.



Note: Accessories such as the pistol grip should probably have pieces of mesh velcro placed on both sides so that the trigger can be used right- or left-handed.

2.7 Belly Board

The belly board has two intended configurations:

- With the neck strap, the belly board can hold the instrument controller without the Ergonomic Pro-Pack, such as when the equipment is carried in the field by two people.
- Without the neck strap, the belly board can be attached directly to the plastic snaps on the shoulder straps of the Ergonomic Pro-Pack, such as when one person operates the instrument.

Before taking the spectroradiometer into the field for the first time, place matching velcro strips on the instrument controller (bottom) and belly board (top) using the following procedures.

Attaching velcro to the instrument controller and belly board

- Step 1 Remove the spectroradiometer and instrument controller from the Ergonomic Pro-Pack.
- Step 2 Put on the empty Ergonomic Pro-Pack and fasten the belt.
- Step 3 Adjust the shoulder straps of the Ergonomic Pro-Pack for comfort.
- Step 4 Detach the belly board from the neck strap and attach it to the shoulder straps of the Ergonomic Pro-Pack, as shown in [Figure 2-17](#).



Figure 2-17 Belly board attached to shoulder straps of the Ergonomic Pro-Pack.



- Step 5 Adjust the straps of the belly board for comfort and utility.
- Step 6 Hold onto the instrument controller at all times. Set instrument controller on the belly board temporarily and observe how close to your body it can be placed on the belly board while still allowing comfortable access to the keyboard. Remember this placement and set the instrument controller on a table.
- Step 7 Remove the belly board from the Ergonomic Pro-Pack.
- Step 8 Locate the two pairs of velcro strips (mating hook side and mesh side) supplied with the belly board.
- Step 9 Leave the hook & mesh velcro strips mated.
- Step 10 Remove the backing from the adhesive on the hook side of one strip and place this adhesive side down onto the belly board an inch or so away from the curve.
- Step 11 Press down firmly on the velcro and smooth out so that the adhesive can stick to the belly board.
- Step 12 Repeat from [Step 9](#) with the other velcro strip but place it a couple of inches or so away from the other strip. This is shown in [Figure 2-18](#).



Figure 2-18 Placing velcro pieces on the belly board and instrument controller.



- Step 13 With the hook & mesh velcro still mated, remove the backing from the adhesive side on the mesh side of one strip.
 - Step 14 Recall the instrument controller's placement on the belly board from [Step 6](#). Set the instrument controller onto the exposed adhesive of the mesh side of the velcro. Press down firmly.
 - Step 15 Gently separate velcro of the instrument controller from that of the belly board. Smooth over the velcro strips on both the instrument controller and belly board.
 - Step 16 Repeat from [Step 13](#) for the other velcro strip.
- The end result is shown in [Figure 2-19](#).

Figure 2-19 The belly board with instrument controller and neck strap.



Chapter 3 Usage and Maintenance

For your safety and to prevent damage to the instrument, please review the following safety precautions. All operators should be familiar with this information.

3.1 Light Sources

Use only light sources supplied by Analytical Spectral Devices, Inc. Light sources supplied by ASD are designed to provide levels of illumination and stability of output that compliment the performance of ASD's instrumentation.

3.1.1 Operate Safely

Caution! *Never touch the light source and avoid contact with metal components near the light sources! Heat transfer from the light source may make these metal components uncomfortably warm to the touch. The light source generates some UV at very low radiance levels from the tungsten filament, quartz envelope, and halogen gas-filled bulb.*

Prevent dirt and oils from contacting the bulb and reflector.

Do not touch the glass envelope of the bulb. Oils on the hand may transfer to the glass envelope, which can significantly affect the bulb temperature and corrupt important operating physics of the bulb.

3.1.2 Changing Bulbs

- Step 1 Wait at least 30 minutes for the bulb to cool before attempting replacement.
- Step 2 Turn off and unplug all power before changing bulbs in any external light source.



- Step 3 See the set-up section of the specific light accessory purchased for the procedure for changing the bulb.

3.2 Access and Ventilation

Provide adequate room ventilation, such as is suitable for human comfort to avoid overheating the equipment. Insufficient ventilation could result in damage to the instrument and corrupted data.

Caution! *Do not cover the vents of the instrument.*

Do not place objects on the unit or its power supplies. Prevent objects from obstructing ventilation slits.

Keep objects and spills from entering or falling onto the instrument, all power supplies, and software disks.

3.3 Cleaning

- Step 1 Turn off the unit.
- Step 2 Disconnect from all power.
- Step 3 Allow the unit to cool down.
- Step 4 Clean unit with a slightly damp cloth and mild soap.
- Note: Be sure all soap residue is removed and all surfaces are dry before use.

3.4 Annual Maintenance

ASD recommends that the instrument be recalibrated once a year. This will ensure that the wavelengths are accurate and that the instrument is still functioning properly. Annual maintenance is covered under ASD's one-year warranty, the extended service contract, or it can be purchased. If you are interested in purchasing annual maintenance or an extended service contract, please contact your sales representative.



3.5 RMA

In order to return the instrument to ASD for maintenance or repair, a Return Merchandise Authorization (RMA) must be issued by ASD Technical Support. The RMA includes scheduling details, contact information, shipping instructions, as well as a brief description of the maintenance or repair requirements. Please contact the Technical Support department at either 303-444-6522 or support@asdi.com.



Notes:

Chapter 4 *Fiber Optic Interface*

ASD offers a variety of fiber optic cable lengths to interface with the FieldSpec® 3 Spectroradiometer. These fiber optic cables are used for reflectance, transmittance, radiance, or irradiance measurements.

The fiber optic cable is routed straight through the front panel to the spectrometer. The FieldSpec spectroradiometer is able to accurately measure radiance and irradiance in absolute units, because there is no front panel connector to add uncertainty in the throughput of the instrument.

Fiber optic cables should be loosely coiled and stored in the mesh compartment provided on the unit. All accessories should be stored in the designated compartments of the carrier or in a separate protective case.

4.1 **Fiber Optics Cables**

The fiber-optic cable is made up of fifty-seven (57) randomly distributed glass fibers. Nineteen (19) of these fibers are 100-micron and are distributed to the VNIR region. The remaining thirty-eight (38) fibers are 200-micron and are evenly divided between the two SWIR regions. All fifty-seven fibers are housed in a plastic sheath. A standard cable has a diameter of 0.19 inches and is an f2 cable.

The fibers are protected by a metal spiral inside the black cable casing. If there are kinks in your cable, the fibers are not necessarily damaged. If, however, your cable has been crunched so severely that you are able to see the protective metal spiral, the chances are high that the fibers have been damaged too. Each broken fiber results in a 5% loss of response.

WARNING! The fiber cable should never be stored with a bend of less than a 5" diameter for long periods of time.

The fibers can be damaged by coiling the cable up too tightly. If left in a tight coil for longer than a week, the fibers are likely to develop longitudinal fractures that will not be detectable. These fractures in the fiber will cause light leakage, resulting in a weaker signal. The fiber optic cables should be stored by placing them loosely within the netting compartment on the instrument or on the fiber optic spool.

**Tips on care for the fiber optic cable:**

- Do not pull or hang the spectroradiometer by the fiber optic cable.
- Do not attach or clamp the fiber optic cable with tightly wound wires or ties, because these might pinch or penetrate the protective jacket thereby damaging the fibers inside.
- Avoid slamming the fiber optic tip onto hard surfaces, because such impacts can cause fractures to the glass fibers.
- Avoid torquing the fiber optic cable around its diameter cross-section, because such forces may cause fractures to fibers.

While the tip of the optical fiber cable is not particularly susceptible to damage, a tip cover is recommended to protect against abrasion and exposure to contamination. Covers can be made by cutting some pieces of eighth-inch shrink tubing to about 1.5" lengths and shrinking them onto the fiber cable tip. They will slide on and off the cable easily.

The loss in response is further amplified when "jumper" cables are utilized. Jumper cables are fiber-optic cables that can be attached to the fixed cable via an SMA adapter. The loss on the jumpers is largely due to the attenuation at the junction between the built-in cable and the jumper.

Individual broken fibers will further decrease the response of the cable. Each broken fiber results in approximately a 5% loss in response.

4.2 LED Check for Fiber Optic Cable

The FieldSpec spectroradiometer allows you to perform a visual verification of the fiber optic cable using built-in LEDs, a magnifier placed on the fiber optic cable, and the **Fiber Check** software.

WARNING! The Fiber Check utility produces rapid flashing lights in the SWIR 1 and 2 region's optical fibers. If you are susceptible to epileptic seizures, exercise caution or avoid using the Fiber Check utility.

- Step 1 Remove any fore optic accessories from the spectrometer's fiber optic cable.
- Step 2 Attach the magnifier to the end of the fiber optic cable, as shown in [Figure 4-1](#).

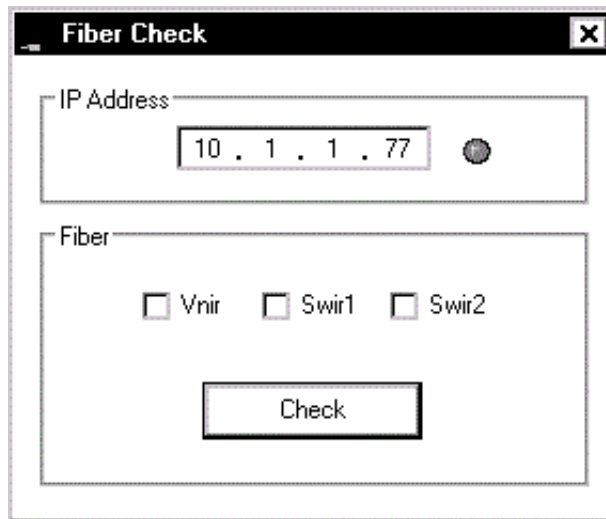


Figure 4-1 Magnifier for testing the fiber optic cable.



- Step 3 On the instrument controller, exit any ASD applications that might be running and communicating with the unit. Such applications include RS³ and Indico.
- Step 4 Make sure that the spectrometer is turned on.
- Step 5 Start the **Fiber Check** application,
 - Through the Desktop icons.
 - From the **Start** menu under **All Programs->ASD Programs->Fiber Check**.

Figure 4-2 **Fiber Check** Program



- Step 6 Make sure the IP address configured is the one for your spectrometer.



Step 7 Use the mouse to select the checkbox for the LED to turn on: VNIR, SWIR1, or SWIR2. One or more may be selected at once.

Note: If you select a range that the spectrometer doesn't have, that particular LED will not be available to turn on. Nothing will be harmed.

Step 8 Select the **Check** button which turns on the selected LEDs.

Step 9 Look through the magnifier to see which fibers light up.

Figure 4-3 Internal spectrometer LED shining to test fiber optic cable.



Step 10 Use the checkboxes and the **Check** button shown in [Figure 4-2](#) to turn on and off different LEDs.

Note: The RED LED for VNIR may be hard to see when the other ranges are enabled.

Step 11 When you are finished, shutdown the **Fiber Check** application.

Things to note:

- The LEDs will only turn on for the ranges installed in the spectrometer. Selecting one that the spectrometer doesn't have will not cause a problem.
- Each range has a different LED color so that you can see the fibers in the cable that are associated with it: RED for VNIR; WHITE for SWIR1; GREEN for SWIR2.
- The fiber bundle for each range contains 19 fibers.
- Each broken fiber results in a 5% loss of response.

The instrument can be successfully used with a few broken fibers in each range, although with a reduction in signal strength.

For severely damaged fiber optic cables, send the instrument back to Analytical Spectral Devices, Inc. in its carrying case for repairs.



4.3 Fore Optic Discussion

The fiber optic cable provides the flexibility to adapt the instrument to a wide range of applications. Field measurements can be performed:

- holding the pistol grip by hand, or
- mounting the pistol grip and other foreoptic accessories to a tripod.

Reflected radiance and surface reflectance measurements are typically made using the hand-held configuration. The pistol grip is available with both a sighting scope and leveling device when required for more precise orientation.

These accessories allow viewing the exact spot where the foreoptic is pointed and orienting the foreoptic in precise, nadir-viewing, geometry. The majority of irradiance measurements are performed with the irradiance receptor mounted level on a tripod because of the need for precise geometric orientation.

Field of View

ASD's line of spectroradiometers is available with a wide selection of foreoptics. These interchangeable foreoptics allow the flexibility to adapt the FieldSpec spectroradiometer to a wide range of applications.

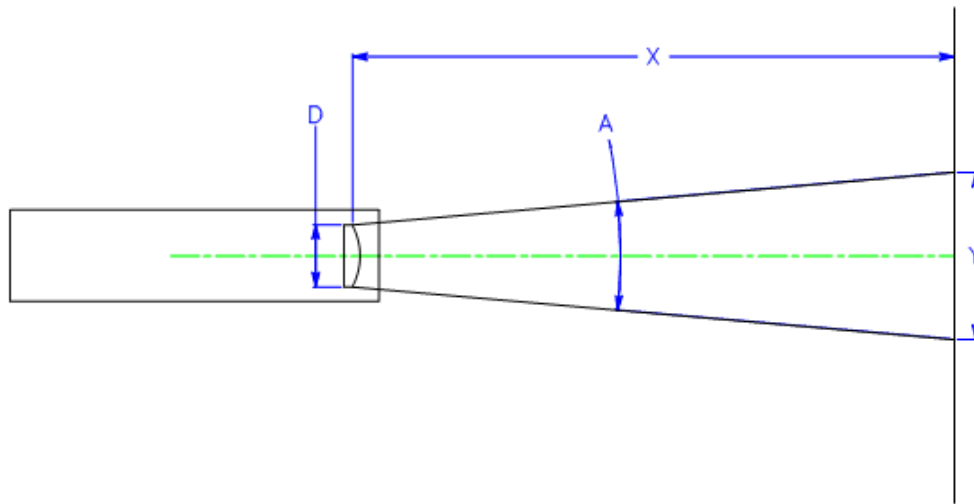
The small size of the FieldSpec's foreoptics allows positioning the foreoptics at a greater distance from the surface under observation.

A field spectroradiometer with a larger field of view means that fewer measurements are needed to approximate the spatial resolution of the imaging sensor, because the pixel size of most imaging sensor systems is several meters or more.

The small size of the pistol grip and foreoptics greatly reduce errors associated with instrument self-shadowing. Even when the area viewed by the foreoptic is outside the direct shadow of the spectrometer, the instrument still blocks some of the illumination that would normally be striking the surface under observation, either diffuse skylight or light scattered off surrounding objects. Thus, the instrument as well as other objects — including the user — should be placed as far as possible from the surface under observation. This orientation requirement also applies to white reference measurements.



Figure 4-4 Field of View and spot size



D == effective diameter of foreoptic lens
 A == foreoptic's angular field-of-view
 X == distance to viewed surface
 Y == diameter of field-of-view

Near Field (less than 1 meter):

$$Y = D + 2 * X * \tan(A/2)$$

Far Field (greater than 1 meter):

$$Y = 2 * X * \tan(A/2)$$

Table 4-1 Values of D in mm for ASD Foreoptics

	FR	VNIR	HH
1°	44.1	17.7	8.6
2°		9.7	
3°	16.5	7.0	
3.5°			3.4
4°		5.7	
7.5°			2.3
8°	7.9	3.7	
10°	6.8	3.3	2.0



Irradiance Observations

ASD has several types of foreoptics for irradiance measurements. These include:

- ASD's in-air cosine corrected receptors for measurement of total irradiance
- ASD's accessories for measurement of direct irradiance
- ASD's under-water cosine corrected receptors for measurement of in-water up- and down-welling irradiance



Notes:

Chapter 5 Batteries

The battery specifications are:

Type:	NiMH (Nickel-Metal Hydride).
Rating:	12 V 9 amp hour
Life:	Over four (4) hours using a full-range FieldSpec spectroradiometer with a Contact Probe in an ambient environment. Nine (9) hours using a VNIR-only FieldSpec spectroradiometer with accessory not powered by the instrument in an ambient environment.

Note: How long the spectroradiometer will run with a fully charged battery depends on many variables including battery age, instrument configuration, environment, and accessories powered by the accessory power port.

5.1 Battery Care

Proper care of the NiMH rechargeable batteries assures long life.

NiMH batteries can store 50% more power than NiCad and do not suffer from memory effects. Unlike NiCad batteries, NiMH batteries do not use heavy metals that may have toxic effects. Still, never drop NiMH batteries on a hard surface.

New NiMH rechargeable batteries can last from 500 to 1000 charges.

When you receive a new battery pack, charge it fully before using it the first time regardless of it showing full voltage and power. It can take from three (3) to five (5) charge-and-discharge cycles before the battery pack reaches its peak performance.

At normal room temperature, NiMH batteries generally lose about 1% of their charge per day. Higher temperatures increases this loss, while lower temperatures (40-60F) can reduce this daily loss. The daily charge loss is not a significant factor if the batteries are used within the first five to ten days after they have been charged.



One of the best ways to ensure that the NiMH batteries last as long as possible is to use them often. The more they are charged and used, the longer the NiMH batteries last.

Whether discharged or not, the NiMH batteries should be charged at least every sixty (60) days.

WARNING! Do not use batteries other than those supplied by ASD. Do not use ASD batteries in a manner unauthorized by ASD. Using improper batteries or improper use of ASD batteries could result in bodily injury or damage to the instrument.

5.2 Battery Charger

The battery charger specifications:

Type:	External Desktop
AC Input:	90-240 VAC, 50/60 Hz
DC Input:	12 V 1.5 A
Charge Time:	under 8 hours for a fully discharged 9 AH battery

Note: Do not unplug the charger and leave the batteries in the charger. Remove the batteries first, or they will discharge through the charger.

The battery charger is designed for indoor use and should not come in contact with water or dust.

Review the charger instruction manual for details.

LED Status indicator:

- The LED will be ORANGE if the battery is not connected.
- The LED will be ORANGE during initialization and analysis.
- The LED will be RED during a fast charge.
- The LED will turn GREEN with intermittent ORANGE flash when in top-off charge.
- The LED will be GREEN during trickle charge.



- The LED will be alternating ORANGE-GREEN when there is an error.

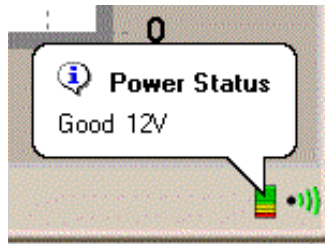
Caution! *The FieldSpec spectroradiometer will stop collecting spectra when the battery drains to about 9.7 volts and the software will post a “Spectrometer Isn’t Ready” message. However, the instrument and attached probe will continue to draw current if power is left on. Power down the instrument and remove probe as soon as possible when the above message occurs.*

5.3 RS₃ Battery Indicator

The RS₃ application from ASD has a **Power Status**. It is located at the bottom of the main window next to the **Connection Status**. The volt level of the spectrometer will be reported in the balloon type window.

- 11-12 Volts is considered good (full).
- <11 Volts issues a warning.

Figure 5-1 Example of a **Power Status**.





Notes:

Chapter 6 *Transporting and Carrying the FieldSpec® 3 Spectroradiometer*

This chapter details how the shipping case, Ergonomic Pro-Pack, and FieldSpec spectroradiometer are designed to be used. This includes:

- [Packing FieldSpec® 3 Spectroradiometer for Shipment](#)
- [Preparing the FieldSpec® 3 Spectroradiometer and Ergonomic Pro-Pack for the Field](#)
- [Carrying Supplies](#)
- [Protecting the Instrument in the Field](#)

6.1 Packing FieldSpec® 3 Spectroradiometer for Shipment

The Ergonomic Pro-Pack is an integral part of the padding used for the FieldSpec spectroradiometer in the shipping case. The main reason for this is to allow the Ergonomic Pro-Pack to be packed with the spectroradiometer, so that both can be conveniently transported to the destination for field work where both would be needed.

Therefore, the first steps required for preparing the FieldSpec spectroradiometer for transport with the shipping case involve putting the spectroradiometer into the Ergonomic Pro-Pack.



Figure 6-1 The FieldSpec spectroradiometer in the Ergonomic Pro-Pack with cable loosely coiled in the netting.



Step 1 Coil the fiber optic cable loosely and place in the netting on top of the FieldSpec spectroradiometer, as is shown in [Figure 6-1](#).

Do not leave the fiber optic cable in the external spool that attaches to the outside of the Ergonomic Pro-Pack or the battery pouches on the belt.

WARNING! **The fiber cable should never be stored with a bend of less than a 5" diameter for long periods of time, because the cable can be damaged with undetectable longitudinal fractures that can cause light leakage and weaker signals.**

Step 2 Place the spectroradiometer into the Ergonomic Pro-Pack with the plastic end-caps towards the top and bottom of the pack.

The spectroradiometer can be oriented in the Ergonomic Pro-Pack with the fiber optic cable either to the right or left. Cut-outs in the shipping case lid and floor provide room for the fiber optic cable for either orientation.

Note: When facing the outside of the pack, we recommend putting the fiber optic cable on the left (as shown in [Figure 6-1](#)), because this puts the cable on top when placed into the shipping case.



Figure 6-2 The FieldSpec spectroradiometer strapped into the Ergonomic Pro-Pack.



Step 3 Fasten the five (5) holding straps of the Ergonomic Pro-Pack to hold the spectroradiometer in place. Two straps are on each side and one at the top.

Figure 6-3 Ergonomic Pro-Pack with the instrument controller.



Step 4 Place the instrument controller into its compartment of the Ergonomic Pro-Pack and zip up the zippers.



Figure 6-4 Folding the left battery pouches into the Ergonomic Pro-Pack.



Figure 6-5 Folding the right battery pouches into the Ergonomic Pro-Pack.



Step 5 When facing the outside of the Ergonomic Pro-Pack, fold the left battery pouch on the pack belt in first and then the right, as is shown in [Figure 6-4](#) through [Figure 6-5](#).

Note: Folding the pack belt (pouches) as given in [Step 5](#) assists sliding the pack into the case, because there is only one orientation for placing the Ergonomic Pro-Pack into the shipping case.



Figure 6-6 Placing the Ergonomic Pro-Pack with FieldSpec spectroradiometer and instrument controller into the shipping case.



Step 6 Place the Ergonomic Pro-Pack with spectroradiometer and instrument controller into the shipping case using the handle straps at the top and the hip belt at the bottom of the pack, as is shown in [Figure 6-6](#).

Note: There is only one orientation for placing the Ergonomic Pro-Pack into the shipping case. The shipping case has cut-outs intended for the fiber optic cable in the floor and the lid. Therefore, the FieldSpec spectroradiometer can be oriented in the Ergonomic Pro-Pack with the fiber optic cable on either side. We recommend following these instructions which puts the fiber optic cable on top when placed in the case.

Figure 6-7 Shipping case with Ergonomic Pro-Pack with FieldSpec spectroradiometer and instrument controller.





- Step 7 Place into the shipping case any accessories for the FieldSpec spectroradiometer, instrument controller, and Ergonomic Pro-Pack.

6.2 Preparing the FieldSpec® 3 Spectroradiometer and Ergonomic Pro-Pack for the Field

When you arrive on site and unpack the FieldSpec spectroradiometer from its shipping case, you will need to re-pack the spectroradiometer in the Ergonomic Pro-Pack before use.

The Ergonomic Pro-Pack and FieldSpec spectroradiometer are designed for both right-handed and left-handed use.

- Note: Think twice before orienting the FieldSpec spectroradiometer to have its fiber optic cable on your dominant side in the Ergonomic Pro-Pack, because you may want your dominant hand free for other tasks, like one-handed typing. Generally speaking, operating the fiber optic accessory will probably require less dexterity than operating the instrument controller and typing one-handed. Taking this into consideration could affect the decision about which side the fiber optic accessory will be placed on.

- Step 1 Follow the instructions given in [Chapter 2](#) for unpacking the FieldSpec spectroradiometer and Ergonomic Pro-Pack from the shipping case.
- Step 2 Place the Ergonomic Pro-Pack on a flat surface with the shoulder straps towards the floor.
- Step 3 Remove the instrument controller from its compartment on the outside of the Ergonomic Pro-Pack.
- Step 4 Undo the five (5) plastic connectors which hold the spectroradiometer in the Ergonomic Pro-Pack.
- Step 5 Determine which hand will be using using the fiber optic accessory. [Figure 6-8](#) shows the fiber optic cable on the left-hand side, because the user wanted his right-hand free to operate the instrument controller.
- Step 6 Orient the spectroradiometer in the Ergonomic Pro-Pack such that the fiber optic cable is on that side.
- Note: The FieldSpec spectroradiometer has to have its plastic end-caps aligned with the top and bottom of the Ergonomic Pro-Pack. Other than this, the orientation of the spectroradiometer in the pack doesn't matter (e.g., cable side on left or right; mesh side close to the shoulder straps or away)
- Step 7 Use the five (5) straps to secure the spectroradiometer in the pack.



Figure 6-8 Fiber optic cable routes to either side.



Step 8 If you are using the fiber optic spool, determine where you want to attach it.

[Figure 6-9](#) and [Figure 6-13](#) show the fiber optic spool on the outside of the Ergonomic Pro-Pack, where it attaches with velcro.

[Figure 6-10](#) and [Figure 6-14](#) show where the fiber optic spool attaches to one of the battery pouches on the hip belt with metal snaps.

The fiber optic spool is optional and may not even be needed for short cables. The battery pouches on the hip belt have velcro loops for holding the cable, as is shown in [Figure 6-11](#).

Figure 6-9 Fiber optic spool on the outside of the Ergonomic Pro-Pack (with velcro).





Figure 6-10 Fiber optic spool and where it attaches with snaps to the battery pouch on the hip belt.



Figure 6-11 Loops for the fiber optic cable on the battery pouch of the hip belt.



- Step 9 Place the battery into the pouch on the belt on the opposite side of the Ergonomic Pro-Pack from where the fiber optic cable is. Refer to [Figure 6-12](#).
- Step 10 Feed the battery cable up from the battery pouch under the cross strap to the power input of the FieldSpec spectroradiometer, as shown in [Figure 6-12](#).



Figure 6-12 Routing the battery cable to the FieldSpec spectroradiometer.



Figure 6-13 Fiber optic cable spool on the outside of the Ergonomic Pro-Pack.





Figure 6-14 Fiber optic cable spool on the battery pouch on the hip belt.



Step 11 Attach the belly board to the plastic connectors on the shoulder straps of the Ergonomic Pro-Pack, as shown in [Figure 6-15](#).

Figure 6-15 Belly board attaches to the shoulder straps of the Ergonomic Pro-Pack.



Step 12 Place the instrument controller onto the velcro of the belly board.



Figure 6-16 FieldSpec spectroradiometer in the Ergonomic Pro-Pack and instrument controller on the belly board.



6.3 Carrying Supplies

The Ergonomic Pro-Pack is designed for the FieldSpec spectroradiometer. The large mesh pocket at the bottom of the pack is intended for ventilation and to keep the instrument from overheating.

WARNING! Do not carrying clothing or other supplies in the lower mesh pocket, particularly if they are large enough to prevent air flow into the FieldSpec spectroradiometer.

The straps on the outside of the pack are intended for tying on clothing or other large items.



Figure 6-17 Allow for proper ventilation of the FieldSpec spectroradiometer.



6.4 Protecting the Instrument in the Field

The Ergonomic Pro-Pack has a small interior pocket near its top which holds a rain flap, as is shown in [Figure 6-18](#) and [Figure 6-19](#).

Caution! *The rain flap is water resistant, but not water proof.*

In the event of bad weather out in the field, place the instrument controller into its compartment on the outside of the Ergonomic Pro-Pack. Make sure both the spectroradiometer and instrument controller are turned off. Then pull the rain flap out of its compartment and over the outside of the pack. The shoulder straps are still free allowing you to hike towards shelter.



Figure 6-18 Rain flap storage in the Ergonomic Pro-Pack.



Figure 6-19 Rain flap covering the unit.



WARNING! Do not attempt to use the spectroradiometer with the rain flap deployed. The spectroradiometer may overheat, because the rain flap prevents adequate air from circulating to the instrument.



Notes:

Chapter 7 *Field Measurements*

Field spectrometry is the quantitative measurement of radiance, irradiance, reflectance or transmission in the field. It involves the collection of accurate spectra and requires an awareness of the influences of:

- Sources of illumination.
- Atmospheric characteristics and stability.
- Winds.
- Instrument field of view.
- Target viewing and illumination geometry.
- Instrument scanning time.
- Spatial and temporal variability of the target characteristics.

Spectral field measurements are desirable for many reasons, not all related to remote sensing.

- Field spectra of ground targets on the scale of the imaging sensor using ambient solar illumination can be used to convert radiance images to reflectance (Conel et al., 1987a & 1987b).
- Field spectra of target materials allows for more precise image analysis and interpretation (Goetz and Srivastava, 1985).
- Field spectroscopy can perform feasibility studies to understand if and how a process or material of interest can be detected using remote sensing.
- Field spectra of both the material(s) of interest and spectra of other materials present in the environment can be used to address:
 - » What spectral and spatial resolutions are required for detection?
 - » What is the best time of year/day for detection?
 - » What signal-to-noise ratio is required for detection?
- Field spectra can be used to make direct material identifications in the field rather than collecting samples for later laboratory analysis.

The first step in the development of a field experiment is the definition of the overall experimental design. Unfortunately, the formulation of an appropriate experimental design is not always obvious.



Issues such as the timing of the data collection, spatial scale of the field measurement, target viewing and illumination geometry, and the collection of ancillary data sets must be considered in light of the objectives of the study. The lack of appropriate ancillary data sets often makes previously collected data sets unusable for a new application.

Frequently, the experimental design must be modified to account for the characteristics of the available instrumentation.

For example, vegetation canopy spectra collected using a slow scanning instrument will sometimes have small wind-induced “absorption” features in those portions of the spectra when the instrument was viewing more shadow.

7.1 Illumination

In order to determine the reflectance or transmittance of a material, two measurements are required:

- The spectral response of a reference sample.
- The spectral response of the target material.

The reflectance or transmittance spectrum is then computed by dividing the spectral response of the target material by that of a reference sample.

Using this method, all parameters which are multiplicative in nature and present in both the spectral response of a reference sample and the target material, are ratio-ed out, such as:

- The spectral irradiance of the illumination source.
- The optical throughput of the field spectrometer.

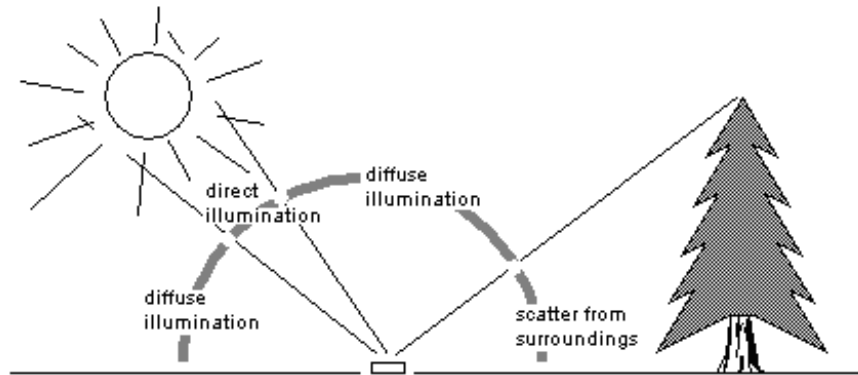
Note: An inherent assumption when determining the reflectance or transmittance of a material in the field is that the characteristics of the illumination are the same for the reference and target materials. *Variability of the illumination characteristics* between the time the reference and target materials are measured *will result in errors in the resultant spectra.*

7.2 Characteristics of Natural Illumination

Field spectrometry typically involves the ambient solar illumination. As such, the target can be illuminated by three or more sources (see [Figure 7-1](#)), each with its own spectral characteristics (Curtiss and Ustin, 1988). Unless the target is in a shadow, the direct solar illumination is the dominant source of illumination.



Figure 7-1 The major sources of illumination.



Note: It is possible to have several sources of light scattered off of surrounding objects, each with its own unique spectral distribution.

Parameters such as solar elevation angle and atmospheric conditions will effect the overall intensity and spectral characteristics of direct solar illumination. Diffuse skylight illumination can contribute as much as 5-10% of the total illumination reaching a surface. At shorter wavelengths, diffuse skylight can contribute as much as 20-25% of the total.

The spectral characteristics of the illumination scattered off of surrounding objects is determined by their reflectance characteristics. In the case of a forest clearing, as much as 20% of the illumination in the 750-1200 nm wavelength range can be attributed to sunlight scattered off the surrounding forest canopy (Curtiss and Ustin, 1988).

One important source of surrounding scattered light is the person and the instrumentation making the measurement. Objects in the surroundings also effect the overall illumination of the target surface by obscuring a portion of the diffuse skylight and, possibly, shading the target from direct solar illumination.

The magnitude of both the diffuse skylight and scattered from surrounding illumination components is determined by the solid angle subtended by these sources when viewed from the reference frame of the target surface.

The surface texture of the material being measured also affects the relative portion of the various sources of illumination. When compared to a smooth surface, a surface with a rough texture will tend to have a higher portion of illumination from the diffuse and scattered-from-surroundings sources relative to the direct solar illumination (Curtiss and Ustin, 1988).

7.3 Characteristics of Artificial Illumination

The use of artificial illumination allows:



- More control over illumination and viewing geometry.
- More control over sample geometry.
- Measurements during non-optimal conditions (e.g. cloud cover or at night).
- Measurement of reflectance and transmittance in the deep atmospheric absorption bands.

Several problems with using artificial illumination include:

- Difficulty in maintaining a constant distance between the sample or reference and the light source when measuring samples with irregular geometry.
- “Cooking” vegetation samples under the lights (water loss, chlorophyll degradation).

In a typical lamp configuration for indoor use, the sample is viewed with the collecting optics of the spectrometer nadir to the sample. Use one or two 200 to 500 Watt quartz-halogen cycle tungsten filament lamps (~3400°K color temperature) in housings with aluminum reflectors about 1 meter above the surface being measured.

Alternatively, the light source can be either incorporated into the field spectrometer (often precluding the use of solar illumination) or can be provided in the form of an optional accessory that mounts to the light collecting optics of the instrument.

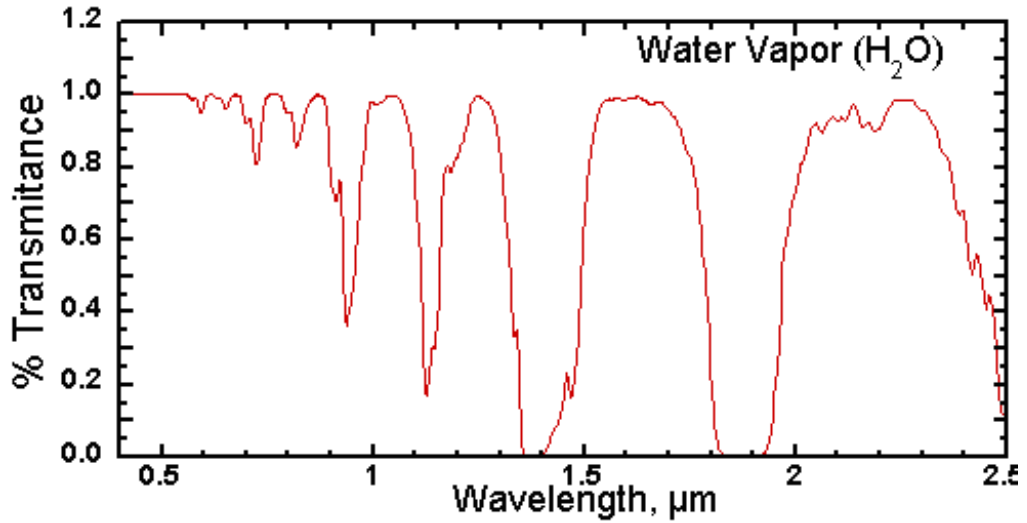
7.4 Atmospheric Characteristics

Absorbing molecules in the atmosphere strongly modify the incoming solar irradiance (Goetz, 1992). All of the absorption features will increase in intensity as the atmospheric path length of the incoming solar radiation increases (e.g. with changing solar elevation angle).

By far, water vapor is the strongest modifier of the incoming solar spectrum (Gao and Goetz, 1990). Water vapor has absorption features spanning the solar reflected region of the spectrum (see [Figure 7-2](#)), and varies both spatially and temporally.

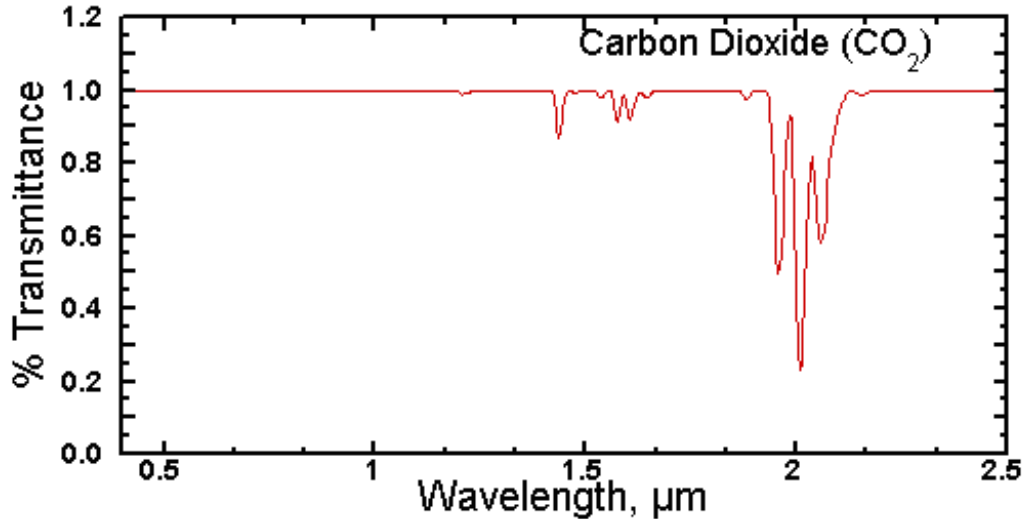


Figure 7-2 Transmission spectrum of water vapor for typical atmospheric conditions



Carbon dioxide has strong features in the 2000-2200 nm range (see [Figure 7-3](#)), a region of major interest for the identification of layered silicate minerals (Goetz, 1992). Carbon dioxide is a well mixed gas, thus the intensity of the absorption features associated with carbon dioxide are not as variable as those of water vapor, but they do decrease with increasing altitude.

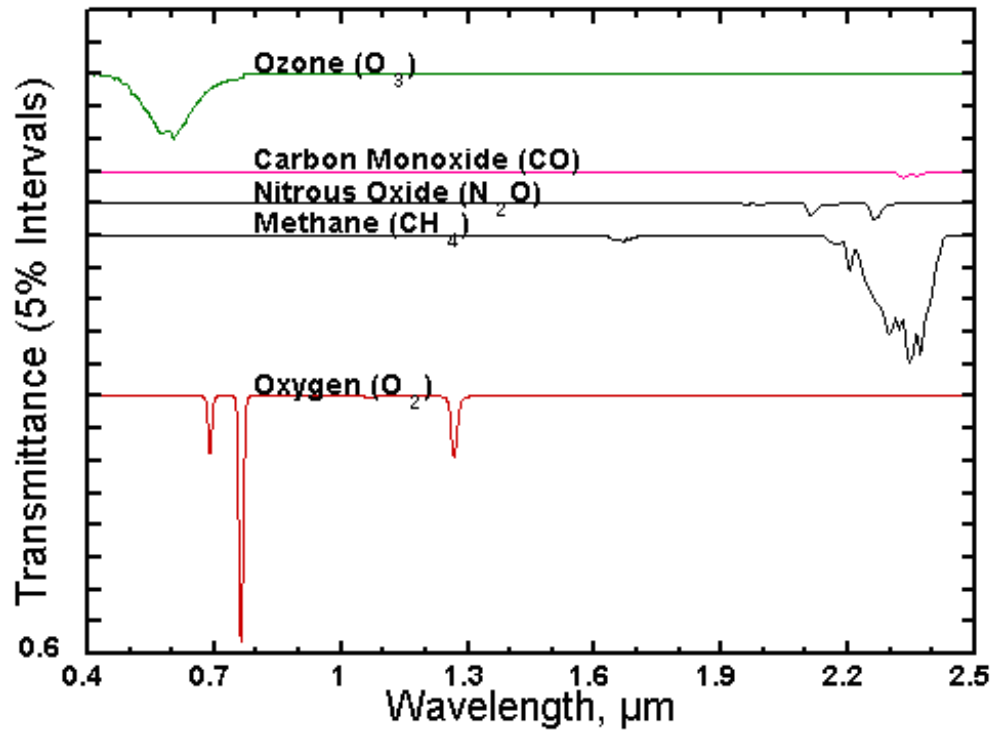
Figure 7-3 Transmission spectrum of carbon dioxide for typical atmospheric conditions.



Other major atmospheric components that influence the atmospheric transmission spectrum are shown in [Figure 7-4](#).



Figure 7-4 Transmission spectrum of various gases for a typical atmospheric conditions.



7.5 Clouds

The presence of partial cloud cover is indicative of highly spatially and temporally variable atmospheric water vapor (Gao and Goetz, 1992).

Because of the large influence of water vapor on the atmospheric transmission (see [Figure 7-2](#)), variability of atmospheric water vapor between the time when the reference and target measurements are made will result in errors in the resultant spectrum.

Note: This error can be reduced by minimizing the length of time between the measurement of the reference sample and the target.

While they are difficult to see and often appear inconsequential, the presence of cirrus clouds tends to educe significant variability in atmospheric water vapor (Gao and Goetz, 1992).

In addition to the errors produced by time varying atmospheric water vapor, partial cloud cover also greatly increases the intensity of diffuse skylight illumination (Curtiss and Ustin, 1988). This tends to “fill in” shadows and reduce the contrast between surfaces with dissimilar surface textures.

Note: If the goal is to collect field spectra for image calibration or interpretation, spectra should be collected under illumination conditions similar to those at the time the image was collected.



Measure the Magnitude of the Effect Cirrus Clouds

- Step 1 Simply standardize the field spectrometer on the reference panel.
- Step 2 Continue to view the reference panel with the instrument.
- Step 3 If the atmospheric conditions are stable, the computed reflectance of the panel will be a flat spectrum with near 100% reflectance.
- Step 4 If atmospheric conditions are unstable, the computed reflectance of the panel will vary over time and will show absorption minima or maxima (depending on whether atmospheric water vapor is increasing or decreasing) at the wavelengths corresponding to the water vapor absorption features.

In this way, it can be determined whether spectral data with sufficient accuracy can be acquired.

7.6 Wind

Wind can be a source of error if the material being measured moves during the time the spectrum is acquired.

If a spectrum is slowly scanned, changes in the amount of shadow in the instrument field-of-view will result in erroneous “features” in the spectrum.

Vegetation canopies, with their large portion of shadow, are especially susceptible to wind induced errors.

Note: Instruments using an array detector or that scan the spectrum rapidly are not significantly affected by wind.

7.7 Vegetation

Because of the complex three dimensional geometry of a plant canopy, light returned from the canopy is a complex mixture of multiply reflected and/or transmitted components (Curtiss, 1990; Curtiss and Maecher, 1991; Curtiss and Ustin, 1989).

The canopy level optical signal is dependant upon:

- Illumination and viewing geometry.
- Canopy structure.
- Leaf optical properties.
- The optical properties of other vegetative and non-vegetative components within and below the canopy.



Only by controlling the viewing and illumination geometry can changes be detected in canopy reflectance. True differences in canopy reflectance between several canopies may be due to either differences in canopy structure or in leaf/needle optical properties (Curtiss and Maecher, 1991).

For example, a conifer canopy will appear darker in the infrared than the broad leaf canopy even though the reflectance of the individual needles and leaves may be almost identical for almost all viewing geometries.

Observed differences in canopy level reflectance may be attributed to differences in either leaf level optical properties or other, larger scale, structural properties of the canopy. Important structural properties include:

- leaf/needle size
- leaf/needle density at the branch level
- number of years of needles retained (conifers)
- branching angles

When differences are observed between canopies of the same species, it is almost always due to differences in canopy or branch level structure.

The absorption features seen in vegetation spectra are all related to organic compounds common to the majority of plant species (Peterson et al., 1988; Gao and Goetz, 1992).

Thus, the information about a plant canopy is contained in the relative intensity of the various absorption features rather than in the presence or absence of a specific absorption feature.

The major spectral absorption features can be attributed to:

- water
- plant pigments
 - » chlorophyll
 - » zanthophyll
 - » carotenoids

Other, minor, absorption features are attributable to other chemical components; these include:

- cellulose
- lignin
- proteins
- starches
- sugars

Non-photosynthetic components of the canopy have spectra which are dominated by absorption features attributed to lignin and cellulose.



The spectral radiance leaving a vegetation canopy is significantly impacted by many factors, such as those listed in [Table 7-1](#).

Table 7-1 Major variables affecting the Bidirectional Reflectance Distribution Function (BRDF) of a vegetated canopy

Illumination	<ul style="list-style-type: none"> • Geometry <ul style="list-style-type: none"> » angle-of-incidence of Sun (or Radar) » azimuth • Spectral characteristics
Sensor	<ul style="list-style-type: none"> • Canopy <ul style="list-style-type: none"> » type (plant or tree nominal class) » closure » orientation <ul style="list-style-type: none"> » systematic (e.g., rows) » unsystematic (random) • Crown <ul style="list-style-type: none"> » shape (e.g., circular, conical) » diameter (m) • Trunk or Stem <ul style="list-style-type: none"> » density (units per m²) » tree diameter-at-breast-height: tree trunks or plant stems have a certain density. • Leaf <ul style="list-style-type: none"> » leaf-area-index: defines the area that interacts with solar radiation; the surface that is responsible for carbon absorption and exchange with the atmosphere. » leaf-angle-distribution: may change throughout the day as the leaves orient themselves toward or away from the incident radiation.
Understory	same as vegetation
Soil	<ul style="list-style-type: none"> • Texture • Color • Moisture content



7.8 Rocks, Soils, and Man-made Materials

The shape of the spectral signature of rocks and soil tends to be invariant with varying viewing geometry, unlike vegetation. The overall brightness of the observed spectrum does change with illumination and viewing geometry due to changes in the amount of shadow in the field-of-view of the spectrometer.

Absorption features in the spectra of rocks and minerals are due to the presence of specific molecular groups and are often diagnostic of the minerals present in the sample (Abrams et al., 1877; Hunt, 1980).

The dependence of the optical properties of man-made objects on the viewing and illumination geometry will fall somewhere between that for vegetation and rocks/soils. This will depend on the amount of light transmission through elements of the target and on the surface texture of the object.

The reflectance spectra of objects with translucent elements and highly textured surfaces have an angular dependence more like vegetation, while those with opaque elements have an angular dependence more like spectra of rocks and soils.

7.9 Experimental Design

7.9.1 Time of Day / Year

The timing of the field data collection is important if field spectra are to be used to calibrate or interpret a hyperspectral image. Reflectance spectra used to interpret a hyperspectral image should be collected under illumination conditions similar to those when the image was acquired.

Time of day and date are the major controlling factors of direct illumination geometry, while atmospheric conditions relating to scattering and clouds are the major factors controlling the geometry and relative intensity of indirect illumination (Curtiss and Ustin, 1988).

If field spectra are to be used to convert a hyperspectral sensor image to reflectance, spectra should be acquired simultaneously with image acquisition. If this is not possible, a water vapor correction should be made to the image prior to its conversion to reflectance (Gao and Goetz, 1990).

7.9.2 Sampling Strategy

The selection of a particular sampling strategy should be based upon the objectives of the study. If the objective is to determine the detectability of either a target material or of a process effecting the spectral signature of a



target material, the sampling strategy must encompass examples of the target material under all expected conditions as well as all other background materials.

Consideration must be given to all the processes modifying target and background spectral signatures; these include illumination, slope and aspect, and target surface architecture. Adequate collection of vegetation is even more problematic due to the wide range of processes that effect their spectral signature. These include soil chemical properties, soil reflectance, water availability, time of day, time of year, cloud cover, temperature, and relative humidity.

If the purpose of a study is to understand how a process effects the spectral signature of a target without consideration of how background materials and other sources of variability effect the spectral signature, variance from sources other than the one of interest should be minimized in the selected targets. This is achieved by carefully controlling viewing and illumination geometry, often in a laboratory. This type of study is often performed as a feasibility study prior to a full study evolving collection of spectra of background material.

7.9.3 Viewing Geometry

The selection of an appropriate viewing geometry depends upon whether the spectra are used for image analysis or for a feasibility study.

Image analysis: a viewing geometry similar to the airborne sensor is required.

Feasibility study: it is possible to eliminate much of the confounding variance typically present in an image data set by fixing the viewing and illumination geometry.

For vegetation, spectra can be acquired at the spatial scale of the leaf/needle, branch, or canopy. Canopy level spectra are most suitable for image analysis and interpretation. Rarely can leaf/needle or branch level spectra be used directly to interpret an image. Leaf/needle and branch level spectra are useful to understand how the canopy level spectra are influenced by changes in leaf/needle and branch spectral changes as opposed to changes in the canopy structure.

7.10 Suggested Set-up

- Step 1 Open the **control configuration** in the application.
- Step 2 Set the sample, white reference, and dark current averages to 10 scans.

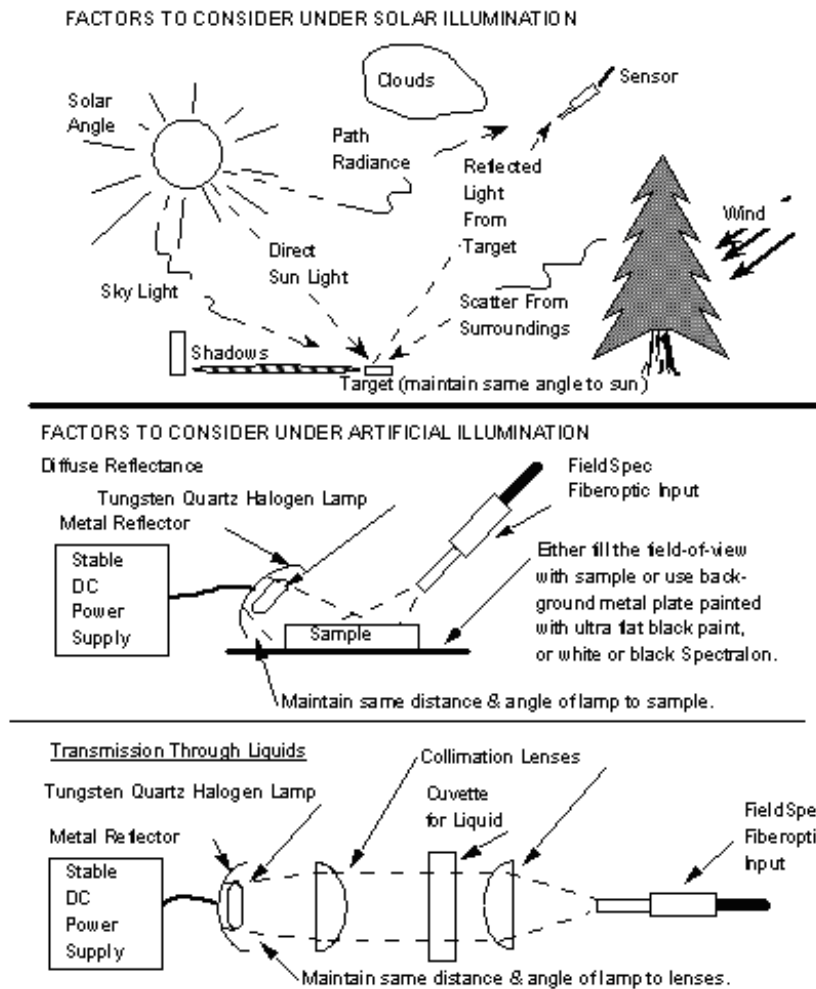
For example, White Spectralon (Labsphere, Inc., Shaker St., PO Box 70, North Sutton, NH 03260-0070, PH: 603-927-4266, FX: 603-927-4694, E-mail: sales@labsphere.com, Website: www.labsphere.com). Spectralon is also available from ASD.



- Step 3 **Optimize** the instrument.
- Step 4 Reopen the **control configuration** window
- Step 5 Set the white reference and dark current averages to 60 for indoor illumination, or 150 for outdoor solar illumination.
- For example, ASD ProLamp is a DC stabilized light source for lab use and includes a power supply.
- Step 6 Take **white reference**.
- Step 7 Reopen the **control configuration** window.
- Step 8 Set the spectrum average to 30 for indoor illumination, or 100 for outdoor solar illumination.
- Note: The actual spectrum average will be determined by striking a compromise between noise reduction through averaging the spectra and the time desired for each spectrum collection. For instance, if you are using the instrument in the field and are walking a large area, you will want a shorter average setting than if you are collecting spectra in-situ and desire the cleanest spectra possible.
- Step 9 Observe samples.



Figure 7-5 Solar illumination factors



7.11 White Reference

A material with approximately 100% reflectance across the entire spectrum is called a *white reference panel* or *white reference standard*.

Because the spectrometer only measures the intensity of a light field through a given point in space, a white reference is one method to correlate that measurement with the physical properties of the sample. Reflectance and transmittance are inherent properties of all materials and are independent of the light source.

The ASD application software, such as RS³ and Indico, can calculate the ratios for reflectance or transmittance of the material being sampled by the FieldSpec® 3 Spectroradiometer using the white reference as the standard.

Spectralon® from Labsphere is the white reference standard that is very suitable for the VNIR and SWIR spectral ranges of ASD instruments.



Spectralon is made of polytetrafluoroethylene (PTFE) and has the characteristic of being nearly 100% reflective within the wavelength range of 350 nm to 2500 nm. A Spectralon white reference scatters light uniformly in all directions within that wavelength range.

7.11.1 Spectralon Reflectance Data

Table 7-2 shows the published reflectance data for an uncalibrated SRM-990. When SRM-990 is used as the white reference for a reflectance measurement with the FieldSpec® 3 Spectroradiometer, an even closer reflectance value for the sample can be calculated.

Table 7-2 Labsphere's published reflectance data for uncalibrated Spectralon® (+/- 0.5%)

Wavelength (nm)	SRM-990 "Uncalibrated" Spectralon® Reflectance
250	0.950
300	0.985
400	0.990
500	0.991
600	0.992
700	0.992
800	0.991
900	0.991
1000	0.993
1100	0.993
1200	0.992
1300	0.992
1400	0.991
1500	0.991
1600	0.991
1700	0.988
1800	0.989
1900	0.981
2000	0.976
2100	0.953
2200	0.973



Table 7-2 Labsphere's published reflectance data for uncalibrated Spectralon® (+/- 0.5%)

Wavelength (nm)	SRM-990 “Uncalibrated” Spectralon® Reflectance
2300	0.972
2400	0.955
2500	0.950

Reflectance = Energy reflected from target/energy incident on target

7.11.2 Maintaining Spectralon References

Spectralon is an optical standard and should be handled in much the same way as other optical standards. Although the material is very durable, care should be taken to prevent contaminants such as finger oils from contacting the material’s surface. Always wear clean gloves when handling Spectralon.

To clean a lightly soiled Spectralon white reference

If the material is lightly soiled, it may be air brushed with a jet of clean dry air or nitrogen.

WARNING! DO NOT use Freon.

To clean a heavily soiled Spectralon white reference

Sand the Spectralon material under running water¹ with a 220-240 grit waterproof emery cloth until the surface is totally hydrophobic (water beads and runs off immediately).

- Step 1 Use a flat surface, such as a thick, flat piece of glass.
- Step 2 Place the glass into the sink.
- Step 3 Place 220 grade wet sandpaper onto the glass.
- Step 4 Gently move the Spectralon reference in a figure 8 motion on the sandpaper, using water as needed to wash away the thin layer that is sanded off.
- Step 5 Blow dry with clean air or nitrogen or allow the material to air dry.
- Step 6 If the material requires high resistance to deep UV radiation, the piece should be prepared as above, then either of the following two treatments performed.
 - 1 Flush the Spectralon piece with >18 m¹/₂ distilled, deionized water for 24 hours.



- 2 Vacuum bake the Spectralon piece at 75° C for a 12 hour period at a vacuum of 1 Torr or less. Then purge the vacuum oven with clean dry air or nitrogen.

WARNING! Do not use oils or soaps to clean the Spectralon white reference.

7.11.3 White Reference Procedures

White references should be collected approximately every ten (10) minutes and can be varied depending on whether conditions are changing rapidly or not changing very much. The Spectralon puck should be used when optimizing and taking a white reference measurement.

Note: For best results, the Spectralon puck should be at the same distance and angle from the foreoptic as the sample will be during measurements.

When saving reflectance data, point the probe at the Spectralon once every few measurements for a minute or two with the same viewing geometry. If the relative reflectance of the Spectralon is less than or greater than one, a new white reference may be needed. If the relative reflectance of the Spectralon is greater than one, re-optimization is recommended.

You can change the screen in the RS³ application to view the spectra in raw DN mode without leaving real-time reflectance. This will give you an idea if you are nearing saturation levels in any of the spectrometers. If you are nearing a saturation level or your response has dropped off to a low level, then you would want to re-optimize.

The FieldSpec spectroradiometer should be re-optimized for:

- Light changes.
- Any atmospheric changes or changes in temperature.

Note: Environmental conditions can change rapidly or slowly. It all depends on clouds, wind (affecting temperature), instrument warm up time, etc.

Appendix A Troubleshooting

A.1 Common Communication Fix

To fix many communication errors (particularly if the instrument has been functioning at some point), power cycle the instrument and/or the instrument controller.

Which sequence to use will vary depending on the computer manufacturer. Either:

- Leave the computer on. Turn off the instrument. Wait for 10 seconds. Turn the instrument back on.
- Or, turn off the computer and the instrument. Turn on the instrument. Then turn on the instrument controller.

The 802.11b wireless Ethernet cards within the FieldSpec spectroradiometer and instrument controller can allow communication distances of 30-40 m (100-150 ft). ASD tests the wireless communication up to 30 m (100 ft). However, obstructions or radio frequency interference in close proximity can cause loss of communication or significantly shorten the communication range.

A.2 Does Not Connect to the Spectrometer

- Refer to section [A.1, Common Communication Fix](#).
- Check that the Ethernet cable is securely inserted into the spectrometer and host computer. Check that the Ethernet LED is on.
- For an isolated network, check that the Ethernet cable is a cross-over Ethernet cable.
- For an established network, check that the Ethernet cable is a standard Ethernet cable.
- Check that the IP Address is in the same range and subnet as the ASD spectrometer.



- Do a ping test to make sure the spectrometer is responding.
 - » Open up a command window by select **Start>Run**
 - » Type **cmd** in the **Run** window.
 - » Select **OK** to open the window.
 - » For an Ethernet connection, type: ping 10.1.1.11
 - » For a wireless connection, type: ping 10.1.1.77

Figure A-1 **Run** window with **cmd**.

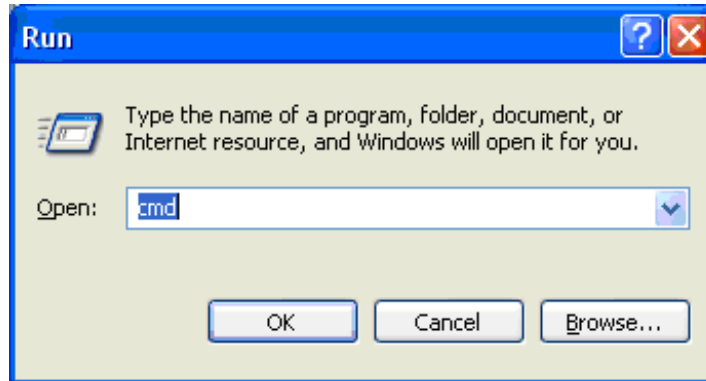
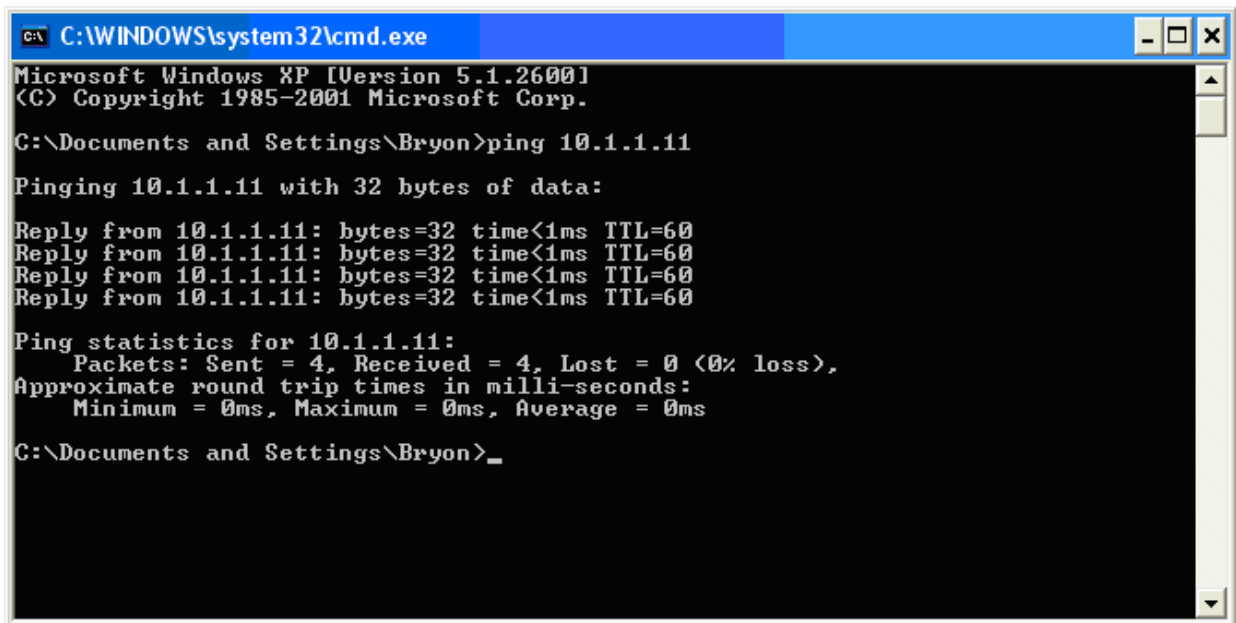


Figure A-2 Successful result of a **ping** operation.



The default IP Address for the ASD spectrometer is:

- 10.1.1.11 for the Ethernet interface, or
- 10.1.1.77 for the wireless interface.

The default subnet mask is 255.255.255.0.



The computer's Ethernet adapter or wireless adapter must have a unique IP address in the same range as the spectrometer, such as 10.1.1.x where **x** is a unique number. The subnet mask must also be the same as the spectrometer, such as 255.255.255.0.

A.3 Can't Get a Wireless Connection

- Refer to section [A.1, Common Communication Fix](#).
- Check to make sure the wireless adapter is in the same range as the ASD spectrometer.

The default IP Address for the ASD spectrometer is:

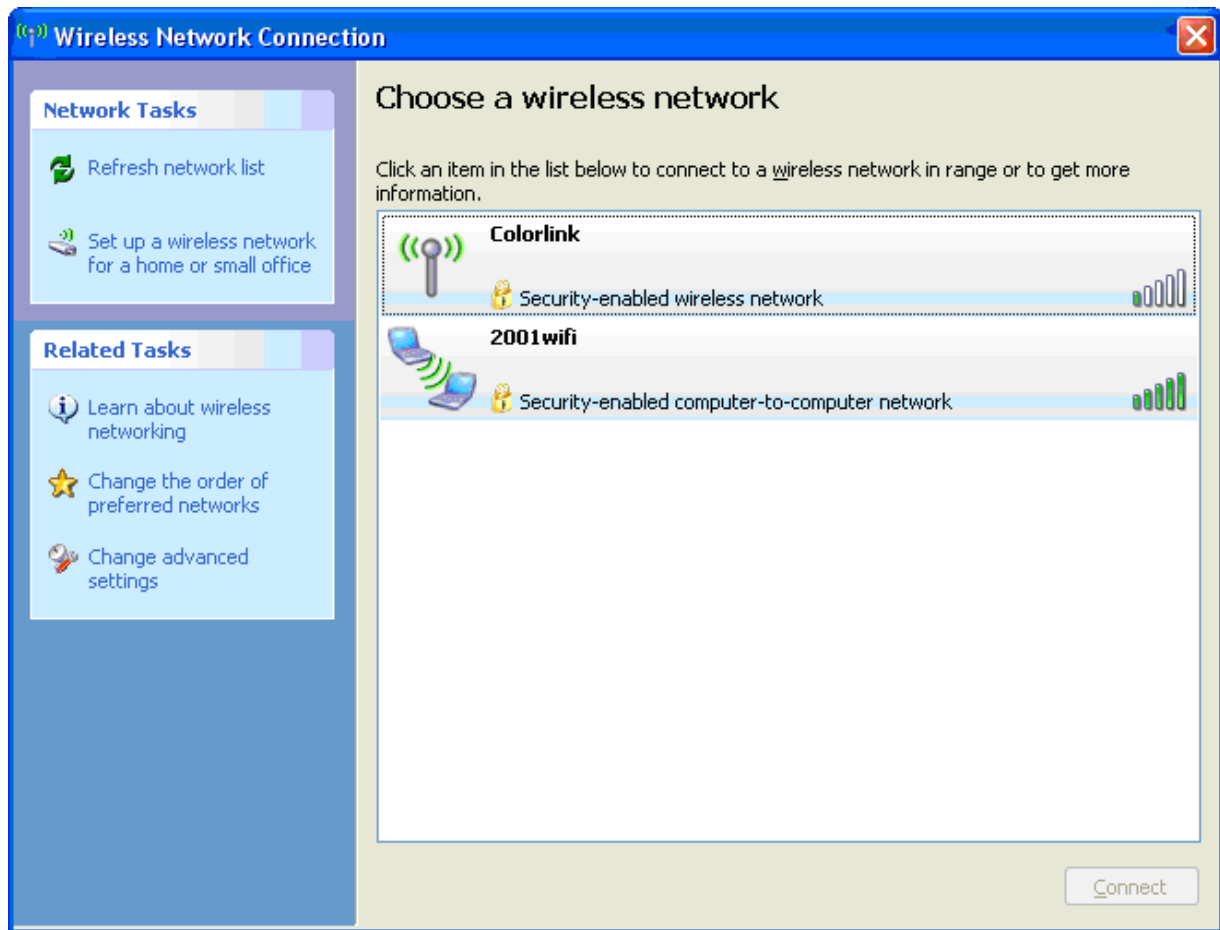
- » 10.1.1.11 for the Ethernet interface, or
- » 10.1.1.77 for the wireless interface.

The default subnet mask is 255.255.255.0.

The computer's Ethernet adapter or wireless adapter must have a unique IP address in the same range as the spectrometer, such as 10.1.1.x where **x** is a unique number. The subnet mask must also be the same as the spectrometer, such as 255.255.255.0.

- Check the to make sure the wireless adapter is connected to the spectrometer. (For Windows XP)
 - » Select **Start>Network Connections**.
 - » Right click on the wireless adapter.
 - » Select **View Available Wireless Networks**.
 - » Make sure the ASD spectrometer shows up in the list of wireless networks. If the spectrometer is not connected,
 - » Select the spectrometer.
 - » Select the **Connect** button.
 - » If you are using encryption, then make sure you are using the same WEP key in the wireless adapter as the ASD spectrometer.
 - » Power cycle the spectrometer.

Figure A-3 Wireless Network Connection.



A.4 Does Not Connect to the Access Point

- Refer to section [A.1, Common Communication Fix](#).
- Check to make sure the wireless interface on the spectrometer is not set to **ad hoc**.
- Check to make sure the **SSID** of the spectrometer is the same as the access point.
- If you are using encryption, then make sure you are using the same **WEP** key in the spectrometer as the access point.
- Move the access point, spectrometer, and instrument controller (computer) to the same room to test the connection.



A.5 Spectrometer Loses its Wireless Connection

- Refer to section [A.1, Common Communication Fix](#).
- Try to minimize the RF noise in your environment. RF noise interference can come from: 2.4 Ghz cordless phones, microwaves, monitors, electric motors, ceiling fan, lights, security systems, etc.
- Positioning of the spectrometer and instrument controller (computer) can affect the wireless range. Minimize obstructions between the spectrometer and the instrument controller. Wall, ceilings, doors, buildings, hills, etc. can degrade the signal of the spectrometer and computer.

A.6 Wireless Interface is Disabled in the Netcfg Application

- Refer to section [A.1, Common Communication Fix](#).
- Check to make sure the wireless adapter is in the same range as the spectrometer.

The default IP Address for the ASD spectrometer is:

- » 10.1.1.11 for the Ethernet interface, or
- » 10.1.1.77 for the wireless interface.

The default subnet mask is 255.255.255.0.

The computer's Ethernet adapter or wireless adapter must have a unique IP address in the same range as the spectrometer, such as 10.1.1.x where **x** is a unique number. The subnet mask must also be the same as the spectrometer, such as 255.255.255.0.

- Unplug the Ethernet cable from the spectrometer.



Notes:

Appendix B Reference Information

B.1 Frequently Asked Questions (FAQ)

B.1.1 How often do I need to optimize?

Optimization has no affect on the data unless the measurement has drifted towards saturation, in which case optimization is mandatory.

To be safe, optimize every 10 to 15 minutes.

B.1.2 How often do I need a White Reference (WR)?

Inside Use

When using the instrument inside under constant lighting conditions, collect a white reference every 10 to 15 minutes while the instrument is warming up and then every 30 minutes thereafter.

Outside Use

When using the instrument outside, you should collect a new white reference frequently for:

- solar changes, like the sun's angle in the sky where 10 minutes can represent a change in the measurement;
- atmospheric changes, like blue sky, cloud cover, humidity, or water vapor
- temperature changes

It is important that the light intensity is the same for when the white reference is collected as for the measurements of the sample.

An experiment to perform when outside is to continue to take measurements of the white reference panel and observe the stability of the white reference line. This will give you an idea of how the current fluctuations in weather affect your measurements.



B.1.3 What spectrum average should I use?

When outside, it is usually sufficient to use 30 scans in the spectrum averaging for the sample and 60 scans for the white reference. The white reference isn't taken as often, which is why you would want to include more scans in its averaging.

The signal-to-noise measurement increases with the square root of the number of scans used in the averaging.

Note: The actual spectrum average will be a compromise between noise reduction through spectra averaging and the time required for each spectra collection. For instance, if you are using the instrument in the field while walking a large area, you will want a smaller number of spectra in the average to decrease the collection time required. If you are collecting spectra in the lab, you'll want to increase the number of spectra in the averaging to obtain the cleanest spectra possible.

B.1.4 What if I want to keep the same integration time, gain value, and offset value for the entire day?

You can't and probably wouldn't want to. Most of the measurements made by the instrument are ratios where such values get cancelled out and become irrelevant.

B.1.5 When do I use absolute reflectance?

It depends on how you are analyzing your data.

It can't hurt to use absolute reflectance. The difference between absolute and relative reflectance is small for wavelengths less than 2000 nm.

Because relative reflectance relies on a physical (Spectralon) white reference, you will see detect deviations from the absolute below 350-400 nm and above 2000-2500 nm.

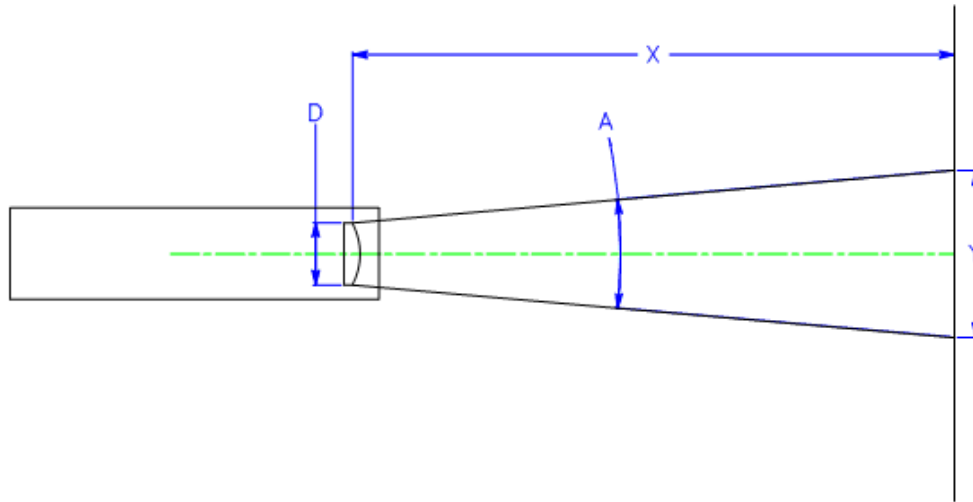
B.1.6 How do I know the field of view that I'm using?

The field of view is labeled on the foreoptic that you use.

When you are measuring radiance, it is important that the RS³ application software is using the correct field of view setting.



Figure B-1 Field of View



D == effective diameter of foreoptic lens
 A == foreoptic's angular field-of-view
 X == distance to viewed surface
 Y == diameter of field-of-view

Near Field (less than 1 meter):

$$Y = D + 2 * X * \tan(A/2)$$

Far Field (greater than 1 meter):

$$Y = 2 * X * \tan(A/2)$$

B.1.7 What are the units of radiance?

Radiance is measured in Watts per square meter (W/m^2).

However, the FieldSpec spectroradiometer measures *spectral radiance*, which is the amount of radiance per unit wavelength. Spectral radiance is measured in Watts per square meter per nanometer ($W/m^2/nm$).

B.1.8 Can I post-process my data?

Yes. ViewSpec is one of many applications that can post-process your data. ENVI is another image processing application. The spectral data can be important into many different applications.

The complete specification of the ASD file format is available upon request.



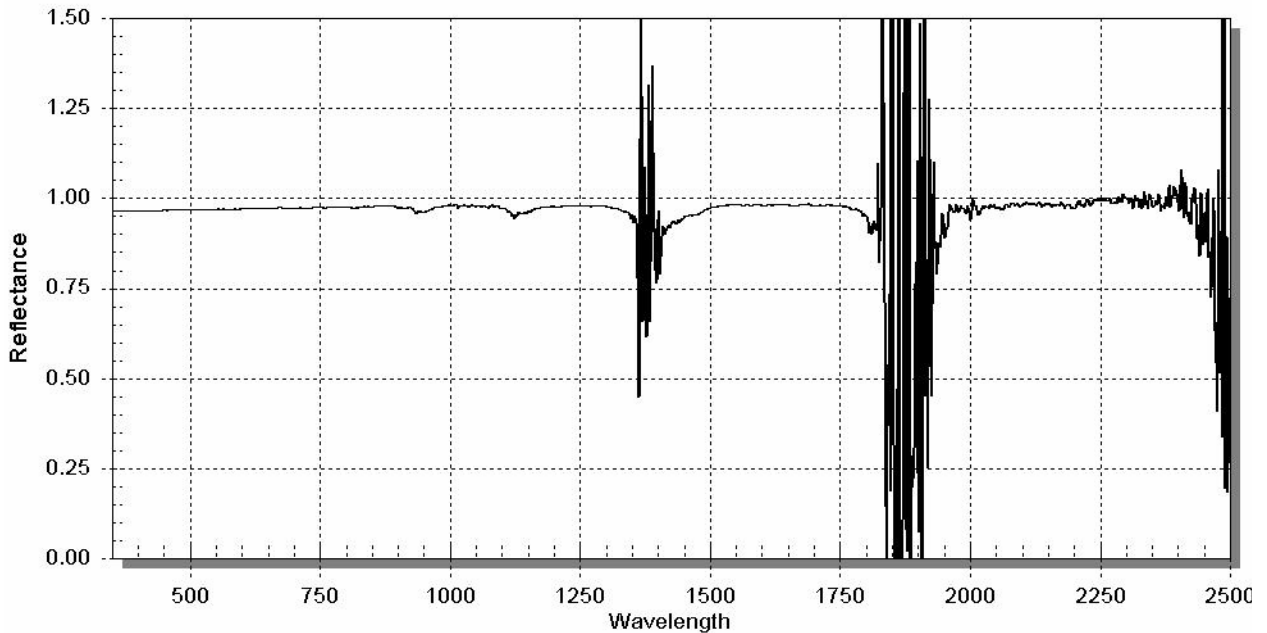
B.1.9 Why do I see oscillations (sine wave) in my data?

Your light source may use AC power. A single SWIR band is about 100 ms. If you observe six (6) waves in a single SWIR, the AC light source is the cause.

B.1.10 What are these large noise bands in my data at 1400nm and 1800nm?

Water vapor in the atmosphere absorbs light in those bands.

Figure B-2 Examples of water vapor absorbing light.



B.1.11 What are these upward or downward spikes in VNIR data?

These result from artificial light sources, in particular fluorescent lights

B.1.12 What are these steps in my data?

The instrument is fed spectral data through 57 fiber optic strands. Each strand has its own field of view (FOV). When the end of the fiber cable is held relatively close to the sample, each strand's FOV may be limited to different features of the sample which can result in the stepped data.

Hold the end of the fiber cable further away from the sample to allow the FOV of the individual strands to overlap and mesh together.



Stepping of data is common when the foreoptics has a lens, and less common when using the bare optics.

B.1.13 What can cause more noise in my data than when I previously used the instrument?

Noise in a reflectance measurement is related to the instrument, the signal level, and noise in the light source.

The angle of the sun at high noon in the Fall has a reduced light level than at high noon in high Summer. Likewise, the time of day and the sun's position affects light levels, as well as atmospheric conditions.

Also, broken fibers in the fiber optic cable can contribute to noise. Perform a fiber optic check to verify.

B.1.14 Why does the VNIR drop to zero after a Dark Current has been collected?

This may indicate a problem with the VNIR shutter or Dark Current collection routine. To verify, optimize the instrument and listen for the click of the shutter activating. If you do not hear the shutter click, contact technical support and obtain an RMA for sending the instrument in for repairs.

B.1.15 How do I collect a reference when my spot size is larger than the Spectralon panel?

Purchase a bigger reference panel or move the foreoptic closer to it.

If you are indoors using artificial light, make sure that the distance and angle from the reference is the same as will be used for the sample.

If you are outdoors and the sun is your light source, it is okay if your reference panel is closer to the foreoptics and the sample is farther away.

B.1.16 How do I clean my Spectralon panel?

Refer to Spectralon's handling procedures for definitive care.

Spectralon is an optical standard and should be handled in much the same way as other optical standards. Although the material is very durable, care should be taken to prevent contaminants such as finger oils from contacting the material's surface. Always wear clean gloves when handling Spectralon.

**To clean a lightly soiled Spectralon white reference**

If the material is lightly soiled, it may be air brushed with a jet of clean dry air or nitrogen.

WARNING! DO NOT use Freon.

To clean a heavily soiled Spectralon white reference

Sand the Spectralon material under running water¹ with a 220-240 grit waterproof emery cloth until the surface is totally hydrophobic (water beads and runs off immediately).

- Step 1 Use a flat surface, such a thick, flat piece of glass.
- Step 2 Place the glass into the sink.
- Step 3 Place 220 grade wet sandpaper onto the glass.
- Step 4 Gently move the Spectralon reference in a figure 8 motion on the sandpaper, using water as needed to wash away the thin layer that is sanded off.
- Step 5 Blow dry with clean air or nitrogen or allow the material to air dry.
- Step 6 If the material requires high resistance to deep UV radiation, the piece should be prepared as above, then either of the following two treatments performed.
 - 1 Flush the Spectralon piece with >18 m¹/₂ distilled, deionized water for 24 hours.
 - 2 Vacuum bake the Spectralon piece at 75° C for a 12 hour period at a vacuum of 1 Torr or less, then purge the vacuum oven with clean dry air or nitrogen.

WARNING! Do not use oils or soaps to clean the Spectralon white reference.

B.1.17 How do I set up GPS?

The GPS feature is enabled in the RS³ application software.

To configure the GPS:

- Step 1 Select either:
 - **GPS->Settings...** pull-down menu item.
 - **Alt+G, S** key combination.

You need a National Marine Electronics Association (NMEA) compatible GPS device. RS³ requires the output of the GPS device to be in the NMEA format. Check your GPS device documentation for output and port settings.



Normally, the Baud rate (4800), Data bits (8), Parity (none), and Stop bits (1) settings will remain the same as what is displayed in the window. The **Write to log file** is checked by default. When this field is checked and the GPS fixed data is enabled, an entry will be made to a daily log file (i.e. 050302gps.log) when a spectrum is saved.

Step 2 In the **GPS Settings** dialog box, enter communication settings appropriate for your instrument controller's port intended for use as well as the GPS device.

Note: The RS³ settings on the instrument controller and the ports that are used must match the actual port used as well as the settings of the GPS device.

Step 3 Connect an appropriate cable between the instrument controller's port and the GPS device.

You may need a serial-USB converter depending upon the instrument controller and GPS device.

Step 4 Enable the GPS functionality in the RS³ application by selecting either:

- **GPS->Enable...** pull-down menu item.
- **Alt+G, E** key combination.

Step 5 Refer to the manual of your actual GPS device for further instructions regarding usage and configuration.

B.1.18 What does a broken fiber mean?

The fiber-optic cable is made up of fifty-seven (57) randomly distributed glass fibers.

- 19 fibers are 100 micron for the VNIR region.
- 19 fibers are 200 micron for the SWIR1 region.
- 19 fibers are 200 micron for the SWIR2 region.

Therefore, a single broken fiber results in a 5% reduction in the signal.

A few broken fibers is not critical when measuring reflectance, because this is a ratio. Any noise introduced by the broken fibers in measuring the sample were also present when measuring the white reference, and therefore cancels out.

Radiance and irradiance are measured using the raw data and comparing to numbers that exist in the calibration file. Therefore, a few broken fibers will result in lower values.

The fibers are protected by a metal spiral inside the black cable casing. If there are kinks in your cable, the fibers are not necessarily damaged. However, if your cable has been crunched so severely that you are able to see



the protective metal spiral, the chances are high that the fibers have been damaged too. Refer to the Fiber Optic Check utility to determine if any fibers are broken.

The fibers can be damaged by coiling the cable up too tightly. If left in a tight coil for longer than a week, the fibers are likely to develop longitudinal fractures that will not be detectable. These fractures in the fiber will cause light leakage, resulting in a weaker signal. The fiber optic cables should be stored by placing them loosely within the netting compartment on the instrument.

WARNING! The fiber cable should never be stored with a bend of less than a 5" diameter for long periods of time.

B.1.19 How long is the battery life?

The NiMH (Nickel-Metal Hydride) battery charge lasts about nine (9) hours using a VNIR-only FieldSpec spectroradiometer with accessory not powered by the instrument in an ambient environment.

The battery charge lasts over four (4) hours using a full-range spectroradiometer with a Contact Probe in an ambient environment.

Note: The limiting factor for how long you can work in the field may be the battery in the instrument controller rather than the spectroradiometer's batteries.

B.1.20 What type of Ethernet cable can I use for the static IP configuration?

The spectrometer can be plugged directly into the instrument controller using a cross-over, shielded Ethernet cable.

B.1.21 Can I install additional software on the instrument controller?

Yes, but with qualifications.

The types of applications that can interfere with the measurement of data are utility programs, network programs, and those working in the background, such as virus checkers.

ASD programs, such as RS³, require real-time access to the data that is being streamed from the FieldSpec spectroradiometer at a high rate of speed. Programs running in the background can cause packets to be lost.

Microsoft Office, image processing programs, and other software applications generally do not interfere with ASD programs, particularly if they are not running and competing for CPU cycles and RAM at the same time that data is being collected from the FieldSpec spectroradiometer.



B.1.22 Why does the software seem to do strange things?

To assure accuracy in the collection and processing of data, the ASD application software is designed to finish its current operation before moving on. The FieldSpec spectroradiometer spews out a lot of data at a high rate of speed for the ASD application software to collect.

In addition, the ASD application software will stack up your keystroke entries and execute them later in the order they were received.

It is important that you wait for the collection to finish before entering the commands to launch another operation. Don't rush into new operations or into issuing new commands until you see the results of the current command.

B.1.23 How long does it take for the FieldSpec® 3 Spectroradiometer to warm up?

The warm-up time of the instrument depends on the environment in which it is used.

One hour is recommended for radiometric work. Only ten minutes is needed for reflectance measurements, particularly if conserving battery life is desirable.

B.1.24 Where is my serial number?

The serial number is a five (5) digit number [16xxx] located on a label on the rear of the FieldSpec spectroradiometer where the power switch is. The label also contains the model number and MAC address for the spectroradiometer.

The serial number is also accessible in the RS³ application from the splash screen or the **Help->About** menu item.

B.2 ASCII Conversion

Use ViewSpec™ to convert spectral data to ASCII text files. This can be done one file at a time or several files can be merged into a single text file, which is a useful feature when inputting data into other analysis grams.



B.3 Gain and Offset

Gain and offset are determined during optimization by an optimization algorithm in the RS³ application. You can observe this process by depressing the OP button on the top right-hand toolbar. The gain, offset and integration time will then appear in the lower left hand corner. These parameters are set by the optimization routine and cannot be set manually.

The Gain Value is the inverse of actual Gain. A decrease in Gain Value will educe a higher Gain. The maximum Gain Value is 16. Under the low light levels that create such a gain, small changes in Offset will translate into large changes in dynamic range.

Offset causes a downward shift (from $Y=32,768$ DN) in a SWIR spectrum such that the max value of the spectrum and the minimum value of the spectrum (Dark Current - off screen) are equidistant from the line $y=32,768$. Under ideal conditions, where there's enough light, there will be about 32,768 DN of signal immediately after optimization, +/- 1,000. This means that optimization “creates” about 16,000 DN of dark current and about 16,000 DN of dynamic range. But this dynamic range will disappear with either a slight increase in signal (if the signal started out low to begin with) or a slight increase in dark current (increases with ambient temperature).

B.4 Light Source

When using ASD's ProLamp illumination source, the less intense the lamp setting (knob on side of light source), the more diffuse (homogeneous) it will be. An average spot size of reasonable homogeneity is about 10 cm at a 50 cm lamp distance. Two lamps improve this geometry significantly, especially for large targets. If lighting conditions are so poor that you are continually re-optimizing, try optimizing with a brighter source:

- For outdoor optimization, tilt the Spectralon® panel directly towards the sun during optimization.
- For enclosed illumination of targets requiring contact measurements, we recommend ASD's High Intensity Reflectance probe.
- Under low light conditions, consider using a reference panel < 99-100% white and then post-process out the difference between the white and gray reference in ViewSpec.



B.5 Optimization

The spectrometer must be re-optimized for:

- Light changes.
- Any atmospheric changes or changes in temperature.
- Outdoor solar changes at least every 10 to 15 minutes.
- Indoor use every 30 minutes.

Note: Conditions can change rapidly or slowly. It all depends on clouds, wind (affecting temperature), instrument warm up time, etc.

The SWIR 2 dark current increases with temperature and dramatically reduces the dynamic range of the spectrometer.

Optimization depends on the response to light in a particular spectral region. A well-optimized instrument will display between 20,000 and 35,000 raw digital numbers, if the source is within the gain and integration time abilities of the system. The magnitude of the VNIR rawDN will be directly dependent on the light intensity.

The Spectralon® blank should be used when optimizing and for taking a white reference measurement.

Note: It is important that the angle for the white reference measurement is the same as the angle used for capturing data from the samples.

When saving reflectance data, point the probe at the Spectralon® once every few measurements for a minute or two with the same viewing geometry. If the relative reflectance of the Spectralon is less than or greater than one, a new white reference may be needed. If the relative reflectance of the Spectralon is greater than one, re-optimization is recommended.

B.6 Spectral Discontinuities

Three separate detectors are used to collect data over the complete spectral range; therefore spectral discontinuities should be expected at 1000 nm and 1830 nm when operating in raw DN mode. These discontinuities decrease in the reflectance mode when the ratio of the raw DN file to the calibration file (a white reference or a radiometric calibration response to a calibrated light field) is calculated because both files will contain the same discontinuities in the data.

Excessive discontinuities in radiometric spectra can be caused by not allowing the instrument to warm up fully. Normal discontinuities can be addressed by using the parabolic correction utility.



B.6.1 Field of View

The VNIR spectrometer/fiber bundle has a slightly broader field of view than the SWIR spectrometers. Discontinuities in reflectance data may be caused by shading differences in the VNIR data as opposed to the SWIR data.

Steps at the spectrometer splices are most commonly associated with measurements of surfaces with very patchy brightness. The steps result from the different spectrometers viewing slightly different areas on the sample. The steps are seen when these three areas (VNIR, SWIR1 & SWIR2) have differing reflectance values at the crossover wavelengths. Averaging several measurements of slightly different areas on the ground will minimize the steps.

B.6.2 White Reference

White references should be collected at least every 10 minutes under typical atmospheric conditions. The frequency of white reference collect should be increased for less stable atmospheric conditions. The “flatness” of the reflectance of the reference panel when observed as a sample can be used to judge changes in the atmospheric conditions from when the white reference was originally collected.

As the instrument warms up, the sensitivity at the red end of the VNIR array will increase while that at the blue end of SWIR2 will decrease, leading to discontinuities. The SWIR 2 dark current increases with temperature and dramatically reduces the dynamic range of the spectrometer.

The Spectralon blank should be used when optimizing and for taking a white reference measurement. It is not necessary to reoptimize the instrument prior to the recollection of the white reference.

When saving reflectance data, point the probe at the Spectralon once every few measurements for a minute or two with the same viewing geometry. If the relative reflectance of the Spectralon is less than or greater than one, a new white reference may be needed. If the relative reflectance of the Spectralon is greater than one, re-optimization is recommended.

B.6.3 Other Tips on Discontinuities

Outdoor spectra typically display a great deal of noise in the water bands, particularly in the 1900 nm region. Indefinable reflectance values due to atmospheric water absorption bands appear as two zones of very noisy data (the first zone located approximately between 1350-1400 nm and the other between 1810-1940 nm). If you look at a typical outdoor spectral irradiance file, you will see the energy in these bands drop to (or very nearly to) zero.



B.7 Spectrum Averaging

If signal levels are low, the only way to increase S/N is by reducing noise through spectrum averaging. However, spectrum averaging takes more time per spectrum. The drawback to this is that the resultant data can be compromised by introducing low-frequency noise factors, such as varying cloud conditions or sudden gusts of wind changing the color of the tree canopy.

To reduce the effects of low-frequency noise conditions like those found outdoors we recommend taking multiple spectra with spectrum averaging set to 10-25, then further average those spectra in post-processing using the ViewSpec program. ViewSpec also permits viewing large groups of files.

B.8 Temperature Effects

The FieldSpec spectroradiometer instruments have thermo-electrically cooled SWIR detectors (to -25 C), significantly reducing noise in those areas.

If the FieldSpec spectroradiometer is exposed to direct sunlight, depending on the intensity of the sunlight, the effective operating period may be shortened. When the system fails due to extreme temperature, it will fail gradually but obviously - the data won't make perfect sense. Shut down and let the instrument cool in the shade before operating again.

You may also see the FieldSpec spectroradiometer saturate in the SWIR 2 region if the instrument is still equilibrating from a cooler environment (e.g., an air conditioned car) to a warm environment. Frequent re-optimizations will address this problem until the instrument comes to equilibrium.

The RS³ application provides a warning when the SWIR detectors are out of thermal regulation.

B.9 Technical Support

If you have any questions or concerns, please contact Analytical Spectral Devices, Inc. by phone, fax, or email:

Phone: 303-444-6522

Fax: 303-444-6825

email: support@asdi.com

Web: www.asdi.com

ftp: ftp.asdi.com



The Technical Support team is committed to providing you with a timely response to your questions. We will work with you to provide solutions to your applications. The Technical Support team is available to answer your questions Monday thru Friday, 8 am to 5 pm Mountain Standard Time. We will happily respond to your e-mail queries as well.

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