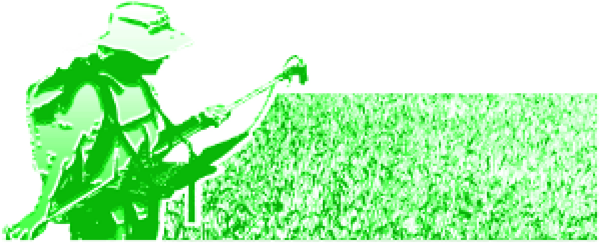
Instrumentos disponibles en el mercado. Análisis comparativo

Dra. Angela De Santis
Jefe de Proyecto
Ingeniería y Servicios Aeroespaciales (INSA)
Departamento de Sistemas y Observación de la Tierra
angela.de.santis@insa.org

SEMINARIO:

AVANCES EN ESPECTRO-RADIOMETRÍA

3 y 4 de diciembre de 2009



Índice

- Definición de espectro-radiometría
- ¿Radiometros o espectro-radiometros?
- ¿Haz único o doble?

- Radiometro de doble haz : CROPSCAN

- Espectro-radiometros de haz único:
  - GER, SVC, ASD

- FOV real y FOV nominal de GER y ASD

- Mini espectro-radiometros: Ocean Optics

- Cámaras hyperespectrales: SPECIM

Espectro-radiometría

- **Estudio de la interacción entre radiación electromagnética y la materia**

- También *espectrometría, espectroscopía, field* ***spectroscopy****…*

- Múltiples aplicaciones - longitud de onda:
  - **Teledetección**:
    - puente entre laboratorio-campo-aire-espacio: validación
    - determinar longitudes de onda apropiadas
    - validación de modelos de reflectividad: datos biofísicos/espectrales
  - **Otras**: medicina (resonancia magnética nuclear), etc.

Tipos de instrumentos

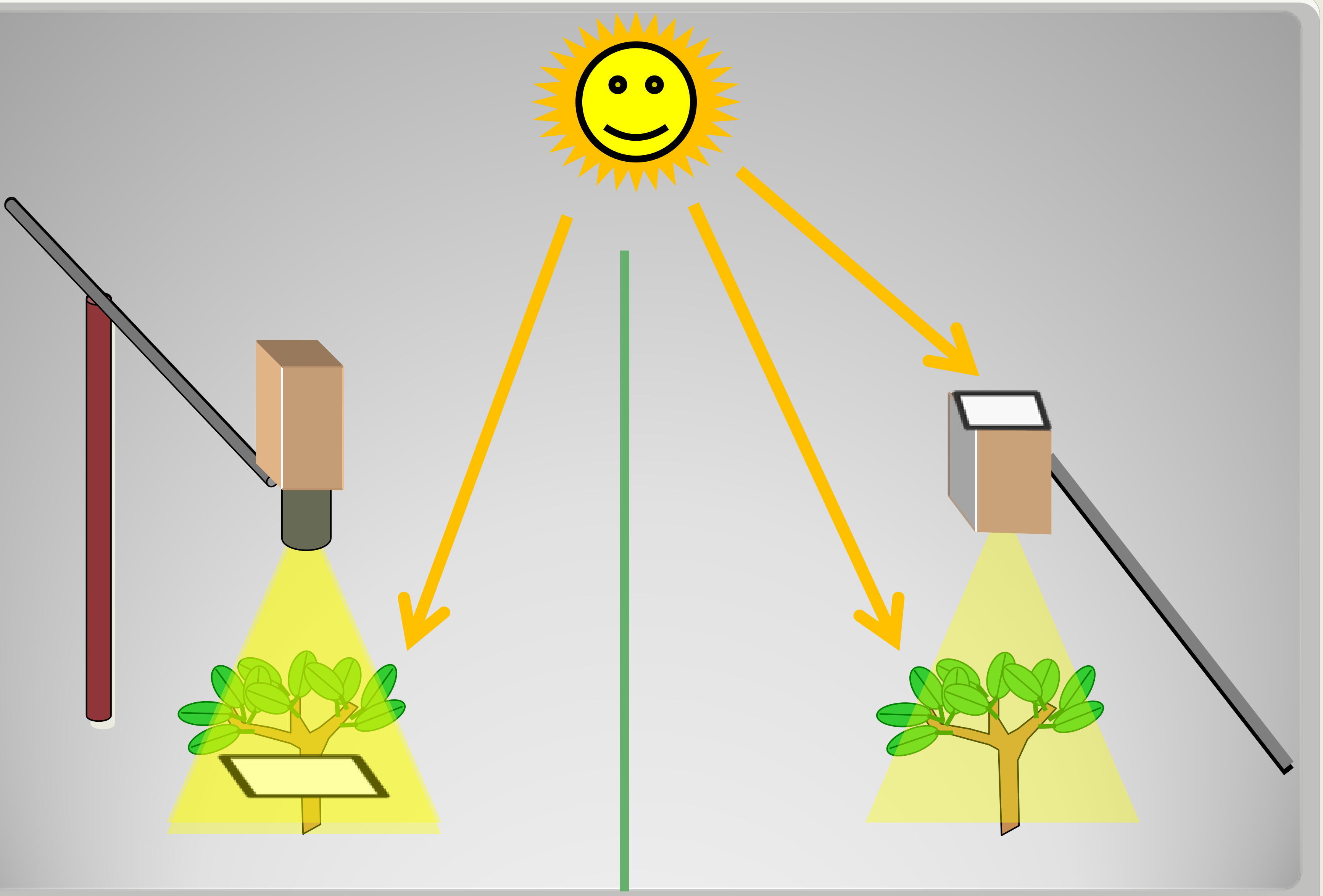
- ¿**Radiometros o espectroradiómetro** ?
  - **Espectro -radiometro**: espectro contínuo (hiperespectral)
  - **Radiometro**: número limitado de bandas (multiespectral)
- ¿**Haz único o doble** ?
  - **Único**: un mismo sensor mide el panel de referencia y luego el objeto
  - **Doble**: un sensor para cada función midiendo simultáneamente > exactitud

Único

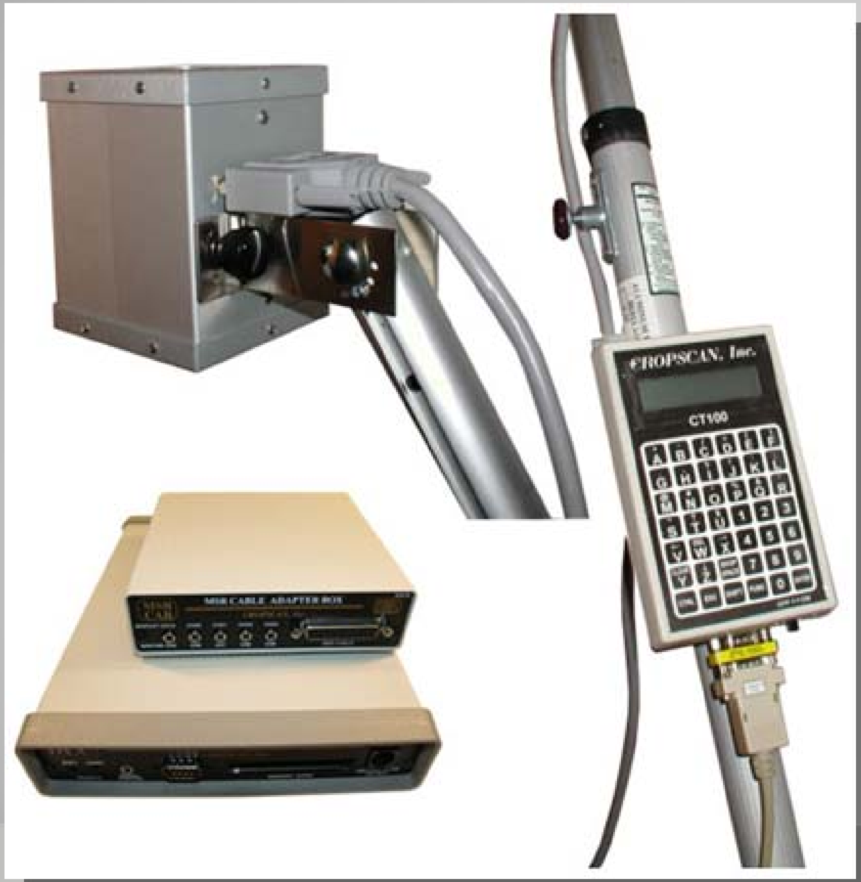
Doble

Hiper-espectral

Multi-espectral

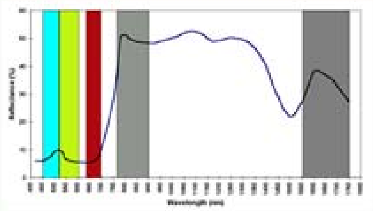
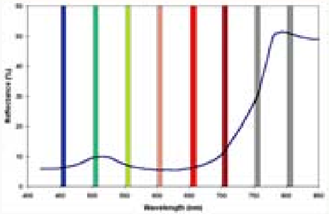
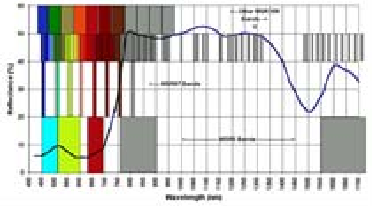


Radiometro multiespectral de doble haz: CROPSCAN


CROPSCAN, Inc.
CT100
MSR CABLE ADAPTER BOX

CROPSCAN, Inc.
1932 Viola Heights Lane NE
Rochester, MN 55906 USA
Phone: (507)285-9230
Fax: (206) 339-5770
Email: Cropscan@compuserve.com
URL: http://www.cropscan.com

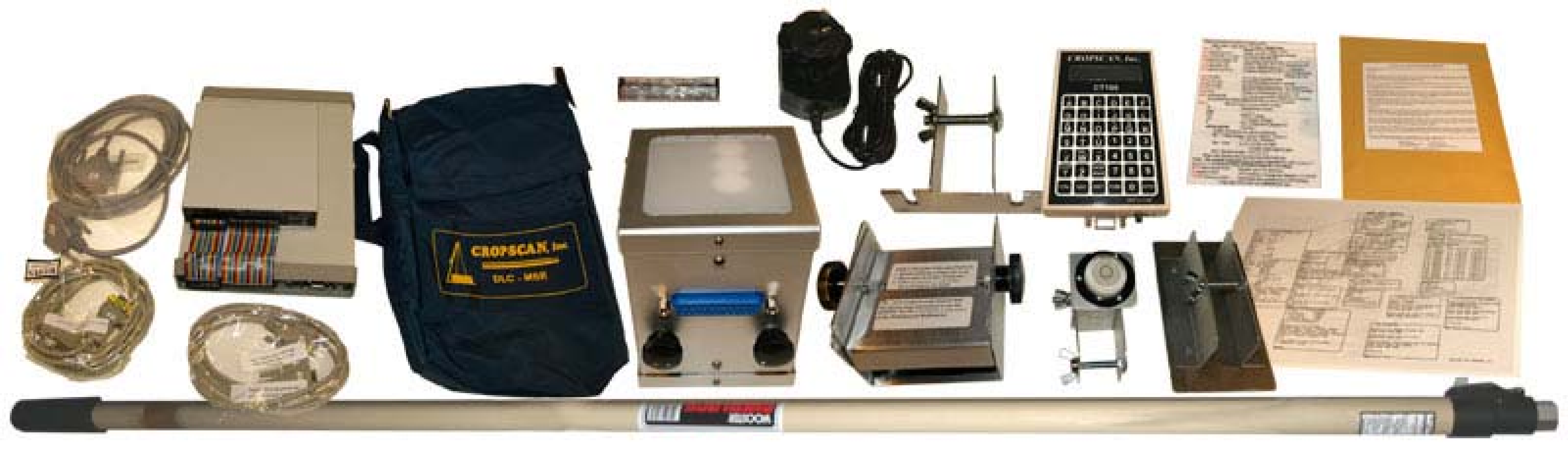
Radiometro de doble haz: CROPSCAN

Cropscan Products FOV=28º			
Multispectral Radiometer (MSR)	MSR5 ~ Landsat TM	MSR87	MSR16R Hasta 16 bandas, 450 - 1750 nm
MSR System	MSRSYS5	MSRSYS92	MSRSYS16R
Spectral Bands Example			

CROPSCAN Inc.
DLC - MSR

Radiometro de doble haz: CROPSCAN

VENTAJAS ☺	INCONVENIENTES ☹
LIGERO Y ROBUSTO	IMPOSIBILIDAD DE COMPROBAR LAS MEDICIONES EN CAMPO
FACIL DE TRANSPORTAR	POCAS BANDAS
MANEJO SENCILLO	



Espectro- radiometro de haz único:
GER

SVC

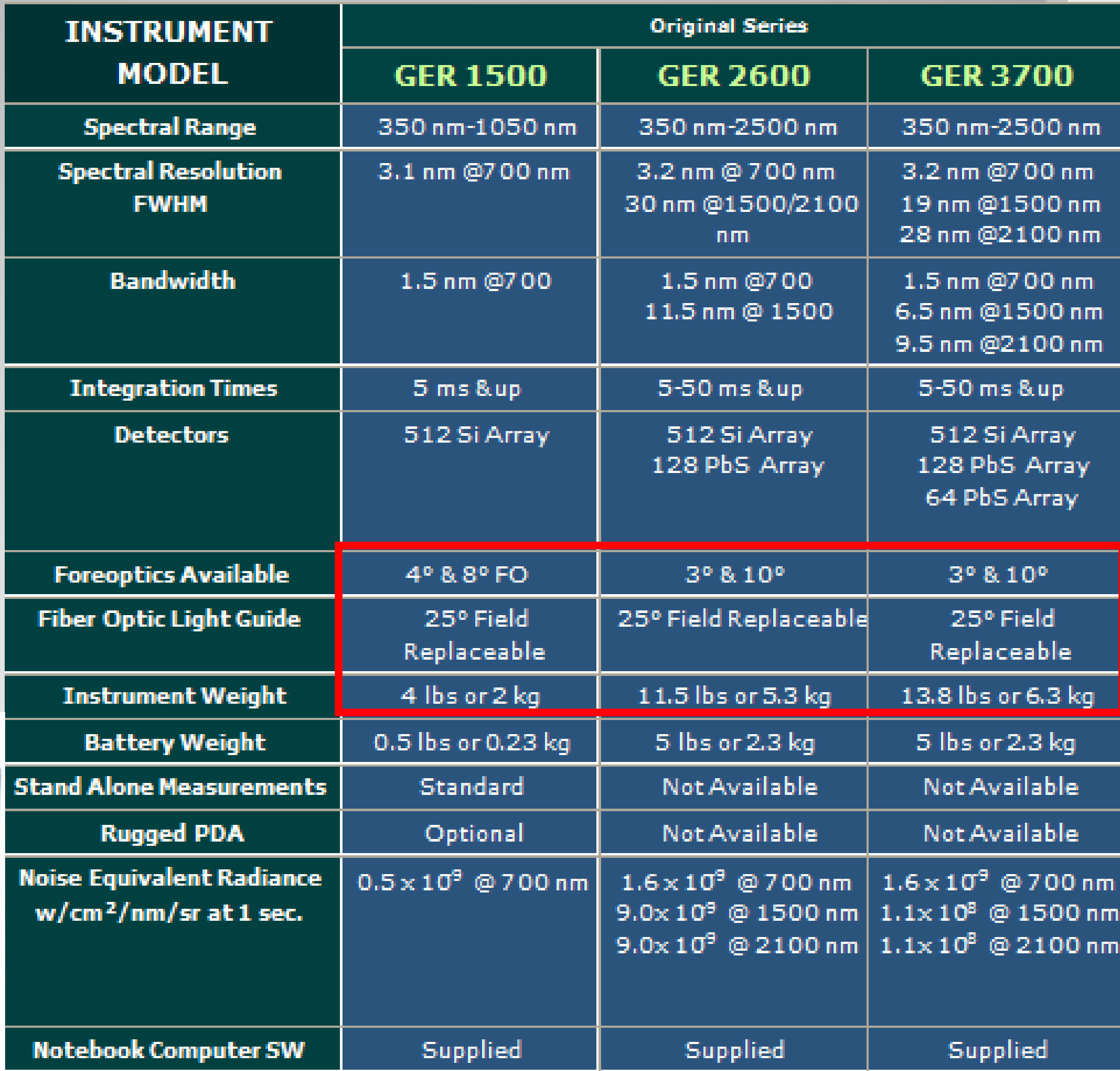
Spectra Vista Corporation, 29 Firemen's Way, Poughkeepsie, New York 12603 USA
E-mail: spectravista@aol.com, Phone: 845-471-7007 Fax: 845-471-7020
http://www.spectravista.com/

Espectro- radiometro de haz único: GER

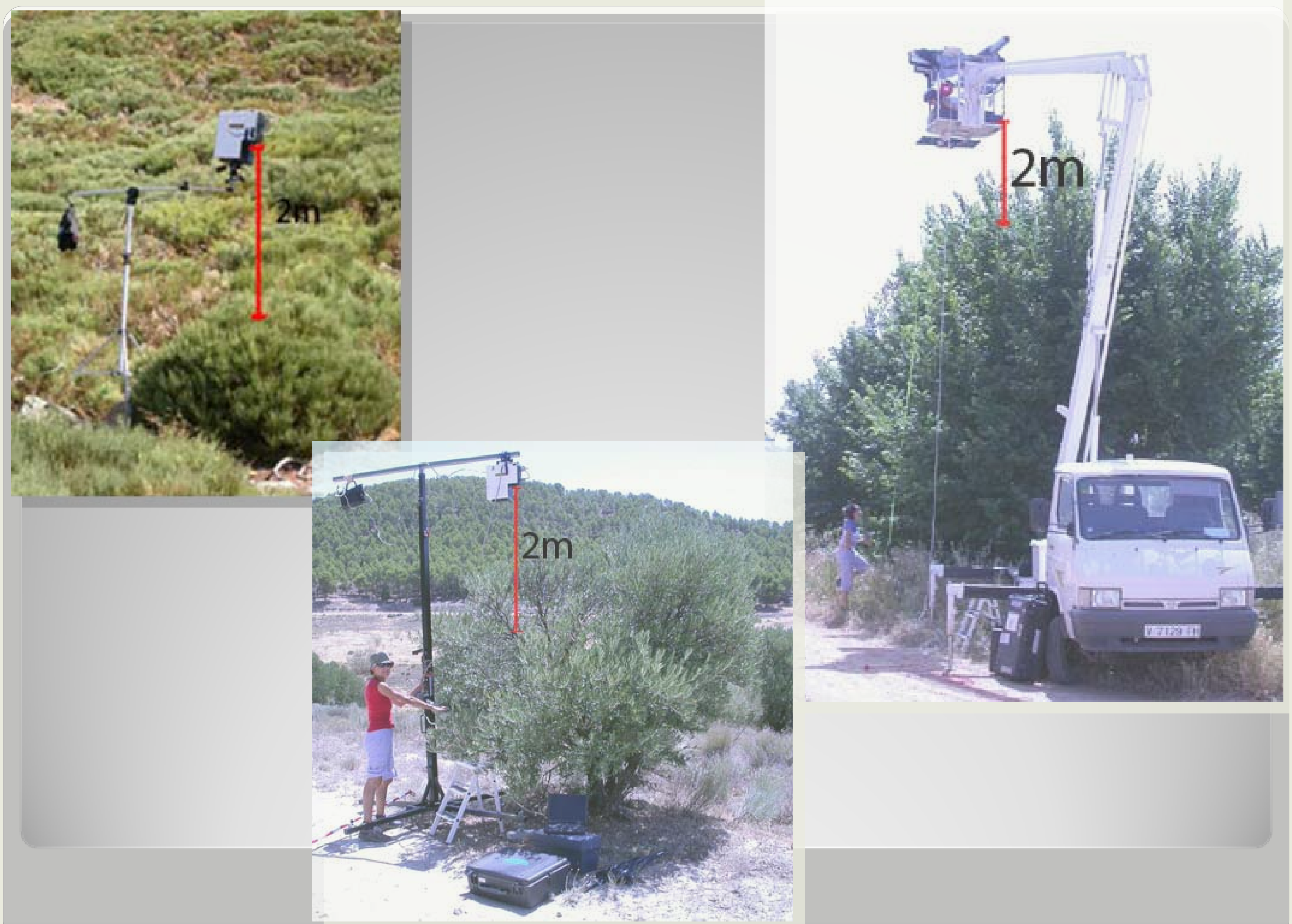
GER1500

GER2600

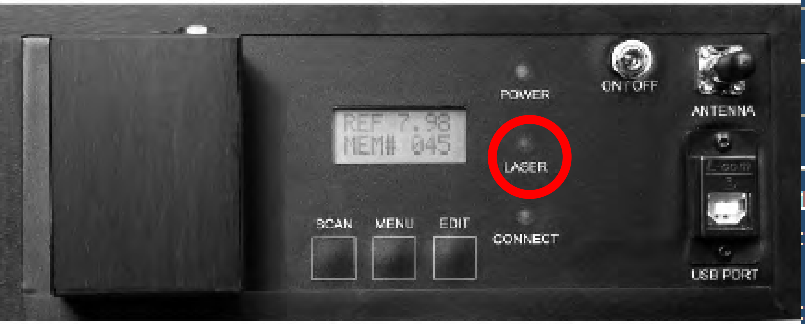
GER3700



INSTRUMENT MODEL	Original Series		
	GER 1500	GER 2600	GER 3700
Spectral Range	350 nm-1050 nm	350 nm-2500 nm	350 nm-2500 nm
Spectral Resolution FWHM	3.1 nm @700 nm	3.2 nm @ 700 nm 30 nm @1500/2100 nm	3.2 nm @700 nm 19 nm @1500 nm 28 nm @2100 nm
Bandwidth	1.5 nm @700	1.5 nm @700 11.5 nm @ 1500	1.5 nm @700 nm 6.5 nm @1500 nm 9.5 nm @2100 nm
Integration Times	5 ms &up	5-50 ms &up	5-50 ms &up
Detectors	512 Si Array	512 Si Array 128 PbS Array	512 Si Array 128 PbS Array 64 PbS Array
Foreoptics Available	4° & 8° FO	3° & 10°	3° & 10°
Fiber Optic Light Guide	25° Field Replaceable	25° Field Replaceable	25° Field Replaceable
Instrument Weight	4 lbs or 2 kg	11.5 lbs or 5.3 kg	13.8 lbs or 6.3 kg
Battery Weight	0.5 lbs or 0.23 kg	5 lbs or 2.3 kg	5 lbs or 2.3 kg
Stand Alone Measurements	Standard	Not Available	Not Available
Rugged PDA	Optional	Not Available	Not Available
Noise Equivalent Radiance w/cm²/nm/sr at 1 sec.	0.5 x 10^{9} @ 700 nm	1.6 x 10^{9} @ 700 nm 9.0x 10^{9} @ 1500 nm 9.0x 10^{9} @ 2100 nm	1.6 x 10^{9} @ 700 nm 1.1x 10^{8} @ 1500 nm 1.1x 10^{8} @ 2100 nm
Notebook Computer SW	Supplied	Supplied	Supplied


2m
2m
2m

INSTRUMENT MODEL	Next Generation			
	SVC MR-768	SVC HR-768S	SVC HR-768	SVC HR-1024
Spectral Range	350 nm-2500 nm	350 nm-1900 nm	350 nm-2500 nm	350 nm-2500 nm
Spectral Resolution FWHM	3.5 nm @ 700 nm 22 nm @1500 nm 22 nm @2100 nm	3.5 nm @ 700 nm 9.5 nm @1500 nm	3.5 nm @ 700 nm 16 nm @1500 nm 14 nm @2100 nm	3.5 nm @ 700 nm 9.5 nm @1500 nm 6.5 nm @2100 nm
Bandwidth	1.5 nm @700 nm 5.8 nm @1500 nm 5.8 nm @2100 nm	1.5 nm @700 nm 3.5 nm @1500 nm	1.5 nm @700 nm 7.5 nm @1500 nm 5.0 nm @2100 nm	1.5 nm @700 nm 3.8 nm @1500 nm 2.5 nm @2100 nm
Integration Times	1-10 ms & up	1-10 ms & up	1-10 ms & up	1-10 ms & up
Detectors	512 Si Array 256 InGaAs Array	512 Si Array 256 InGaAs Array	512 Si Array (2) 128 InGaAs Arrays	512 Si Array 256 InGaAs Array 256 Ext. InGaAs Array
Foreoptics Available	4° std., 8° and 14° foreoptics, irradiance spheres, reflectance probes are optioinal			
Fiber Optic Light Guide	25° fiber optic light guides are available in various lengths (Field replaceable)			
Instrument Weight	7.3 lbs or 3.3 kg			
	1 lb or 0.45 kg			
	Stand Alone Capability is Standard-No Field Computer is Required			
	A Rugged PDA with Internal GPS and Bluetooth is Supplied with the System			
	10^9 @ 700 nm : 10^9 @ 1500 nm : 10^9 @ 2100 nm	1.2 x 10^9 @ 700 nm 1.5 x 10^9 @ 1500 nm	1.2 x 10^9 @ 700 nm 2.2 x 10^9 @ 1500 nm 2.2 x 10^9 @ 2100 nm	0.8 x 10^9 @ 700 nm 1.5x 10^9 @ 1500 nm 3.0x 10^9 @ 2100 nm
Notebook Computer SW	Supplied	Supplied	Supplied	Supplied

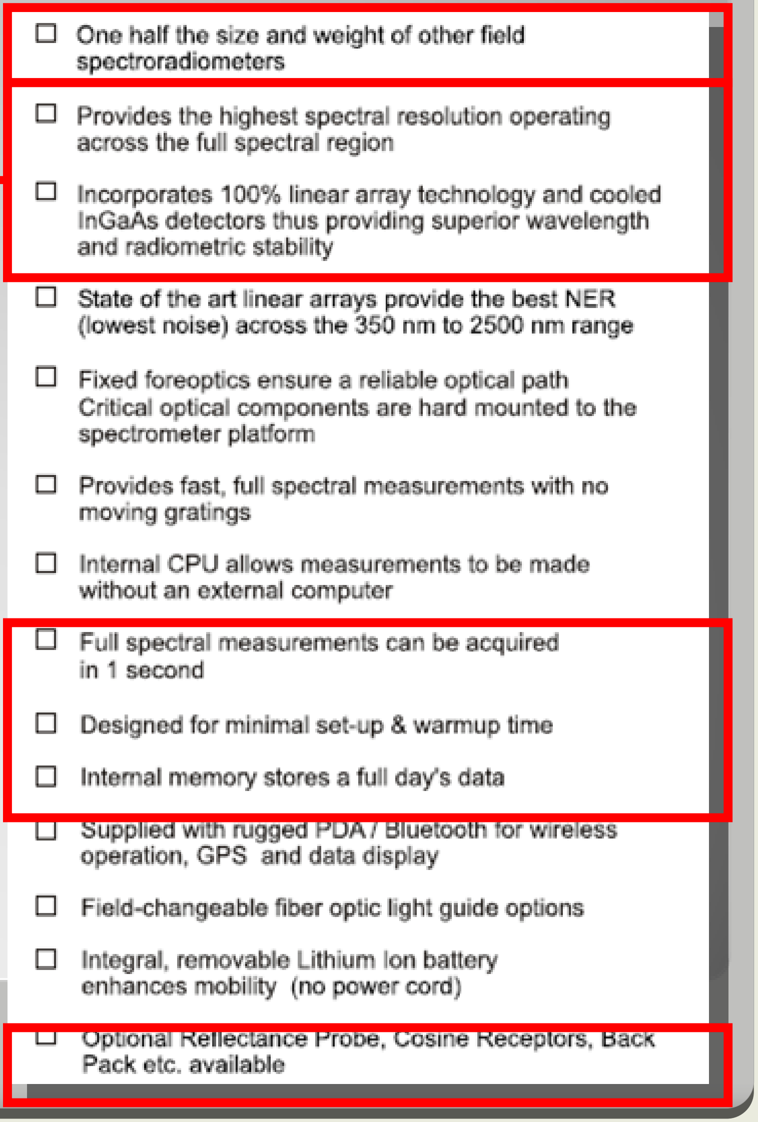


STAND-ALONE INSTRUMENT CONTROL PANEL

Ventajas de los SVC HR

GER 2600-3700:
Si and **PbS** arrays

InGaAS array (Indium-Galium-Arsenide):
- Extremely high sensitivity
- Dinamic range
- Signal-to-noise performance and stability

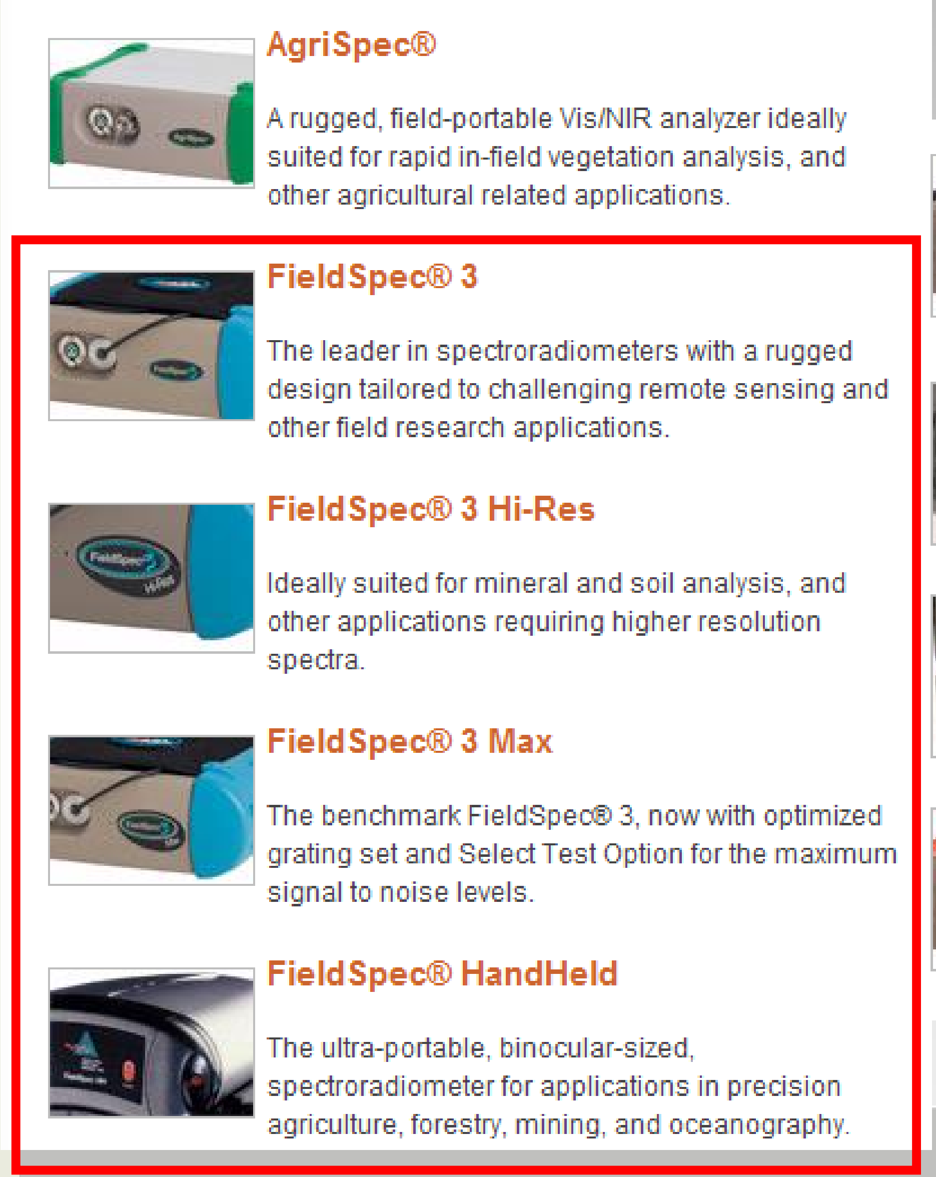


- ☐ One half the size and weight of other field spectroradiometers
- ☐ Provides the highest spectral resolution operating across the full spectral region
- ☐ Incorporates 100% linear array technology and cooled InGaAs detectors thus providing superior wavelength and radiometric stability
- ☐ State of the art linear arrays provide the best NER (lowest noise) across the 350 nm to 2500 nm range
- ☐ Fixed foreoptics ensure a reliable optical path Critical optical components are hard mounted to the spectrometer platform
- ☐ Provides fast, full spectral measurements with no moving gratings
- ☐ Internal CPU allows measurements to be made without an external computer
- ☐ Full spectral measurements can be acquired in 1 second
- ☐ Designed for minimal set-up & warmup time
- ☐ Internal memory stores a full day's data
- ☐ Supplied with rugged PDA / Bluetooth for wireless operation, GPS and data display
- ☐ Field-changeable fiber optic light guide options
- ☐ Integral, removable Lithium Ion battery enhances mobility (no power cord)
- ☐ Optional Reflectance Probe, Cosine Receptors, Back Pack etc. available

TIPO	Rango espectral (nm)	Res. Espectral (band sampling)	Ancho banda	Mediciones sin PC	Peso (kg)	Portabilidad	Accesorios	Conexiones inalámbricas
GER1500	350-1050	**3.1**nm@ 700nm	**1.5**nm@ 700nm	STANDARD	2	alta	NO	NO
GER2600	350-2500	**3.2**nm@ 700nm **30**nm@ 1500/2100 nm	**1.5**nm@ 700nm **11** nm@ 1500	NO	5.3	media	NO	NO
GER3700	350-2500	**3.2**nm@700nm **19**nm@1500 nm **28**nm@2100 nm	**1.5**nm@ 700nm **6.5** nm@ 1500 **9.5** nm@ 2100	NO	6.3	media	NO	NO
SVC MR-768	350-2500	**3.5**nm@700nm **22**nm@1500 nm **22**nm@2100 nm	**1.5**nm@ 700nm **5.8** nm@ 1500 **5.8** nm@ 2100	STANDARD	3.3	alta	SI	SI
SVC HR-768S	350-1900	**3.5**nm@700nm **9.5**nm@1500 nm	**1.5**nm@ 700nm **3.5** nm@ 1500	STANDARD	3.3	alta	SI	SI
SVC HR-768	350-2500	**3.5**nm@700nm **16** nm@1500 nm **14**nm@2100 nm	**1.5**nm@ 700nm **7.5** nm@ 1500 **5**nm@ 2100	STANDARD	3.3	alta	SI	SI
SVC HR-1024	350-2500	**3.5**nm@700nm **9.5** nm@1500 nm **6.5**nm@2100 nm	**1.5**nm@ 700nm **3.8** nm@ 1500 **2.5** nm@ 2100	STANDARD	3.3	alta	SI	SI

Espectro- radiometro de haz único: ASD

ASD Inc.
2555 55th Street, Suite 100
Boulder, CO 80301
Phone: (303) 444-6522
Fax: (303) 444-6825
http://www.asdi.com/



AgriSpec®

A rugged, field-portable Vis/NIR analyzer ideally suited for rapid in-field vegetation analysis, and other agricultural related applications.

FieldSpec® 3

The leader in spectroradiometers with a rugged design tailored to challenging remote sensing and other field research applications.

FieldSpec® 3 Hi-Res

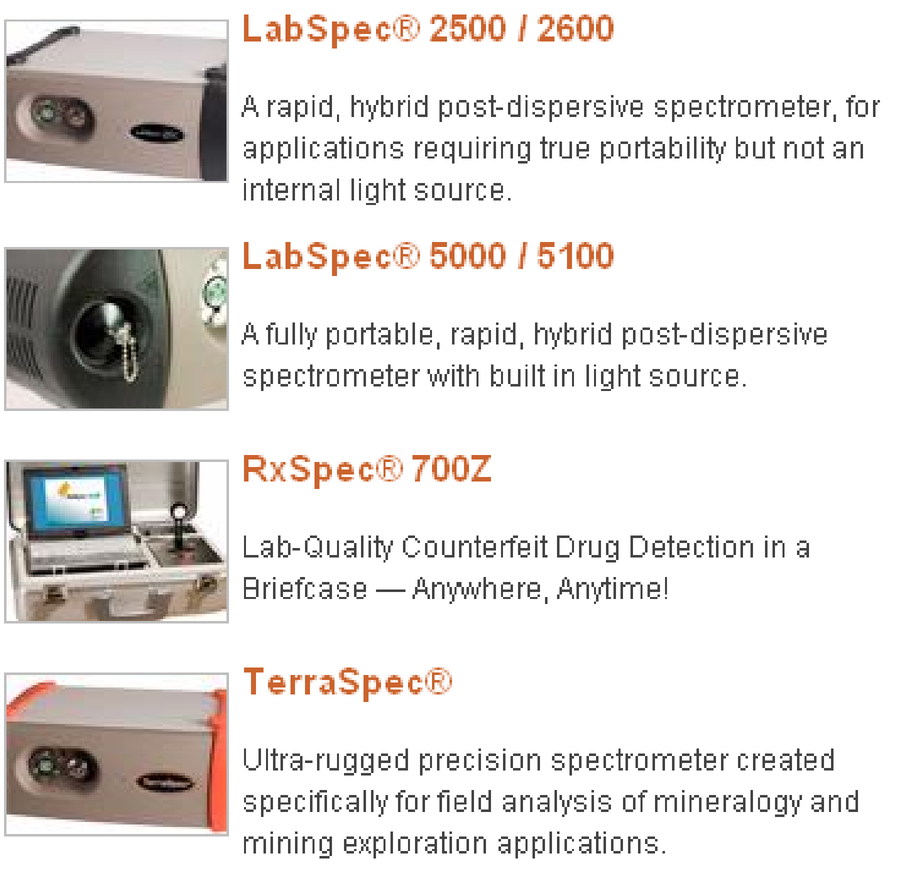
Ideally suited for mineral and soil analysis, and other applications requiring higher resolution spectra.

FieldSpec® 3 Max

The benchmark FieldSpec® 3, now with optimized grating set and Select Test Option for the maximum signal to noise levels.

FieldSpec® HandHeld

The ultra-portable, binocular-sized, spectroradiometer for applications in precision agriculture, forestry, mining, and oceanography.



LabSpec® 2500 / 2600

A rapid, hybrid post-dispersive spectrometer, for applications requiring true portability but not an internal light source.

LabSpec® 5000 / 5100

A fully portable, rapid, hybrid post-dispersive spectrometer with built in light source.

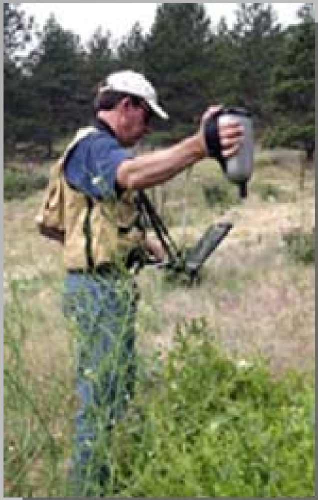
RxSpec® 700Z

Lab-Quality Counterfeit Drug Detection in a Briefcase — Anywhere, Anytime!

TerraSpec®

Ultra-rugged precision spectrometer created specifically for field analysis of mineralogy and mining exploration applications.

FieldSpec® HandHeld



Spectral Range
325 - 1075 nm

Spectral Resolution
3.5 nm @ 700 nm

Sampling Interval
.6 nm @ 325 - 1075 nm

Typical Data Collection Rate (solar illumination)
- FieldSpec® Handheld: 0.7 spectra/second
- FieldSpec® Handheld Pro: 3.7 spectra/second

Detectors
- FieldSpec® Handheld: One 512 element Si photodiode array 325 - 1075 nm
- FieldSpec® Handheld Pro: One taller 512-element photodiode array 325 - 1075 nm

Input
- Fixed 25° field of view. Optional fiber optic and foreoptics available

Calibration
Wavelength, reflectance, radiance*, irradiance*. All calibrations are NIST traceable (*radiometric calibrations are optional)

Noise Equivalent Radiance (NEdL)
- FieldSpec® Handheld: UV/VNIR 5.0 x 10 -9 | W/cm 2 /nm/sr @ 700 nm
- FieldSpec® Handheld Pro: UV/VNIR 5.0 x 10 -10 | W/cm 2 /nm/sr @ 700 nm (NeDL is 10 times better)

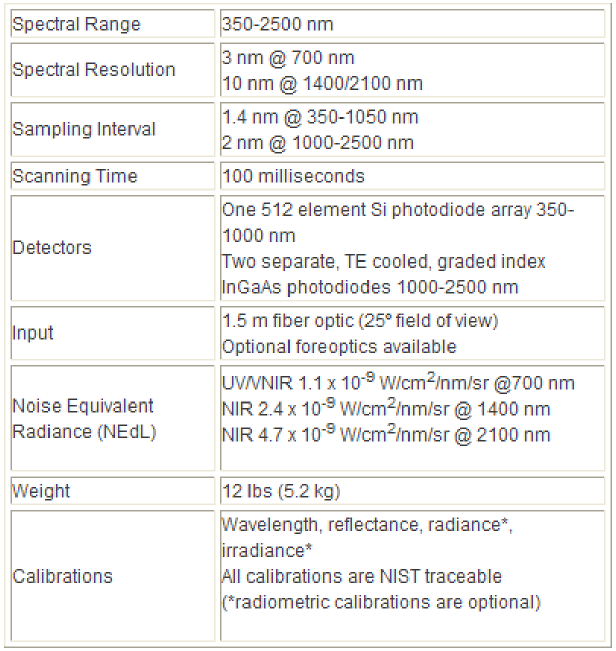
Notebook Computer
Optional

Weight
2.7 lbs or 1.23 kg

Power
Standard camcorder, lithium ion batteries provide up to six hours of portable testing per battery, with two battery slots available

FieldSpec® 3

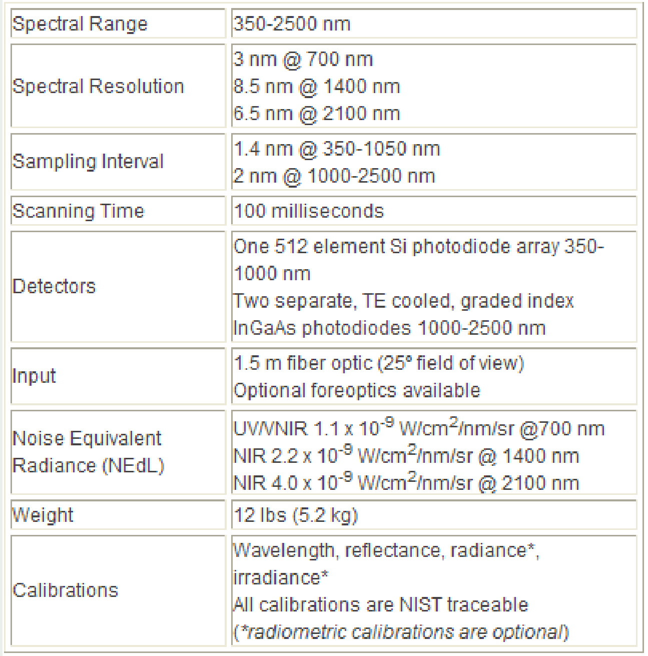
Designed by researchers, for researchers to perform solar spectral reflectance, radiance, and irradiance measurements.



Spectral Range	350-2500 nm
Spectral Resolution	3 nm @ 700 nm 10 nm @ 1400/2100 nm
Sampling Interval	1.4 nm @ 350-1050 nm 2 nm @ 1000-2500 nm
Scanning Time	100 milliseconds
Detectors	One 512 element Si photodiode array 350-1000 nm Two separate, TE cooled, graded index InGaAs photodiodes 1000-2500 nm
Input	1.5 m fiber optic (25° field of view) Optional foreoptics available
Noise Equivalent Radiance (NEdL)	UV/VNIR 1.1 x 10^{-9} W/cm^2/nm/sr @700 nm NIR 2.4 x 10^{-9} W/cm^2/nm/sr @ 1400 nm NIR 4.7 x 10^{-9} W/cm^2/nm/sr @ 2100 nm
Weight	12 lbs (5.2 kg)
Calibrations	Wavelength, reflectance, radiance*, irradiance* All calibrations are NIST traceable (*radiometric calibrations are optional)

FieldSpec® 3 Hi-Res

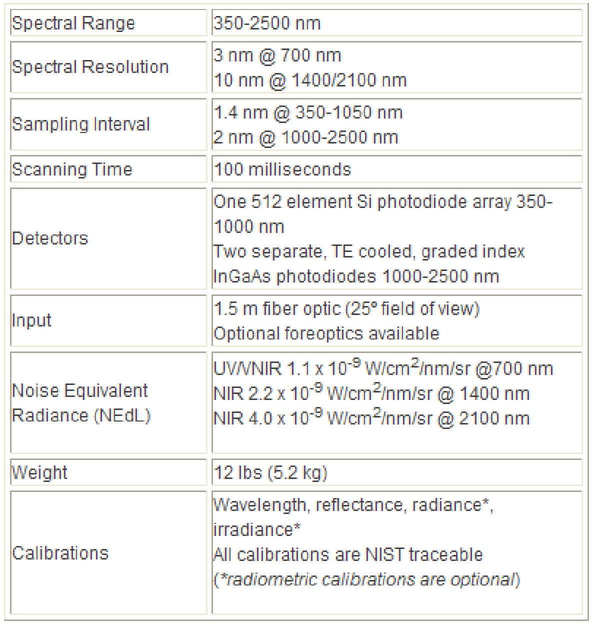
Higher resolution in the SWIR1 and 2 regions for greater definition of hard-to-resolve features often found in minerals and soils.



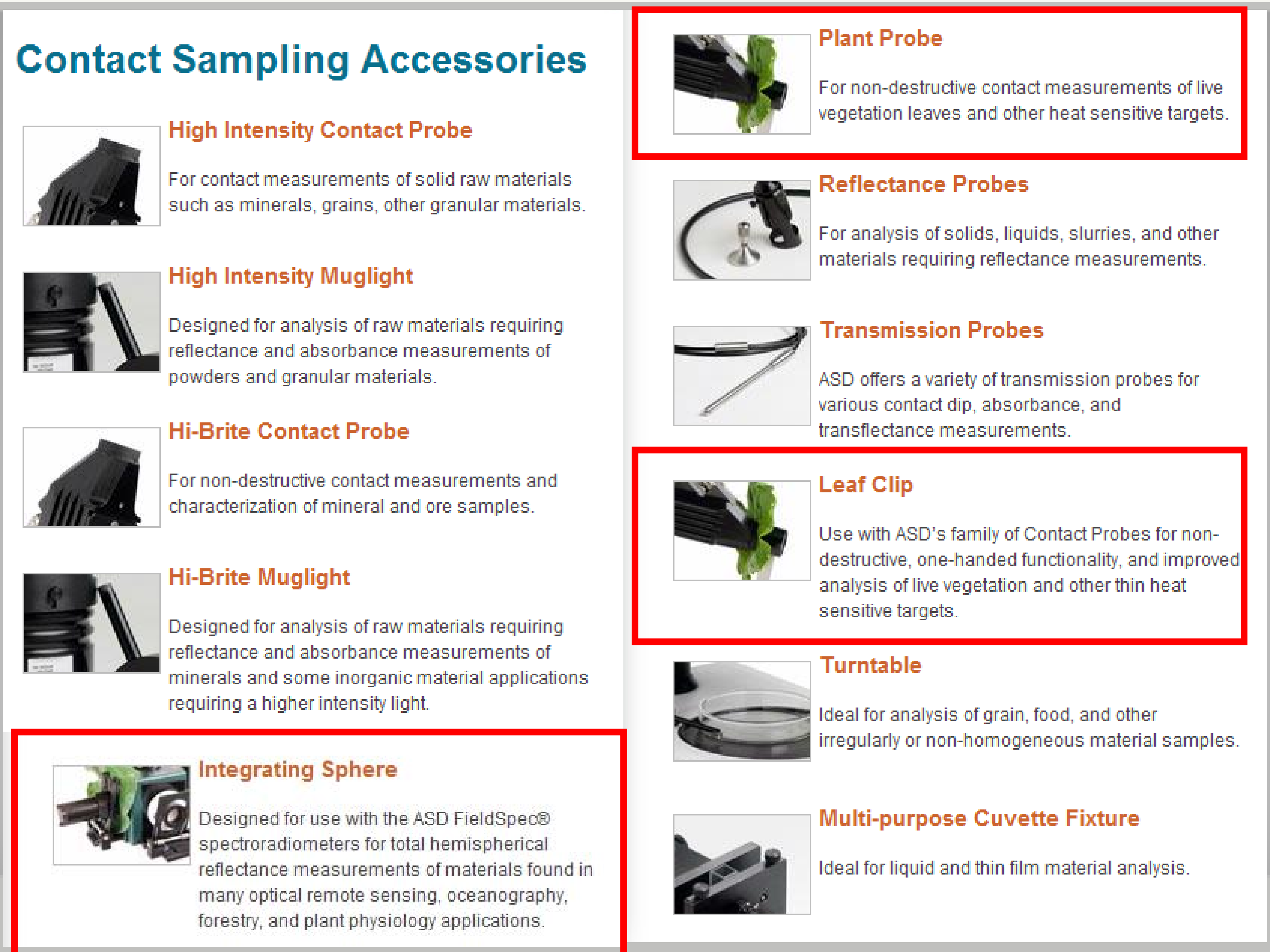
Spectral Range	350-2500 nm
Spectral Resolution	3 nm @ 700 nm 8.5 nm @ 1400 nm 6.5 nm @ 2100 nm
Sampling Interval	1.4 nm @ 350-1050 nm 2 nm @ 1000-2500 nm
Scanning Time	100 milliseconds
Detectors	One 512 element Si photodiode array 350-1000 nm Two separate, TE cooled, graded index InGaAs photodiodes 1000-2500 nm
Input	1.5 m fiber optic (25° field of view) Optional foreoptics available
Noise Equivalent Radiance (NEdL)	UV/VNIR 1.1 x 10^{-9} W/cm^2/nm/sr @700 nm NIR 2.2 x 10^{-9} W/cm^2/nm/sr @ 1400 nm NIR 4.0 x 10^{-9} W/cm^2/nm/sr @ 2100 nm
Weight	12 lbs (5.2 kg)
Calibrations	Wavelength, reflectance, radiance*, irradiance* All calibrations are NIST traceable (*radiometric calibrations are optional)

FieldSpec® 3 Max

Maximum Signal-to-Noise ratios for Maximum performance in the SWIR2 region.



Spectral Range	350-2500 nm
Spectral Resolution	3 nm @ 700 nm 10 nm @ 1400/2100 nm
Sampling Interval	1.4 nm @ 350-1050 nm 2 nm @ 1000-2500 nm
Scanning Time	100 milliseconds
Detectors	One 512 element Si photodiode array 350-1000 nm Two separate, TE cooled, graded index InGaAs photodiodes 1000-2500 nm
Input	1.5 m fiber optic (25° field of view) Optional foreoptics available
Noise Equivalent Radiance (NEdL)	UV/VNIR 1.1 x 10^{-9} W/cm^2/nm/sr @700 nm NIR 2.2 x 10^{-9} W/cm^2/nm/sr @ 1400 nm NIR 4.0 x 10^{-9} W/cm^2/nm/sr @ 2100 nm
Weight	12 lbs (5.2 kg)
Calibrations	Wavelength, reflectance, radiance*, irradiance* All calibrations are NIST traceable (*radiometric calibrations are optional)



Contact Sampling Accessories

High Intensity Contact Probe

For contact measurements of solid raw materials such as minerals, grains, other granular materials.

High Intensity Muglight

Designed for analysis of raw materials requiring reflectance and absorbance measurements of powders and granular materials.

Hi-Brite Contact Probe

For non-destructive contact measurements and characterization of mineral and ore samples.

Hi-Brite Muglight

Designed for analysis of raw materials requiring reflectance and absorbance measurements of minerals and some inorganic material applications requiring a higher intensity light.

Integrating Sphere

Designed for use with the ASD FieldSpec® spectroradiometers for total hemispherical reflectance measurements of materials found in many optical remote sensing, oceanography, forestry, and plant physiology applications.

Plant Probe

For non-destructive contact measurements of live vegetation leaves and other heat sensitive targets.

Reflectance Probes

For analysis of solids, liquids, slurries, and other materials requiring reflectance measurements.

Transmission Probes

ASD offers a variety of transmission probes for various contact dip, absorbance, and transflectance measurements.

Leaf Clip

Use with ASD's family of Contact Probes for non-destructive, one-handed functionality, and improved analysis of live vegetation and other thin heat sensitive targets.

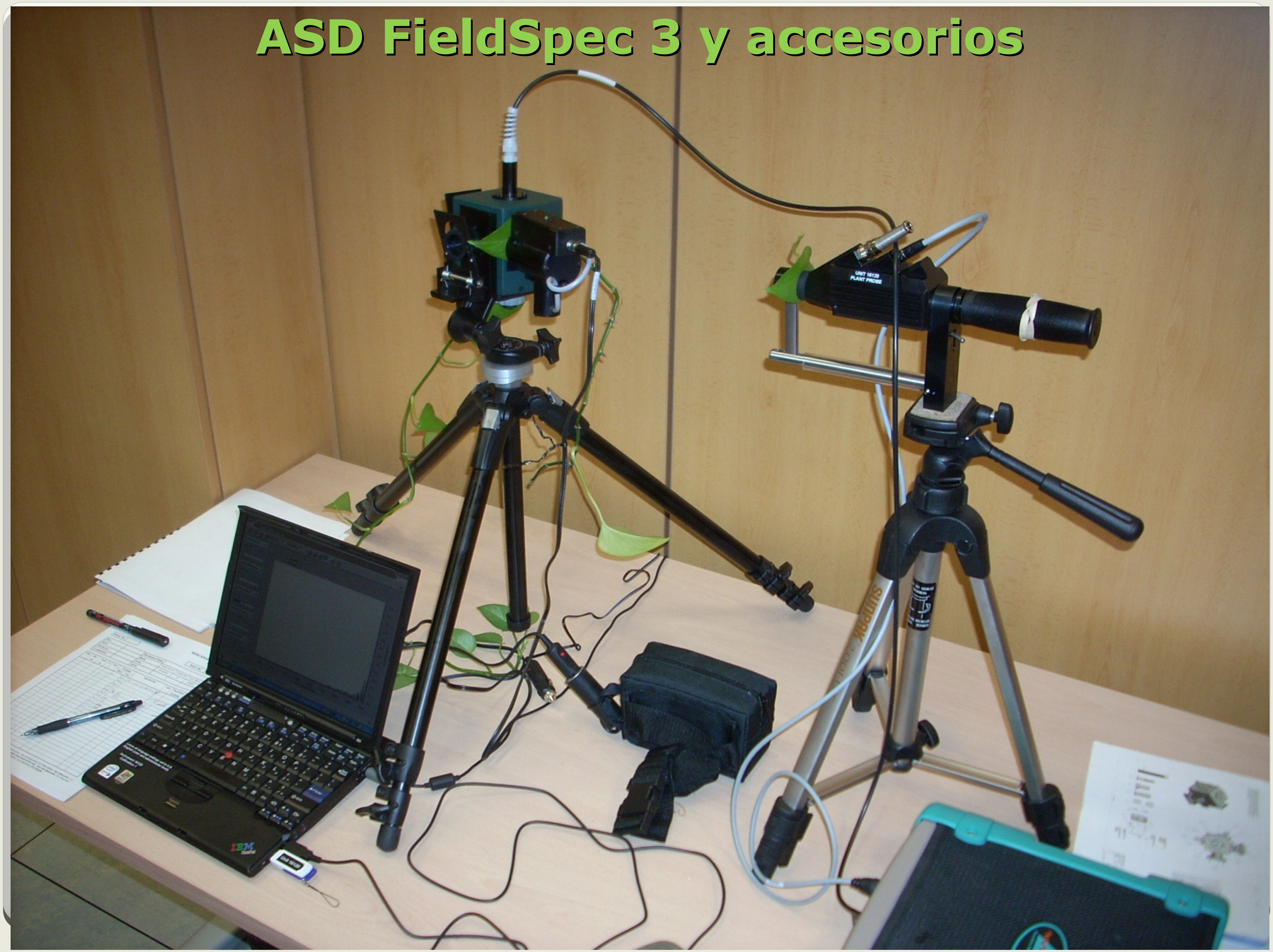
Turntable

Ideal for analysis of grain, food, and other irregularly or non-homogeneous material samples.

Multi-purpose Cuvette Fixture

Ideal for liquid and thin film material analysis.

ASD FieldSpec 3 y accesorios


PLANT PROBE
SUNPAK
IBM

TIPO	Rango espectral (nm)	Res. Espectral (band sampling)	Ancho banda	Mediciones sin PC	Peso (kg)	Portabilidad	Accesorios	Conexiones inalámbricas
SVC HR-768	350-2500	**3.5**nm@700nm **16** nm@1500 nm **14**nm@2100 nm	**1.5**nm@ 700nm **7.5** nm@ 1500 **5**nm@ 2100	STANDARD	3.3	alta	SI	SI
SVC HR-1024	350-2500	**3.5**nm@700nm **9.5** nm@1500 nm **6.5**nm@2100 nm	**1.5**nm@ 700nm **3.8** nm@ 1500 **2.5** nm@ 2100	STANDARD	3.3	alta	SI	SI
FieldSpec 3	350-2500	**3.5**nm@700nm **10** nm@1500 / 2100 nm	**1.4** nm@350-1050nm **2** nm @1000-2500 nm	DISPARADOR REMOTO	5.2	Medio-alta	SI	SI
FieldSpec 3 Hi-Res	350-2500	**3.5**nm@700nm **8.5** nm@1500 nm **6.5**nm@2100 nm	**1.4** nm@350-1050nm **2** nm @1000-2500 nm	DISPARADOR REMOTO	5.2	Medio-alta	SI	SI

GER y ASD: muy probados
SVC: por determinar

FOV y RESPUESTA DIRECCIONAL de GER 3700 y ASD FieldSpec 3 Pro

- Estudio de: **Alasdair A. Mac Arthur** (NERC) y **Tim J. Malthus** (Univ. Edimburgo)

- **PROBLEMA**: Generalmente se asume que:
  - el FOV nominal de un espectro-radiometro para un determinado ángulo es la extensión máx. del área medida
  - el FOV es simétrico respecto a los haces ópticos en todas las direcciones (elipse).
  - La sensibilidad a la luz en el FOV (Directional Response Function-DRF) muestra una distribución "Top Hat" o "Gaussiana".

Analizando el GER 3700 y el ASD FieldSpec Pro se ha demostrado que estas asunciones son erróneas.

→ El fabricante no especifica adecuadamente el FOV

MacArthur and Malthus (200) 5 Determining the FOV and directional response field radiometers. EARSeL 2007

- La incorrecta caracterización del FOV puede causar incertidumbres a la hora de atribuir las variaciones de reflectividad a los distintos factores biofísicos que describen el muestra.
- **MUY IMPORTANTE**: conocer con precisión la extensión y la posición de la escena medida por el espectroradiometro
- →eso requiere conocer:
  - Altura del espectroradiometro respecto a la muestra
  - La RESPONSIVIDAD del sistema óptico en el FOV

Metodología

- Habitación oscura (refl<3%)
- Fuente de iluminación móvil
- GER y ASD alineados
- Datos espectrales medidos cada 5mm (ASD) y 10 mm (GER) en vertical y horizontal hasta que la reflectividad medida es <1%.

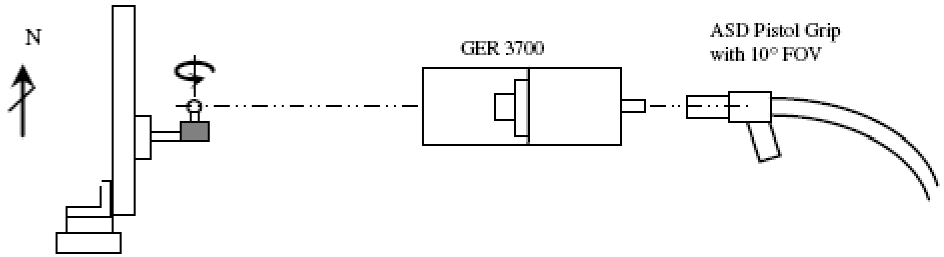


Figure 1. Orientation of GER 3700 and ASD Fore Optics

MacArthur and Malthus (200) 5 Determining the FOV and directional response field radiometers. EARSeL 2007

Resultados: ASD FieldSpec Pro

- La función de respuesta direccíonal (DRF) para 3 longitudes de onda caracteristicas han sido geostadisticamente interpoladas (ver fig.2).
- La cobertura del FOV del ASD para cada canal es rala y su distribución es altamente irregular.
- La responsividad de los canales sale fuera del FOV nominal.
- SWIR 1: baja sensibilidad en el cuadrante inferior-derecho.
- SWIR 2: tiene una desviación hacia la mitad inferior de la DRF.
- La magnitud de los hot spots es variable en las 3 bandas analizadas, con algunos picos que corresponden a solo el 50% del máximo.

- El FOV combinado de las 3 bandas pone en evidencia la alta DEPENDECIA ESPACIAL de la respuesta espectral del ASD (fig.2d)
- Los 3 canales miden porciones distintas del FOV nominal (en negro) y hay algunas zonas ciegas.
- VNIR (en verde) mide más fuera del FOV que dentro!
- **DEPENDE DE COMO CADA FIBRA OPTICA ESTÁ CONECTADA CON CADA DETECTOR (RANDOM)→ CADA INSTRUMENTO ≠**

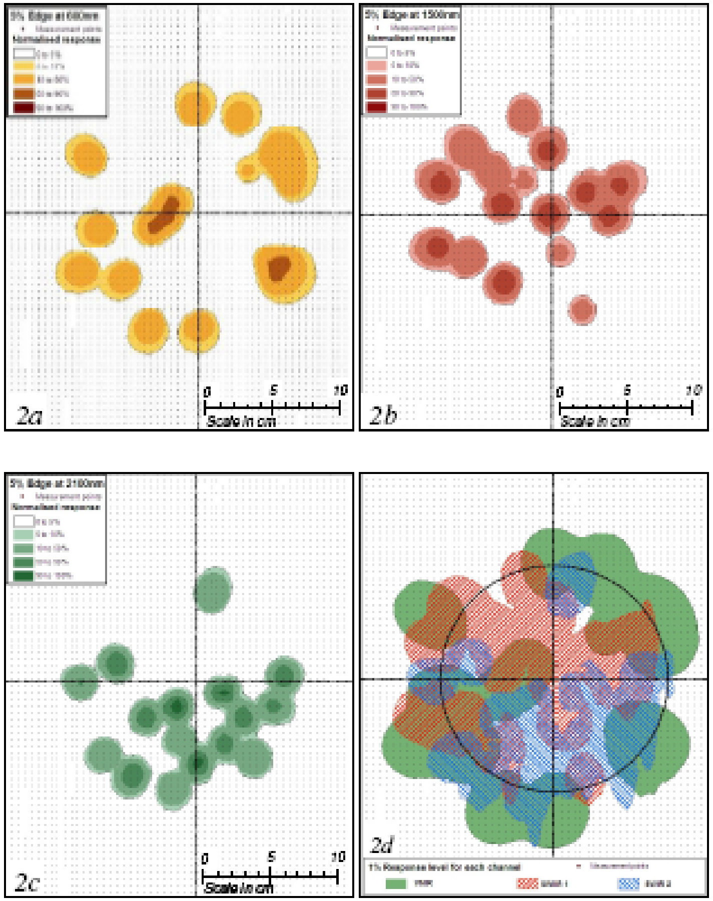


Figure 2. Normalised response contours for ASD FieldSpec Pro FR with 10° FOV lens: (2a) VNIR channel @ 600nm ; (2b) SWIR-1 channel @1600nm ; (2c) SWIR-2 channel @ 2100nm . The data points in the diagram represent a 5mm grid with contours scaled at 5, 10, 50 and 90% of peak value recorded for each wavelength. For clarity values below 5% are omitted. Figure (2d) ASD 1% contour plots at 600, 160 and 2100nm

MacArthur and Malthus (200) 5 Determining the FOV and directional response field radiometers. EARSeL 2007

Resultados: GER3700

- Fig 3: Respuesta de SWIR 1 y SWIR 2.
- Ambos FOVs presentan una respuesta rectangular, relacionada con la gometria de la ranura de entrada del espectrografo y las dimensiones de los pixeles de cada detector.
- Las proporciones de estas ranuras puede tambien ser afectada por ligeras diferenciasen la magnificación de cada banda.
- Fig 4: VNIR: forma rectangular pero en centro muestra un desplazamiento de izquierda a derecha del FOV , cuando se mide desde el AZUL hasta el NIR.
- **PUEDEN EXISTIR DIFERENCIAS ENTRE INSTRUMENTOS DEL MISMO MODELO, PERO EN ESTE CASO PODRÍAN SER MENORES YA QUE NO HAY FIBRAS ÓPTICAS.**

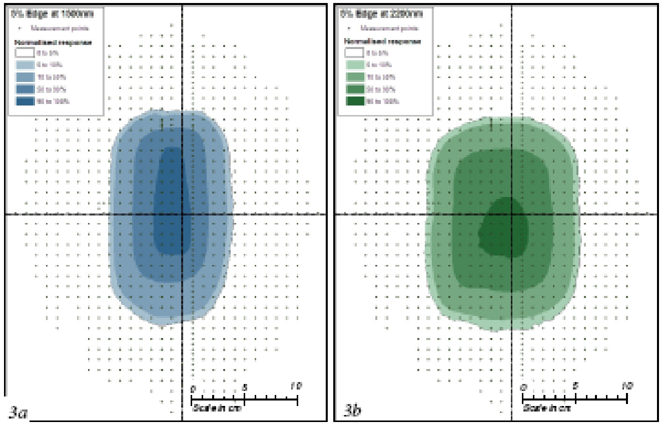


Figure 3. Normalised response across field-of-view of the GER 3700 with 10° fore optic. (3a) SWIR1,3(b) SWIR2.

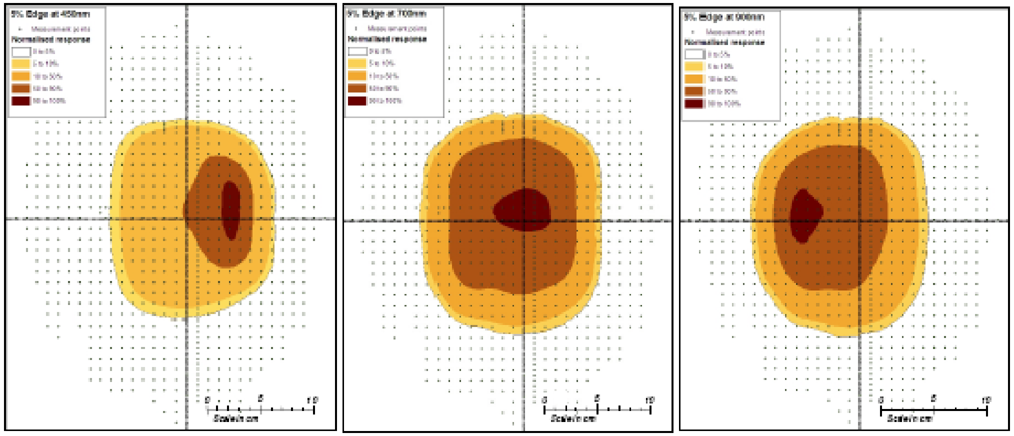


Figure 4. Normalised response across field-of-view of the GER 3700 with 10° fore optic at 400nm (left), 700nm (middle) and 900 nm (right)

MacArthur and Malthus (200) 5 Determining the FOV and directional response field radiometers. EARSeL 2007

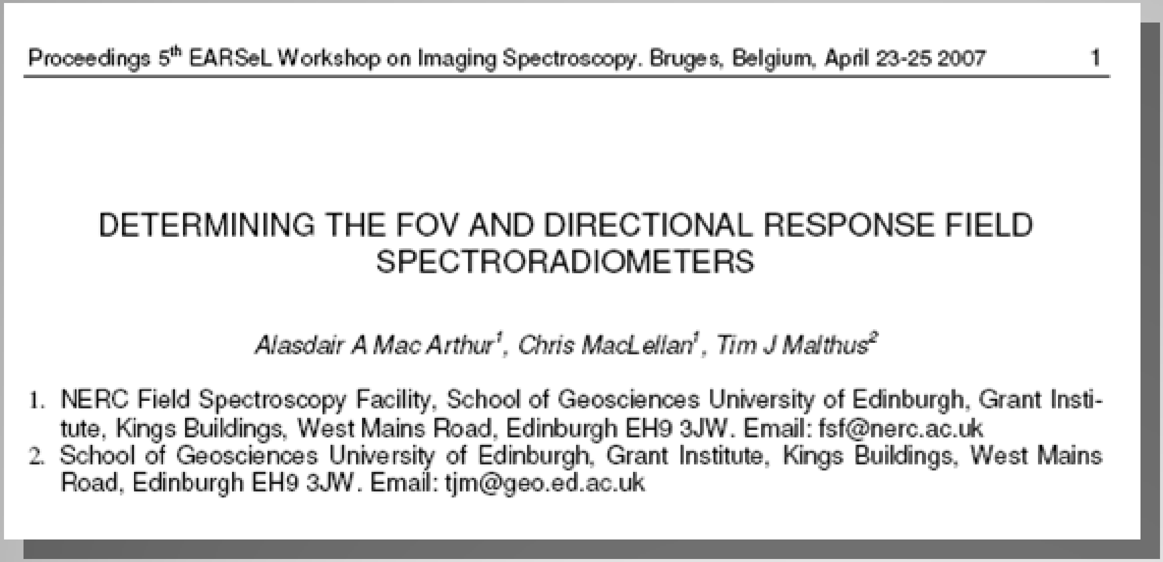
Conclusiones

- Los resultados confirman que ambos espectroradiometros presentan unas funciones de respuesta direccional muy variables en el espacio y muy distintas del FOV nominal especificado por el fabricante.
- **ADS FieldSpec Pro**: Alta variabilidad en la sensibilidad espacial de cada banda.
- **GER 3700:** la respuesta también no es uniforme pero más homogénea que la del ASD. La respuesta es muy dependiente de la longitud de onda.
- **→ TENER EN CUENTA ESTE ANALISIS A LA HORA DE PLANTEAR EL MUESTREO, SOBRETODO EN SUPERFICIES NO HOMOGENEAS**
- El **GER 3700** tiene algunas carateristicas que mejoran la repetitividad de las mediciones: laser, un sistema de óptica fijo y una respuesta direccional más espacialmente independiente.

  Pero, el montaje y las mediciones son más complejas debido a el tamaño y el peso del instrumento, respecto al ASD.

MacArthur and Malthus (200) 5 Determining the FOV and directional response field radiometers. EARSeL 2007

Para más información:

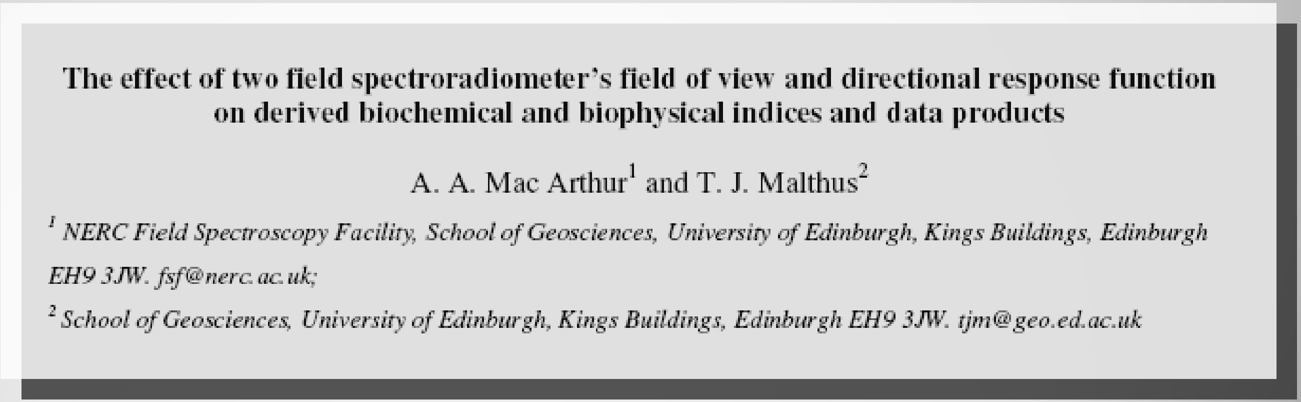


Proceedings 5th EARSeL Workshop on Imaging Spectroscopy. Bruges, Belgium, April 23-25 2007 1

DETERMINING THE FOV AND DIRECTIONAL RESPONSE FIELD SPECTRORADIOMETERS

Alasdair A Mac Arthur[1], *Chris MacLellan*[1], *Tim J Malthus*[2]

1. NERC Field Spectroscopy Facility, School of Geosciences University of Edinburgh, Grant Institute, Kings Buildings, West Mains Road, Edinburgh EH9 3JW. Email: fsf@nerc.ac.uk
2. School of Geosciences University of Edinburgh, Grant Institute, Kings Buildings, West Mains Road, Edinburgh EH9 3JW. Email: tjm@geo.ed.ac.uk



The effect of two field spectroradiometer's field of view and directional response function on derived biochemical and biophysical indices and data products

A. A. Mac Arthur[1] and T. J. Malthus[2]

[1] *NERC Field Spectroscopy Facility, School of Geosciences, University of Edinburgh, Kings Buildings, Edinburgh EH9 3JW. fsf@nerc.ac.uk;*

[2] *School of Geosciences, University of Edinburgh, Kings Buildings, Edinburgh EH9 3JW. tjm@geo.ed.ac.uk*

Espectro- radiometro de haz único: OceanOptics

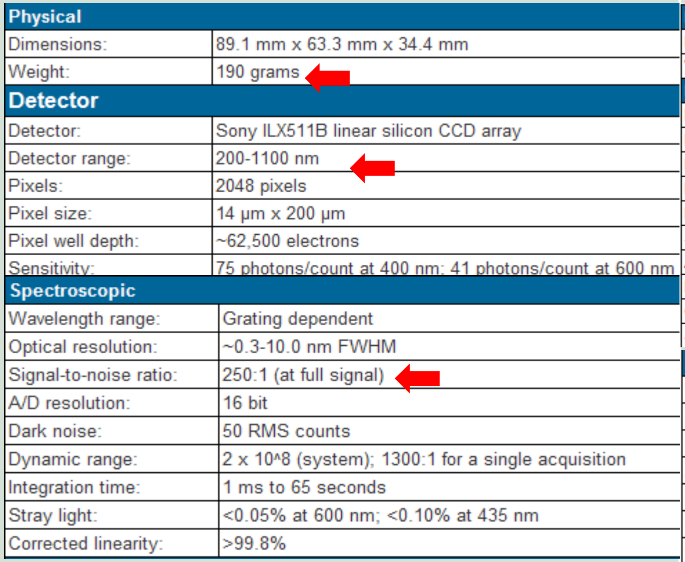
Ocean Optics
USB2000+VIS-NIR
Ocean Optics
USB2000+UV-VIS

Ocean Optics
USB2000+

Ocean Optics
inventors of the world's first miniature spectrometer

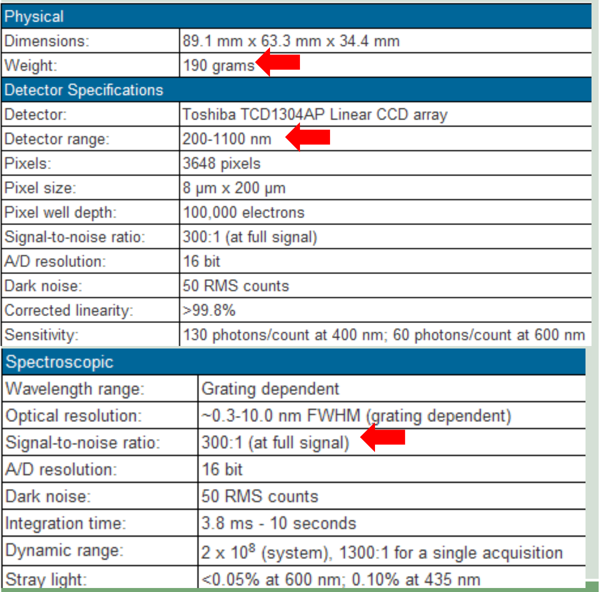
Telephone: +1 727-733-2447 | Facsimile +1 727-733-3962 | Email: info@oceanoptics.com http://www.oceanoptics.com/

USB2000+ Miniature Fiber Optic Spectrometer



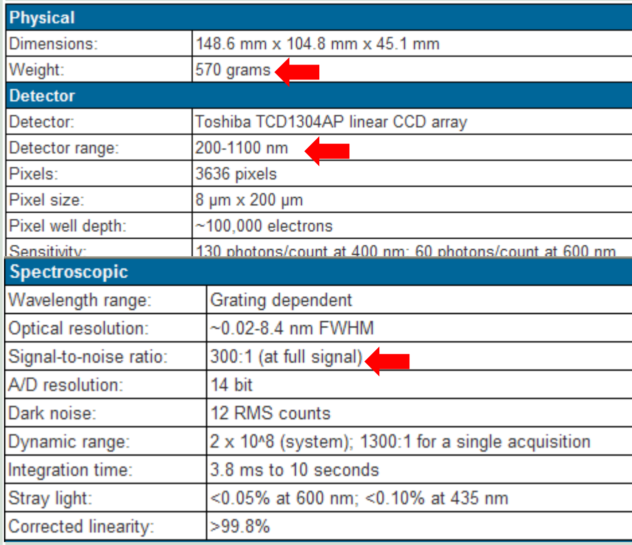
Physical	
Dimensions:	89.1 mm x 63.3 mm x 34.4 mm
Weight:	190 grams
Detector	
Detector:	Sony ILX511B linear silicon CCD array
Detector range:	200-1100 nm
Pixels:	2048 pixels
Pixel size:	14 µm x 200 µm
Pixel well depth:	~62,500 electrons
Sensitivity:	75 photons/count at 400 nm; 41 photons/count at 600 nm
Spectroscopic	
Wavelength range:	Grating dependent
Optical resolution:	~0.3-10.0 nm FWHM
Signal-to-noise ratio:	250:1 (at full signal)
A/D resolution:	16 bit
Dark noise:	50 RMS counts
Dynamic range:	2 x 10^8 (system); 1300:1 for a single acquisition
Integration time:	1 ms to 65 seconds
Stray light:	<0.05% at 600 nm; <0.10% at 435 nm
Corrected linearity:	>99.8%

USB4000 Miniature Fiber Optic Spectrometer



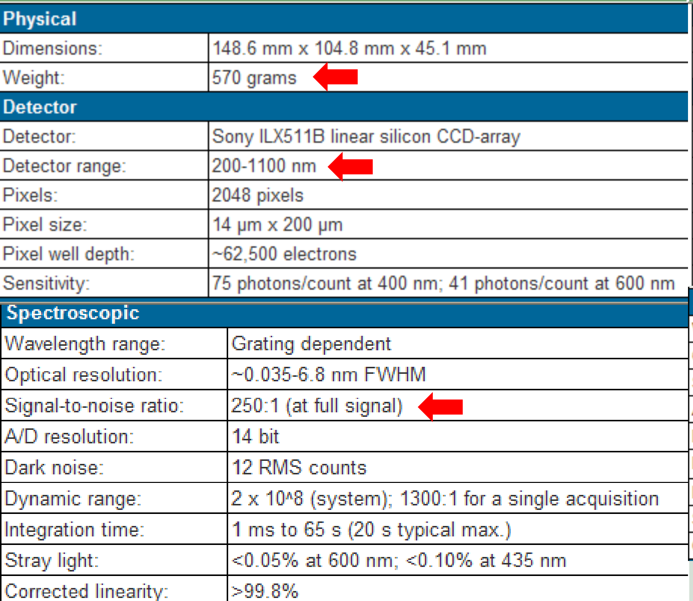
Physical	
Dimensions:	89.1 mm x 63.3 mm x 34.4 mm
Weight:	190 grams
Detector Specifications	
Detector:	Toshiba TCD1304AP Linear CCD array
Detector range:	200-1100 nm
Pixels:	3648 pixels
Pixel size:	8 µm x 200 µm
Pixel well depth:	100,000 electrons
Signal-to-noise ratio:	300:1 (at full signal)
A/D resolution:	16 bit
Dark noise:	50 RMS counts
Corrected linearity:	>99.8%
Sensitivity:	130 photons/count at 400 nm; 60 photons/count at 600 nm
Spectroscopic	
Wavelength range:	Grating dependent
Optical resolution:	~0.3-10.0 nm FWHM (grating dependent)
Signal-to-noise ratio:	300:1 (at full signal)
A/D resolution:	16 bit
Dark noise:	50 RMS counts
Integration time:	3.8 ms - 10 seconds
Dynamic range:	2 x 10^8 (system), 1300:1 for a single acquisition
Stray light:	<0.05% at 600 nm; 0.10% at 435 nm

HR4000 High-Resolution Spectrometer



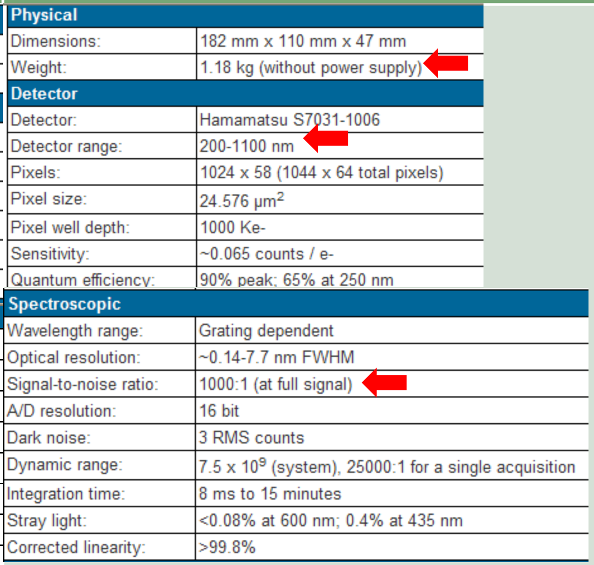
Physical	
Dimensions:	148.6 mm x 104.8 mm x 45.1 mm
Weight:	570 grams
Detector	
Detector:	Toshiba TCD1304AP linear CCD array
Detector range:	200-1100 nm
Pixels:	3636 pixels
Pixel size:	8 µm x 200 µm
Pixel well depth:	~100,000 electrons
Sensitivity:	130 photons/count at 400 nm; 60 photons/count at 600 nm
Spectroscopic	
Wavelength range:	Grating dependent
Optical resolution:	~0.02-8.4 nm FWHM
Signal-to-noise ratio:	300:1 (at full signal)
A/D resolution:	14 bit
Dark noise:	12 RMS counts
Dynamic range:	2 x 10^8 (system); 1300:1 for a single acquisition
Integration time:	3.8 ms to 10 seconds
Stray light:	<0.05% at 600 nm; <0.10% at 435 nm
Corrected linearity:	>99.8%

HR2000+ High-resolution Spectrometer



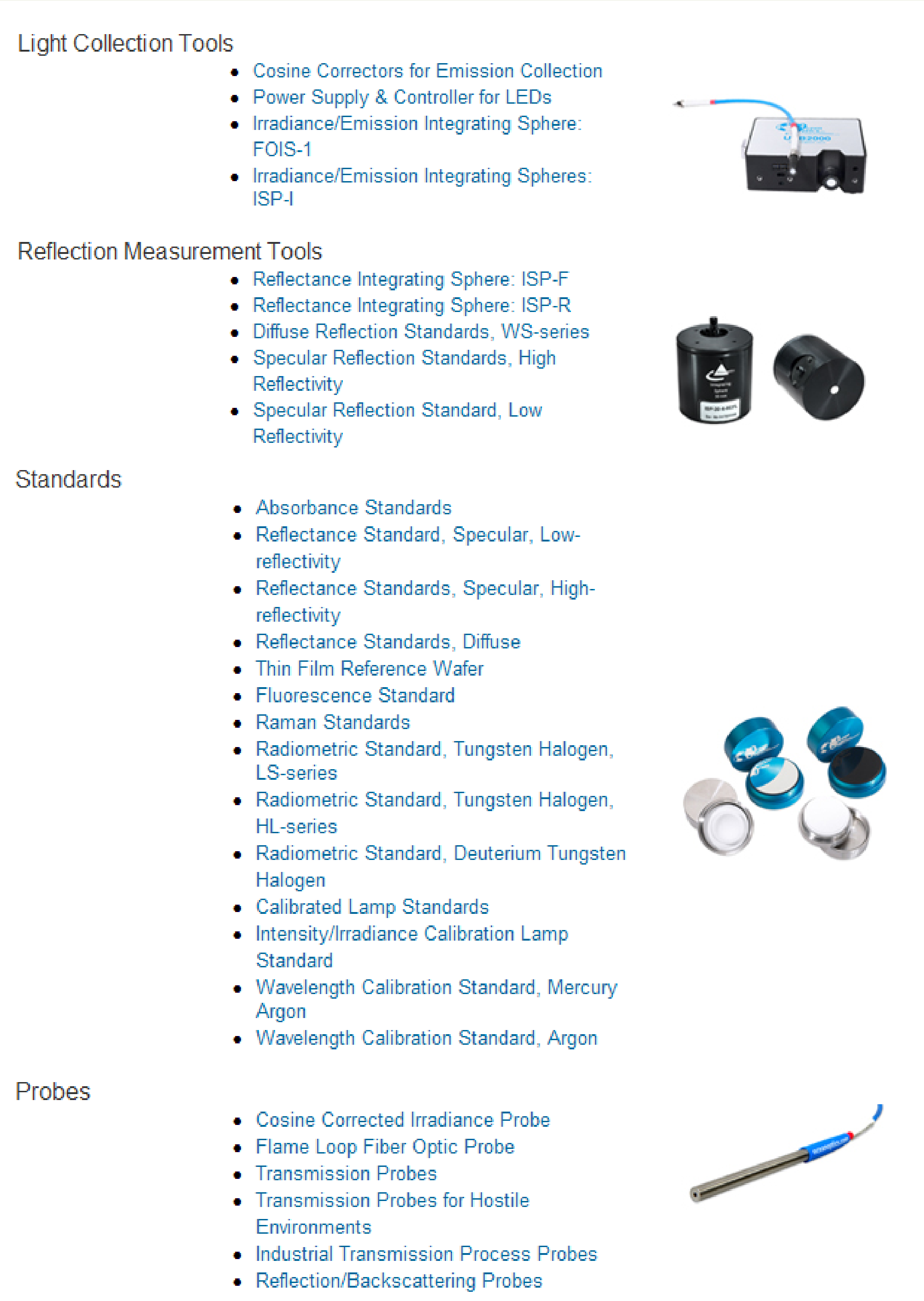
Physical	
Dimensions:	148.6 mm x 104.8 mm x 45.1 mm
Weight:	570 grams
Detector	
Detector:	Sony ILX511B linear silicon CCD-array
Detector range:	200-1100 nm
Pixels:	2048 pixels
Pixel size:	14 µm x 200 µm
Pixel well depth:	~62,500 electrons
Sensitivity:	75 photons/count at 400 nm; 41 photons/count at 600 nm
Spectroscopic	
Wavelength range:	Grating dependent
Optical resolution:	~0.035-6.8 nm FWHM
Signal-to-noise ratio:	250:1 (at full signal)
A/D resolution:	14 bit
Dark noise:	12 RMS counts
Dynamic range:	2 x 10^8 (system); 1300:1 for a single acquisition
Integration time:	1 ms to 65 s (20 s typical max.)
Stray light:	<0.05% at 600 nm; <0.10% at 435 nm
Corrected linearity:	>99.8%

QE65000-FL Scientific-grade Spectrometer



Physical	
Dimensions:	182 mm x 110 mm x 47 mm
Weight:	1.18 kg (without power supply)
Detector	
Detector:	Hamamatsu S7031-1006
Detector range:	200-1100 nm
Pixels:	1024 x 58 (1044 x 64 total pixels)
Pixel size:	24.576 µm^2
Pixel well depth:	1000 Ke-
Sensitivity:	~0.065 counts / e-
Quantum efficiency:	90% peak; 65% at 250 nm
Spectroscopic	
Wavelength range:	Grating dependent
Optical resolution:	~0.14-7.7 nm FWHM
Signal-to-noise ratio:	1000:1 (at full signal)
A/D resolution:	16 bit
Dark noise:	3 RMS counts
Dynamic range:	7.5 x 10^9 (system), 25000:1 for a single acquisition
Integration time:	8 ms to 15 minutes
Stray light:	<0.08% at 600 nm; 0.4% at 435 nm
Corrected linearity:	>99.8%

Accesorios Ocean Optics



Light Collection Tools

- Cosine Correctors for Emission Collection
- Power Supply & Controller for LEDs
- Irradiance/Emission Integrating Sphere: FOIS-1
- Irradiance/Emission Integrating Spheres: ISP-I

Reflection Measurement Tools

- Reflectance Integrating Sphere: ISP-F
- Reflectance Integrating Sphere: ISP-R
- Diffuse Reflection Standards, WS-series
- Specular Reflection Standards, High Reflectivity
- Specular Reflection Standard, Low Reflectivity

Standards

- Absorbance Standards
- Reflectance Standard, Specular, Low-reflectivity
- Reflectance Standards, Specular, High-reflectivity
- Reflectance Standards, Diffuse
- Thin Film Reference Wafer
- Fluorescence Standard
- Raman Standards
- Radiometric Standard, Tungsten Halogen, LS-series
- Radiometric Standard, Tungsten Halogen, HL-series
- Radiometric Standard, Deuterium Tungsten Halogen
- Calibrated Lamp Standards
- Intensity/Irradiance Calibration Lamp Standard
- Wavelength Calibration Standard, Mercury Argon
- Wavelength Calibration Standard, Argon

Probes

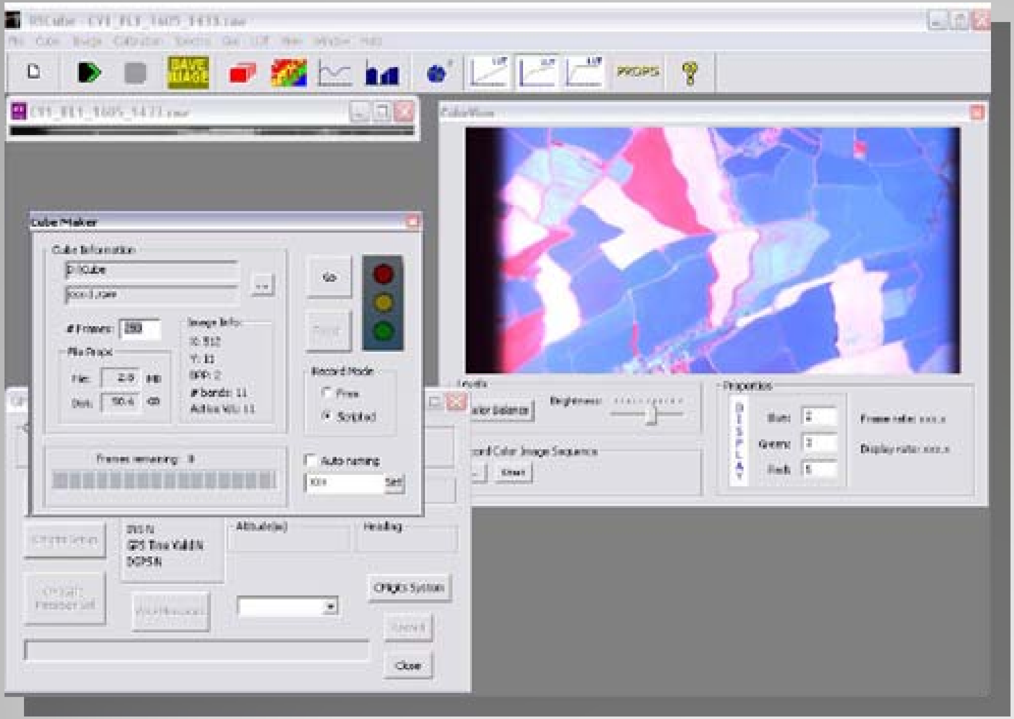
- Cosine Corrected Irradiance Probe
- Flame Loop Fiber Optic Probe
- Transmission Probes
- Transmission Probes for Hostile Environments
- Industrial Transmission Process Probes
- Reflection/Backscattering Probes

Espectro- radiometro de haz único: OceanOptics

VENTAJAS ☺	INCONVENIENTES ☹
EXTREMADAMENTE LIGERO	RANGO ESPECTRAL
FACIL DE TRANSPORTAR	CALIBRACIÓN ??
MANEJO SENCILLO	ESTABILIDAD DE LAS MEDICIONES ??
BARATO	FUNCIONALIDAD EN CAMPO (T, polvo, golpes)??

Ocean Optics
USB2000+

Cámaras hiperespectrales: SPECIM

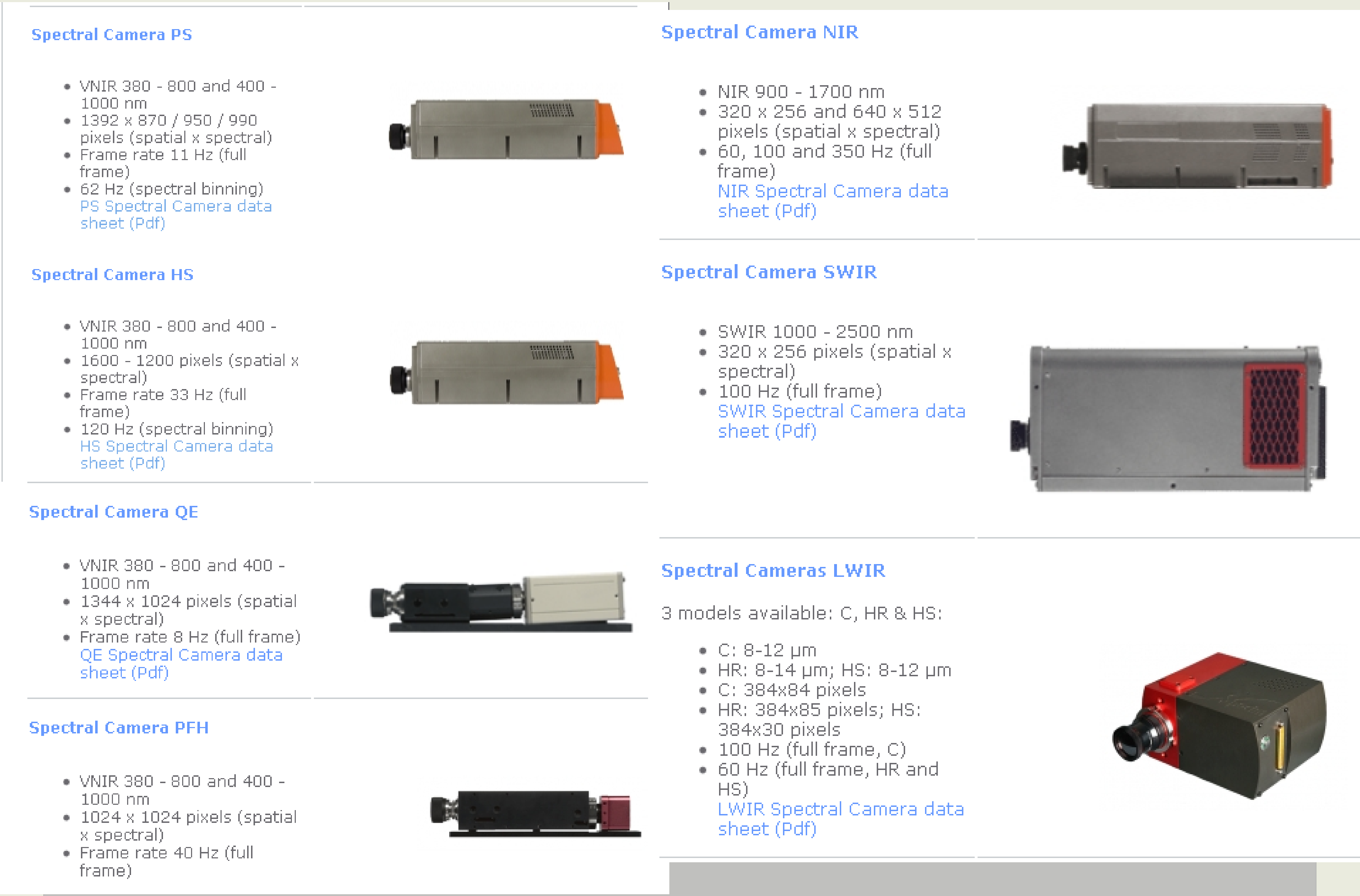

PROPS
Cube Maker
Cube Information
# Frames:
Image Info:
File Props
Go
Record Mode
Free
Scripted
Frames remaining: 0
Auto naming
Set
Altitude(m)
Heading
Close
Brightness:
Properties
DISPLAY
Frame rate:
Display rate:

Specim

ENHANCE YOUR PERCEPTION

SPECTRAL IMAGING LTD.

Teknologiantie 18 A
90570 Oulu
Finland
Tel: +358 (0)10 4244 400
Fax: +358 (0)8 388 580
web: http://www.specim.fi



Spectral Camera PS

- VNIR 380 - 800 and 400 - 1000 nm
- 1392 x 870 / 950 / 990 pixels (spatial x spectral)
- Frame rate 11 Hz (full frame)
- 62 Hz (spectral binning)
  PS Spectral Camera data sheet (Pdf)

Spectral Camera HS

- VNIR 380 - 800 and 400 - 1000 nm
- 1600 - 1200 pixels (spatial x spectral)
- Frame rate 33 Hz (full frame)
- 120 Hz (spectral binning)
  HS Spectral Camera data sheet (Pdf)

Spectral Camera QE

- VNIR 380 - 800 and 400 - 1000 nm
- 1344 x 1024 pixels (spatial x spectral)
- Frame rate 8 Hz (full frame)
  QE Spectral Camera data sheet (Pdf)

Spectral Camera PFH

- VNIR 380 - 800 and 400 - 1000 nm
- 1024 x 1024 pixels (spatial x spectral)
- Frame rate 40 Hz (full frame)

Spectral Camera NIR

- NIR 900 - 1700 nm
- 320 x 256 and 640 x 512 pixels (spatial x spectral)
- 60, 100 and 350 Hz (full frame)
  NIR Spectral Camera data sheet (Pdf)

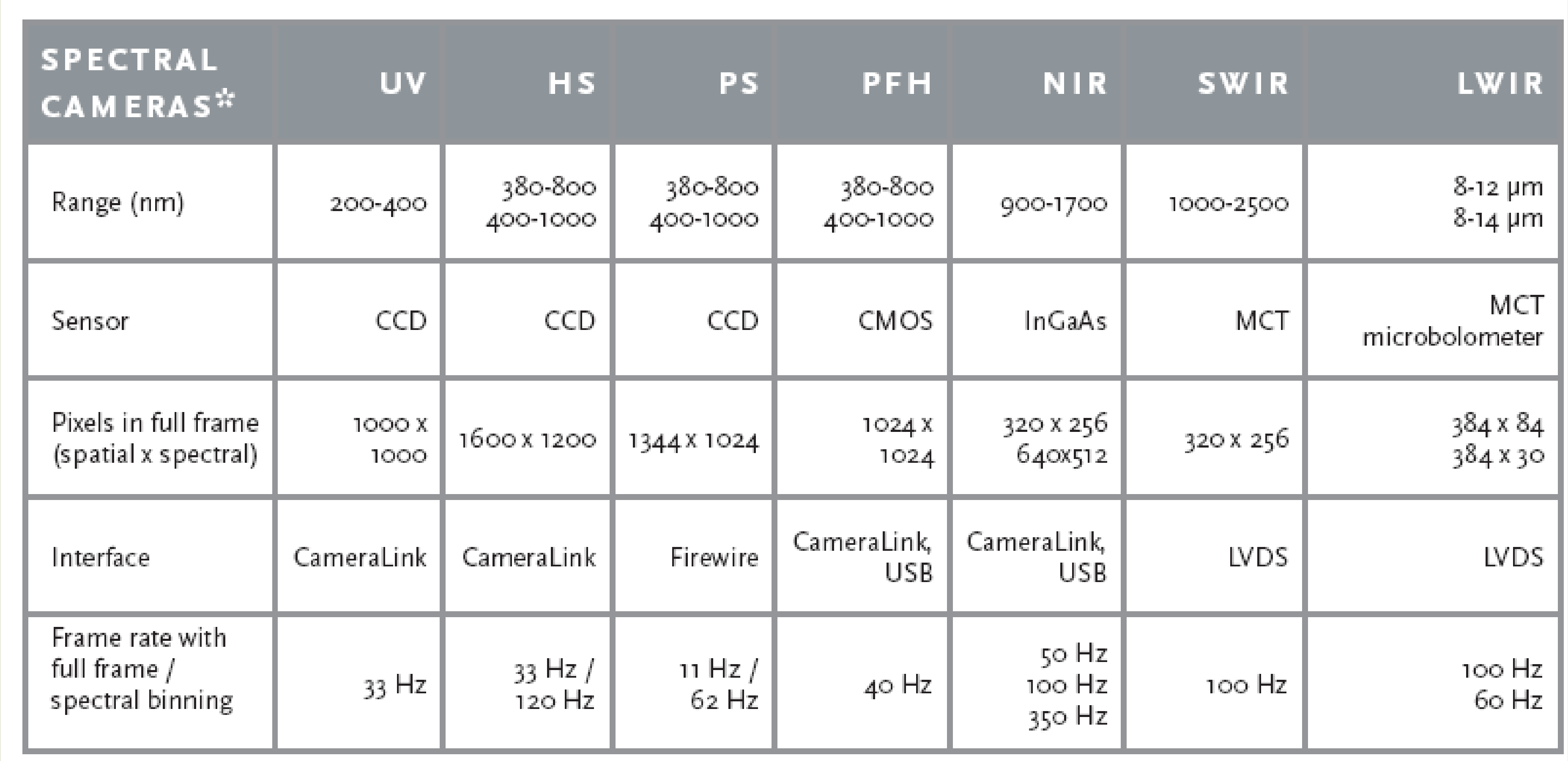
Spectral Camera SWIR

- SWIR 1000 - 2500 nm
- 320 x 256 pixels (spatial x spectral)
- 100 Hz (full frame)
  SWIR Spectral Camera data sheet (Pdf)

Spectral Cameras LWIR

3 models available: C, HR & HS:

- C: 8-12 μm
- HR: 8-14 μm; HS: 8-12 μm
- C: 384x84 pixels
- HR: 384x85 pixels; HS: 384x30 pixels
- 100 Hz (full frame, C)
- 60 Hz (full frame, HR and HS)
  LWIR Spectral Camera data sheet (Pdf)



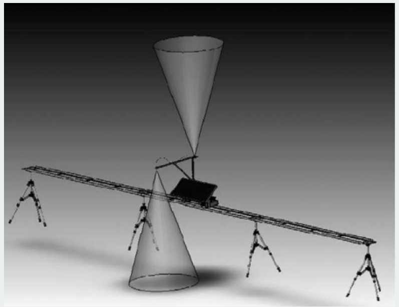
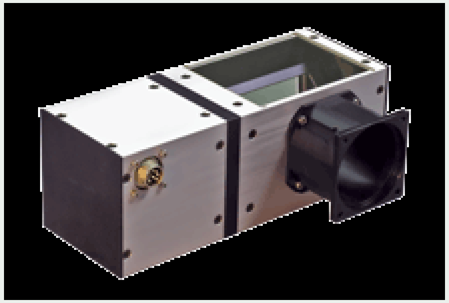
SPECTRAL CAMERAS*	UV	HS	PS	PFH	NIR	SWIR	LWIR
Range (nm)	200-400	380-800 400-1000	380-800 400-1000	380-800 400-1000	900-1700	1000-2500	8-12 μm 8-14 μm
Sensor	CCD	CCD	CCD	CMOS	InGaAs	MCT	MCT microbolometer
Pixels in full frame (spatial x spectral)	1000 x 1000	1600 x 1200	1344 x 1024	1024 x 1024	320 x 256 640x512	320 x 256	384 x 84 384 x 30
Interface	CameraLink	CameraLink	Firewire	CameraLink, USB	CameraLink, USB	LVDS	LVDS
Frame rate with full frame / spectral binning	33 Hz	33 Hz / 120 Hz	11 Hz / 62 Hz	40 Hz	50 Hz 100 Hz 350 Hz	100 Hz	100 Hz 60 Hz

ACCESSORIES

SPECIM provides various accessories for the Spectral Cameras to broaden their applicability.

- Several **fore objective lenses** with different FOVs are available which have been designed to provide the optimal image and spectral quality across the full spectral range of the Spectral Camera.
- The Spectral Camera can also be delivered with **collection fiber optics** to convert the camera into a multiple point spectrometer. All the points are measured simultaneously without a moving multiplexer.
- The Spectral Camera can be delivered with **a Mirror Scanner or rotating stage** for scanning static targets and outdoor scenes, or with **a linear sample mover (X-stage)** for desktop and microscope applications.

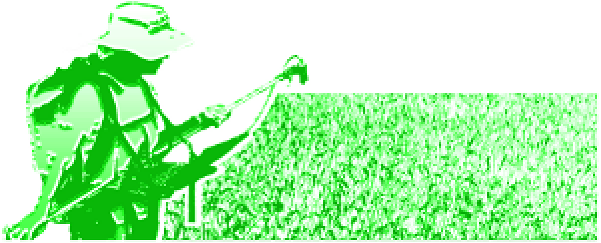
Cámara hiperespectral: SPECIM

VENTAJAS ☺	INCONVENIENTES ☹
2D	RANGO ESPECTRAL (SOLO VIS-NIR O NIR-SWIR,ETC.)
ALTA RESOLUCIÓN	ALINEACIÓN SENSORES PARA CUBRIR TODO EL RANGO ÓPTICO
PARA AVIÓN/CAMPO/LAB	PRECIO
CONTROL DURANTE LA MEDICIÓN (RS-CUBE), SW AMIGABLE	TAMAÑO FICHEROS
COMPACTO	MENOS ROBUSTO QUE UN RADIOMETRO (CAMPO)
 	MEDICIONES: -SIN ESPEJO: estructura (velocidad movimiento ~ velocidad escaneo líneas) -CON ESPEJO: distorsiones primeras y ultimas líneas, bordes→ corrección como desde avión en swath y along track pixeles deformados

Instrumentos disponibles en el mercado. Análisis comparativo

MUCHAS GRACIAS
¿PREGUNTAS?

Dra. Angela De Santis
Jefe de Proyecto
Ingeniería y Servicios Aeroespaciales (INSA)
Departamento de Sistemas y Observación de la Tierra
angela.de.santis@insa.org

SEMINARIO:
AVANCES EN ESPECTRO-RADIOMETRÍA
3 y 4 de diciembre de 2009