DMC PRODUCT MANUAL FOR THE DMC EUROPE 2007 COVERAGE

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1 DOCUMENT REVISION STATUS

Issue	Date	Name	Change Reference
01	27-Jun-2008	Gary Crowley	ALL

2 SCOPE

The data products supplied by DMCII are derived from images acquired by the DMC satellites. The primary payload on the DMC satellites is the SLIM-6 imager manufactured by SSTL, UK.

This manual will aid users in their analysis of the data products to maximise the information they can extract from the DMC images by providing a thorough description of the data products, the imaging payload, the calibration procedure and the orthorectification process.

3 APPLICABLE DOCUMENTS

These are documents that are owned or controlled by DMCII or SSTL. Applicable documents identified in the following text are identified by **AD#n**, where "n" indicates the actual document, from the following list:

AD#	Reference	Title
01	0062733	Post-launch Calibration of the UK-DMC Satellite Sensor
02	0105469	Orthorectification Procedure
03	0052791	DMC 32m MS Filter Spectral Response Profiles
04	0104039	DMC DIMAP: A Technical Note On The Dimap Metadata Format For DMCII Products
05	0074903	Metadata Files Distributed with the DMC Images
06	0075257	Radiance Calculation Formulae for DMC Images
07	0049911	DMC Image Format
09	0086432	TIFF Tags for Radiance Calculation
09	0112168	FAQ on DMC Data Supplied to ESA for Europe 2007
10	0115064	Beijing-1 32m MS Filter Spectral Response Profiles

4 RELATED DOCUMENTS

These are external documents that are NOT owned or controlled by DMCII or SSTL. Reference documents identified in the following text are identified by **RD#n**, where "n" indicates the actual document, from the following list:

RD#	Reference	Title
01		TIFF Revision 6.0
02		Dimap Dictionary: Generic Profile Version 1.1 (Ed. May 9, 2006)
03		Dimap Dictionary: SPOT Scene Profile Version 1.1.2 (Ed. May 9, 2006)
04		KLI-10203 Datasheet Revision No. 6

5 ACRONYMS AND ABBREVIATIONS

The following acronyms and abbreviations are used within this document:

Acronym	Description
AOCS	Attitude and Orbit Control System
BIL	Band Interleave by Line
CCD	Charge Coupled Device
CGIAR	Consultative Group for International Agricultural Research
CGIAR-CSI	CGIAR - Consortium for Spatial Information
CIAT	International Centre for Tropical Agriculture
CRS	Coordinate Reference System
DEM	Digital Elevation Model
DIMAP	Digital Image Map
DMC	Disaster Monitoring constellation
DMCII	DMC International Imaging Ltd.
DN	Digital Number
EO	Earth Observation
EOST	Earth Observation Scheduling Task
EPSG	European Petroleum Survey Group
ETM+	Enhanced Thematic Mapper Plus
FoV	Field of View
GCP	Ground Control Point
GCS	Geographic Coordinate System
GeoTIFF	Geo-referenced Tagged Image File Format
GLCF	Global Land Cover Facility
GLOBE	Global Land One-km Base Elevation
GSD	Ground Sample Distance
HDDR	Hard Drive Data Recorder
HTML	Hypertext Markup Language
IFD	Image File Directory
iFoV	Instantaneous Field of View
LEO	Low Earth Orbit
LTAN	Local Time Ascending Node
LUT	Look-Up Table
NEΔL	Noise Equivalent Difference in Radiance
NGDC	National Geophysical Data Center
NIR	Near Infrared
NOAA	National Oceanic and Atmospheric Administration
NRT	Near Real-Time
OBC	On-Board Computer
OGP	International Association of Oil & Gas Producers
PAN	Panchromatic
QE	Quantum Efficiency
RGB	Red Green Blue
RMS	Root Mean Square
RMSE	Root Mean Square Error
RRV	Railroad Valley
RSG	Remote Sensing Group at The University of Arizona
SLIM-6	Surrey Linear Imager – 6 Channels

Acronym	Description
SNR	Signal to Noise Ratio
SRTM	Shuttle Radar Topography Mission
SSDR	Solid State Data Recorder
SSTL	Surrey Satellite Technology Ltd.
TIFF	Tagged Image File Format
Tlm	Telemetry
TOA	Top of Atmosphere
UTC	Universal Time Coordinated
UTM	Universal Transverse Mercator
WGS84	World Geodetic System 1984
XML	Extensible Markup Language

6 UNITS OF MEASUREMENT

The following units of measurement are used within this document:

Unit	Description
°	Degree
µm	Micrometre = 10^{-6} m
µs	Microsecond = 10^{-6} s
arc sec	Arc second = 1/3600 °
AU	Astronomical Unit
B	Bytes
b	Bits
bps	Bits per second
GB	Gigabyte = 10^{9} B
kg	Kilogram
km	Kilometre = 10^{3} m
kms^{-1}	Kilometres per second = 10^{3} ms^{-1}
m	Metre
MB	Megabyte = 10^{6} B
Mbps	Megabits per second = 10^{6} bps
min	Minute = 60 s
mm	Millimetre = 10^{-3} m
ms	Millisecond = 10^{-3} s
ms^{-1}	Metres per second
nm	Nanometre = 10^{-9} m
ns	Nanosecond = 10^{-9} s
rad	Radian
s	Second
sr	Steradian
TB	Terabyte = 10^{12} B
W	Watt
$Wm^{-2}sr^{-1}\mu m^{-1}$	Watts per square metre steradian micrometre

7 DATA PRODUCTS

DMCII currently offers the data products outlined in Table 1, which are derived from 32m multi-spectral images captured by the DMC SLIM-6 imager.

Product	Description
L0R	Raw satellite data split into the 3 spectral bands (NIR, Red and Green) with a radiometric correction applied to all bands.
L1R	Band registered product derived from the L0R product.
L1T	Orthorectified product derived from the L1R product using manually collected GCPs from IMAGE2000 data and SRTM DEM V3[1] data.
L1T_QL	Quicklook L1T product, which has been resampled to the equivalent of 320m GSD.

Table 1: DMC data products

The SRTM DEM V3 only covers the Earth's land mass between ±60° latitude. Where the acquired image exceeds ±60° latitude, orthorectification will be performed using the 1km GLOBE DEM[2] supplied by NGDC.

The IMAGE2000 dataset only covers 25 out of the 38 countries acquired in the Europe 2007 coverage. For countries where IMAGE2000 data is not available, GCP collection is performed using the Landsat ETM+ data.

For the DMC Europe 2007 coverage only L1R, L1T, and L1T_QL products were delivered.

8 DMC IMAGER PAYLOAD

8.1 SLIM-6 Imager Design

The primary DMC imaging payload is the SLIM-6 imager built by SSTL UK, which is an evolution of multi-spectral imagers flown on previous SSTL missions. The SLIM-6 design provides a 3 spectral band, nadir pointing imager capable of providing mid-resolution images of the Earth's surface when operating in a low Earth sun-synchronous orbit.

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[1] Void-filled SRTM DEM V3, 2006, International Centre for Tropical Agriculture (CIAT), available from the CGIAR-CSI SRTM 90m Database: http://srtm.csi.cgiar.org

[2] The GLOBE DEM is supplied by NOAA, available from NGDC http://www.ngdc.noaa.gov/mgg/topo/globe.html

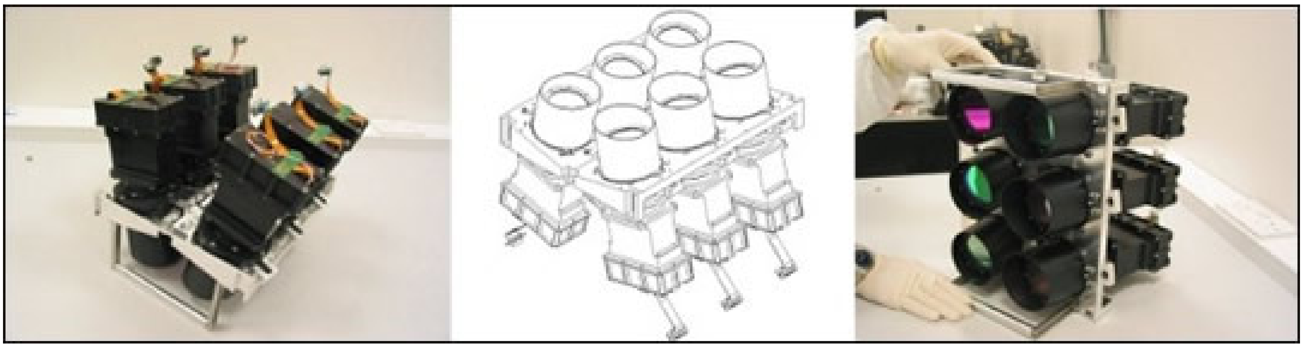

Figure 1: The SLIM-6 imager

The SLIM-6 imager is a dual bank linear push broom imager utilising the orbital motion of the DMC platform to capture radiation reflected from the Earth's surface within a 600 km swath.

The spectral filter of each channel is protected by a fused silica radiation absorption window, which is positioned on the space facing side of the filter. The spectral filters are located in front of the camera lens. Each of the 6 SLIM-6 imager channels has a linear CCD array at its focal plane.

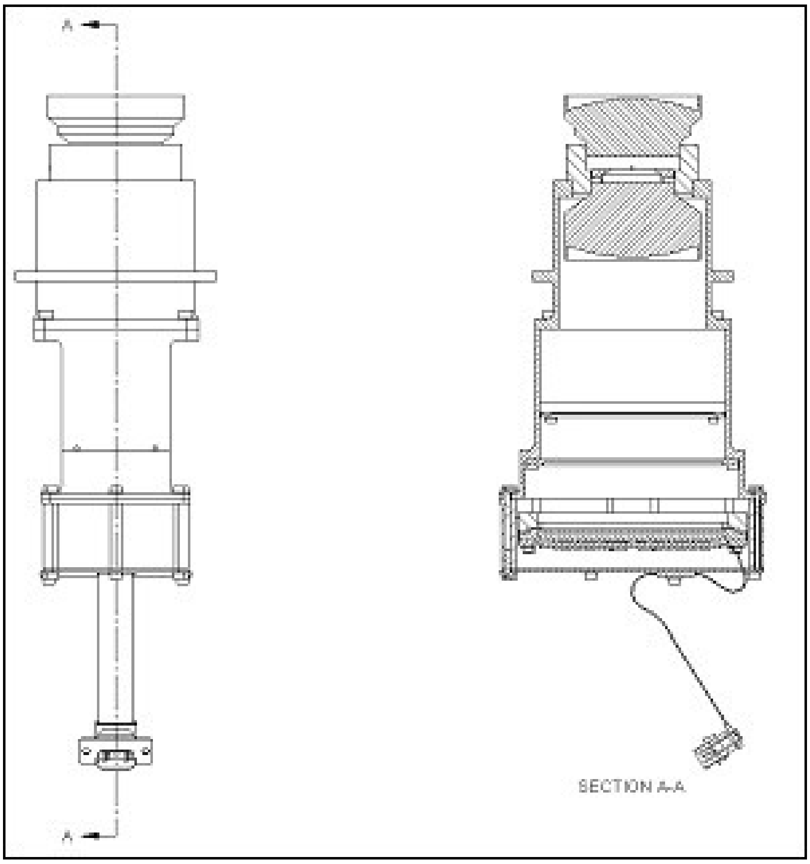

Figure 2: SLIM-6 single channel focal plane assembly

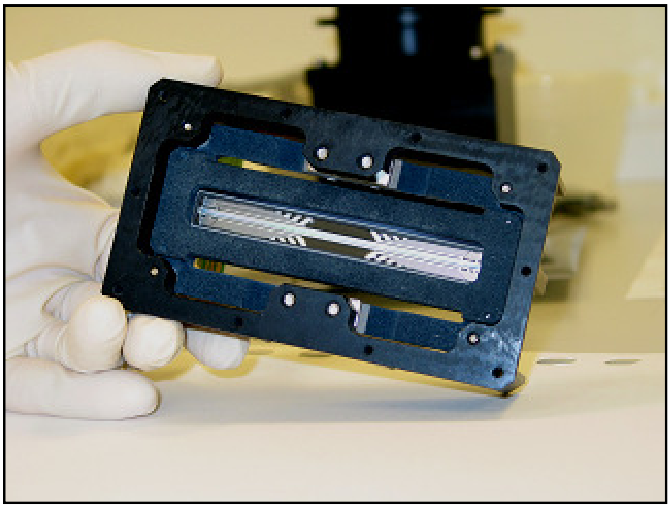

Figure 3: Eastman Kodak KL10203 Linear CCD

	Specification
Sensor	Eastman Kodak KLI-10203 Linear CCD: Number of Detectors = 10,224[3] Detector Size = 7.0 µm x 7.0 µm Data Capture = 11-bit[4]
Lens	Schneider Apo-Componon HM 150mm focal length, f/6.3 Focal length = 150.9 mm F-number = f/6.3
iFoV	46.388×10^{-6} rad = 0.00266° = 9.568 arc sec
FoV	$2 \times \mathrm{TAN}^{-1} [(7.0 \times 10^{-6} \times 5100) / (150.9 \times 10^{-3})] = 26.62°$
GSD	31.822 m at nadir
Swath	31.822 x 10200 = 324.58 km

Table 2: Single channel optical specification

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[3] Only 10,200 detectors are used for image capture. The other 24 detectors are used to measure the dark current.

[4] Only the most significant 8-bits of data are captured to the storage device.

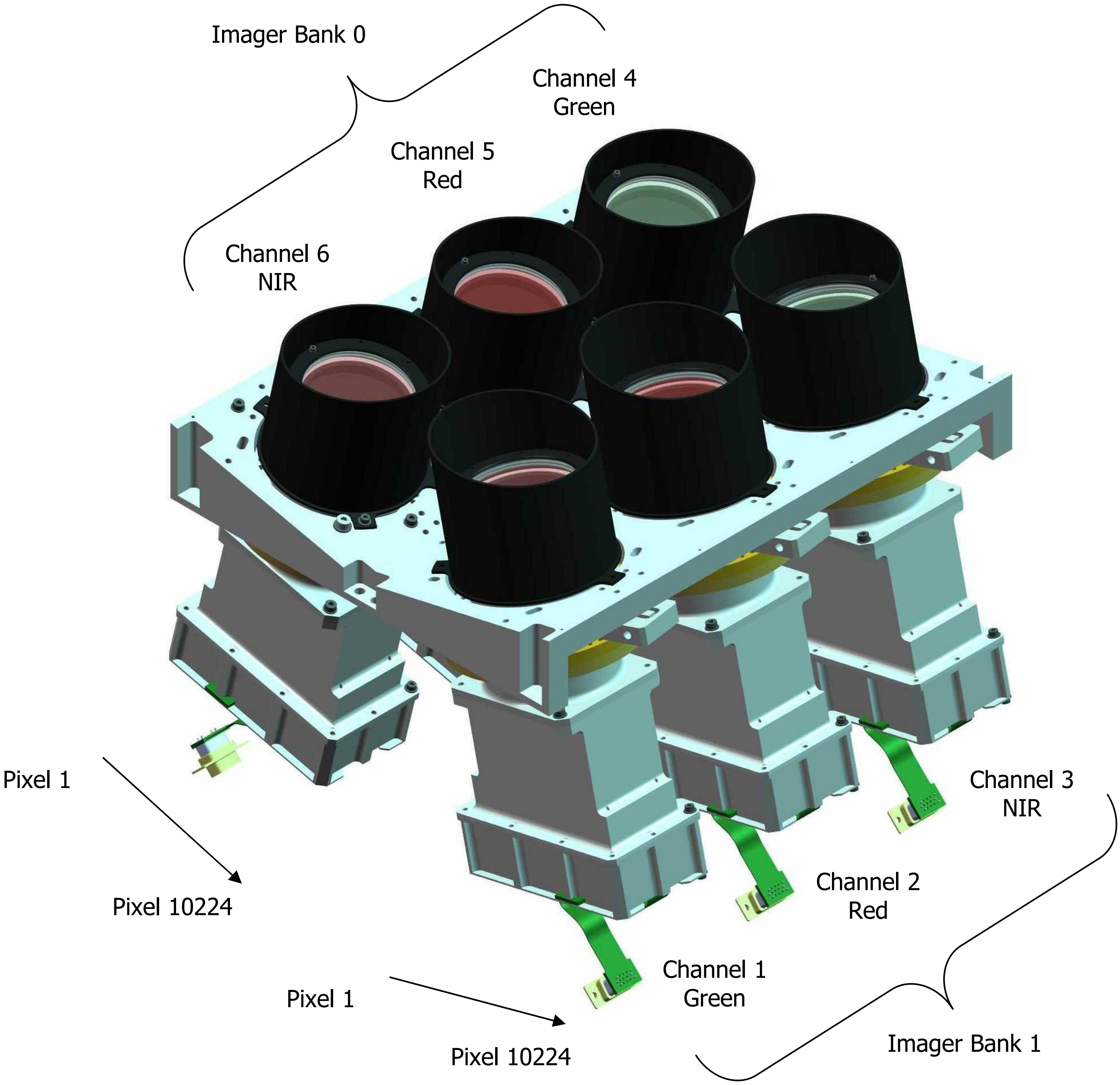

Figure 4: Detector and channel layout of the SLIM-6 imager

8.2 Sensor Model

The SLIM-6 imager is composed of 2 banks, each bank consisting of 3 channels (NIR, Red, Green spectral bands). The 2 imager banks are mounted at an angle to provide a total imaging swath of 600 km and an overlap between the simultaneously acquired images.

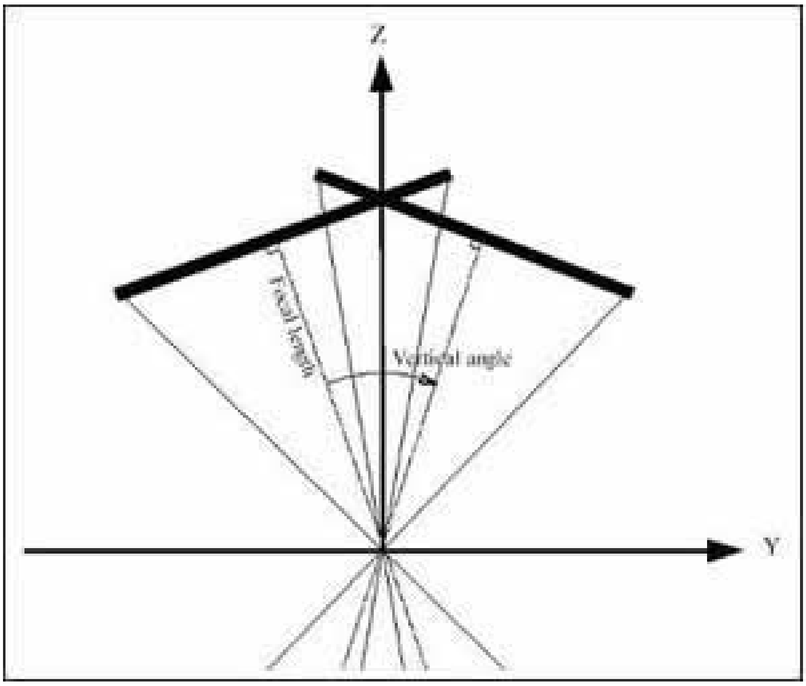

Figure 5: DMC sensor model

Parameter	Nominal Value
Vertical Angle	25.2896°
Focal Length	21,557 detector units
Number of Detectors	10,224
Overlap Between Imager Banks	567 detectors
Clock Period	800 ns
Scan Line Duration	4.8 ms

Table 3: Sensor model parameters

8.3 Spectral Filters

The SLIM-6 spectral filters were manufactured by Barr Associates Inc., USA using the same materials and processes as the spectral filters on the Landsat ETM+ instrument. The spectral bandwidth and channel characteristics are outlined in Table 4 along with the equivalent Landsat ETM+ spectral channel.

Spectral transmission profiles for the fused silica radiation absorption windows and the DMC spectral band filters can be found in Appendix A. These profiles were generated by Barr Associates Inc., USA.

Spectral Band Description	Spectral Band ID	Imager ID	Channel ID	Spectral Bandwidth	iFoV	GSD at Nadir	Equivalent Landsat ETM+ Spectral Channel
NIR	0	0	6	0.77 – 0.90 µm	46.388×10^{-6} rad	31.822 m	ETM+4
		1	3	0.77 – 0.90 µm	46.388×10^{-6} rad	31.822 m	ETM+4
RED	1	0	5	0.63 – 0.69 µm	46.388×10^{-6} rad	31.822 m	ETM+3
		1	2	0.63 – 0.69 µm	46.388×10^{-6} rad	31.822 m	ETM+3
GREEN	2	0	4	0.52 – 0.60 µm	46.388×10^{-6} rad	31.822 m	ETM+2
		1	1	0.52 – 0.60 µm	46.388×10^{-6} rad	31.822 m	ETM+2

Table 4: Spectral channel specification

9 ORBIT

The DMC is a constellation of EO satellites operating in a low Earth orbit. Each satellite in the constellation is phased at 90° to the next to enable a daily revisit of a point target on the Earth's surface.

The nominal orbital parameters of a DMC satellite are described in Table 5.

Parameter	Nominal Value
Orbit Type	Sun Synchronous
Altitude	686 km
Inclination	98.2°
Orbital Period	98.4 min
LTAN	10:15 UTC
Orbital Velocity	7.5 kms^{1}
Ground Velocity	6.8 kms^{-1}

Table 5: Nominal orbital parameters

10 RADIANCE CALCULATION

When calculating the radiance values for DMC images, there are two formulae that can be used. The correct formula to use will depend upon the product level of the image.

Table 6 is a quick reference to illustrate the correct formula that should be used to convert the DN values to radiance values, depending on the product level.

Product Level	Formula
L0R	Equation 2
L1R	Equation 1
L1T	Equation 1

Table 6: Radiance conversion formulae

10.1 L1R and L1T Products

Equation 1 is the convention used in the DIMAP files. This formula should only be applied to DMC images that are processed to the L1R or L1T product levels.

$$\text{RADIANCE} = \left[\frac{\text{DN}}{\text{RESCALE GAIN}}\right] + \text{RESCALE BIAS}$$

Equation 1: Radiance conversion formula for L1R and L1T products

The DN parameter in Equation 1 is scaled radiance. The rescale gain and rescale bias terms are unitless scaling coefficients used to convert the scaled radiance back to true radiance.

The scaling coefficients (rescale gain and rescale bias) are unique for every image and these unique coefficients are stored in the metadata files that accompany every L1R and L1T product.

The unit of radiance is Watts per square metre steradian micrometre ($Wm^{-2}sr^{-1}\mu m^{-1}$).

10.1.1 Reading the Scaling Coefficients for L1R and L1T Products

These rescale gain and rescale bias values can be extracted from the DIMAP file or read from the html file via a web browser.

See §11.1 for more information on the metadata files for L1R and L1T products.

10.2 L0R Products

Equation 2 is the convention used by DMCII when rescaling the scaled radiance. This formula should only be applied to DMC images that are processed to the L0R product level.

$$\text{RADIANCE} = [\text{DN} \times \text{RESCALE GAIN}] + \text{RESCALE BIAS}$$

Equation 2: Radiance conversion formula for L0R products

The DN parameter in Equation 2 is scaled radiance. The rescale gain and rescale bias terms are unitless scaling coefficients used to convert the scaled radiance back to true radiance.

The scaling coefficients (rescale gain and rescale bias) are unique for every image and these unique coefficients are stored in the TIFF tags of the L0R products.

The unit of radiance is Watts per square metre steradian micrometre ($Wm^{-2}sr^{-1}\mu m^{-1}$).

10.2.1 Reading the Scaling Coefficients for L0R Products

This section describes how to extract the scaling coefficients from the TIFF tags of the L0R product, but it assumes a working knowledge of TIFF file structures and the TIFF Image File Directory (IFD). The tags to look for are given in Table 7.

Data relevant to radiance calculations is stored in its own private block. The block has the same format as a standard IFD, which is defined by the TIFF Revision 6.0 specification, including the use of the Value Offset field to either contain or point to the data. The block is referenced by a custom tag in the main IFD, which contains the offset from the beginning of the file of the start of the Smart-i IFD.

1. Search the TIFF IFD for a tag with the ID value of 0xFE0B. The Type of this tag is LONG, and the Count value is set to one.

2. Use the Value Offset from the tag to set the position of the next file-read operation. If successful, this will be set to the start of the Smart-i IFD.

3. Read two bytes from the file: this SHORT value contains the number of tags in the Smart-i IFD.

4. Read up to *n* tags, where *n* is the SHORT value that has just been read in.

As with the TIFF standard IFD, the end of the custom IFD is followed by four bytes, which will always be set to NULL for Smart-i.

Tag ID	Tag Type	Tag Name	Tag Description
0xC000	DOUBLE	NIR Rescale Bias	Rescale Bias value for the Near Infra-Red band.
0xC001	DOUBLE	NIR Rescale Gain	Rescale Gain value for the Near Infra-Red band.
0xC002	DOUBLE	Red Rescale Bias	Rescale Bias value for the Red band.
0xC003	DOUBLE	Red Rescale Gain	Rescale Gain value for the Red band.
0xC004	DOUBLE	Green Rescale Bias	Rescale Bias value for the Green band.
0xC005	DOUBLE	Green Rescale Gain	Rescale Gain value for the Green band.

Table 7: TIFF tags containing rescale information for the L0R product

11 METADATA

The DMC products are generated using two different software tools, which results in the metadata for each product being stored in a different format.

11.1 L1R and L1T Products

The L1R and L1T products are generated by Keystone with the metadata captured in several files. However, the primary source of the product's metadata is the DIMAP (.dim) file. More information on the contents of the DIMAP file can be found in §13, RD#02 and RD#03.

The L1R and L1T data products are delivered in a zip file with its associated metadata files. A description of the file types contained in the zip file is given in Table 8.

File Extension	Description
dim	The DIMAP file containing all the information about the image, such as date and time of acquisition, rescale gain and rescale bias values, geopositioning information etc. The L1R product level uses the tie-point[5] transformation model to provide an approximation of the geographic extents of the image.
htm	The htm file is easily read using a web browser and contains most of the information stored in the DIMAP.
jpg	The quick look image of the product that is displayed in the htm file.
sip	The SIP file is the primary metadata file for the image. It contains all the information stored in the DIMAP and a rigorous adjustment model for the image. The SIP file can only be read by an application called SIPOrtho, developed by Spacemetric AB, SE.
tif	The actual data product.
xsl	The style sheet used to present the information stored in the htm file.

Table 8: Product metadata description

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[5] The tie-point transformation model is not read by all remote sensing packages. If your software cannot read the tie-point information of the image, then please read the htm file to extract the coordinates of the vertices and apply them to the image.

11.2 L0R Products

The L0R products are generated by the Smart-i radiometric processor and the metadata is stored in the TIFF tags of the L0R products.

TIFF tags with IDs in the range 0-0x8FFF are members of the standard TIFF header. IDs in the range 0xC000-0xCFFF are custom tags containing data that are used for calculating the radiance of the image. IDs in the range 0xFE0C are also custom tags, and contain data that have been extracted from the raw satellite image file. The special tag ID 0xFE0B is used to determine the start of the custom tag block.

A full list of tags contained in the L0R product file header is given in Appendix B. See §10.2.1 for a description on how to read these tags from the TIFF file header.

12 REFLECTANCE CALCULATION

The TOA reflectance of an image can be calculated by using Equation 3, regardless of the product level, however, this does not take into account atmospheric effects.

$$\rho_\lambda = \frac{\pi d^2 L_\lambda}{E_{0\lambda} \cos\theta_s}$$

Equation 3: Reflectance conversion formula

Where:
ρ_λ = Reflectance in spectral band λ
d = Earth-Sun distance [AU]
L_λ = Radiance in spectral band λ [$\mathrm{Wm^{-2}sr^{-1}\mu m^{-1}}$]
$E_{0\lambda}$ = Exo-atmospheric solar irradiance [$\mathrm{Wm^{-2}\mu m^{-1}}$]
θ_s = Solar zenith angle [°]

TOA radiance values can be extracted by applying the scaling coefficients as described in §10. As the date and time of image acquisition is known (see §11), then the Earth-Sun distance and solar zenith angle can be calculated. The exo-atmospheric solar irradiance at the time of acquisition can be calculated from in-situ measurements or found on the web.

Equation 3 is just a conversion of the radiance at sensor into TOA reflectance. The actual TOA reflectance values are dependent, not just on the surface reflectance, but also on the atmospheric absorptions and scattering, which are not determined by this simple conversion.

An alternative to this simple calculation of reflectance is to use a radiative transfer code such as MODTRAN or 6S, which can assess scattering and absorption effects of the atmosphere and give true surface reflectance, rather than TOA reflectance.

13 DMC DIMAP

The metadata for L1R and L1T products are contained within the DIMAP (.dim) files. The DMC DIMAP is based upon the DIMAP generic profile version 1.1 developed by SpotImage and CNES, and is implemented through the use of XML.

Some elements of the DIMAP are not clearly defined and open for data providers to define their own parameters. For such elements used in the DMC DIMAP, a description of these elements and examples will be given in this section.

Appendix C and Appendix D contain a full DIMAP sample for the L1R and L1T products, respectively.

Documentation on DIMAP version 1.1 and the DIMAP XML implementation can be found at the following URL:

http://www.spotimage.fr/dimap/spec/documentation/refdoc.htm

The DIMAP elements and their implementation are described in documents RD#02 and RD#03, which can be found at the following URL:

http://www.spotimage.fr/dimap/spec/dictionary/dictionary.htm

`<Quality_Assessment>`

The following DIMAP elements and sub-elements have values and attributes that are unique to DMC data products. A full description of these elements and sub-elements and how they are implemented can be found in RD#02.

```
<Quality_Assessment>
    <QUALITY_TABLES>
    <Quality_Parameter>
        <QUALITY_PARAMETER_DESC>
        <QUALITY_PARAMETER_CODE>
        <QUALITY_PARAMETER_VALUE>
```

Details on the values and attributes of the elements and sub-elements that are unique to DMC data products can be found in the tables below.

Element	**Element Value**	**Attribute**	**Attribute Value**
`<QUALITY_TABLES>`	`SPACEMETRIC`	`version`	`1.0`
Description			
Quality assessment table labelled as "SPACEMETRIC" – version 1.0.			

Element	**Element Value**	**Attribute**	**Attribute Value**
`<QUALITY_PARAMETER_DESC>`	`Number of control points`	`N/A`	`N/A`
`<QUALITY_PARAMETER_CODE>`	`SPACEMETRIC:NGCP`	`N/A`	`N/A`
`<QUALITY_PARAMETER_VALUE>`	*variable*	`N/A`	`N/A`
Description			
Describes the number of GCPs collected to derive the model for the data product.			

<table>
<tr><th>Element</th><th>Element Value</th><th>Attribute</th><th>Attribute Value</th></tr>
<tr><td>`<QUALITY_PARAMETER_DESC>`</td><td>`Root Mean Square residual error X component`</td><td>`N/A`</td><td>`N/A`</td></tr>
<tr><td>`<QUALITY_PARAMETER_CODE>`</td><td>`SPACEMETRIC:RMSX`</td><td>`N/A`</td><td>`N/A`</td></tr>
<tr><td>`<QUALITY_PARAMETER_VALUE>`</td><td>*`variable`*</td><td>`unit`</td><td>• `DEG`
• `M`</td></tr>
<tr><th colspan="4">Description</th></tr>
<tr><td colspan="4">Describes the RMS error in the x-direction of the data product. The units will depend upon the GCS and projection used.

"DEG" – Decimal Degrees
"M" – Metres

Typical units for DMC data products are decimal degrees for CS of type "GEOGRAPHIC" and metres for CS of type "PROJECTED", but others are available.</td></tr>
</table>

<table>
<tr><th>Element</th><th>Element Value</th><th>Attribute</th><th>Attribute Value</th></tr>
<tr><td>`<QUALITY_PARAMETER_DESC>`</td><td>`Root Mean Square residual error Y component`</td><td>`N/A`</td><td>`N/A`</td></tr>
<tr><td>`<QUALITY_PARAMETER_CODE>`</td><td>`SPACEMETRIC:RMSY`</td><td>`N/A`</td><td>`N/A`</td></tr>
<tr><td>`<QUALITY_PARAMETER_VALUE>`</td><td>*`variable`*</td><td>`unit`</td><td>• `DEG`
• `M`</td></tr>
<tr><th colspan="4">Description</th></tr>
<tr><td colspan="4">Describes the RMS error in the y-direction of the data product. The units will depend upon the GCS and projection used.

"DEG" – Decimal Degrees
"M" – Metres

Typical units for DMC data products are decimal degrees for CS of type "GEOGRAPHIC" and metres for CS of type "PROJECTED", but others are available.</td></tr>
</table>

Example 1: <Quality_Assessment> - RMS Error in Metres

```
<Quality_Assessment>
    <QUALITY_TABLES version="1.0">SPACEMETRIC</QUALITY_TABLES>
    <Quality_Parameter>
        <QUALITY_PARAMETER_DESC>Number of control points</QUALITY_PARAMETER_DESC>
        <QUALITY_PARAMETER_CODE>SPACEMETRIC:NGCP</QUALITY_PARAMETER_CODE>
        <QUALITY_PARAMETER_VALUE>28</QUALITY_PARAMETER_VALUE>
    </Quality_Parameter>
    <Quality_Parameter>
        <QUALITY_PARAMETER_DESC>Root Mean Square residual error X
component</QUALITY_PARAMETER_DESC>
        <QUALITY_PARAMETER_CODE>SPACEMETRIC:RMSX</QUALITY_PARAMETER_CODE>
        <QUALITY_PARAMETER_VALUE unit="M">13.2</QUALITY_PARAMETER_VALUE>
    </Quality_Parameter>
    <Quality_Parameter>
        <QUALITY_PARAMETER_DESC>Root Mean Square residual error Y
component</QUALITY_PARAMETER_DESC>
        <QUALITY_PARAMETER_CODE>SPACEMETRIC:RMSY</QUALITY_PARAMETER_CODE>
        <QUALITY_PARAMETER_VALUE unit="M”>10.5</QUALITY_PARAMETER_VALUE>
    </Quality_Parameter>
</Quality_Assessment>
```

Example 2: <Quality_Assessment> - RMS Error in Decimal Degrees

```
<Quality_Assessment>
    <QUALITY_TABLES version="1.0">SPACEMETRIC</QUALITY_TABLES>
    <Quality_Parameter>
        <QUALITY_PARAMETER_DESC>Number of control points</QUALITY_PARAMETER_DESC>
        <QUALITY_PARAMETER_CODE>SPACEMETRIC:NGCP</QUALITY_PARAMETER_CODE>
        <QUALITY_PARAMETER_VALUE>0</QUALITY_PARAMETER_VALUE>
    </Quality_Parameter>
    <Quality_Parameter>
        <QUALITY_PARAMETER_DESC>Root Mean Square residual error X
component</QUALITY_PARAMETER_DESC>
        <QUALITY_PARAMETER_CODE>SPACEMETRIC:RMSX</QUALITY_PARAMETER_CODE>
        <QUALITY_PARAMETER_VALUE
unit="DEG">0.28647889756541156</QUALITY_PARAMETER_VALUE>
    </Quality_Parameter>
    <Quality_Parameter>
        <QUALITY_PARAMETER_DESC>Root Mean Square residual error Y
component</QUALITY_PARAMETER_DESC>
        <QUALITY_PARAMETER_CODE>SPACEMETRIC:RMSY</QUALITY_PARAMETER_CODE>
        <QUALITY_PARAMETER_VALUE
unit="DEG">0.20970255301788127</QUALITY_PARAMETER_VALUE>
    </Quality_Parameter>
</Quality_Assessment>
```

<Coordinate_Reference_System>

The following DIMAP elements and sub-elements have values and attributes that are unique to DMC data products. A full description of these elements and sub-elements and how they are implemented can be found in RD#02.

```
<Coordinate_Reference_System>
    <GEO_TABLES>
    <Horizontal_CS>
        <HORIZONTAL_CS_CODE>
        <HORIZONTAL_CS_TYPE>
        <HORIZONTAL_CS_NAME>
```

Details on the values and attributes of the elements and sub-elements that are unique to DMC data products can be found in the tables below.

Element	Element Value	Attribute	Attribute Value
`<GEO_TABLES>`	• EPSG • CUSTOM	version	*variable*
Description			
System used to identify the geodetic parameters. "EPSG" - parameters are defined in the EPSG database version 6.13. "CUSTOM" - user specified parameters.			

Element	Element Value	Attribute	Attribute Value
`<HORIZONTAL_CS_CODE>`	*variable*	N/A	N/A
Description			
Unique identification code that defines the horizontal CS used by the data product. This code relates to the geodetic table defined by the element <GEO_TABLES>. The code is variable, but it is prefixed by the geodetic table used followed by ":", i.e. "EPSG:4258" or "CUSTOM:50008". To avoid overlapping of the horizontal CS codes from the EPSG database, all CUSTOM horizontal CS codes (i.e. not defined in the EPSG database) will start at 50001.			

Element	Element Value	Attribute	Attribute Value
`<HORIZONTAL_CS_TYPE>`	• GEOGRAPHIC • PROJECTED	N/A	N/A

Description

Describes the type of horizontal CS used.

"GEOGRAPHIC" – Horizontal CS is not projected.
"PROJECTED" – Horizontal CS is a cartographic projection.

Element	Element Value	Attribute	Attribute Value
`<HORIZONTAL_CS_NAME>`	*variable*	N/A	N/A

Description

Name of the horizontal CS used by the data product.

Example 3: <Coordinate_Reference_System> - EPSG Geodetic Parameters

```
<Coordinate_Reference_System>
    <GEO_TABLES>EPSG</GEO_TABLES>
    <Horizontal_CS>
        <HORIZONTAL_CS_CODE>EPSG:4258</HORIZONTAL_CS_CODE>
        <HORIZONTAL_CS_TYPE>GEOGRAPHIC</HORIZONTAL_CS_TYPE>
        <HORIZONTAL_CS_NAME>ETRS89</HORIZONTAL_CS_NAME>
        ...
    </Horizontal_CS>
</Coordinate_Reference_System>
```

Example 4: <Coordinate_Reference_System> - Custom Geodetic Parameters

```
<Coordinate_Reference_System>
    <GEO_TABLES>CUSTOM</GEO_TABLES>
    <Horizontal_CS>
        <HORIZONTAL_CS_CODE>CUSTOM:50008</HORIZONTAL_CS_CODE>
        <HORIZONTAL_CS_TYPE>PROJECTED</HORIZONTAL_CS_TYPE>
        <HORIZONTAL_CS_NAME>ED50 / Turkish Lambert 2007</HORIZONTAL_CS_NAME>
        ...
    </Horizontal_CS>
</Coordinate_Reference_System>
```

<Image_Display>

The following DIMAP elements and sub-elements have values and attributes that are unique to DMC data products. A full description of these elements and sub-elements and how they are implemented can be found in RD#02.

```
<Image_Display>
    <Special_Value>
        <SPECIAL_VALUE_INDEX>
        <SPECIAL_VALUE_TEXT>
```

Details on the values and attributes of the elements and sub-elements that are unique to DMC data products can be found in the tables below.

Element	Element Value	Attribute	Attribute Value
<SPECIAL_VALUE_INDEX>	0	N/A	N/A
<SPECIAL_VALUE_TEXT>	nodata	N/A	N/A
Description			
Data points in the product that have a DN value of 0 are described as being data points of no significance and should be ignored in any analysis performed.			

Example 5: <Image_Display> - No Data Value

```
<Image_Display>
    ...
    <Special_Value>
        <SPECIAL_VALUE_INDEX>0</SPECIAL_VALUE_INDEX>
        <SPECIAL_VALUE_TEXT>nodata</SPECIAL_VALUE_TEXT>
    </Special_Value>
    ...
</Image_Display>
```

`<Dataset_Sources>`

Due to the nature of the DIMAP format, there is the potential for data to be duplicated under different elements. In the case of the `<Dataset_Sources>` element there is a sub-element called `<Coordinate_Reference_System>`, which contains the same information as the `<Coordinate_Reference_System>` element that preceded it. Information about this element has been documented for completeness.

The following DIMAP elements and sub-elements have values and attributes that are unique to DMC data products. A full description of these elements and sub-elements and how they are implemented can be found in RD#02.

```
<Dataset_Sources>
    <Coordinate_Reference_System>
        <GEO_TABLES>
        <Horizontal_CS>
            <HORIZONTAL_CS_CODE>
            <HORIZONTAL_CS_TYPE>
            <HORIZONTAL_CS_NAME>
```

Details on the values and attributes of the elements and sub-elements that are unique to DMC data products can be found in the tables below.

Element	**Element Value**	**Attribute**	**Attribute Value**
`<GEO_TABLES>`	• `EPSG` • `CUSTOM`	`version`	*`variable`*
Description			
System used to identify the geodetic parameters. "EPSG" - parameters are defined in the EPSG database version 6.13. "CUSTOM" - user specified parameters.			

Element	**Element Value**	**Attribute**	**Attribute Value**
`<HORIZONTAL_CS_CODE>`	*`variable`*	`N/A`	`N/A`
Description			
Unique identification code that defines the horizontal CS used by the data product. This code relates to the geodetic table defined by the element <GEO_TABLES>. The code is variable, but it is prefixed by the geodetic table used followed by ":", i.e. "EPSG:4258" or "CUSTOM:50008". To avoid overlapping of the horizontal CS codes from the EPSG database, all CUSTOM horizontal CS codes (i.e. not defined in the EPSG database) will start at 50001.			

Element	Element Value	Attribute	Attribute Value
`<HORIZONTAL_CS_TYPE>`	• GEOGRAPHIC • PROJECTED	N/A	N/A
Description			
Describes the type of horizontal CS used. "GEOGRAPHIC" – Horizontal CS is not projected. "PROJECTED" – Horizontal CS is a cartographic projection.			

Element	Element Value	Attribute	Attribute Value
`<HORIZONTAL_CS_NAME>`	*variable*	N/A	N/A
Description			
Name of the horizontal CS used by the data product.			

Example 6: <Dataset_Sources> - EPSG Geodetic Parameters

```
<Dataset_Sources>
    ...
    <Coordinate_Reference_System>
        <GEO_TABLES>EPSG</GEO_TABLES>
        <Horizontal_CS>
            <HORIZONTAL_CS_CODE>EPSG:4258</HORIZONTAL_CS_CODE>
            <HORIZONTAL_CS_TYPE>GEOGRAPHIC</HORIZONTAL_CS_TYPE>
            <HORIZONTAL_CS_NAME>ETRS89</HORIZONTAL_CS_NAME>
            ...
        </Horizontal_CS>
    </Coordinate_Reference_System>
    ...
</Dataset_Sources>
```

Example 7: <Dataset_Sources> - Custom Geodetic Parameters

```
<Dataset_Sources>
    ...
    <Coordinate_Reference_System>
        <GEO_TABLES>CUSTOM</GEO_TABLES>
        <Horizontal_CS>
            <HORIZONTAL_CS_CODE>CUSTOM:50008</HORIZONTAL_CS_CODE>
            <HORIZONTAL_CS_TYPE>PROJECTED</HORIZONTAL_CS_TYPE>
            <HORIZONTAL_CS_NAME>ED50 / Turkish Lambert 2007</HORIZONTAL_CS_NAME>
            ...
        </Horizontal_CS>
    </Coordinate_Reference_System>
    ...
</Dataset_Sources>
```

`<Data_Strip>`

The following DIMAP elements and sub-elements have values and attributes that are unique to DMC data products. A full description of these elements and sub-elements and how they are implemented can be found in RD#03.

```
<Data_Strip>
    <Sensor_Configuration>
        <Time_Stamp>
            <LINE_PERIOD>
            <SCENE_CENTER_TIME>
            <SCENE_CENTER_LINE>
            <SCENE_CENTER_COL>
```

Details on the values and attributes of the elements and sub-elements that are unique to DMC data products can be found in the tables below.

Element	**Element Value**	**Attribute**	**Attribute Value**
`<LINE_PERIOD>`	`0.0048`	`N/A`	`N/A`
Description			
Time period for the acquisition of one line of image data. The unit of this element the second.			

Element	**Element Value**	**Attribute**	**Attribute Value**
`<SCENE_CENTER_TIME>`	*variable*	`N/A`	`N/A`
Description			
Defines the scene centre time. The unit of this element is UTC. The format of this element is YYYY-MM-DD HH:mm:ss.			

Element	**Element Value**	**Attribute**	**Attribute Value**
`<SCENE_CENTER_LINE>`	*variable*	`N/A`	`N/A`
Description			
Defines the scene centre line number (starting at 1).			

Element	Element Value	Attribute	Attribute Value
`<SCENE_CENTER_COL>`	*variable*	N/A	N/A
Description			
Defines the scene centre column number (starting at 1).			

Example 8: <Data_Strip> - Time Stamp Parameters

```
<Data_Strip>
    <Sensor_Configuration>
        <Time_Stamp>
            <LINE_PERIOD>0.0048</LINE_PERIOD>
            <SCENE_CENTER_TIME>2007-07-30 16:14:39</SCENE_CENTER_TIME>
            <SCENE_CENTER_LINE>5000</SCENE_CENTER_LINE>
            <SCENE_CENTER_COL>7030</SCENE_CENTER_COL>
        </Time_Stamp>
    </Sensor_Configuration>
</Data_Strip>
```

14 IMAGE PROCESSING

The raw images acquired by the DMC satellites undergo various processing stages to reach their final deliverable product. The generation of each product level is performed by various software applications at different stages of the process. The image processing chain implemented is displayed in Figure 6 and the software responsible at each stage of the process is shown in Figure 7.

14.1 Radiometric Correction

The radiometric correction is performed by applying a LUT to the image. This allows each pixel to be corrected individually, based upon the detector that captured it.

This correction converts the raw image from an 8-bit DN image to a 32-bit radiance image. In order to keep the image file size low, the radiance image is then scaled back to an 8-bit DN image. However, the image is scaled to the range of DN=1 to DN=254. Pixels with DN=0 are special value pixels representing pixels of no data and can be ignored during analysis.

The scaling coefficients are preserved in the metadata for the product and converting the DN image back to a radiance image is a simple task described in §10.

The radiometric correction process is performed by the Smart-i radiometric processor and the output from this process is the L0R product.

A full report on the radiometric calibration of the DMC satellites can be found in Appendix E.

14.2 Georeferencing

The georeferencing process uses tie-point transformation to generate a model to apply to the final L1R product. The model is generated based upon the attitude and ephemeris data stored in the metadata of the L0R product.

The GCS used for the final L1R product is the WGS84 (EPSG:4326).

The georeferencing process is performed during the import of the L0R product files, before the band registration process.

14.3 Band Registration

The band registration process is performed on the single band L0R products output from the radiometric correction process. The three spectral bands from one imager bank are co-registered to provide a 3-band RGB image.

Geometric correction is also performed during this stage of the processing to remove the following sources of geometric distortion from the image:

- Sensor Geometry
- Lens Distortion
- Curvature of the Earth
- Rotation of the Earth
- Spacecraft Attitude
- Spacecraft Motion

If the image was acquired as a single bank image event, then the process for the L1R product ends here. If the image was acquired as a dual bank image event, then the two single bank L1R products are passed on to the bank mosaic processing stage.

The band registration process is performed by Keystone and the output from this process is the L1R product for a single bank image event.

14.4 Bank Mosaic

The bank mosaic process is performed on the single bank L1R products output from the band registration process. The two single bank images are mosaiced together at the point of overlap between the two images.

The bank mosaic process is performed by Keystone and the output from this process is the L1R product for a dual bank image event.

14.5 Orthorectification

The orthorectification process is a two stage process; GCP collection and image rectification.

The first stage involves manual GCP collection against a standard reference data set and DEM using an application called SIP/Ortho. Each GCP updates the georeferencing of the L1R product and includes the height information from the DEM, thus correcting image distortions due to the Earth's topography. The output from the GCP collection is a rigorous image model to pass on to the next stage of the process.

The second and final stage of the process is image rectification. This process is performed by Keystone, which rectifies the L1R product using the updated image model produced in the first stage.

The final output from the orthorectification process is the L1T product rectified to the defined projection.

The orthorectification process is a flexible process whereby GCP collection can be performed using any reference data set and DEM provided, and the final L1T product can be rectified to any projection requested.

A full description of the orthorectification procedure can be found in Appendix F.

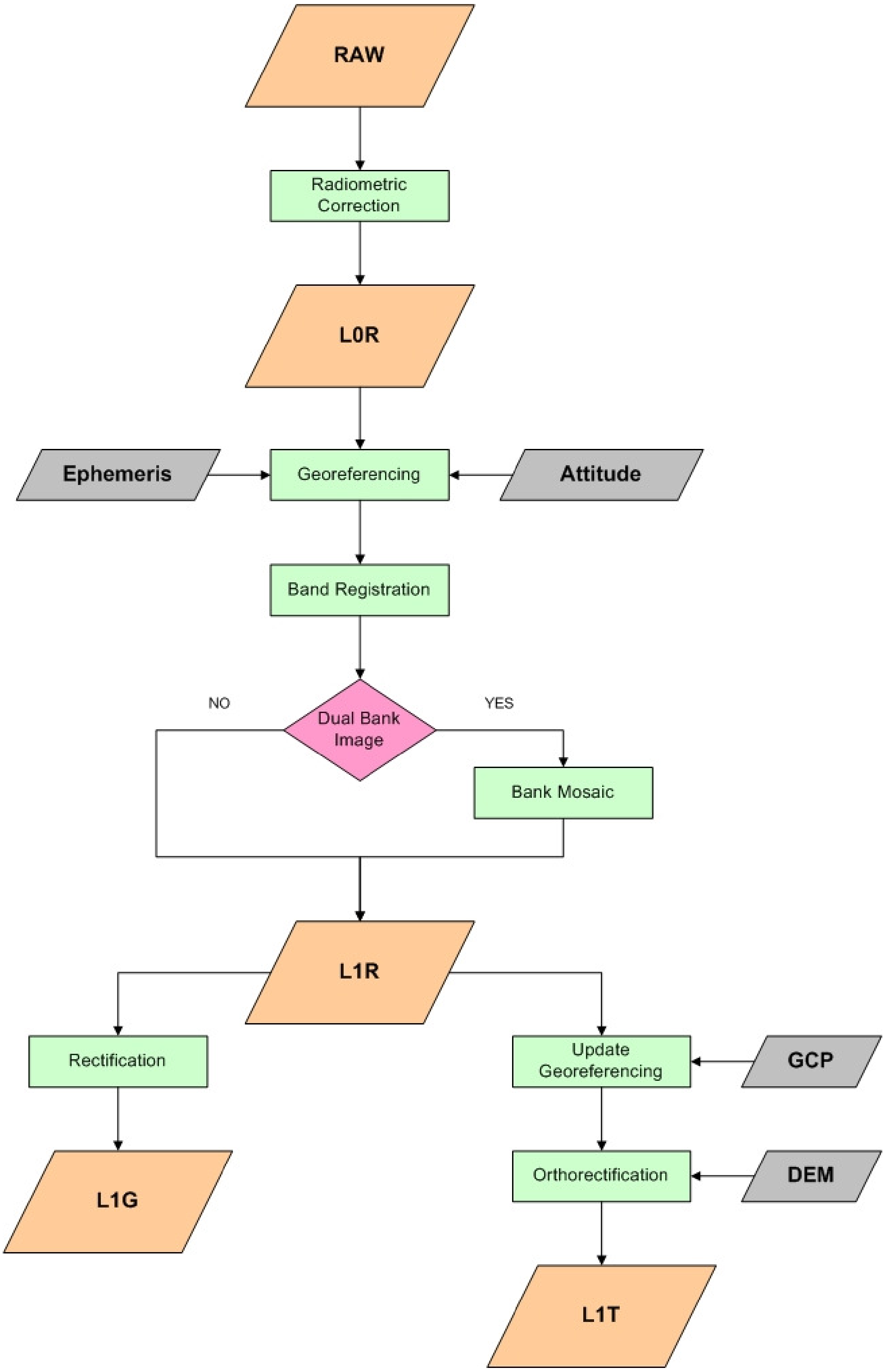


Figure 6: Image processing chain

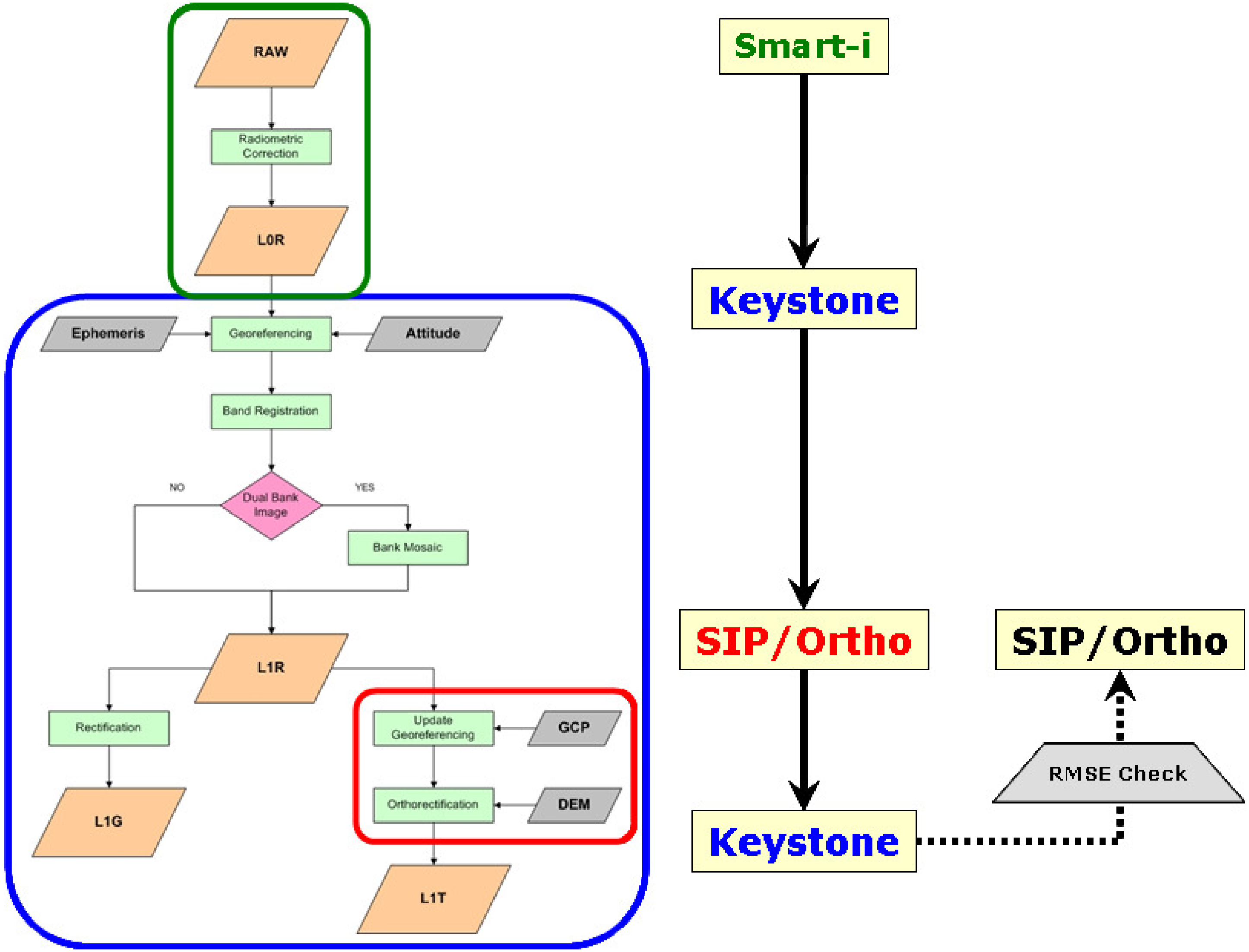


Figure 7: Software used in the processing chain

15 FILENAME FORMAT

The products derived from DMC images of a nominal size, will assume the filename convention specified in §15.1 and §15.2. However, due to the capability of Beijing-1 to acquire long image strips, the filename convention for such images will assume the format described in §15.3 and §15.4.

A full description of the parameters used in each filename convention can found in Table 9.

15.1 L1R Products

The filename convention for L1R products will assume the general format:

sseeeeeeb_p_cc.ext

Example:

DA000123p_L1R_NL.tif

15.2 L1T Products

The filename convention for L1T products will assume the general format:

sseeeeeeb_p_EPSG_EEEE(E)_cc.ext

Example:

DU000ef0T_L1T_EPSG_27700_UK.tif

15.3 Beijing-1 L1R Products

For long image strips acquired by Beijing-1, the filename convention for L1R and products will assume the general format:

sseeeeee_SL_EL_b_p_cc.ext

Example:

DC0004d8_000000_010499_p_L1R_IT.tif
DC0004d8_000000_010499_s_L1R_IT.tif
DC0004d8_010000_020499_p_L1R_IT.tif
DC0004d8_010000_020499_s_L1R_IT.tif

15.4 Beijing-1 L1T Products

For long image strips acquired by Beijing-1, the filename convention for L1T products will assume the general format:

sseeeeee_SL_EL_b_p_EPSG_EEEE(E)_cc.ext

Example:

DC0004ee_000000_010499_p_L1T_EPSG_27572_FR.tif
DC0004ee_000000_010499_s_L1T_EPSG_27572_FR.tif
DC0004ee_010000_020499_p_L1T_EPSG_27572_FR.tif
DC0004ee_010000_020499_s_L1T_EPSG_27572_FR.tif

Parameter	Description	Value
ss	Satellite Name	**DA** AlSat-1 **DC** Beijing-1 **DN** NigeriaSat-1 **DU** UK-DMC
eeeeee	Event ID Number	Unique 6 digit hexadecimal value
SL	Scene Start Line Number	6 digit scene start line number
EL	Scene End Line Number	6 digit scene end line number
b	Imager Bank	**p** Primary imager bank **s** Secondary imager bank **T** Two imager banks mosaiced
p	Product Level	**L1R** As described in Table 1 **L1T** As described in Table 1 **L1T_QL** As described in Table 1
EPSG	Text String	N/A
EEEE(E)	EPSG Code	Defined as required
cc	Country Code	Unique 2 character country identifier (see Table 10 for a complete list of codes)
ext	File Extension	**tif** TIFF / GeoTIFF image file format

Table 9: Filename convention parameter description

Country Code	Country
AL	Albania
AT	Austria
BA	Bosnia and Herzegovina
BE	Belgium
BG	Bulgaria
CH	Switzerland
CS	Serbia and Montenegro
CY	Cyprus
CZ	Czech Republic
DE	Germany
DK	Denmark
EE	Estonia
ES	Spain
FI	Finland
FR	France
GR	Greece
HR	Croatia
HU	Hungary
IE	Ireland
IS	Iceland
IT	Italy
LI	Liechtenstein
LT	Lithuania
LV	Latvia
LU	Luxembourg
ME	Montenegro
MK	Republic of Macedonia
MT	Malta
NL	Netherlands
NO	Norway
PL	Poland
PT	Portugal
RO	Romania
SE	Sweden
SI	Slovenia
SK	Slovakia
TR	Turkey
UK	United Kingdom

Table 10: Country code ID

16 SPECIAL NOTES ON DMC DATA

16.1 DN Range and Special DN Values

During the radiometric correction of an image, there is a scaling process that scales all pixels containing valid image data to the range DN=1-254, whereas pixels containing no data are set to DN=0.

16.2 Holes

Holes are lost data packets that are caused by interference during data downlink. Figure 8 shows the artefacts seen in a DMC image where holes are present.

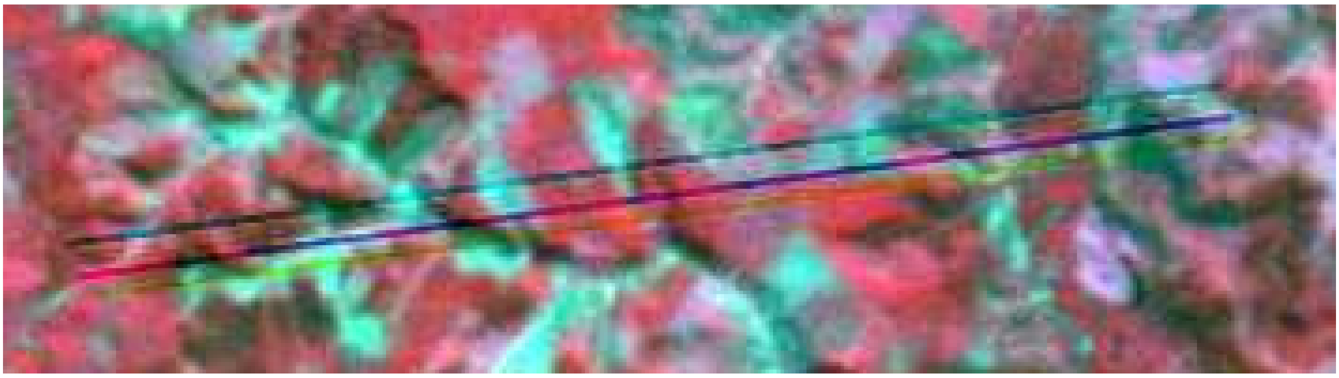


Figure 8: Image artefacts due to holes

To prevent holes in an image, the DMC groundstations implement a system that detects the lost data packets and subsequently sends a request to the satellite to transmit the lost data packet again. Because of this system, it is very rare for a DMC image to contain holes.

The holes exhibit themselves in an image as pixels of no data, i.e. DN=0, and can be present in any or all bands at any point within the image.

For example, holes may occur at one or many points in the image and only occurs in the NIR band, in which case only the NIR band will show these pixels as being DN=0; the red and green bands will still contain valid data at these points. This is illustrated in Figure 9.

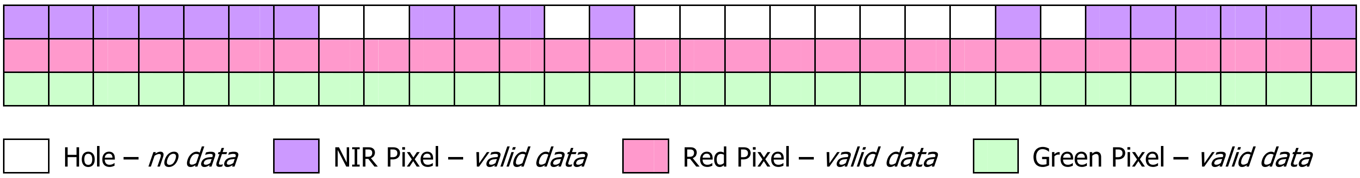
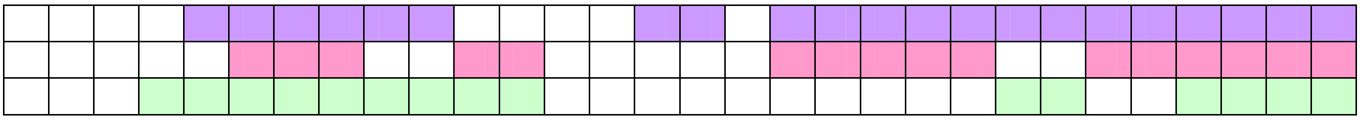


Figure 9: Holes in one band

Another example could be where holes are present at one or many points in the image and occurs in all three bands, so all three bands will show these pixels as being DN=0, as illustrated in Figure 10.



☐ Hole – *no data* 🟪 NIR Pixel – *valid data* 🟥 Red Pixel – *valid data* 🟩 Green Pixel – *valid data*

Figure 10: Holes in all bands

16.3 Band Fringes

Fringes occur in all DMC products and are the result of the physical misalignment of the spectral channels in the imager bank. These fringes are visible at the edges of the image and appear as colour bands, as shown in Figure 11.

Due to the physical nature of the SLIM-6 imager (as shown in Figure 1 and Figure 4), each spectral channel effectively points to slightly different locations on the ground. During the band registration process, the spectral bands are realigned to produce the 3-band multispectral image. Fringes occur in the areas where the rows and columns of the spectral bands do not overlap or partially overlap.

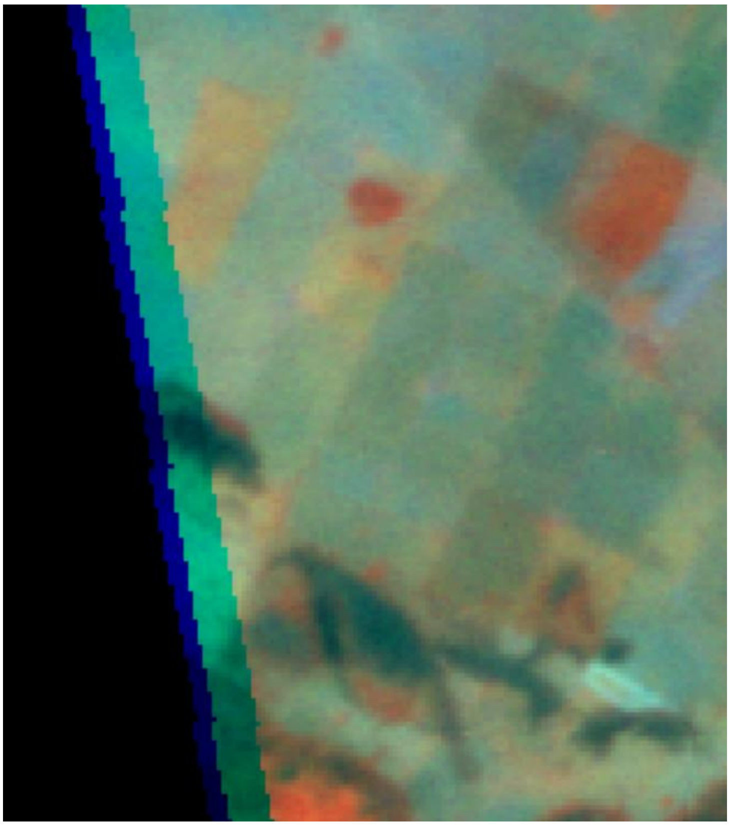


Figure 11: Fringes along the edge of a DMC image

16.4 Bank Shift

The bank shift occurs in all dual bank images and is exhibited as a vertical step in the image, which is visible along the top and bottom edges of the image, as shown in Figure 12.

Apart from the physical misalignment in the spectral channels, there is also a physical misalignment between the two banks of the SLIM-6 imager described in Figure 1 and Figure 4. During the bank mosaic process, the single bank images are shifted and the overlapping pixels from each image are removed to produce a seamless mosaic.

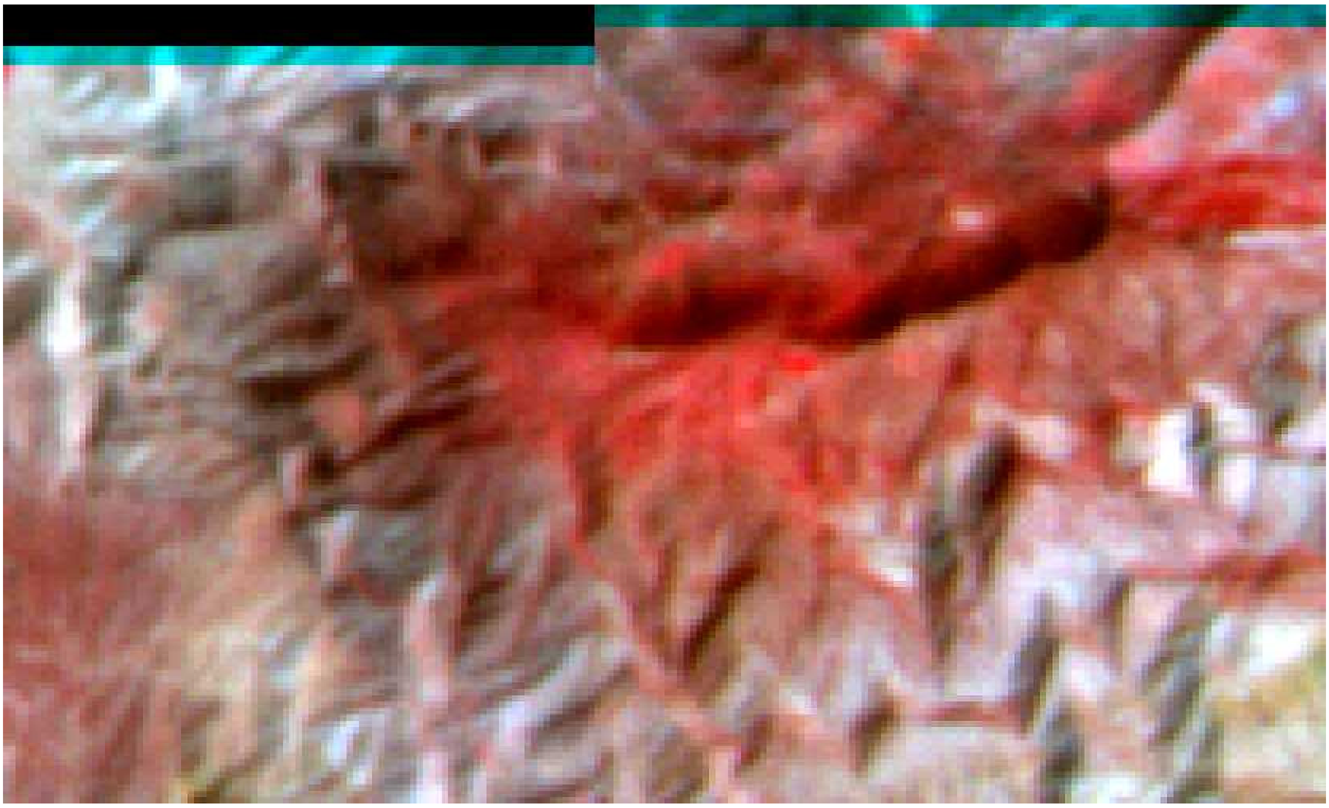


Figure 12: Bank shift across the top of a dual bank DMC image

17 FREQUENTLY ASKED QUESTIONS

17.1 Radiometry

What is the radiometric resolution of the data product?

Although 11 bits of data are captured in the initial data collection, only the most significant 8 bits are stored on-board and sent to the ground.

What are the units of the data product?

The data is scaled radiance with units $Wm^{-2}sr^{-1}\mu m^{-1}$. There is a scaling gain and scaling bias to apply to convert the data back into radiance, also with units $Wm^{-2}sr^{-1}\mu m^{-1}$.

The image data is scaled to fit inside a byte value, while maximising the amount of information

How accurate are the radiance values given in the data product?

The instrument is calibrated in a vicarious calibration campaign over the Railroad Valley site in Nevada, USA. The field measurements and radiance calculation is performed by the world renowned Remote Sensing Group at The University of Arizona (RSG) under Kurt Thome. The estimated accuracy given by RSG is 3-5% for the radiance calculation.

Given that only a limited number of pixels are used in the calculation, we have increased this estimate to 5-7% to cover the increased standard deviation in the estimate based on the noise in the data for the limited number of pixels used.

The absolute calibration is transferred from the few pixels calibrated to the whole array using a site at DOME-C in Antarctica.

How are cross-track illumination differences and BRDF dealt with over the calibration sites?

For the absolute site, only a few pixels are chosen to derive calibration coefficients. Pixels chosen are close to nadir to minimise BRDF effects.

For the transfer calibration in Antarctica the spacecraft is yawed prior to scene acquisition so that the imaging plane is orthogonal to the principal plane to the sun, giving equal illumination across the swath and minimising BRDF effects.

The band to band radiometry varies from scene to scene!

For any single satellite the band to band radiometry has proven to be very stable (RMS error of less than 0.34% over a three year period). However between satellites, variations of a few percent are possible due to differences in the absolute calibration of any specific satellite.

The more likely problem is that the user is looking at scaled radiances (the scaling is band and image content dependent). Convert the images to radiance using the scaling gain and bias before carrying out the comparison.

Is the data atmospherically corrected?

No. However, using a radiative transfer code and atmospheric measurements it is possible to convert the radiance (after applying the scaling gain and bias correction) to reflectance.

Is it possible to get the Quantum Efficiency (QE) of the CCD detectors?

The manufacturer's nominal QE curve for the Eastman Kodak KL10203 Linear CCD array is given in Figure 13.

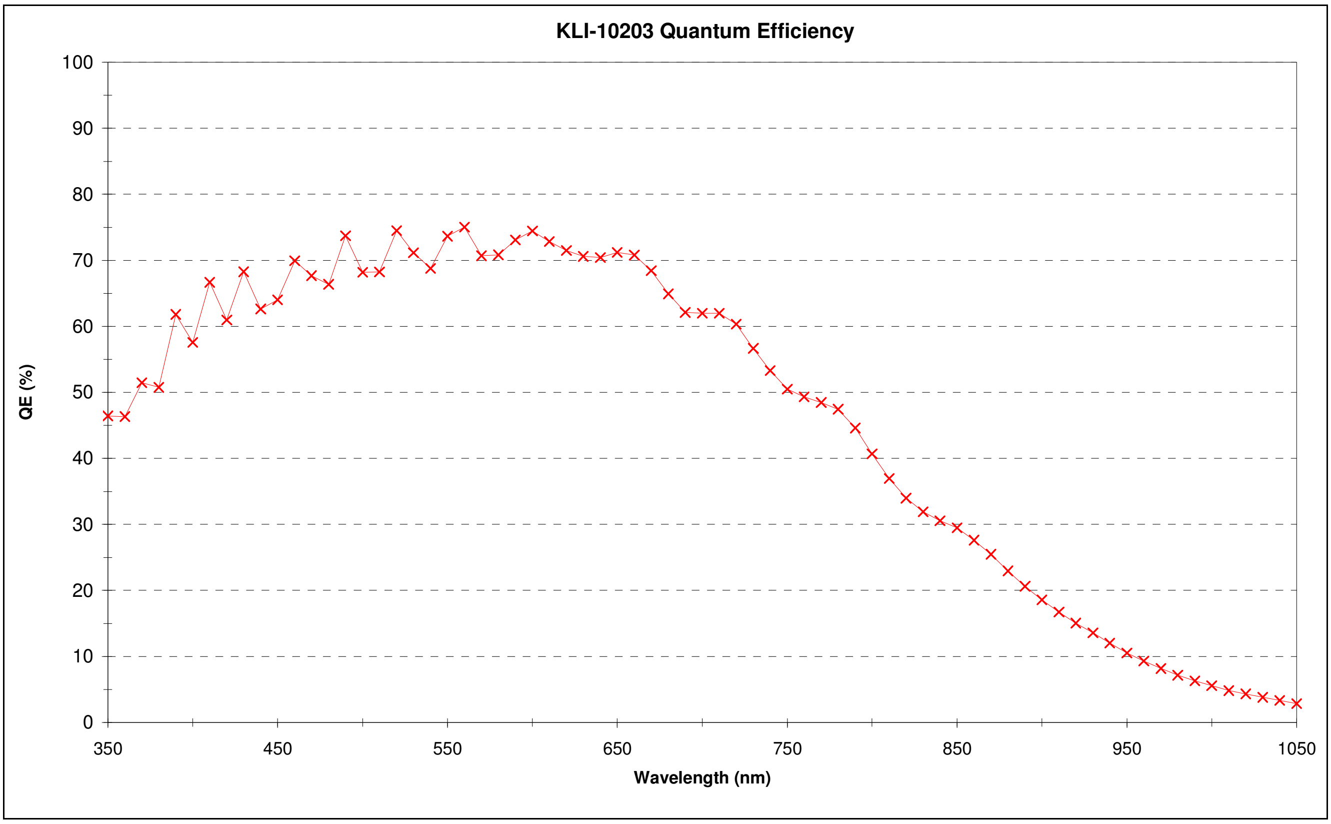


Figure 13: KLI-10203 Quantum Efficiency Curve

17.2 Geometry

How accurate is the band registration?

The band registration has sub-pixel accuracy, usually around 0.3 of a pixel.

How accurate is the orthorectified product?

During orthorectification, an RMS error of 0.25 of a pixel can be achieved. However, typically the RMS error is of the order of 0.5 to 0.75 of a pixel.

What map projection is used for the orthorectified image?

The image projection and EPSG code are defined in the metadata for that product. See §11 for more details. The L0R product levels are not projected.

There seem to be errors in parts of the image after the orthorectification process!

The GCPs in the orthorectification process should produce reasonable RMS errors across the scene, unless there was a significant high frequency oscillation of the spacecraft. This is very unlikely, as if this was the case, systematic biases in the errors across the scene would be noted during the orthorectification process.

17.3 Data Quality

There are some vertical striping in the imagery, is there a fault with the calibration?

Some vertical striping can be seen when the image has a small dynamic range, especially over homogeneous targets where the target DN range is very low. The small noise element caused by a separation in the odd and even detector response can produce small but noticeable effects.

What is the SNR of the DMC imagers?

For a nominal vegetated scene at mid-latitude summer the SNRs for all three bands approach 100:1, with the green spectral band having the highest SNR.

What is the NEΔL of the DMC imagers?

The NEΔL values for DMC have been measured for all three spectral bands and compared to the equivalent Landsat bands. The NEΔL values for DMC are given in Table 11 and the values for Landsat are given in Table 12.

Band	DMC
0	0.85
1	0.87
2	0.77

Table 11: DMC NEΔL values

Band	Landsat-5 TM	Landsat-7ETM+ High Gain
1	0.7	0.90
2	0.6	0.69
3	0.7	0.75
4	0.4	0.37
5	0.1	0.10
7	0.06	0.056
8 (pan)	N/A	1.4

Table 12: Landsat band-averaged dark-noise levels NEΔL

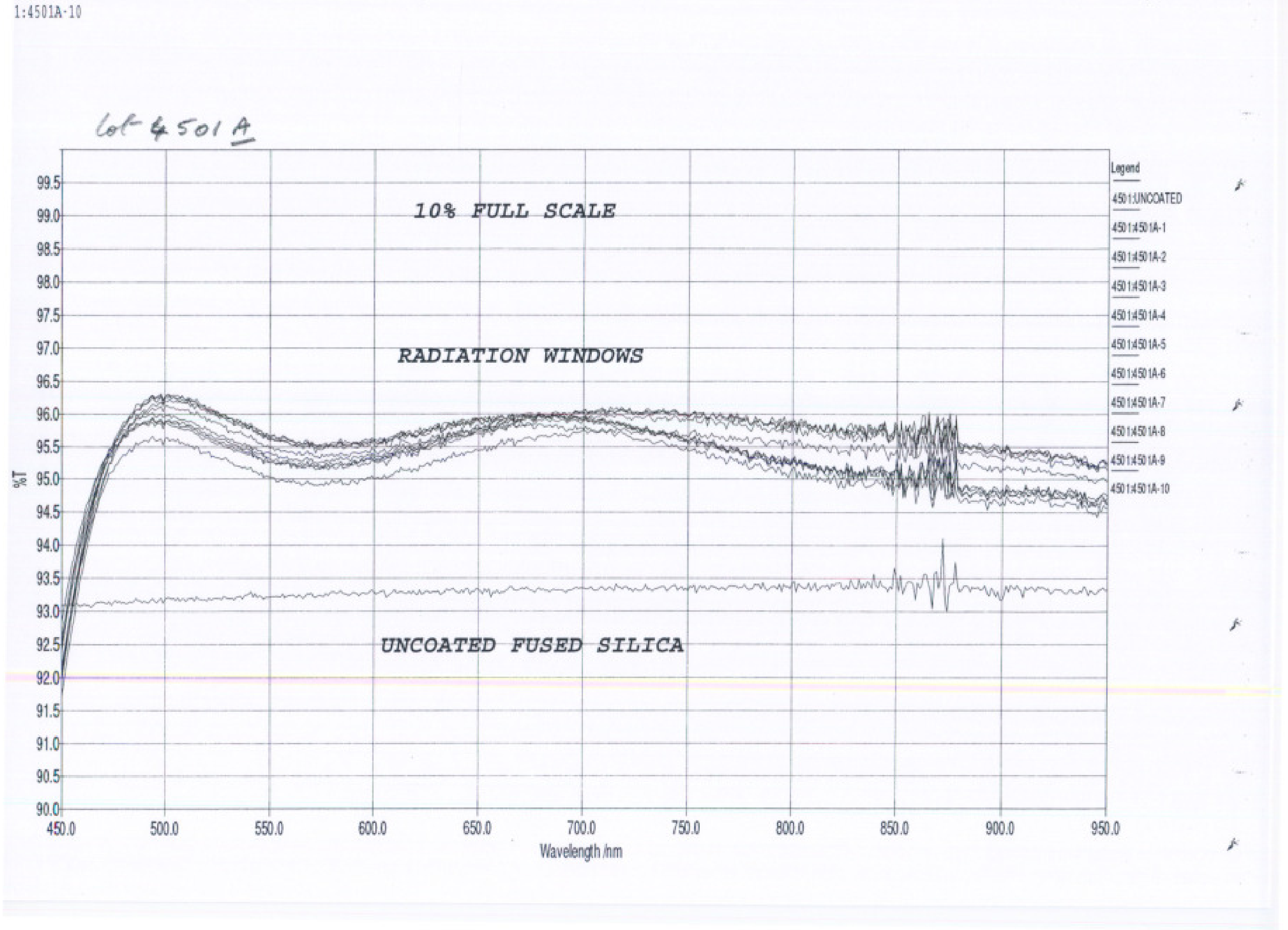
APPENDIX A: SPECTRAL TRANSMISSION PROFILES

The following plots show the spectral transmission profiles for the fused silica radiation absorption windows and the spectral band filters on the DMC spacecraft.

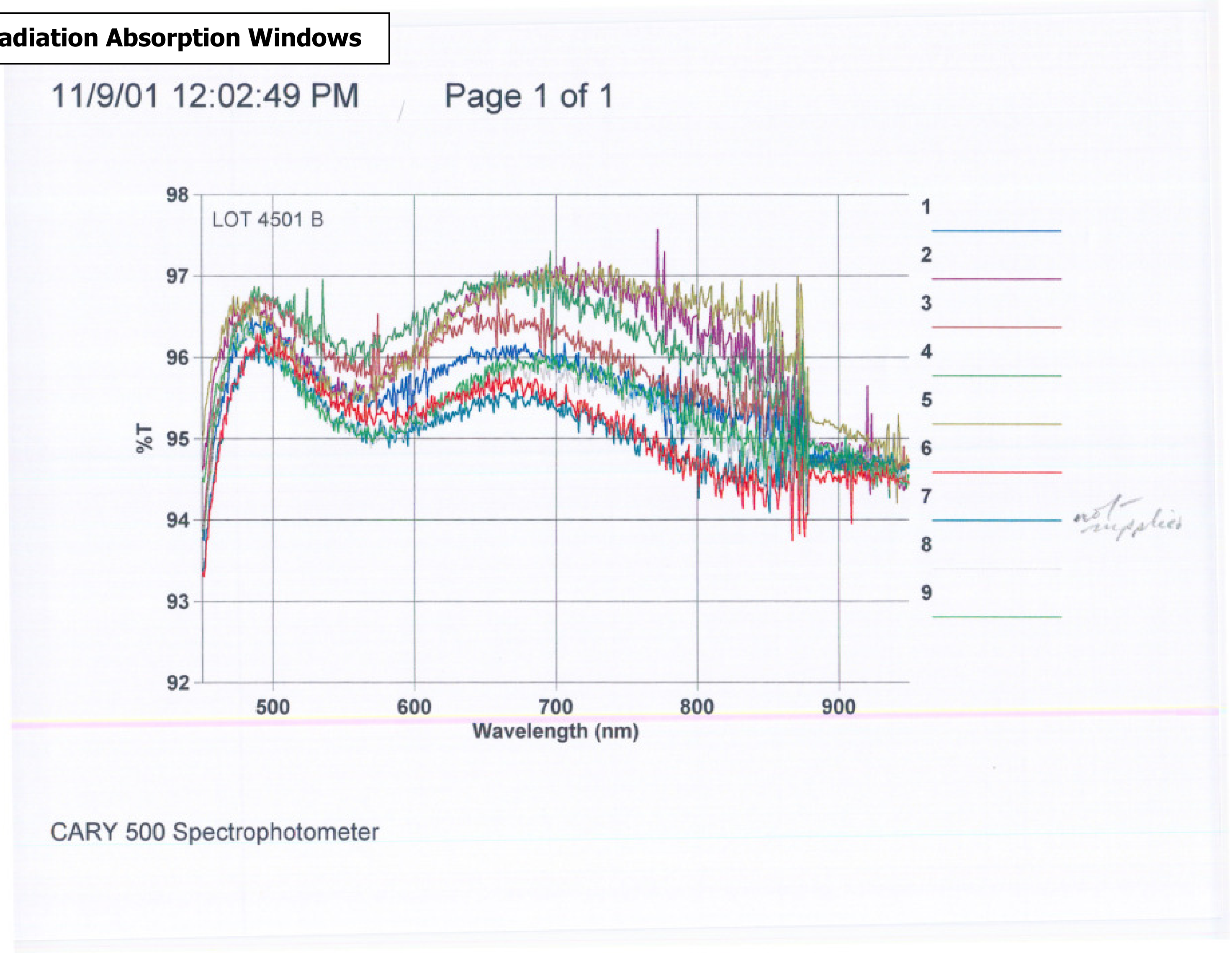
The level of information captured in these plots, although limited, should be enough to perform a spectral analysis.

These plots were provided by Barr Associates Inc., USA in a hard copy format only, so electronic versions detailing each point on these plots are not available. These plots were scanned or the purposes of this document.

Fused Silica Radiation Absorption Windows



Fused Silica Radiation Absorption Windows



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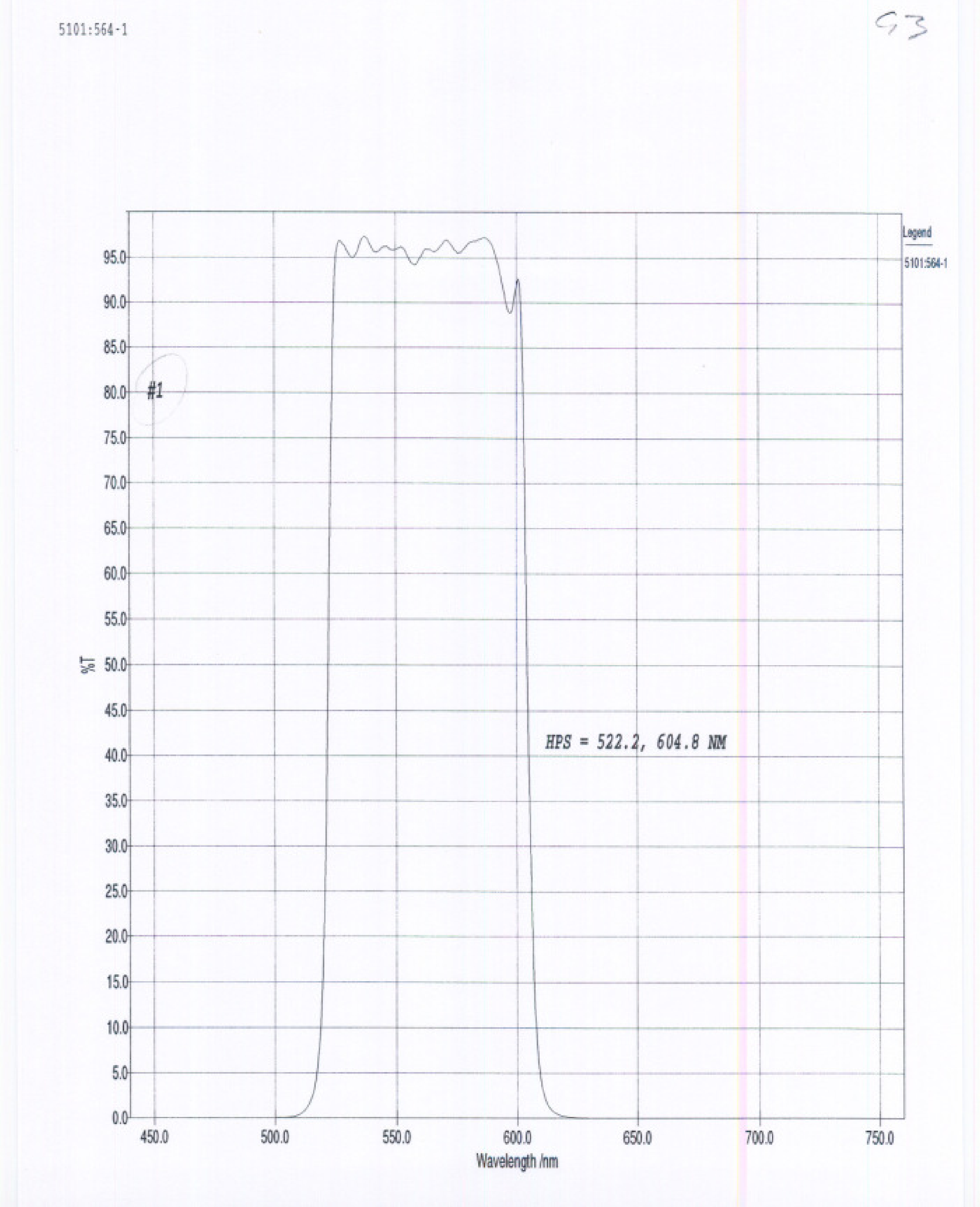
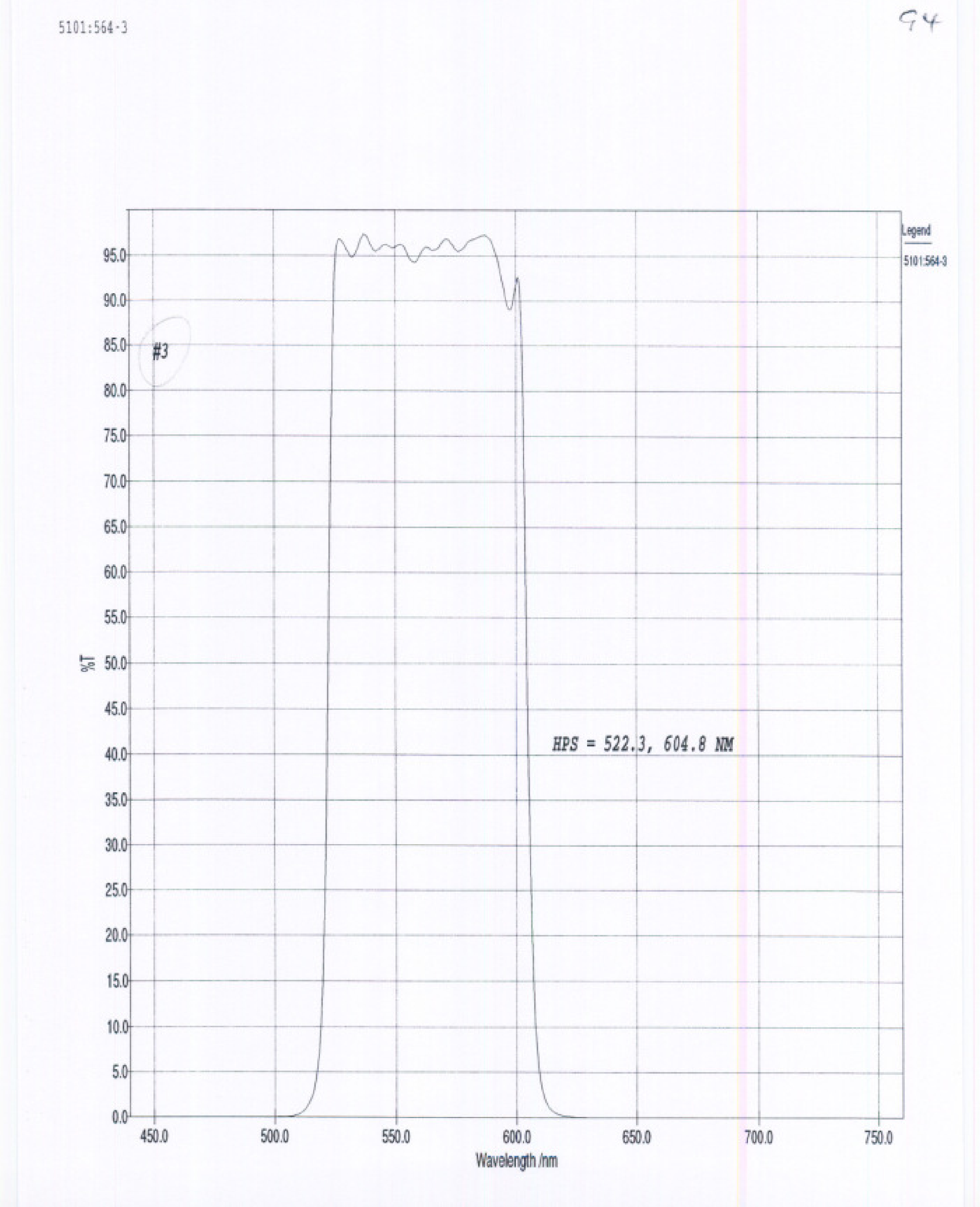
not supplied

CARY 500 Spectrophotometer

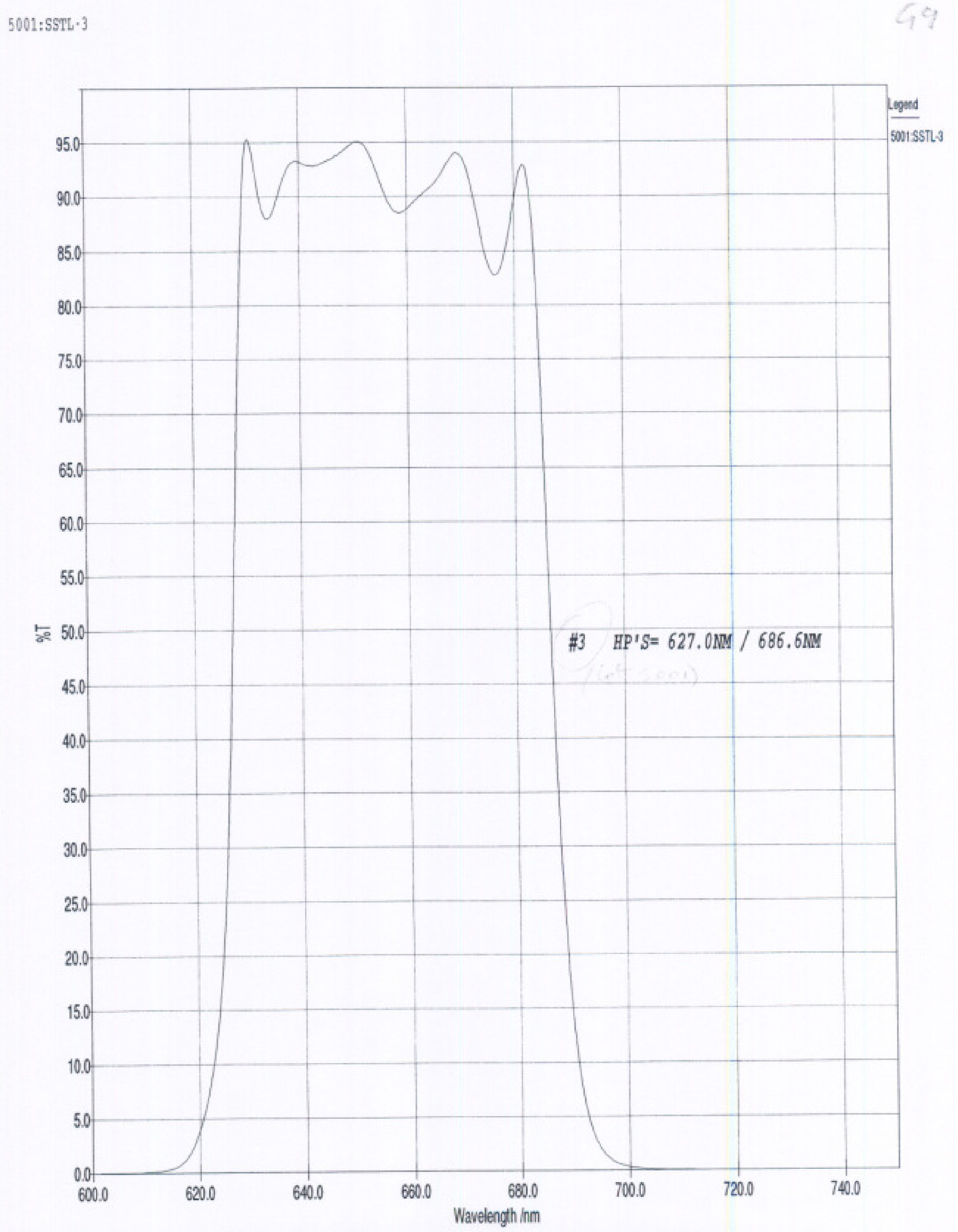
AlSat-1 Green Spectral Transmission Profile



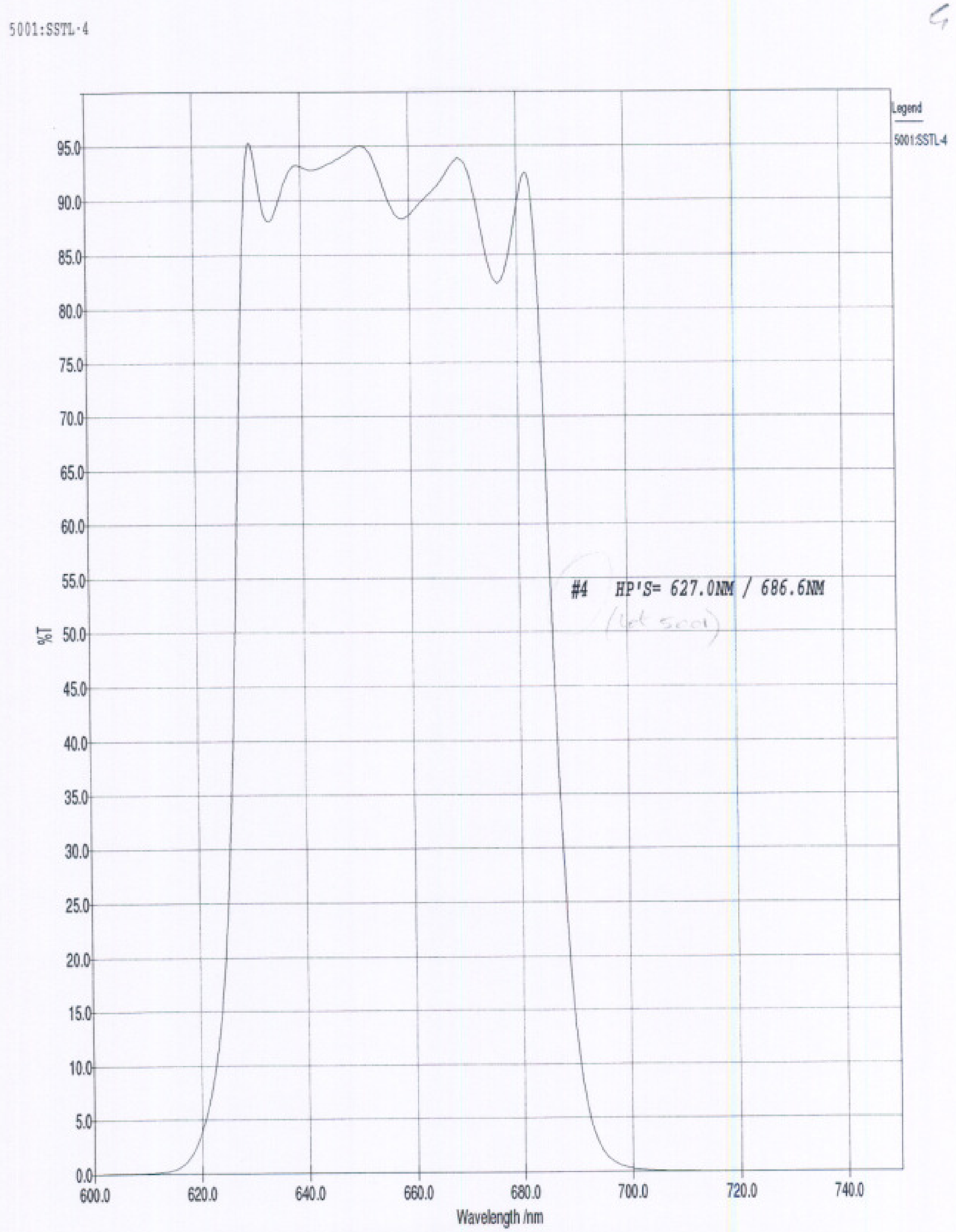
AlSat-1 Green Spectral Transmission Profile



AlSat-1 Red Spectral Transmission Profile



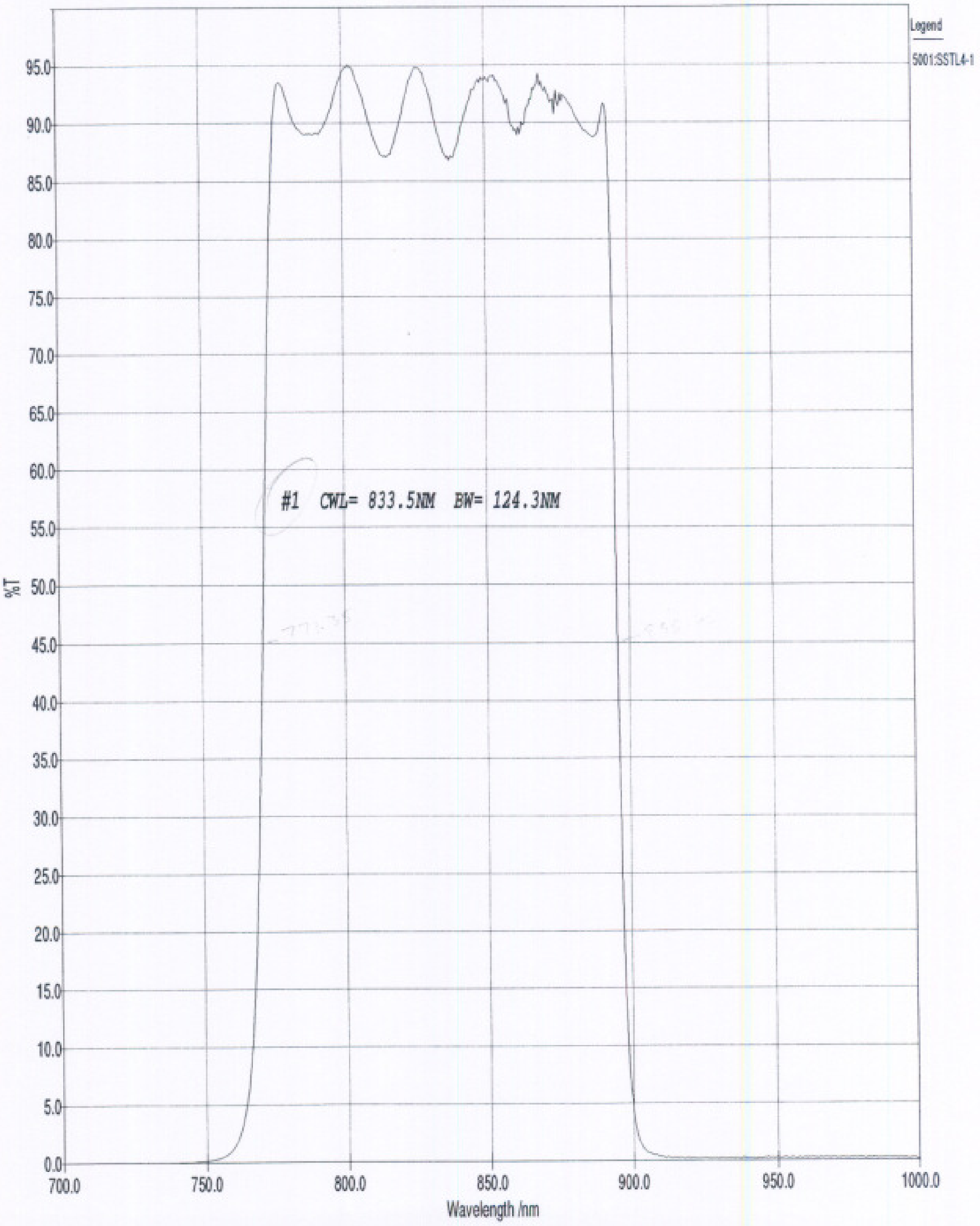
AlSat-1 Red Spectral Transmission Profile



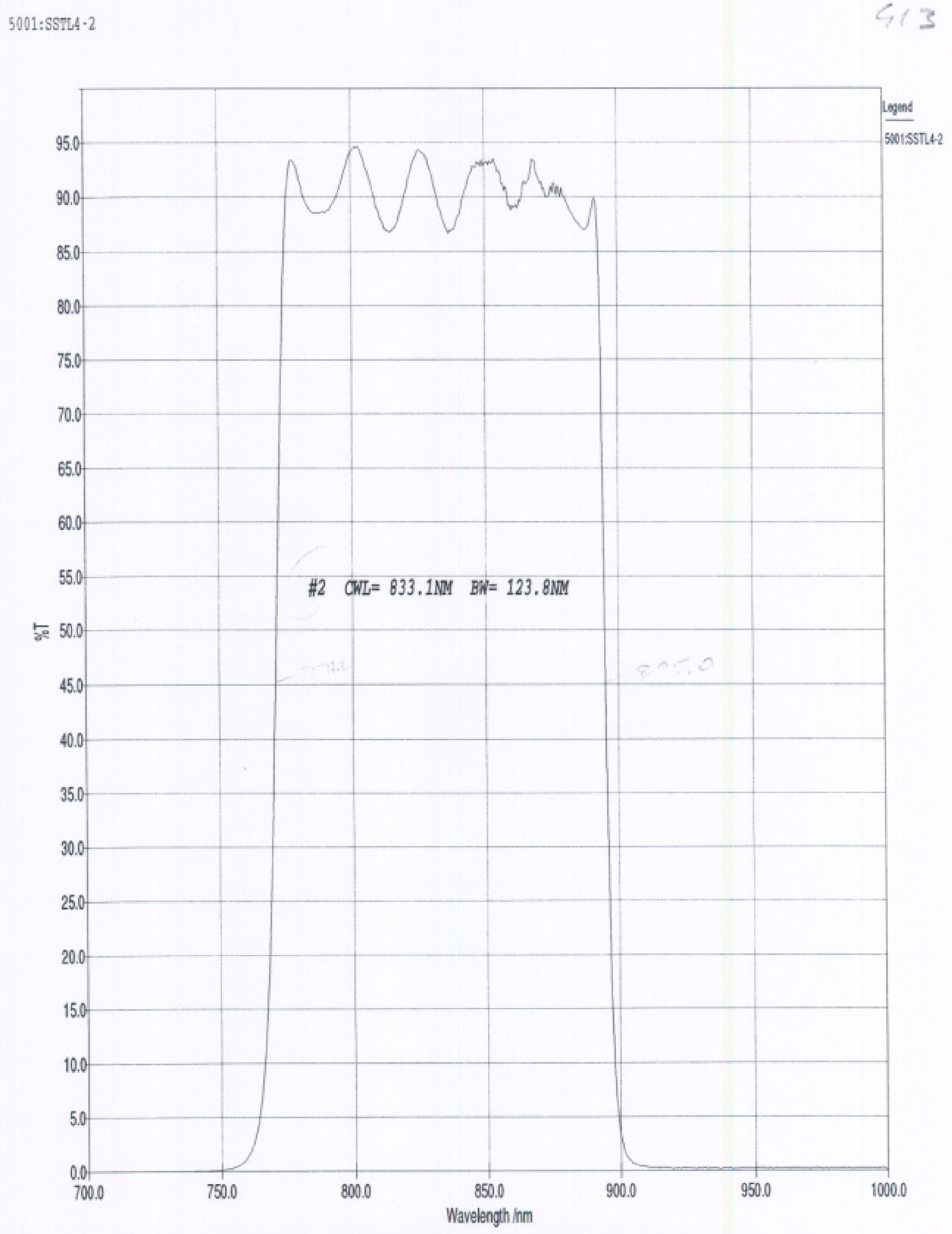
AlSat-1 NIR Spectral Transmission Profile

G12

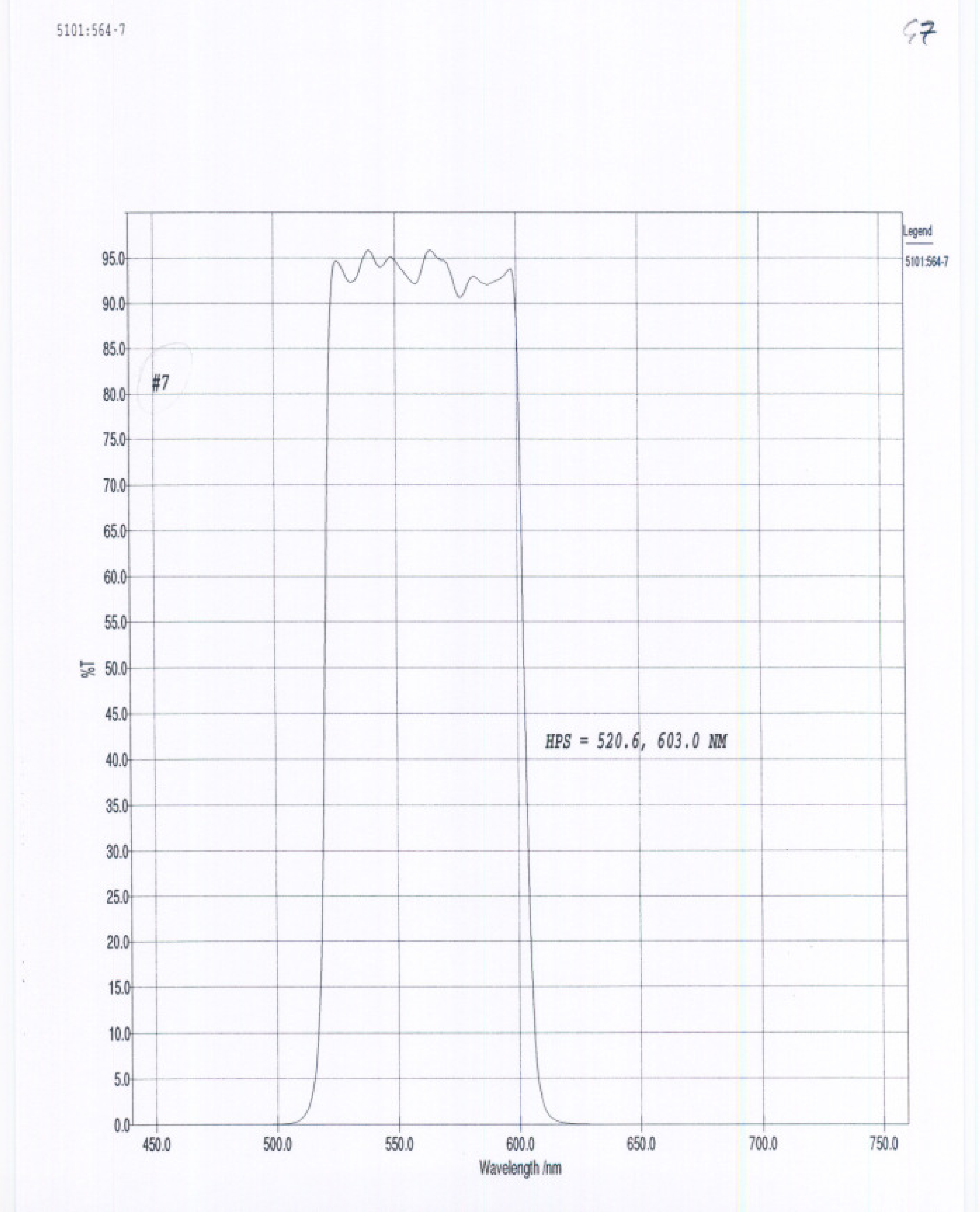
5001:SSTL4-1



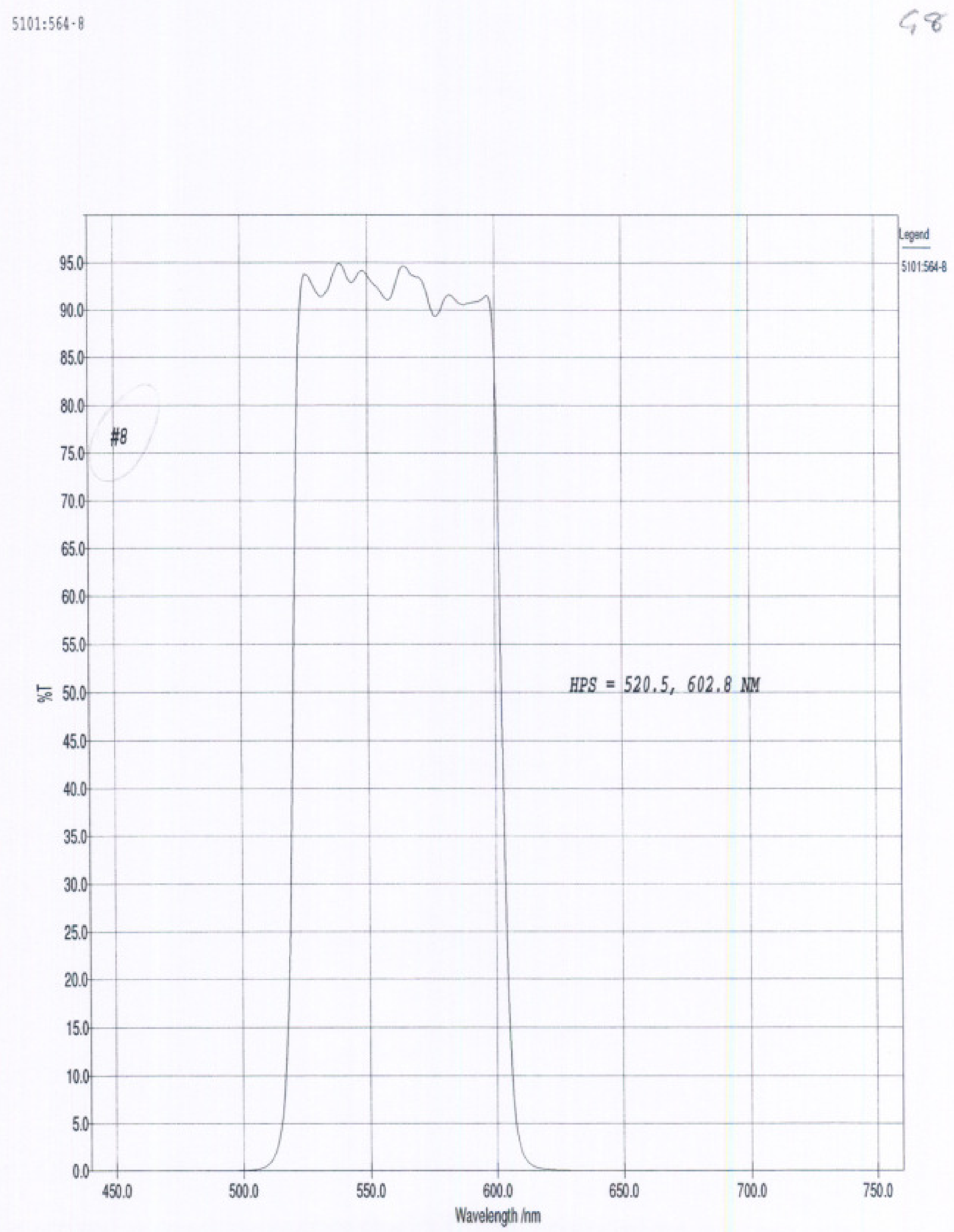
AlSat-1 NIR Spectral Transmission Profile



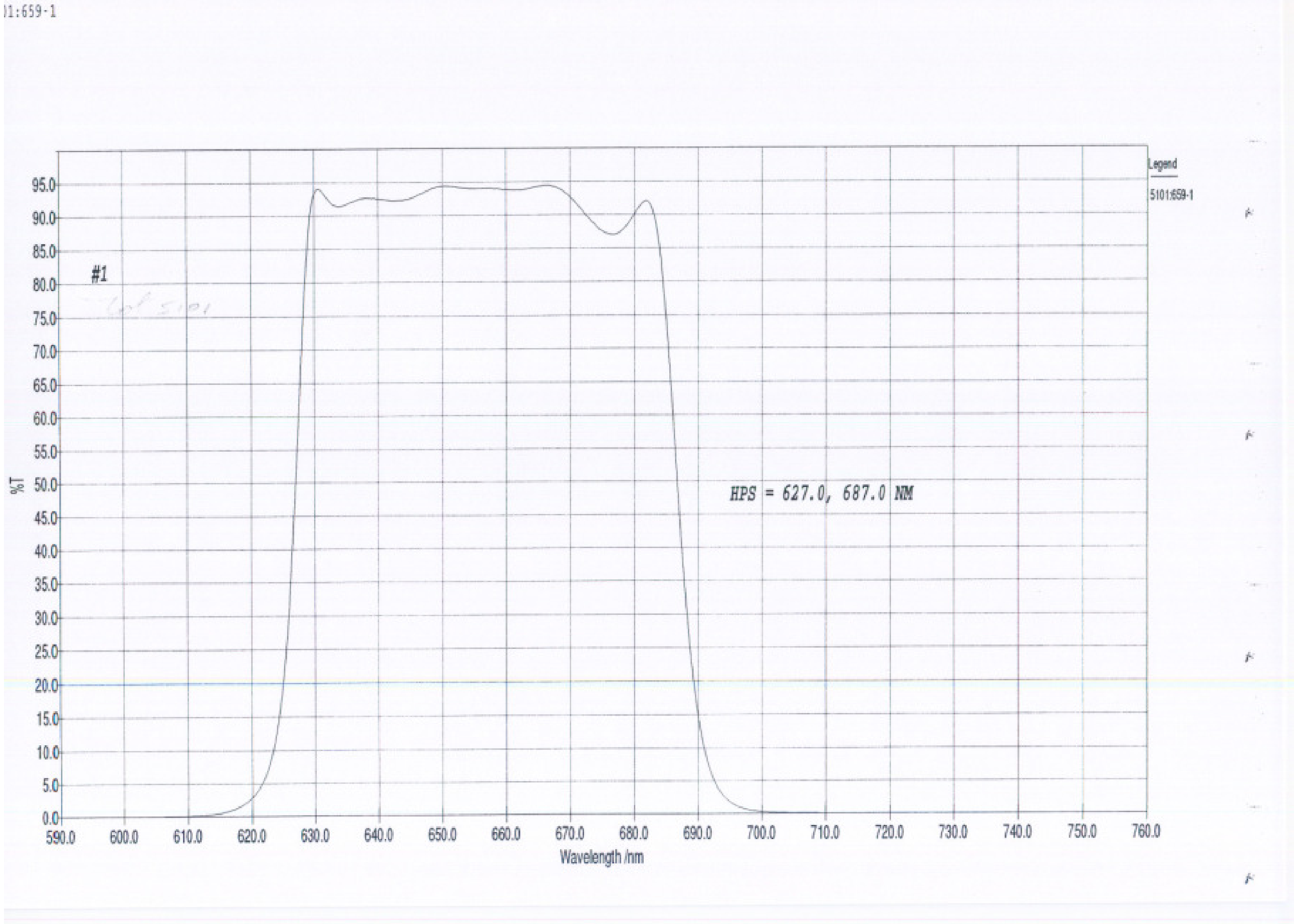
NigeriaSat-1 Green Spectral Transmission Profile



NigeriaSat-1 Green Spectral Transmission Profile

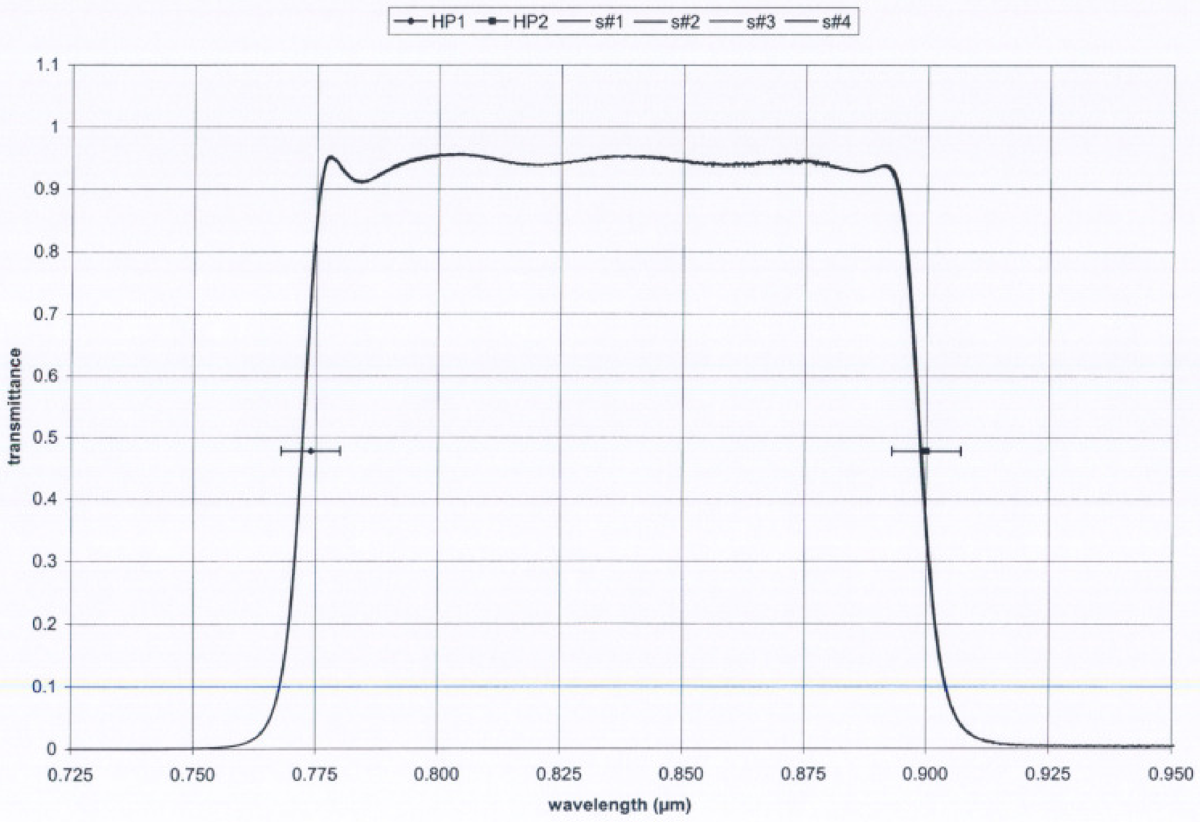


NigeriaSat-1 Red Spectral Transmission Profile (Generic)



NigeriaSat-1 NIR Spectral Transmission Profile (Generic)

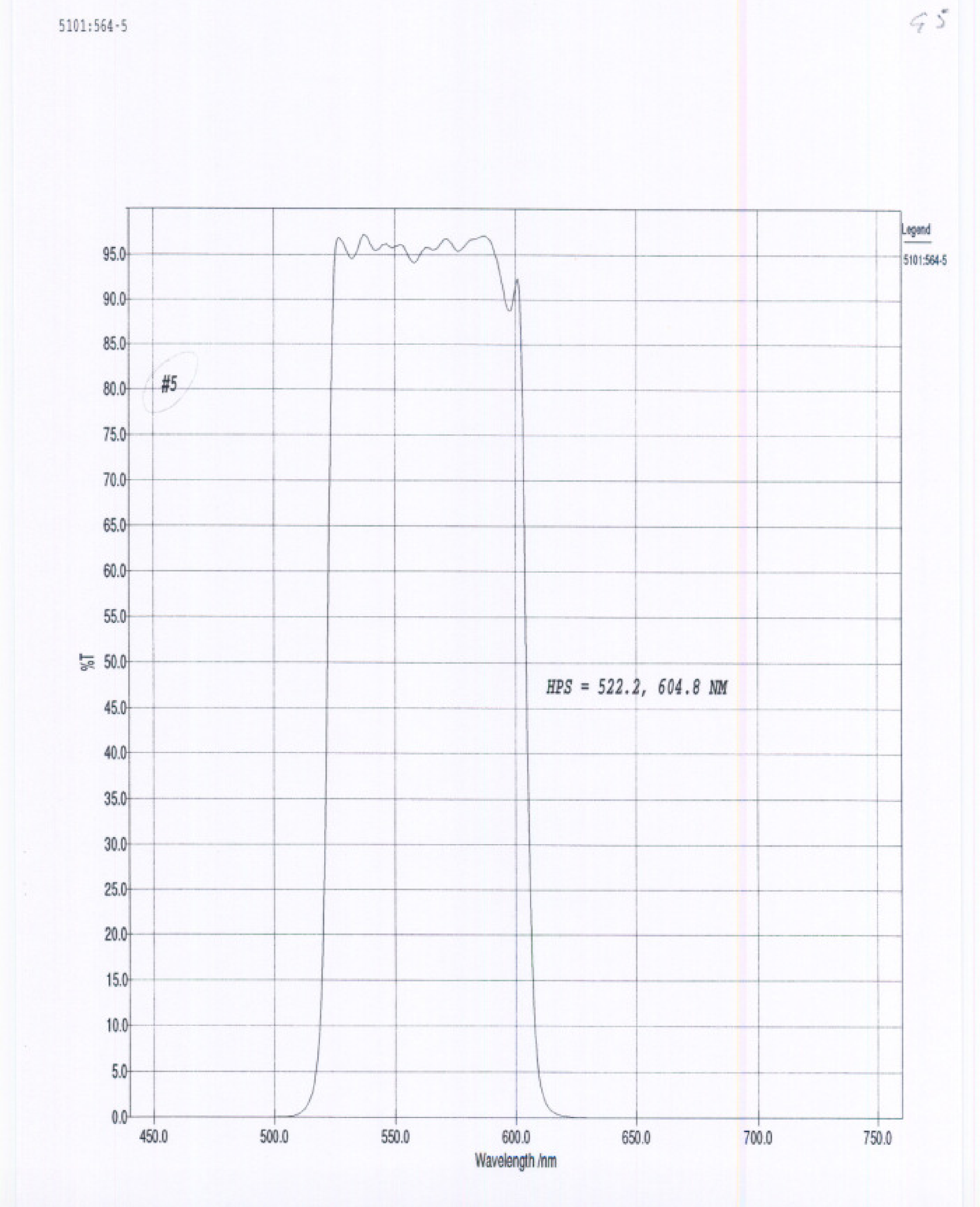
G16



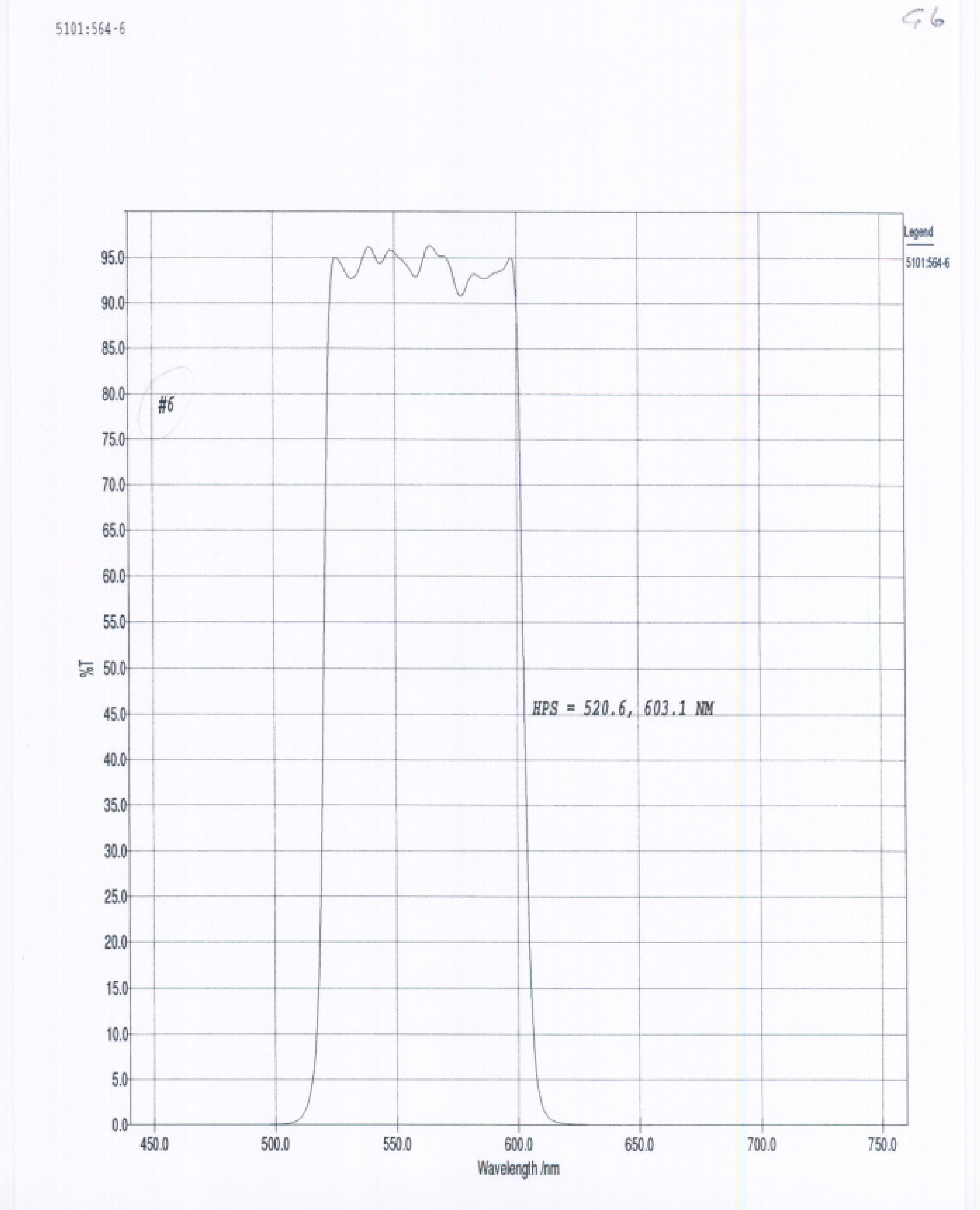
OPT4233 lot 1303 \ inband graph

3/27/2003 \ 1:31 PM

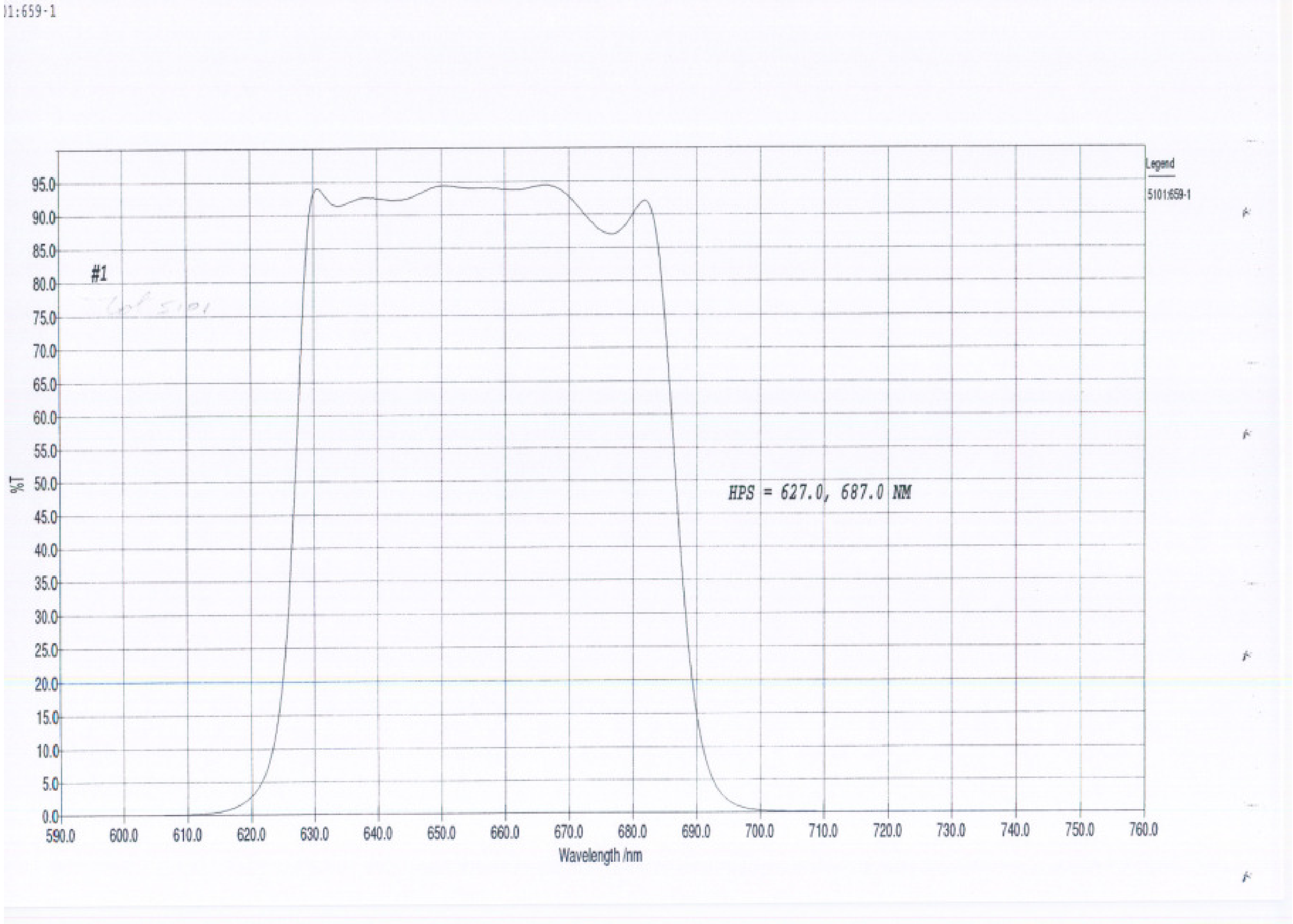
UK-DMC Green Spectral Transmission Profile



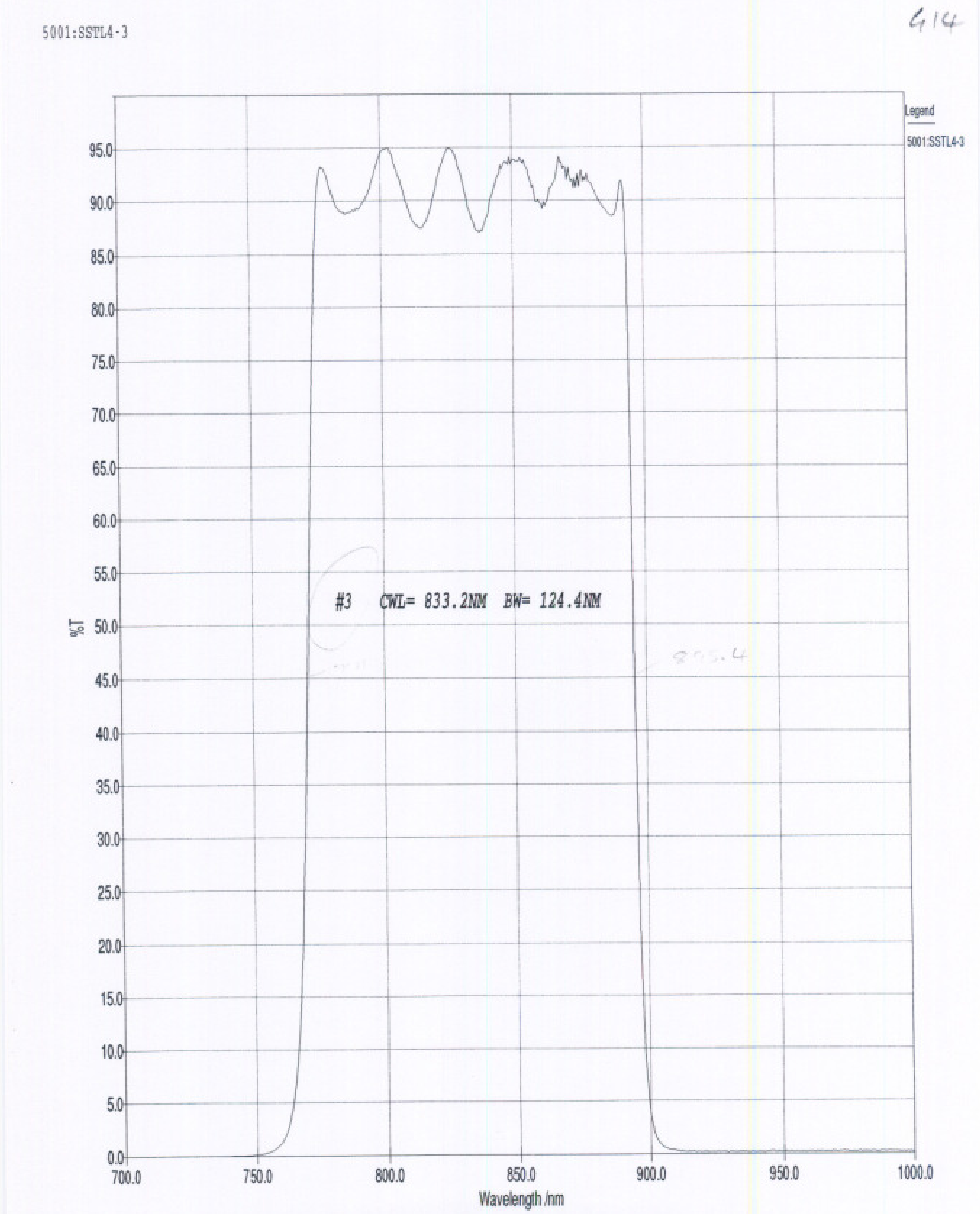
UK-DMC Green Spectral Transmission Profile



UK-DMC Red Spectral Transmission Profile (Generic)

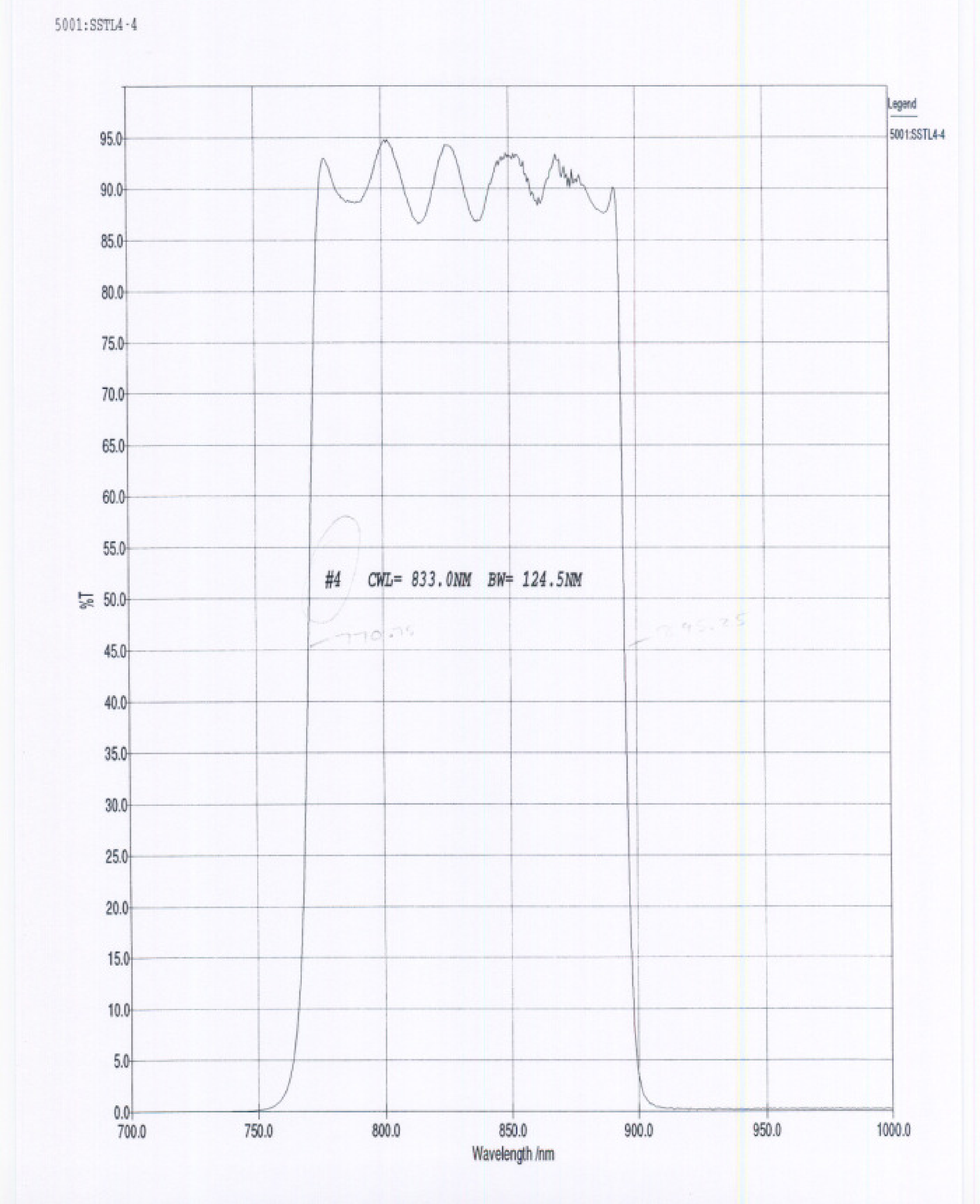


UK-DMC NIR Spectral Transmission Profile

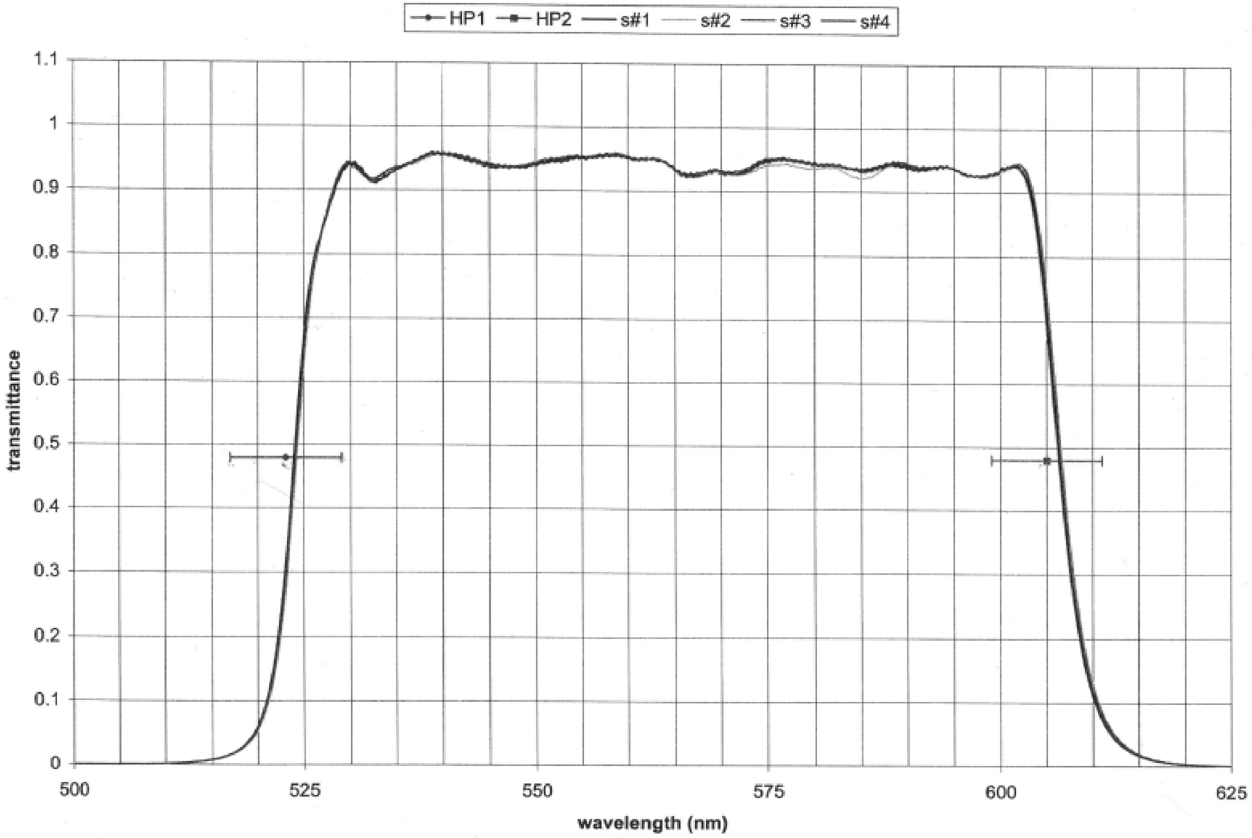


UK-DMC NIR Spectral Transmission Profile

915



Beijing-1 Green Spectral Transmission Profile (Generic)

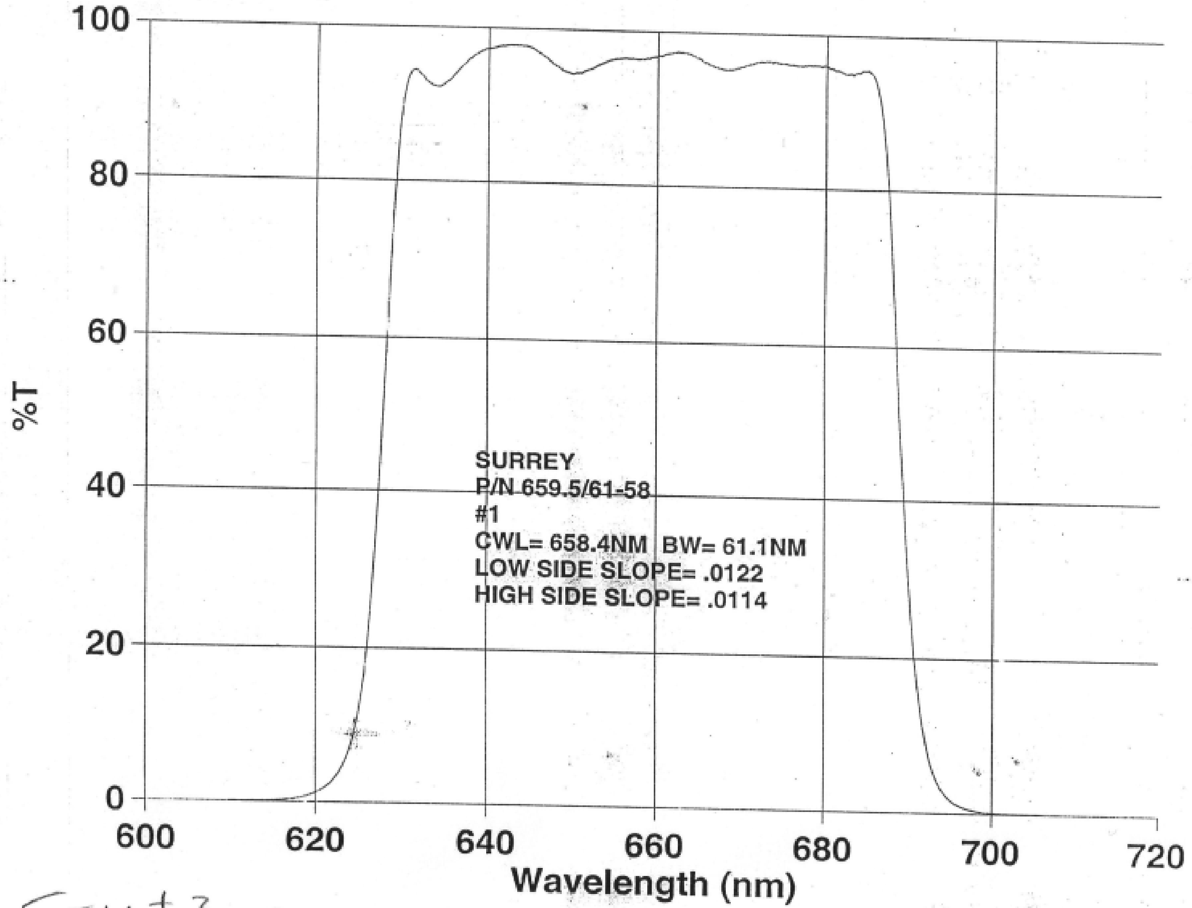


OPT4231 lot 1403 \ inband chart

4/1/2003 \ 2:34 PM

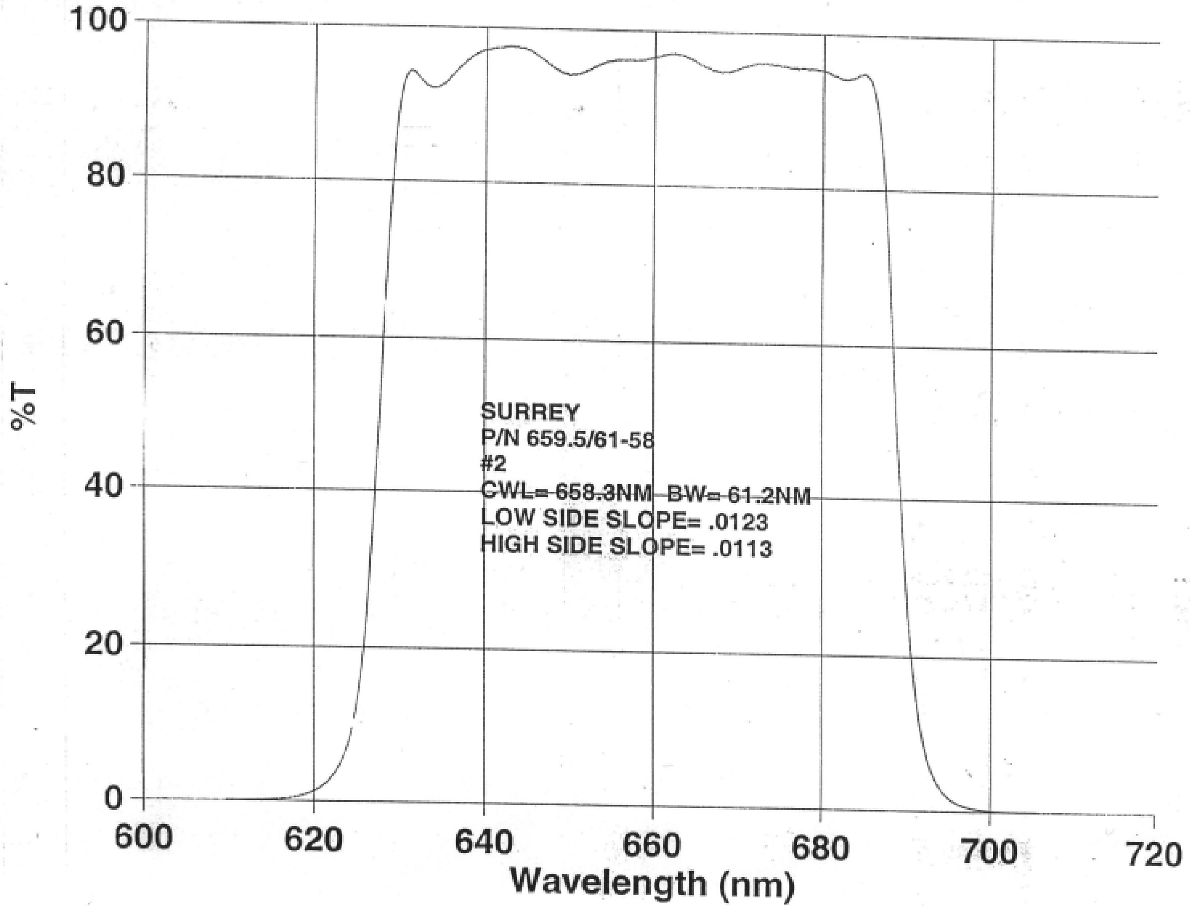
ETM +2 = GREEN

Beijing-1 Red Spectral Transmission Profile



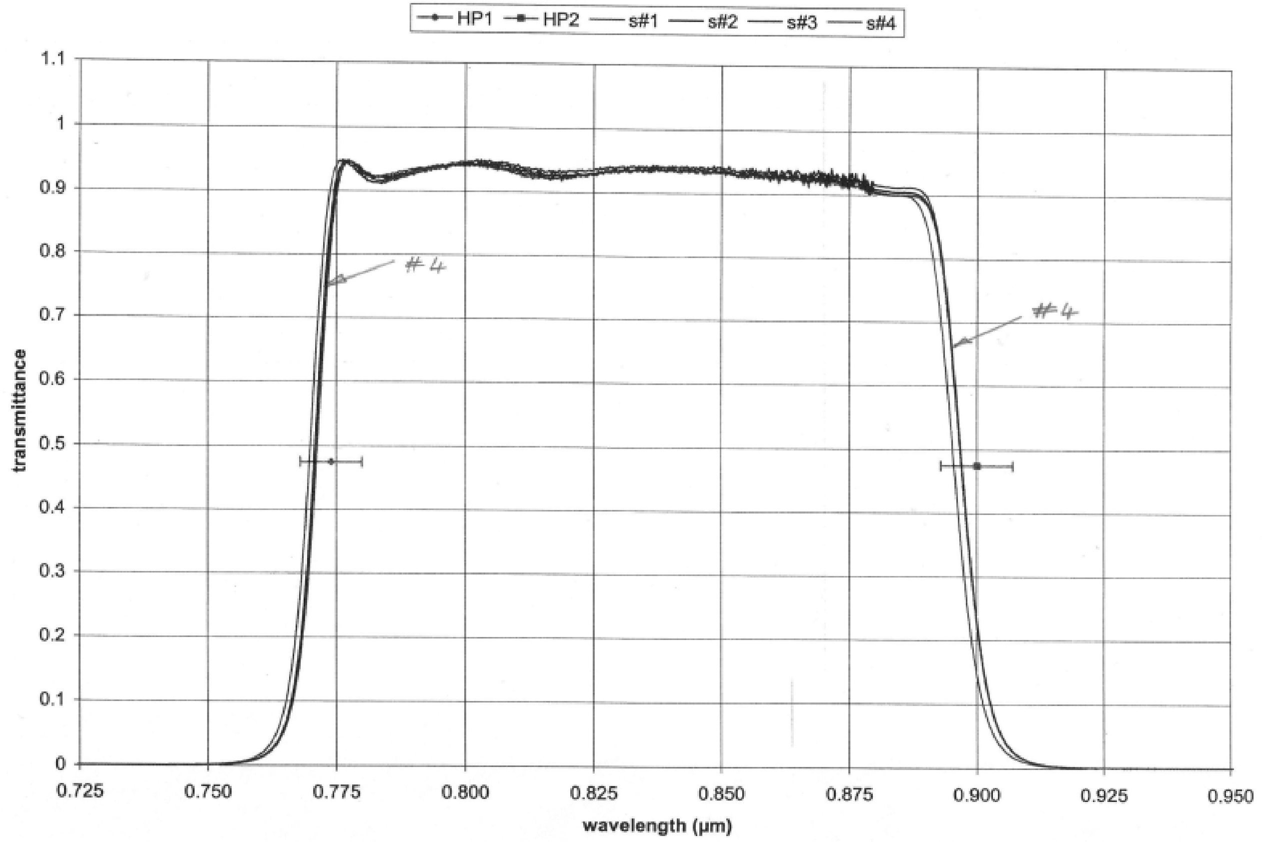
ETM^{+}3 =RED.

Beijing-1 Red Spectral Transmission Profile



ETM^{+3} = RED

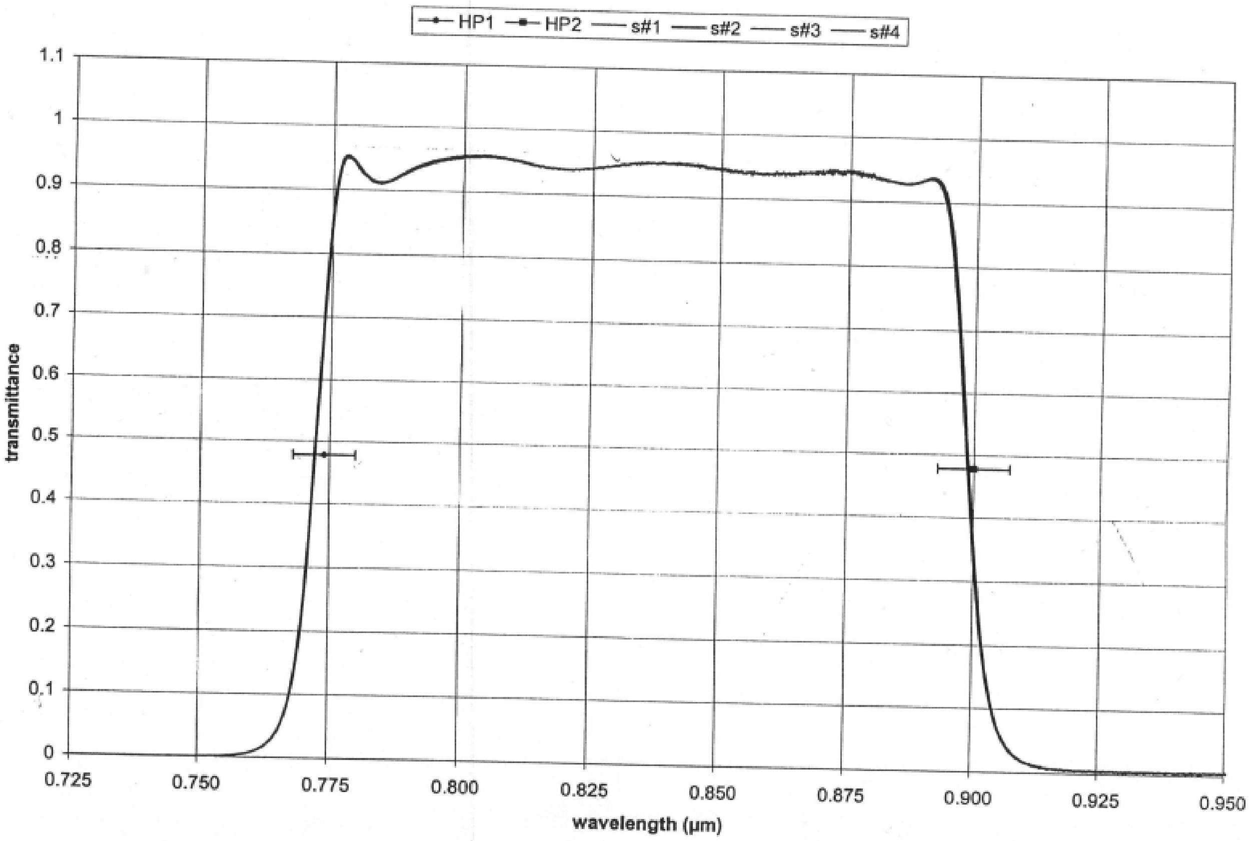
Beijing-1 NIR Spectral Transmission Profile



OPT4233 lot 1403 \ inband graph

4/11/2003 \ 1:29 PM

Beijing-1 NIR Spectral Transmission Profile



OPT4233 lot 1303 \ inband graph

3/27/2003 \ 1:31 PM

ETM+4 = nrIR

APPENDIX B: TIFF TAG IDS FOR L0R PRODUCTS

See §10.2.1 for a description on how to read these tags from the TIFF file header

Tag ID	**Tag Name**	**Tag Type**	**Tag Description**
0xC000	NIR Rescale Bias	Double	Rescale Bias value for the Near Infra-Red band.
0xC001	NIR Rescale Gain	Double	Rescale Gain value for the Near Infra-Red band.
0xC002	Red Rescale Bias	Double	Rescale Bias value for the Red band.
0xC003	Red Rescale Gain	Double	Rescale Gain value for the Red band.
0xC004	Green Rescale Bias	Double	Rescale Bias value for the Green band.
0xC005	Green Rescale Gain	Double	Rescale Gain value for the Green band.
0xFE0C	IMHD_ROWS	Long	Number of Rows in Image
0xFE0D	IMHD_COLS	Long	Number of Columns in Image
0xFE0E	IMHD_FORMAT	Long	Format of Image Capture.
0xFE0F	IMHD_SATELLITE	Short sat id; Unsigned Char []	SSTL satellite Number and Name of Satellite: 18 = AlSat-1 20 = BILSAT-1 21 = UK-DMC 22 = NigeriaSat-1 23 = Beijing-1
0xFE10	IMHD_CAMERA_CHAN	Long	Camera/Channel identifier 1 = NIR on Imager 0 2 = Red on Imager 0 4 = Green on Imager 0 7 = Imager 0 (= 1+2+4) 8 = NIR on Imager 1 16 = Red on Imager 1 32 = Green on Imager 1 56 = Imager 1 (= 8+16+32)
0xFE11	IMHD_EVENT_NR	Long	Image Event ID
0xFE12	IMHD_REQ_START_TIME	*Timestamp* t	Image Capture Start Time
0xFE13	IMHD_0B_LINE_DUR	Long	Bank0 Line Duration
0xFE14	IMHD_CENTRE_OFFSET	Long	Image Offset in Detector Array.
0xFE18	IMHD_FILENAME	Unsigned Char []	Suggested filename within SSDR
0xFE19	IMHD_TEXT_DESC	Unsigned Char []	Text description of Image
0Xfe1B	IMHD_EOST_VERSION	Unsigned Char []	Version of EOST software
0Xfe1C	IMHD_PRIORITY	Short	Priority of Image
0Xfe1D	IMHD_GSN_ID	Unsigned Char []	Source of Image Request
0Xfe1E	IMHD_REQUEST_ID	Long	ID of original request.
0xFE1F	IMHD_MASTERSLAVE	Long	0 = Master, 1 = Slave.
0xFE20	IMHD_1B_LINE_DUR	Long	Bank1 Line Duration

Tag ID	Tag Name	Tag Type	Tag Description
0xFE24	IMHD_EVENT_CAMS	Long	1 = Bank0 only 2 = Bank1 only 3 = Bank0 + Bank1
0xFE2B	IMHD_0B0_EXP	Long	Imager 0 Band 0 Exposure
0xFE2C	IMHD_0B1_EXP	Long	Imager 0 Band 1 Exposure
0xFE2D	IMHD_0B2_EXP	Long	Imager 0 Band 2 Exposure
0xFE2E	IMHD_0B0_OP	Long	Imager 0 Band 0 Op Mode
0xFE2F	IMHD_0B1_OP	Long	Imager 0 Band 1 Op Mode
0xFE30	IMHD_0B2_OP	Long	Imager 0 Band 2 Op Mode
0xFE31	IMHD_0B0_VGA_GAIN	Long	Imager 0 Band 0 VGA Gain
0xFE32	IMHD_0B1_VGA_GAIN	Long	Imager 0 Band 1 VGA Gain
0xFE33	IMHD_0B2_VGA_GAIN	Long	Imager 0 Band 2 VGA Gain
0xFE34	IMHD_0B0_CLAMP_LEVEL	Long	Imager 0 Band 0 Clamp Level
0xFE3B	IMHD_0B1_CLAMP_LEVEL	Long	Imager 0 Band 1 Clamp Level
0xFE3C	IMHD_0B2_CLAMP_LEVEL	Long	Imager 0 Band 2 Clamp Level
0xFE3D	IMHD_0B0_CONTROL	Long	Imager 0 Band 0 Control
0xFE3E	IMHD_0B1_CONTROL	Long	Imager 0 Band 1 Control
0xFE3F	IMHD_0B2_CONTROL	Long	Imager 0 Band 2 Control
0xFE40	IMHD_0B0_CDS_GAIN	Long	Imager 0 Band 0 CDS Gain
0xFE41	IMHD_0B1_CDS_GAIN	Long	Imager 0 Band 1 CDS Gain
0xFE42	IMHD_0B2_CDS_GAIN	Long	Imager 0 Band 2 CDS Gain
0xFE4B	IMHD_1B0_EXP	Long	Imager 1 Band 0 Exposure
0xFE4C	IMHD_1B1_EXP	Long	Imager 1 Band 1 Exposure
0xFE4D	IMHD_1B2_EXP	Long	Imager 1 Band 2 Exposure
0xFE4E	IMHD_1B0_OP	Long	Imager 1 Band 0 Op Mode
0xFE4F	IMHD_1B1_OP	Long	Imager 1 Band 1 Op Mode
0xFE50	IMHD_1B2_OP	Long	Imager 1 Band 2 Op Mode
0xFE51	IMHD_1B0_VGA_GAIN	Long	Imager 1 Band 0 VGA Gain
0xFE52	IMHD_1B1_VGA_GAIN	Long	Imager 1 Band 1 VGA Gain
0xFE53	IMHD_1B2_VGA_GAIN	Long	Imager 1 Band 2 VGA Gain
0xFE54	IMHD_1B0_CLAMP_LEVEL	Long	Imager 1 Band 0 Clamp Level
0xFE5B	IMHD_1B1_CLAMP_LEVEL	Long	Imager 1 Band 1 Clamp Level
0xFE5C	IMHD_1B2_CLAMP_LEVEL	Long	Imager 1 Band 2 Clamp Level
0xFE5D	IMHD_1B0_CONTROL	Long	Imager 1 Band 0 Control
0xFE5E	IMHD_1B1_CONTROL	Long	Imager 1 Band 1 Control
0xFE5F	IMHD_1B2_CONTROL	Long	Imager 1 Band 2 Control
0xFE60	IMHD_1B0_CDS_GAIN	Long	Imager 1 Band 0 CDS Gain
0xFE61	IMHD_1B0_CDS_GAIN	Long	Imager 1 Band 1 CDS Gain
0xFE62	IMHD_1B0_CDS_GAIN	Long	Imager 1 Band 2 CDS Gain
0xFF0B	IMHD_TLM_ROLL	Short roll *timestamp* t	Roll in centidegrees at time t
0xFF0C	IMHD_TLM_PITCH	Short pitch *timestamp* t	Pitch in centidegrees at time t
0xFF0D	IMHD_TLM_YAW	Short yaw *timestamp* t	Yaw in centidegrees at time t

Tag ID	**Tag Name**	**Tag Type**	**Tag Description**
0xFF0E	IMHD_TLM_ROLL_RATE	Short roll rate *timestamp* t	Roll in millidegrees/s at time t
0xFF0F	IMHD_TLM_PITCH_RATE	Short pitch rate *timestamp* t	Pitch in millidegrees/s at time t
0xFF10	IMHD_TLM_YAW_RATE	Short yaw rate *timestamp* t	Yaw in millidegrees/s at time t
0xFF11	IMHD_CAM_TEMP_1	Long	Tlm from camera temp sensor 1.
0xFF12	IMHD_CAM_TEMP_2	Long	Tlm from camera temp sensor 2.
0xFF13	IMHD_CAM_TEMP_3	Long	Tlm from camera temp sensor 3.
0xFF14	IMHD_CAM_TEMP_4	Long	Tlm from camera temp sensor 4.
0xFF15	IMHD_CAM_TEMP_5	Long	Tlm from camera temp sensor 5.
0xFF16	IMHD_CAM_TEMP_6	Long	Tlm from camera temp sensor 6.
0xFF17	IMHD_CAM_TEMP_7	Long	Tlm from camera temp sensor 7.
0xFF18	IMHD_CAM_TEMP_8	Long	Tlm from camera temp sensor 8.
0xFF19	IMHD_CAM_TEMP_9	Long	Tlm from camera temp sensor 9.
0xFF1A	IMHD_CAM_TEMP_10	Long	Tlm from camera temp sensor 10.
0xFF1B	IMHD_SSDR_VERSION	Long	Version of SSDR software
0xFF2B	IMHD_GPS_POSITION_X	Float posX *timestamp* t	GPS position X at time t.
0xFF2C	IMHD_GPS_POSITION_Y	Float posY *timestamp* t	GPS position Y at time t.
0xFF2D	IMHD_GPS_POSITION_Z	Float posZ *timestamp* t	GPS position Z at time t.
0xFF2E	IMHD_GPS_VELOCITY_X	Float velX *timestamp* t	GPS velocity X at time t.
0xFF2F	IMHD_GPS_VELOCITY_Y	Float velY *timestamp* t	GPS velocity Y at time t.
0xFF30	IMHD_GPS_VELOCITY_Z	Float velZ *timestamp* t	GPS velocity Z at time t.
0xFF3B	IMHD_NORAD_POSITION_X	Long posX *timestamp* t	Norad position X at time t.
0xFF3C	IMHD_NORAD_POSITION_Y	Long posY *timestamp* t	Norad position Y at time t.
0xFF3D	IMHD_NORAD_POSITION_Z	Long posZ *timestamp* t	Norad position Z at time t.
0xFF3E	IMHD_NORAD_VELOCITY_X	Short velX *timestamp* t	Norad velocity X at time t.
0xFF3F	IMHD_NORAD_VELOCITY_Y	Short velY *timestamp* t	Norad velocity Y at time t.
0xFF40	IMHD_NORAD_VELOCITY_Z	Short velZ *timestamp* t	Norad velocity Z at time t.

Tag ID	Tag Name	Tag Type	Tag Description
0xFF5B	IMHD_RT_TLM	Long Clock Count Short roll Short pitch Short yaw *Timestamp* ta Float GPSposX Float GPSposY Float GPSposZ Float GPSvelX Float GPSvelY Float GPSvelZ *Timestamp* tg	Clock Count over 16 s Roll in centidegrees at time ta Pitch in centidegrees at time ta Yaw in centidegrees at time ta Attitude timestamp GPS position X at time tg (m) GPS position Y at time tg (m) GPS position Z at time tg (m) GPS velocity X at time tg (ms^{-1}) GPS velocity Y at time tg (ms^{-1}) GPS velocity Z at time tg (ms^{-1}) GPS timestamp
0xFF5C	IMHD_RT_TLM2	Long Clock Count Short roll Short pitch Short yaw *Timestamp* ta Long NoradposX Long NoradposY Long NoradposZ Short NoradVelX Short NoradvelY Short NoradvelZ	Clock Count over 16 s Roll in centidegrees at time ta Pitch in centidegrees at time ta Yaw in centidegrees at time ta Attitude timestamp Norad position X at time ta (m) Norad position Y at time ta (m) Norad position Z at time ta (m) Norad velocity X at time ta (ms^{-1}) Norad velocity Y at time ta (ms^{-1}) Norad velocity Z at time ta (ms^{-1})
0xFF5D	IMHD_ST_TLM	Short roll Short pitch Short yaw Short roll rate Short pitch rate Short yaw rate *Timestamp* ta Float GPSposX Float GPSposY Float GPSposZ Float GPSvelX Float GPSvelY Float GPSvelZ *Timestamp* tg	Roll in centidegrees at time ta Pitch in centidegrees at time ta Yaw in centidegrees at time ta Roll rate in centidegrees/s at time ta Pitch rate in centidegrees/s at time ta Yaw rate in centidegrees/s at time ta Attitude timestamp GPS position X at time tg (m) GPS position Y at time tg (m) GPS position Z at time tg (m) GPS velocity X at time tg (ms^{-1}) GPS velocity Y at time tg (ms^{-1}) GPS velocity Z at time tg (ms^{-1}) GPS timestamp

Tag ID	Tag Name	Tag Type	Tag Description
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APPENDIX C: DIMAP SAMPLE – L1R PRODUCT

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APPENDIX D: DIMAP SAMPLE – L1T PRODUCT

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                </Vertex>
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                <IMAGING_TIME>16:14:39</IMAGING_TIME>
                <VIEWING_ANGLE unit="DEG">1.70751061117751</VIEWING_ANGLE>
                <SUN_AZIMUTH unit="DEG">101.74181569705586</SUN_AZIMUTH>
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    <Data_Strip>
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                <SCENE_CENTER_COL>7030</SCENE_CENTER_COL>
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</Dimap_Document>
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APPENDIX E: RADIOMETRIC CALIBRATION REPORT

Post-Launch Calibration of the UK-DMC Satellite Sensor

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Document Version 1.3

CONTENTS

1 Introduction

In this document the calibration procedure of the UK-DMC satellite sensor is described. The study was carried out in several phases, the initial phase was to analyse the data and characterise the responses from dark (no signal) and bright targets. Once completed an extensive literature search was carried out to determine the best procedures to apply to calibrate such a large sensor array (20,000 detectors over two arrays).

Absolute calibration is described only in overview, as the data collection and data analysis were carried out by the Remote Sensing Group at the University of Arizona (RSG) under Kurt Thome. However, the results of the analysis are presented later in this document.

The extension of the absolute calibration of a few detectors to the whole array (the relative calibration), is described in some detail, including some of the issues related to data collection and variations in the surface response.

Finally the results of the study are illustrated (comparing the raw and calibrated data) and further work required is indicated.

2 Initial Data Analysis And Characterisation

Prior to developing the full calibration methodology, we carried out a series of tests for each detector array (Imager0 and Imager1) for each sensor (green, red and NIR bands) to characterise their response to both dark and bright targets.

2.1 Deep Space Images

Immediately after launch, UK-DMC had not deployed the gravity gradient boom and thus was more manoeuvrable. It was decided therefore to use this opportunity to collect deep space images to help characterise the sensor arrays. Only two imaging opportunities were available prior to boom deployment.

2.2 Snow Scenes

Given the size of the image arrays and the requirements for a very large swath with a uniform background radiance, a brief review of the literature pointed to targets used by the AVHRR sensor in Antarctica and Greenland (see Figure 14), which covered the required area extent and had the necessary radiometric stability. Given the autumn launch data, targets were acquired over the Antarctic, coinciding with the DOME-C site used by AVHRR and the SPOT-Vegetation instruments.

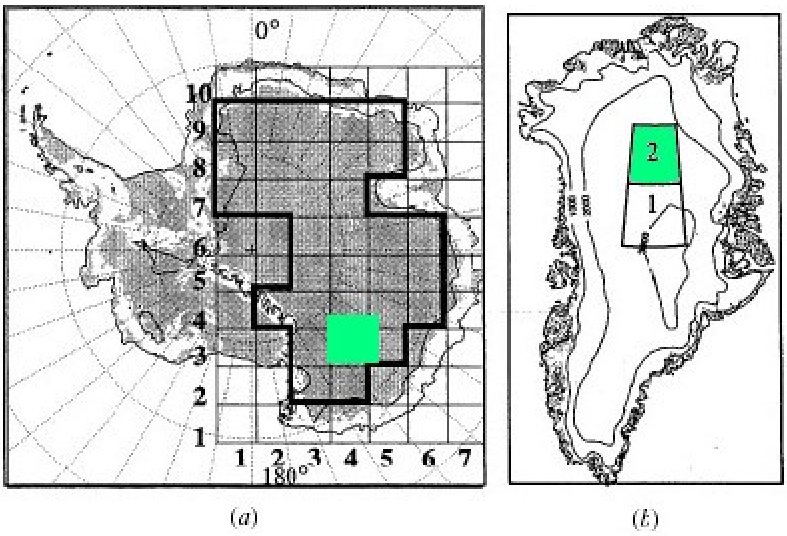

Figure 1 (a) Regions of the Antarctic continent with slope < 0.006 radians (0.34°) at 10km resolution (shaded), with the height contour for 2000m superimposed. The 32 gridboxes (~444km on a side) for which individual monthly plots of χ_n are generated are outlined. (b) The two gridboxes on the Greenland high plateau used in this study. Both gridboxes are bounded by longitudes 35° and 45° W; the latitudes spanned are 72–75° N for gridbox 1 and 75–78° N for gridbox 2. The two maps are on different scales.

Figure 14: Site location map showing Antarctic and Greenland test sites (green boxes)[6]

3 Procedural Overview

Based on the initial data characterisation, we were able to clearly define a procedure of data collection for the relative calibration of our DMC sensor arrays. The final element required was to then tie these relative values to a set of absolute physical measurements of radiance.

3.1 Relative Calibration

3.1.1 Dark Images

The initial results of our study showed that the dark images from deep space had a fixed pattern structure for each CCD array that was not dependent on the integration time used for the image acquisition (in other words an additive component).

Figure 15 and Figure 16 show the average detector responses (in DN) across the even pixels for the red band of Imager0. Note the fixed pattern variation across the CCD array for these two deep space images. Peaks coincide in location and amplitude, suggesting a stable, additive response for our dark images. Note also the small step (pixel 4000 in Figure 15 and pixel 3000 in Figure 16), these features will be discussed later in the report.

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[6] Masonis and Warren (2001).

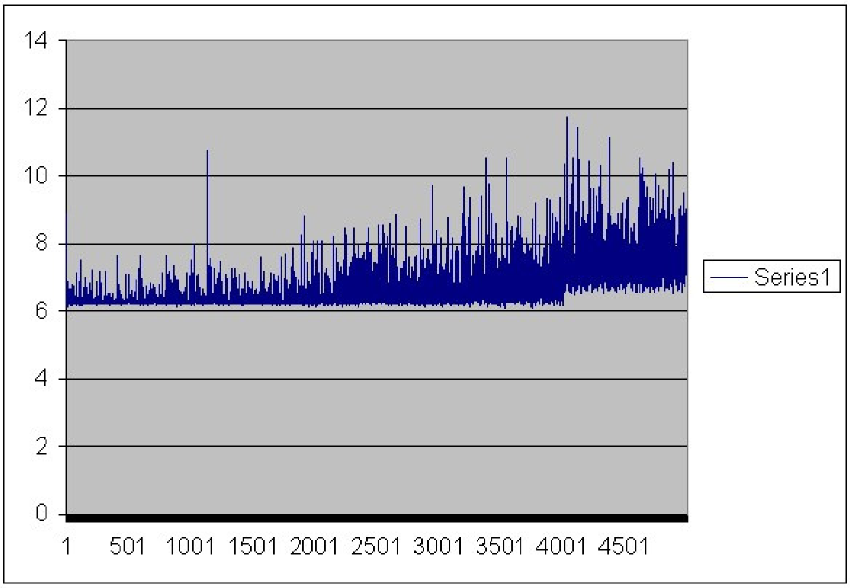


Figure 15: Red even pixels – DU000009pm (integration time 1,500 µs)

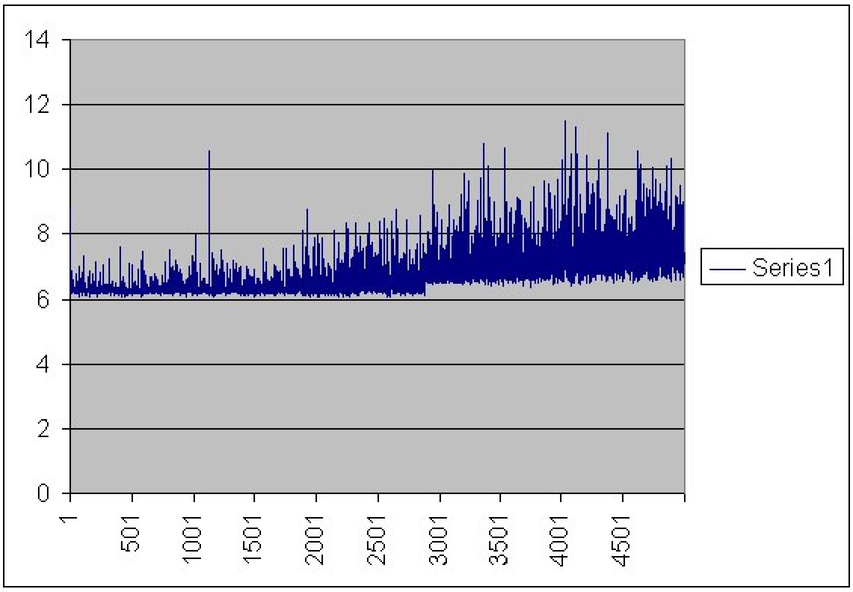


Figure 16: Red even pixels – DU000010pm (integration time 2,400 µs)

The results gave us confidence that we could extract stable measurements of the additive component for our calibration. However, as soon as the gravity gradient boom was extended, we could not carry out further observations of deep space. Hence, we had to consider alternatives to our deep space measurements. In this case we chose to observe the Pacific Ocean at night to try and derive our coefficients. The results confirmed that the Pacific Ocean at night provided the same level of information as derived from our deep space observations.

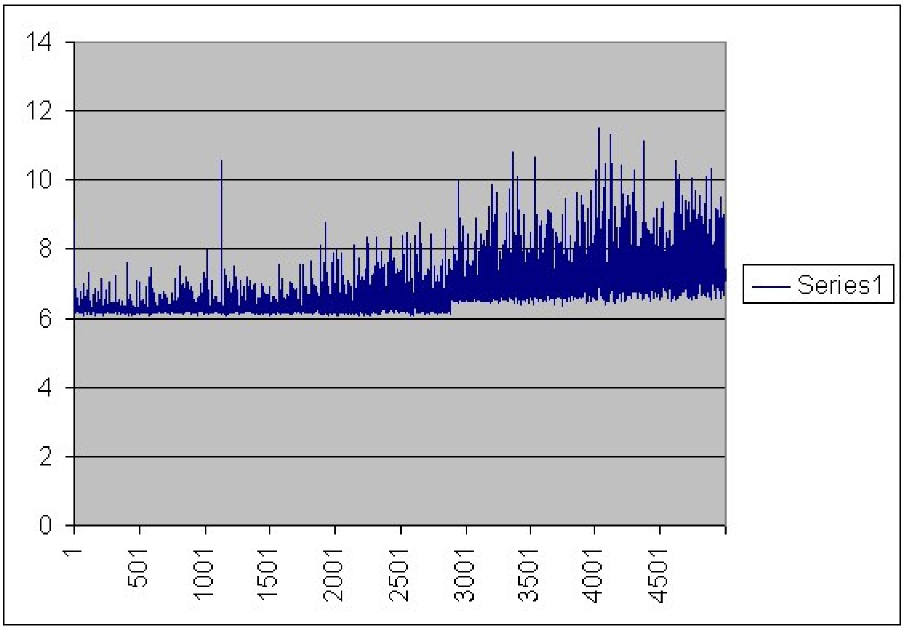


Figure 17: Deep Space image (DU000010pm red even pixels)

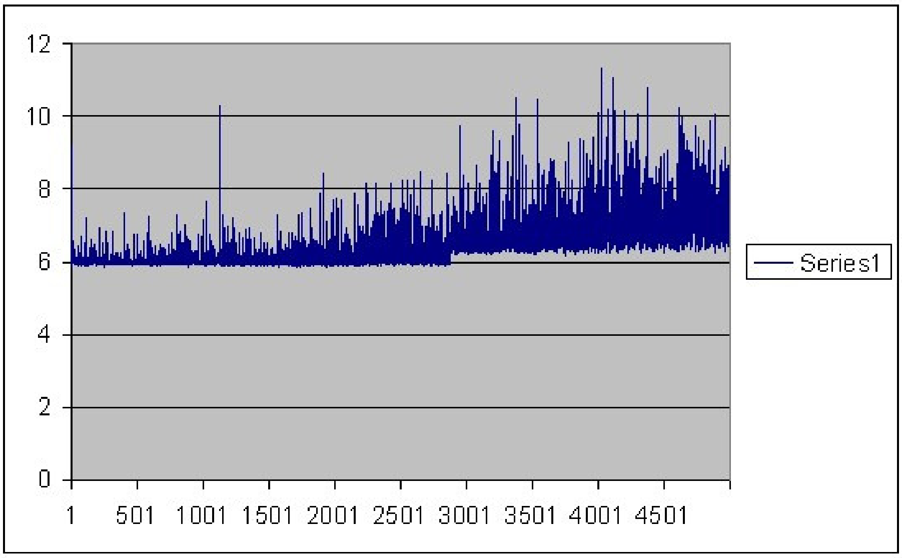


Figure 18: Pacific Ocean at night image (DU000020pm red even pixels)

In Figure 17 and Figure 18 we compare the Deep Space image for the Imager0, red band, even pixels; against the equivalent Pacific Ocean at night image. The offsets and magnitude are comparable to a high level of precision.

3.1.2 Snow Scenes

The initial results of the snow scene analysis also showed a very stable result under varying integration times, the overall scene DN scaling in proportion to the integration time in a linear manner (as determined in the lab, pre-launch).

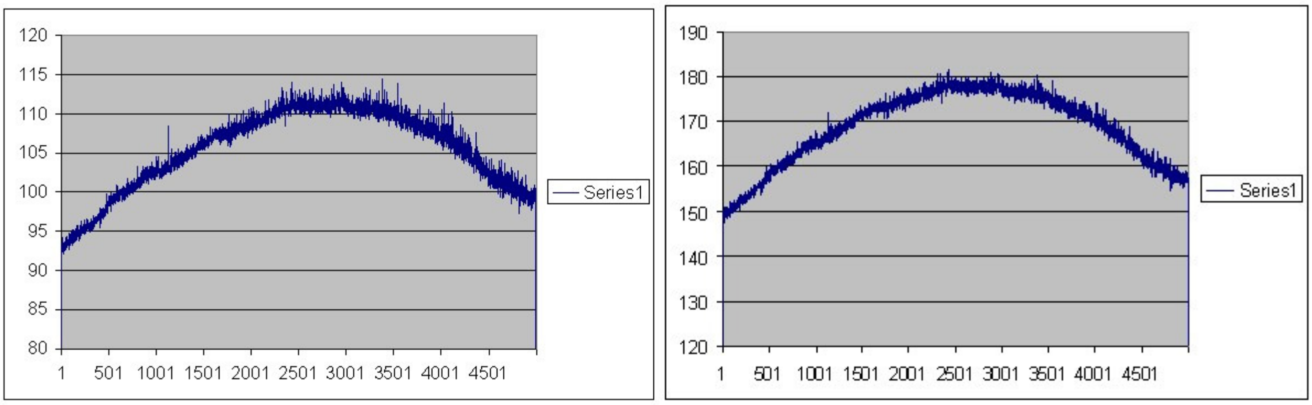


Figure 19: Comparison of Antarctic scenes DU00001cpm (left) and DU00001apm (right)

As shown in Figure 19 the overall response is similar, the DN values are different as different integration times were used. DU00001cpm had an integration time of 320 μs, whereas DU00001apm had an integration time of 512 μs.

The curvature of the response shown in Figure 19 is expected, as it is a function of the $\cos^4$ variation between a detector in the centre of the CCD array and one at the edge of the CCD array. Also, note the slight asymmetry in the snow scene response across the array.

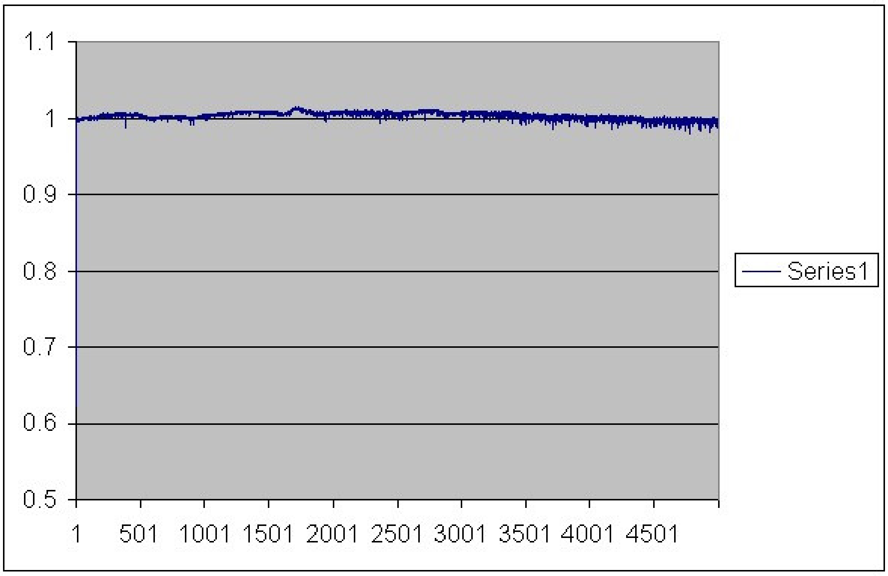


Figure 20: Ratio of the two plots in Figure 19

The results in Figure 20 suggest that the system response is stable for our snow scenes at the 1-2% level. Several other images were examined to confirm this result.

3.2 Absolute Calibration.

For an accurate absolute calibration we require a homogeneous site, with relatively stable atmospheric conditions, that is large enough to cover several pixels within our scene. We also require the necessary instrumentation at the site to characterise the surface at the time of scene acquisition and measure various atmospheric parameters such as aerosol size distribution (using a sun photometer) and variations in atmospheric parameters such as water vapour (using radiosondes).

None of this was available to us in the UK. We therefore decided to carry out a co-operative study with Kurt Thome and RSG to carry out this essential step. A two-week block of time in July 2004 was allocated for the study at the Railroad Valley site in Nevada, USA.

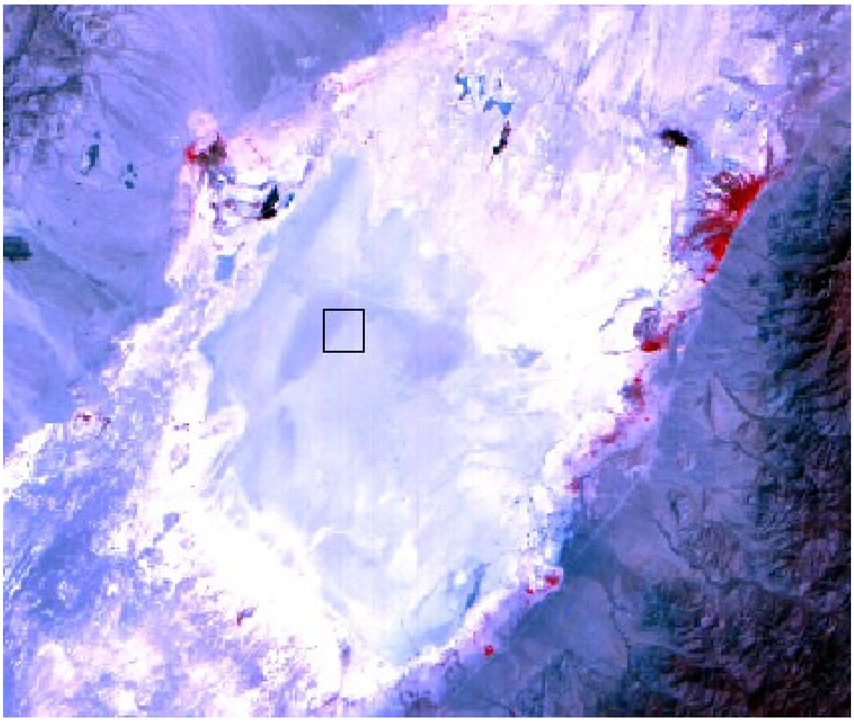


Figure 21: Railroad Valley calibration site (DMC image)

The equipment and some of the personnel were provided by RSG, along with two members of SSTL staff to help in the data collection. Ground data collection with field spectrometers, combined with atmospheric measurements were timed to occur with each overpass of all four of the satellites currently in the DMC constellation (including the UK-DMC). The ground data was retained by RSG and the results of the analysis were provided in the form of TOA radiances to SSTL.

It was decided to repeat this study on an annual basis to monitor degradation of the satellite sensor response over the satellite lifetime (nominally five years).

4 Procedural Details

In this section the detailed analysis of the dark images and snow scenes is given and the corresponding procedures to obtain the absolute calibration coefficients for the whole scene.

4.1 Relative Calibration

4.1.1 Dark Images

Initial results of comparing deep space images and those taken over the Pacific Ocean at night, showed that the pattern variation of the CCD arrays was constant and independent of the integration time. However, it was noted that there were small step features in the output data from the different data collections.

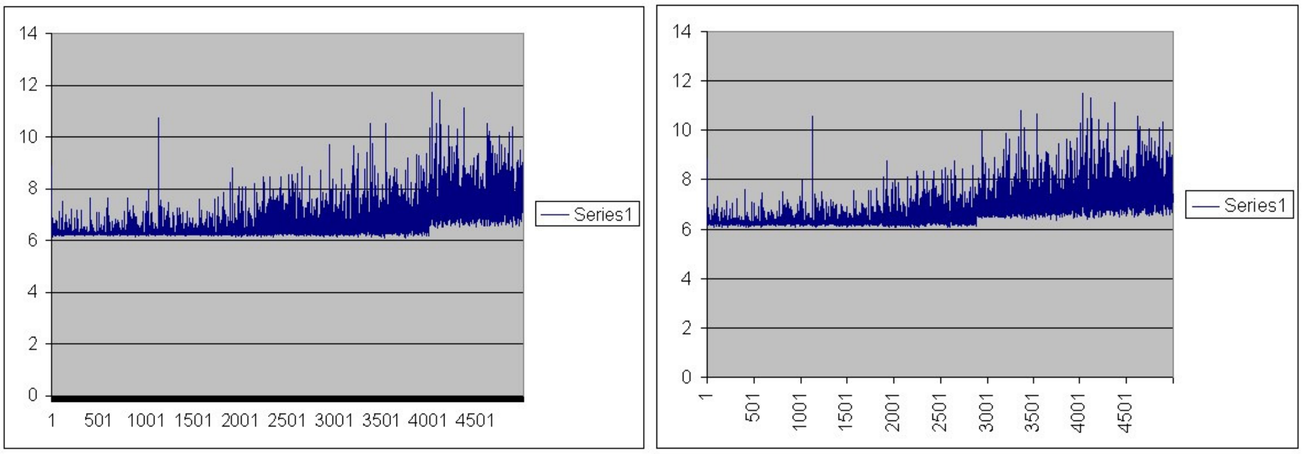


Figure 22: Comparison of dark images DU000009pm (left) and DU000010pm (right)

Figure 22 shows the comparison between two dark images of deep space; note the difference in the step position in the two plots. For any particular image these step features were in the same position for all spectral bands, but from one image to the next the position and magnitude of the step did vary. To highlight these features, we ratioed the plots, we also subtracted one plot from the other to measure the magnitude of the variations.

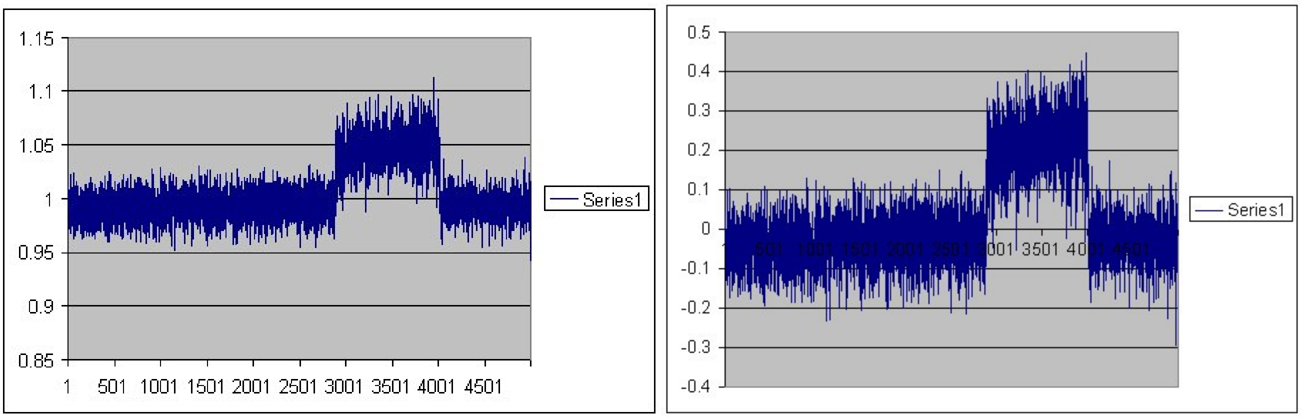
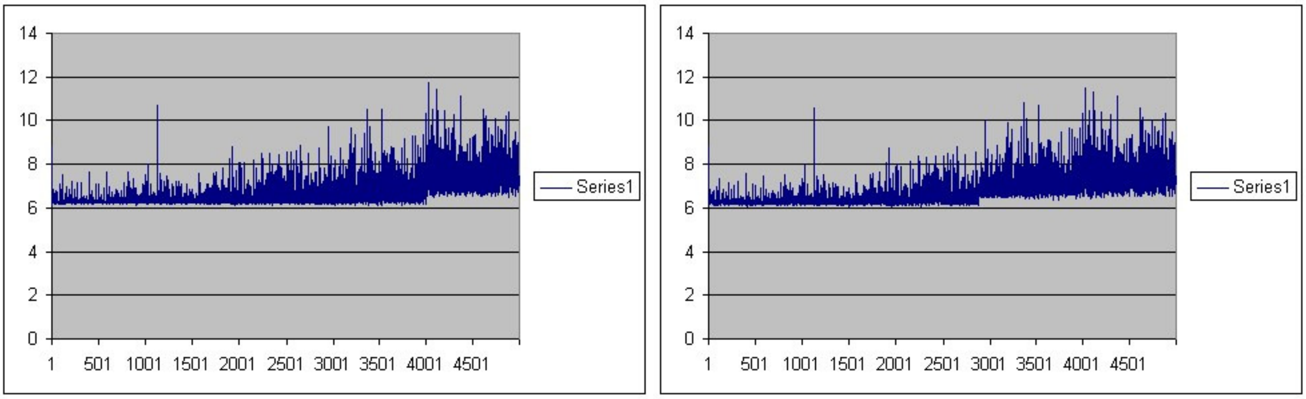
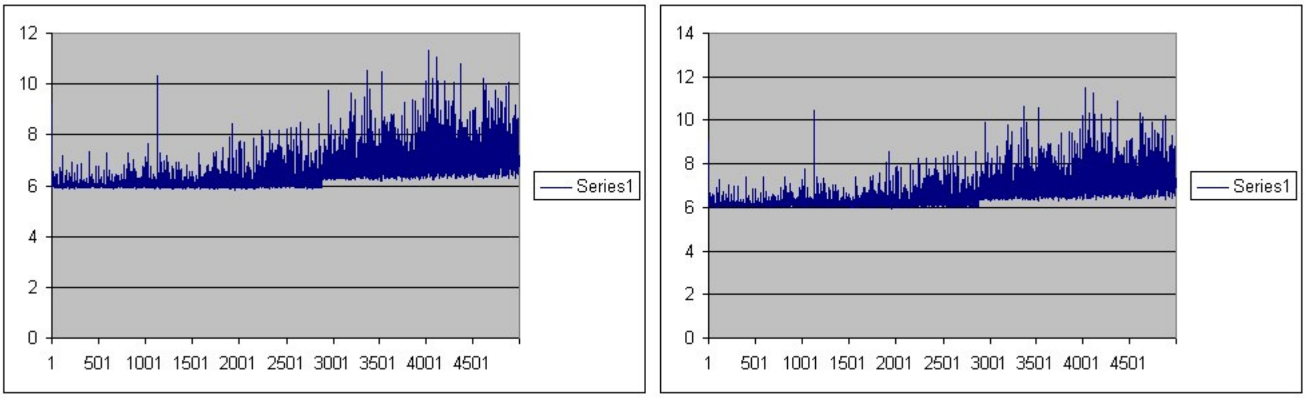


Figure 23: Analysis of the two plots in Figure 22 - ratio (left); magnitude difference (right)

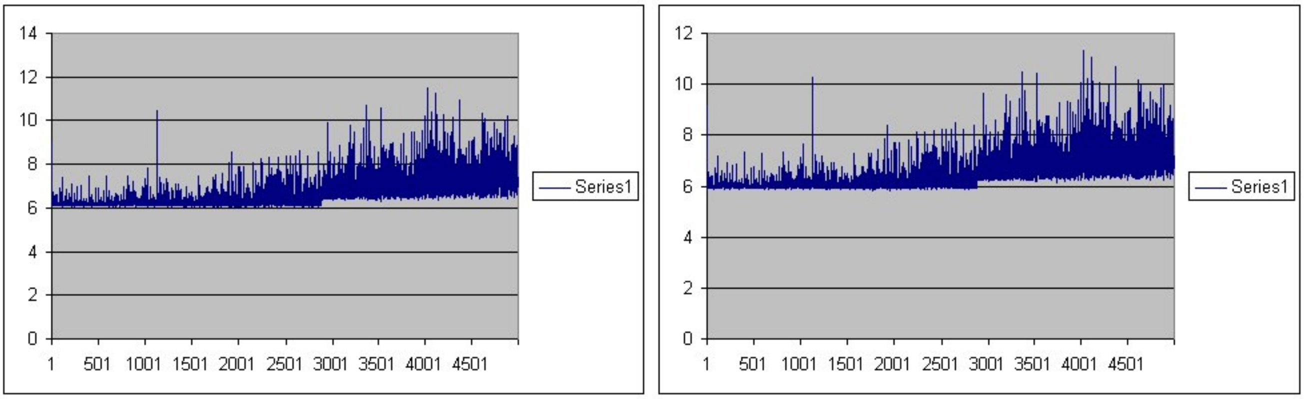
The results show that the offsets produce a 5% difference in the values between two different dark images. This seems large, but only produces a 0.25 DN variation in the output values. However, it was decided to analyse all the dark images and determine the best image (most stable) to use to calculate the dark image calibration bias values to apply in the calibration process. Comparisons showed that these offsets were present in almost all the images to a larger or smaller degree.



DU000009pm (Deep Space) DU000010pm (Deep Space)



DU000020pm (Pacific Ocean at Night) DU000026pm (Pacific Ocean at Night)



DU00003dpm (Pacific Ocean at Night) DU00003fpm (Pacific Ocean at Night)

Figure 24: Comparison of the dark images for the red even pixels on Imager0

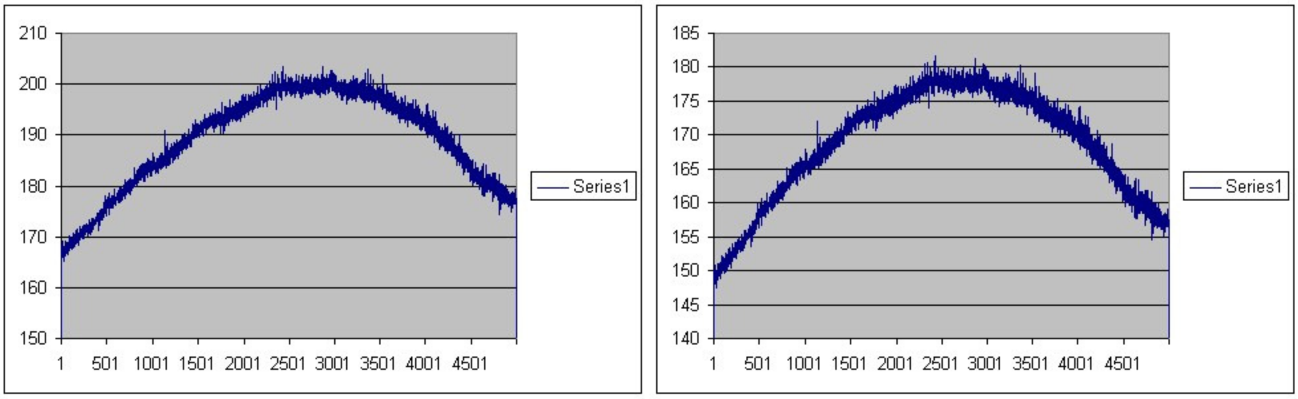
Figure 24 shows that the position of the offset, although variable, did occur in more or less the same place for any single image, the only unusual image being DU000009pm, which had a different offset to the rest. It was decided therefore to use the deep space image DU000010pm as the baseline image for calculation of the calibration bias values.

4.1.2 Snow Scenes

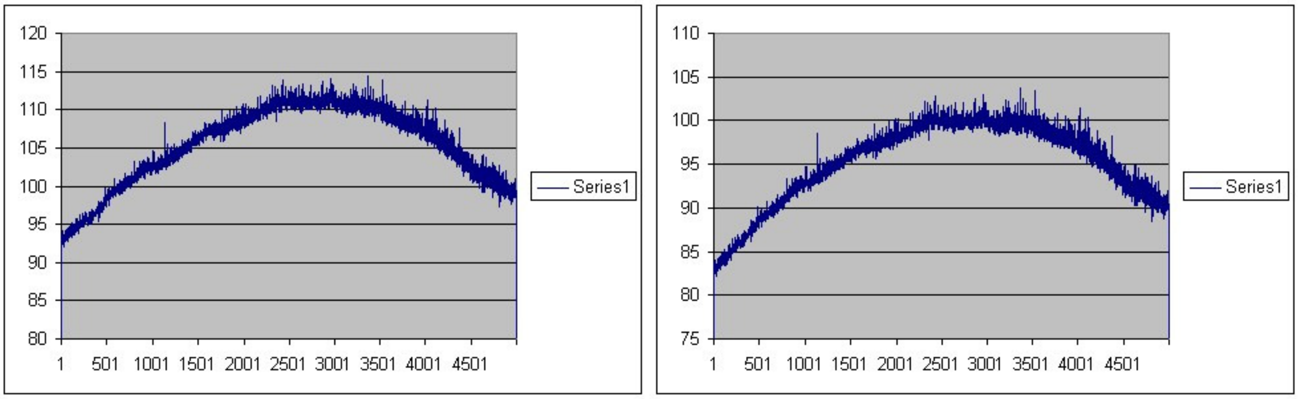
4.1.2.1 Antarctica

The initial data collection of snow scenes took place over the Antarctic site (DOME-C) during the period November 2003 – February 2004. Initial data collections were saturated in the green and red bands and the integration time was therefore reduced to capture suitable images for calibration. Images were also captured in the period November 2004 – February 2005.

The data collections were remarkably cloud free, as shown by the repeatability of the results and the absence of artefacts when comparing scene acquisitions from different dates.



DU000017pm (24-Nov-03) – red even pixels DU00001apm (26-Nov-03) – red even pixels

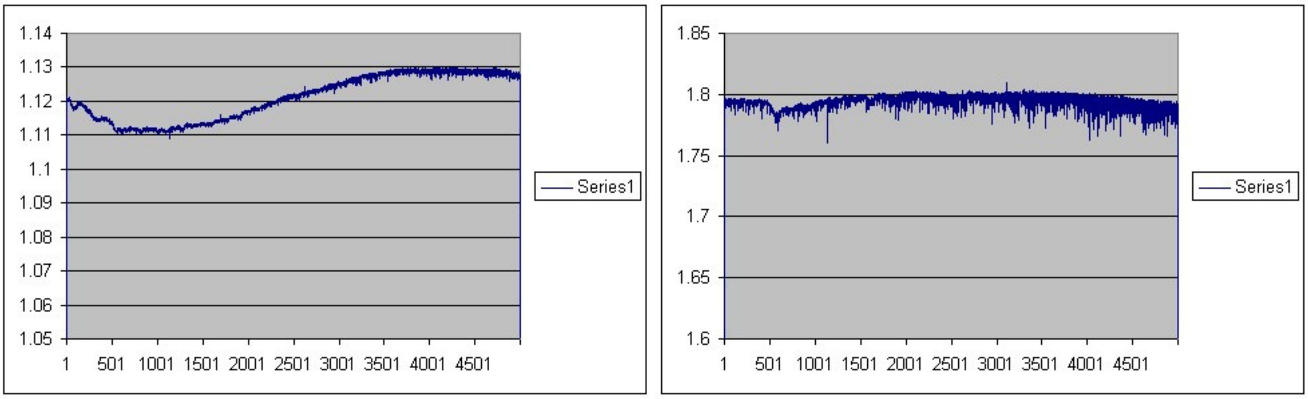


DU00001cpm (27-Nov-03) – red even pixels DU000403pm (25-Jan-05) – red even pixels

Figure 25: Comparison of the Antarctic images for the red even pixels on Imager0

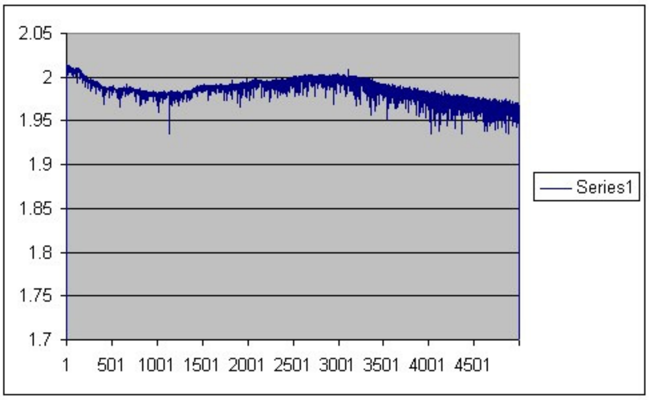
Figure 25 confirms that images taken over one year after the initial data collections show the same level of stability in terms of relative response across the detector arrays (comparing DU000017pm with DU000403pm).

If we ratio the corresponding plots we can see any specific differences between image acquisitions. Figure 26 illustrates the ratios of DU000017pm against the other three images (DU00001apm, DU00001cpm and DU000403pm).



Ratio of DU000017pm and DU00001apm

Ratio of DU000017pm and DU00001cpm



Ratio of DU000017pm and DU000403pm

Figure 26: Ratio of Antarctic plots from Figure 25 for the red even pixels on Imager0

The plots in Figure 26 show that the response is reasonably consistent across the detector array. There is some structure present, which may be due to a combination of surface features, plus variations in the illumination geometry (see §4.2.3). When compared against other images, scene DU00001cpm was considered the most stable and free from artefacts. This was selected for the initial calibration of the UK-DMC to derive the calibration gain values.

4.1.2.2 Greenland

Over 30 images were taken over Greenland during the northern hemisphere summer of 2004. Almost all these images contained cloud, which could be easily discriminated from the underlying snow.

To date, no Greenland images have been used in the analysis due to the high level of cloud present in the imagery.

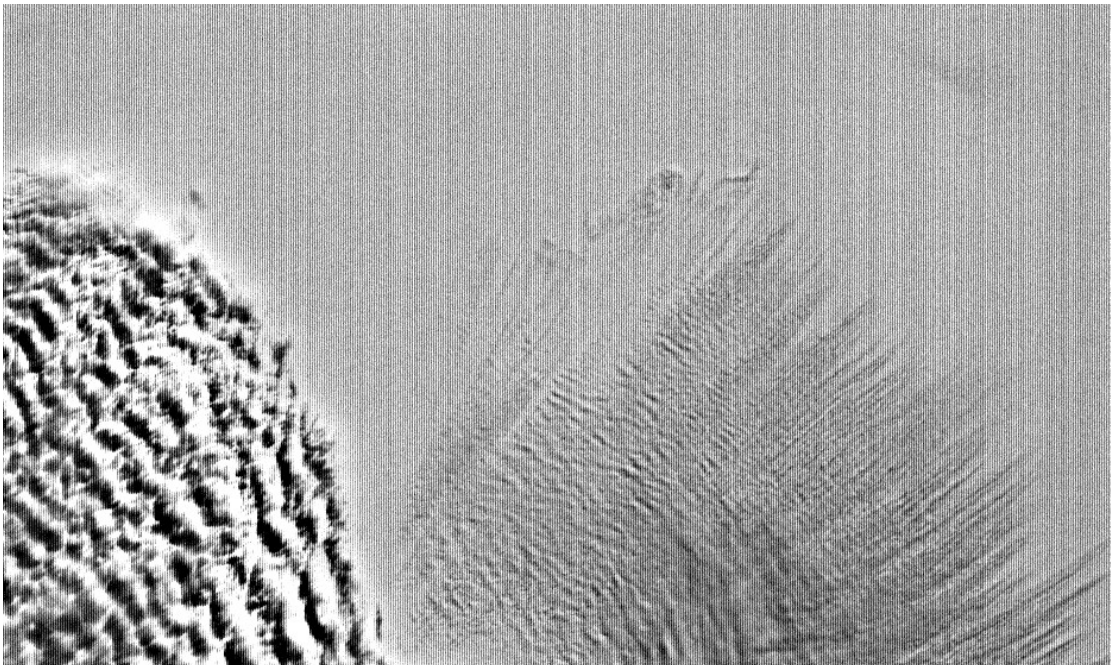


Figure 27: Subsection of a UK-DMC image over Greenland

Figure 27 shows the presence of cloud, which was typical for the Greenland images, and vertical striping due to the odd-even detector processing.

4.1.2.3 Geometry And BRDF Effects

As noted earlier in this report, the plots of the response curves for the red even pixels on Imager0 showed a marked asymmetry (Figure 25), with a much lower value on the left limb than the right, by as much as 9%.

It was considered that this variation could have three possible sources:

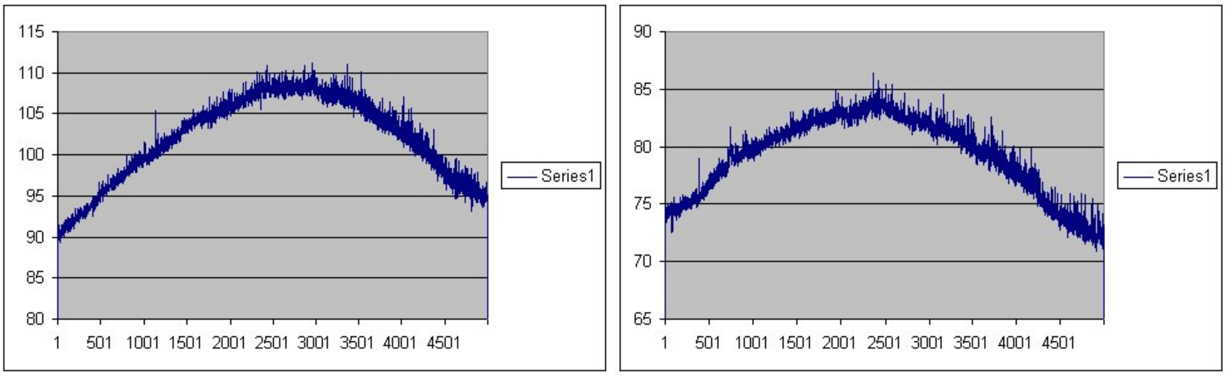
- Variation in the response of the optical system across the scene.
- Geometric considerations, a variable solar zenith angle will produce a higher response for the detector imaging an area closer to the sub-solar point.
- BRDF effects, due to the natural surface variability of snow (strongly forward scattering) over the 26° FOV of each imager.

To test this we carried out three experiments:

- Image acquisition during nominal spacecraft operations (spacecraft yaw=0°)
- Image acquisition when spacecraft yawed 180°
- Image acquisition when spacecraft yawed to illuminate both sides of the CCD array equally

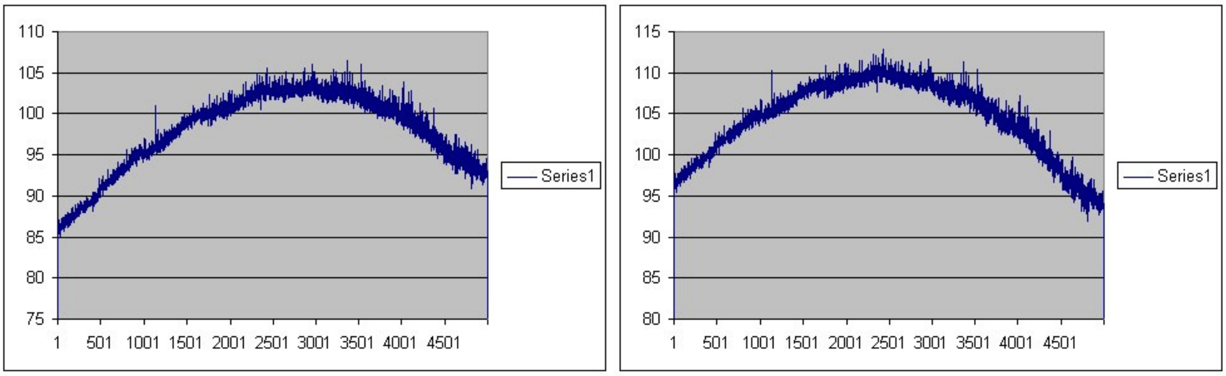
4.1.2.3.1 Test 1 – Nominal Acquisition / Yaw 180° Acquisition

Several images were taken in January 2005 using the normal imaging orientation to provide a benchmark for the comparison against the yawed image. The plots for the red even pixels on Imager0 are shown in Figure 28. Details for each image are given in Table 13.



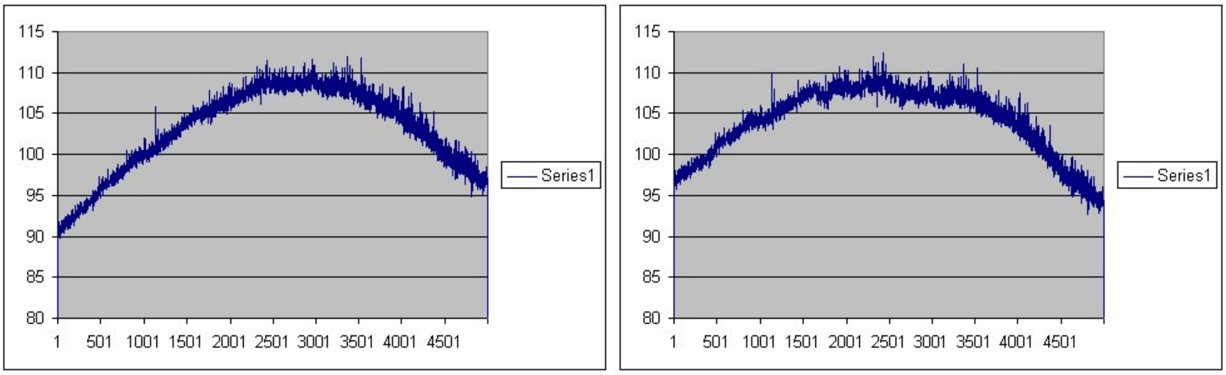
DU0003f1pm (yaw=0°)

DU0003f4pm (yaw=180°)



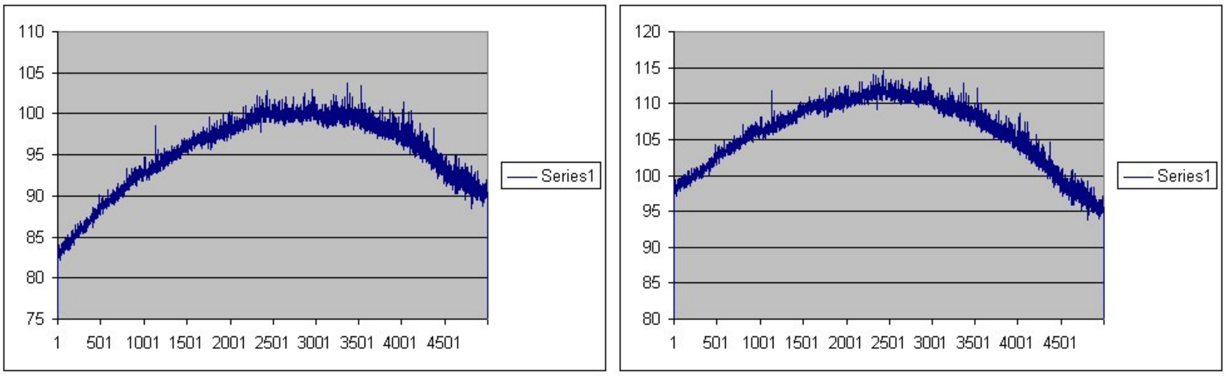
DU0003f6pm (yaw=0°)

DU0003fbpm (yaw=180°)



DU0003fdpm (yaw=0°)

DU000400pm (yaw=180°)



DU000403pm (yaw=0°)

DU00040epm (yaw=180°)

Figure 28: Comparison of responses for images acquired when yaw=0° and yaw=180°

In the normal imaging mode, there is a distinct asymmetry across Imager0. With a much lower value on the extreme left compared to the extreme right. However, when the spacecraft is yawed through 180°, the direction of the asymmetry is reversed, which suggests that it is largely due to surface variations in reflected radiation, rather than the optics. These variations will be due to both geometry and BRDF effects of the surface.

Scene ID	Image Date	Image Time (UTC)	Solar Elevation Angle	Spacecraft Yaw Angle
DU0003f1	19-Jan-2005	04:23:30	35.292°	0°
DU0003f4	20-Jan-2005	03:23:06	34.742°	180°
DU0003f6	20-Jan-2005	05:00:43	34.702°	0°
DU0003fb	22-Jan-2005	04:37:45	34.546°	180°
DU0003fd	23-Jan-2005	03:37:24	34.241°	0°
DU000400	24-Jan-2005	04:14:44	34.188°	180°
DU000403	25-Jan-2005	04:51:59	33.687°	0°
DU00040e	28-Jan-2005	03:28:43	32.874°	180°

Table 13: Acquisition details for the images in Figure 28

Note that the magnitude of the variation is greater in the normal flight images rather than the yawed images. This suggests that there is an asymmetry in response of the imager combined with the surface effects.

4.1.2.3.2 Test 2 – Yawed Imager For Equal Illumination Conditions

To test this we orientated the spacecraft so that each side of the imager had the same effective illumination, by yawing the spacecraft through 36.8 degrees, so that the imaging array was lined up at 90 degrees to the projected plane containing the sub-solar point.

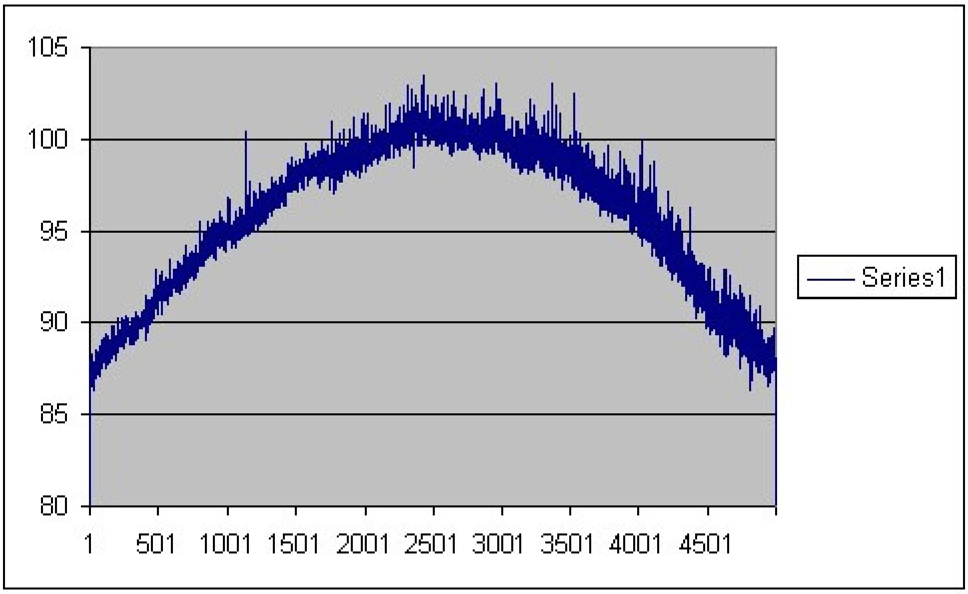


Figure 29: Response of red even pixels on Imager0 for equally illuminated scene (DU000420pm)

As can be seen in Figure 29, there is no pronounced asymmetry in the response when the scene is equally illuminated. Further work is required to identify the cause of the differences in the normal flight and yawed images in Figure 28.

However, the more uniform response from image DU000420pm (Figure 29) can be used to replace scene DU00001cpm in deriving the coefficients for calibration of the UK-DMC in future, removing a substantial part of the effects due to geometry and BRDF of the snow surface.

4.2 Absolute Calibration

In this section we will briefly describe the ground site and observations made, the results from the test site at Railroad Valley (RRV) in Nevada, USA and how the final calibration was carried out for all the detectors (20,000) over the two CCD arrays for each spectral band.

4.2.1 Ground Site And Observations

The ground measurements were performed at the small footprint test site (see Figure 30), located next to the atmospheric measurement area and CIMEL sun photometer. Table 14 shows the date, collection type and the DMC satellites that acquired an image over the test site.

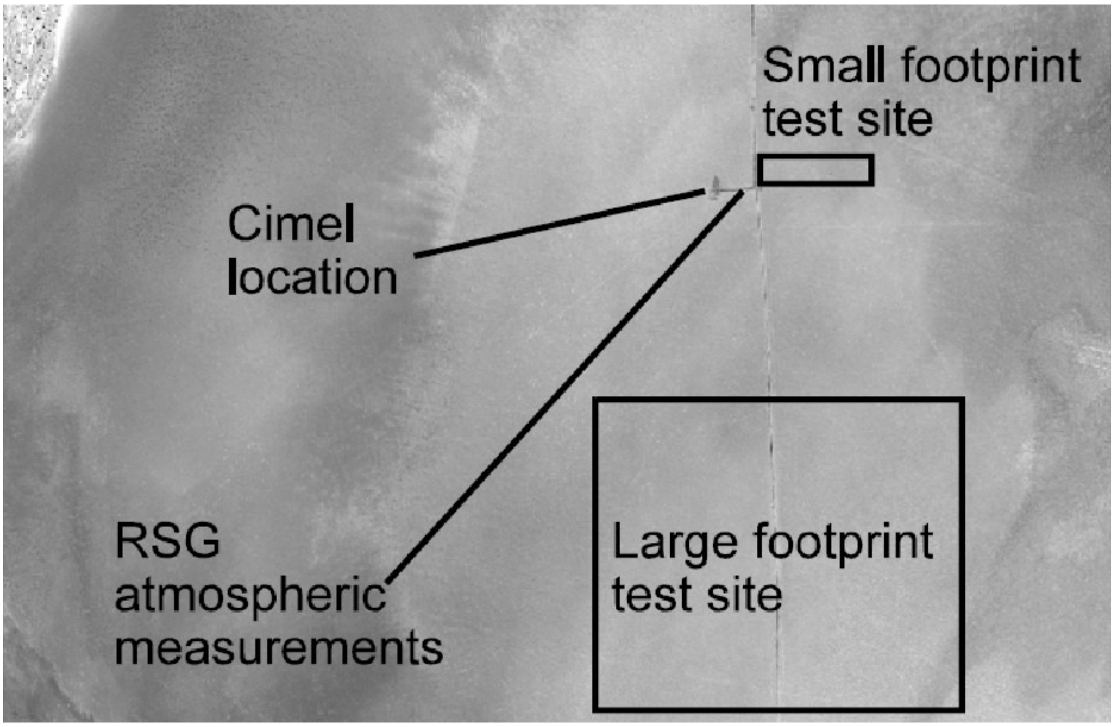


Figure 30: Railroad Valley test site (ASTER image provided by RSG)

Date	Collection Type	Satellite
03-July-2004	Dedicated	AlSat-1, UK-DMC
04-July-2004	Dedicated	BILSAT-1
05-July-2004	Dedicated	AlSat-1, NigeriaSat-1
06-July-2004	Poor Weather	---
07-July-2004	Dedicated	BILSAT-1, NigeriaSat-1
08-July-2004	Associated	AlSat-1
09-July-2004	Dedicated	BILSAT-1, UK-DMC
10-July-2004	Associated	NigeriaSat-1
11-July-2004	Dedicated	UK-DMC

Table 14: List of acquisitions over the RRV test site in July 2004

Most acquisitions were dedicated (the data were collected specifically for the satellite overpass), some were associated with other satellites. The important overpasses for our study were those for UK-DMC.

For each of the overpasses, ground measurements were taken, starting half an hour before the overpass, until half an hour after the overpass. Meteorological parameters were also measured at the same time.

Once the images were collected, the SSTL imaging team determined which pixels from the imagery coincided with the test site and determined the corresponding view zenith and view azimuth angles, as well as the solar zenith and solar azimuth at the time of acquisition. The values in Table 15 show the X and Y offsets in the imagery for each spectral band and the corresponding DN values captured in the raw imagery for image scene DU00017dpm, which was acquired on 03-July-2004 with a view zenith angle of 23.49°.

NIR			Red			Green		
X	Y	DN	X	Y	DN	X	Y	DN
785	1213	91	773	1216	113	786	1226	156
786	1213	98	774	1216	118	787	1226	153
786	1212	100	774	1215	117	787	1225	153
787	1212	92	775	1215	114	788	1225	157
788	1212	95	776	1215	121	789	1225	155
788	1211	100	776	1214	120	789	1224	156
789	1211	91	777	1214	115	790	1224	160
790	1211	101	778	1214	122	791	1224	154
791	1211	93	779	1214	115	792	1224	161
791	1210	91	779	1213	115	792	1223	159
792	1210	98	780	1213	123	793	1223	154
793	1210	91	781	1213	116	794	1223	156

Table 15: Pixel location and DN values from image scene DU00017dpm

Similar values were extracted for the other acquisitions, each with different view zenith angles to the calibration test site, as illustrated in Table 16.

Date	Scene ID	Imager ID	View Zenith
03-July-2004	DU00017dpm	Imager0	23.49°
09-July-2004	DU000186sm	Imager1	25.32°
11-July-2004	DU00018apm	Imager0	14.08°

Table 16: View zenith angles for the UK-DMC image acquisitions

As can be seen, the first two images were from the extremes of Imager0 and Imager1. Given that BRDF effects are more prominent at angles exceeding 18°, it was decided to use the third image (DU00018apm) as the primary acquisition to derive the calibration coefficients for the imaged area at the test site.

The RSG requested the filter specifications for each of the sensors and the corresponding information on view zenith, solar zenith and solar azimuth of each acquisition, so as to derive the equivalent radiance at the top of the atmosphere (TOA), by using a radiative transfer code to transform the measured surface reflectances to equivalent TOA radiances. Examples of the filter response data used by the RSG are shown in Figure 31.

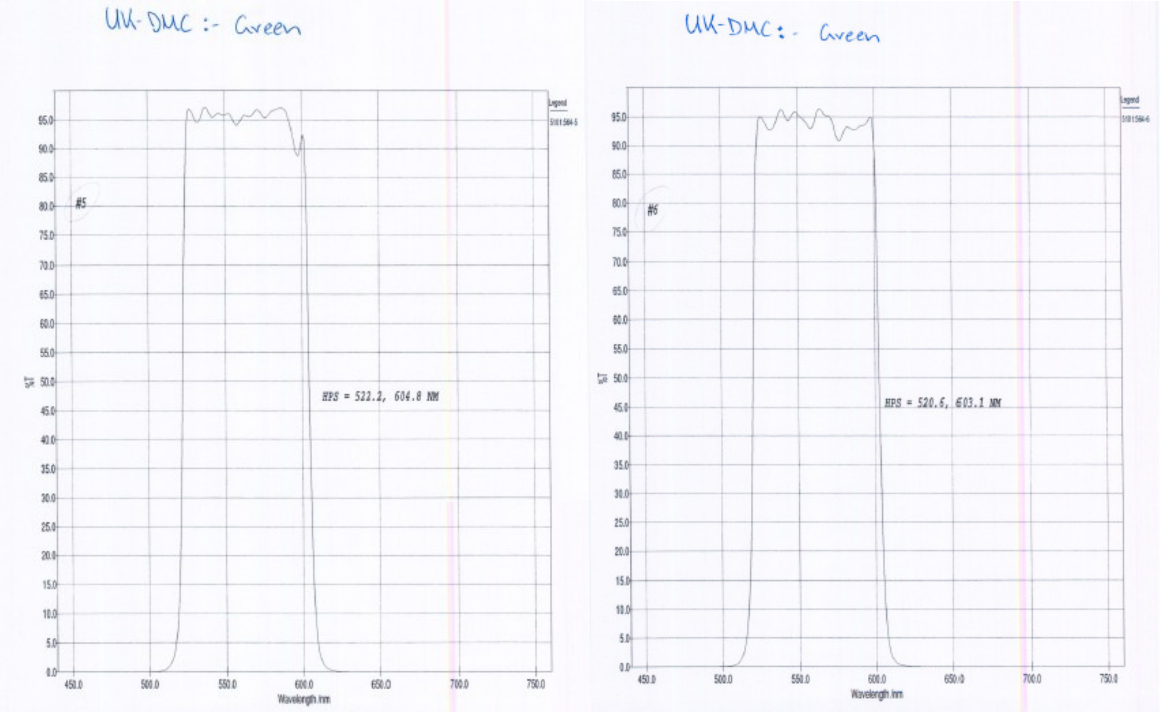
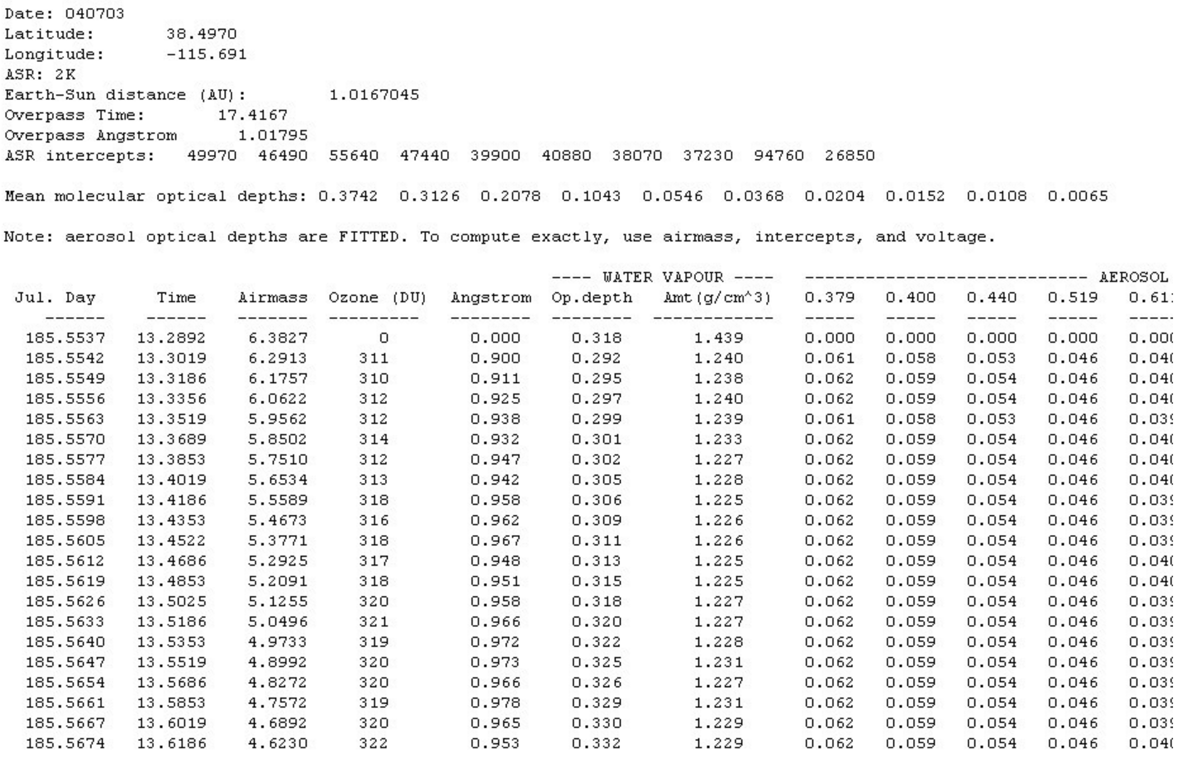


Figure 31: Filter response curves for the green spectral filter on Imager0 and Imager1

The results of the TOA calculation are split over three files for each acquisition, detailing the atmospheric conditions, the radiometry and summary radiometry values for each spectral band. These files were supplied by the RSG and example data from each file are shown in Figure 32, Figure 33, and Figure 34.



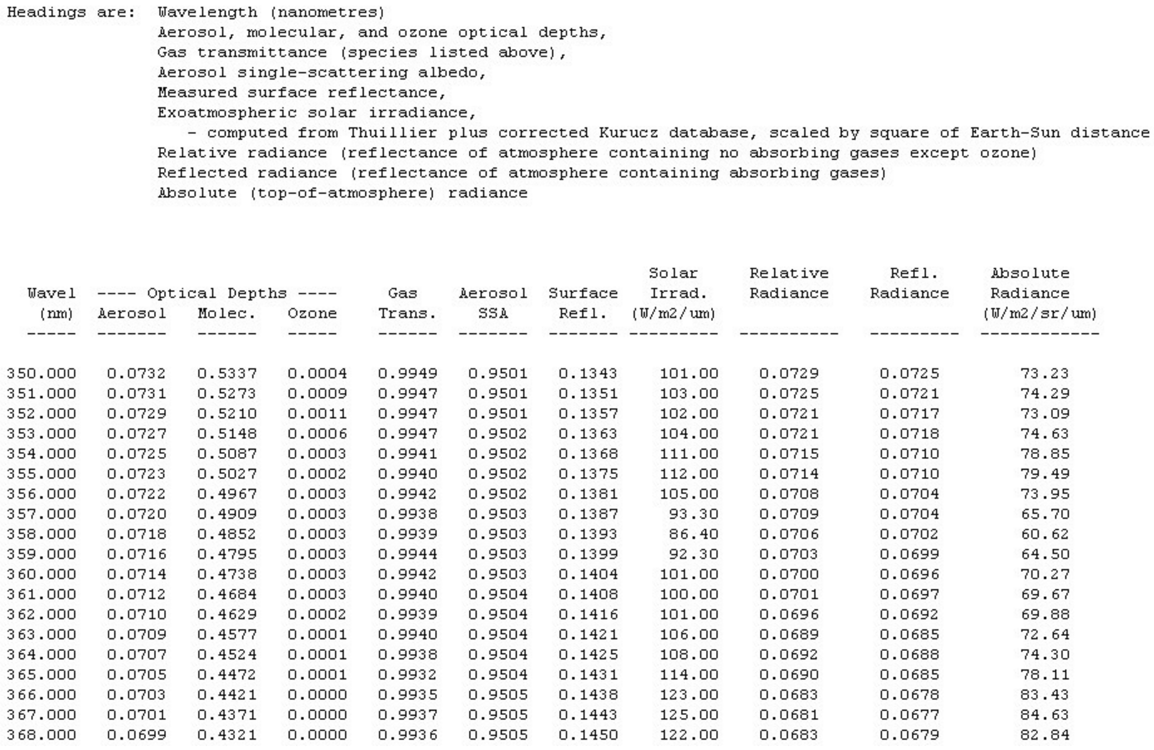
```
Date: 040703
Latitude:        38.4970
Longitude:       -115.691
ASR: 2K
Earth-Sun distance (AU):         1.0167045
Overpass Time:        17.4167
Overpass Angstrom      1.01795
ASR intercepts:    49970  46490  55640  47440  39900  40880  38070  37230  94760  26850

Mean molecular optical depths: 0.3742  0.3126  0.2078  0.1043  0.0546  0.0368  0.0204  0.0152  0.0108  0.0065

Note: aerosol optical depths are FITTED. To compute exactly, use airmass, intercepts, and voltage.

                                                      ---- WATER VAPOUR ----   ---------------------------- AEROSOL
 Jul. Day       Time     Airmass  Ozone (DU)  Angstrom Op.depth   Amt(g/cm^3)   0.379   0.400   0.440   0.519   0.61
   ------      ------     ------  ---------   -------- --------  ------------   -----   -----   -----   -----   ----
  185.5537   13.2892     6.3827          0      0.000    0.318        1.439     0.000   0.000   0.000   0.000   0.00
  185.5542   13.3019     6.2913        311      0.900    0.292        1.240     0.061   0.058   0.053   0.046   0.04
  185.5549   13.3186     6.1757        310      0.911    0.295        1.238     0.062   0.059   0.054   0.046   0.04
  185.5556   13.3356     6.0622        312      0.925    0.297        1.240     0.062   0.059   0.054   0.046   0.04
  185.5563   13.3519     5.9562        312      0.938    0.299        1.239     0.061   0.058   0.053   0.046   0.03
  185.5570   13.3689     5.8502        314      0.932    0.301        1.233     0.062   0.059   0.054   0.046   0.04
  185.5577   13.3853     5.7510        312      0.947    0.302        1.227     0.062   0.059   0.054   0.046   0.04
  185.5584   13.4019     5.6534        313      0.942    0.305        1.228     0.062   0.059   0.054   0.046   0.04
  185.5591   13.4186     5.5589        318      0.958    0.306        1.225     0.062   0.059   0.054   0.046   0.03
  185.5598   13.4353     5.4673        316      0.962    0.309        1.226     0.062   0.059   0.054   0.046   0.03
  185.5605   13.4522     5.3771        318      0.967    0.311        1.226     0.062   0.059   0.054   0.046   0.03
  185.5612   13.4686     5.2925        317      0.948    0.313        1.225     0.062   0.059   0.054   0.046   0.04
  185.5619   13.4853     5.2091        318      0.951    0.315        1.225     0.062   0.059   0.054   0.046   0.04
  185.5626   13.5025     5.1255        320      0.958    0.318        1.227     0.062   0.059   0.054   0.046   0.03
  185.5633   13.5186     5.0496        321      0.966    0.320        1.227     0.062   0.059   0.054   0.046   0.03
  185.5640   13.5353     4.9733        319      0.972    0.322        1.228     0.062   0.059   0.054   0.046   0.03
  185.5647   13.5519     4.8992        320      0.973    0.325        1.231     0.062   0.059   0.054   0.046   0.03
  185.5654   13.5686     4.8272        320      0.966    0.326        1.227     0.062   0.059   0.054   0.046   0.03
  185.5661   13.5853     4.7572        319      0.978    0.329        1.231     0.062   0.059   0.054   0.046   0.03
  185.5667   13.6019     4.6892        320      0.965    0.330        1.229     0.062   0.059   0.054   0.046   0.03
  185.5674   13.6186     4.6230        322      0.953    0.332        1.229     0.062   0.059   0.054   0.046   0.04
```

Figure 32: Example data detailing the atmospheric conditions

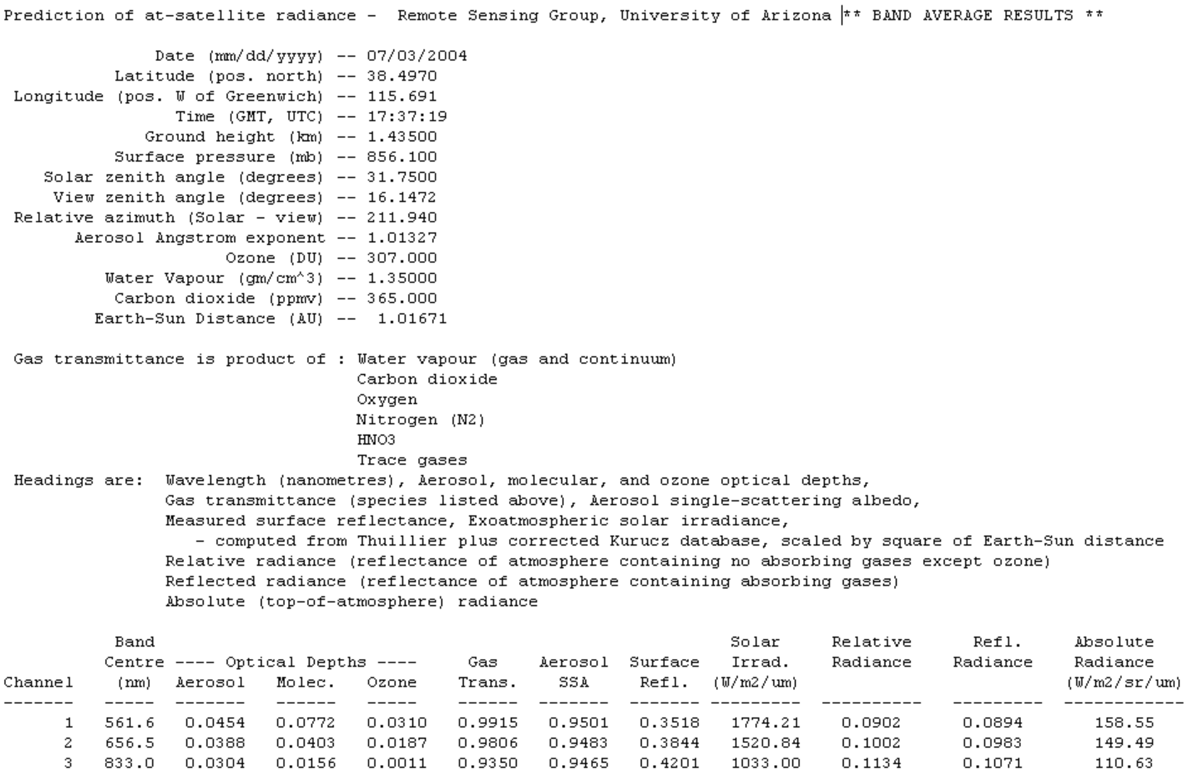


```
Headings are:  Wavelength (nanometres)
               Aerosol, molecular, and ozone optical depths,
               Gas transmittance (species listed above),
               Aerosol single-scattering albedo,
               Measured surface reflectance,
               Exoatmospheric solar irradiance,
                  - computed from Thuillier plus corrected Kurucz database, scaled by square of Earth-Sun distance
               Relative radiance (reflectance of atmosphere containing no absorbing gases except ozone)
               Reflected radiance (reflectance of atmosphere containing absorbing gases)
               Absolute (top-of-atmosphere) radiance


                                                                  Solar    Relative      Refl.      Absolute
  Wavel  ---- Optical Depths ----     Gas    Aerosol  Surface    Irrad.    Radiance     Radiance     Radiance
   (nm)  Aerosol   Molec.   Ozone    Trans.    SSA     Refl.   (W/m2/um)                          (W/m2/sr/um)
  -----  -------   ------   -----    ------  -------  ------- ---------  ----------   ---------   ------------

350.000   0.0732   0.5337   0.0004   0.9949   0.9501   0.1343    101.00    0.0729       0.0725        73.23
351.000   0.0731   0.5273   0.0009   0.9947   0.9501   0.1351    103.00    0.0725       0.0721        74.29
352.000   0.0729   0.5210   0.0011   0.9947   0.9501   0.1357    102.00    0.0721       0.0717        73.09
353.000   0.0727   0.5148   0.0006   0.9947   0.9502   0.1363    104.00    0.0721       0.0718        74.63
354.000   0.0725   0.5087   0.0003   0.9941   0.9502   0.1368    111.00    0.0715       0.0710        78.85
355.000   0.0723   0.5027   0.0002   0.9940   0.9502   0.1375    112.00    0.0714       0.0710        79.49
356.000   0.0722   0.4967   0.0003   0.9942   0.9502   0.1381    105.00    0.0708       0.0704        73.95
357.000   0.0720   0.4909   0.0003   0.9938   0.9503   0.1387     93.30    0.0709       0.0704        65.70
358.000   0.0718   0.4852   0.0003   0.9939   0.9503   0.1393     86.40    0.0706       0.0702        60.62
359.000   0.0716   0.4795   0.0003   0.9944   0.9503   0.1399     92.30    0.0703       0.0699        64.50
360.000   0.0714   0.4738   0.0003   0.9942   0.9503   0.1404    101.00    0.0700       0.0696        70.27
361.000   0.0712   0.4684   0.0003   0.9940   0.9504   0.1408    100.00    0.0701       0.0697        69.67
362.000   0.0710   0.4629   0.0002   0.9939   0.9504   0.1416    101.00    0.0696       0.0692        69.88
363.000   0.0709   0.4577   0.0001   0.9940   0.9504   0.1421    106.00    0.0689       0.0685        72.64
364.000   0.0707   0.4524   0.0001   0.9938   0.9504   0.1425    108.00    0.0692       0.0688        74.30
365.000   0.0705   0.4472   0.0001   0.9932   0.9504   0.1431    114.00    0.0690       0.0685        78.11
366.000   0.0703   0.4421   0.0000   0.9935   0.9505   0.1438    123.00    0.0683       0.0678        83.43
367.000   0.0701   0.4371   0.0000   0.9937   0.9505   0.1443    125.00    0.0681       0.0677        84.63
368.000   0.0699   0.4321   0.0000   0.9936   0.9505   0.1450    122.00    0.0683       0.0679        82.84
```

Figure 33: Example data detailing the radiometry



```
Prediction of at-satellite radiance -  Remote Sensing Group, University of Arizona |** BAND AVERAGE RESULTS **

               Date (mm/dd/yyyy) -- 07/03/2004
           Latitude (pos. north) -- 38.4970
 Longitude (pos. W of Greenwich) -- 115.691
                 Time (GMT, UTC) -- 17:37:19
              Ground height (km) -- 1.43500
           Surface pressure (mb) -- 856.100
    Solar zenith angle (degrees) -- 31.7500
     View zenith angle (degrees) -- 16.1472
 Relative azimuth (Solar - view) -- 211.940
       Aerosol Angstrom exponent -- 1.01327
                      Ozone (DU) -- 307.000
          Water Vapour (gm/cm^3) -- 1.35000
           Carbon dioxide (ppmv) -- 365.000
         Earth-Sun Distance (AU) --  1.01671

 Gas transmittance is product of : Water vapour (gas and continuum)
                                   Carbon dioxide
                                   Oxygen
                                   Nitrogen (N2)
                                   HNO3
                                   Trace gases
 Headings are:  Wavelength (nanometres), Aerosol, molecular, and ozone optical depths,
                Gas transmittance (species listed above), Aerosol single-scattering albedo,
                Measured surface reflectance, Exoatmospheric solar irradiance,
                   - computed from Thuillier plus corrected Kurucz database, scaled by square of Earth-Sun distance
                Relative radiance (reflectance of atmosphere containing no absorbing gases except ozone)
                Reflected radiance (reflectance of atmosphere containing absorbing gases)
                Absolute (top-of-atmosphere) radiance

           Band                                                       Solar     Relative      Refl.      Absolute
          Centre ---- Optical Depths ----    Gas    Aerosol Surface   Irrad.    Radiance     Radiance     Radiance
Channel    (nm)  Aerosol   Molec.   Ozone   Trans.    SSA    Refl.  (W/m2/um)                          (W/m2/sr/um)
-------   -----  -------  ------   -----    ------  ------- ------- --------- ----------   ---------   ------------
      1   561.6   0.0454   0.0772  0.0310   0.9915   0.9501  0.3518   1774.21   0.0902      0.0894        158.55
      2   656.5   0.0388   0.0403  0.0187   0.9806   0.9483  0.3844   1520.84   0.1002      0.0983        149.49
      3   833.0   0.0304   0.0156  0.0011   0.9350   0.9465  0.4201   1033.00   0.1134      0.1071        110.63
```

Figure 34: Example data showing the derived absolute radiance values

4.2.2 Results And Processing The Coefficients

The important values derived from the absolute calibration campaign form the final column in the table in Figure 34. These are the absolute radiance values for each spectral band on each imager. Therefore, for each imaging acquisition we now had the absolute radiance (TOA) for our target and the corresponding DN values (shown in Table 15). We can now calculate the calibration gains, using the following equation, where x is the detector number of the detectors covering the calibration target (9 detectors).

$$\boxed{G_x = \frac{R_{\text{target}}}{(DN_x - BIAS_x)}}$$

Equation 4

Where,

G_x is the calculated gain value for detector x

R_{target} is the measured TOA radiance for the target covered by detectors

DN_x is the measured digital number for the target covered by detector x

$BIAS_x$ is the additive term from our dark images for detector x

Equation 4 was applied to the nine detectors in the array that covered the target area. The results produced nine different gain values. Since these values are at most the average of two pixels per column, we have to consider that there will be a certain inaccuracy due to noise in the data (RMS noise is at the 0.8 DN level based on analysis of the dark images).

To monitor the variation induced by this, we applied the gains derived to the column mean data derived from our snow images over Antarctica, resulting in a small but measurable variation in the calculated radiances for these scenes. As we had insufficient information to determine which of the 9 pixels was the most accurate, we took an average radiance determined from the 9 pixels and set our snow scene radiance for the scene to be equal to that average.

One modification of the calibration is required to carry out this calculation of radiance for our Antarctic scene. We would normally calculate the radiance of the scene using Equation 5

$$\boxed{R_{scene} = (DN_x - BIAS_x) * G_x}$$

Equation 5

However, we have a variable integration time. The RRV images used a 640µs integration time, while the Antarctic scenes used a 320 µs integration time. Lab tests prior to launch showed that the DN scales up with integration time in a linear manner. Hence we need to multiply the right hand side of the equation by the ratio of the two integration times; I_s, the standard time, divided by I_t, the target time. This will produce the correct radiance.

So Equation 5 becomes Equation 6 and we can now calculate the radiance of the Antarctic scene. Or in fact 9 radiances, and use the average radiance in Equation 7.

$$\boxed{R_{scene} = (DN_x - BIAS_x) * G_x * \left(\frac{I_s}{I_t}\right)}$$

Equation 6

Once we have this we can now work backwards as we did in Equation 4 to derive a gain value for each detector in the array, applying the same radiance to both Imager0 and Imager1, where y is the detector number (1 to 20,000) in this case.

$$G_y = \frac{R_{scene}}{\left[(DN_y - BIAS_y) * \left(\frac{I_s}{I_t}\right)\right]}$$

Equation 7

For any new scene acquisitions we can now apply the gain and bias values derived from this calculation to directly get calibrated radiances as in Equation 8.

$$R_y = \left[(DN_y - BIAS_y) * \left(\frac{I_s}{I_t}\right)\right] * G_y$$

Equation 8

4.2.3 Scaling

The final scaling of the data product is also considered within our radiometric calibration processing. The initial data received from the satellite is in byte form. After application of the calibration coefficients, the output is a floating-point value and the dynamic range of the data is changed. An example is an image of the UK captured by Imager0 (DU00010cpm), which has a very good data range in the downloaded raw data, covering almost the whole of the 0-255 byte range (see Figure 35).

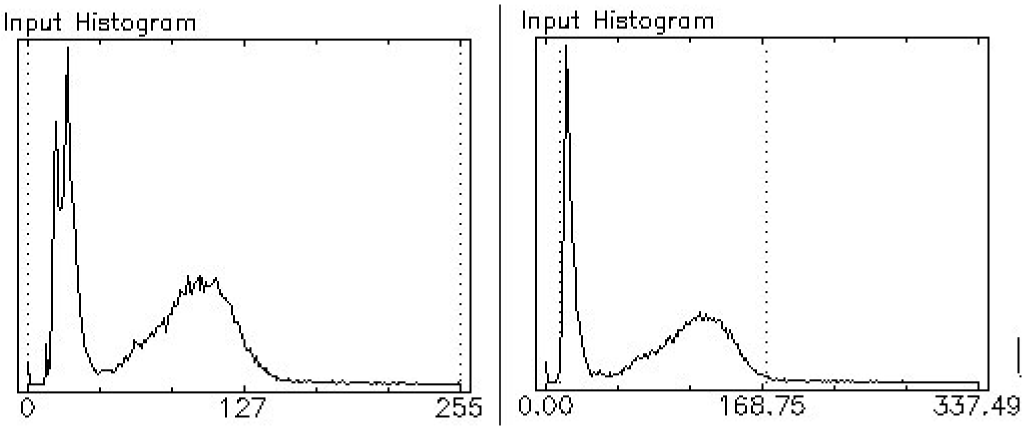


Figure 35: Histogram of original data (left); histogram of data after calibration (right)

After application of the calibration coefficients the data range is increased to cover the range 0 to 337.49, as can be seen in Figure 35.

Given the increased range and the need to keep the distributed images as small as possible, a series of compression tests were carried out on two images. The first image used a scaling where we rescaled the maximum value after calibration to be 255. This is the simplest form of scaling. The second image used a scaling based on the min-max method used for Landsat 5, where the minimum value in the data is scaled to zero and the maximum value in the data is scaled to 255.

The outputs were compared against the original data using a simple metric to measure data loss. The data after each scaling and quantisation was correlated against the original float data after calibration. The data loss is represented by the similarity of the scaled to this original data.

The method was tested on two very different scenes. The first scene was the UK data, which had a very large original data range. The second scene was a snow scene of Antarctica, with a very limited and narrow data range. The results are shown in Table 17.

Image	Simple Scaling	Min-Max
UK Image	99.09%	99.09%
Antarctica Image	92.07%	92.51%

Table 17: Comparison of data variation retention during scaling

As you can see, both scaling methods for the UK image show very little data loss. Over 99% of the original variation is preserved. However, with a limited data range in the original data, then large losses are apparent, with only 92% of the original variation being preserved. The losses mainly being due to quantisation losses on losing the less significant fractional numbers.

The metric used to measure the data variation retention is based on cross-correlation. This is a normalising process and so you would expect that a scene with a lot of variation would preserve most of its variation and a scene with a narrow data range to "lose" more information. Additional methods to assess data loss on scaling back within the byte range are being assessed.

For the moment it has been decided to retain a simple scaling method initially in the processing chain. The only way to preserve most of the information is to use a method similar to Landsat 7, where the data is multiplied by 100 and scaled into a short integer, preserving another two digits of the fractional data. This is being considered for the future.

5 Results

In this section we will briefly show the original image quality and that after calibration. This section is not intended to show the band-to-band radiometric integrity, but purely to show that the process does compensate for the striping artefacts of the sensor, as shown in Figure 36.

For the moment, prior to any cross-calibration exercise with other sensors, we can only assume that the radiometry is correct.

However, given that it is based on the absolute radiance values derived from the work of the Remote Sensing Group at The University of Arizona, we have high confidence that the band radiometry will be accurate to within the figure stated by the RSG (that is 5-10%).

Figure 36: Comparison of the calibrated data (left) and the raw data (right)

6 Further Work

6.1 Cross-Calibration

One area that would help in characterising the accuracy of the band-to-band radiometry is a cross-calibration exercise with another sensor with similar band characteristics. Currently we are considering more data acquisitions at our primary calibration site in Antarctica. This site at DOME-C (75°S, 123°E) has been part of an extensive study carried out using SPOT-Vegetation, which has an on-board calibrator.

The site is being run as part of a French-Italian collaboration. In past years both meteorological and tower mounted BRDF measurements have been acquired, as part of the SPOT-Vegetation calibration exercise. Our aim would be to gather images which coincided with those from the SPOT-Vegetation sensor and compare the inter-band radiometry. This would help identify any anomalies in the sensor performance and/or calibration procedure.

6.2 Stability Measurements

Additionally we need to measure the long-term stability of the instrument. We can monitor trends in behaviour using regular images over our snow-field sites and identify individual detectors that have changed in their behaviour (inducing striping in the imagery). However, if the overall optical transmission is reduced due to changes in the filter or optical performance, we cannot detect this change in absolute radiometry. Hence, we will review the absolute calibration on a yearly basis, with the next proposed absolute calibration campaign in the summer of 2005.

6.3 BRDF Studies

Additional work is required in characterising the snow surface at the main calibration sites. We wish to characterise the BRDF of the surface in a campaign scheduled for November 2005 – February 2006. This will consist of building up a BRDF map by yawing the spacecraft in various positions over the DOME-C site, we can build up a complete map of the BRDF variations for various solar elevation (0° – 45°), view zenith (0° - 26°) and solar and view azimuth angles.

This may require fieldwork to characterise the variation is Sastrugi (snow dunes) in terms of size and distribution across the area of study, and by modelling assess the effects they have on the determination of our calibration coefficients.

7 Summary

The UK-DMC sensor has now been calibrated using a combination of absolute measurements at the Railroad Valley site in collaboration with the Remote Sensing Group at The University of Arizona, and using "flat-field" snow images captured over Antarctica.

The overall result has removed residual striping, visible in processed post-launch imagery and provided a baseline absolute calibration.

Further work is required to compare the results of the calibration against other well-calibrated sensors and a proposed program is being developed. Additional work is addressing the possible effects of BRDF on the sensor calibration and monitoring the longer-term changes in the sensor behaviour.

These techniques are now being applied to the other satellites in the DMC constellation and will form the basis for future calibration campaigns.

8 Acknowledgements

We gratefully acknowledge the help of Kurt Thome and Chris Cattrall from the Remote Sensing Group at The University of Arizona for their help in setting up the absolute calibration activity at the Railroad Valley site in Nevada, USA and their later processing of the data.

APPENDIX F: ORTHORECTIFICATION PROCEDURE

1 Setting Up The SipOrtho Workspace

1.1 Open image to orthorectify by clicking open folder icon on the toolbar.

1.2 To open a zoom window of the image, right click anywhere on the image and select child (see Figure 37). Repeat on child window to open another zoom window.

1.3 Open reference data image as described in task 1.1 and 1.2.

1.4 Open a new control point list by selecting Points > Control Point List from toolbar.

1.5 Select Geodetic System by selecting Geodesy > Select Geodetic System from toolbar and by either entering the code or by searching the database. Once selected, click OK and the code should appear in the box.

1.6 Select DEM by clicking DTM > Open.

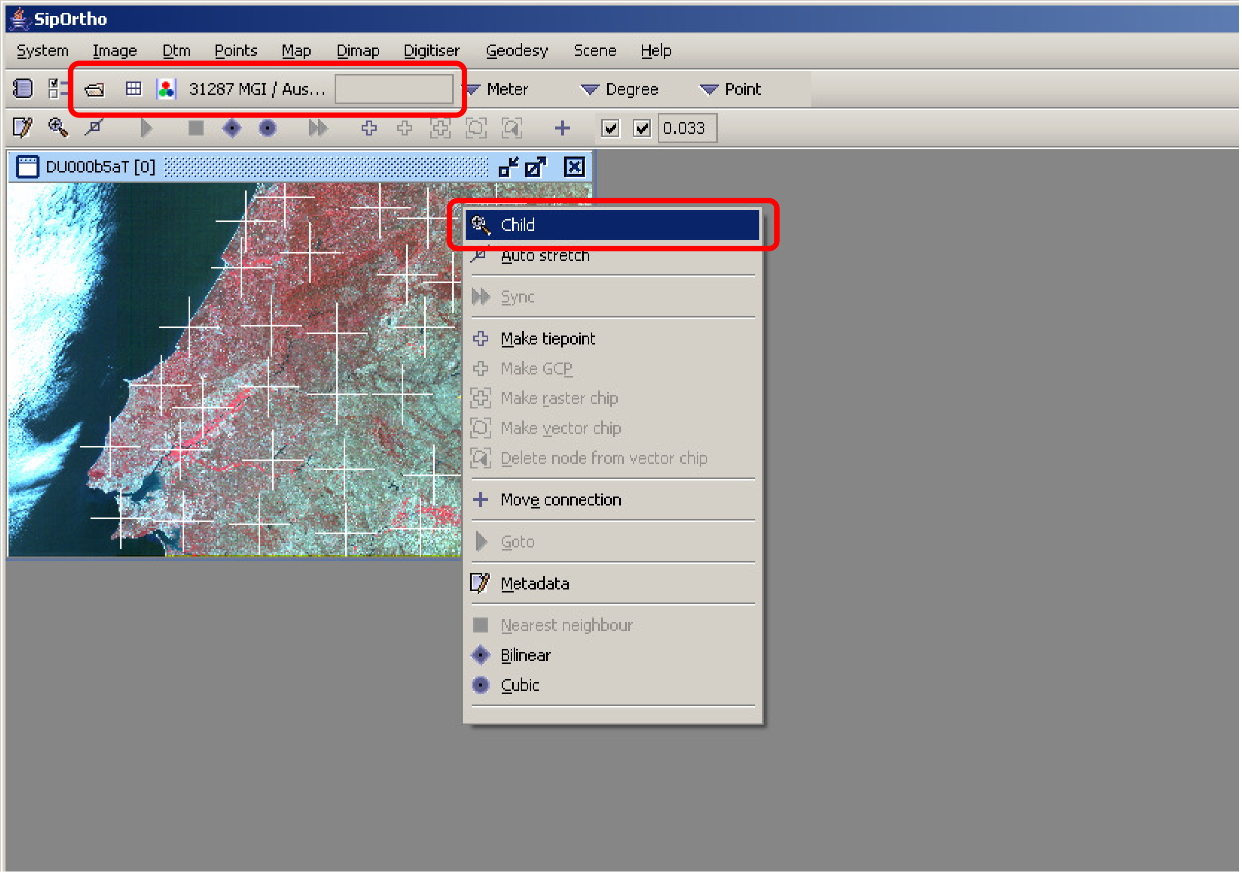
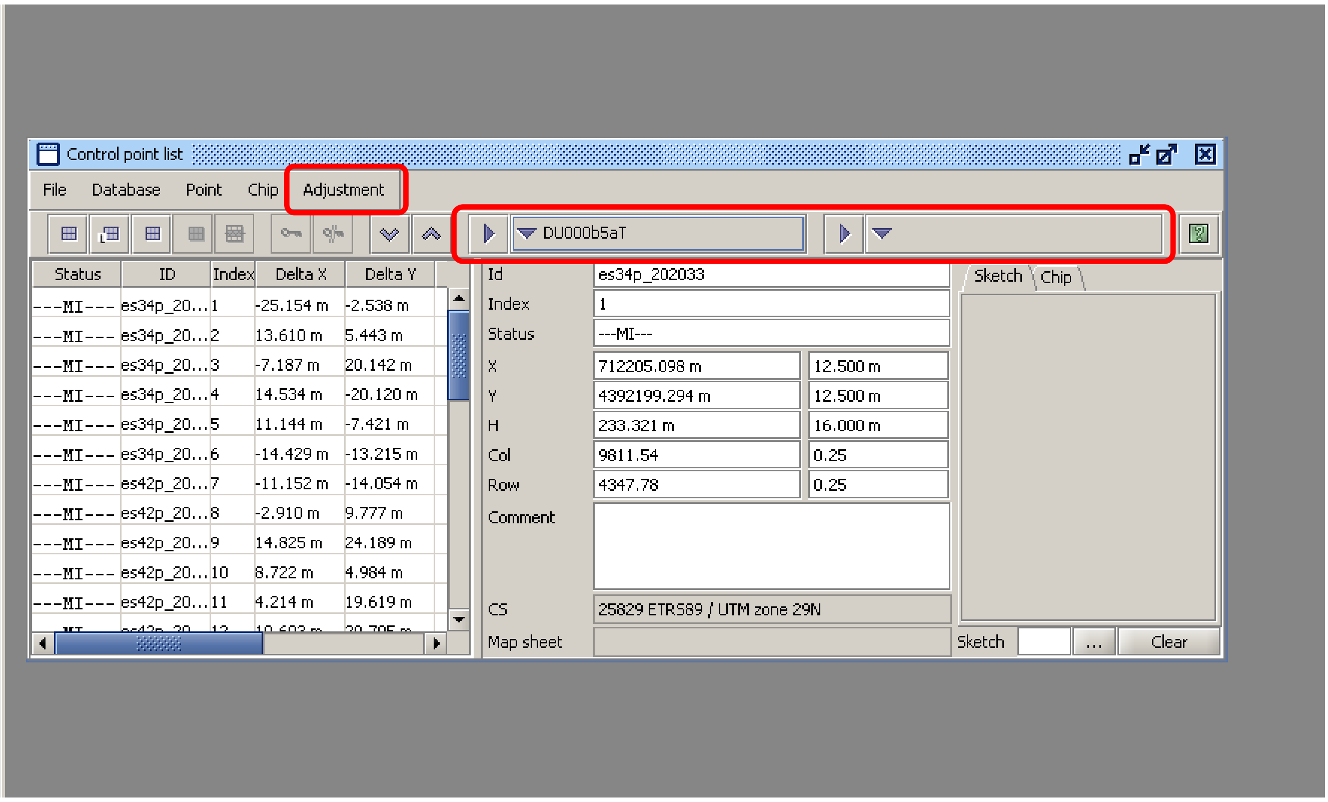


Figure 37: SipOrtho Workspace

2 Collecting Ground Control Points

2.1 Select the image to orthorectify in the left hand drop down menu on the Control Point List (see Figure 38).

2.2 Select the reference data image in the right hand drop down menu on the Control Point List (see Figure 38).



Status	ID	Index	Delta X	Delta Y
---MI---	es34p_20...	1	-25.154 m	-2.538 m
---MI---	es34p_20...	2	13.610 m	5.443 m
---MI---	es34p_20...	3	-7.187 m	20.142 m
---MI---	es34p_20...	4	14.534 m	-20.120 m
---MI---	es34p_20...	5	11.144 m	-7.421 m
---MI---	es34p_20...	6	-14.429 m	-13.215 m
---MI---	es42p_20...	7	-11.152 m	-14.054 m
---MI---	es42p_20...	8	-2.910 m	9.777 m
---MI---	es42p_20...	9	14.825 m	24.189 m
---MI---	es42p_20...	10	8.722 m	4.984 m
---MI---	es42p_20...	11	4.214 m	19.619 m

Id	es34p_202033	
Index	1	
Status	---MI---	
X	712205.098 m	12.500 m
Y	4392199.294 m	12.500 m
H	233.321 m	16.000 m
Col	9811.54	0.25
Row	4347.78	0.25
Comment		
CS	25829 ETRS89 / UTM zone 29N	
Map sheet		

Figure 38: Control Point List

2.3 To place a control point, place the child view over the desired area on the image to orthorectify. Right click, and on the drop down menu that appears select sync. This will automatically move the child viewer for the reference data image to the same area.

2.4 In the child view on the reference data image, right click and select Make GCP. The pointer will turn into a yellow cross. Place the cross where a GCP is desired.

2.5 On the child viewer of the image to orthorectify, move the GCP cross to the same point on this image as it is on the reference data image. A new GCP will appear in the Control Point List.

2.6 To fine tune the placement of this GCP, Select Image>Image Overlay. A new window will appear which overlays the two images. Using the mouse pointer the images can be adjusted to overlay to the best fit.

2.7 Repeat steps 2.3 to 2.6 to produce GCPs for the remainder of the image to orthorectify, ensuring GCPs are uniformly distributed (see Figure 39).

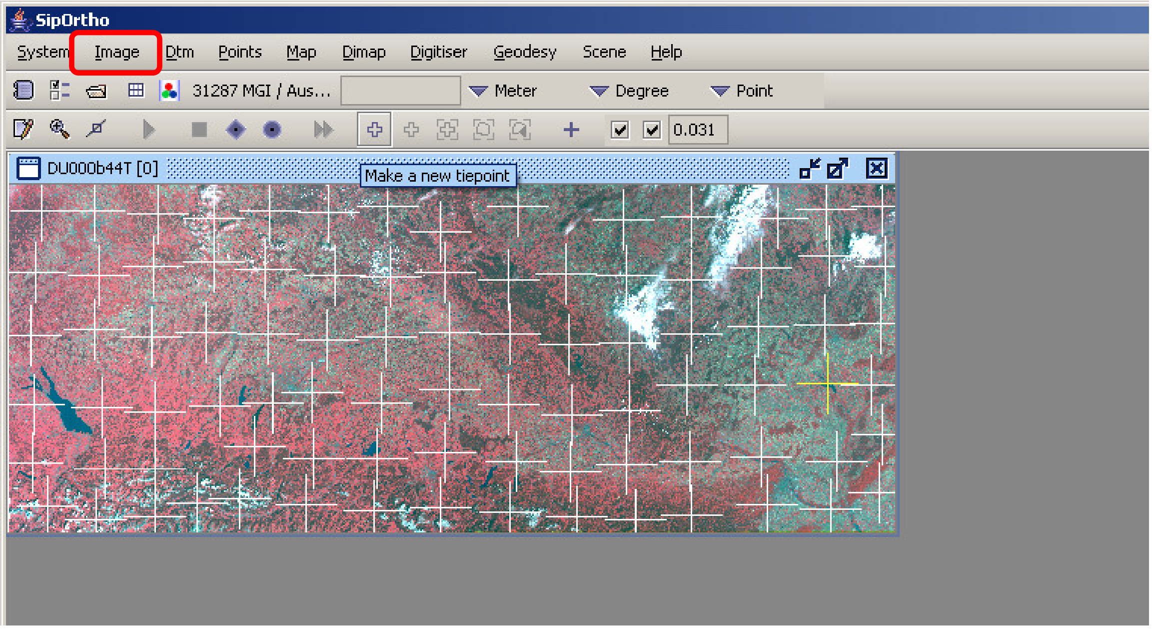


Figure 39: Distribution of GCPs

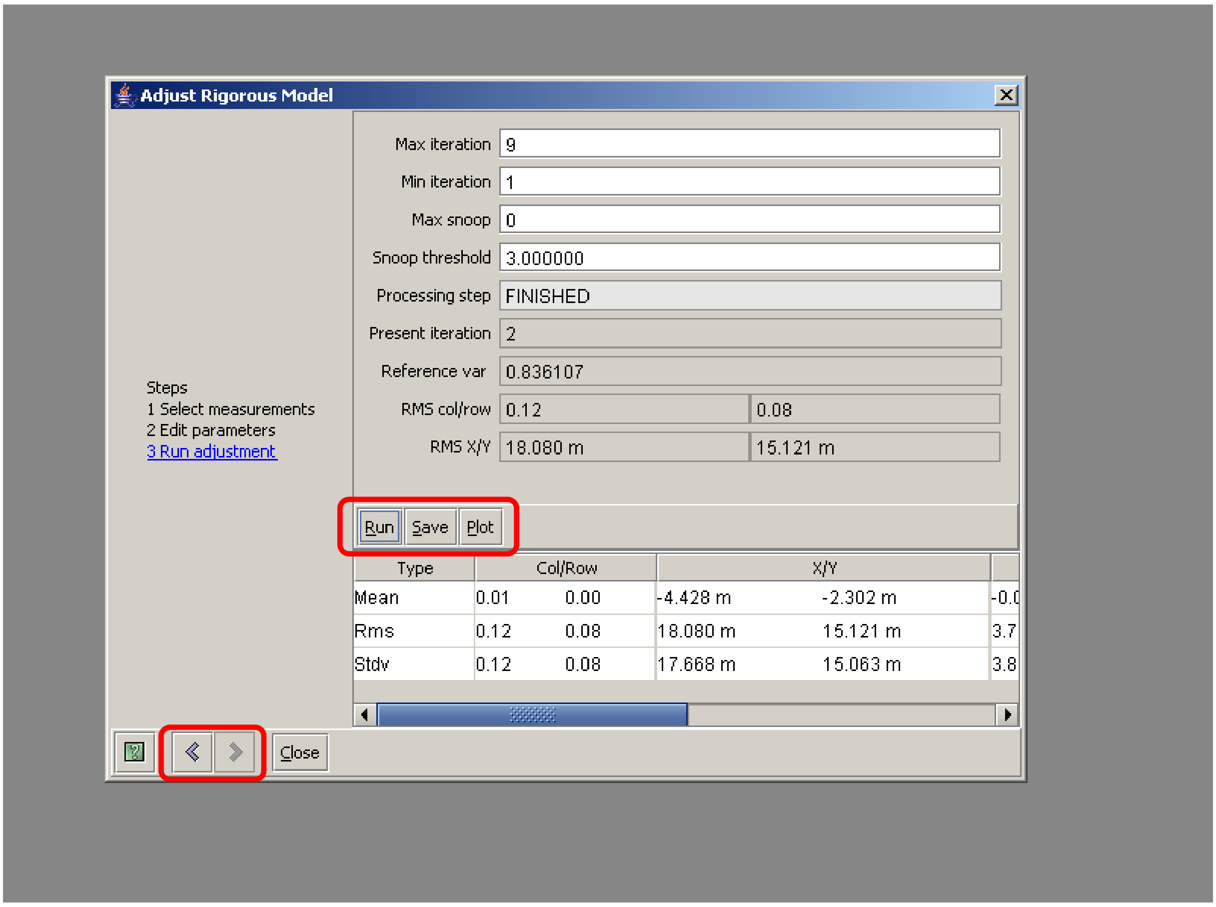
3 Editing Control Points and Running a Model

3.1 Select all GCPs in Control Point List. Edit the points by clicking Point>Edit Selected Points. A new window, Point List Editor, will appear. Populate the X, Y and H fields on the right hand side of the editor with the standard deviation values relevant to the reference data and DEM used. For example, when using Image2000 reference data with an SRTM DEM, the values will be 12.5m, 12.5m, and 16m respectively. Click apply.

NOTE: If more than one set of reference data is used, the GCPs may have to be edited in more than one batch with the values corresponding to the reference data.

3.2 With all the GCPs highlighted, click Adjustment>Adjust Rigorous Model (see Figure 38). A new window, Adjust Rigorous Model will appear. Using the navigation arrows at the bottom left hand corner of this window, skip through to the last screen available (see Figure 40).

3.3 Click Run.



Max iteration 9
Min iteration 1
Max snoop 0
Snoop threshold 3.000000
Processing step FINISHED
Present iteration 2
Reference var 0.836107
RMS col/row 0.12 0.08
RMS X/Y 18.080 m 15.121 m

Steps
1 Select measurements
2 Edit parameters
3 Run adjustment

Type	Col/Row		X/Y		
Mean	0.01	0.00	-4.428 m	-2.302 m	-0.0
Rms	0.12	0.08	18.080 m	15.121 m	3.7
Stdv	0.12	0.08	17.668 m	15.063 m	3.8

Figure 40: Adjust Rigorous Model

3.4 To achieve sub-pixel accuracy, RMS values of less than 75% of the pixel size is required. If the RMS values for X and Y are greater than this value, then clicking on Plot will show a plot of the points which can indicate if there is a particular point or area on the image to orthorectify where the errors are larger. Alternatively, by using the navigation arrows skip to the first screen to the list of all the GCPs (see Figure 41). The right hand column, labelled Std. Res., details the standardised residual error of each GCP. This value should be less than 3.0[7]. If one or more points have a standardised residual error greater than 3.0 then return to the image and re-adjust the corresponding GCPs. Repeat this adjustment process until all points have a standardised residual error less than 3.0 and the RMS values of X and Y are less than the required value for sub-pixel accuracy. Assuming there are no faults in the image itself, these standards should be achievable.

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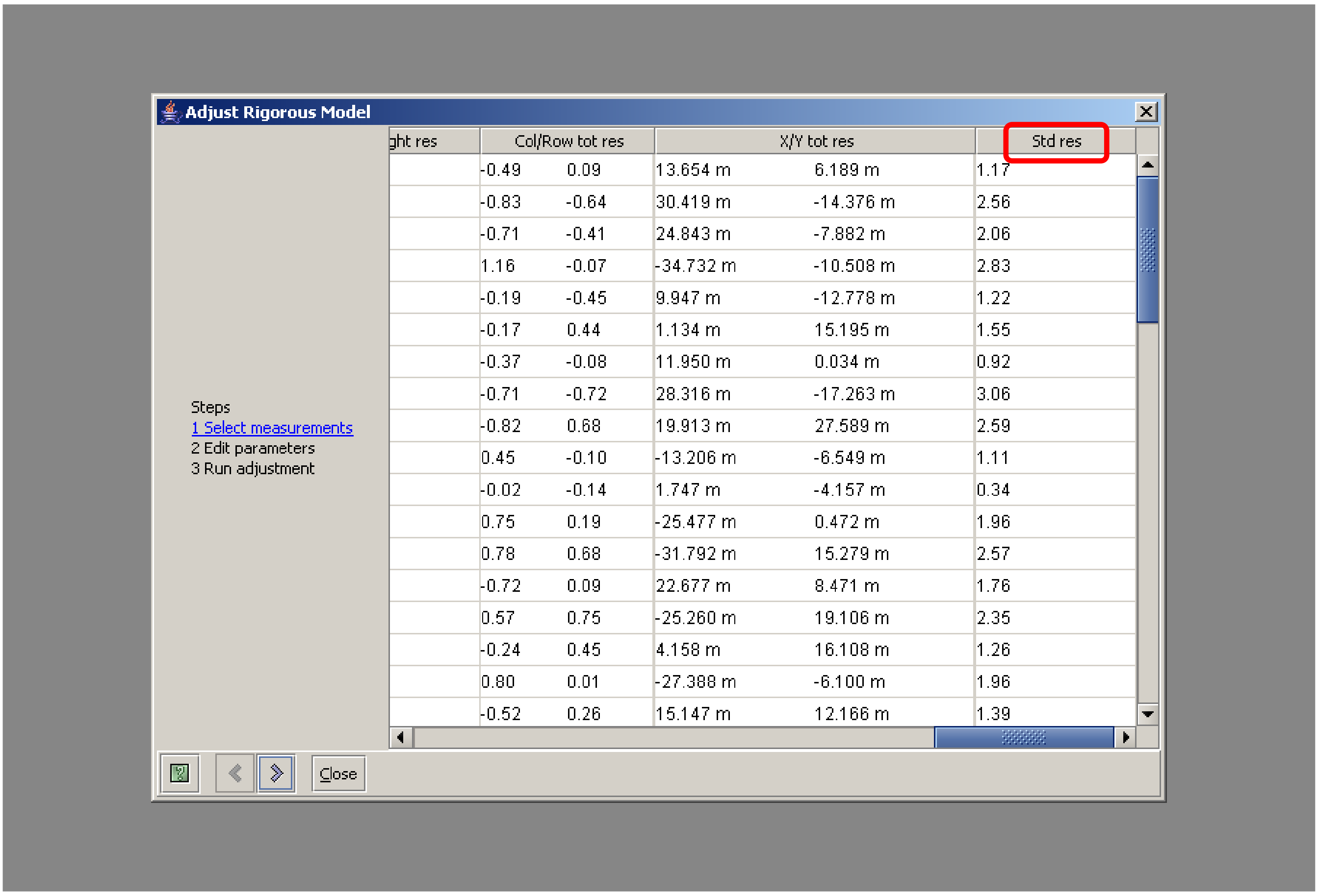
[7] SipOrtho User Guide, SipOrtho B2239, Spacemetric



ght res	Col/Row tot res		X/Y tot res		Std res
	-0.49	0.09	13.654 m	6.189 m	1.17
	-0.83	-0.64	30.419 m	-14.376 m	2.56
	-0.71	-0.41	24.843 m	-7.882 m	2.06
	1.16	-0.07	-34.732 m	-10.508 m	2.83
	-0.19	-0.45	9.947 m	-12.778 m	1.22
	-0.17	0.44	1.134 m	15.195 m	1.55
	-0.37	-0.08	11.950 m	0.034 m	0.92
	-0.71	-0.72	28.316 m	-17.263 m	3.06
	-0.82	0.68	19.913 m	27.589 m	2.59
	0.45	-0.10	-13.206 m	-6.549 m	1.11
	-0.02	-0.14	1.747 m	-4.157 m	0.34
	0.75	0.19	-25.477 m	0.472 m	1.96
	0.78	0.68	-31.792 m	15.279 m	2.57
	-0.72	0.09	22.677 m	8.471 m	1.76
	0.57	0.75	-25.260 m	19.106 m	2.35
	-0.24	0.45	4.158 m	16.108 m	1.26
	0.80	0.01	-27.388 m	-6.100 m	1.96
	-0.52	0.26	15.147 m	12.166 m	1.39

Figure 41: Standardised Residual Error of GCPs

3.5 Once these requirements are fulfilled, the image is ready to be processed. On the Adjust Rigorous Model final screen click save (see Figure 40).

The meta.sip file is then processed using Keystone and the product is then subject to quality assessment.

APPENDIX G: WEBLINKS

DIMAP
http://www.spotimage.fr/dimap/spec/dimap.htm

DMCII
http://www.dmcii.com

Eastman Kodak KLI-10203 Linear CCD Data Sheet
http://www.micronkk.com/1_imaging/kodak/DataSheet/KLI-10203%20Rev.6.pdf

GLCF
http://glcf.umiacs.umd.edu/index.shtml

GLOBE
http://www.ngdc.noaa.gov/mgg/topo/globe.html

OGP Surveying & Positioning Committee
http://www.epsg.org/

IMAGE2000
http://image2000.jrc.it/

Spacemetric
http://www.spacemetric.se/

SRTM
http://srtm.csi.cgiar.org/

SSTL
http://www.sstl.co.uk

TIFF Revision 6.0
http://partners.adobe.com/public/developer/en/tiff/TIFF6.pdf

APPENDIX H: EUROPE 2007 - IMAGE RMS ERRORS

ALBANIA

Image ID	Acquisition Date	Rows	Columns	NGCP	RMSX	RMSY
DC000636_020000_030499_s	28 Jun 2007	10,000	9,984	33	13.09	16.92
DC00063c_000000_010499_p	01 Jul 2007	10,000	9,984	26	13.12	7.63
DC00063c_010000_020499_p	01 Jul 2007	10,000	9,984	30	11.20	8.40
DU000b56	27 Jul 2007	8,199	19,432	45	11.86	18.12

AUSTRIA

Image ID	Acquisition Date	Rows	Columns	NGCP	RMSX	RMSY
DC00063c_030000_040499_p	01 Jul 2007	10,000	9,984	43	40.24	19.46
DC000659_000000_010499_p	16 Jul 2007	10,000	9,984	55	20.91	22.74
DC000659_000000_010499_s	16 Jul 2007	10,000	9,984	60	24.46	20.10
DU000b44	20 Jul 2007	7,569	19,108	45	30.05	17.07

BELGIUM

Image ID	Acquisition Date	Rows	Columns	NGCP	RMSX	RMSY
DC000660_000000_010499_s	21 Jul 2007	10,000	9,984	42	20.97	22.26
DU000bac	29 Aug 2007	7,571	19,432	54	8.51	9.81

BOSNIA & HERZEGOVINA

Image ID	Acquisition Date	Rows	Columns	NGCP	RMSX	RMSY
DC00063c_020000_030499_p	01 Jul 2007	10,000	9,984	50	22.80	13.40
DU000b60	30 Jul 2007	7,569	19,432	45	10.60	10.03
DU000ba9	28 Aug 2007	7,570	16,140	44	10.77	12.77

BULGARIA

Image ID	Acquisition Date	Rows	Columns	NGCP	RMSX	RMSY
DN000530	11 Jun 2007	7,607	15,447	44	15.89	17.02
DU000ab7	09 May 2007	7,574	16,984	34	15.38	11.44
DU000b4e	24 Jul 2007	7,542	17,320	42	17.08	15.39

CROATIA

Image ID	Acquisition Date	Rows	Columns	NGCP	RMSX	RMSY
DC00063c_010000_020499_p	01 Jul 2007	10,000	9,984	30	11.20	8.40
DC00063c_010000_020499_s	01 Jul 2007	10,000	9,984	29	12.96	10.82
DC00063c_020000_030499_p	01 Jul 2007	10,000	9,984	50	22.80	13.40
DC00063c_020000_030499_s	01 Jul 2007	10,000	9,984	29	14.41	9.14
DU000b17	01 Jul 2007	7,588	13,004	43	9.04	16.64

CYPRUS

Image ID	Acquisition Date	Rows	Columns	NGCP	RMSX	RMSY
DU000aac	03 May 2007	7,576	18,960	49	13.97	11.53

CZECH REPUBLIC

Image ID	Acquisition Date	Rows	Columns	NGCP	RMSX	RMSY
DC0005f2_030000_040499_p	25 May 2007	10,000	9,984	41	18.31	11.88
DC0005f2_030000_040499_s	25 May 2007	10,000	9,984	42	18.28	21.92
DC0005f2_040000_050499_s	25 May 2007	10,000	9,984	36	24.97	23.07
DC000619_000000_010499_p	11 Jun 2007	9,583	9,984	35	17.37	14.62
DC000619_000000_010499_s	11 Jun 2007	9,583	9,984	41	13.83	16.38
DC000659_010000_020499_p	16 Jul 2007	10,000	9,984	49	18.48	14.50

DENMARK

Image ID	Acquisition Date	Rows	Columns	NGCP	RMSX	RMSY
DC0005ee_000000_010499_p	23 May 2007	10,000	9,984	51	18.03	17.10
DC0005ee_000000_010499_s	23 May 2007	10,000	9,984	31	24.61	19.31
DC000659_030000_040499_p	16 Jul 2007	10,000	9,984	48	24.11	21.05
DC000659_040000_050499_p	16 Jul 2007	10,000	9,984	14	9.55	5.85
DU000aaf	04 May 2007	8,258	19,432	50	21.42	26.87
DU000ad5	31 May 2007	7,624	17,508	43	8.53	13.27

ESTONIA

Image ID	Acquisition Date	Rows	Columns	NGCP	RMSX	RMSY
DC000617_000000_010499_p	10 Jun 2007	10,000	9,984	37	28.17	14.32
DC000617_000000_010499_s	10 Jun 2007	10,000	9,984	23	65.3	60.7
DC000617_010000_020499_p	10 Jun 2007	10,000	9,984	28	10.60	7.85
DC000617_010000_020499_s	10 Jun 2007	10,000	9,984	23	9.78	11.37

FINLAND						
Image ID	**Acquisition Date**	**Rows**	**Columns**	**NGCP**	**RMSX**	**RMSY**
DC000664_010000_025499_p	23 Jul 2007	15,500	9,984	32	23.95	22.28
DC000683_030000_040499_p	05 Aug 2007	10,000	9,984	30	22.34	15.02
DC000689_000000_010499_p	07 Aug 2007	10,000	9,984	37	10.43	12.29
DC000689_000000_010499_s	07 Aug 2007	10,000	9,984	39	16.15	17.24
DC000689_010000_020499_p	07 Aug 2007	10,000	9,984	39	9.37	12.40
DC000689_010000_020499_s	07 Aug 2007	10,000	9,984	31	9.02	13.64
DC000689_020000_030499_p	07 Aug 2007	10,000	9,984	40	10.10	14.14
DC000689_020000_030499_s	07 Aug 2007	10,000	9,984	30	8.46	9.49
DC000689_030000_040499_p	07 Aug 2007	10,000	9,984	52	15.34	10.56
DC000689_030000_040499_s	07 Aug 2007	10,000	9,984	35	18.78	19.32
DC00068e_000000_010499_p	08 Aug 2007	10,000	9,984	40	7.35	11.64
DC00068e_010000_020499_p	08 Aug 2007	10,000	9,984	32	7.25	11.24
DC000694_040000_050499_p	10 Aug 2007	10,000	9,984	37	13.98	19.20

FRANCE						
Image ID	**Acquisition Date**	**Rows**	**Columns**	**NGCP**	**RMSX**	**RMSY**
DC000638_020000_030499_s	29 Jun 2007	10,000	9,984	36	14.42	15.69
DC00064d_020000_030499_p	10 Jul 2007	10,000	9,984	26	109.15	21.45
DC000659_000000_010499_s	16 Jul 2007	10,000	9,984	60	24.46	20.10
DC000659_010000_020499_s	16 Jul 2007	10,000	9,984	56	17.53	11.70
DC00066d_010000_020499_p	27 Jul 2007	10,000	9,984	22	20.72	18.47
DC00066d_010000_020499_s	27 Jul 2007	10,000	9,984	31	15.33	21.20
DC00066d_020000_030499_p	27 Jul 2007	10,000	9,984	33	17.18	13.72
DC00066d_020000_030499_s	27 Jul 2007	10,000	9,984	19	14.78	16.26
DC000677_010000_020499_s	31 Jul 2007	10,000	9,984	21	18.76	19.53
DC0006b0_000000_010499_p	25 Aug 2007	10,000	9,984	15	16.53	8.58
DC0006b0_000000_010499_s	25 Aug 2007	10,000	9,984	14	19.03	8.23
DC0006b0_010000_020499_p	25 Aug 2007	10,000	9,984	28	10.99	10.52
DC0006b0_010000_020499_s	25 Aug 2007	10,000	9,984	27	18.72	19.33
DC0006b0_020000_030499_p	25 Aug 2007	10,000	9,984	31	16.26	15.13
DC0006b0_020000_030499_s	25 Aug 2007	10,000	9,984	20	19.95	15.61
DC0006b0_030000_040499_s	25 Aug 2007	10,000	9,984	32	17.13	13.98
DC0006c9_000000_010499_s	04 Sep 2007	10,000	9,984	19	16.25	17.33
DC0006c9_010000_020499_p	04 Sep 2007	10,000	9,984	17	21.18	9.73
DU000ba5	29 Aug 2007	7,566	18,344	36	18.97	49.79
DU000bac	27 Aug 2007	7,571	19,432	54	8.51	9.81
DU000bc4	07 Sep 2007	7,606	18,120	27	18.48	16.07
DU000bce	12 Sep 2007	7,539	18,280	64	16.35	17.75
DU000bef	25 Sep 2007	6,738	14,916	62	9.01	9.46
DU000bf7	28 Sep 2007	7,575	13,944	33	16.10	18.63

GERMANY

Image ID	Acquisition Date	Rows	Columns	NGCP	RMSX	RMSY
DC000657_020000_030499_s	15 Jul 2007	10,000	9,984	59	20.33	19.43
DC000657_030000_040499_s	15 Jul 2007	10,000	9,984	33	17.24	19.22
DC000659_000000_010499_p	16 Jul 2007	10,000	9,984	55	20.91	22.74
DC000659_000000_010499_s	16 Jul 2007	10,000	9,984	60	24.46	20.10
DC000659_010000_020499_p	16 Jul 2007	10,000	9,984	49	18.48	14.50
DC000659_010000_020499_s	16 Jul 2007	10,000	9,984	56	17.53	11.70
DC000659_020000_030499_p	16 Jul 2007	10,000	9,984	60	16.51	15.43
DC000659_020000_030499_s	16 Jul 2007	10,000	9,984	57	22.73	15.62
DC000659_030000_040499_p	16 Jul 2007	10,000	9,984	48	24.11	21.05
DC000660_000000_010499_p	21 Jul 2007	10,000	9,984	54	11.25	12.26
DC000660_000000_010499_s	21 Jul 2007	10,000	9,984	42	20.97	22.26
DC000660_010000_020499_p	21 Jul 2007	10,000	9,984	48	15.12	11.20
DC000660_010000_020499_s	21 Jul 2007	10,000	9,984	26	12.86	10.67
DU000b39	15 Jul 2007	7,555	14,472	83	7.47	7.88
DU000b3e	17 Jul 2007	7,555	18,308	39	14.65	8.63
DU000b6f	05 Aug 2007	7,555	14,932	45	10.72	16.04

GREECE

Image ID	Acquisition Date	Rows	Columns	NGCP	RMSX	RMSY
DC000600_000000_010499_p	01 Jun 2007	10,000	9,984	15	8.01	10.33
DC000600_010000_020499_p	01 Jun 2007	10,000	9,984	40	12.84	12.16
DC000636_000000_010499_p	28 Jun 2007	10,000	9,984	31	11.76	10.30
DC000636_000000_010499_s	28 Jun 2007	10,000	9,984	11	7.21	6.51
DC000636_010000_020499_p	28 Jun 2007	10,000	9,984	43	8.92	8.23
DC000636_010000_020499_s	28 Jun 2007	10,000	9,984	33	7.80	11.56
DC000636_020000_030499_p	28 Jun 2007	10,000	9,984	41	14.32	9.09
DC000636_020000_030499_s	28 Jun 2007	10,000	9,984	33	13.09	16.92
DC00063c_000000_010499_p	01 Jul 2007	10,000	9,984	26	13.12	7.63

HUNGARY

Image ID	Acquisition Date	Rows	Columns	NGCP	RMSX	RMSY
DC00063c_020000_030499_p	01 Jul 2007	10,000	9,984	50	22.80	13.40
DC00063c_030000_040499_p	01 Jul 2007	10,000	9,984	43	40.24	19.46
DC000657_000000_010499_p	15 Jul 2007	10,000	9,984	66	16.61	11.57
DC000657_000000_010499_s	15 Jul 2007	10,000	9,984	52	24.80	13.46

ICELAND

Image ID	Acquisition Date	Rows	Columns	NGCP	RMSX	RMSY
DC00067c_000000_010499_p	02 Aug 2007	10,000	9,984	40	20.18	20.09
DC00067c_000000_010499_s	02 Aug 2007	10,000	9,984	22	16.35	15.89
DC00067c_010000_020499_p	02 Aug 2007	10,000	9,984	15	18.77	10.78
DC00067c_010000_020499_s	02 Aug 2007	10,000	9,984	9	13.10	16.47
DU000b2c	09 Jul 2007	7,545	17,204	46	24.37	23.33
DU000bbf	05 Sep 2007	7,471	17,956	29	22.56	14.93
DU000bca	08 Sep 2007	7,471	17,364	49	18.07	20.22

IRELAND

Image ID	Acquisition Date	Rows	Columns	NGCP	RMSX	RMSY
DC0005b6_010000_020499_p	28 Apr 2007	10,000	9,984	30	11.89	12.64
DC0005b6_020000_030499_p	28 Apr 2007	10,000	9,984	23	12.31	10.13
DC0005b6_020000_030499_s	28 Apr 2007	10,000	9,984	9	9.30	4.33
DC0005bb_010000_020499_s	30 Apr 2007	10,000	9,984	44	17.59	16.76
DC0005bb_020000_030499_s	30 Apr 2007	10,000	9,984	27	9.10	9.75
DC000610_010000_020499_p	06 Jun 2007	10,000	9,984	66	19.90	19.98
DC000610_010000_020499_s	06 Jun 2007	10,000	9,984	38	21.86	16.50
DC000610_020000_030499_p	06 Jun 2007	10,000	9,984	52	15.20	13.27
DN000531	11 Jun 2007	7,619	16,687	22	67.1	33.1
DU000aae	04 May 2007	7,612	19,072	34	14.16	10.77

ITALY

Image ID	Acquisition Date	Rows	Columns	NGCP	RMSX	RMSY
DC0005d3_000000_010499_p	09 May 2007	10,000	9,984	21	8.98	7.06
DC0005d3_000000_010499_s	09 May 2007	10,000	9,984	25	15.41	10.46
DC0005d3_010000_020499_p	09 May 2007	10,000	9,984	27	17.82	13.39
DC0005e9_000000_010499_p	21 May 2007	10,000	9,984	28	18.16	16.65
DC0005e9_000000_010499_s	21 May 2007	10,000	9,984	20	17.79	16.01
DC000624_000000_010499_s	19 Jun 2007	10,000	9,984	45	14.10	11.31
DC000624_010000_020499_s	19 Jun 2007	10,000	9,984	26	10.65	10.23
DC000624_020000_030499_s	19 Jun 2007	10,000	9,984	57	17.33	16.28
DC000624_030000_040499_s	19 Jun 2007	10,000	9,984	74	11.38	9.74
DC00063c_000000_010499_p	01 Jul 2007	10,000	9,984	26	13.12	7.63
DC00063c_000000_010499_s	01 Jul 2007	10,000	9,984	40	17.25	12.77
DC00063c_010000_020499_p	01 Jul 2007	10,000	9,984	30	11.20	8.40
DC00063c_010000_020499_s	01 Jul 2007	10,000	9,984	29	12.96	10.82
DC00063c_020000_030499_s	01 Jul 2007	10,000	9,984	29	14.41	9.14
DC000659_000000_010499_p	16 Jul 2007	10,000	9,984	55	20.91	22.74
DC000659_000000_010499_s	16 Jul 2007	10,000	9,984	60	24.46	20.10
DU000ab9	11 May 2007	8,258	19,432	35	21.98	18.97
DU000b5d	29 Jul 2007	7,557	18,592	29	6.65	8.62

LATVIA

Image ID	Acquisition Date	Rows	Columns	NGCP	RMSX	RMSY
DC000617_000000_010499_p	10 Jun 2007	10,000	9,984	37	28.17	14.32
DC00065a_020000_030499_p	17 Jul 2007	10,000	9,984	37	11.84	11.08
DC00065a_020000_030499_s	17 Jul 2007	10,000	9,984	29	17.32	11.93
DC00065a_030000_040499_p	17 Jul 2007	10,000	9,984	30	11.53	10.16
DU000acf	24 May 2007	7,558	18,500	28	9.82	14.31

LIECHTENSTEIN

Image ID	Acquisition Date	Rows	Columns	NGCP	RMSX	RMSY
DC000624_030000_040499_s	19 Jun 2007	10,000	9,984	74	11.38	9.74

LITHUANIA

Image ID	Acquisition Date	Rows	Columns	NGCP	RMSX	RMSY
DC00063e_000000_010499_s	27 Jul 2008	10,000	9,984	25	22.64	20.32
DC000657_030000_040499_p	15 Jul 2007	10,000	9,984	16	12.74	15.11
DC00065a_010000_020499_p	17 Jul 2007	10,000	9,984	56	15.51	17.91
DC00065a_020000_030499_p	17 Jul 2007	10,000	9,984	37	11.84	11.08
DC00065a_020000_030499_s	17 Jul 2007	10,000	9,984	29	17.32	11.93

LUXEMBURG

Image ID	Acquisition Date	Rows	Columns	NGCP	RMSX	RMSY
DC000659_010000_020499_s	16 Jul 2007	10,000	9,984	56	17.53	11.70

MACEDONIA

Image ID	Acquisition Date	Rows	Columns	NGCP	RMSX	RMSY
DC000636_020000_030499_p	28 Jun 2007	10,000	9,984	41	14.32	9.09
DC000636_020000_030499_s	28 Jun 2007	10,000	9,984	33	13.09	16.92

MALTA

Image ID	Acquisition Date	Rows	Columns	NGCP	RMSX	RMSY
DC0005d7_000000_010499_s	11 May 2007	10,000	9,984	22	19.22	13.58

MONTENEGRO

Image ID	Acquisition Date	Rows	Columns	NGCP	RMSX	RMSY
DC00063c_010000_020499_p	01 Jul 2007	10,000	9,984	30	11.20	8.40
DU000b60	30 Jul 2007	7,569	19,432	45	10.60	10.03
DU000ba9	28 Aug 2007	7,570	16,140	44	10.77	12.77

NETHERLANDS

Image ID	Acquisition Date	Rows	Columns	NGCP	RMSX	RMSY
DC000660_000000_010499_s	21 Jul 2007	10,000	9,984	42	20.97	22.26
DC000660_010000_020499_s	21 Jul 2007	10,000	9,984	26	12.86	10.67
DN000501	04 May 2007	7,619	19,487	54	16.06	20.12
DU000b2a	10 Jul 2007	7,573	17,080	44	15.24	9.69

NORWAY

Image ID	Acquisition Date	Rows	Columns	NGCP	RMSX	RMSY
DC000601_030000_040499_p	02 Jun 2007	10,000	9,984	37	14.46	17.11
DC00060b_000000_010499_p	04 Jun 2007	10,000	9,984	35	25.46	12.37
DC00060b_000000_010499_s	04 Jun 2007	10,000	9,984	26	26.90	20.28
DC00060b_010000_020499_p	04 Jun 2007	10,000	9,984	68	23.94	18.15
DC00060b_010000_020499_s	04 Jun 2007	10,000	9,984	36	24.14	24.53
DC00068e_020000_030499_s	08 Aug 2007	10,000	9,984	38	14.61	8.93
DC00068e_030000_040499_p	08 Aug 2007	10,000	9,984	38	19.81	16.53
DC00068e_030000_040499_s	08 Aug 2007	10,000	9,984	21	13.92	8.93
DC00068e_040000_050499_p	08 Aug 2007	10,000	9,984	17	9.49	9.79
DU000ad8	02 Jun 2007	8,224	17,384	54	21.80	26.50

POLAND

Image ID	Acquisition Date	Rows	Columns	NGCP	RMSX	RMSY
DC0005eb_030000_040499_s	22 May 2007	10,000	9,984	37	17.98	16.90
DC000657_010000_020499_s	15 Jul 2007	10,000	9,984	52	14.95	13.56
DC000657_020000_030499_s	15 Jul 2007	10,000	9,984	59	20.33	19.43
DC00065a_000000_010499_s	17 Jul 2007	10,000	9,984	59	30.41	25.27
DC00065a_010000_020499_p	17 Jul 2007	10,000	9,984	56	15.51	17.91
DC00065a_010000_020499_s	17 Jul 2007	10,000	9,984	68	23.14	18.44
DC00065a_020000_030499_s	17 Jul 2007	10,000	9,984	29	17.32	11.93
DU000b3e	17 Jul 2007	7,555	18,308	39	14.65	8.63

PORTUGAL

Image ID	Acquisition Date	Rows	Columns	NGCP	RMSX	RMSY
DC00068a_000000_010499_p	07 Aug 2007	10,000	9,984	27	10.23	7.73
DN000558	03 Aug 2007	7,633	18,979	38	8.35	11.43
DU000b45	20 Jul 2007	7,618	13,256	34	9.28	8.69
DU000b58	27 Jul 2007	7,623	11,932	21	9.68	9.45
DU000b5a	28 Jul 2007	7,609	11,932	38	9.51	9.92
DU000b5e	29 Jul 2007	5,817	8,048	15	9.70	10.23
DU000b62	30 Jul 2007	7,576	16,836	26	10.81	7.22
DU000bc0	05 Sep 2007	7,576	13,384	24	9.26	11.79
DU000bc5	07 Sep 2007	7,615	10,000	10	16.66	11.65

ROMANIA

Image ID	Acquisition Date	Rows	Columns	NGCP	RMSX	RMSY
DC0005da_030000_040499_p	12 May 2007	10,000	9,984	29	18.87	15.32
DC0005da_030000_040499_s	12 May 2007	10,000	9,984	47	24.73	22.59
DC0005da_040000_050499_p	12 May 2007	10,000	9,984	32	85.1	64
DC0005da_040000_050499_s	12 May 2007	10,000	9,984	44	77.6	81.3
DC0005eb_000000_010499_p	22 May 2007	10,000	9,984	62	18.58	16.11
DC0005eb_000000_010499_s	22 May 2007	10,000	9,984	74	28.03	22.87
DC00061d_030000_040499_p	13 Jun 2007	10,000	9,984	35	16.59	17.84
DC00061d_030000_040499_s	13 Jun 2007	10,000	9,984	32	21.23	20.88
DC00061d_040000_050499_p	13 Jun 2007	10,000	9,984	36	11.84	16.61
DC00061d_040000_050499_s	13 Jun 2007	10,000	9,984	34	14.13	11.48
DC000622_000000_010499_p	18 Jun 2007	10,000	9,984	65	19.97	17.03
DC000622_000000_010499_s	18 Jun 2007	10,000	9,984	53	32.41	21.05
DC000622_010000_020499_p	18 Jun 2007	10,000	9,984	64	16.38	19.81
DC000622_010000_020499_s	18 Jun 2007	10,000	9,984	48	19.11	21.61
DC000657_000000_010499_p	15 Jul 2007	10,000	9,984	66	16.61	11.57
DU000bd8	17 Sep 2007	7,581	16,404	64	18.04	15.26

SERBIA & MONTENEGRO

Image ID	Acquisition Date	Rows	Columns	NGCP	RMSX	RMSY
DC00061d_040000_050499_s	13 Jun 2007	10,000	9,984	34	14.13	11.48
DC00063c_010000_020499_p	01 Jul 2007	10,000	9,984	30	11.20	8.40
DC00063c_020000_030499_p	01 Jul 2007	10,000	9,984	50	22.80	13.40
DN000530	11 Jun 2007	7,607	15,447	44	15.89	17.02
DU000b56	27 Jul 2007	8,199	19,432	45	11.86	18.12
DU000b60	30 Jul 2007	7,569	19,432	45	10.60	10.03
DU000b9e	25 Aug 2007	7,570	18,180	52	13.64	11.96
DU000ba9	28 Aug 2007	7,570	16,140	44	10.77	12.77

SLOVAKIA

Image ID	Acquisition Date	Rows	Columns	NGCP	RMSX	RMSY
DC000657_000000_010499_p	15 Jul 2007	10,000	9,984	66	16.61	11.57
DC000657_000000_010499_s	15 Jul 2007	10,000	9,984	52	24.80	13.46
DC000657_010000_020499_p	15 Jul 2007	10,000	9,984	49	12.06	11.85
DC000657_010000_020499_s	15 Jul 2007	10,000	9,984	52	14.95	13.56

SLOVENIA

Image ID	Acquisition Date	Rows	Columns	NGCP	RMSX	RMSY
DC00063c_020000_030499_p	01 Jul 2007	10,000	9,984	50	22.80	13.40
DC000659_000000_010499_p	16 Jul 2007	10,000	9,984	55	20.91	22.74
DU000b80	15 Aug 2007	7,570	13,172	45	8.24	11.96

SPAIN

Image ID	Acquisition Date	Rows	Columns	NGCP	RMSX	RMSY
DC000653_000000_010499_p	13 Jul 2007	10,000	9,984	29	14.57	11.91
DC000653_000000_010499_s	13 Jul 2007	10,000	9,984	33	17.02	15.32
DC000653_010000_020499_p	13 Jul 2007	10,000	9,984	36	14.14	9.04
DC000653_010000_020499_s	13 Jul 2007	10,000	9,984	34	16.85	14.60
DC000653_020000_030499_p	13 Jul 2007	10,000	9,984	35	14.30	9.83
DC000653_020000_030499_s	13 Jul 2007	10,000	9,984	33	12.43	15.47
DC00066d_000000_010499_p	27 Jul 2007	10,000	9,984	15	12.50	7.77
DC00066d_000000_010499_s	27 Jul 2007	10,000	9,984	24	15.91	15.60
DC00066d_010000_020499_p	27 Jul 2007	10,000	9,984	22	20.72	18.47
DC00066d_010000_020499_s	27 Jul 2007	10,000	9,984	31	15.33	21.20
DC00066d_020000_030499_s	27 Jul 2007	10,000	9,984	19	14.78	16.26
DU000b67	01 Aug 2007	7,603	10,000	30	24.9	19.5
DU000b6c	03 Aug 2007	7,611	12,956	35	15.04	17.77
DU000b6d	04 Aug 2007	7,573	19,432	39	12.37	10.67
DU000b98	23 Aug 2007	7,577	14,052	25	15.50	19.83
DU000bb4	31 Aug 2007	7,617	14,388	28	15.43	13.57

SWEDEN

Image ID	Acquisition Date	Rows	Columns	NGCP	RMSX	RMSY
DC000601_020000_030499_p	02 Jun 2007	10,000	9,984	33	13.38	15.53
DC000601_030000_040499_p	02 Jun 2007	10,000	9,984	37	14.46	17.11
DC00060b_000000_010499_p	04 Jun 2007	10,000	9,984	35	25.46	12.37
DC00060b_010000_020499_p	04 Jun 2007	10,000	9,984	68	23.94	18.15
DC00065a_030000_040499_s	17 Jul 2007	10,000	9,984	19	10.85	11.48
DC00065a_040000_050499_s	17 Jul 2007	10,000	9,984	12	8.41	6.55
DC000689_030000_040499_s	07 Aug 2007	10,000	9,984	35	18.78	19.32
DC00068e_000000_010499_s	08 Aug 2007	10,000	9,984	18	6.85	8.29
DC00068e_010000_020499_s	08 Aug 2007	10,000	9,984	32	12.62	16.85
DC00068e_020000_030499_p	08 Aug 2007	10,000	9,984	37	12.55	13.07
DC00068e_020000_030499_s	08 Aug 2007	10,000	9,984	38	14.61	8.93
DC00068e_030000_040499_p	08 Aug 2007	10,000	9,984	38	19.81	16.53
DC00068e_030000_040499_s	08 Aug 2007	10,000	9,984	21	13.92	8.93
DC000694_030000_040499_p	10 Aug 2007	10,000	9,984	30	12.71	12.25
DC000694_030000_040499_s	10 Aug 2007	10,000	9,984	30	12.79	16.81
DC000694_040000_050499_p	10 Aug 2007	10,000	9,984	37	13.98	19.20
DC000711_000000_010499_p	09 Oct 2007	10,000	9,984	25	9.36	12.64
DC000711_000000_010499_s	09 Oct 2007	10,000	9,984	14	7.00	9.94
DC000711_010000_020499_p	09 Oct 2007	10,000	9,984	40	16.14	22.66
DC000711_010000_020499_s	09 Oct 2007	10,000	9,984	31	17.96	19.90
DC000711_020000_030499_p	09 Oct 2007	10,000	9,984	10	9.23	16.31
DN00055a	06 Aug 2007	7,626	18,315	70	27.72	28.04
DU000ae1	07 Jun 2007	7,563	19,104	46	15.08	16.47
DU000bdc	18 Sep 2007	7,554	16,340	53	17.80	26.91

SWITZERLAND						
Image ID	**Acquisition Date**	**Rows**	**Columns**	**NGCP**	**RMSX**	**RMSY**
DC000659_000000_010499_s	16 Jul 2007	10,000	9,984	60	24.46	20.10
DU000b53	26 Jul 2007	7,566	18,576	40	14.22	11.37

TURKEY						
Image ID	**Acquisition Date**	**Rows**	**Columns**	**NGCP**	**RMSX**	**RMSY**
DC0005c8_000000_010499_p	04 May 2007	10,000	9,984	33	17.89	15.81
DC0005c8_000000_010499_s	04 May 2007	10,000	9,984	28	15.40	12.95
DC0005c8_010000_020499_p	04 May 2007	10,000	9,984	28	31.24	34.15
DC0005c8_010000_020499_s	04 May 2007	10,000	9,984	34	73.53	27.35
DC0005c8_020000_030499_s	04 May 2007	10,000	9,984	20	19.24	36.75
DC0005da_000000_010499_p	12 May 2007	10,000	9,984	16	14.11	5.68
DC0005da_000000_010499_s	12 May 2007	10,000	9,984	28	16.14	11.10
DC0005da_010000_020499_p	12 May 2007	10,000	9,984	33	23.22	10.14
DC0005da_010000_020499_s	12 May 2007	10,000	9,984	43	22.93	20.22
DC0005da_020000_030499_p	12 May 2007	10,000	9,984	55	22.78	18.75
DC0005da_020000_030499_s	12 May 2007	10,000	9,984	54	21.55	16.71
DC00061d_000000_010499_p	13 Jun 2007	10,000	9,984	39	16.01	9.61
DC000647_000000_010499_p	06 Jul 2007	10,000	9,984	33	18.83	10.60
DC000647_000000_010499_s	06 Jul 2007	10,000	9,984	36	17.01	12.01
DC000647_010000_020499_p	06 Jul 2007	10,000	9,984	30	16.66	14.40
DC000647_010000_020499_s	06 Jul 2007	10,000	9,984	33	14.48	9.95
DU000af7	16 Jun 2007	7,558	18,860	28	11.53	9.78
DU000b13	30 Jun 2007	7,568	19,252	48	12.60	14.77

UNITED KINGDOM						
Image ID	**Acquisition Date**	**Rows**	**Columns**	**NGCP**	**RMSX**	**RMSY**
DC0005b6_000000_010499_p	28 Apr 2007	10,000	9,984	17	12.82	10.79
DC0005b6_030000_040499_p	28 Apr 2007	10,000	9,984	16	14.96	10.42
DC0005bb_010000_020499_p	20 Apr 2007	10,000	9,984	33	16.21	10.99
DC0005bb_010000_020499_s	20 Apr 2007	10,000	9,984	44	17.59	16.76
DC0005bb_020000_030499_p	20 Apr 2007	10,000	9,984	30	12.32	10.30
DC0005bb_020000_030499_s	20 Apr 2007	10,000	9,984	27	9.10	9.75
DC0005bb_030000_040499_p	20 Apr 2007	10,000	9,984	14	10.92	6.65
DC000610_010000_020499_p	06 Jun 2007	10,000	9,984	66	19.90	19.98
DC000610_010000_020499_s	06 Jun 2007	10,000	9,984	38	21.86	16.50
DC000610_020000_030499_p	06 Jun 2007	10,000	9,984	52	15.20	13.27
DU000a88	07 Apr 2007	7,546	5,000	28	9.18	6.12
DU000aa8	01 May 2007	8,004	19,432	57	22.15	34.15
DU000b2a	10 Jul 2007	7,573	17,080	44	15.24	9.69
DU000b9a	24 Aug 2007	7,513	15,240	9	15.27	18.46

APPENDIX I: EUROPE 2007 - REFERENCE IMAGE AND DEM DATASET

SRTM DEM V3 and IMAGE2000 were the primary datasets used for orthorectification. For geographic areas where the primary dataset was absent, GLOBE DEM and Landsat ETM+ datasets were used instead.

IMAGE2000 Tiles refers to the individual image scenes acquired over Europe. These images are projected according to the country's national projection.

IMAGE2000 Mosaic refers to the image subsets that collectively form the cloud-free mosaic of Europe. These image subsets are projected to the European Terrestrial Reference System 1989 (ETRS89) projection.

COUNTRY	REFERENCE IMAGE	DEM
Albania	GLCF	SRTM V3
Austria	IMAGE2000 Tiles IMAGE2000 Mosaic	SRTM V3
Belgium	IMAGE2000 Tiles	SRTM V3
Bosnia & Herzegovina	GLCF	SRTM V3
Bulgaria	IMAGE2000 Tiles	SRTM V3
Croatia	GLCF	SRTM V3
Cyprus	GLCF	SRTM V3
Czech Republic	IMAGE2000 Tiles IMAGE2000 Mosaic	SRTM V3
Denmark - Mainland	IMAGE2000 Tiles	SRTM V3
Denmark - Faroe Islands	GLCF	GLOBE
Estonia	IMAGE2000 Tiles	SRTM V3
Finland	IMAGE2000 Tiles GLCF	GLOBE
France - Mainland	IMAGE2000 Tiles	SRTM V3
France - Corsica	IMAGE2000 Tiles	SRTM V3
Germany	IMAGE2000 Tiles	SRTM V3
Greece	IMAGE2000 Tiles	SRTM V3 GLOBE
Hungary	IMAGE2000 Tiles IMAGE2000 Mosaic	SRTM V3
Iceland	GLCF	GLOBE
Ireland - Republic of Ireland	IMAGE2000 Tiles	SRTM V3
Ireland - Northern Ireland	IMAGE2000 Tiles	SRTM V3
Italy - Mainland	IMAGE2000 Tiles	SRTM V3
Italy - Sicily	IMAGE2000 Tiles	SRTM V3
Italy - Sardinia	IMAGE2000 Tiles	SRTM V3

COUNTRY	REFERENCE IMAGE	DEM
Latvia	IMAGE2000 Tiles	SRTM V3
Liechtenstein	GLCF	SRTM V3
Lithuania	IMAGE2000 Tiles	SRTM V3
Luxembourg	IMAGE2000 Tiles	SRTM V3
Macedonia	GLCF	SRTM V3
Malta	GLCF	SRTM V3
Montenegro	GLCF	SRTM V3
Netherlands	IMAGE2000 Tiles	SRTM V3
Norway	GLCF	GLOBE
Poland	IMAGE2000 Tiles GLCF	SRTM V3 GLOBE
Portugal - Mainland	IMAGE2000 Tiles	SRTM V3
Portugal - The Azores	IMAGE2000 Tiles	SRTM V3
Portugal - Madeira	IMAGE2000 Tiles	SRTM V3
Portugal - Selvages Islands	GLCF	SRTM V3
Romania	MAGE2000 Tiles IMAGE2000 Mosaic GLCF	SRTM V3
Serbia & Montenegro	GLCF	SRTM V3
Slovakia	IMAGE2000 Tiles	SRTM V3
Slovenia	IMAGE2000 Mosaic	SRTM V3
Spain - Mainland	IMAGE2000 Tiles GLCF	SRTM V3
Spain - Canary Islands	IMAGE2000 Tiles GLCF	SRTM V3
Sweden	IMAGE2000 Tiles GLCF	GLOBE
Switzerland	GLCF	SRTM V3
Turkey	GLCF	SRTM V3
United Kingdom	IMAGE2000 Tiles	SRTM V3
United Kingdom - Northern Ireland	IMAGE2000 Tiles	SRTM V3

APPENDIX J: EUROPE 2007 - NATIONAL EPSG CODES

COUNTRY	COUNTRY CODE	NATIONAL EPSG CODE	PROJECTION NAME	AREA OF USE
Albania	AL	2462	Albanian 1987 / Gauss-Kruger zone 4	
Austria	AT	31287	MGI / Austria Lambert	
Belgium	BE	50007	ETRS89 / Belgian Lambert 2008	
Bosnia & Herzegovina	BA	31276	MGI / Balkans zone 6	Bosnia and Herzegovina - **EAST** of 16 deg 30 min E.
Bulgaria	BG	3047	ETRS89 / ETRS-TM35	
Croatia	HR	31275	MGI / Balkans zone 5	Croatia - **WEST** of 16 deg 30 min E.
		31276	MGI / Balkans zone 6	Croatia - **EAST** of 16 deg 30 min E.
Cyprus	CY	32636	WGS 84 / UTM zone 36N	
Czech Republic	CZ	28403	Pulkovo 1942 / Gauss-Kruger zone 3	
Denmark - Mainland	DK	25832	ETRS89 / UTM zone 32N	Denmark - **BETWEEN** 6 and 12 deg E.
		25833	ETRS89 / UTM zone 33N	Denmark - **BETWEEN** 12 and 18 deg E.
Denmark - Faroe Islands	DK	25829	ETRS89 / UTM zone 29N	Denmark - The Faroe Islands
Estonia	EE	3301	Estonian Coordinate System of 1997	
Finland	FI	2393	KKJ / Finland Uniform Coordinate System	
France - Mainland	FR	27572	NTF (Paris) / Lambert zone II	

COUNTRY	**COUNTRY CODE**	**NATIONAL EPSG CODE**	**PROJECTION NAME**	**AREA OF USE**
France - Corsica	FR	27572	NTF (Paris) / Lambert zone II	
Germany	DE	31466	DHDN / Gauss-Kruger zone 2	Germany - **WEST** of 7 deg 30 min E.
		31467	DHDN / Gauss-Kruger zone 3	Germany - **BETWEEN** 7 deg 30 min and 10 deg 30 min E.
		31468	DHDN / Gauss-Kruger zone 4	Germany - **BETWEEN** 10 deg 30 min and 13 deg 30 min E.
		31469	DHDN / Gauss-Kruger zone 5	Germany - **EAST** of 13 deg 30 min E.
Greece	GR	2100	GGRS87 / Greek Grid	
Hungary	HU	23700	HD72 / EOV	
Iceland	IS	3057	ISN93 / Lambert 1993	
Ireland - Republic of Ireland	IE	29903	TM75 / Irish Grid	
Ireland - Northern Ireland	IE	29903	TM75 / Irish Grid	
Italy - Mainland	IT	32632	WGS 84 / UTM zone 32N	
Italy - Sicily	IT	32632	WGS 84 / UTM zone 32N	
Italy - Sardinia	IT	32632	WGS 84 / UTM zone 32N	
Latvia	LV	3059	LKS92 / Latvia TM	
Liechtenstein	LI	31287	MGI / Austria Lambert	
Lithuania	LT	3346	LKS94 / Lithuania TM	
Luxembourg	LU	2169	Luxembourg 1930 / Gauss	
Macedonia	MK	31277	MGI / Balkans zone 7	

COUNTRY	COUNTRY CODE	NATIONAL EPSG CODE	PROJECTION NAME	AREA OF USE
Malta	MT	23033	ED50 / UTM zone 33N	
Montenegro	ME	31277	MGI / Balkans zone 7	Montenegro - **BETWEEN** 19 deg 30 min and 22 deg 30 min E.
Netherlands	NL	28992	Amersfoort / RD New	
Norway	NO	32633	WGS 84 / UTM zone 33N	Norway - **BETWEEN** 12 and 18 deg E.
Poland	PL	2180	ETRS89 / Poland CS92	
Portugal - Mainland	PT	20790	Lisbon (Lisbon) / Portuguese National Grid	Portugal - Mainland.
Portugal - The Azores	PT	2188	Azores Occidental 1939 / UTM zone 25N	Portugal - Western Azores - Flores, Corvo.
		2189	Azores Central 1948 / UTM zone 26N	Portugal - Central Azores - Graciosa, Terceira, Sao Jorge, Pico, Faial.
		2190	Azores Oriental 1940 / UTM zone 26N	Portugal - Eastern Azores - Sao Miguel, Santa Maria.
Portugal - Madeira	PT	2942	Porto Santo / UTM zone 28N	Portugal - Madeira, Porto Santo and The Desertas Islands.
Portugal - Selvages Islands	PT	2943	Selvages Grande / UTM zone 28N	Portugal - The Salvages Islands (Madeira province).
Romania	RO	31700	Dealul Piscului 1970 / Stereo 70	
Serbia & Montenegro	CS	31277	MGI / Balkans zone 7	Serbia and Montenegro - **BETWEEN** 19 deg 30 min and 22 deg 30 min E.
Slovakia	SK	28404	Pulkovo 1942 / Gauss-Kruger zone 4	
Slovenia	SI	2170	MGI / Slovenia Grid	
Spain - Mainland	ES	25829	ETRS89 / UTM zone 29N	Spain - **BETWEEN** 12 and 6 deg W.
		25830	ETRS89 / UTM zone 30N	Spain - **BETWEEN** 6 deg W and 0 deg E.
		25831	ETRS89 / UTM zone 31N	Spain - **BETWEEN** 0 and 6 deg E.

COUNTRY	COUNTRY CODE	NATIONAL EPSG CODE	PROJECTION NAME	AREA OF USE
Spain - Canary Islands	ES	25828	ETRS89 / UTM zone 28N	Spain - The Canary Islands.
Sweden	SE	3021	RT90 2.5 gon V	
Switzerland	CH	21781	CH1903 / LV03	
Turkey	TR	50008	TURKEY EUROPE 2007	
United Kingdom	UK	27700	OSGB 1936 / British National Grid	
United Kingdom - Northern Ireland	UK	27700	OSGB 1936 / British National Grid	