

## **HYMAP DATA PRODUCTS**

The data processing and data products that HyVista Corporation delivered were radiance calibrated data (at sensor), atmospheric correction (to apparent reflectance) and geometric correction. All data are delivered as ENVI™ compatible files and was delivered on DVD-R (4.7GB).

In operation, the HyMap sensor records 128 spectral bands of data. However, the delivered data contains 126 bands because two bands (band 1 and 32 of the VIS module) are deleted during the pre-processing steps.

Spectral and radiometric calibration of the HyMap sensor was accomplished prior to the survey and this information was used to allow the conversion of the raw DN counts to radiance values in  $\mu\text{W}/\text{cm}^2 \text{ nm sr}$ .

Atmospheric correction (spectral processing to remove the effects of atmospheric absorptions and scattering) was performed using the HyCorr software package. HyCorr is a program for converting raw, “near-raw” or radiance HYMAP images to apparent surface reflectance. HyCorr offers two levels of processing. The simpler level is essentially compatible with ATREM3 processing. The more advanced level consists of an ATREM pass followed by an EFFORT polishing pass to remove systematic ATREM errors.

Geometric correction algorithms were used to correct the hyperspectral data. The HyMap system is mounted on a Zeiss SM2000 gyro-stabilised platform that provides 5 degrees of pitch and roll correction and 8 degrees of yaw correction. High quality DGPS integrated with a Boeing CMIGITS II GPS/INS inertial monitoring unit was used to provide sensor pointing data to precisely geocode the raw data. Geometric correction factors are provided to convert the data to map coordinates and provide GIS ready, map-based products.

Below is listed the files that are delivered followed by a complete description of each.

### ***Radiance Data Files***

*“filename”*\_rad.bil – HyMap image data, 126 channels x 512 pixels x N lines (BIL format).  
*“filename”*\_rad.hdr – associated ENVI header file.  
*“filename”*\_q.img – single band (VIS ch25) quicklook image (BSQ format). *\*image will be flipped*  
*“filename”*\_q.hdr – associated ENVI header file.  
*“filename”*\_mask.bsq – masking output file (BSQ format).  
*“filename”*\_mask.hdr – associated ENVI header file.  
*“filename”*\_c.cal – internal lamp data, 128 channels x 10 pixels.  
*“filename”*\_c.hdr – associated ENVI header file.  
*“filename”*\_d.drk – dark current data, 128 channels x 10 pixels.  
*“filename”*\_d.hdr – associated ENVI header file.  
*“filename”*.JPG – composite true colour (3 band RGB) image in JPG format.

### ***Reflectance Data Files***

*“filename”*\_ref.bil – HyMap image data, 126 channels x 512 pixels x N lines (BIL format).  
*“filename”*\_ref.hdr – associated ENVI header file.  
*“filename”*\_h2o.bil – water vapour band image.  
*“filename”*\_h2o.hdr – associated ENVI header file.  
*“filename”*\_eff\_gain\_sli – HyCorr EFFORT gain spectral library.  
*“filename”*\_eff\_gain\_sli.hdr – associated ENVI header file.  
*“filename”*\_eff\_model\_sli – HyCorr EFFORT model spectral library.  
*“filename”*\_eff\_model\_sli.hdr – associated ENVI header file.  
*“filename”*\_eff\_raw\_sli – HyCorr EFFORT final calibration spectral library.  
*“filename”*\_eff\_raw\_sli.hdr – associated ENVI header file.

### ***Geocorrection Data Files***

*“filename”*\_geo.img – 3 band colour (RGB) geocoded “quicklook” image.  
*“filename”*\_geo.hdr – associated ENVI header file.  
*“filename”*\_geo.ers – associated ER-MAPPER header file.  
*“filename”*\_glt.bsq – Geographic Lookup Table file.  
*“filename”*\_glt.hdr – associated ENVI header file.  
*“filename”*\_igm.bil – Input Geometry file.  
*“filename”*\_igm.hdr – associated ENVI header file.  
*“filename”*.gps – HyMap navigation file.  
*“filename”*\_ephemeris.txt – Aircraft ephemeris data for each scan line.  
*“filename”*\_report.txt – summary of the geocorrection parameters.

## 1 Radiance Data Files

### *“filename”\_rad.bil*

This file is the 126 band, 512 pixel wide image in BIL format that has been converted to physical units of radiance (strictly, the measurement is “at sensor radiance”). The data is in  $\mu\text{W}/\text{cm}^2 \text{ nm sr}$ .

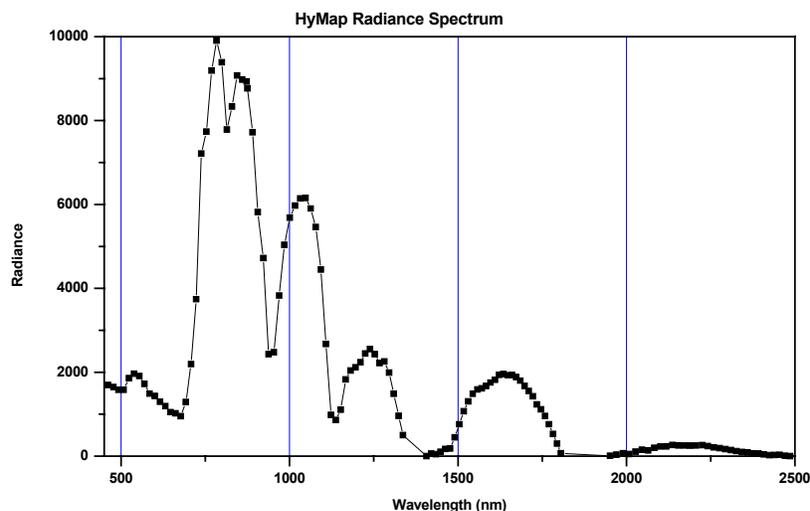
The in-flight recorded DN (digital numbers) have been corrected for dark current/electronic offsets and converted to radiance using laboratory radiometric calibration information and in-flight measurements of the on-board calibration lamp.

Typically the file will be labelled as “filename”\_rad.bil or “filename”\_radiance.bil to further indicate that the data is in radiance units.

The preferred data format is a two byte, integer format and the data is rescaled to preserve dynamic range, especially in the SWIR range. This rescaling involves multiplying bands 1 – 62 by 1000 and bands 63 – 126 by 4000.

The wavelength and bandwidth (in nanometres) information is imbedded in the ENVI header file (\*.hdr).

A typical radiance spectrum (over a vegetated scene) is shown below.



The HyMap sensor has 4 spectrometers (VIS, NIR, SWIR1 and SWIR2), each producing 32 spectral bands of imagery. The VIS and NIR provide contiguous sampling across the 900 nm region. In fact, the spectrometers are set up to provide a slight overlap in the long wavelength region of the VIS spectrometer and the short wavelength region of the NIR spectrometer.

Image data is written in band order from the VIS to the NIR to the SWIR1 to the SWIR2 spectrometer and this leads to the bands being in wavelength order except at the VIS – NIR overlap.

Typically, band 30 (the last band of the VIS spectrometer) of the radiance data will have a wavelength larger than band 31 (the first band of the NIR spectrometer).

When radiance spectra are plotted as a Z-profile in ENVI, the line of the plot is connected to the data points in band order, not wavelength order. This can give a “strange” appearance to the plot in the VIS-NIR overlap region.

### ***“filename”\_q.img***

This file is a single band image in BSQ format. The file is used to provide a “quicklook” at the HyMap image. The image has the same dimensions as the radiance file but will be displayed in a mirrored orientation as it has been derived from the “raw” HyMap data. Therefore the image is displayed “as it is recorded on the HyMap system”. The band used is from VIS ch25.

### ***“filename”\_mask.bsq***

This file is the masking output file. The file has the same dimensions as a 1-band image with byte formatting. A 1 value in a pixel represents a valid pixel while a 0 in the pixel represents an invalid mapped pixel in the radiance file. The masking process also sets pixels between 0 and the MinDN value back to zero, thus removing any negative radiance values that may have been generated due to very low signal bands with noise levels of greater than 1DN standard deviation. The file is imported by ENVI and used for masking corrupt pixels during data analysis.

### ***“filename”\_c.cal***

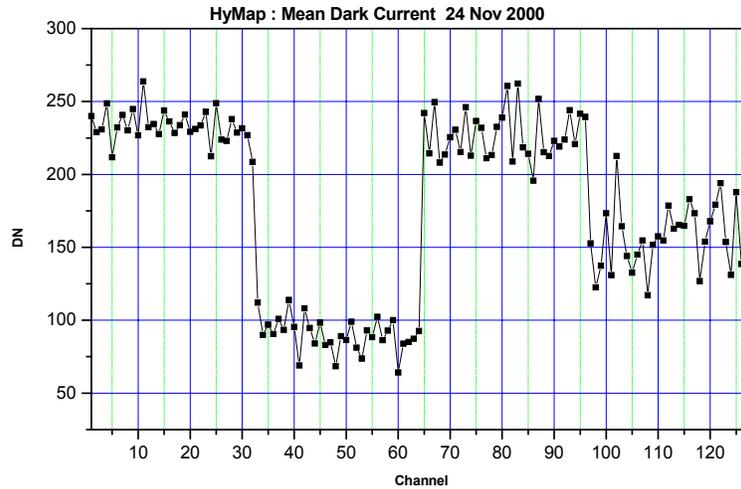
During image acquisition, the HyMap sensor measures the on-board calibration lamp, acquiring a 10 pixel wide “image” after alternate image scan lines. This data is in DN and is used by HyVista Corp. during the radiometric pre-processing. The data in this file are not dark current/offset corrected. Typically, this file will be delivered in the HyMap 128 channel mode. (NOTE: in the 126 band radiance data, bands 1 and 32 have been deleted)

To most users, this file is of little value and has some properties that require additional information from HyVista Corp for a complete understanding.

### ***“filename”\_d.drk***

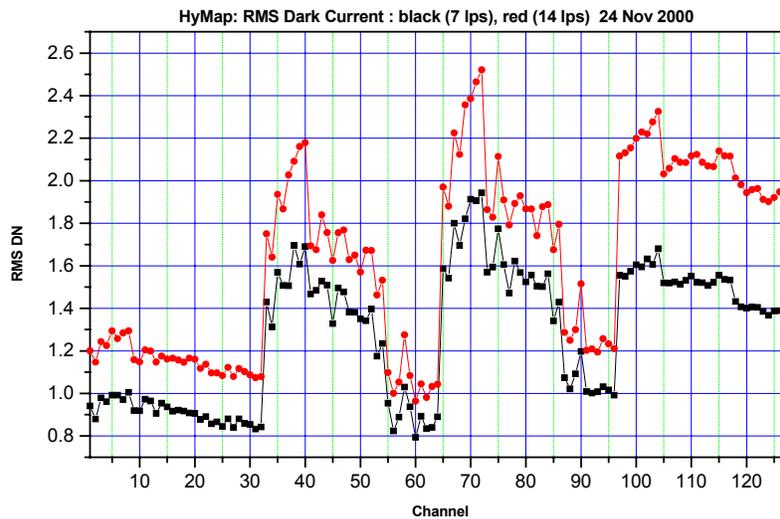
During image acquisition, the HyMap sensor measures detector dark currents and offsets, acquiring a 10 pixel wide “image” after alternate image scan lines. The data is in DN and can be used to examine the dark current statistics. Typically, this file will be delivered in the HyMap 128 channel mode. (NOTE: in the 126 band radiance data, bands 1 and 32 have been deleted)

A typical mean dark current spectrum is shown below where data from the 4 spectrometers can be easily recognised.



Typical dark current noise (in rms DN) is shown in the following figure. Again the 4 spectrometer data can be easily recognised. Note that the details of both the mean and rms dark currents will be dependent of which detector array is installed at the time of the survey and on the electronic gains set during the laboratory calibration.

Note also that the rms dark current noise is dependent on the scan line acquisition rate. The higher the line rate, the higher the rms noise.



### ***“filename”.JPG***

This file is a 3-band colour image of the imported data. It is displayed as RGB as R-VISch18, G-VISch10, B-VISch4. It is radiance corrected and gaussian stretched to provide the best quality picture and is provided in the common JPG image format.

## **2 Reflectance Data Files**

HyVista Corporation produces reflectance data files from the software HYCORR. HYCORR is a program for converting radiance HYMAP images to apparent surface reflectance. It offers two levels of processing. The simpler level is essentially compatible with ATREM3 processing. The more advanced level consists of an ATREM pass followed by an EFFORT polishing pass to remove systematic ATREM errors. EFFORT processing has been used on this dataset and the derived files are explained below.

### ***“filename”\_ref.bil***

This is the main reflectance product. It is an ENVI file-pair with the same dimensions as the input image. It is also a BIL short-integer image and has been scaled by 10,000. (reflectance\*10000.) Wavelength is displayed as um.

### ***“filename”\_h2o.bil***

This file is the water-vapour band image. This gives the amount of water vapour modelled for each pixel. It has the same #samples and #lines as the input image but only 1 band. It is a short-integer image. It has (water vapour in atm-cm) \* 1000.

### ***“filename”\_eff\_gain\_sli***

This file is the HyCorr EFFORT gain spectral library. It is the EFFORT gain and error in finding the gain: It is in ENVI spectral library format.

### ***“filename”\_eff\_model\_sli***

This file is the HyCorr EFFORT model spectral library. It is in ENVI spectral library format.

### ***“filename”\_eff\_raw\_sli***

This file is the HyCorr EFFORT final calibration spectral library. It is in ENVI spectral library format.

### 3 Geocorrection Data Files

HyVista Corporation uses proprietary software for geocorrecting hyperspectral images collected by the HyMap airborne hyperspectral scanner. The software uses HyMap sensor position and orientation data collected at the same time as the image to calculate the position of each pixel in the image. The software uses this position information to map input image pixel values onto a geo-referenced grid of output image pixels.

The geocorrection software also makes use of a Digital Elevation Model (or DEM) of the geographic region containing the imagery.

The geocorrection software produces an "\_igm" input geometry file, a "\_glt" geometry lookup table file and, finally, the geo-corrected output image. All geocoded products are in the UTM projection and WGS84 datum. These files are explained in detail as follows.

#### ***"filename"\_geo.img***

Typically a 3 band colour (RGB) geocoded "quicklook" image. Bands used to derive the "true colour" image are R-ch15, G-ch9, B-ch3. When geocoded flight lines are mosaiced together, make sure to set the background value to ignore to -99. The null pixels around the images have this value. The "quicklook" image is produced with an associated ENVI header file and also produced with an associated ER-MAPPER header file. ("*filename*"\_geo.ers)

#### ***"filename"\_glt.bsq***

The geometric lookup table file represents much of the important information that is created in the geo-correction process. The "\_glt" file contains the information about which original pixel occupies which output pixel in the final product. Additionally, it is sign-coded to indicate if a certain output pixel is "real" or a nearest-neighbor in-fill pixel. The "\_glt" file is a geo-corrected product, with a fixed pixel size projected into a rotated UTM system. The pixel size, scene elevation, UTM zone number, and rotation angle information is reported in an associated ASCII header file. The "\_glt" file is two-byte integer binary data in a BIL format. The two bands of the "\_glt" file refer to original sample number and original line number, respectively. The sign of the value indicates whether the pixel is an actual image pixel, located at its proper position indicated by a positive value) or a nearest-neighbor in-fill pixel placed to fill an under-sampled image gap (indicated by a negative value). A zero value signifies that no input pixel corresponds to this output pixel.

The importance of the "\_glt" image and its role in identifying image gaps and in-fill pixels must be stressed, especially for studies involving small targets. The geometric lookup table file can be used to geo-correct any band or derived product through a simple lookup table procedure.

### ***“filename”\_igm.bil***

Input geometry file that denotes the UTM Easting and Northing values derived by the geo-correction process for each original image pixel. The first band contains UTM Easting values in meters and the second band contains UTM Northing values in meters for each original pixel. The input geometry file has the same spatial size as the raw HyMap imagery. The file is double precision, binary data in a BIL format. The pixel size, and UTM zone number information are given in an associated ASCII header file. The input geometry file itself is not geo-corrected, but does contain the geo-location information for each original raw pixel.

### ***“filename”.gps***

This file is the HyMap navigation file. The \*.gps files is a multi-column ASCII file that is derived from the \*.log file by HyVista Corp. proprietary software. The program “unpacks” the \*.log file, synchronises times and generates an output which is indexed by scan line number. Not all possible parameters are supplied to a client; again it depends on the specifics of the survey contract. The table below shows the total list of possible output parameters.

<b>Parameter</b>	<b>Example</b>	<b>Description</b>	<b>Comment</b>
CMIGITS Time	419819098.2	Internal CMIGITS time in microseconds	Of no interest or value to end user
Pitch	0.85741807	IMU output Decimal degrees	
Roll	1.14817758	IMU output Decimal degrees	
Heading	-67.36104012	IMU output Decimal degrees	
Lat	39.9147011	DGPS output Decimal degrees (neg = Sth)	
Long	-116.3251269	DGPS output Decimal degrees (0 to 180 E, 0 to -180 W)	
Alt	4754.163811	DGPS output Metres above MSL	
UTC Time	61606.1032/5/10/2000	DGPS output Time of day in seconds /day/month/year	61606.1032= 17 Hrs,6 Min,46.1 Seconds
Grnd Spd	81.97301031	DGPS output Metres per second	
True Track	293.4184839	DGPS output Decimal degrees (0 to 360)	
DGPS	1	DGPS status 1 = DGPS being received 0 = no DGPS received	
Satellites	5	Number of satellites being received	
Line Num.	1	Image scan line number	
VME time	344844473	Internal computer tick time in microseconds	Of no interest or value to end user

All of the above timing, position and pointing information has been referenced to the **end** of the image scan line.

The parameters are derived as follows.

Once per second, the DGPS receiver generates an interrupt signal. At the time of this interrupt, the system records the VME time (referred to as tick time) and the CMGITS time, both in microseconds. The DGPS receiver then sends UTC time, lat, long, altitude etc to the system referenced to the time of the interrupt signal.

At the end of each image scan line, VME time is recorded. The CMIGITS sends pitch, roll and heading information to the system at a 10 Hz rate and time tagged with CMIGITS time.

The program uses the CMIGITS and VME tick times to synchronise (and interpolate) the other parameters, including UTC time, to the time corresponding to the end of a scan line.

One question that might arise is “if the time is referenced to the end of the image scan line, what positional difference occurs from the centre pixel of the scan line to the end pixel?”

In the following table, the relationship between scan rate (lines per second) and along track positional difference between middle and end pixel is shown.

Line Rate (lines per second)	Time period per scan line (pixel 1 to pixel 512) in milliseconds	Difference (centre to last pixel) at 100 Kts	Difference (centre to last pixel) at 120 Kts	Difference (centre to last pixel) at 140 Kts
8	42.6	1.05 m	1.3 m	1.5 m
10	34.1	1.35 m	1.0 m	1.2 m
12	28.4	0.7 m	0.85 m	1.0 m
14	24.3	0.6 m	0.75 m	0.85 m
16	21.3	0.55 m	0.65 m	0.75 m

Thus it can be seen that unless positional information and/or geo-correction is being attempted at the metre or less precision, that the fact that the timing information generated is referenced to the end of the scan line rather than the centre contributes minimal error. The differences are smaller than the positional information derived from the DGPS and smaller than the accuracy of the IMU pointing information when traced to actual ground positions.

***“filename”\_ephemeris.txt***

Aircraft ephemeris information for each scan line. The file contains: line number, UTM X meters), UTM Y (meters), altitude (meters), pitch (degrees), roll (degrees), and heading (degrees).

***“filename”\_report.txt***

This file contains a summary of data used and generated by the geo-correction process.