# Appendix 2: Worked example using GPS

This appendix will talk the reader through how to use a GPS, get data out of the unit and use that data in the expedition GIS. The specific example used is a simple image rectification process. This chapter will describe all the principles behind using GPS data and show how quickly it can be used to create an expedition map. To understand all the terms and processes in this appendix the user will have to read and understand the basic GPS chapter (Chapter 6) and the Photogrammetry and rectification chapter (Chapter 9).

Using GPS to Rectify Images

When collecting GPS points for rectification they must be taken as accurately as possible. This is done by locating a visible object in an image and determining the co-ordinate for that object either from a previous map, a rectified image or from ground control in the field. Taking these rectification points in the field is very difficult. An example of how difficult it is to locate point features on raster imagery is shown below. There is a clear difficulty in mapping the co-ordinates for the SE corner of the Royal Albert Memorial for ASTER (left) and even in an aerial photograph (right). Locating an exact pixel in the ASTER data to match a GPS co-ordinate is difficult even though the pixels for the statue are very different from the surrounding park. This example is substantially easier than the type of exercise expeditions will encounter in the field.
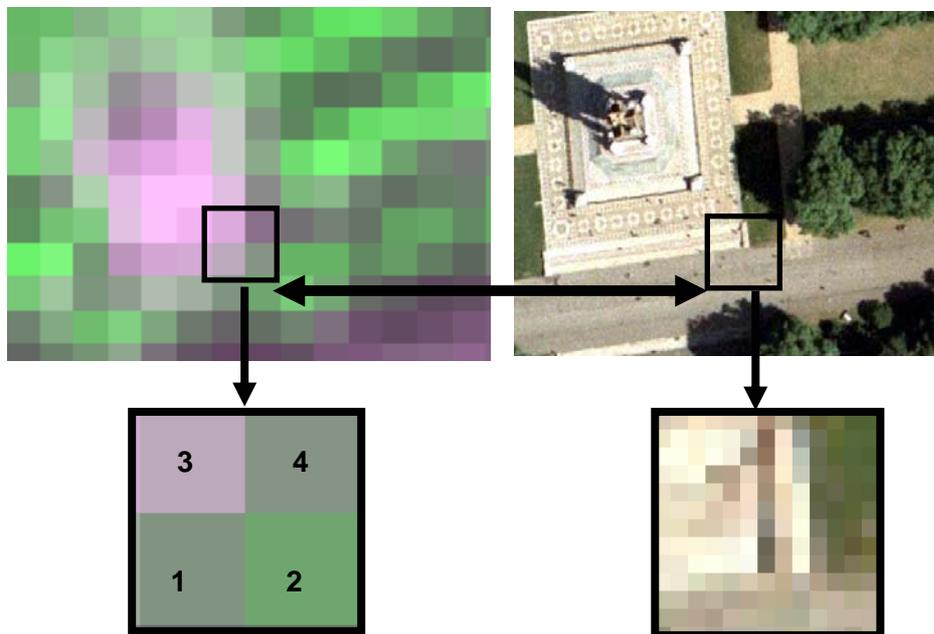

Selecting Control Points. Difficulty in accurately mapping pixels for different data sets.

The pixels labelled 1, 2, 3 and 4 in the ASTER enlargement show the problem of signal returns in areas of mixed ground types. Pixel 4 is clearly grass and pixel 1 appears to be urban and therefore part of the statue. It is therefore tempting to place the rectification mark at the edge of pixel 1 and pixel 3. Pixel 1 is not, however, as bright as some of the other pixels in the image above and therefore may be part of the path not the statue. The

aerial photograph clearly shows that the statue is not the only urban object in the area and the returns might be those of the pathway so the actual point may be further back. Pixels 2 and 3 are even more difficult to interpret because their returns are definitely a mix of urban and grass. The edge of the statue might be somewhere in the middle of pixels 2 and 3 or back to the NW of pixel 1. Even on this simplest of exercises there is already a 2 pixel margin of error which in ASTER is at least 30 m.

The Bogda Shan expedition discussed in Section 17.1 relied heavily on field rectified imagery. This was because maps better than 1:500,000 were considered sensitive and not made readily available to the team. Reading information off a map of 1:500,000 scale gives an error of 500 m for every millimetre of error. Lines and points plotted on this map may be plotted with an error of more than 2 mm making all the information less accurate than 1 km. The Corona data was rectified by identifying common features on both the scanned imagery and the Landsat ETM+ panchromatic image. Even though the images were taken at a comparable time of the year, the different sun angle, differences in the terrain due to the temporal differences in the data, made the task very time consuming and inaccurate.

Image to image rectification can be very difficult and some example screen grabs of rectifying a Corona image from a Landsat pan band is shown below:
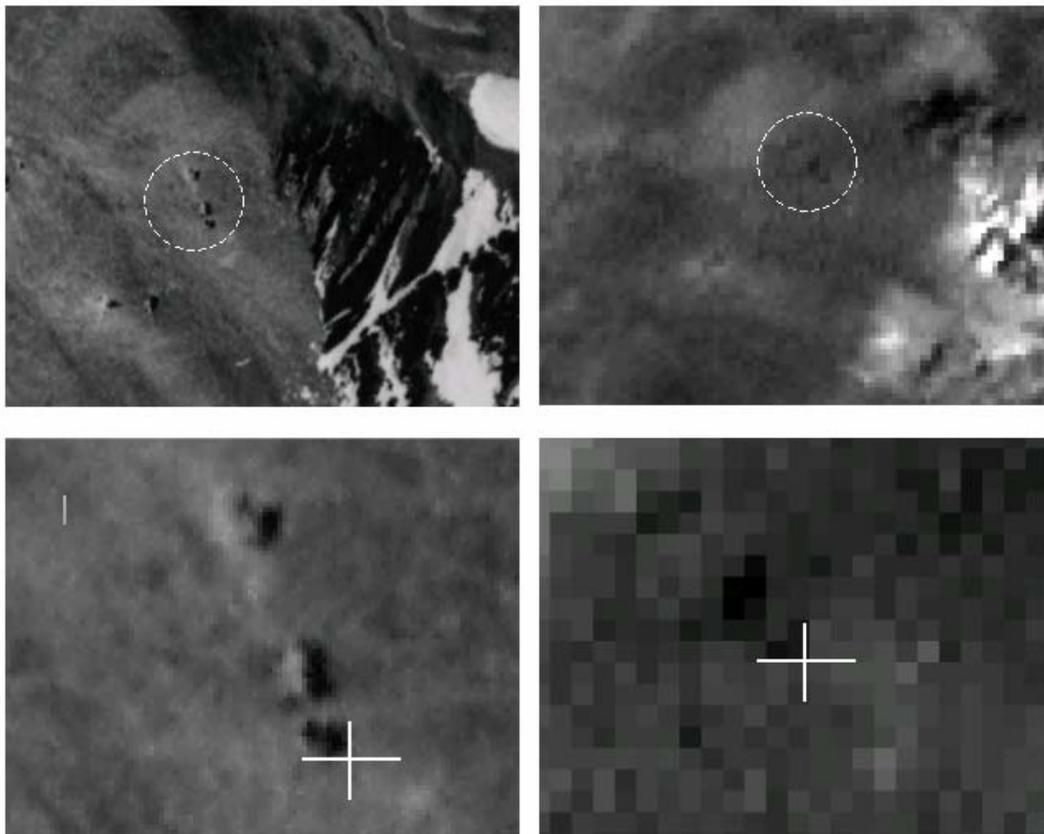
Example of Corona image (left) and Landsat pan band (right) showing three boulders used for rectification. Even with precise boulders and outcrops this exercise is difficult.

The greater the difference in image formats the more difficult this exercise becomes. A common data source for expeditions will be aerial photography. Aerial photography has a much greater spatial resolution than satellite data and can be more difficult to rectify.

Because of these differences in the Corona and Landsat imagery, identifying features was difficult and no confidence could be given in anything other than a 6x6, 36-pixel grid. This introduced large errors, as shown in the table below.

Errors generated from GPS rectification.

Error Type	Degree of Error	Real World Error
Landsat Geometric Error	~ ± 1 pixel (TM)	~50 m total (± 25 m)
Point Identification	~ ± 3 pixels (Pan)	~90 m total (± 45 m)
Error Propagation	Unknown (~±1 pixel Pan)	~30 m Total (± 15 m)

A much better method would have been to quickly use a GPS in the field to rectify the data. Once an expedition has collected GPS points they will need to be accessed to process out the data. To get the data out of the GPS needs some form of communication between the device and the expedition PC.

Using HyperTerminal to Check a GPS signal

When using a GPS and a PC together you first need to connect your GPS to a computer's serial port. Most manufacturers have a proprietary cable connector so make sure you obtain the correct one. It is often a good idea to keep GPS units the same for all members, so that if one cable is lost or fails it can be substituted with an identical one.

When physically connected a piece of software will be needed to bridge between the unit and the PC. This software is very rarely supplied with either the GPS or the cable. HyperTerminal is Microsoft's software for communicating with connected devices. Though not very useful for expedition work, it is an excellent place to start and a good method for checking a GPS is working and that you understand GPS data. It can be used to test your settings and make sure everything is working before connecting to more in-depth software. Check HyperTerminal is installed: it should be located under Programmes ⇒ Accessories ⇒ Communications. If it is not present, it can be loaded by going to Control Panel ⇒ Add Remove Programmes ⇒ Windows Settings.

When installed and located, open HyperTerminal and create a new connection. These instructions assume you are using a standard RS-232 connection but they can easily be adapted for either Bluetooth or USB connections. HyperTerminal must be told which port the GPS is connected to. Commonly this would be COM 1. Set the software to listen on Com port 1 unless instructed to do otherwise (a modem could be using COM 1 and the GPS may be assigned COM 2). A Bluetooth connection might be using a virtual port on COM 16, a USB – Serial adaptor commonly uses either COM 4 or 6. Set the Com port settings to the NMEA standard. Baud Rate 4800, Data Bits 8, No Parity, 1 stop bit as shown below. The GPS will then start sending the data to the screen. To log this to a text file select Transfer ⇒ Send to text file.

GPS NMEA settings.	
Baud Rate	4800 bits per second
Bits	8 bit
Parity	None
Stop Bits	1
Flow Control	Hardware Controlled

This should demonstrate if the GPS is working and you should see a text stream like the following.

$GPGGA,172704,5126.7759,N,00020.6673,W,1,05,1.3,13.8,M,47.4,M,,*67

It is common if one of the settings is wrong, to see a string of random characters, usually using symbols. This suggests that the baud rate has been set incorrectly. Bear in mind that some GPS units do not broadcast a standard NMEA string and some Bluetooth devices commonly broadcast at 38400 bits. This will allow you to test all possibilities and see the actual data before using a more automated solution.

Using GPS software to Download Data

A better method than streaming the data into HyperTerminal is to use a dedicated piece of software to extract stored data from the memory of a GPS. The advantage of this approach is that the GPS can be used separately from the PC for a sustained period before coming back to have its data downloaded. The other advantage of dedicate software is that it can overcome problems with projections. The X and Y data in the GPS is always stored in WGS84, so if the GPS is required to process an image into any other format, the software will have to reconvert the data back to the display information. There are many packages on the market that can do this and some GIS packages have built in scripts to handle data downloads.

A good product for converting co-ordinates and for accessing the GPS memory is GPS Utility sometimes referred to as GPSU. GPS Utility can be downloaded free from *www.gpsu.co.uk*. To use the full product requires a registered licence. On registration (£25 GBP), the programme can be used for downloading large files of data. The programme is predominantly configured for downloading stored GPS waypoint, trackpoints and routes. It is not designed for real-time access to NMEA data or for pseudo range extraction.

**Using GPS Utility to download data**

GPS Utility's strong points are its ability to interface with many models of GPS and to correct/reproject co-ordinates. It can also be used to generate ArcView and MapInfo files from the GPS data. The three steps in using GPSU to download data from GPS are:

Step 1: Tell the Software about the GPS type you are using
*Step 2*: Define datum and projection
Step 3: Connect to the GPS

Step 1: the first step is to tell the software about the receiver being used. Go to the menu item GPS ⇒ Setup and set the parameters as shown below.
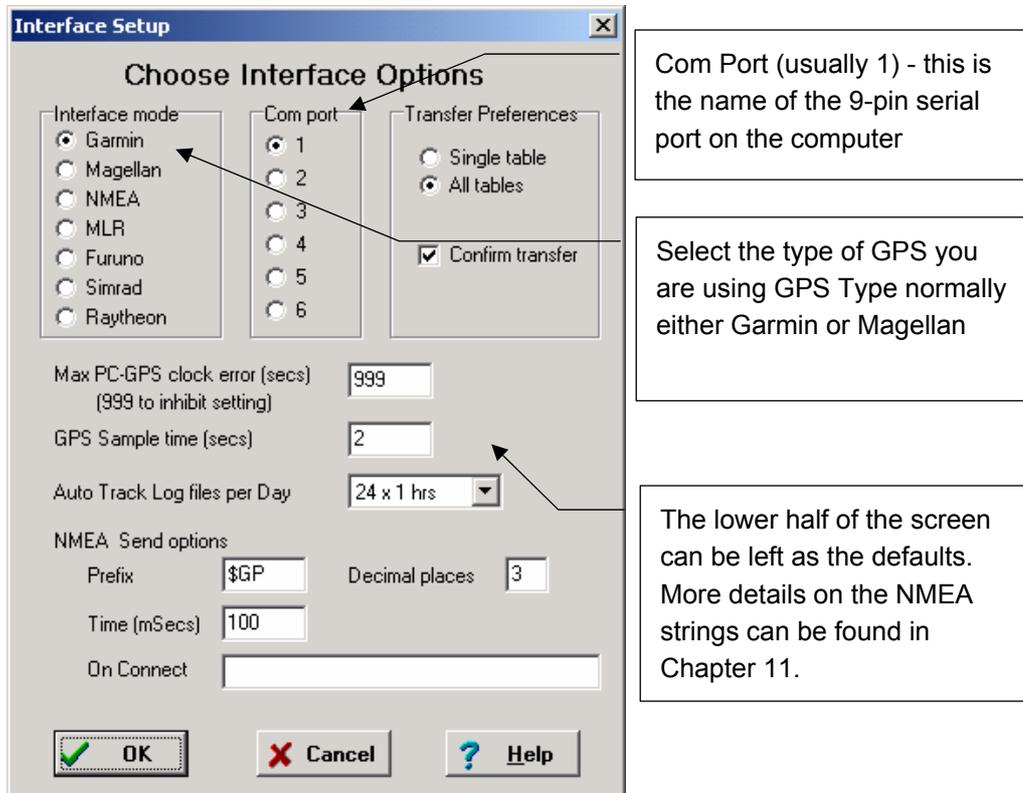
It is also worth checking Options ⇒ Field Properties to ensure that any altitude data is being downloaded correctly and that stored symbols can be output to GPS Utility. It is important to be aware what altitude data is stored in both waypoints and trackpoints by the expedition GPS receivers.

Step 2: define the co-ordinate system and datum, using File ⇒ New (or CTRL-N). First set the co-ordinate system being used (see Chapter 2), then select the appropriate datum to its right. These settings do not affect the format in which data is downloaded; rather, it determines the format that GPSU uses for displaying and saving data.
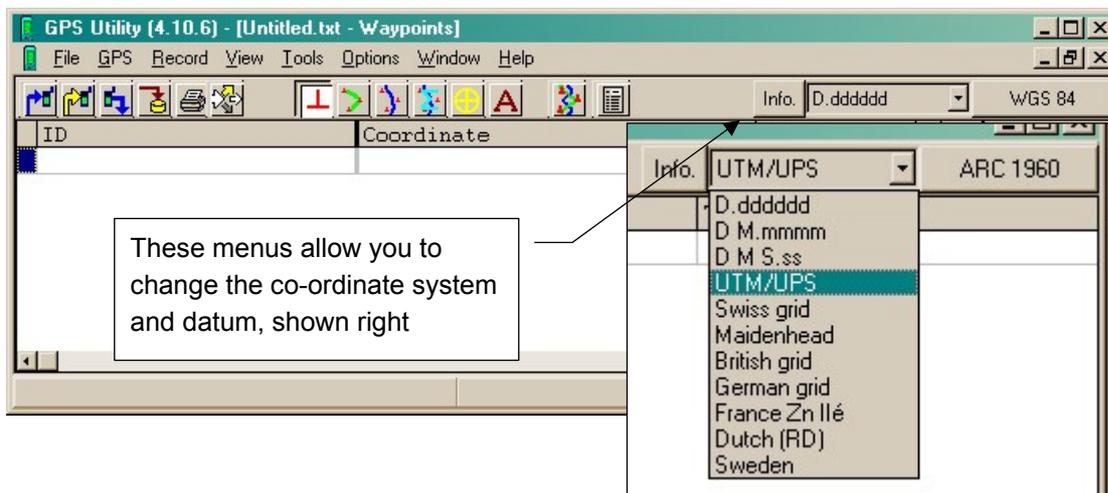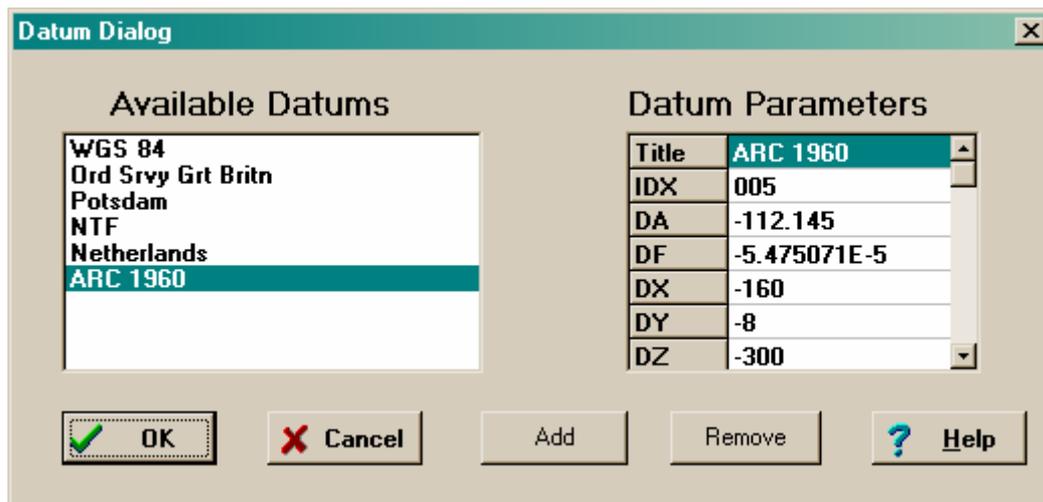
The datum is selected from a pre-defined list. If a required datum is not already held in GPSU, then a custom datum can be defined (in terms of angular and distance offsets from the WGS84 datum). A far greater selection is available than listed in this dialog: use 'Add' to include further datums. In this example, 'Arc 1960' has been added; it is used in much mapping of East and Central Africa.

Step 3: connect to the GPS using GPS $\Rightarrow$ Connect. This will automatically find the GPS model attached to the PC and display its details down in the status bar at the bottom of the screen. Next go to GPS $\Rightarrow$ Download all. This gives the opportunity to select all the GPS point types that are required for the study (i.e. tracks waypoints etc.). Click OK and the programme downloads all the data. To save the data for import into a GIS click File $\Rightarrow$ Save. There are many file format options here, making GPSU a useful adjunct to most GIS programmes.

Three commonly used formats are:

Shapefile: these can be read directly into ArcView (versions 3.x and 8.x), as well as many other GIS programmes. There is the option of saving Shapefiles as points, or in the case of track-logs, as lines. Shapefiles comprise several separate files: GPSU typically saves three (.dbf, .shp, .shx). The .dbf file can also be read by database and spreadsheet applications such as Excel, Access and FoxPro.

MapInfo Interchange File (.MIF): for import into MapInfo. Waypoints are saved as individual points, while tracklogs are saved as lines.

Text file: this can be useful for several reasons. Proprietary file formats change and may be error-prone, so it is always advisable to make a plain-text copy of all downloaded data. It also allows greatest flexibility if you are unsure which format to use: it can later be read back into GPSU for re-export in a particular format. Finally, plain text files can readily be edited in any text editor, such as Notepad or Wordpad, explained in the next section.

```
d1_15_05_01.txt - Notepad
File  Edit  Format  Help
H   SOFTWARE NAME & VERSION
I   GPSU 4.02   REGISTERED to 'Daniel Hourigan'          [Header information]
S   DateFormat=dd/mm/yy
S   Units=M,M
S   SymbolSet=2

H R DATUM
M E              WGS 84 100  0.0000000E+00  0.0000000E+00 0 0 0

H   COORDINATE SYSTEM
U   UTM UPS

F  ID-------- Zne Easting  Northing Symbol------- T O  Alt(m) Comment
W  002        30S 592111 4111359 Waypoint       I E   132
W  003        30S 592111 4111358 Waypoint       I E   132
W  004        30S 592111 4111358 Waypoint       I E   132
W  005        30S 592111 4111358 Waypoint       I E   132
W  006        30S 592111 4111357 Waypoint       I E   133      [Section 1]
W  007        30S 592112 4111358 Waypoint       I E   132      [Waypoint Data]
W  008        30S 592112 4111359 Waypoint       I E   131
W  009        30S 592112 4111359 Waypoint       I E   132
W  010        30S 592111 4111360 Waypoint       I E   132
W  GARMIN     15S 343898 4302285 Waypoint       I E   325
W  GRMEUR     30U 607825 5649045 Waypoint       I E    36
W  GRMPHX     12S 411947 3688292 Waypoint       I E   361      [Section 2]
W  GRMTWN     51R 362850 2772478 Waypoint       I E    38      [Track Summary]
W  RIO HAUTO1 30S 592112 4111358 Waypoint       I E   133

H TRACK SUMMARY
H Track            Pnts Date      Time      StopTime   second
H ACTIVE LOG         24 15/05/01 11:20:35 11:32:26      711       10    0.0   134
H                    23 16/05/01 10:25:37 10:37:08      691       18    0.0   141

F Zne Easting  Northing Alt(m) Date      Time     S  seconds      m    m/s
T 30S 592109 4111355    134 15/05/01 11:20:35 1 ACTIVE LOG
T 30S 592109 4111358    134 15/05/01 11:21:07 0       32       2    0.1
T 30S 592109 4111358    133 15/05/01 11:21:37 0       62       2    0.0
T 30S 592109 4111358    133 15/05/01 11:22:07 0       92       2    0.0
T 30S 592109 4111360    132 15/05/01 11:22:37 0      122       5    0.1
T 30S 592109 4111358    132 15/05/01 11:23:07 0      152
T 30S 592109 4111358    132 15/05/01 11:23:37 0      182      [Section 3]
T 30S 592109 4111358    132 15/05/01 11:24:07 0      212      [Track Data]
T 30S 592109 4111358    133 15/05/01 11:24:37 0      242
T 30S 592109 4111358    132 15/05/01 11:25:07 0      272
T 30S 592109 4111358    133 15/05/01 11:25:37 0      302
T 30S 592109 4111358    133 15/05/01 11:26:07 0      332
T 30S 592109 4111358    132 15/05/01 11:26:37 0      362       7    0.0
T 30S 592109 4111358    131 15/05/01 11:27:07 0      392       7
T 30S 592109 4111358    132 15/05/01 11:27:37 0      422
T 30S 592109 4111358    133 15/05/01 11:28:07 0      452
T 30S 592109 4111358    133 15/05/01 11:28:37 0      48
T 30S 592109 4111358    132 15/05/01 11:29:07 0
T 30S 592109 4111358    131 15/05/01 11:29:37 0
T 30S 592109 4111358    131 15/05/01 11:30:07 0
T 30S 592109 4111358    131 15/05/01 11:30:
T 30S 592109 4111358    132 15/05/01 11:3
T  592109 4111360    132 15/05/01 1
      4111360    131 15/05
        360    132
```

Editing GPS data in text format

Though there are ways of bringing data directly into a GIS, converting it to a text file first can be useful because it allows initial checks and editing to be carried out and un-needed data to be weeded out. Because we need the data for Ground Control Points (GCPs) we require the data in a text format, so we will look at methods for exporting the data. The figure above shows how a text file saved by GPSU is structured. The header specifies the co-ordinate system and datum, followed by the sections containing waypoint data, a track summary (which can usually be ignored), and track point data.

Before data can be read by a GIS or database it requires cleaning and formatting. If an application such as HyperTerminal or GPSU has been used to export a text file, then the text will have to be converted to its correct data type before being analysed (see Chapter 4 for more details on data types). The best way to achieve this formatting is by using a parsing filter. Microsoft Excel has a good parsing filter built in as standard and is a reasonably common piece of software. This section will concentrate on how Excel can be used as part of the GISci software suite.
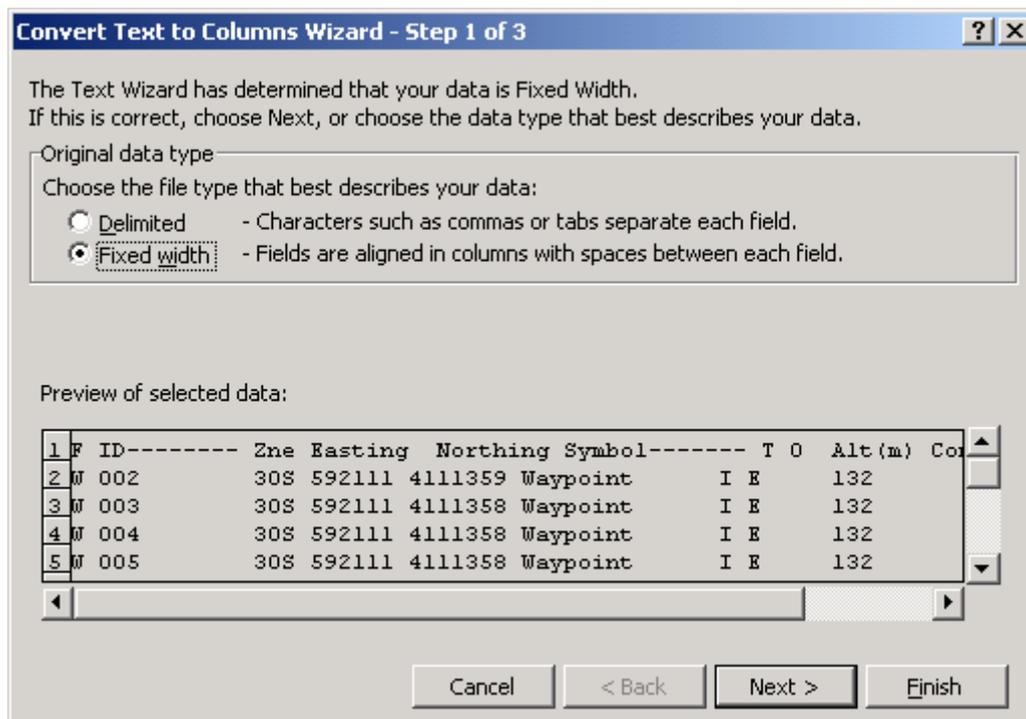
Microsoft Excel's parsing filter.

Copy the waypoints from the text file and paste them into Excel (remembering to delete any spurious header data). The data will be pasted into Excel as text, usually all together in one column. To divide the data into the correct columns and restore the appropriate data types to each field, use the parsing filter 'Text to Columns': highlight the column that the data has been exported to (usually column A) and choose Data > Text to Columns. Select 'Fixed Width', then 'Next'. Check the new columns look right (a line should separate each column, and no data should have been chopped from one column into another), then click 'Finish'. The data will now be in columns for the import. Instead of pasting, you can also open the text file using 'File $\Rightarrow$ Open', then follow the 'Import' dialog, similar to 'Convert Text'.

Save as a Dbase IV file and then repeat for the track data. Clean out any data that looks spurious. Garmin GPS units often have strings of test data in the downloads; these will need to be deleted before loading the information into the GIS. When the data is formatted and cleaned, it can be imported into the GIS. The GPS data can also be used to rectify raw satellite data. This process can be seen schematically over the page.

For many expeditions raw, high resolution data such as Corona may be ideal. Depending on how Corona data is imported into the computer, the imagery can have a spatial resolution of down to six feet. When in the PC the GPS can be used to make a map from the raw data. The four steps in this process are shown below.

1

Visit USGS EROS Data centre to acquire data http://eros.usgs.gov/

Corona data is in strips of film measuring approx 2 inches by 2 foot covering a swath on the ground of 8.6 miles by 117 miles.

117 miles convert to feet = (5280*117) = 61,7760 feet
61,7760 / 29 = 20730 ∴ each inch on the negative = 20730 feet

2

Acquire negatives and have them scanned or select the scanning method straight from the USGS. Scan type affects the pixel size in the raster images.

Scan types available from USGS and resultant pixel resolutions:

21 micron scan 1200 dots per inch = 20730.2/1200 = **17.28 feet**

14 micron scan 1800 dots per inch = 20730.2/1800 = **11.52 feet**

7 micron scan 3600 dots per inch = 20730.2/1200 = **5.76 feet**

3

Acquire ground control points using a GPS in the field or other data such as maps or rectified imagery.

4

Rectify the data using the expedition PC. This can then be overlain with a grid to create a map.

Rectifying Data using ER Mapper

To demonstrate the power of accurate GPS co-ordinates this section will demonstrate the rectification of a Corona scene of Southern Spain. ER Mapper (described in Section 14.4.2) has a good geocoding wizard that is very simple to follow. It might not be the best suited to expeditions but it should allow a good understanding of how GPS data can be used when extracted from the unit. The geocoding wizard has a series of tabs and this tutorial will work through each of the five steps in turn. This is a very rough and ready walk through for using GPS data with your imagery and the team should understand the principles of rectification outlined in Chapter 9.

The Geocoding Wizard can be found under the Process menu item.
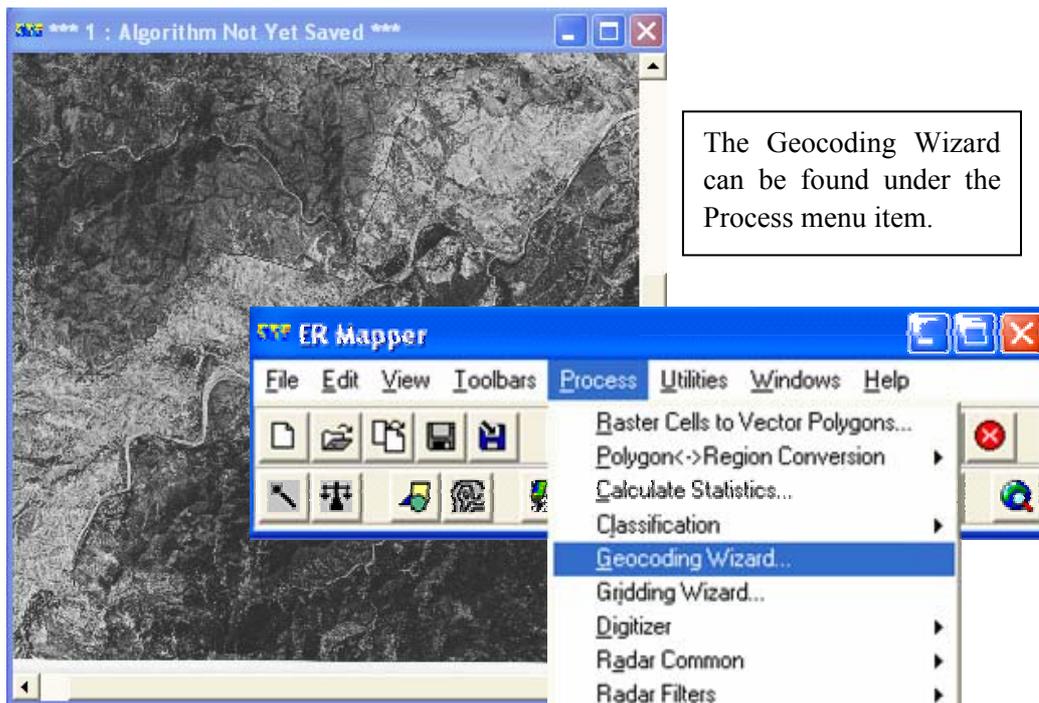
On Tab 1 select the input file. ER Mapper will not detect this from the open window and you must specify it separately. Then you must select the geocoding type. The critical choices are either polynomial or orthorectify. These options are displayed below.

Polynomial rectification is used for individually recorded points such as GPS data or points read off a map; whereas orthorectification requires a 3D model.
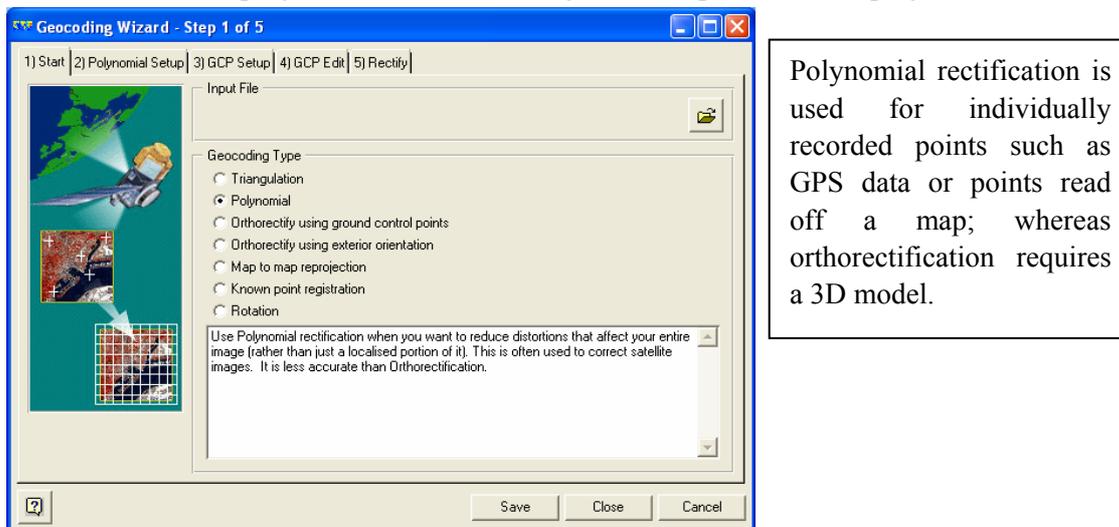
The most common choice when using GPS data is Polynomial. When this option is selected the wizard guides moves onto Tab 2.

Tabs 2 and 3
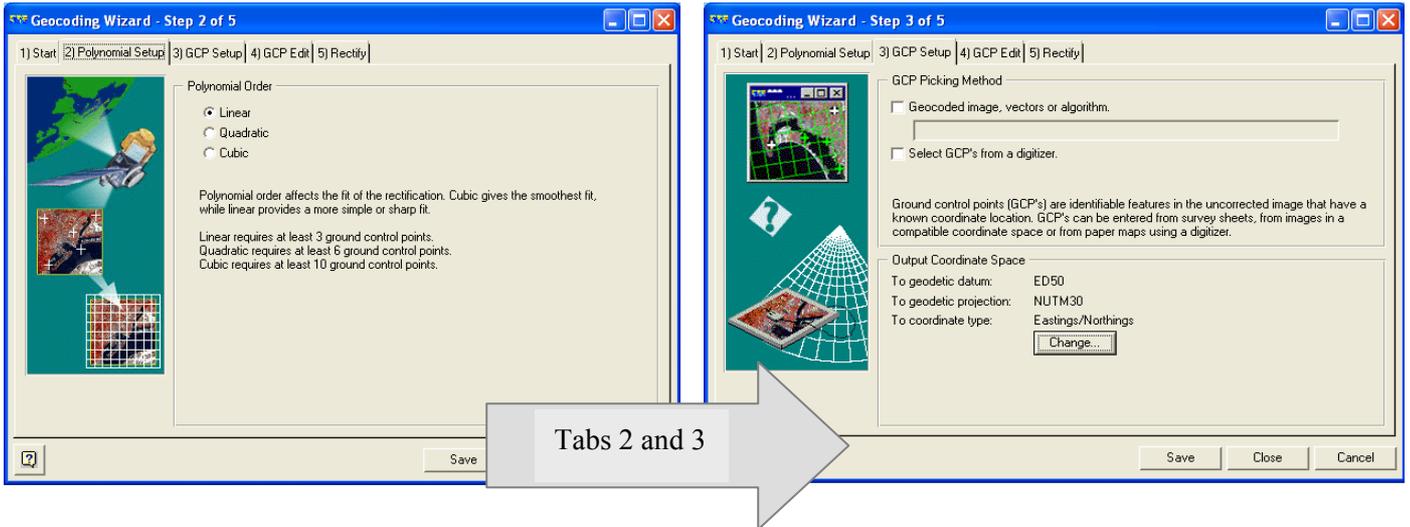
On Tab 2 the polynomial order is selected. A general equation for polynomial order is GCP+1*GCP+2 / 2. The reader is advised to read Chapter 9 to understand the different options available when rectifying data. This is only a brief walk-through of how one program handles the operations and the expedition needs to understand the concepts in detail so they can apply them across the board to any software they encounter. ER Mapper offers three degrees of transformation. A linear transformation requires 3 GCP, Quadratic requires 6, points and cubic requires 10 GCP. Select the transformation that matches the number of GCP recorded. Tab 3 determines the output co-ordinate types for the finished data. Though this might seem complicated at first, there are various options to help you. The projection defines the method of laying the 3D surface onto a 2D plane. The system defines how these co-ordinates are entered and the choices will be dictated by the maps or imagery the rectified data needs to be referenced against. In this case, a UTM projection for Spain is used. Tab 3 allows you to select the method for transferring your co-ordinates from your corrected data to your raw data. Select the Geocoded image, vector or algorithm dialogue and in the bottom half of the screen click 'change'. Then input the correct datum, projection and co-ordinate type. A co-ordinate space is defined by a datum, a projection and a system. The datum defines where the ellipsoid intersects the geoid. The projection defines the method of laying the 3D surface onto a 2D plane. The software delineates where and how these co-ordinates should be entered. Existing maps and imagery will largely dictate the choices made. In this case, a UTM projection for Spain is used. When an image is first brought into the system it has no co-ordinates and is described as being "RAW" data.
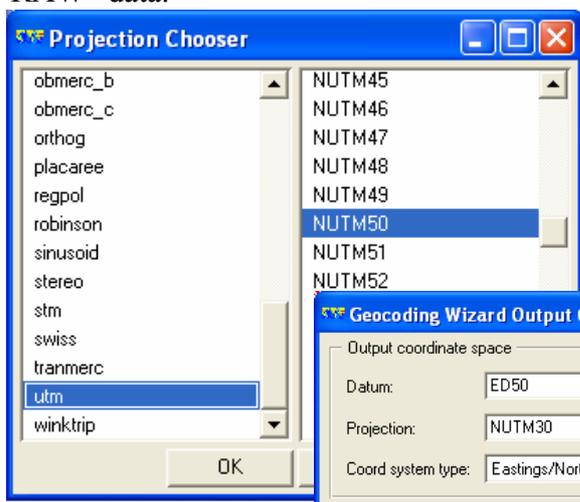
The choice of a projection, datum etc. will largely be determined for the expedition by existing maps etc. A full discussion on how to select this data is given in Chapter 2.

Once these decisions have been made the Ground Control Points can be added to the image and the GPS co-ordinates can be entered. GCPs can be added and manipulated at will. Each GCP will have an estimated RMS error. Try to keep these errors as low as possible but refer to Chapter 9 (especially Figure 9-18) to see the pitfalls when only relying on RMS. The error should preferably be around the error of your collected data, though this is not always possible. In this case, the GPS data has an error of around 10-20 m so the RMS errors should not be more than twice this level.
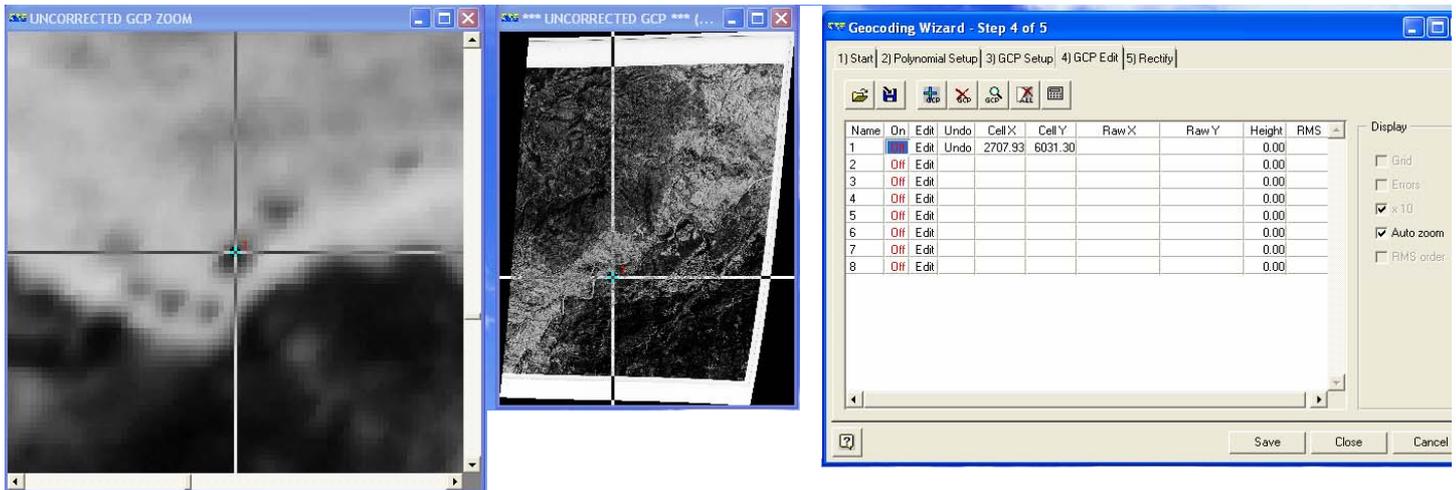
The finished project should look something similar to the table below:
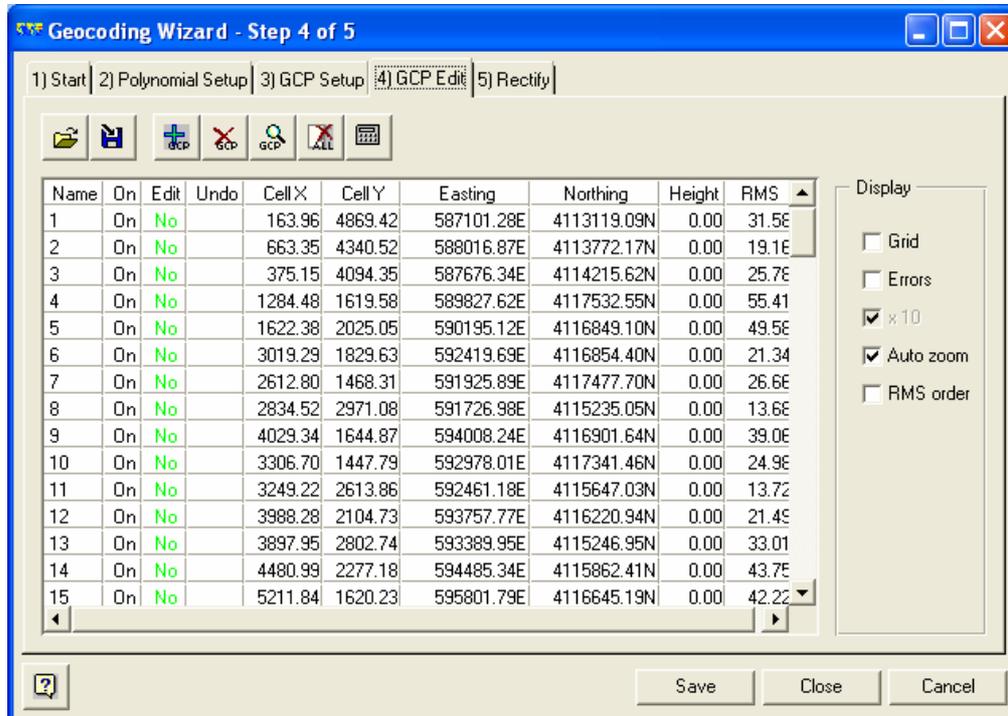
The data can then be used with other datasets such as SRTM to give perspective views or used with other 2D datasets to give change images.