Understanding GPS Processing and Results

Maxwell Owusu ANSAH, Ghana

Key words: Cadastre, Capacity building, CPD, Education, GPS, Positioning

SUMMARY

The use of Global Positioning Systems has undauntedly brought with it many welcome advances in its applications in surveying. The high accuracies achievable with the technology accompanied by its ability to overcome the age old problem of intervisibility have made GPS surveys a first choice for most surveyors. GPS accuracies and applications are increasing by the day.

The understanding of the physics of GPS working is of little concern to the surveyor, who most of the time does not interfere with the data capture. The non-interference of the surveyor as regards the capture of data deceives many surveyors into thinking that the GPS is error-proof as no human errors are incorporated (unlike say in a theodolite traverses). For the surveyor however, errors in any measurement and the reliability of any such survey measurement has to be evaluated and understood clearly.

There is the need for a clear understanding of the processing of GPS data and the results obtained from a GPS processing report. These results need to be interpreted rightly in order to give a clear understanding between the surveyor and the client and all users of the results.

Standards need to be developed quickly to meet the changing trends in GPS surveys if we are not be end up with very weak survey control networks, bad cadastre, boundary surveys, etc just because when the processing results were saying the result were bad, we just did not understand the report.

The surveyor clearly needs to be able to tell the difference between a bad GPS survey and a good one.

Understanding GPS Processing and Results

Maxwell Owusu ANSAH, Ghana

1. INTRODUCTION

The issue of standards is of paramount importance to the surveyor and with the ever increasing advancement of technology, surveys have become faster and milestone successes have been achieved. Some of the most important ones have come in the form of software which can greatly improve the speed of delivery and the GPS's ability to overcome the problem of intervisibility.
Such technological advances first have to stand the rigorous accuracy standards of the surveying however.
Standards are clear statements of the requirements of an acceptable survey. So we need to be clear of the accuracies that are needed and look out for these accuracies. We need these clear statements just as we need laws in a state to guard law and order.To the surveyor these lowing of standards will bring long with it:

- Weakening of the various survey networks,
- A cause for conflict along boundaries,
- Cost of redoing surveys etc.

Fortunately there are various indicators of the quality of a GPS survey and these indicators are a communicated through a number of reports generated by the GPS data processing software. Some of the main reports to be looked at are as listed below:

- Process Summary reports
- Repeat Vector Summary
- Loop Closure Summary
- Network Adjustment reports

These reports will be discussed and their indicators pointed-out.
Before that however the proper way of carrying out a good GPS survey on the field will have to be discussed.

2. PROCEDURES FOR FIELD WORK

The GPS generally follows many of the already established principles relating to survey methods as triangulation, trilateration, resection etc. Such principles as strength of triangles, good control network and proper setup of equipment over stations, are as important in GPS surveys as in any other type of survey. Other factors as ensuring a clear sky within the elevation mask to avoid multipath, keeping base lengths within distances where it can be safely assumed that all receivers receive signal that have gone through almost the same atmospheric conditions and therefore needing the same amount of correct need to be considered in GPS surveys.

It is important that a GPS survey has a minimum of two known points or controls to be used as checks of the reliability of results and every point will belong to a closed network linked to the known control point.

3. PREPROCESSING OF GPS DATA

This refers to all activities done before the actual processing of the data to obtain the final coordinates of the unknowns. Theses could range from the importing observed data into the processing software through editing of the station names, editing of coordinates, choosing the base or reference station to be used for the processing, specifying the type and height of antenna, editing of satellite data collected to the computation of the vectors. It is important to make this distinction between preprocessing and actual processing of data which ends with a constrained adjustment carried out on the unknowns. The erroneous application of the terms has resulted in the mistaken use of unadjusted coordinates in many instances.
After the preprocessing of the data, a report may be generated to give an indication of the type of solution reached. In the sample report (`in Courier New Font`) generated by a Sokkia post processing software, *Sokkia Spectrum Survey*, the first part (between the first two horizontal broken lines) indicates the project path and the type of coordinate system, the Datum, the units and date for the preprocessing. The second row gives the total number of vectors in the project. The third row gives a breakdown of the type of solution reached for the total number of vectors stated in the previous row. The last row gives an indication of the specific solution reached (Solution) for the individual occupations or vectors (vectors/occ), the various standard deviations (SD), Root Mean Square (RMS), the slant distances (Length) between occupations, the percentage of the data (Used) of the total collected for the particular occupation and the (Ratio) of best solution to the next-best solution.

```
Spectrum® Survey 3.51                                          PROCESS
SUMMARY
---------------------------------------------------------------------------
---
Project:             C:\...\Common\Spectrum Projects\Transformation 2.spr

Coordinate System:   ghTM [Transverse Mercator]      Datum:            GH
xyz
Geoid Model:         <None>                          Units:
Meters
Processing Date:     2005/05/13 18:29:58.96 (UTC)

---------------------------------------------------------------------------
---
VECTORS  [19 total]
---------------------------------------------------------------------------
---

Fixed: 14
Float:  5 (*)

Vector/Occ.     Solution               Length    Used   Ratio     RMS
SD
```

```
------------------------------------------------------------------------------
---
GRR 05 FTP1-GRR 05 FTP2
     01      Fixed (L1)             8960.016   99.04%    4.0   0.010
0.008
GRR 05 FTP1-GRR YSO 1
     01      Fixed (L1)             6619.008   97.85%    4.0   0.012
0.010
     02   *  Float (L1)             6619.473   40.73%          0.011
0.164
GRR 05 FTP1-GRR 05 FTP3
     01      Fixed (L1)             8896.303   93.04%    3.0   0.010
0.010
GRR 05 FTP1-GRR 05 FTP4
     01      Fixed (L1)               64.467   87.75%    4.1   0.010
0.011
CFP179-GRR 05 FTP2
     01      Fixed (L5 narrowlane)  4066.299   56.24%    5.4   0.006
0.016
     02   *  Float (L1)             4066.225   57.34%          0.007
0.076
     03   *  Float (L1)             4066.781   62.43%          0.010
0.139
CFP179-GRR YSO 1
     01   *  Float (L1)             3678.690   68.26%          0.009
0.097
     02      Fixed (L1)             3678.634   75.44%    2.0   0.010
0.010
     03   *  Float (L1)             3679.769   42.51%          0.011
0.130
GRR 05 FTP2-GRR YSO 1
     01      Fixed (L1)             2976.412   97.88%    4.4   0.008
0.008
     02      Fixed (L1)             2976.416   99.11%    8.3   0.009
0.008
     03      Fixed (L1)             2976.414   99.96%    5.2   0.007
0.006
GRR 05 FTP2-GRR 05 FTP3
     01      Fixed (L1)               63.701  100.00%    5.5   0.005
0.005
GRR 05 FTP2-GRR 05 FTP4
     01      Fixed (L1)             8895.652   92.73%    5.3   0.011
0.011
GRR 05 FTP3-GRR 05 FTP4
     01      Fixed (L1)             8831.931   96.15%    2.2   0.011
0.012
GRR 05 FTP4-GRR YSO 1
     01      Fixed (L1)             6556.714   93.68%    4.6   0.012
0.012
CFP179-GRR 05 FTP1
     01      Fixed (L1)             5752.912   86.16%    3.8   0.010
0.013
```

One of the more important features of this report is the type of solution reached which gives an indication of whether all the integer cycle ambiguities were solved. If all are solved the type of solution reached will be a Fixed one otherwise the solution is a Float. There we always want to see fixed solutions. Note that the SD of many of the fixed solutions is generally lower than those with float solutions. There are instances where SD of float solutions is less than some of those with fixed solutions.

4. TROUBLESHOOTING USING GPS REPORTS

We shall now take a closer look at some of the GPS software generated reports which can be used to find out blunders in observed vectors and also serve as a guide to understand the results obtained after the processing of the field data collected.

4.1 The Repeat Vector Summary

The repeat vector summary shows the variation in the slope distances changes in easting, northing and elevation of all vectors that have had multiple occupations. The maximum differences are shown below each line and this is a very good identifier of blunders which can be used to eliminate bad observations from the multiple observations.

```
Spectrum® Survey 3.51                                       REPEAT VECTOR
SUMMARY
-------------------------------------------------------------------------
---
Project:              C:\...\Common\Spectrum Projects\Transformation 2.spr

Coordinate System:    ghTM [Transverse Mercator]      Datum:            GH
xyz
Geoid Model:          <None>                          Units:
Meters
Processing Date:      2005/05/13 18:29:58.96 (UTC)
```

Vector/Occ.	Slope Distance(m)	dE(m)	dN(m)	dH(m)
GRR 05 FTP1-GRR YSO 1				
01	6617.115	-6584.102	-660.141	-5.197
02	6617.580	-6584.574	-660.091	-5.042
Max Diff.	0.465	0.472	0.050	0.155
CFP179-GRR 05 FTP2				
01	4065.042	4002.093	-657.085	-275.786
02	4064.968	4002.021	-657.085	-275.743
03	4065.524	4002.576	-657.088	-275.868
Max Diff.	0.556	0.555	0.003	0.125
CFP179-GRR YSO 1				
01	3677.557	2139.194	-2977.208	-290.705
02	3677.502	2139.098	-2977.211	-290.679
03	3678.636	2140.874	-2977.286	-291.197

Max Diff.	1.134	1.776	0.078	0.518
GRR 05 FTP2-GRR YSO 1				
01	2975.554	-1862.993	-2320.121	-14.814
02	2975.558	-1862.996	-2320.123	-14.931
03	2975.556	-1862.992	-2320.124	-14.858
Max Diff.	0.004	0.004	0.003	0.117

4.2 Loop Closure Summary

Loop closure can be a very important identifier of blunders. When closed loops are selected and their closures calculated, particular vectors can easily be identified as degrading the misclose and therefore eliminated from further adjustments. The precisions can easily be compared to the criterion for rejection and accepted or rejected accordingly.

Sample Loop Closure Report:

```
Spectrum® Survey 3.51                                           LOOP
SUMMARY
---------------------------------------------------------------------------
---
Project Name:      C:\Sokkia\Common\SPECTR~1\TRANSF~1.SPR

Coordinate System: ghTM [Transverse Mercator]      Datum:              GH
xyz
Geoid Model:       <None>                          Units:
Meters
Report Date:       2006/07/13 22:16:17 (UTC)

---------------------------------------------------------------------------
---

Loop Name:   Loop5
---------------------------------------------------------------------------
---
From     To       Occ    Soln        Slope          dE          dN
dHgt
---------------------------------------------------------------------------
---

GRRFTP4- GRRFTP2* 01     L1Fix    8893.099   -8386.711   -2957.996     -
23.389
GRRFTP2- CFP179   01     L5Fix    4065.042    4002.093    -657.085    -
275.786
GRRFTP1- CFP179   01     L1Fix    5751.141   -4444.992   -3637.330    -
295.794
GRRFTP4-GRRFTP1 * 01     L1Fix      64.448      60.388      22.263      -
3.361
                                ------------------------------------------
---
                            Closure  0.027      -0.014      -0.013      -
0.019
Total Segments:  4
```

```
Total Length:    18779.330
Precision:       1/688803 (= 1.45 PPM)

Loop Name:   Loop4
---------------------------------------------------------------------------
---
From     To       Occ    Soln        Slope          dE          dN
dHgt
---------------------------------------------------------------------------
---

GRRFTP4- GRR YSO1 01     L1Fix    6554.841   -6523.725    -637.876      -
8.462
GRR YSO1-GRRFTP2  01     L1Fix    2975.554   -1862.993   -2320.121     -
14.814
GRRFTP4- GRRFTP2  01     L1Fix    8893.099   -8386.711   -2957.996     -
23.389
                                 ------------------------------------------
---
                            Closure  0.113      -0.006      -0.001
0.112
Total Segments:  3
Total Length:    18428.778
Precision:       1/163785 (= 6.11 PPM)
```

In the above report the closure indicates the amount of adjustment to be applied to the various components to bring them to the ideal situation of no errors (mathematically at least) and thereby force a closure i.e closure values for all the components must be zero. It is clear from the above tables that the Loop4 has more errors (larger closure values) than Loop5 and may have blunder(s).

4.3 Network Adjustment

Network adjustment is carried out on the various networks observed in the project. At this stage the various loop closures are expected to be corrected for a mathematical closure and in doing so some vectors are moved. There are two kinds of adjustment namely the Free adjustment and the Constrained adjustment.

4.4 Free Adjustment

In this type of adjustment the internal consistencies of the survey is checked. This can also be a very good identifier of blunders. Only one measured control (three dimensional) is held fixed in this process which allows differences in observed values to be obtained as residuals, with the exclusion of errors between coordinates of other known points. The blunders identified in this process are excluded from the next stage of adjustment which is the constrained adjustment.

4.5 Constrained Adjustment

In a constrained more than one measured control (three dimensional) are held fixed and the coordinates of the unknowns are computed for. The unknowns are calculated for while the consistency in known values is still maintained.

4.6 Interpreting Adjustment Reports

The adjustment report is about the one most important report that could be generated at the end of a GPS survey processing. In the sample report below, some of the more important highlights are shaded and they are:

– The type of adjustment to specify the kind of adjustment being currently applied. In the current adjustment the type is constrained as two controls are held fixed to calculate the coordinates as it the unknown.
– The second is the summary of adjusted statistics which shows the numbers observations, unknowns, knowns and the redundancies and the number of iterations used.
– Next is the Chi Square Test on the Variance Factor which does a test on the hypothesis that the predicted error applied to each vector observation in the network is realistic, based on the adjustment. The predicted errors before adjustment are shown by the a priori variance. The test is done by a comparison of the a priori variance to the variance after adjustment called the A Posteriori. The closer the test result is to 1.0, the better the applied weight. However, a value below the test range does not necessarily mean that the GPS survey is bad but that the errors were estimated to be too high i.e. the precision of the survey is higher than initially assumed. On the other hand a value higher than the range although could mean that there are blunders still inherent in the survey, could also be revealing inconsistencies in the previous surveys from which coordinates of the controls were derived.

Sample Report:

```
Spectrum® Survey 3.50                                 Network Adjustment
Report
---------------------------------------------------------------------------
---
Project:           C:\Sokkia\Common\Spectrum Projects\Fig
Controls171205\191205ExpPts.spr

Coordinate System: GHTM [Transverse Mercator]        Datum:            GH
xyz
Geoid Model:       <None>                            Units:
Meters
Adjustment Time:   2005/12/19 10:57:33 (LOCAL)       Time Zone:
GMT+0.00h

---------------------------------------------------------------------------
---
Adjustment Type:                                       Constrained
Computation Level:                                  Full Adjustment

Additional Parameters:
```

```
   - Deflection of vertical (N-S)                        Not used
   - Deflection of vertical (E-W)                        Not used
   - Horizontal rotation                                 Not used
   - Scale difference                                    Not used
Iteration Criteria:
   - Maximum iteration                                          5
   - Maximum coordinate difference (m)                     0.0001

Reference Datum:
   - Datum Name                                            GH xyz
   - Semi-major axis (m)                              6378306.064
   - Flattening (m)                              1.0/296.002627791

Weight Options:
   - Use modeled standard deviations
   - Use individual weighting scale

Modeled Standard Deviations
   - X component                               5.0 mm +   1.0 ppm
   - Y component                               5.0 mm +   1.0 ppm
   - Z component                               5.0 mm +   1.0 ppm

Geoid Model:   NONE
   - Orthometric heights will not be computed

Transformation to Map Coordinate System     ...YES
   - System name                                             GHTM
   - System type                             Transverse Mercator
   - Linear unit                                           Meters
   - Parameters:  Latitude                    N  4 40 00.00000
                  Longitude                   W  1 00 00.00000
                  False Northing (m)                     0.000
                  False Easting (m)                 274320.000
                  Scale                                0.99975

   - Centroid:    Latitude                    N  6 20 39.52569
                  Longitude                   W  1 01 07.51356
                  Elevation (m)                        181.528

                  Northing (m)                      185470.972
                  Easting (m)                       272245.504
                  Combined Factor                   0.99972151

---------------------------------------------------------------------------
                       Summary of Adjustment Statistics
---------------------------------------------------------------------------
Number of Points:
   - Horizontal fixed & height fixed             2
   - Horizontal fixed & height free              0
   - Horizontal free & height fixed              0
   - Horizontal free & height free               6
                                             -----
                                        total    8
```

```
Number of Unknowns:
   - Latitude                                       6
   - Longitude                                      6
   - Height                                         6
   - Additional parameters                          0
                                                -----
                                    (a)   total   18
Number of observations
   - X component                                   24
   - Y component                                   24
   - Z component                                   24
                                                -----
                                    (b)   total   72

Number of Rank Defect               (c)             0
Number of Total Redundancy          (b)+(c)-(a)   54
Iterations Used                                     2
---------------------------------------------------------------------------
---
                   Chi Square Test on the Variance Factor
---------------------------------------------------------------------------
---

                  Total Number of Observations:       72
                  Redundancy:                         54
                  Confidence Level:                   95%
                  A Priori Variance Factor:           1.0000
                  A Posteriori Variance Factor (VF):  1.1591

               Chi Square Test on the Variance Factor (1.1591)
                          0.6584 < VF < 1.4128

   Standard Deviations for the observations are within the desired range.

 ** Note: The Standarded Deviation of Unit Weight is the square root of the
          Variance Factor.


---------------------------------------------------------------------------
---
                     Input Coordinates and Corrections
---------------------------------------------------------------------------
---
      Point       Input Coordinates       Corrections        Horizontal
                                        Seconds      m         Vector

100
                 P     6 20 35.14187   - 0.00082   -0.025      0.073 m
                 L  -  1 00 56.09626   - 0.00221   -0.068      250 deg
                 H         166.426 m                0.036

YSO2
                 P     6 20 31.07221   - 0.00024   -0.007      0.021 m
                 L  -  1 00 44.79524   - 0.00064   -0.020      250 deg
                 H         178.648 m                0.011
```

```
FJN4
                 P     6 20 57.69938   - 0.00125   -0.039      0.111 m
                 L  -  1 01 53.30096   - 0.00339   -0.104      250 deg
                 H         195.296 m                0.056

121
FIXED 3-D        P     6 20 23.38484     0.00000    0.000      0.000 m
                 L  -  1 00 21.84567     0.00000    0.000      0 deg
                 H         160.645 m                0.000

YSO1
                 P     6 20 32.68791   - 0.00031   -0.009      0.027 m
                 L  -  1 00 51.24661   - 0.00081   -0.025      249 deg
                 H         175.395 m                0.013

CMP1
                 P     6 20 59.78600   - 0.00037   -0.011      0.033 m
                 L  -  1 02 03.25490   - 0.00099   -0.031      249 deg
                 H         190.187 m                0.016

128
FIXED 3-D        P     6 20 59.74992     0.00000    0.000      0.000 m
                 L  -  1 02 15.67956     0.00000    0.000      0 deg
                 H         220.181 m                0.000

JNC
                 P     6 20 16.68342   - 0.00018   -0.005      0.015 m
                 L  -  0 59 53.88928   - 0.00047   -0.014      250 deg
                 H         165.443 m                0.008


---------------------------------------------------------------------------
---
                 Adjusted Coordinates and Standard Deviations
---------------------------------------------------------------------------
---
      Point     Adjusted Coordinates          Std Dev          95% Ellipse
                                         (0.001sec)  (mm)

100
                 P     6 20 35.14105      0.15310     4.7    major 11.5 mm
                 L  -  1 00 56.09847      0.15302     4.7    azm.  90 deg
                 H         166.462 m                         minor 11.5 mm

YSO2
                 P     6 20 31.07197      0.06620     2.0    major 5.0 mm
                 L  -  1 00 44.79588      0.06617     2.0    azm.  90 deg
                 H         178.658 m                         minor 5.0 mm

FJN4
                 P     6 20 57.69813      0.10014     3.1    major 7.5 mm
                 L  -  1 01 53.30435      0.10009     3.1    azm.  90 deg
                 H         195.352 m                         minor 7.5 mm
```

```
121
FIXED 3-D        P     6 20 23.38484      0.00000     0.0    major 0.0 mm
                 L  -  1 00 21.84567      0.00000     0.0    azm.  0 deg
                 H         160.645 m                         minor 0.0 mm

YSO1
                 P     6 20 32.68760      0.08133     2.5    major 6.1 mm
                 L  -  1 00 51.24742      0.08128     2.5    azm.  90 deg
                 H         175.408 m                         minor 6.1 mm

CMP1
                 P     6 20 59.78563      0.07702     2.4    major 5.8 mm
                 L  -  1 02 03.25589      0.07698     2.4    azm.  90 deg
                 H         190.203 m                         minor 5.8 mm

128
FIXED 3-D        P     6 20 59.74992      0.00000     0.0    major 0.0 mm
                 L  -  1 02 15.67956      0.00000     0.0    azm.  0 deg
                 H         220.181 m                         minor 0.0 mm

JNC
                 P     6 20 16.68324      0.11711     3.6    major 8.8 mm
                 L  -  0 59 53.88975      0.11704     3.6    azm.  90 deg
                 H         165.451 m                         minor 8.8 mm


---------------------------------------------------------------------------
---
                Transformation into Map Coordinates  (meters)
---------------------------------------------------------------------------
---
        Point       Geodetic Coordinate     Map Coordinate
Conv./Scale

100
                 P     6 20 35.14105     N      185336.306   -  0 00
06.19787
                 L  -  1 00 56.09847     E      272596.252
0.99975004
                 H           166.462

YSO2
                 P     6 20 31.07197     N      185211.334   -  0 00
04.94826
                 L  -  1 00 44.79588     E      272943.546
0.99975002
                 H           178.658

FJN4
                 P     6 20 57.69813     N      186029.124   -  0 00
12.53039
                 L  -  1 01 53.30435     E      270838.519
0.99975015
                 H           195.352
```

```
121
FIXED 3-D          P     6 20 23.38484     N      184975.246   -  0 00
02.41231
                   L  -  1 00 21.84567     E      273648.740
0.99975001
                   H           160.645

YSO1
                   P     6 20 32.68760     N      185260.955   -  0 00
05.66131
                   L  -  1 00 51.24742     E      272745.309
0.99975003
                   H           175.408

CMP1
                   P     6 20 59.78563     N      186093.251   -  0 00
13.63218
                   L  -  1 02 03.25589     E      270532.744
0.99975018
                   H           190.203

128
FIXED 3-D          P     6 20 59.74992     N      186092.181   -  0 00
15.00622
                   L  -  1 02 15.67956     E      270151.005
0.99975022
                   H           220.181

JNC
                   P     6 20 16.68324     N      184769.433      0 00
00.67453
                   L  -  0 59 53.88975     E      274507.753
0.99975000
                   H           165.451


---------------------------------------------------------------------------
---
                          Observations and Residuals
---------------------------------------------------------------------------
---
      Observations      Std Dev     Residuals    Standardized      PPM
          (m)             (m)          (m)         Residuals

Vector: 128-YSO2  weight= 1.00
  dN    -880.9046       0.0018       0.015        -1.839          3.441
  dE    2793.3738       0.0037       0.007         1.387          2.594
  dH     -42.1873       0.0074      -0.009         2.615 *        4.892

Vector: 128-YSO1  weight= 1.00
  dN    -831.2808       0.0063       0.013        -0.516          0.983
  dE    2595.0791       0.0061       0.006         1.078          2.058
  dH     -45.3539       0.0107      -0.001         2.508          4.785

Vector: 128-YSO2 Occ.[02]  weight= 1.00
```

```
  dN    -880.8893       0.0040      0.000         1.791         3.349
  dE    2793.3708       0.0049      0.011         1.891         3.537
  dH     -42.2055       0.0090      0.010         0.204         0.382

Vector: 121-CMP1  weight= 1.00
  dN    1118.2866       0.0045     -0.005        -1.980         3.337
  dE   -3116.8782       0.0069     -0.002        -0.405         0.682
  dH      28.7099       0.0098     -0.012        -1.113         1.875

Vector: YSO1-FJN4  weight= 1.00
  dN     768.3276       0.0045      0.004         2.032         4.372
  dE   -1907.3507       0.0057      0.004         0.960         2.067
  dH      19.6022       0.0080      0.009         1.090         2.349


Vector: 121-YSO2  weight= 1.00
  dN     236.1531       0.0012     -0.008         0.004         0.027
  dE    -705.3856       0.0021     -0.007        -1.538         9.690
  dH      17.9704       0.0085     -0.001        -1.702        10.725

Vector: 128-CMP1  weight= 1.00
  dN       1.0962       0.0022      0.002         1.988        23.393
  dE     381.8414       0.0045      0.005         0.965        11.357
  dH     -29.9981       0.0205      0.009         0.657         7.728

Vector: 121-YSO1  weight= 1.00
  dN     285.7827       0.0024     -0.004         0.723         3.460
  dE    -903.6763       0.0040     -0.008        -1.880         8.978
  dH      14.6898       0.0057      0.003        -0.883         4.220

Vector: YSO2-FJN4  weight= 1.00
  dN     817.9692       0.0025      0.000        -1.848         3.789
  dE   -2105.6404       0.0034      0.003         0.763         1.567
  dH      16.3019       0.0056     -0.009        -0.239         0.491

Vector: 121-FJN4  weight= 1.00
  dN    1054.1385       0.0027      0.002        -0.490         0.829
  dE   -2811.0129       0.0046     -0.009        -1.682         2.848
  dH      34.0017       0.0067     -0.002         0.375         0.636

Vector: 121-YSO2 Occ.[03]  weight= 1.00
  dN     236.1515       0.0025     -0.006        -0.141         0.887
  dE    -705.3871       0.0039     -0.006        -1.207         7.607
  dH      17.9709       0.0064     -0.001        -1.382         8.709

Vector: YSO1-CMP1  weight= 1.00
  dN     832.4664       0.0043      0.001        -1.419         2.888
  dE   -2213.2029       0.0067     -0.004        -0.851         1.730
  dH      14.3632       0.0101     -0.007         0.141         0.288

Vector: 121-CMP1 Occ.[02]  weight= 1.00
  dN    1118.2833       0.0024     -0.002         1.109         1.869

  * - Possible Outlier
 ** - Likely Outlier
```

Reliability of Observations

	Standard Deviations Corr Obs (mm)	Residuals (mm)	Redundancy	Reliability Internal	External
Vector: FJN4-100 weight= 1.00					
N	3.88	3.30	0.42	0.03	4.85
E	4.46	3.80	0.42	0.03	4.85
H	4.76	4.05	0.42	0.03	4.85
Vector: CMP1-100 weight= 1.00					
N	3.90	3.45	0.44	0.03	4.67
E	4.48	3.97	0.44	0.03	4.67
H	4.78	4.23	0.44	0.03	4.67
Vector: 121-YSO2 weight= 1.00					
N	1.80	4.47	0.86	0.02	1.66
E	2.07	5.14	0.86	0.02	1.66
H	2.21	5.48	0.86	0.02	1.66
Vector: 121-YSO2 Occ.[02] weight= 1.00					
N	1.80	4.47	0.86	0.02	1.66
E	2.07	5.14	0.86	0.02	1.66
H	2.21	5.48	0.86	0.02	1.66
Vector: YSO2-YSO1 weight= 1.00					
N	2.47	4.08	0.73	0.02	2.50
E	2.84	4.69	0.73	0.02	2.50
H	3.03	5.01	0.73	0.02	2.50
Vector: YSO2-CMP1 weight= 1.00					
N	2.24	4.87	0.83	0.03	1.90
E	2.58	5.60	0.83	0.03	1.90
H	2.75	5.97	0.83	0.03	1.90
Vector: 128-YSO2 weight= 1.00					
N	1.80	5.22	0.89	0.03	1.42
E	2.07	6.00	0.89	0.03	1.42
H	2.21	6.41	0.89	0.03	1.42
Vector: YSO1-FJN4 weight= 1.00					
N	2.96	4.22	0.67	0.03	2.90
E	3.40	4.85	0.67	0.03	2.90
H	3.63	5.18	0.67	0.03	2.90
Vector: CMP1-FJN4 weight= 1.00					
N	2.73	3.92	0.67	0.03	2.87
E	3.13	4.51	0.67	0.03	2.87
H	3.34	4.81	0.67	0.03	2.87

```
Vector: 121-YSO1  weight= 1.00
  N     2.21      4.32          0.79          0.02     2.12
  E     2.54      4.96          0.79          0.02     2.12
  H     2.71      5.30          0.79          0.02     2.12

Vector: 121-YSO1 Occ.[02]  weight= 1.00
  N     2.21      4.32          0.79          0.02     2.12
  E     2.54      4.96          0.79          0.02     2.12
  H     2.71      5.30          0.79          0.02     2.12

Vector: 121-CMP1  weight= 1.00
  N     2.09      5.32          0.87          0.03     1.63
  E     2.41      6.12          0.87          0.03     1.63
  H     2.57      6.53          0.87          0.03     1.63

Vector: 128-YSO1  weight= 1.00
  N     2.21      4.96          0.83          0.03     1.84
  E     2.54      5.70          0.83          0.03     1.84
  H     2.71      6.08          0.83          0.03     1.84

Vector: YSO1-CMP1  weight= 1.00
  N     2.60      4.59          0.76          0.03     2.34
  E     2.99      5.27          0.76          0.03     2.34
  H     3.19      5.63          0.76          0.03     2.34

Vector: 121-JNC  weight= 1.00
  N     3.18      3.64          0.57          0.03     3.61
  E     3.66      4.19          0.57          0.03     3.61
  H     3.91      4.47          0.57          0.03     3.61

Vector: YSO2-JNC  weight= 1.00
  N     3.22      3.84          0.59          0.03     3.47
  E     3.70      4.41          0.59          0.03     3.47
  H     3.95      4.71          0.59          0.03     3.47


---------------------------------------------------------------------------
---
                              Relative Precision
---------------------------------------------------------------------------
---
  Ellip. Dist.
  Height Diff.                     Relative
    Azimuth          Std Dev       Precision             95% Ellipse
      (m)             (mm)

Vector: YSO2-YSO1  weight= 1.00
     204.404           2.8        Hor. 1/73374         major 6.8 mm
      -3.250           2.8        Ver. 1/73372         azm.  90 deg
 284 03 06.9           2.8sec                          minor 6.8 mm

Vector: YSO2-CMP1  weight= 1.00
    2567.691           2.5        Hor. 1/1014499       major 6.2 mm
      11.545           2.5        Ver. 1/1014470       azm.  90 deg
```

```
 290 05 31.6          0.2sec                          minor 6.2 mm

Vector: YSO2-JNC  weight= 1.00
    1625.835          3.6       Hor. 1/446759         major 8.9 mm
     -13.207          3.6       Ver. 1/446747         azm.  0 deg
 105 46 26.4          0.5sec                          minor 8.9 mm

Vector: YSO2-FJN4  weight= 1.00
    2258.864          3.2       Hor. 1/714422         major 7.7 mm
      16.694          3.2       Ver. 1/714400         azm.  90 deg
 291 13 46.0          0.3sec                          minor 7.7 mm


 Desired Network Accuracy was met for all Vectors
```

5. CONCLUSION

There is the need for the surveyor and the users of GPS survey data to have a basis of accepting and rejecting a GPS survey result as these results are clearly not sacrosanct. There is the need to know what to look out for in the various GPS reports and keep the surveyor on his toes to keep the survey standards high.

REFERENCES

Bomford, Guy, 1980, Geodesy: Clarendon Press, Oxford, 4th ed.
Point, Inc., 2003, Spectrum Survey Reference Manual.

BIOGRAPHICAL NOTES

Academic experience: BSc. Geodetic Engineering, Kwame Nkrumah Univ. of Science & Technology, Kumasi, Ghana.
Current position: Ag. Survey Manager, Geotech Systems Ltd.
Practical experience: Cadastral surveying, mapping, Engineering Surveys, GPS Surveys / Training.

CONTACTS

Maxwell Owusu Ansah
Geotech Systems Ltd.
27 Samora Machel Rd
Asylum Down, Accra
GHANA
Tel. +233 24 4810288
Fax + 233 21 236475
Email:max.ansah@geotechsys.com
Web site: www.geotechsys.com