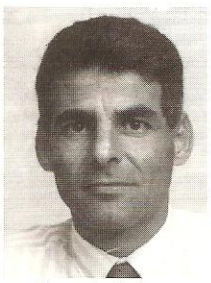
Peter Dare



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Malta - A New Precise Network

The principal objective of Project Malta'93, organised by students from the Department of Land Surveying, University of East London, was to establish a new primary network spanning the three main islands. This article outlines the Global Positioning System (GPS) work carried out as part of the project and the subsequent heighting of points by the Republic of Malta's Mapping Unit.

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The Republic's Mapping Unit was only created in 1988 and so all previous control was established by foreign agencies. The US Defense Mapping Agency was the first to use satellites when it fixed Luqa Barracks using Doppler in 1973. In 1988, the Institut Geographique National of France carried out some GPS work (see Figure 1) written up by Le Pape and Carnino. Racal Survey Limited have positioned a number of points using GPS. They have also computed precise coordinates for Luqa Barracks on World Geodetic System 1984 (WGS84) and also on International Earth Rotation Service Terrestrial Reference Frame 1991 Epoch 1992.5 (ITRF91 Epoch 1992.5).

Various terrestrial surveys were carried out in 1896, 1928 and during the second world war. In 1900 a connection from Sicily to the islands of Malta and Gozo was observed. A complete retriangulation of Malta took place during 1955 and 1956 to provide control for new 1:2500 mapping. In 1968 the Directorate of Overseas Surveys (DOS) provided control, through a network of over 80 stations, for aerial photography so that new contoured maps could be produced. This DOS work and previous survey work is documented in detail in a 1973 RICS thesis by Ian Logan.

It is the survey work of 1955, 1956 and 1968 that defines the existing network for Malta. A total of 13 existing points evenly spread across the republic were included in the new network.

Network Design

A network of 26 stations was designed based around a requirement for intervisibility. Thus the network stations were predominantly on roof tops or hill tops with one station being on the top of the lighthouse on Gozo (see Figure 2). This necessity for using roof tops sometimes caused access problems. The choice of location for the stations was usually quite easy due to the lack of tree cover which could have obstructed the GPS signals (see Figure 2).

For the GPS section of the work 61 baselines were measured including 3 long baselines to improve the overall accuracy of the solution in scale and orientation,(see Figure 3). None of the stations established by Racal Survey Limited were fully incorporated into the new primary network as they were not intervisible and the precise station mark could not be identified.

A mask angle of 10° and an epoch interval of 15 seconds was used. Values for temperature, pressure and humidity were obtained from the Malta Meteorological Office at Luqa at 3 hourly intervals throughout the period of work.

A plot showing the Geometric Dilution of Precision was produced to check suitable times for using the GPS equipment (see Figure 4). This indicated that GDOP was lower than 8 at all times of the working day. Simultaneous observations were to be made for about 20 minutes on each baseline.

For the heighting, 4 traverses were carried out. One traverse connected Malta, Gozo and Comino. Another 2 traverses heighted points on Malta and Gozo. The final traverse

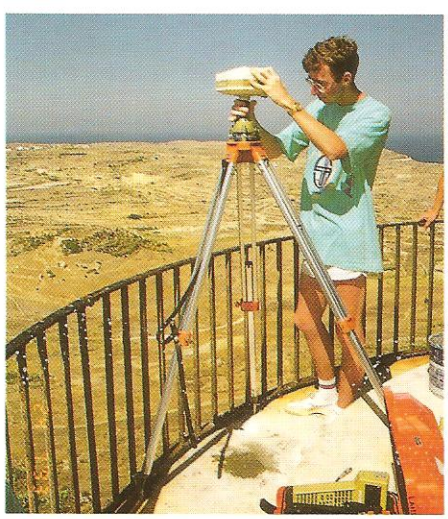

Figure 1, *Observation points from IGN's work carried out in 1988 (from Le Pape & Carnino)*

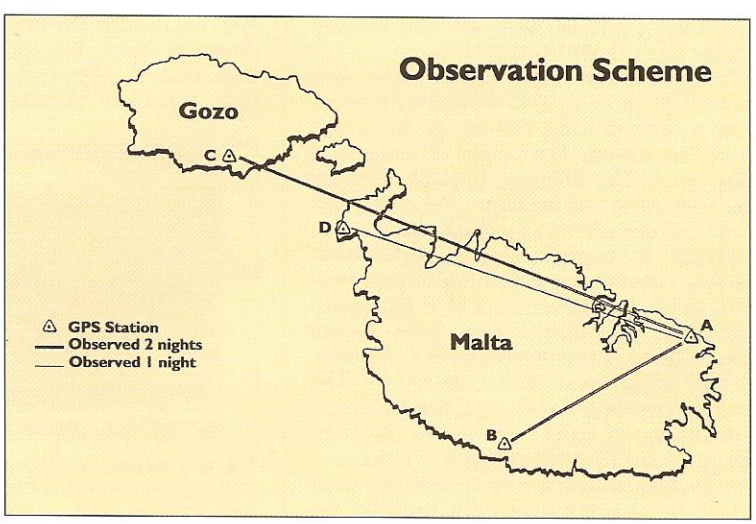

Figure 2, *GPS at the network station on top of the Gordon Lighthouse on Gozo*

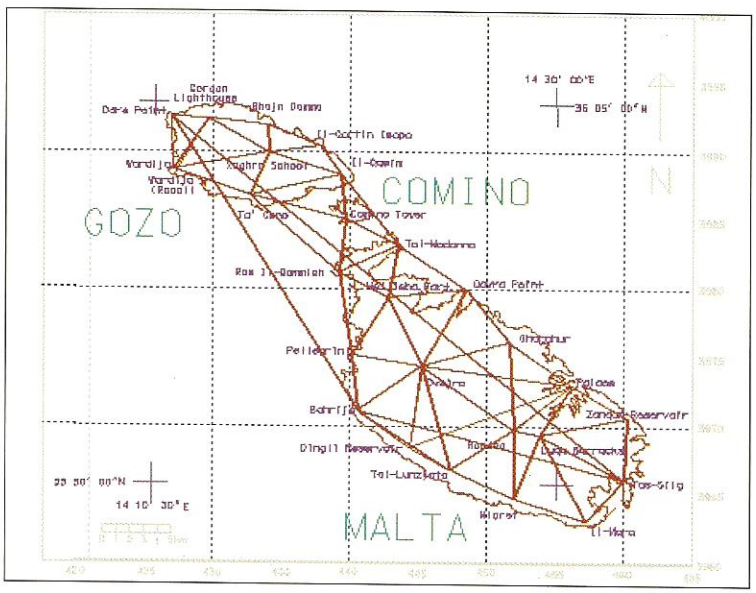

Figure 3, The adopted network design used 61 baselines

heighted the point on the top of the school building at Xaghra on Gozo.

Equipment

The GPS work used Leica dual frequency System 200 GPS receivers. As some of the points were on roof tops ladders were needed. Communication was maintained by the use of hand held transceivers. For the heighting the following equipment was used: 2 Wild T2 Theodolites, 1 Wild DI 3000 EDM, 3 Wild halogen lamps as targets, 2 pocket barometers (direct reading to 1Mb), 2 thermometers (direct reading to 1° Celsius, 2 steel tapes, 1 special ruler 2 hand held transceivers.

Heighting Observational Procedures

The procedure used was simultaneous reciprocal vertical angles. As 0.0005 grades, on a distance of 1km, results in a displacement of approximately 1cm, at least five angles having residuals less than 0.0005 grades had to be measured. On the longest lines, and on lines across water, this was not always easy to achieve. For example, between Qawra Point and Tal-Madonna a total of 15 sets had to be observed due mainly to excessive shimmer; problems were also encountered on the line Tal-Madonna to Il-Qasim.

The theodolite was setup slightly higher than normal. A second tripod was set underneath and a halogen lamp centred on this tripod over the station. The height of target was now taken. The difference in height between the instrument and the target was also measured and this served as a check against misbooking. Although, ideally, the angle observations should have taken place around midday, this was not always possible, but no observations were made before 10am. Angles were observed simultaneously by 'counting down' using hand held transceivers. The transceivers were usually operated by the assistants and in some cases by the observer, using a voice operated switch (vox) unit.

Six individual distance measurements were made by re-collimating each time on the prisms that replaced the halogen lamp. Pressure and temperature readings were made at the start and end of the distance measurement operation.

Processing and Analysis

The GPS processing was carried out in a baseline-by-baseline approach starting from Luqa Barracks using the Leica SKI software. The WGS84 value of Luqa Barracks was that supplied by Racal Survey Limited.

All baselines were processed using the SKI default processing parameters, which included a mask angle of 15°. With these parameters the integer ambiguities for all baselines less than 20km in length were successively resolved. The met. values have not yet been included in any of the computations but the results should be acceptable due to the stable climate, shortness of the baselines and small changes in height over the survey area.

Least-squares was then used to produce the final coordinates with Luqa Barracks held fixed. Ignoring Wardija (Racal) the largest horizontal absolute error ellipse semi-major axis is 0.012m. This is at Dare Point which is to be expected as this is one of the furthest point from Luqa Barracks. Again ignoring Wardija (Racal) the largest height standard deviation from the GPS observations is 0.017m at Wardija. It should be emphasised here, especially with regards to the height, that these figures relate to the precision of the GPS results and not their accuracy.

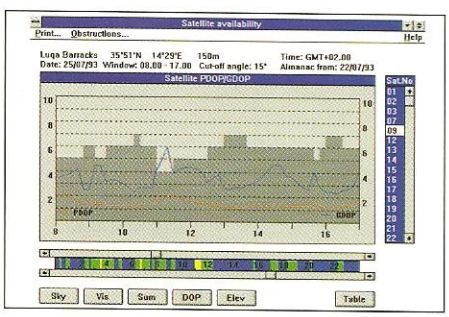

Figure 4, Geometric Dilution of Precision (GDOP) was lower than 8 at all times in the period 0800 to 1700

The coordinate system used by GPS is WGS84. Coordinates, however, were required in ED50 and ITRF91 (Epoch 1992.5). The GPS coordinates resulting from the least-squares adjustment were therefore converted to the required datum by standard datum transformation procedures.

Based upon procedures published by the Japan International Co-operation Agency, the permissible misclosure accepted for trigonometrical levelling of first order points, in cm, was taken as:

$$\pm 1.5 \sqrt{\Sigma S^2_i}$$

where S_i is the length of leg i in km, and the summation is over the total number of legs in the traverse. From the results shown in Figure 5 it is clear that the trigonometrical levelling is within the specifications for first order work. However, it can be seen that the obtained misclosure for Traverse 4 is close to the permissible misclosure. The observations to Xaghra School have therefore been repeated and the final misclosure obtained was 0.6cm.

For the least-squares estimation of the heights the 4 traverses were combined to form one integrated network in which 3 stations were held fixed. The largest height standard deviation was 0.033m at Dare Point.

	Distance (km)	Misclosure (cm)	Permissible misc. (cm)
Traverse 1	10.57	0.8	9.66
Traverse 2	31.79	8.7	18.37
Traverse 3	30.65	6.2	16.34
Traverse 4	5.39	4.3	5.94

Figure 5, Preliminary results of trigonometrical levelling

Conclusions

A new precise network for the Republic of Malta has been created by a combination of GPS and trigonometrical heighting. Coordinates on WGS84, ITRF91 (Epoch 1992.5) and ED50 are available. A distance comparison with Racal work showed agreement of 0.017m which equated to 0.67ppm. Comparisons with the work of the IGN have also been made with acceptable results. Further work (e.g., incorporating meteorological data, use of precise ephemeris) may modify slightly the GPS derived coordinates.

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