SPACe PHOTOGRAPHY AND NAUTICAL CHARTING

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Abstract

Photography from Space has been used successfully by the Hydrographic Department in order to resolve some long standing positional discrepancies on Admiralty Charts.

Spacelab photography represents an important new source for small scale chart compilation and revision, offering significant advantages over both conventional air photography and other forms of satellite imagery.

Traditional stereoplotting equipment can be used for processing purposes. The vast area covered by a single frame and excellent clarity in the coastal zone enable offshore reefs and islands to be correctly positioned in relation to the mainland.

Case studies are presented involving Metric Camera photography of Northern France, Belize and the Red Sea. Results from Large Format Camera photography of Southern Oman are also discussed.
INTRODUCTION

The worldwide requirement for topographic mapping at 1:50,000 scale is well known. The nautical chart compiler is also frequently faced with the problem of inadequate data, particularly in remote areas. Photogrammetrists and cartographers have waited a long time for a space system capable of meeting these needs.

In late 1983 and in 1984 two photographic missions were flown on the Space Shuttle – the European Metric Camera and the US Large Format Camera – to test the potential of spaceborne metric stereo photography.

The European developed Metric Camera was carried on mission STS 9 in November/December 1983. A total of 350 colour infra-red and 470 black and white photographs were obtained. Many of the photographs were of exceptional quality but due to the time of year there was often excessive cloud cover and low sun illumination at the northern limits of the flight. The 23 x 23 cm photographs give a ground coverage of 190 x 190 km at an image scale of 1:820,000.

The NASA Large Format Camera was flown on mission STS 41C in October 1984. In all 2160 black and white, natural colour or colour infra-red photographs were obtained. The resolution is superior to that of the metric camera as a result of the provision of forward motion compensation. The 23 x 46 cm photographs (long dimension in the direction of flight) give a ground coverage of 170 x 340 to 285 x 570 km at image scales of 1:730,000 to 1:1,230,000.

This space photography represents an important new source for small scale nautical chart compilation and revision offering significant advantages over both conventional air photography and other forms of satellite imagery.

Traditional stereo plotting equipment can be used for processing purposes. The vast area covered by a single frame together with the extremely high resolution and excellent clarity in the coastal zone enable accurate positions to be determined for offshore reefs and islands.

Space shuttle photography of Northern France, Belize, the Red Sea and Oman has been examined in the Hydrographical Department. These examples serve to illustrate the particular advantages and limitations of space photography when applied in the context of nautical charting.

THE LE HAVRE STEREOPAIR

The Metric Camera mission on Spacelab 1 was the first time that a calibrated photogrammetric camera had been used in space and it was therefore necessary to select a suitable test area for initial evaluation of the photography. Ideally such a region would have a clearly defined coastline, a considerable amount of cultural detail and excellent map coverage at 1:50,000 scale. Having established the potential for accuracy here work could then concentrate on one of the many areas where source data for charts compilation was deficient. (3)

A stereopair of infra-red colour photographs was considered covering an area in North Western France to the south of Le Havre. The area was ideal for test purposes with a wealth of fine detail visible on the photography. Good quality ground control was available in the form of IGN mapping.

A major advantage claimed for space photography is that of extremely high resolution. (5) Detailed examination of the French stereopair has confirmed this to be the case. It was encouraging to find that coastal features showed up particularly well. Both natural coastlines and artificial developments were generally distinct despite the low sun angle and unfavourable illumination. In the vicinity of Le Havre the Antifer...
development was very clearly defined as were similar features at Dieppe. Numerous other smaller harbour constructions were apparent. The rectilinear lines of wharves and docks stood out well at Le Havre and Rouen and individual buildings could be distinguished together with the tanks at Honfleur on the southern bank of the Seine. The river itself was a very distinct feature together with major tributaries and numerous small drainage channels.

Problems tended to arise inland particularly in rural areas where it was difficult to identify even road intersections with any degree of certainty. This is not likely to concern the nautical chart compiler whose interest in topographic detail diminishes rapidly as distance inland increases.

The photography was examined using traditional photogrammetric equipment comprising an Officine Galileo G6 stereoplotter linked to a Hewlett Packard 9826 desk top computer and Wild TA/TA table.2

Relative orientation was carried out without difficulty. However, the process of absolute orientation was complicated by the effect of earth curvature. This assumes considerable significance at a photoscale of 1:820,000 and as a result points given equal elevations in a ground co-ordinate system do not have the same heights in the model.

The system of ground co-ordinates used must take account of this and a geocentric system was considered to be the most appropriate. Having obtained geocentric co-ordinates a program was written for the HP 9826 computer in order to carry out a transformation between the model and geocentric co-ordinate systems. This involved a scaling, rotation and translation in three dimensions. The rotation was orthogonal so that no deformation was introduced. Seven transformation parameters were computed by an iterative process which was greatly facilitated by good initial approximations for scale and rotation angles. Model co-ordinates could then be converted to the geocentric system and finally to UTM co-ordinates for plotting.

Co-ordinates generated as the operator scanned the model were converted by the computer to ground co-ordinates and transmitted to the TA table in appropriate units. The HP 9826 computer is powerful enough to carry out these calculations with the required degree of efficiency for real time plotting.

The results achieved with the Le Havre stereopair are summarised in Table 1. Accuracies of 30m to 40m were obtained in plan co-ordinates. These results were based on 43 control points well distributed over the model area. Plots produced, on line, at scales of 1:50,000 and 1:250,000 on transverse mercator projection agreed closely with IGN topographic maps. Heighting accuracy was less impressive and was generally worse than 100m.

An interesting fact to emerge was that earth curvature does not appear to have any significant effect on planimetric accuracy. The model was levelled approximately using points of known elevation around the periphery and a two-dimensional transformation of the Helmert type was computed between model co-ordinates and ground control in a UTM system. Ground co-ordinates were derived for the same 43 check points as before yielding a similar order of accuracy in plan. (Table 1). A plot at 1:250,000 scale, covering the whole model area, was produced with no attempt to correct for earth curvature and gave a close fit to the IGN mapping.

The analog model formed using the G6 plotter was based on a principal distance setting of 152.5 mm constrained by the mechanical limitations of the instrument. The principal distance of the metric camera is 305 mm which necessitates a suitable adjustment to all Z model co-ordinates. This approximation introduces an important
source of error if the photographs are tilted. In order to check the validity of the results obtained from the Le Havre analog model, relative orientation was carried out twice analytically using picture co-ordinates measured on a stereo comparator. An affine transformation was employed in order to correct for the effect of film distortion. The models were based on principal distances of 305 mm and 152 mm respectively. Both analytical models, based on 21 well distributed control points, gave the same degree of accuracy as that achieved with the analog model. Plan co-ordinates were acceptable for charting purposes but heighting accuracy was very poor. (Table 1)

SPACE PHOTOGRAPHY AND NAUTICAL CHARTING

Hydrographer’s basic aim is to maintain the Admiralty chart series in an accurate, adequate and up to date condition. However, resources available to hydrographic surveyors do not match this immense task. Only 20% of the UK continental shelf has been surveyed to full modern standards. A further 20% has been surveyed by echo sounder but not fully examined by sonar and 60% has been surveyed by lead line only or remains unsurveyed. Comparative figures for the rest of the world are not available but in many cases the situation is even worse and it is still true to say that some of the world’s largest vessels pass through waters which were last surveyed more than 100 years ago or indeed which have never been surveyed. Spacelab photography may have an important role particularly in the charting of more remote areas where conventional aerial photography is unlikely to be available. The vast area covered by a single stereomodel means that islands and other offshore features may be accurately positioned in relation to the main land. Extensive stretches of coastline may be plotted correctly, perhaps for the first time.

Belize in Central America and Mohammad Qol in the Red Sea are two areas which illustrate the potential of Metric Camera photography for small scale charting. Southern Oman was selected as a test area for the evaluation of Large Format Camera photography.

(1) BELIZE

Extracts from Admiralty charts showing Lighthouse and Glover Reefs in the vicinity of Belize are shown in figs 1 and 2. Although modern conventional air photography is available there is no ground control and hence no means of locating the reefs in relation to the mainland. The charts are based on 19th century surveys and ships reports have indicated that the reefs are mischarted by up to one nautical mile. A stereopair of black and white Metric Camera photography was available and absolute orientation based on 10 control points yielded planimetric accuracies of around 40m. The pecked lines in figs 1 and 2 show the reef edges as derived from the Spacelab photography. Not only has this photography enabled Lighthouse and Glover reefs to be accurately positioned it has also provided a means of controlling the larger scale air photography which may then be used for detailed plotting. These results provide confirmation of the ships reports and also show close agreement with those obtained from Landsat multispectral scanner (MSS) imagery using GEMS image processing equipment at the Royal Aircraft Establishment, Farnborough (1).

In addition to superior resolution a major advantage of Spacelab photography over digital forms of satellite imagery is the possibility of using traditional stereopliners. Specialisation of image processing facilities may well lie beyond the scope of a small photogrammetric department.

(2) MOHAMMAD QOL

Spacelab Metric Camera photography of Mohammad Qol in the Red Sea has also been examined. This area has the all too frequent conjunction of increasing maritime traffic and old inadequate surveys.
Absolute orientation based on 10 control points gave planimetric accuracies of around 88 metres and a detailed plot of coastline and offshore detail was produced at a scale of 1:250,000.

An important aspect of hydrographic photogrammetry using conventional aerial photography is the measurement of depths in areas of clear shallow water and accurate heighting in the intertidal zone. The desired accuracy of ± 0.5m is clearly not possible with a photoscale of 1:820,000. Nevertheless where water clarity permits, as in the Red Sea, it is possible to identify and accurately define the extent of submerged features considered to be dangerous to navigation.

The Mohammad Qol coastline derived from Metric Camera photography did not differ significantly from existing mapping but a much improved depiction of offshore reefs and shoals was achieved.

(3) THE LARGE FORMAT CAMERA - OMAN

An area in Southern Oman extending from RA's Mab to RA's Fararah was selected for the purpose of evaluating the potential of NASA Large Format Camera photography for nautical charting purposes.

Two stereopairs of black and white photography were examined, deriving control from modern 1:100,000 mapping. Absolute orientation based on 7 control points gave planimetric accuracies of 24 metres and 35 metres respectively. A plot produced at 1:250,000 scale on transverse mercator projection gave an excellent fit to the maps.

The provision of forward motion compensation appears to have had a beneficial effect on overall resolution. The coastline was very sharp as were a variety of natural features such as watercourses and escarpments. Roads, tracks and settlements were clearly defined and a vast amount of detail was visible under magnification.

The central 23 cm x 23 cm section of each frame was selected from the overall 23 cm x 46 cm format in order to accommodate the photography on a Wild A8 stereoplotter. The full scenes must have at least 75% forward overlap in order to achieve complete stereo coverage along strips when central sections are used. The Oman photography had 80% overlap and therefore presented no problem. Unfortunately about 40% of the total Large Format Camera coverage has either 70% or 60% forward overlap and is unsuitable for use with an analogue plotting instrument.

CONCLUSIONS

The value of Spacelab photography in a Hydrographic context has been clearly demonstrated. Its greatest potential appears to lie in the resolution of positional discrepancies and as a source for charting new developments in the absence of alternative information.

Planimetric accuracies achieved using Metric Camera and Large Format Camera photography are in general more than adequate for chart scales of 1:100,000 and smaller. In practise the opportunity to significantly improve a chart in an area where source data is particularly deficient will often take precedence over any rigid requirements for absolute accuracy.

The very small photoscales of space photography prevent the measurement of drying heights or depths. However as shown in the cases of Belize and the Red Sea where water clarity permits shoals and reefs may be identified and accurately mapped.

The compiler of topographic maps from space photography may well be frustrated by the difficulty experienced in distinguishing some inland cultural features. Fortunately from the hydrographic point of view the coastline is inevitably distinct, and usually the most clearly defined feature.
Spacelab photography should no longer be considered as an 'experiment' as far as small scale nautical charting is concerned. The greatest need is for more coverage. "On the Metric Camera mission within 4 operating hours 11 million Km² of the Earth's surface was photographed, 70% of which was suitable for mapping. This amounts to 5% of the land surface of the earth in a single experimental mission. A repeated use of photogrammetric cameras on subsequent shuttle missions can therefore gradually acquire a global image archive (Konecny)" (4).

It remains to be seen what impact recent events will have on the Space Shuttle programme but it is to be hoped that mapping cameras are given high priority on future flights.

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ACKNOWLEDGEMENT

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Investigations of Metric Camera Data Quality University of Hanover. Commission 1 WG 1/1
TABLE 1

Accuracies achieved using Metric Camera photography of Northern France:

<table>
<thead>
<tr>
<th>Model</th>
<th>System of Ground Co-ordinates</th>
<th>No of Points Used</th>
<th>rmse (m)</th>
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<tbody>
<tr>
<td>Analogue</td>
<td>Geocentric</td>
<td>43</td>
<td>28 28</td>
</tr>
<tr>
<td>Analogue</td>
<td>UTM</td>
<td>43</td>
<td>29 27</td>
</tr>
<tr>
<td>Analytical</td>
<td>Geocentric</td>
<td>21</td>
<td>31 44</td>
</tr>
<tr>
<td>(f = 152mm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analytical</td>
<td>Geocentric</td>
<td>21</td>
<td>32 43</td>
</tr>
<tr>
<td>(f = 305mm)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Fig 1

An extract from Admiralty Chart No 959 showing Lighthouse Reef in the vicinity of Belize. The pecked line indicates the reef edge as determined from Spacelab photography. Planimetric accuracy of about 40m was achieved.

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An extract from Admiralty Chart No 1797 in the same sea area is Fig 1. The use of Spacelab photography has enabled the position of Glover Reef to be determined as is shown by the pecked line. Planimetric accuracy is in the order of 40m.