REMOTE SENSING: A TOOL FOR TOPOGRAPHIC MAPPING PAST PRESENT AND FUTURE

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Abstract. Remote sensing a tool capable of generating vast amounts of spatial data. Although the term remote sensing is generally taken to refer to the acquisition of data from satellite platforms, it has most usefully been used by map makers when acquired from lower altitudes. Satellite remote sensing has nevertheless been used for topographic mapping purposes since the launch of ERTS-1 in 1972. Since that time, it has variously been described as "offering real opportunities to the cartographer" [1] and "a tool that has failed to deliver" [2]. This paper will examine ways in which satellite remote sensing has been used in the past, during the present and attempts to forecast developments in the future. It will concentrate on those systems for which data was, has, or will be readily available rather than discussing the 'experimental' programmes.

1. INTRODUCTION

Throughout the history of map making, surveyors and cartographers have continually strived to improve ways of both acquiring and presenting data. Traditional methods of land surveying offer techniques that are capable of a very high degree of accuracy, but are rarely capable of generating sufficient data to allow map makers to keep pace with an ever changing landscape. Historically, most developments in mapping techniques have followed the requirements of the military and, with the development of 'scientific' warfare, accurate maps were needed to support the requirements of new methods of warfare.

A 'new' method of data acquisition emerged with the invention of photography and the development of a platform to allow a phenomena to be observed and recorded from a distant vantage point. Shortly after the invention of photography, a French geodesist advocated its use as an aid to topographic mapping, whilst in 1858, another Frenchman, Laussedat, used a system of kites to produce the first 'aerial photographs'. Aerial photography was also used during the American Civil War in 1862 by the Union Armies to obtain information of land and troop displacements. Also during this period, plans were being made by the Royal Engineers to link together tethered balloons and photography to provide data to allow rapid sketches to be made of battle fields [3].

The next stage in the evolution of remote sensing came with the evolution of powered flight, the first recorded example of a photograph taken from an aeroplane by Wilbur Wright, of Centocelli, in 1909. The first known aerial photographs to be taken for mapping purposes were of Benghazi, taken by Captain Tardivo in 1913. The Great War (1914-1918) brought great advances in the development of powered flight, the development of special aerial cameras, photographic interpretation and the development of the fundamental principles of photogrammetry. It also brought about a greater awareness of the benefits of aerial photography as a mapping tool as well as providing a pool of trained personnel, many of whom were later to pioneer the use of aerial photography for civilian mapping purposes.

Between the two World Wars many technical and scientific developments took place, but the advances of photogrammetric mapping were relatively slow, partly due to resistance by traditional map makers but also because of imperfections in both equipment and techniques. It was during this period that much important development work took place in the application of radar - principally by Britain, Germany and the USA.

The Second World War (1939-1945) formed the major impetus for the development of remote sensing as it is currently recognised. During this period, great developments were made in high altitude powered flight, improved photogrammetric instrumentation, imaging radar, thermal imaging, rocketry, and the development of electronic computing. Many of these developments were improved and refined during the 'Cold War' and have eventually been made available to the civilian mapping sector.

2. THE EARLY YEARS

Satellite remote sensing first provided sufficient quantities of data for potential topographic mapping purposes with the launch of ERTS-1 in 1974. Prior to that, the appetites of the mapping community had been whetted by the limited availability of S-190A and S190-B satellite photographs from the Skylab mission of 1973 [4,5]. Although the resolution and geometric fidelity of the imagery was sufficient to permit 1:200,000 to 1:250,000 topographic mapping [6,7], its lack of geographical spread meant that it could be virtually dismissed as a source of data for general topographic mapping.

ERTS-1 was never designed as a cartographic system but nevertheless, the virtually global availability of data, derived principally from the Multispectral Scanning System (MSS) created intense interest on the part of the mapping profession. A great deal of experimental work was initially carried out, particularly in the generation of image maps, the first of which was of the Lake Tahoe area of the USA at a scale of 1:1,000,000 in September 1974. This was actually derived from data acquired two days after the launch of ERTS-1. Other early image mapping projects included gridded and cartographically enhanced image maps of Chesapeake Bay and New Jersey at 1:500,000 which went on public sale in 1974 [8].

Early investigation of the geometric and cartographic accuracy of MSS data suggested that it had sufficient geometric fidelity to meet National Map Accuracy Standards for mapping at 1:500,000 [9, 10]. The interpretation of linear features and mapping from this data was far less satisfactory. Whilst image maps were capable of depicting a general impression of an area, a topographic map of the corresponding area can only be produced if line and point symbols can be consistently detected form the imagery. Unfortunately, the resolution and nature of the raster data was generally too poor to consistently map those features normally represented on a standard topographic map of a similar scale. In some instances, particularly with high contrast linear images such as drainage networks and motorways, features with a width considerably less than the resolution of the data (79 m) can be detected [11], whilst in low contrast areas similar features will be impossible to detect. One of the great potential uses for satellite imagery was in the production of up-to-date topographic maps of remote parts of the world. Unfortunately, most of the features required to be included on maps of this type (the man-made infrastructure) proved to be very difficult to detect in a consistent manner and local settlements, particularly when constructed from local materials, could only be identified by their ring of cultivation [12]. The general experience of ERTS (Landsat) MSS data was generally unsatisfactory because of its low resolution and inability to consistently detect and identify the main cultural features within the landscape [6].

A significant advantage of MSS data was to allow the creation of cloud-free, digital mosaics of large areas of land [13]. The relatively low resolution MSS data was geometrically corrected and 'stitched together' to form a data set that could be conveniently handled. Such digital mosaics have formed the basis of atlases in which land areas can be systematically portrayed using satellite data [14].

3. THE YEARS OF DEVELOPMENT

This period can be defined as that leading to the consolidation of remote sensing as a true source of data for topographic mapping purposes. Although the Landsat (ERTS) MSS was still generating data, it had been supplemented by two other, potentially valuable sensors - the Landsat Thematic Mapper (TM) and SPOT HRV. With the launch of Landsat-4 and -5 (1982 and 1984), the mapping community had at last a source of remotely sensed data with an acceptable spatial resolution (30 m). Such a resolution enables the data to be used for 1:100,000 image mapping purposes [15], two such examples being the enhanced digital image maps at 1:100,000 of Berlin and Bârîs (Egypt) by the Technical University of Berlin [16]. Many other maps of similar scales have now been produced.

For conventional topographical mapping purposes, the relationship between the pixel size of TM data and the identification of topographic features remains relatively poor. Where a good contrast exists, such as a road or a water feature against a background of vegetation, the feature can be easily identified. There is a similar level of inconsistency to that found in MSS data and is particularly noticeable in the representation of road networks in built-up areas [17,18]. Despite these drawbacks, TM data has been used extensively for a variety of primary mapping purposes and for both direct map revision and change detection [19,20]. An important factor, however, which limits the effective use of TM data for primary topographic mapping purposes is its lack of true stereographic cover [21,22].

A further source of data, made available during this period, was the space photography of the Metric and Large Format Cameras (MC and LFC) carried by the Shuttle during 1983 and 1984, respectively. An extensive evaluation programme suggested both sources of data could satisfy the demands of 1:100,000 mapping but owing to the experimental nature of the missions and the limited geographical availability of data, it has been of very little practical use [23,24].

Although the greatest impetus for readily available satellite imagery had come from the USA, it was a French led consortium which provided the first 'high' resolution data available for topographic mapping purposes - SPOT. With this satellite, the spatial resolution of the two identical High Resolution Visible (HRV) sensors is 20 m or 10 m, depending upon their mode of operation. Furthermore, the sensors were capable of providing the first consistently available stereographic imagery. SPOT-1 was launched in 1986 following a long series of feasibility studies. During a pre-launch meeting, experts were sufficiently confident in the expected quality of the data to forecast that it would allow the production of image maps at 1:25,000 from the 10 m resolution data and contoured topographic maps (contour intervals between 40 and 50 m) at scales between 1:50,000 and 1:250,000 [25]. One of the first major topographic mapping projects to be completed using SPOT imagery was by the Ordnance Survey, when 10 m resolution stereographic imagery was used to map inaccessible parts of Yemen. The scale of the line mapping was 1:100,000 with a 40 m contour interval. Subsequent tests proved that there was no difference between the mapping derived from SPOT imagery and conventional aerial photography [26,27,28]. Further evidence of the viability of SPOT data were evidenced in tests in which the detail plotted from 10 m SPOT imagery was compared with Ordnance Survey 1:50,000 and 1:25,000 maps. In the case of the 1:50,000 comparison, some of the detail (rivers and canals) was 100% complete, whilst the lowest level of completeness was for minor roads and tracks (24%). With the 1:25,000 comparison the percentage of features extracted ranged between roads (89% complete) to tracks (50%) complete

[29]. These levels of completeness would suggest that with SPOT 10 m resolution imagery, the mapping community have at last a satellite remote sensing tool that is capable of producing imagery with sufficient resolution for medium-scale topographic mapping.

The final source of satellite imagery to be considered during this broad period is the Russian space photography. The resolution of this imagery ranges between 10-15 m (MKF-6M camera) to between 5-10 m resolution (KFA-1000 camera). This type of imagery was used for the production and revision of topographic maps in the former German Democratic Republic and the generation of image maps between 1:500,000 and 1:50,000. KFA-1000 imagery has proved suitable for 1:25,000 map revision using conventional photogrammetric techniques [30].

4. THE FUTURE

In many respects, the future of topographic mapping from remotely sensed data is already with us! Russian imagery from the KVR-100 camera is capable of generating panchromatic imagery with a 2 m resolution. These images can be enlarged up to scales of 1:10,000 without significant loss of quality. Images can be delivered on film, as paper prints and as digital data [31].

Although the Landsat programme has suffered serious problems, with the loss of Landsat-6, the initiative for high resolution satellite images may once again pass to the USA with three companies being licensed to provide 1 m(?) resolution imagery (Worldview, Lockhead and Eyeglass) [31]. Both Landsat-7 and SPOT-5 are planned to have an improved resolution sensor.

Given that SPOT, with its 10 m resolution imagery is capable of meeting most of the demands for topographic mapping (at least as far as 1:100,000), it therefore seems likely that the improved resolution sensors of the future will be capable of enhancing the ability of remote sensing as a means of providing an increasing amount of data for topographic mapping purposes.

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