

# THE USE OF SATELLITE IMAGES IN PREPARATION FOR THE ESTABLISHMENT OF INTERNATIONAL BOUNDARIES

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## ABSTRACT

Within the stage of boundary creation and drafting of border treaties or agreements, the boundary engineer is serving as technical adviser to the negotiator (statesmen, lawyer, politician,) of the treaty or the agreement. One essential tool of the boundary engineer is the use of satellite images which would serve as an illustration and sometimes update of the real situation on the ground. Satellite images can be an essential resource at the negotiating table and revise existing maps or serve as map substitutes in poorly or even non mapped areas. In this case however annotated images should be used and may be extremely helpful. In addition recent satellite data contains much information missing from the maps or other descriptive materials, such as details of agricultural activities, density of trees, existence and course of waters, temporary structures, such as ditches and fences, destroyed buildings, or even dismantled roads, which would serve as prove of sovereignty during negotiations and decision making and the writing of the treaty or agreement between countries involved.

Satellites images are also one of the best means to ensure that the decisions of negotiators are transformed to the ground in the demarcation and delineation stages.

This paper will reflect to the practical experiences which have been made in writing and implementation of the international boundary treaty between the Kingdom of Saudi Arabia and the Republic of Yemen. The work shown here will focus on the use of rectified satellite images in the delimitation stage, for reconnaissance tasks (office and field), and the production of “fly through’s” for the border area. The latter proved as very useful. During the negotiations and decision making they could be used as confining tools, supporting the formulations in the writing of the treaty, like adding some clauses on the modification of the border line, when it passes through villages. Further essential applications of satellite data concentrated in survey demarcation and delineation tasks, photo control planning and map production of the unmapped areas of the treaty. A small scale mapping was agreed upon for regions outside the area covered by aerial photography. Quite a number of factors effect the considerations to use the satellite imagery in the large scale boundary mapping such as the size of the area, its topography and environment, the technical characteristics of the final product and its accuracy limitations, the availability of image data and last not least the cost of the data required. In conclusion the principal advantage of satellite images in international boundary application tasks is their availability on a commercial basis without the well known problem of getting authorization in over- flying certain territories or censorship of any kind. Examples will be shown that demonstrate the importance of such tools bringing the terrain to the negotiating table and enabling the enhancement of existing GIS, maps or map substitutes in poorly or unmapped areas.

# 1 INTRODUCTION

## 1.1 INTERNATIONAL BOUNDARIES GENERAL DEFINITIONS

During the preparation and drafting of any treaty or agreement of international boundaries, there are many terminologies which are commonly used and should be distinguished such as Delimitation, Demarcation, and Delineation. They appear in many stages of establishing the international boundary, and their definitions are found in [1,5] and many literatures as follows:

Delimitation is the legal process by which two sovereign nations establish and describe in writing the location of their common boundary, mainly as the output of the decision making on the negotiation table.

Demarcation is a field operation. Its purpose is to mark the position of the Boundary on the ground so it is visible to all, and this normally starts by surveying which is the initial stage of demarcation. The objective of demarcation is to place or adopt physical marks that accurately represent the location of a delimited boundary. Wherever possible, demarcation by artificial marks should consist of monuments placed directly on the boundary line (see figure 1). A joint commission, composed of an equal number of members from each country, normally undertakes the physical Demarcation.



*SUBSIDIARY POINT S(304)B SAUDI SIDE*

*SUBSIDIARY POINT S(304)B YEMENI SIDE*

Figure 1: Monumentations as tool for boundary demarcation

Delineation is the graphical or mathematical representation of the boundary. Quite frequently, a joint commission undertakes both demarcation and delineation. The Commission's published results consist of reports, photographs and other illustrations, maps, and tables showing geographic positions of boundary monuments and survey control stations used for the entire period of field work.

In this way delineation is the comprehensive description of the entire demarcation and mapping activities that is able to document the boundary for future reference.

## **1.2 SAUDI YEMENI INTERNATIONAL BOUNDARY TREATY.**

The creation of an international border between countries is one of the most important elements in the development of peace between countries[6].

On June, 12th, 2000, the Kingdom of Saudi Arabia and Republic of Yemen, signed the International Boundary Treaty that was the culmination of negotiations which began in the 1930s. The preparation of the international treaty from the engineering point of view went through some technical input information processes such as maps, reports, satellite images, office and field reconnaissance. At the negotiation of the treaty it was agreed to start with a common line map at scale of 1:1.000.000 which was prepared using satellite images (LANDSAT) for the desert and open area in the Empty Quarter. For inhabitant and mountainous areas French SPOT images and Russian satellite images (KVR 1000, TDK 350) were used.

Delimitation line was defined through political negotiations. This line acts as a guide line to the field team to enable them to proceed in the general direction and aid to define the boundary during the field reconnaissance of the land boundary aiming to identify the locations for all boundaries markers for constructions during the demarcation stage of the treaty. The satellite images were used also for production of "fly through's" for selected areas within the border. They proved as very useful during negotiation to support the formulations in the writing of the treaty. The annotated satellite images were also used in the writing of some clauses on the treaty for the modification of the boundary line when it passes through villages. More than fifty villages were affected by the border line and problems were solved during the demarcation stage.

The process of demarcation and delineation Saudi and Yemen was started by establishing a joint technical committee which includes technical experts mainly in surveying, monumentation, and mapping. They were responsible for executing the treaty in its framework. The treaty extended in geodetic lines connecting boundary points (main boundary points), identified by coordinates in the World Geodetic System 1984 (WGS 84) with a total length of the land boundary of 1326.6 KM with 667 boundary markers. The maritime boundary extends from the land terminus into the Red Sea along latitude and geodetic lines connecting two further points defined by the coordinates, from the last point the line continues parallel to the latitude until the end of the boundary between the two countries.

The final products of the demarcation were printed line maps with orthophoto background in a corridor which according to the technical specifications had to be mapped by photogrammetric services. The satellite images were used as background showing topography and height features in the areas of non-photogrammetric mapping (outside corridor). These products were required as attachment to the treaty. In addition to the printed paper maps, digital data sets were prepared to be used in Geographical Information Systems (GIS).

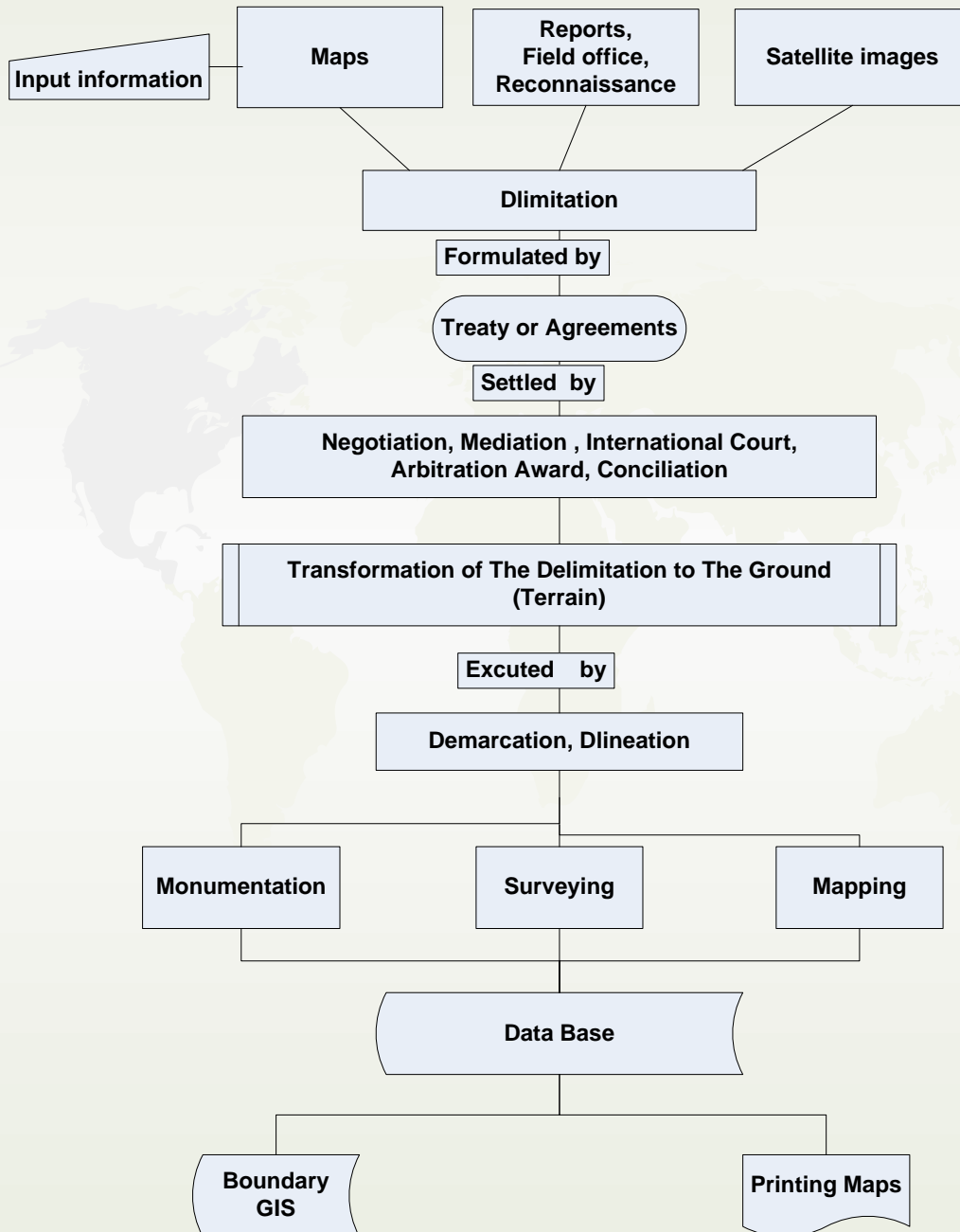
Figure 2 shows the process of the establishments of international boundaries.

## **2 THE USE OF SATELLITE IN THE PREPARATION OF THE BOUNDARY TREATY BETWEEN KINGDOM OF SAUDI ARABIA AND REPUBLIC OF YEMEN.**

High resolution satellite images have been used to detect environmental changes on the earth surface, a topic which plays an important role in territorial negotiations, by providing boundary negotiators a means to better assess on ground conditions that could affect the delimitation (such as avoidance of intersecting villages and properties by the boundary line).

Satellites data are accepted as legally binding proof [4], and there are many cases where satellite images were used in international court of justice (ICJ) e.g. in the Qatar /Bahrain case, Nigeria, Cameroon, and more...

Figure 2: The process of the establishments of international boundaries.



## 2.1 SATELLITE IMAGES USED

Satellite images such as LANDSAT were used for the production of preliminary map scale 1:1.000.000 which was the common initial planning map between the two countries. The work shown here will focus on the use of rectified satellite images in the delimitation stage, for reconnaissance tasks (office and field), and the production of “fly through’s” for the border area. For certain areas Russian Satellites KVR 1000 and TDK 350 were used for production of maps of scale 1:50.000 and also for photo interpretations during the office and field reconnaissance. An important application of the use of satellite images was the production of fly through’s. The satellite sensor for this application was SPOT. A corridor of about 4 km was selected, and then the control data and DTM were gathered from available digital information which also was used for the production of 1:100.000, and 1:250.000 maps. The software used was the ERDAS program. At that time we had big problems handling the huge amount data due to the limitation of the Computers capacity which is not a problem nowadays. An example of the fly through is given in figure 3.

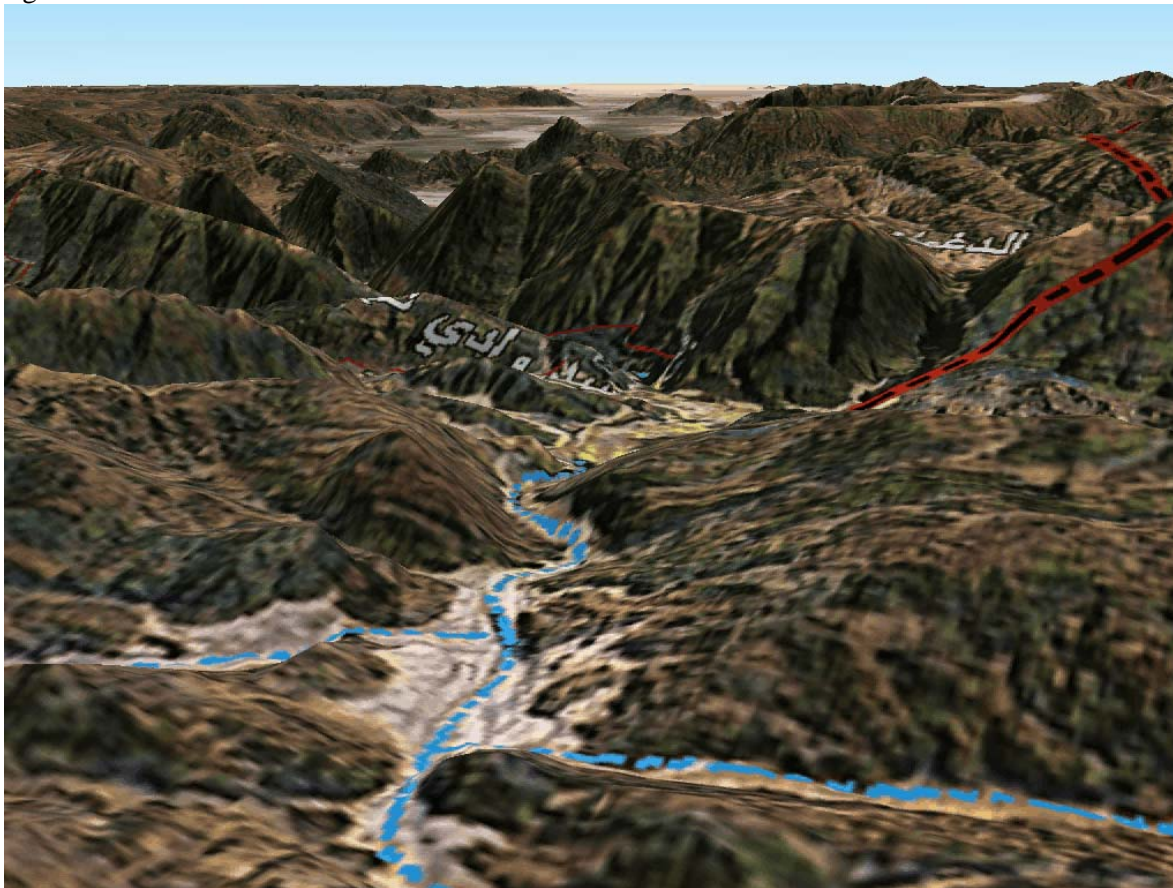


Figure 3: Example fly through

The “fly-through’s” proved as a very useful convincing and confining tool supporting the formulations in the writing of the treaty, like adding some clauses on the modification of the border line, when it passes through villages, and where modification to the treaty had to be done. In accordance with paragraph (a) of Article 2 of the International Border Treaty the delimitation of the

Borderline had to be modified in case that any of the coordinates was located in positions of villages of one of the two Countries. While field works were underway a Committee was formed by the two Countries (Joint Committee for the Execution of Paragraph A of Article 2 of the International Border Treaty between the two Countries) to investigate concerned Border Marker locations. The Committee decided to add a total of 9 Main Border Points in relevant positions and to modify the positions of 62 Main Border Points.

### 3 THE USE OF SATELLITES IMAGES IN IMPLEMENTATION OF THE TREATY

Further essential applications of satellite data concentrated in survey demarcation and delineation tasks, photo control planning and map production of the unmapped areas of the treaty. A medium to small scale mapping was agreed upon for regions outside the area covered by aerial photography.

The Technical Specifications clearly separate between photogrammetric mapping and non-photogrammetric mapping in documenting the International Borderline between the Kingdom of Saudi Arabia and the Republic of Yemen. The separation is by intended mapping scale, as shown below in figure 4. The corridor zone was mapped by photogrammetric mapping, the outer area was done using satellites images or other sources (see table 1). Guidelines for map making have been defined and applied to each individual border map series.

Photogrammetric mapping scales	Non-photogrammetric mapping scales
1: 10.000	1:200.000
1: 25.000	1:250.000
1: 50.000	1:500.000
1: 100.000	1:1.000.000

Table 1: Mapping Scales and Methods used

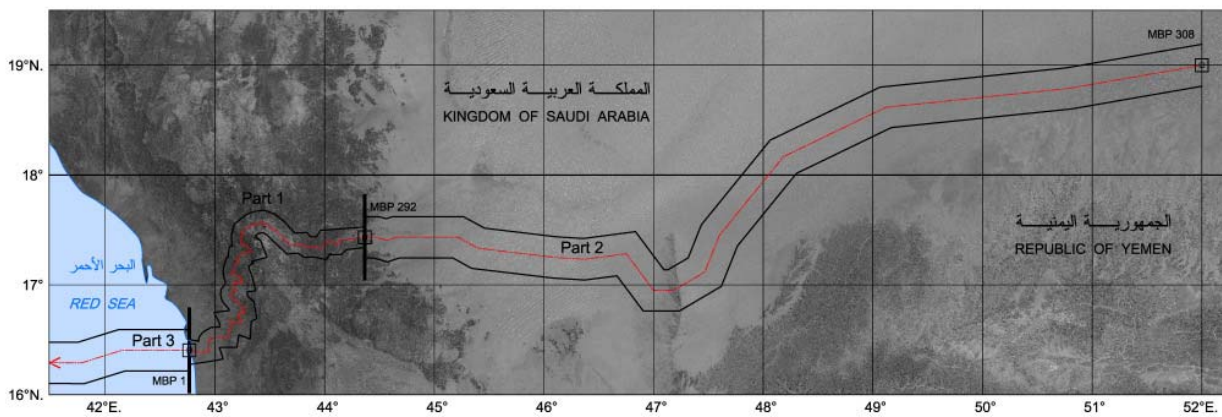


Figure 4: The indicated corridor zone



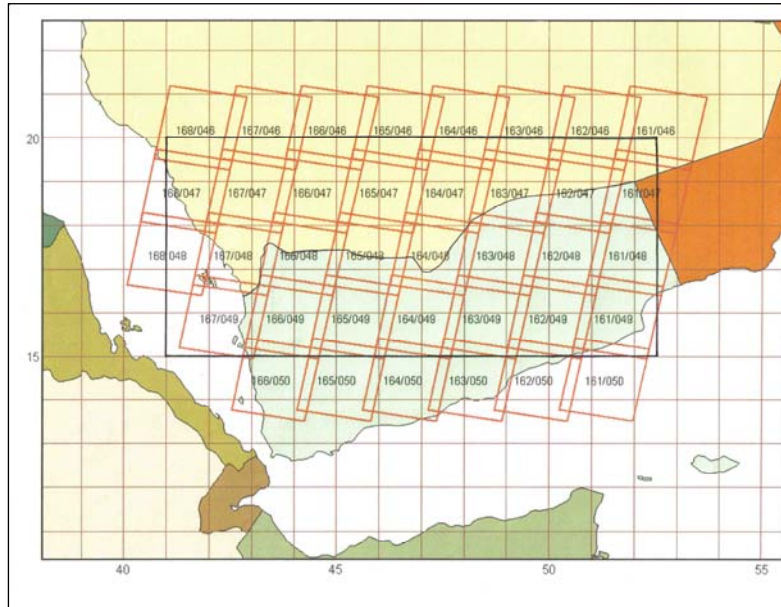


Figure 5: Landsat 7 ETM+ satellite coverage of the border area

Investigations have been done by Hansa Luftbild [2] to choose the most suitable satellite sensor for providing images for the production and background to the medium to small scale border maps ranging from 1:200.000 to 1:1.000.000, the LANDSAT 7 Enhanced Thematic Mapper Plus [ETM+] was chosen. The LANDSAT series of satellites provides one of the most extensive global imagery archives. No other system matches LANDSAT's combination of synoptic coverage, high spatial resolution, spectral range and radiometric calibration. The raw image data are available in digital format.

The band considered most suitable for image mapping of the small scale border maps was the panchromatic band, providing good detail definition at 15m ground sampling distance. The following criteria were considered for the selection of satellite scenes:

- full coverage of the area to be mapped
- same season for acquired images
- cloud-free coverage
- recent coverage
- acquisition of each image data set at similar sun elevation angles.

As a result, 36 Landsat 7 ETM+ panchromatic scenes were chosen (see figure 5). The maps for the chosen area were produced according to the technical specifications in the treaty.

Quite a number of factors effect the considerations to use the satellite imagery in the large scale boundary mapping such as the size of the area, its topography and environment, the technical characteristics of the final product and its accuracy limitations, the availability of image data on time, and last not least the cost of the data required .

#### **4 CONCLUSIONS**

The principal advantage of the satellite images in boundary applications is their availability on commercial basis with out problem of over flying certain territories or censorship of any kind. Satellites images application for international boundaries is important tools which bring the terrain to the negotiating table and enhance existing maps or map substitute in non mapped or poorly mapped area.

The used of satellite images gave the decision makers the possibility and confining support during the formulations in the writing of the treaty between kingdom of Saudi Arabia and Yemen to add clauses to solve the problem when the borderline cross villages.

Satellite images have proven a cost effective for the production and background of the medium to small scale border maps.

#### **LITERATURE**

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