1.0 Introduction

On September 27, 2003 Nigeria proudly joined the elite club of nations who own and operate spaceborne remote sensing satellite systems. On that very day Nigeria made an indelible historic inroad into the annals of time following the successful launch of her first ever satellite (NigeriaSat-1) in Plesetsk, Russia. NigeriaSat-1 was one of the seven Earth Observation Satellites (EOS) launched worldwide in 2003.

One of the major factors that necessitated the putting into orbit of NigeriaSat-1 by the Nigerian government was the felt need to rapidly provide environmental data for various mapping purposes. Till date a critical and comprehensive evaluation of the actual economic benefits of the NigeriaSat-1 project in general, and its cartographic benefits in particular, is yet to be done. No doubt it would prove to be a worthwhile exercise to objectively appraise the real contributions of the NigeriaSat-1 venture to the growth and development of the Nigerian economy. While we await that desirable economic appraisal, this paper is primarily concerned with a technical assessment of the usefulness of NigeriaSat-1 imagery for cartographic applications. The paper further highlights some of the strengths and shortfalls of NigeriaSat-1 image data in relation to various mapping purposes. Some suggestions are also made towards improving the utilization of the satellite data for mapping in particular and national development in general.

2.0 The Satellite

NigeriaSat-1 is a passive, camera-based remote sensing system. It is equipped with Normalised Differential Vegetative Index (NDVI) technology that enables it to give early warning signals of natural and environmental disasters. NigeriaSat-1 is one of the spacecrafts in the Disaster Monitoring Constellation (DMC) consortium. Apart from Nigeria, other countries that are part of the DMC international partnership are United Kingdom, Algeria, China, Turkey, Vietnam, and Thailand. All the satellites in the DMC group have similar characteristics. Moreover, by the agreement binding them, any country that is part of the DMC partnership can request for, and download relevant images from any of the DMC satellites. NigeriaSat-1 is a Low Earth Orbital (LEO) spacecraft. It has a Sun synchronous orbit. It is a Microsatellite. It makes use of a linear pushbroom scanning system. It is a multispectral remote sensing satellite; it operates within three spectral wavebands of the electromagnetic spectrum namely green, red and near infrared (NIR). The satellite has an imaging payload on board which houses six imagers (i.e. 2 imagers per spectral band). It also has a very wide swath of 600km; actually each image scene covers a ground area of about 600 x 500 km. (i.e. 300,000km²). Some additional major technical details of NigeriaSat-1 are shown in Table 1.

| Table 1: Technical Details of NigeriaSat-1 |
|-----------------------------------------|---|
| **Spectral Bands**                      | **Details** |
| Green                                   | 0.53-0.59μm |
| Red                                     | 0.63-0.69μm |
| Near Infrared (NIR)                     | 0.76-0.90μm |
| **Swath**                               | 600km |
| **Image Scene Area**                    | 600 x 500 km² |
| **On-Board Imaging Payload**            | 6 imagers (2 per band) |
### Table 1: Some technical details of NigeriaSat-1

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swath width</td>
<td>600km</td>
</tr>
<tr>
<td>Typical revisit cycle (temporal resolution)</td>
<td>3 - 5 days (but 1 day when used in conjunction with other DMC satellites)</td>
</tr>
<tr>
<td>Ground Sampling Distance (GSD) i.e. spatial resolution</td>
<td>32m</td>
</tr>
<tr>
<td>Maximum image size (Pixels)</td>
<td>20,000 x 16,000 pixels ~ 300,000km²</td>
</tr>
<tr>
<td>Wavebands (spectral resolution)</td>
<td>Channel 1 (Green: 0.52 µm - 0.62 µm)</td>
</tr>
<tr>
<td></td>
<td>Channel 2 (Red: 0.63 µm - 0.69 µm)</td>
</tr>
<tr>
<td></td>
<td>Channel 3: (NIR: 0.76 µm - 0.90 µm)</td>
</tr>
<tr>
<td>Average orbital altitude</td>
<td>684km (perigee 676, apogee 692)</td>
</tr>
<tr>
<td>Orbital period</td>
<td>98.4min</td>
</tr>
<tr>
<td>Inclination</td>
<td>98.1°</td>
</tr>
<tr>
<td>Weight</td>
<td>98kg</td>
</tr>
<tr>
<td>Life span</td>
<td>5 years</td>
</tr>
</tbody>
</table>

*Source*: varied

Images are usually downloaded from the NigeriaSat-1 spacecraft by NASRDA at its Mission Control Ground Station in Asokoro, Abuja. One can obtain the images from NASRDA in either raw state or pre-processed form. The image data could be processed to various quality levels; for instance, from low-level (bits and bytes) to full false colour. For commercial purposes, the level of processing of each image determines its price. The image specifications on the basis of level of processing are:

- **L0** – Raw image (individual band)
- **L0R** – Radiometric corrected image
- **L1** – Band Registered image
- **L1R** – Radiometric corrected L1
- **L1G** – Geometric corrected L1R
- **High Processing Level (HPL):**
  - **Stage I**: Precision Geo-referenced image
  - **Stage II**: Ortho-rectified image

### 3.0 Potential Uses of NigeriaSat-1

Images and data from NigeriaSat-1 and other DMC satellites have a wide range of applications. In the booklet, *NigeriaSat-1: a medium resolution satellite for Earth observation*, the National Space Research and Development Agency (NASRDA) identified a range of broad thematic areas of application of NigeriaSat-1 imagery. Some of the wide-ranging application areas include:

- Disaster management
- Agriculture
- Mapping
- Water resources development and management
- Solid mineral exploration/exploitation
- Ecosystems management
- Demographic and cadastral operations
- Transportation and utilities management
- Environmental management
• Defense and security
• Health and public health delivery
• Education and capacity building

With particular reference to mapping, however, some of the specific intended potential areas of cartographic utilization of NigeriaSat-1 data include:

• Mapping land use
• Mapping pest infestation
• Mapping distressed crop areas
• General geological mapping and map update/revision
• Mapping/differentiation of host mineralized zones and rocks in oil/gas and solid mineral exploration
• Preparation of geomorphologic maps
• Mapping of floral and fauna species and habitats
• Mapping/planning population surveys and census enumeration areas
• Rural and urban growth mapping
• Mapping and planning utilities location
• Mapping/planning sewage location and domestic and industrial waste disposal sites
• Risk zone mapping and environmental inventory and monitoring
• Mapping of state and international boundaries
• Mapping terrain trafficability for movement of ground troops and military wares
• Mapping of camouflages for military operations
• Bathymetric mapping of coastal areas

Using images from NigeriaSat-1 NASRDA has been able to generate a total of 354 map sheets showing different categories of settlements and major highways across the country. The maps were produced at a scale of 1:100,000. However, the maps, which were extracted from the images using the GIS technology, have noticeable cartographic deficiencies – obviously they were not produced by qualified cartographers, and some basic cartographic standards were not observed. The lineworks in particular are significantly lacking in cartographic finesse. Nonetheless, the initiative is quite commendable.

On the international scene, the European Space Agency (ESA) and some other global agencies have been making use of images from NigeriaSat-1 to produce geospatial databases and maps to assist in disaster management and humanitarian services. Amongst other applications, the NigeriaSat-1 images were used for managing the catastrophic tsunami that ravaged parts of South-East Asia in December 2004. Similarly, NigeriaSat-1 provided the U.S. Geological Surveys with images of the Gulf Coast of the US which was seriously bashed by Hurricane Katrina in August 2005.

4.0 Methodology

The image scenes used in this study were obtained from NASRDA. The images which covered various parts of the country, were obtained in digital format on CD-ROM. The digital images were managed using ESRI's ArcGIS Desktop 9.0 software. Although the images were already pre-processed to some extent, they were however subjected to further pre-processing to improve more on the radiometric quality.
The images used were tested using both analogue and automated techniques to assess their potential for cartographic applications. The images were subjected to standard image preprocessing procedures – visual inspection, image statistics display, radiometric enhancement and geometric correction. The visual inspection of the data revealed an inherent banding or stripping in some of the images used. This stripping greatly reduced the visual quality of the data. For data extraction, the study relied mostly on visual image interpretation, which entailed manual detection, recognition, identification (i.e. classification) of land use/land cover features.

5.0 Cartographic Utility of NigeriaSat-1 Image Data

Two broad potential cartographic applications of NigeriaSat-1 image data were considered in this study namely, Land use/Land cover (LU/LC) mapping, and Map revision/updating. The discussion in this section is not comprehensive; in other words, the section did not treat the mapping of all the possible categories of LU/LC features in the areas covered by the images used. Rather the section presents an overview of some of the issues involved in the use of NigeriaSat-1 images for mapping purposes.

5.1 Land use/Land cover Mapping

The term “land use” commonly refers to the various classes of anthropogenic activities to which land of any geographic extent is put. Hence it includes the totality of infrastructures, superstructures, amenities, and human activities in any place. On the other hand, “land cover” deals with those geographical features such as water bodies and vegetation which naturally exist in a place. In a nutshell, therefore, land use/land cover (LU/LC) refers to the physical cultural facilities/activities as well as natural features occupying the landscape of any geographical area.

Certain land use/land cover (LU/LC) features are discernible on the NigeriaSat-1 imagery. The medium resolution of the satellite image, however, affects the effective, efficient and precise discrimination, classification and delineation of features. This in turn could affect the accurate mapping of features and hence the enumeration of discrete point features or the measurement of some attributes of polygonal (areal) features on the image. The quality of the image could only allow for LU/LC mapping at the regional level to scales of 1:100,000 or smaller. This means then that the NigeriaSat-1 image is suitable for mapping macro or primary class LU/LC features. Very specific classes of LU/LC characteristics in this medium resolution imagery may be difficult to discriminate and map; secondary class level features are difficult to discern while tertiary class features are almost invisible.

The outlines of built-up areas are quite visible on the image. The precise borders or limits of the built-up areas are, though, not quite distinct on the image. Hence one would encounter some problems while trying to delimit the borders of such built-up areas. Built-up areas that are densely populated and with clustered houses are visible and their outlines can be mapped. Sparsely populated areas are visible but difficult to discriminate; to map such areas an extensive fieldwork would be required to establish their outlines.

NigeriaSat-1 data seems good enough to identify and map urban spread or extent. Extensive field verification exercise, however, would need to be conducted to appropriately correlate image data with the realities on ground. One can safely say, therefore, that NigeriaSat-1 image data can be use to monitor and map urban physical growth to a reasonable extent.
Owing to its spatial resolution (32m) the satellite image of urban settlement does not show the internal structure of the settlements. Consequently, it would not be quite possible to clearly distinguish internal road network, buildings and other city facilities that are less than 32x32m. The implication of this is that NigeriaSat-1 is not suitable for the production of township and other urban maps at a large scale.

Some transportation lines are equally observable on NigeriaSat-1 imagery, and they can be mapped with relative ease. The expressways and major tarred roads can easily be identified on an image scene containing such features. However, smaller roads and street patterns are difficult to identify. Hence, whereas Expressways and major tarred roads can be mapped from NigeriaSat-1, inner city street network comprising mostly feeder roads cannot be mapped. As a matter of fact, roads other than expressways are hardly visible in heavily built-up or vegetated areas. At a scale of 1: 250000, only the expressways and some primary or Trunk A inter-state highways are identifiable; all other road networks are unidentifiable.

Large water bodies such as rivers, lakes, lagoons and other big open waters can easily be identified on the image and hence mapped. Vast wetlands and swamps can also be distinguished. On the other hand, smaller rivers, rivulets, and creeks are difficult to discriminate on the image.

Vegetation is one land use/cover feature that is clearly visible on the imagery. In some areas grasslands, farmlands, forests and wooded areas and bush-thickets could be identified with a high level of confidence. However, as a result of the low radiometric quality of the image data many green vegetation canopies have very similar spectral signatures, thus making it difficult to discriminate between them and map their boundaries. This problem was particularly encountered with the images covering some parts of the humid tropical regions of the south which have dense mixtures of species. In order to use NigeriaSat-1 for vegetation mapping there will be the need to support the initiative with additional ground truth and aerial photographs or very high resolution satellite images.

5.2 Map revision/update

The NigeriaSat-1 data can be utilized for map revision or update. Its high temporal resolution (3-5 days revisit period or 1-day in collaboration with the other DMC satellites) empowers the satellite to acquire images in near-real time. Hence, the imagery is suitable for more frequent revision of maps. Nonetheless, the images are not fit for revising large scale maps; they can better be used in revising regional general maps at medium scales, especially within the range of scales 1:100,000 - 1:250,000. If the imagery is subjected to a very high level of pre-processing, though, it might be used to a reasonable extent to revise the 1:50,000 topographic maps. It should however be noted that the satellite imagery is apposite for updating primary or high class level features; it may not be suitable for updating secondary or lower class level of features. For instance, Expressways and inter-state (Trunk A) roads are easily identifiable on the image and can, therefore, be easily updated on general maps using the image data. On the other hand, however, secondary (Trunk B) roads and other lower categories of road are more or less indiscernible on the images; hence it would be difficult to use the satellite image to update any maps displaying such features.
5.3 General discussion on cartographic utility of NigeriaSat-1

The 32m spatial resolution of the NigeriaSat-1 is considered rather coarse for several cartographic applications. The resolution significantly affects the planimetric accuracy – a factor that is of utmost consideration in large scale mapping.

Given the medium spatial resolution and somewhat low radiometric quality of its images, any major mapping project involving the use of NigeriaSat-1 as a major source of data will definitely require elaborate fieldwork to collect ground control points (for image georeferencing). Also extensive ground-truthing exercise would be needed for the collection of collateral data and field verification of some of the visible features on the imagery which may not be easily identifiable. For the purpose of image registration and verification, already existing georeferenced general maps, aerial photographs, high resolution satellite images, or GPS readings may also be used.

To achieve any reasonable degree of mapping from NigeriaSat-1 data, the image would need to be processed to the highest level possible. Even at that, owing to the limitations inherently place on the imagery by its spatial resolution, it can only be capable of being used for macro-level mapping. For instance, in a typical urban LU/LC mapping exercise, the imagery may just be useful for the detection, recognition, and identification of outline and lateral spatial spread of the cityscape or any large feature. The 32m ground sampling distance (GSD) of the image is not high enough as to reveal the internal structural characteristics of an urban area.

The range of possible suitable scale for mapping from NigeriaSat-1 imagery is 1:100,000 to 1:250,000. This makes the imagery mostly suitable for regional general mapping at the medium scale level. The image data is obviously not suitable for large scale mapping. The 32m spatial resolution of the satellite, which is similar to the American Landsat TM with 30m resolution, is equally good for generating medium to small scale regional thematic maps showing individual layers of various LU/LC features.

But how economical is it to use NigeriaSat-1 image data for mapping purposes? As noted earlier, owing to the spatial resolution of the NigeriaSat-1 imagery many ground back-up points may be needed for a given area for mapping purpose. Invariably, extensive and expensive ground-truthing would need to be carried out for any major mapping project involving the use of the images. In the long-run this is likely to add significantly to the overall cost of using the image data. Conversely, the exceptionally wide-area swath width (about 600km) which the satellite’s optical imaging payload provides confers an economic advantage on the satellite imagery for cartographic work. A single full image scene covers a wide geographical area (about 300,000km²). Consequently, rather than acquire several image scenes to form an expensive mosaic of a region (as would be the case if, for instance, one is using Landsat TM images), only one image scene may be required if NigeriaSat-1 imagery is used.

5.4 Strengths and Weaknesses of NigeriaSat-1 for Mapping

It would be instructive to highlight and take cognizance of some of the strong points and shortcomings of NigeriaSat-1 imagery with respect to cartographic applications. The essence is to provide some useful insight that could guide one in deciding to what extent one can rely on the satellite data for mapping.
5.4.1 Strong points

Generally speaking, there is a commercial demand for data from the DMC satellites due to the unique strengths of the Constellation. The following are some of the strong points identified with the NigeriaSat-1 imagery used in this study:

- The 32m spatial resolution of the image makes it good for regional environmental and resource mapping.

- The large swath or wide area coverage of the image (a full image scene covers an area of about 600 x 570 km) is quite advantageous; it makes it possible to map a large region with just a single image scene. Obviously this translates to cost effectiveness, in economic terms since it reduces the problem of creating a mosaic of an area from several image scenes.

- Data from the DMC satellites of which NigeriaSat-1 is part of, is suitable for a wide range of mapping and other applications (see section 3.0).

- The strong potential for NDVI (Normalized Differential Vegetation Index) possessed by the satellite makes it quite useful for regional mapping of vegetation types and their conditions.

- In comparison with the Landsat system, the DMC satellite images have similar spatial and (multi)spectral resolutions with Landsat data. The DMC satellites, however, have a higher temporal resolution than the Landsat; whereas the DMC satellites working as a constellation have a daily revisit time, Landsat has a revisit time of 16 days.

- The availability of the image data can greatly inspire and enhance the frequent revision of Nigerian regional maps at scales of 1:100,000 or less, especially in sparsely populated areas.

- The NigeriaSat-1 project has the propensity of contributing significantly to the growth and development of digital cartography in Nigeria. Since the image data is acquired in digital format this would encourage its direct use in digital mapping operations.

- Expectedly, images from the satellite will equally contribute greatly to the pool of information or databases that will form part of the proposed National Geospatial Data Infrastructure (NGDI) for Nigeria, for mapping and other geospatial activities.

5.4.2 Shortcomings

Without any prejudice to the merits of NigeriaSat-1 highlighted above, certain potential constraints to its use for cartographic and allied applications can also be identified. Some of such shortcomings include the following:

- The coarse image resolution (32m) does not permit mapping secondary or lower class land use/land cover features at a large scale.
Similarly, due to the medium spatial resolution of the image extensive fieldwork or ground-truthing exercise would often be required to properly use the image. Such an exercise could be quite expensive, especially if the project at hand is an extensive one.

The medium resolution of the image coupled with the fact that it cannot be used for stereoscopic observation makes it impossible to use the image for the establishment of contoured topographic maps showing various relief features.

Coupled with the relatively low spatial resolution of the imagery, its low radiometric quality equally makes the edges of some features to appear hazy. Apart from increasing the burden of georeferencing the image, the fuzzy appearance equally makes it difficult to properly delimit polygonal features. A situation like this often makes it quite imperative to embark on extensive field verification.

The 3-band spectral resolution of Nigeria Sat-1 may be deficient for some applications such as geological mapping, which often require high multispectral resolution images.

A common characteristic observed on many of the image scenes used in this study was that certain different individual LU/LC features tend to display the same or similar spectral signature or colour in two or all the three bands of the satellite. For instance, in some cases roads and rivers/streams may have the same or very similar colour. This is perhaps owing to the somewhat low radiometric resolution of the imagery. This deficiency makes it difficult to discriminate between different surface features which share similar spectral signature. In a situation like this, the image interpreter will need to rely heavily on experience and field verification to achieve a dependable supervised image features classification.

The satellite imagery shows strong tendencies towards suffering remarkably from atmospheric attenuation. This point is underlined by the high percentage of cloud cover which caused the poor visibility observed on some of the image scenes. This problem was observed mostly on those image scenes covering sections of the southern part of the country. Poor visibility can strongly undermine identification of image features as well as the georeferencing of the image.

6.0 Recommendations and Concluding remarks

It is not just enough to acquire the satellite data and images. Beyond the mere acquisition of the imagery, concrete and well-orchestrated effort should be geared towards converting the data into maps and other useful information for sound decision making as well as the planning, monitoring, development and management of our resources. A specific mapping programme should be put in place by government to harness Nigeria Sat-1 images for the revision of some of our out-of-date medium scale regional maps and the production of new sets of maps to meet some of the geospatial information needs of the country.

Mapping from space should form part of the capacity building plans of NASRDA. More Nigerians should be trained (or retrained) to acquire the requisite skill for generating maps from satellite images using modern cartographic and other geospatial technologies and techniques.
The Federal Government of Nigeria has already given approval for the launch of a second Earth observation satellite (NigeriaSat-2), and work is currently on-going to determine the exact specifications of the satellite (Federal Ministry of Science and Technology, 2006). NigeriaSat-2 is conceived to be a high spatial resolution (2.5m) Earth observation satellite. Hopefully, the satellite will be launched into orbit in 2008. The deficiencies of NigeriaSat-1, some of which have been identified in this paper, should be noted and taken into consideration during the design and building of NigeriaSat-2. Moreover, the necessary structures should be put in place now to fully exploit the cartographic potentialities of the new satellite when it becomes operational.

The NigeriaSat-1 project is a step in the right direction. The satellite (and subsequent earth observation remote sensing satellites that would be launched by Nigeria) has the capability of changing the parlous state of cartography in the country. Despite its numerous deficiencies, at least from a cartographic view-point, NigeriaSat-1 has really opened the gateway to mapping from space in the country. It behooves us as a nation, therefore, to piggyback on the NigeriaSat-1 initiative to improve on our national mapping policies and programmes in general. Maps and mapping remains an untapped catalyst for economic development in the country (Uluocha, 2007). But no country can develop in a systematic and sustainable manner without a strong and rich cartographic tradition. Cartography, per se, is the basis of the development of any country (Bied-Charretton and Cazaux, 1986).

References


National Space Research and Development Agency (nd) *NigeriaSat-1: a medium resolution satellite for Earth observation*, Federal Ministry of Science and Technology, Abuja, Nigeria
