



Paper for presentation at UN Regional Workshop on the Use of Space Technology for  
Disaster Management for Africa  
Addis Ababa, 1-5 July 2002

AFRICAN SATELLITE CONSTELLATION FOR  
TRANSNATIONAL RESOURCE MANAGEMENT:  
TOWARDS DISASTER PREVENTION

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**Abstract**

*A new approach to disaster management is required, instead of focusing on relief and recovery efforts, the salience of establishing prevention and mitigation measures as the core principles of a future disaster management policy is emphasised. This paper examines the role of inexpensive space resources - micro-satellites in achieving this goal. With their applications for resource management micro and small satellites in constellation provide timely information for the management of natural resources in order to either prevent or lessen the impact due to disasters, of particular importance are transnational natural assets such as the African transfrontier parks. African collaboration further provides the platform for cooperative programmes in the monitoring of such natural resources as envisaged in an African Micro-Satellite Constellation for Transnational Resource Management.*

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# 1 INTRODUCTION

Developments in space technology are opening new avenues to monitoring natural resources and are providing valuable input into decision-making for the management and monitoring of water and land resources. This is important for disaster management in Africa as it enables a proactive and pre-emptive approach. One such space technology is micro-satellites and their potential applications for the prevention and mitigation of disasters through natural resource management.

Micro-satellites are providing viable access to space for countries emerging in space technology, through lowering the cost threshold, whilst simultaneously making the necessary technological advancements. Micro-satellite systems offer increased performance and are an inexpensive platform for remote sensing compared to the traditional large satellites. Over the next 10 years, the need for dedicated missions can be addressed by mission-specific micro-satellites each optimised for a specialised application. In particular, a constellation of micro-satellites to enable increased temporal coverage is now possible.

Disaster management requires co-ordinated regional natural resource management activities. Regional collaboration provides the platform for cooperative programmes in the monitoring of natural resources such as the African Transfrontier Parks, resources that are often not confined to man-made borders. To fulfil these requirements an African Satellite Constellation for Transnational Resource Management is envisaged.

Technology developed in Africa and demonstrated with South Africa's SUNSAT 1 micro-satellite programme, is an affordable platform from which a satellite constellation, dedicated to the needs of African governments, can be developed. SUNSAT 1 proved that high resolution remote sensing is possible on such a small platform and established a technology base free from any external technology licenses. The success of the SUNSAT mission paves the way for cultivating African know-how and expertise for an African-originated satellite

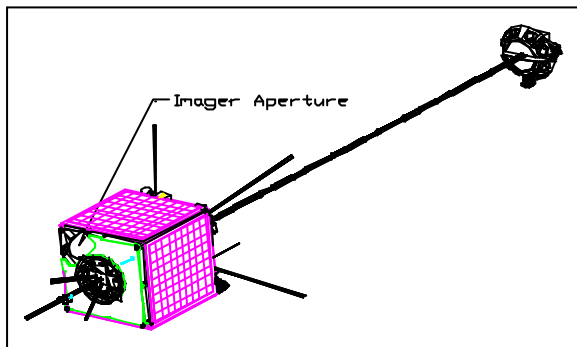
constellation mission for transnational resource management as a constellation of Low Earth Orbiting (LEO) satellites offers the required regular coverage.

The aim of this paper is to examine the role of micro-satellites in natural resource management. An African Micro-satellite Constellation for Transnational Resource Management is advocated for three primary reasons:

1. The application of such a constellation provides resources for priority regional resource management towards disaster prevention and mitigation.
2. A constellation offers viable and affordable access to space for African countries, also those that are emerging in space technology.
3. As an expression of the New Partnership for Africa's Development (NEPAD) the establishment of such a constellation involves the development, transference and application of indigenous knowledge through transnational cooperation and a fulfilment of one of NEPAD's key aims, namely "bridging the digital divide".

The principles of NEPAD and its call for regional cooperation are explored as foundational for the establishment of a transnational micro-satellite constellation. The indigenous capabilities towards achieving this constellation are reported on, namely, South Africa's micro-satellite technology and the results achieved with SUNSAT 1. An assessment is finally given of its potential applications for the monitoring and management of natural resources.

Previous papers have focused on the contribution of SUNSAT 1 to space development<sup>4</sup>, its payloads<sup>7</sup> the services<sup>1</sup> and early flight results.<sup>6</sup>



**Figure 1 SUNSAT 1 in-orbit configuration**

## **2 REGIONAL COOPERATION FOR TRANSNATIONAL RESOURCE MANAGEMENT**

South Africa's White Paper on disaster management, which was published in January 1999, advocates a new approach to disaster management, instead of focusing on relief and recovery efforts, it emphasises the need for establishing prevention and mitigation measures as the core principles of a future disaster management policy. Thus, the call for effective natural resource management. In its approach the White Paper calls for "an increased commitment to prevention and mitigation actions that will reduce the probability and severity of disastrous events by incorporating these actions into policies, plans and projects of both governments and the private sector"<sup>7</sup>. Within the Disaster Management Bill it further recommends that the national disaster management framework facilitate "South Africa's co-operation in international disaster management" and "regional co-operation in disaster management in Southern Africa" (Article 6(c))<sup>7</sup>.

In essence, it is fast becoming apparent that natural resources and disasters such as droughts, floods, major fires and oil spills, and their subsequent ramifications are often transboundary in nature and will thus need to be approached in a unified way. Such issues cannot be solved or managed by fragmented sectoral or national approaches alone. Their solutions therefore require joint undertakings.

In this regard and in the spirit of the New

Partnership for Africa's Development (NEPAD) the establishment of an African Constellation is envisaged.

NEPAD<sup>8</sup> is an African programme promoting sustainable African development. It is founded on the determination of African leaders to free themselves from the malaise of underdevelopment, to eradicate poverty and to place their countries, both individually and collectively, on a path of sustainable growth. Amongst the foundations for development NEPAD recognises regional cooperation and integration as one of the key requirements. Such cooperation is embodied in the potential success of an African micro-satellite constellation.

### **2.1 Transnational Resources**

The issue of water is often referred to as the security concern of the coming decade. It also serves as an important example of the transnational nature of many natural resources and the subsequent ramifications thereof - shared rivers have proven to be problematic in disaster management. Mozambique is a case in point. Each time Zambia and Zimbabwe agree to open the floodgates of the Kariba dam along the Zambezi River during a wet season, Mozambique's Tete Province has suffered as a result of the river swelling and bursting its banks. In order to alleviate or manage such risks the harmonisation of mechanisms by countries sharing watercourses is necessary to curb flooding - consequences which joint water management can avert or at least effectively manage.

### **2.2 Transfrontier Parks**

An apt illustration of transnational resource management, was ushered in with the official launch of the 38 000 km<sup>2</sup> Kgalagadi Transfrontier Park in May 2000 between Botswana and South Africa<sup>9</sup>. The Park provides an instructive example for a new approach to disaster management.

Transfrontier parks are protected areas that straddle international boundaries, their authorities formally agree to manage these areas as one integrated unit

according to a streamlined management plan. The management of the individual parks is often based on principles that are very different from each other. On the other hand a transfrontier park provides a mechanism whereby these differences can be minimised in order to arrive at a uniform management system. The advantage of such a system is to weaken the “virtual barriers” separating the parks and to find a common approach to management. In this way the provision of transfrontier parks will serve the interests of improved resource management by enabling a homogenous and concerted approach to management.

Through the use of Geographical Information Systems (GIS), the Peace Parks Foundation<sup>9</sup>, a catalyst in the establishment of transfrontier parks in southern Africa, is establishing a spatial database for each of the transfrontier conservation areas (TFCAs). Data is being obtained from various sources, for example, remote data from satellite imagery is being used to observe the location of settlements as well as their current land-use practices. These spatial databases are tools that will be used during the facilitation and management of the Transfrontier Parks and associated projects.

Lessons to be learnt from transfrontier parks and water resources are that natural resources often do not respect man-made boundaries and their effective management requires regional cooperation and coordinated management plans. In turn, data from satellite imagery enables the relevant authorities to see the “bigger picture” for effective management.

### **3 SOUTH AFRICA’S FIRST MICRO-SATELLITE: SUNSAT-1**

The current challenge is to take this new approach further and empower African governments with local access to satellite imaging data for local processing in resource management. With the indigenous technology from the SUNSAT programme the African region can now also have ownership of the satellite technology and imagery.

South Africa demonstrated successful entry into space with the SUNSAT micro-satellite project. Technology developed for SUNSAT established a new benchmark for the highest performance imager in a 64kg satellite. The SUNSAT 1 micro-satellite pioneered a 3 band multispectral, 15m per pixel spacing Ground Sampling Distance imaging system in a 64 kg satellite.

SUNSAT 1 was developed and built under the leadership of experienced professionals by a team of engineers and students that formed part of a graduate technology development and education program. The core group of lecturers assisted over 100 engineers and students to participate in the SUNSAT 1 micro-satellite mission and established a key capability in Africa.

The SUNSAT 1 in-orbit configuration was achieved after the tip mass was deployed in orbit to obtain the gravity gradient stabilised configuration in figure 1<sup>5</sup>.

The satellite comprises a number of stacked electronics trays providing a rigid structure that supports the fixed solar panels. A spin about the boom axis is induced by activation of torque coils for temperature equalisation.

The lower tray is 12cm high to contain the imager, which fits diagonally across it. The earth below is viewed via a 45-degree mirror. The diagonal tube contains the optics and CCD-related electronics, and the tube can be rotated left/right for cross-track or stereo viewing.

The other electronics in SUNSAT were packaged in trays for power control, telemetry, tele-command, VHF communications, UHF communications (see figure 2), On Board Computer 1 (OBC1), OBC2, RAM disk, Attitude Determination and Control System (ADCS), and top plate. The top plate carries horizon, sun, and star sensors, and also holds the deployable boom.

#### **IN-ORBIT RESULTS OF SUNSAT 1**



**Figure 2 Imager tray with power and communication trays stacked on it.**

### **3.1 Launch and orbit**

SUNSAT 1<sup>5</sup> was launched on 23 February 1999 on the USAF Delta II ARGOS mission from Vandenberg Air Force Base. NASA provided the launch in exchange for carrying a Turbo-Rogue GPS receiver identical to that on the Oersted satellite which was the primary secondary payload. Oersted's requirements led to SUNSAT being in a 655km x 857km, 96.4 degree orbit that drifts an hour earlier every seventy days from its initial 15:30 local time. SUNSAT's design assumed an 11:00 sun-synchronous orbit. The design was not changed for Orsted's orbit since the goal was to evaluate SUNSAT in a sun-synchronous remote sensing role.

It was accepted that the orbital drift into the dusk-dawn position would make imaging inoperable and raise mean satellite temperature to a point that would have negative effects on NiCd life.

### **3.2 On board data handling**

The ability to upload software has proven a key factor in the success of imaging with the 64kg micro-satellite. Improving the communication bandwidth, image compression, flexible programming of the imager payload, reprogramming the DSP modem, testing the global broadcast network protocol were only possible due to the ability to replace all the software except for the boot loaders.

The 64Mbyte RAM disk has proven to be flexible data store maintaining images for some time so that it can be downloaded successfully.

### **3.3 TT&C links**

The uplink margin was improved with tracking antennas and higher power transmitters to give

reliable all-attitude uplink communication. Downlink performance was improved using a 70cm helical feed around the S-band feed on a 4.5m open-loop tracking dish antenna. During most passes excellent UHF communications from horizon to horizon is achieved. This provided for the 1200 and 9600 baud links.

### **3.4 Microwave downlink**

SUNSAT 1 has a 5 W S-band transmitter for television and 40Mb/s data down linking. The TV modulator and power amplifier operated as expected. The image had to be down-linked via the backup communication channel from the RAM-disk.

This spurred several initiatives to improve the efficiency of the communication down link. Image compression in particular, as well as, effective bandwidth increases was the primary focus of this effort. The engineering challenges for the next generation imager are in the same areas of handling the increases in data rates.

Data bandwidth was successfully increased by a factor two<sup>1</sup>. Use of loss-less compression algorithms led to a 40% reduction in the amount of data.

The most significant bandwidth utilisation improvement is offered by a novel global broadcast network of receiving stations<sup>1</sup>. With an international network of autonomous stations participating, it is possible to download an image at 9600 bits/s in 24 hours, as opposed to 21 days without any bandwidth improving capability.

### **3.5 Pushbroom imager**

The push-broom imager operated as expected, and in early July 1999 was storing 3456 pixel by 3500 pixel images on the 64 Mbyte RAMDisk. The RAMDisk proved to be a reliable backup mechanism for the high speed down link.

The spectral range covered by readily available silicon CCDs enabled the imager on Sunsat 1 to cover the green, red and near infrared bands. Referring to table 1, it is clear that covering the short wave infra red bands should be one of the priorities of future small satellites to provide more useful image data for the spectral band sets that are

in wide spread use due to being available from the large remote sensing satellites.

## 4 APPLICATIONS

In the achievement of resource management, affordable high-resolution imagery for use by African governments is a basic need in order to monitor and manage the vast expanses of geographic area under their management. Micro-satellite technology such as that of SUNSAT, can provide such a source of images.

Each participating country can contribute a satellite to the constellation and share in the image output of all the satellites.

### 4.1 Mission studies: Micro-satellite Constellation

Following the technology demonstration of high performance remote sensing by SUNSAT 1, a follow on mission using an improved imager within a dedicated imaging mission, is the next goal. The real advantage of a micro-satellite mission results from the multiple deployment of such satellites.

A single satellite, although it covers the whole earth, has a limited revisit time, only once every 3 to 26 days, unsuitable for the requirements of regular monitoring required for unpredictable processes in natural resource management. Other major benefits of satellites in constellation include: backup to single satellite and increased communication cover. Thus a constellation can offer more use for the applications necessary for transnational resource management.

The constellation provides access to the space resources and ground station resources of participating members in proportion to the resources made available to the constellation by the participating member. It is expected that the next generation South African satellite will also form part of this constellation. Each participating nation or region in the constellation can achieve the following goals:

1. Local access to satellite imaging data for local processing in disaster management
2. Ownership of a national satellite with full participation in the development and construction of the satellites
3. Satellite technology development and transfer

### 4.2 Mission options

A number of remote sensing applications that are suitable for micro-satellites are briefly examined.

#### 4.2.1 Water Resource

One of the applications is possibly multi spectral imaging, up to wavelengths of  $1.8\mu\text{m}$ , targeted for the management of water resources. Water has major spectral features in this band, to the extent that the various phases of water can be distinguished. For the many water-scarce countries in Africa, this could lead the beginning of an efficient water resource status information network. Thus, in the context of disaster management, images taken can provide a tool for more efficient planning, for example where to position a dam, or for monitoring for example the effects of siltation

#### 4.2.2 Agriculture Resource

The SUNSAT 1 imager with SPOT's bands 1 and 2 and Landsat's band 4 can be augmented with an extended short-wave infrared band ( $1.55\text{-}1.75\mu\text{m}$ ) to provide an instrument optimized for vegetation and hence agricultural applications. Precision agriculture can be applied to various crops including maize, corn, viticulture, etc.

Being compatible with an existing satellite resource, opens up a large user community. For instance the Spot 4 spectral bands could form a reference set of bands for use on the small satellite. The bands are:

1. Green band B1: 0.50 to 0.59  $\mu\text{m}$
2. Red band B2: 0.61 to 0.68  $\mu\text{m}$
3. NIR band B3: 0.78 to 0.89  $\mu\text{m}$
4. Shortwave infrared (SWIR) band: 1.58 to 1.75  $\mu\text{m}$

<b>Blue, Green</b>	0.47-0.57	Water penetration	10
<b>Red</b>	0.57-0.69	Vegetation and cultural features discrimination	10
<b>Near IR</b>	0.76-1.05	Land, water interface and vegetation discrimination	10
<b>Short Wave IR</b>	1.55-1.75	Vegetation type, soil moisture	10 – 30
<b>Panchromatic</b>	0.51-0.73	Topographic mapping	5
<b>Short wave IR</b>	2.08-2.35	Mineral exploration, soil types	5-20

**Table 1:** Spectral regions useful for mapping, interpretation and Earth science applications.

The opportunity to deploy a unique set of spectral bands, optimised for a particular application, makes the use of micro-satellites particularly attractive. Planning for the use of hyper-spectral imagers to be integrated on micro-satellites are at an advanced stage and would assist greatly in enhancing spectral signature identification of various crops. This information would assist in the planning and management of agricultural resources, for example determining the effects of crop rotation or soil erosion.

In 1999 Cape Town's renowned Table Mountain was ravaged by fires, it was later discovered that its ferocity and widespread damage was largely a result of the alien vegetation with its susceptibility to fire. With the use of the satellite imagery alien vegetation can be identified and strategy for its removal implemented more effectively.

#### **4.2.3 Disaster mitigation, response and recovery**

Being prepared for disasters is a salient aspect with which a space borne information gathering and communication platform can assist. Given that frequent updates are required of remotely sensed data, a dedicated constellation of small satellites with sensors optimised for a particular disaster set, can provide that reality. The short-term pre-disaster phase can be mitigated more effectively if the correct information is available. The response and long-term recovery phase can be assisted with timely, correct information from a platform that is not subject to influences of the disaster. Micro-satellites in a constellation have a particular contribution to make here from the point of view that the frequency of passes can be increased and that the unit launch cost for multiple small satellites are far lower than that for single launches.

#### **4.3 Satellite Bus Development**

Sun Space and Information Systems and Stellenbosch University have base-lined the following parameters as key to the micro-satellites

envisaged for a constellation; a 100kg to 120kg small remote sensing satellite, 3-axis stabilised. It should include an imager with less than 5m GSD (ground spacing distance), on-board processing, VHF/UHF telecommand and telemetry links, X-band transmitter for the image data, and constellation management thrusters. This baseline can form the departure point for establishing the African Transnational Resource Management Satellite Constellation mission parameters.

## **5 SUSTAINABLE MICRO-SATELLITE APPLICATIONS**

During the SUNSAT 1 programme, the Electronic Systems Laboratory was established at Stellenbosch University where the SUNSAT 1 programme was executed. The combination of research, education, training, satellite development and international collaboration, has proven to be a success recipe for starting a sustainable micro-satellite programme.<sup>2</sup>

Over a period of 10 years, Stellenbosch University has demonstrated its ability to participate successfully in international missions. These include carrying piggyback instruments for NASA, supplying instruments for other satellites such as Safir-2, Fedsat and consultation to various organisations around the world.

Bridging the digital divide in Africa, as espoused by NEPAD, requires indigenous technology development and transfer. And, a commitment to long-term research and development can only be sustained by repeatable development and utilisation of technology and know-how. For this reason the University of Stellenbosch incorporated Sun Space and Information Systems (SunSpace) to make the technology and systems that resulted from the SUNSAT micro-satellite programme available for wider application. The successful launch and operation of the SUNSAT micro-satellite,

demonstrated that the technology base for earth applications (i.e. environmental, agricultural and agro-meteorological) could be achieved in a very small, high-performance satellite platform.

The satellite technology base and related expertise at the University have expanded to such an extent that SunSpace is now in a position to offer complete, structured technology transfer programmes to build capacity in Africa. These programmes not only involve the transfer of knowledge and know-how, but also hands-on experience in the development and application of precision control micro-satellite technology and systems. As a consequence, the University has relevant research topics for its students as well as additional funding, thus, maintaining and developing local intellectual capital.

It is imperative that the ability that was built up in Africa be further developed for the benefit of the whole of Africa. The African Constellation with applications for natural resource management is a step in the correct direction.

## 6 CONCLUSION

For effective disaster management a pre-emptive approach is required through proper natural resource management and where unavoidable, disaster mitigation. Thus, satellite imagery enables African governments to plan and to understand the greater picture for more decisive and effective action. Furthermore, an integrated approach is necessary as evidenced in the often transboundary nature of natural resources and illustrated with the African transfrontier parks. The mechanism recommended for achieving this pre-emptive, integrated approach is an African Micro-Satellite Constellation for Transnational Resource Management.

To date much of the African region has access to satellite imagery and data, albeit limited, and with the indigenous technology developed with the SUNSAT mission the African region can also have ownership of the micro-satellite technology. The success of SUNSAT 1 has led to the build up of the capacity to support a large-scale satellite training initiative in Africa. The partnership of SunSpace and

Stellenbosch University offers the SUNSAT satellite technology for use in the African Micro-satellite Constellation programme including the application of the data for resource management and a satellite technology development and know how transfer programme to ensure effective disaster management within Africa by Africa.

### Acknowledgements:

SUNSAT has been completed through engineers, graduate students, lecturers, friends and colleagues in many organisations. The following organisations have supplied funds or facilities:

Altech-Alcatel, ECS, First National Bank, FRD, Grintek, Houwteq, Irdeto, Malaysian Airlines, MTN, Orbicom, Plessey, Reumech, SARL, SA AMSAT, Siemens, Somchem, Telkom, University of Stellenbosch, Vodacom.

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