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Small Satellites, CubeSats and University Satellites in Africa and their Missions

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Satellite Technology Transfer to African Countries

During 1992-2007 several developing countries in Africa, and others in Asia and Latin America started comprehensive programs for technology transfer of small satellites aiming at building their own satellites for Remote Sensing.

Algeria, AlSat-1 &2

Egypt: EgyptSat-1 (Launched 17-4-20017)

Morocco- Zarkaa Alyamama

Nigeria : Nigeria one and Two

South Africa : SunSat (Launched 1999)- Technology Development

There are Five experiences of Small Satellite Technology Transfer to Africa.

Generally, these (EARLIER) experiences concentrated on the following:

-Launch of Remote Sensing Satellite.

-Large numbers of trained Engineers.

-Participation of National Space Agencies (not Universities)

-Intense level of technology participation and training.

-Use of generated Space Products (Images) in development.

Change of the Scene .. **Enter CubeSats ..**

-Many countries moved to CubeSats in their development of Satellites.

-Some larger programs in Africa still continuing (second Generation satellites from Algeria, Nigeria, and South Africa).

New Comers: (All Cube sats)

Ghana

Kenya

Sudan

Tunisia

Objectives of new entries in Space ranged from:

(1) Education, to

(2) (some) Technology acquisition, to

(3) developing their own experiments in Space (being in Space).

So, Now we have nine countries in Africa dealing with Space.

In this paper we examine …

Aspects of the CubeSats and University Satellites being developed and used in African countries and their missions.

1-We examine these satellites and programs from the aspect of technology development and the technology transfer associated with their development.

2-And to some extent the relationship between these programs and the earlier (pioneering) programs in technology transfer.

3-The educational aspect associated with the University satellites.

4-The aspect of the utilization of the space benefits in development is not yet mature for examining.

International cooperation

plays an important both in the early phase of RS satellites for technology transfer and the current phase.

1-Role in providing the technology,

2-The opportunity for entry into the Space Field.

3- Providing launch opportunities for developing countries as an asset for encouraging the trend of developing this type of satellite.

The general features and trends of space program development in this specific group of developing countries are extracted.

Space Activity in Africa in CubeSats and University Satellites:

Space activity in Africa in the area of CubeSats and University Satellites is going on in 8 countries, Algeria, Egypt, Ghana, Kenya, South Africa, Sudan and Tunisia.

Four of these countries had prior experience with Technology Transfer and Development of Remote Sensing Satellites via technology transfer programs established in the period 1992-2002 (South Africa, Algeria, Nigeria and Egypt ordered according to the date of launching their first satellite).

Four other countries in Africa are new to Satellite Technology (Ghana, Kenya, Sudan and Tunisia).

The experiences of those 8 countries produced 9 Cube satellites of different sizes, five of which were actually launched.

Launched Cube Satellites in Africa were,

(1) **AlSat-Nano** from Algeria in 26.09.2016 on board PSLV-G(3),

(2) Ghana **ANUSAT-1** or **Bird G**, (Reference 6) onboard Falcon-9 v1.2 in 03.06.2017.

(3) Kenya, **1KUN-PF** scheduled for Launch on Kibo Module, Jan 2018.

(4) Nigeria **EduSat-N or Bird N**, (Reference 6), onboard Falcon-9 v1.2 in 03.06.2017 (with Ghana).

(5) South Africa, **Zacube-1** , onboard Dneper in 21-11-2013

Table 1. Summary of Cube Satellite Activity in Africa.

Country	Earlier Sat in RS Program	Cube Satellite, Size	Edu/Tech	Self Dev	Coop	Status
Algeria	AlSat-1	AlSat-Nano	Tech	Co-op	Uk Space Agency	L
Egypt	EgyptSat-1	EgyCubeSat-1	Tech	Y-National Agency	-	No Launch
Ghana (Bird)	NEW	Bird-G	Edu	No	KIT Japan	L- Falcon 03-06-2017
Kenya	NEW	1KUNS-PF	Tech Transfer/ Edu	No	La Sapienza Univ. Rome	To be De-ployed from ISS Jan 2018
Nigeria (Bird)	Nigeria Sat-1 and 2	EduSat-1-Bird N-Operated by Nigeria's Federal University of Technology	Edu	No	KIT Japan	L- Falcon 03-06-2017
South Africa	SunSat and Slumbandina	Zacube 1 or Tscheposat	Edu	Yes- Student Develop.	Stellenbosch University	L- Dneper 21-11-2013
Sudan	NEW	KN-Sat-1 1U Cube Sat	Edu	Yes-Student Develop.	-	Unknown
Tunisia	NEW	ERPSat-1 1U Cube Sat University of Sfax	Edu	Yes Student Develop.		Unknown

CubeSat Activity in Africa: Classification by Country and Mission/Objective

1-Algeria-*AlSat-Nano*- Technology Cooperation

3U CubeSat

Cooperation between ASA and UK Space Agency

-launched aboard PSLV-G(3), on 26.09.2016

-main use is Technology Development by the UK participating companies - 1 unit of the AlSat-Nano platform has been made available to host self-funded payloads from the UK CubeSat community as a free flight opportunity.

-For Algeria it is a technology transfer vehicle but to a narrower extent than previously experienced.

Mission/Objectives :Development and test of several technologies, namely

1-Flight test of a retractable CubeSat-compatible boom.

2-A miniaturized magnetometer

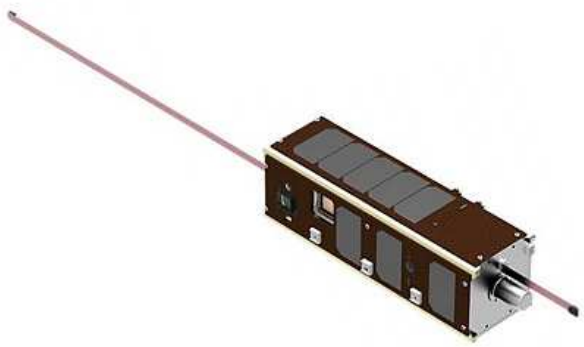
3-Radiation monitors

4-Test tokens of a flexible solar cell material.

5-C3D2– a three fields of view CubeSat camera

6-Thin Film Solar Cell technology test. Novel solar cell structure which is directly deposited on cover glass just 1/10th of a millimeter thick.

Training and Education of a number of Algerian students will be provided during the development and launch phases as part of the cooperation agreement within an education program which SSC will provide.



II-Egypt – EgyCubeSat –

Objective Technology Transfer Enhancement (Follow Up)

The Egycubesat 1 is the first Egyptian CubeSat developed by NARSS (National Authority for Remote Sensing and Space Sciences).

Objective and Mission:

The Egycubesat-1 mission goals are: to Provide experience in building and operating a picosatellite, to enhance the previous experience in design and operation of small satellites and finally to promote applied space research and engineering in Egyptian universities and research Institutes

Launch Vehicle and Possible Launch Opportunities:

Originally a piggy-back launch on a Japanese H-2A-202 rocket in 2010 was planned. In 2013, a launch on an Indian PSLV rocket was planned.

Currently launch planned are not known.

Participating technology developer/provider: Self Development

Local agency: National Authority for Remote Sensing and Space Sciences-NARSS

Onboard Technologies and Payloads: The satellite carries a small camera with a ground resolution of 100 meter to take snapshots for Egypt territories.

III-Ghana:

GHANA SAT-1- (ANUSAT 1)-BIRD G

Ghana ANUSAT-1 or Bird G is part of the BIRD constellation developed by Japan. Bird are a small technological CubeSat (1U) built by Kyushu Institute of Technology (KIT) as the Joint Global Multi-Nation Birds Satellite project, which is a cross-border satellite project for non-space faring countries supported by Japan.

Objective and Mission:

Technology Demonstration- Education. Bird is the simplest form available for a new entrant into the space field. It provides hands-on technology of building satellites for a limited number of graduate students from the participating developing country.

Launch Vehicle and Date of Launch: Falcon-9 v1.2- 03.06.2017

Participating technology developer/provider:
Kyushu Institute of Technology/

Technology Receiver:

All Nations University, GHANA
Education: Three graduate students at All Nations University BIRD program.
Technology Transfer/Technology Development N/A

IV-KENYA-1KUNS-PF [3]

(1st Kenyan University NanoSatellite-Precursor Flight)

1U CubeSat developed by the University of Nairobi, Kenya, as a precursor for the Kenayan-Italian IKUNS earth observation CubeSat. Extension of IKUNS (Italian-Kenyan University NanoSatellite)

Objective and Mission

The aim of 1KUNS-PF is developing a Cubesat for Earth Observation, technological testing in orbit and proving functionality of several components, intended for use in the IKUNS mission.

Launch and Vehicle:

1KUNS-PF has been selected by the

To be launched by the Japanese Kibo module in the International Space Station (ISS), as part of the "KiboCube" program supported by the Japanese Space Agency (JAXA) and the United Nations Office for Outer Space Affairs (UNOOSA).
Launch Date January 2018.

The cooperation between Kenya and Italy in developing an operational CubeSat for Earth observation can be considered the first Capacity Building/Technology Transfer program in Africa using CubeSats.

Developed Technologies:

The in-house developed systems are:Silicon cell solar panel

Telemetry Electronic Board

3-DOF attitude control system, using a momentum wheel

Three-Degrees Of Freedom attitude control system, using a momentum wheel

Participating technology developer/provider:

"La Sapienza" University of Rome and ASI, the Italian Space Agency,

Local agency:

Project run by University of Nairobi under the Convention for managing activities at Broglio Space Centre in Malindi (Kenya)

V- NIGERIA: Nigeria EduSat-1

Bird 1U CubeSat , 1 kg, Part of BIRD project with Ghana from Africa, Mongolia and Bangladesh from Asian non space faring nations

Objective and Mission

Education of non-space faring and developing nations-International coopera-tion-Pooling and joint receiving of info via 7 Ground Stations.

Launch Vehicle and Date of Launch: Falcon-9 v1.2, 03.06.2017

Participating technology developer/provider:

Kyushu Inst. Of Tech (KIT) Japan

Local Agency or University

Nigeria's Federal University of Technology

Payload or Technology

Each satellite carries

1-Earth imager, Camera

2-amateur radio

3- microcontroller technology demonstration experiments.

Training and Education:

15 students from 6 participating countries

VII-Sudan ,7-KN-Sat 1,

A student-developed 1U CubeSat KN-Sat 1 is the first Sudanese satellite project.

It is an educational satellite designed at the University of Khartoum
No Launch Date is Planned.

MISSION AND OBJECTIVE /EDUCATION AND TECHNOLOGY

UNIV-EDU

An educational satellite designed at the University of Khartoum complying with the 1U-CubeSat specifications.

Objectives are:

1-Edu- hands-on space project experience.

2-To document the process and skills

3-To promote space engineering and space science education

4-Monitoring and tracking the CubeSat after Launch, and Collecting the telemetry and the mission data for analysis and evaluation.

Launch Date and Vehicle:

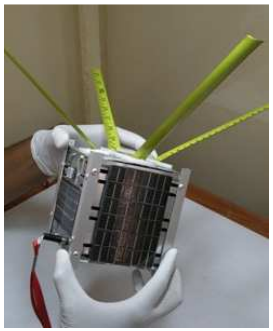
Unknown

Developing Agency

Sudan-University of Khartom

Agency Giving The technology:

self developed



VIII- Tunisia

Name and Type of Satellite, ERPSat 1

The first Tunisian 1U CubeSat, a student-developed CubeSat

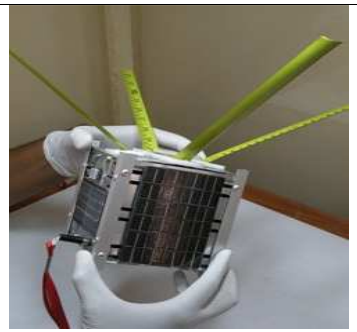


Figure 1. ERPSat 1 , **Tunisia**

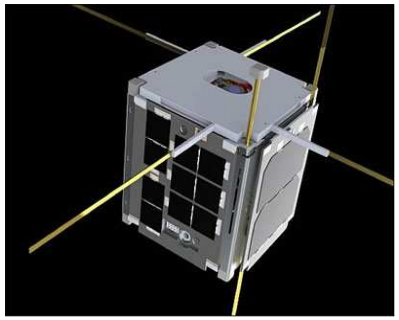


Figure 2. ZACUBE 1, South Africa

Mission and Objective /Technology and Payload

The satellite will test technologies in space, among them strip antennas developed at Sfax university.

Agency Giving The technology:

self developed - University of Sfax.

Launch Date and Vehicle:

The satellite was planned for a launch in 2013. Current status of the project is unknown.

VI- South Africa -ZACUBE 1

The South African ZACUBE 1 (South Africa CubeSat-1) **or** TshepisoSat

TYPE OF SATELLITE:

A student-developed 1U CubeSat

MISSION AND OBJECTIVE

Its main payload is a high frequency (HF) beacon transmitter that will be used to help characterize the Earth's ionosphere and to calibrate SANSA's (South African National Space Agency) auroral radar installation at the SANAE-IV base in Antarctica.

Launch Date and Vehicle:

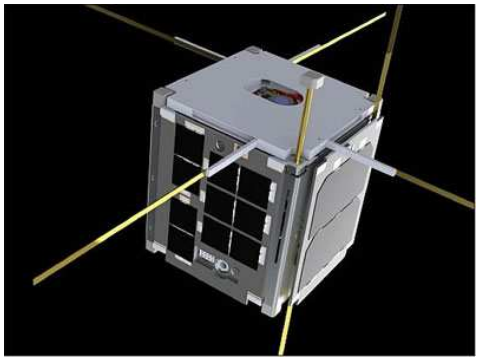
The launch is provided by ISI Space and was launched with a Dnepr from Dombarovsky (Yasny), Russia, Dneper, 21-11-2013

Local Developing Agency:

French South African Institute of Technology (F'SATI), CPUT (Cape Peninsula University of Technology), Cape Town, South Africa Development of ZACUBE-1 commenced in early 2011.

Agency Giving Technology Transfer

ZACUBE-1's ADCS was developed in collaboration with F'SATI and ESL (Electronic System's Laboratory) at Stellenbosch University, Stellenbosch, South Africa.



ZACUBE 1 *[CPUT]*

The South African ZACUBE 1 (South Africa CubeSat-1) or TshepisoSat

University Satellites

University Satellites are built by Universities and in a university environment. Their objectives, generally vary from education to technology development to being used as a vehicle for first entry of a country in the Space Technology field.

University satellites are not favored for technology transfer. The reason is that the teams which work on University Satellite projects are changeable and transient. They are not usually fixed for long enough periods that are necessary for transfer of technology.

Some of the major developments in small satellites happened in Universities. Some of the University satellites became classical. After all the satellite UoSat-1 which started the small satellite revolution was a University Satellite.

University satellites are not necessarily used only for education. Often times they are pioneering in technology development. The satellite SUNSAT of South Africa which was the leader in technology transfer and development in Africa and the developing countries worldwide was developed at Stellenbosch University in Cape Town, SA.

University Satellite Activity in Africa:

Universities started to shoulder increased share of the activity in space in two areas, Education and Technology development and transfer.

Of the eight Cube satellites that are developed in Africa, six can be classified as University Satellites, according to the rule of being developed by universities and in a university environment.

Two of these satellites are BIRD satellites developed by KIT of Japan and used as an educational tool (Nigeria and Ghana). These are international cooperation projects. No major role is played by the local students. One is used additionally, as an entry for a developing country into the space field (the case of Ghana).

The student developed satellites are those of South Africa, Sudan and Tunisia. Two of these satellite projects are self-developed by university students in Sudan (KN-Sat-1, Sudan University of Khartoum), Tunisia (ERPSat-1, University of Sfax.

The third satellite developed by university student is the one developed by students of the French South African Institute of Technology (F'SATI), CPUT (Cape Peninsula University of Technology), Cape Town, South Africa. The ZACUBE-1's ADCS was developed in collaboration between F'SATI and ESL (Electronic System's Laboratory) at Stellenbosch University, Stellenbosch, South Africa.

Algeria is developing a CubeSat *(ALCUBESAT-1)* at the Graduate School of Technology and Space Applications (EDTAS) at the University Sciences and Technology Oran, Algeria. The satellite aims at providing educational experience to the students, but more importantly, it is intended to provide technical and developmental experience to the faculty and researchers at the Graduate School.

A notable example to the role of the university in space, is when a university plays the role of a national agency of space and enters into long term agreements with a foreign technology provider for satellite technology transfer as in the case of Kenya.

Kenya and Algeria programs are Technology development and capacity building satellites.

CUBESATS AS A VEHICLE FOR TRANSFER OF TECHNOLOGY:

The Italian Kenyan Cooperation (Reference 8,9):

The Kenyan-Italian cooperation for development of a 1U CubeSat, 1KUNS-PF as a precursor to a joint CubeSat 1KUNS for Earth Observation can be viewed as the new model for Small Satellite Technology Transfer and capacity building between the two countries of Kenya and Italy. The project is run by University of Nairobi under the Convention for managing activities at Broglio Space Centre in Malindi (Kenya). The technology providers are "La Sapienza" University of Rome together with ASI, the Italian Space Agency.

Algeria-UK cooperation:

This is a new promising model of cooperation using CubeSats as a new platform for mission testing and technology development. The project is a technology development/demonstration project with a smaller element of technology transfer and training. The benefit to Algeria is the exposure to the new technologies.

INTERNATIONAL COOPERATION PROJECTS OF CUBE AND UNIVERSITY SATELLITES, AND THEIR BENEFIT TO AFRICA

In terms of cooperation with advanced space faring countries and agencies, four African countries benefited from technical international cooperation and support. These are Algeria, Ghana, Kenya, and Nigeria.

The cooperation took the form of satellites developed by advanced countries for Education and for Entry into the space field. African countries in the this case receive only the educational experience obtained from such satellites.

The second form of cooperation is sharing the experience of developing new technologies for CubeSats. This is the experience of Kenya and Algeria and it is the most beneficial form of international cooperation.

The third form is the provision of launch opportunities. This came primarily in the form of initiative for launch from the Japan module in ISS.

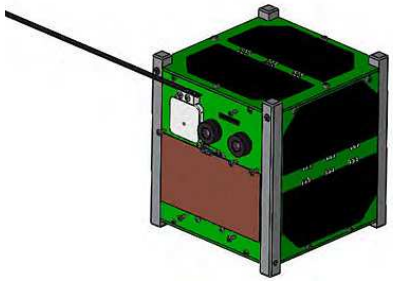


Figure 3. Bird [KIT]

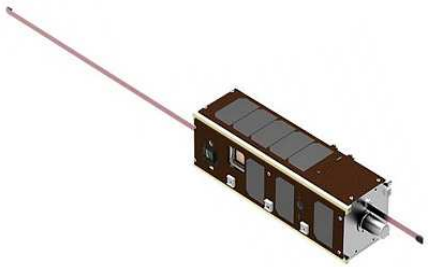


Figure 4. AlSat-Nano, Algeria

Cooperation in Technology Development and Transfer

This included The Italian Kenyan Cooperation (Reference 8,9] and **Algeria-UK co-operation**. Both were discussed in some detail Section IV before.

Launch Opportunities from the ISS on the *kibo* module

1KUNS-PF has been selected by the Japanese Space Agency (JAXA) and the United Nations Office for Outer Space Affairs (UNOOSA) to benefit from the opportunity to be launched by the Japanese *Kibo* module in the International Space Station (ISS), as part of the "Kibo-Cube" program. The program offered by the UN and JAXA is still available for other launches.

Conclusion:

In Africa eight developing countries had a CubeSat satellite program in the last few years.

Four of these countries are new comers to space activity who had the objective of entry in the space field. These are Ghana, Kenya, Sudan and Tunisia. The other four are veterans of early Remote Sensing Satellite technology transfer programs.

Five of the CubeSats developed in Africa were actually launched. These are the satellites from Algeria (26.09.2016 PSLV-G(3)), Ghana (03-06-2017 Falcon), Kenya (to be deployed from ISS in Jan. 2018) ,Nigeria (03-06-2017 Falcon), South Africa (21-11-2013 Dneper), not launched: Egypt, Sudan, Tunisia.

In the area of technology, one starting space faring nation, Kenya, had a strong capacity building and technology transfer program in conjunction with the Italian Space Agency. Among the veteran countries in space technology,

Algeria had a sound technology sharing and enhancement program with the UK.

In terms of entering of new comers into the space field, two countries achieved this objective. One is Ghana via the BIRD program and the other is Kenya through its cooperation with the Italian Space Agency.

In self-development South Africa, a pioneer in technology development in the continent of Africa had a student development program for its satellite ZACUBE-1.

Another two start up programs, namely, Tunisia and Sudan had self-developed programs which are aimed mainly at education.

Educational experiences were provided by two satellites of the type BIRD provided by Japan. These are BIRD-G or for Ghana and BIRD-N for Nigeria.

The self-developed satellites of Sudan and Tunisia are directed mainly towards education.

Algeria, which has a technology development satellite, also has another satellite under development which is directed mainly to education.

THANK YOU