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A Survey of Locally Available Subsystems for Cubesat Projects in Nigerian Market

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Abstract
There are quite a lot of cube sat subsystems that can be procured on the African continent to develop Cube Satellite (CubeSats). However these are not noticed by many relevant professionals that can design and integrate them to functional CubeSats in Nigeria.frican countries And other This is despite the ever increasing role this class of satellite is playing in educational, scientific research and commercial satellite weather, earth observation and communication services. The paper also identified basic physics principles and mathematical models for the prediction of the attitude of a spacecraft and the units that makes up the CubeSat. The thrust of this paper is to explore and bring to fore these vital subsystems, their uses and configuration for CubeSat project with a view of encouraging increased research activities in CubeSat development, with some information on their power requirements, typical cost, sources, their interrelationship and combination to perform the task of a weather monitoring CubeSat.
Keywords: *Survey, Local, Cubesat, Available, Nigeria, Subsystems*

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I. Introduction

A Cube Satellite is a small artificial object which has been intentionally deployed to encircle a bigger object; such objects are sometimes called artificial satellites to distinguish them from natural satellites such as the Moon, the only natural satellite of the earth. Satellites fly high in the sky, above the Earth's clouds and air and can see larger areas of Earth than ground based or any other scientific platform. The last decade has seen an increased growth in the need to design and manufacture small or miniaturised satellites, at a lower cost and a shorter time of completion as envisioned for this class of satellites for cheaper platform for communication and earth observation and other developmental purposes, prior to 2003, which marked the beginning of the Cube Satellite (CubeSat) era.

Satellites continue to play a key role in the acceleration of global technology, media and communication industries growth over the last fifty years. They have made it possible to deliver high-quality video and digital content, as well highly efficient broadband networks. Nigeria's dream of joining the league of global satellite owners started at a pan African summit in Addis Ababa in 1976, The Daily Trust (25th February 2014) reported that the then Head of State of Nigeria, General Murtala Mohammed, told the member nations of the Economic Council of Africa/Organisation of Africa Union (ECA/OAU) about the history of satellites and that Nigeria will soon own a satellite. In furtherance of this dream, his administration launched a development plan and disbursed N10 million on satellites project between 1976 and 1980, a plan that did not materialize until 1998. In 2018, *Space in Africa* (2018), reported that, of the over USD 4.7 billion spent on fifty eight (58) satellite projects in Africa between 1998 and 2018, Nigeria spent over 500 million dollars leading to acquisition of 6 satellites but still, without capability of manufacturing or deploying her own in the country. In spite of the increasing revenues from space activities corroborated by Sheetz, writing in the CNBC newsletter of October 4th 2020, (Sheetz. 2020) 'using a compound annual growth rate of 10.6%, the average from the last two years, Bank of America forecast that the space industry's revenue will grow by 230% from $424 billion in 2019 to about $1.4 trillion in 2030" (Sheetz, 2020).The beneficiary countries covered in the satellite manufacturing and launch systems market report are Australia, Brazil, China, France, Germany, India, Indonesia, Japan, Russia, South Korea, UK, USA; showing that no African countries is revenue beneficiary but net consumers. Similarly, for internet satellite service provision, Africa with over one billion people, sixty five percent of which are youths, spends millions of dollars daily on various digital applications. This bring the imperative of focusing on manpower and resource development by our universities and research centers in the continent to provide high-quality workforce for high-tech companies in Africa to be able to participate in spacecraft manufacturing activities and own these vital infrastructures to harness these nature provided resources, become important space research players, particularly, given the enduring perception that a presence in space brings prestige, geopolitical advantages, protected airspace, secure data and economic opportunities.

Laws For Mechanics And Gravitational Attraction

Some of the useful laws for mechanics and gravitational attraction used in the analysis of celestial and spacecraft orbit dynamics were formulated by Newton. These have tremendously helped the various activities on space flights. The three (3) laws of Newton for motion and gravitational attraction are as stated:

(i) Every particle remains in a state of rest or uniform motion in a straight line with constant velocity, unless acted upon by an external force or stated in another way "If an object does not interact with other objects, it is possible to identify a reference frame in which the object has zero acceleration", such a reference frame is called an inertial frame of reference.

(ii) The second law states that "when viewed from an inertial reference frame, the acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass".

(1.6)

The rate of linear momentum p of a body is equal to the force F applied on the body,

= **mv** (1.7)

and F = = (1.8)

where m is the mass of the body v is the velocity and t is the time. For a constant mass, this law takes the form

$F = ma$ (1.9)

where $a =$ (1.10) a is the acceleration.

(iii) The third law states that "If two objects interact, the force F_{12} exerted by object 1 on object 2 is equal in magnitude and opposite in direction to the force F_{21} exerted by object 2 on object 1 or that for any force F_{12} exerted by particle 1 on a particle 2, there must likewise exist a force F_{21} exerted by a particle 2 on a particle 1 (Figure 1.2), equal in magnitude and opposite in direction"

$F_{12} = F_{21}$ (1.11)

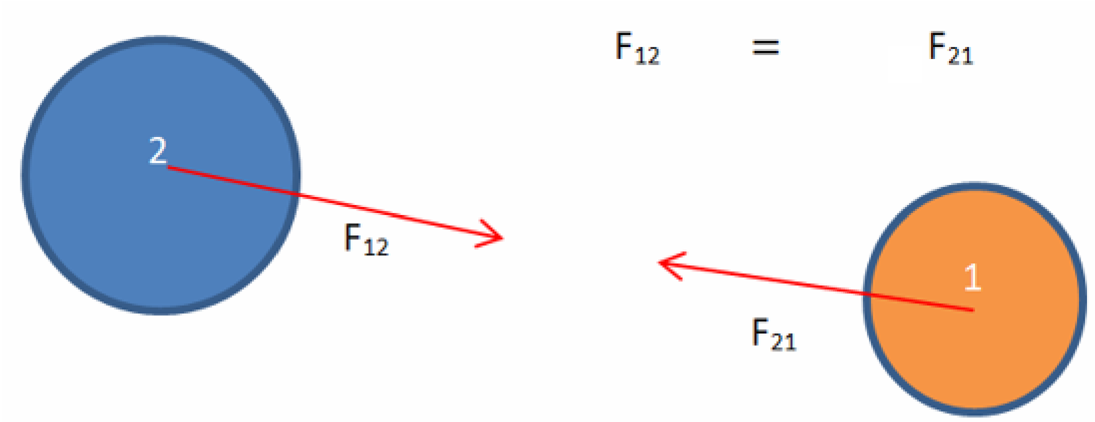

Figure 1.2: Illustration of Third Newton's Law of Motion.

II. Types of Satellite

Broadly these are Weather, Earth Observation and Communication satellites, but vary in sophistication, depending on the quality and precision of the instrument on the satellite. This study will be limited to these three types in research class.

The Weather Observation Satellite

Weather observation satellites are equipped with sensors and instruments to observe and collect data about the Earth's surface, atmosphere, and oceans. Payloads may include cameras, multispectral or hyper spectral imagers, synthetic aperture radar (SAR), Ocean colour instruments (OCI), multiple direction/polarization radiometers and other remote sensing instruments

The Earth Observation Satellite

Earth observation satellites are equipped with Cameras, Ocean colour instruments (OCI) and Multiple direction/polarization radiometers

The Cubesat Subsystems

Generally, the Satellite system can be broken into six major subsystems:

(i) The bus or structure;
(ii) The Communication system;
(iii) The Electrical Power System

(iv) The Attitude determination and control system(ADCS);
(v) The Command and Data Handling (CDH)
(vi) The payload; and
(vii) The Thermal control subsystem

III. Satellite Subsystems

THE BUS/ OR STRUCTURE :The structure is the mechanical base that provides adequate stiffness and support to spacecraft subsystems during launch, maintains structural integrity and stability while on station in orbit, and protects satellite subunits and payloads from extreme

The primary material utilized is aluminum alloy, and the surfaces are subjected to hard anodizing in order to prevent cold welding while in orbit.

The Communication System;

The functions of a communications system are three, namely; receiving commands from Earth (uplink), transmitting or receiving information from another satellite (crosslink or inter-satellite link) and transmitting data down to Earth (downlink). Components associated with the communications subsystem are antennas, receivers, transmitters, and amplifiers

The Electrical Power System

Electrical power system (EPS) covers electrical power generation, power conversion, power regulation and control, power storage, and power distribution (or power management and distribution (PMAD)). It is a primary and important subsystem, which the life of a satellite system greatly depends. Power System consists of primary batteries or rechargeable secondary batteries which act also as storage medium for the continuous supply of power when the primary source (solar, nuclear, e t c) is inhibited.

The Attitude Determination And Control System (ADCS);

The attitude determination and control system (ADCS) maintain the spacecraft in the correct orientation. It consists of sensors to measure spacecraft's orientation, control laws embedded in the flight software, and actuators (magnetorquers, reaction wheel, thrusters). The actuators apply the torques needed to re-orientate the spacecraft to the desired attitude, thereby keeping the satellite in the correct orbital position, and the antennas pointed in the right directions

The Command And Data Handling (CDH)

The CDH monitors the on-board electronics and interfaces status of the spacecraft; transmits equipment operation data to the ground control station, and receives the ground control station's commands to perform equipment operation necessary adjustments and measurements. CDH components include data recorders, attitude determination and control system with microcontroller or processors, interface units, data buses, encryption and decryption equipment.

The Thermal Control Subsystem

The thermal control subsystem helps protect the electronic equipment system inside a safe temperature range over the life of the nanosatellite from extreme temperatures due to intense sunlight or the lack of sun exposure especially on different sides of the satellite's body on which solar cells are mounted

The Payloads System

Payload is the term used to describe the function of a spacecraft or its the mission's primary objective. Payload can be communication transceiver equipment for sending and receiving information, earth observation camera for taking images of the earth or other objects of other planets. Figure 1show the various payloads for some of the space crafts in orbit.

IV. Vital Sensors and Components of Cubesat In Nigeria:

Some of the vital components of CubeSat projects obtainable in Nigerian electronic stores are Sun sensors (Photodiodes), Magnetometer, GPS, Gyroscope, Accelerometer. Microcontrolers (Arduino nano, Arduino Mega) . Others are Transceivers, power and power management units**.**

Sources of Procuring Cubesat Subsystems in Nigeria.

Table 2 show typical subsystems used in the development of a weather monitoring CubeSat in Nigeria. As indicated in the Table, all the items bought were available on shelf in Nigeria at electronic shops at Ile Ife, Ibadan and Lagos. Other places these components can be procured are Port Harcourt and Abuja. Figures and 2 1 shows some of the mentioned vital components, a variant of the microcontrollers used in the CubeSat project Arduino Mega 2560 Pro mini Microcontroller with dimension of 3855 mm, and a suitable miniature IMU procured locally. Those that were not bought could be designed and fabricate in house. These include antennae, Magnetorquer for the Attitude Determination and control, thermal control system, Power and Power management unit while the bus or CubeSat structure can fabricated with available local materials using basic machine tools.

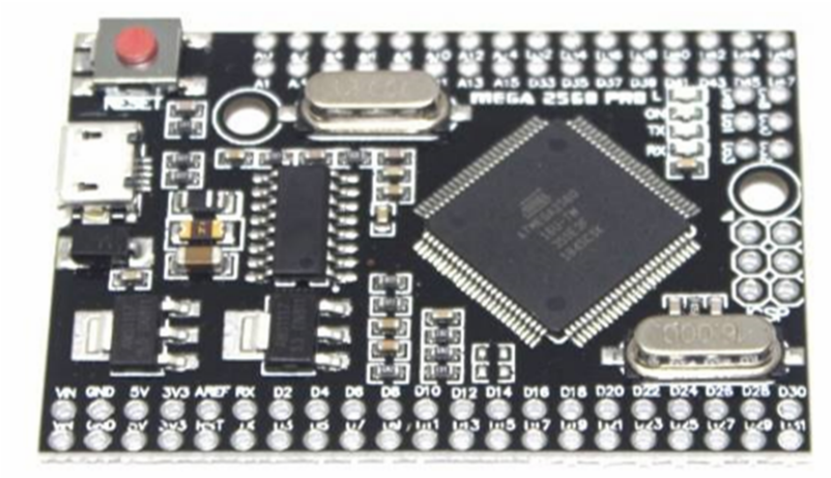

Figure 1 Arduino Mega 2560 Pro mini Microcontroller

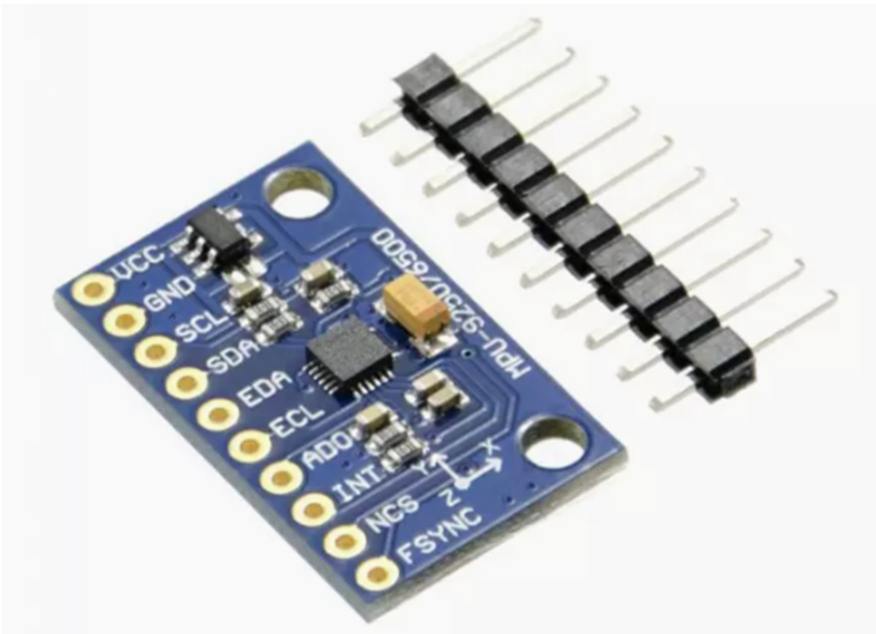

Figure 2 : 9 Degree of Freedom Inertia Measuring Unit (IMU)

V. Conclusion

As outlined in this paper, Africa possesses necessary human and material resources to develop and acquire requisite skills in small satellite development, the various building blocks of small satellite and their functions on the space craft have been discussed, their power requirements and typical cost identified. As the world is a global village, any of the subsystems that are not available on the shelf can be procured online from relevant vendors like e bay, jumia, amazon, etc. This presentation is, with a view to encouraging active participation of our scientist in personnel training and onshore space craft development at our schools and colleges instead of developing this vital space exploration equipment overseas.

Table 1: Typical Subsystem procured in Nigeria for a Cube Satellite.

	Description	Number Needed	Power Requirement	Model	Source	Cost
1	Magnetorquer	3	275 mW		Made in house	5000 .00
2	Magnetometer	1	0.25 mw		Bought	38 981.21
3	Accelerometer	1	30 mW		Bought	do
4	Gyroscope	1			Bought	do
5	Microcontroller	2			Bought	26800.00
6	Transceiver	2			Bought	22000.00
7	Weather Measuring Instrument	1			Bought	19500.00
8	Micro SD card 125 GB	2			Bought	25000.00
9	Cube Structure	1				12000 00
10	Base Station Structure	1				5000 .00
11	Liquid Crystal Display	1			Bought	14800.00
12	Miscellaneous					25000.00
13	GPS	1			Bought	9500.00
	TOTAL					203581.21

Table 2: Typical payloads for some Satellites

S/No	Mission	Typical Payload
1	Scientific	Magnetometer, Spectrometer (Neutron Ray, Gamma Ray), Ocean colour imager, Ionospheric Plasma and Electrodynamics Instrument
2	Navigation	Software defined radio(SDR) for system users positioning
3	Weather Monitoring	Scatterometer, Ice cloud Imager, Microwave imager Temperature, Pressure, Humidity, Magnetic Field Sensors
4	Earth Observation	Infra-Red Sensors optical, hyperspbectral, multispectral, panchromatic imagers and cameras,

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