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# Geospatial Sciences and Space Law: Legal Aspects of Earth Observation, Remote Sensing and Geoscientific Ground Investigations in Africa

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**Abstract:** Geospatial sciences play crucial roles in and have effects on the socioeconomic, political and security fortunes of states. Earth observation, remote sensing and geoscientific ground investigation increasingly occupy vantage positions in the legal order of states, particularly in evidential terms and in the verification of facts under international law. How then do these aspects of space law and space sciences affect contemporary Africa and the commercial fortunes, as well as international relations among some African states? What impact do they have in relation to: (a) international boundaries disputes and demarcation activities; (b) management and the preservation of the African heritage; (c) disaster and conservation management? The paper will test the hypothesis that it is crucial for the development of the continent especially in the areas mentioned above that states should sustain and increase investment in the following areas: archaeological prospection, condition assessment of heritage assets; Geographic Information System (GIS) analysis of spatial settlement patterns in modern landscapes and assessment of natural or human-induced threats to conservation.

**Keywords:** space law; disaster and conservation management; Geographic Information System (GIS); international boundaries; Africa; Cameroon-Nigeria Mixed Commission; satellite imagery; Boundary Demarcation; international law; relict boundaries

## 1. Introduction

It is a truism that geospatial sciences have crucial roles and effects on the socioeconomic, political and security fortunes of states. Earth observation, remote sensing and geoscientific ground investigation increasingly occupy vantage positions in the legal order of states, particularly in evidential terms and in the verification of facts under international law. How then do these aspects of space law and space sciences affect contemporary Africa and the commercial fortunes as well as international relations among some African states? What impact do they have in relation to: (a) international boundaries disputes and demarcation activities; (b) management and the preservation of the African heritage; (c) disaster and conservation management?

The paper will test the hypothesis that it is crucial for the development of the continent especially in the areas mentioned above that states should sustain and increase investment in the following areas: archaeological prospection, condition assessment of heritage assets; Geographic Information System (GIS) analysis of spatial settlement patterns in modern landscapes and assessment of natural or human-induced threats to conservation.

The paper will thus, establish how the geospatial sciences, earth observation, remote sensing and geoscientific ground investigation in their interactions with space law can aid the significant thirst for development in Africa. The obvious facts are that the space sciences are the progenitors of space activities which are all governed by space law. Thus, space law governs earth observation and remote sensing activities among others. Which specific principles of space law govern these sciences

and towards what developmental ends is an enquiry worth having? It is suggested that certain legal problems may arise in the gathering of geodetic information particularly in the use of remote sensing technology. The paper examines some of these in relation to Africa as a developing region. Our methodology is critical, comparative and socio-legal but includes a focus on the space active African states. In the area of demarcation of boundaries and geodetic ground investigation, we will examine specifically the adoption of space based solutions to the resolution of the Cameroon-Nigeria boundary demarcation process.

## 2. The Scope of Space Law in Africa

It is necessary to lay out the province of space law especially as it affects our discussion herein this paper. Space law has been defined by the United Nations Office for Outer Space Affairs as the body of law applicable to and governing space-related activities. The term “space law” is most often associated with the rules, principles and standards of international law appearing in over a dozen international treaties, standards and rules governing outer space which have been elaborated since the first space flight in 1957 [1]. It is also important to emphasize the broader conceptualization of space law so as to capture the multidimensional discipline it has become, extending among others to satellite telecommunications, intellectual property, environmental as well as military and security applications [2]. Space law has preponderantly been drawn up under the leadership of the United Nations Organization especially through the development of the five UN-originating space treaties. It however, includes and is enriched by other treaties, conventions, international agreements, rules and regulations of international/intergovernmental organizations (e.g., the International Telecommunications Union (ITU), ITU is the United Nations specialized agency for information and communication technologies–ICTs. The organisation allocates global radio spectrum and satellite orbits, develop the technical standards that ensure networks and technologies seamlessly interconnect and strive to improve access to ICTs in underserved communities worldwide [3] and the Committee for Peaceful Uses of Outer Space (COPOUS: was set up by the General Assembly in 1959 to govern the exploration and use of space for the benefit of all humanity: for peace, security and development. The Committee was instrumental in the creation of the five treaties and five principles of outer space.) [4] as well as national laws, rules and regulations, executive and administrative orders and judicial decisions. The increasing formulation of national space laws, space policies and the establishment of national space agencies create another level of regulatory framework which must be reckoned with in understanding legality of space related activities [5].

Overall it is fair to state that contemporary rules of public international space law are based on time tested principles of law recognised by civilised nations [6].

Particular mention must be made of the following ten instruments for which it may be said constitute the *corpus juris spatialis*. They are best understood in two groups as follows:

- The “five United Nations ‘originating’ treaties on outer space” (a) Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (1967) [7];
- (b) Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space (1968), U.K.T.S. 56 (1969), Cmnd. 3997; (1969) 63 A.J.I.L. 382. In force 1968. 86 parties, including the five permanent members of the Security Council [8];
- (c) Convention on International Liability for Damage caused by space Objects (1972), U.K.T.S. 16 (1974), Cmnd. 5551; 961 U.N.T.S. 187; 10 I.L.M. 965. In force 1973. 76 parties, including the five permanent members of the Security Council [9];
- (d) Convention on Registration of Objects Launched into Outer Space (1975), UNTS 187; 14 ILM 43; UKTS 70 (1978); In force 1976 39 parties including the five permanent members of the Security Council [10];

- (e) Agreement Governing the Activities of States on the Moon and other Celestial Bodies (1979), G.A. Res. 34/68, U.N. GAOR, 34th Sess. Supp. No. 46 at 77, U.N. Doc. A/34/664 (1979) [11].

The five declarations and legal principles

- (a) The Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and Under Water 1963 [12];
- (b) The Principles Governing the Use by States of Artificial Earth Satellites for International Direct Television Broadcasting (1982) [13];
- (c) The Principles Relating to Remote Sensing of the Earth from Outer Space [14];
- (d) The Principles Relevant to the Use of Nuclear Power Sources in Outer Space [15];
- (e) The Declaration on International Cooperation in the Exploration and Use of Outer Space for the Benefit and in the Interest of All States, Taking into Particular Account the Needs of Developing Countries [16].

In addition to the above there are other national and bilateral agreements relating to activities in outer space that all together provide legal cover for all of man's endeavours in outer space. It is a remarkable feature of space law and a silent success of international relations that most of the regime governing outer space has been drawn up several decades ago. Another underreported success of this law is that African states have a very strong showing in terms of acceptance of these laws and they have signed and/or ratified them in very large numbers. Indeed our table below reveals that 53 African States have signed and/or ratified space related treaties. This primarily indicates that African governments have embraced the idea of international scientific exploration of outer space and that they do have national aspirations thereto. It also reveals their readiness to partake in space policy, cooperation and exploration activities both directly and indirectly as equal partners and as sovereign states.

The following; Table 1 is revealing of the impressive level of African States integration into the general field of space law and legal ordering.

An increasing number of states worldwide are responding to the opportunities of active outer space exploration by implementing dedicated legislation. States which have national legislation governing space-related activities in a holistic manner include inter alia Argentina, Australia, Canada, Finland, France, Germany, Hungary, Indonesia, Japan, New Zealand, Philippines, Republic of Korea, Russian Federation, Slovakia, Sweden, South Africa, Ukraine, the United Kingdom of Great Britain and Northern Ireland and the United States of America.

**Table 1.** African States and the Status of International Agreements on Activities in Outer Space (as at 1 January 2017).

State	OST 1967	ARRA 1968	LIAB 1972	REG 1975	MOON 1979	NTB 1963	BRS 1974	ITSO 1971	INTR 1971	ESA 1975	ARB 1976	INTC 1976	IMSO 1976	EUTL 1982	EUM 1983	ITU 1992
Algeria	R		R	R		S		R			R		R			R
Angola								R								R
Benin	R		R			R	R	R								R
Botswana	S	R	R			R		R								R
Burkina Faso	R					S		R								R
Burundi	S					S		S*								R
Cameroon	S	R				S		R				R				R
Cape Verde						R		R								R
Cent. Afr. Rep.	S		S			R		R								R
Chad						R		R								R
Comoros								R				R				R
Congo								R								R
Cote d'Ivoire						R	S	R								R
Dem. Rep. Of Congo	S	S	S			R		R								R
Djibouti											R					R
Egypt	R	R	S			R		R			R					R
Eq. Guinea	R					R		R								R
Eritrea																R
Ethiopia	S					S		R								R
Gabon		R	R			R		R				R				R
Gambia	S	R	S			R		R								R
Ghana	S	S	S			R		R				R				R
Guinea								R								R
Guinea-Bissau	R	R				R		R								R
Kenya	R		R			R	R	R					R			R
Lesotho	S	S														R
Liberia						R						R				R
Libya																R
Madagascar	R	R				R		R								R
Malawi						R		R								R
Mali	R		R			S		R								R
Mauritania						R		R			R					R
Mauritius						R		R				R				R
Mozambique								R				R				R
Namibia								R								R

Table 1. Cont.

State	OST 1967	ARRA 1968	LIAB 1972	REG 1975	MOON 1979	NTB 1963	BRS 1974	ITSO 1971	INTR 1971	ESA 1975	ARB 1976	INTC 1976	IMSO 1976	EUTL 1982	EUM 1983	ITU 1992
Niger	R	R	R	R		R		R					R			R
Nigeria	R	R	R	R		R		R					R			R
Rwanda	S	S	S			R	R	R								R
Sao Tome and Principe																R
Senegal		S	R			R	S	R					R			R
Seychelles	R	R	R	R		R										R
Sierra Leone	R	S	S			R										R
Somalia	S	S				S		R	R		R					R
South Africa	R	R	R	R		R		R					R			R
South Sudan																R
Sudan						R		R			R					R
Swaziland		R				R		R								R
Tanzania			S			R		R					R			R
Togo	R		R			R	R	R								R
Tunisia	R	R	R			R		R			R		R			R
Uganda	R					R		R								R
Zambia	R	R	R			R		R								R
Zimbabwe								R			R					R

R means treaty has been ratified. S means treaty has been signed.

*Emergent Patterns in African Domestic Space related Policies and Space Dedicated Legislation*

Our research here shows that there are four categories of states in Africa in relation to Space Activities and space regulation.

- First, there are the majority of states that participate in space treaties but do not have active space investments and/or domestic space specific regulations.
- Second, there are those countries with active space interest, aims and aspirations but which however, do not have any comprehensive legal text regulating outer space activities. These group consist of Libya (A membership of a regional agency Centre Régional de Télédétection des Etats de l’Afrique du Nord (CRTEAN) (North African Centre for Remote Sensing) and the international organization—ITU), Sudan (A member -CRTEAN and the international organizations—Inter Islamic Network on Space Sciences and Technology—(ISNET) and the ITU.), Senegal (A member of ISNET and the ITU.), Kenya (Kenya’s progress in space sector has taken major strides over the last decade with the formation of the Kenya National Space Agency. In addition Kenya has established a National Space Secretariat (see further <http://www.mod.go.ke/?p=1932>). Kenya interestingly is not in any African cooperation organisation but is in the Asia-Pacific Regional Space Agency Forum (APRSAF) which was established in 1993 to enhance space activities in the Asia-Pacific region. In addition Kenya is a member of UNCOPUOS and ITU. Kenya is also currently considering its own space law), Niger (A member of ISNET and the ITU), Mauritania (A membership of CRTEAN and the ITU.) and Morocco (It has its own AGENCY—the CRTS and it has a pertinent Decree creating the Royal Remote Sensing Centre (CRTS), of 17 January 1990. Morocco has membership of UNCOPUOS, CRTEAN, ISNET, ITU.).
- Third group of states consist of Algeria and Tunisia that have no comprehensive legal text at the moment but have an impressive array of space connected or related legislation. Algeria has established an Algerian Space Agency and several space related decrees. These Include Presidential Decree No. 02-49 “Creation, Organization and Functioning of the Algerian Space Agency (ASAL)” of 16 January 2002; Presidential Decree No. 06-225 “Ratifying the Convention for Damage Caused by Space Objects” of 24 June 2006 and Presidential Decree No. 06-468 “Ratifying the Convention on Registration of Objects Launched into Outer Space” of 11 December 2006 [17], Tunisia has a National Outer Space Commission (CNEEA), created by Decree n° 84-1125 (24 September 1984) and also established a National Mapping and Remote Sensing Centre of Tunisia (CNCT), (Established under Law 88-83 of June 11 1988. Conformity with international and domestic telecommunications law is maintained through laws such as the Tunisian Order of the Minister of Communication Technologies dated 11 February 2002, approving the National Radio Frequency Plan. See the Tunisian -Order of the Minister of Communication Technologies dated 11 February 2002, approving the National Radio Frequency Plan. The Minister of Communication Technologies, passed this Order having regard inter alia to Law No. 2001-110 of 9 November, 2001, ratifying the Final Acts of the Congress of Plenipotentiaries of the International Telecommunication Union) [18]. The Country retains membership of UNCOPUOS, CRTEAN, ISNET, ITU and UNIDROIT and the ITU, for more information on this organisation see [www.cn.t.nat.tn](http://www.cn.t.nat.tn) visited 15 December 2018. It has domesticated several international space treaties into national law [8,19,20], also has a Law on Telecommunications of 2008 and has created its own national laws of a limited purpose for space activities, Such as the Order on Radio Frequencies of 2002, Minister of National Defense Order on the National Remote Sensing Center Fees. Tunisian law importantly identifies the state’s strategic interest and provides mechanisms for registration processes for space objects and provides the functions of state of registry.
- Fourth category consist of those states that have shown a high degree of political and infrastructural commitment to space exploration backed up with elaborate dedicated domestic space law regime. The two countries that currently satisfy these characteristic the most are Nigeria and South Africa.

African countries, both individually and as a regional bloc have at least in the last decade began seriously expressing with increasing interest the development of space programmes. These programmes aim at harnessing and optimising the general societal benefits derived from space applications. In ideal circumstances, space programmes would be carefully designed through carefully crafted space policies, strategies, technology roadmaps and dedicated space laws. However, the development of dedicated national space policies and legislation in Africa has been rather slow and insufficient given the appetite for space technological products in all parts of the continent. It has been correctly noted that much of African space policies, to the extent, they exist at all, appear to have been drawn up without the benefit of specialist knowledge [21].

There are however, a couple of models of good example principally led by Nigeria and South Africa, which both have National Space Policies, instituted in 2001 [22] and 2008 respectively [23]. It is significant to note that at the continental level, African Heads of States and Government in January 2016 adopted the African Space Policy and Strategy [24]. Overall Etim and Munsami aptly described the tenuous state of elaboration of space policies and legislation:

“... an underlying challenge is the requisite skills and experience needed for drafting such Space Policies. Much of the space policy developments on the continent have happened through on-the-job learning and a look elsewhere-and-adopt approach. In some cases, a foreign company is contracted for sector analysis. Although this informal learning and experience is valuable for the ongoing developments of national and regional space programmes, it is not the most efficient and effective means of achieving the end product. Reliance on foreign parties may not be the nation’s interest” [21].

The existence of a Space Policy provides an overarching interdisciplinary framework that informs the development of a space sector, based on its connections to the national ecosystem of corporate, industrial, educational and other sectors as well as human needs. It draws from and feeds into national economic policies, social development policies, national security policies and foreign policies, among other policy frameworks [21,25].

In terms of legislation Africa is already very well subscribed to the main space treaties and other relevant international instruments. From the Table 1 above we can see that 53 out of the existing 57 African states are subscribed to the multilateral space treaties but the question is whether these states have backed up their readiness to accept space law on the international level with adequate domestic regulations.

South Africa has perhaps the most comprehensive national space legislation/regulatory environment in Africa. Applicable legislation in force include: Statutes of the Republic of South Africa—Trade and Industry, Space Affairs Act, No. 84 (1993); Space Affairs Amendment Act, No. 64 (1995); South African National Space Act 36 of 2008; No. 21 of 2007: Astronomy Geographic Advantage Act, 2007; Spatial Data Infrastructure Act No. 54 of 2003; Electronic Communications Act No.36 of 2005 (ECA). The South African National Space Agency (SANSA) came into being in December 2010 and is guided by the National Space Policy, 2008 and National Space Policy, 2009 [26], SANSA operations fall into four programme areas: Earth Observation, Space Engineering, Space Operations, and Space Science. South Africa is also member of UNCOPUOS, APRSFAF and ITU and UNIDROIT.

It is notable that South Africa alone has made elaborate provisions jointly for laws over persons in space (jurisdiction *ratione personae*: refers to the personal jurisdiction over natural and corporate persons bearing the nationality of a state.) [27] and over space objects (jurisdiction *ratione materiae* which is the jurisdiction of states over vessels and objects like ships, aircraft, spacecraft that bear the flag of a state and are therefore, subject to the jurisdiction of the flag state) [27]. In South Africa’s jurisdictional powers as a state are expressed in its space law with respect to personal application, territorial application and extraterritorial application [28].

Nigeria’s comprehensive national space legislation/regulation is the National Space Research and Development Agency (NASDRA) Act 2010 [29] which among other things created its own space agency.



Nigeria is a member of UNCOUOS, ITU and UNIDROIT. The scope of the NASRDA Act covers regulation of Space objects launch and return; Space objects control; Ground segment operation and Space technology. The country has legal mechanisms in place to monitor and control; Authorization and licensing; Continuous supervision of non-governmental activity; Liability and insurance; Transfer of ownership in space or space objects control; Safety or space debris removal; State strategic interest; Registration process or registry.

Nigeria for its part similarly provides for jurisdiction over materials placed in space and space objects. Indeed only Nigerian Law specifically provides for space objects control. However, by leaving out provisions *rationae personae*, the country's space regime arguably falls short of its ambitious space programme which includes running its own indigenous astronauts programme. Furthermore, specific rules regarding space object launch and return, space technology and ground segment operation provisions are to be found in the dedicated, domestic legislation of Nigeria and South Africa. Nigeria, alone has fairly suitable provisions on the transfer of ownership in space for space objects control as well as for the safety of operations and space debris control. South Africa uniquely has provisions providing for an insurance ceiling [28].

Both Nigeria and South Africa commendably provide specific rules for authorisation and licensing, as well as mandatory rules prescribing continuous exercise of supervision. Both countries laws control non-governmental entities and the duty of operators to maintain liability and insurance. With respect to provisions indicating the State's strategic interests, the policies and laws of Algeria, Nigeria and South Africa are presently the clearest and most ambitious. This includes transparent provisions covering the registration process for all materials in space and establishment of registry for space objects launched on the account or with the permission of the state, such as Licensing and Duties and Liabilities of Licensee of the Space Affairs Act (respectively) (South Africa, 1993) Statutes of the Republic of South Africa–Trade and Industry No. 84 of 1993 (Assented to 23 June 1993) (Date of Commencement: 6 September 1993). For Nigeria's licensing and registration regimes see S. 9 and 10 of the NASRDA Act (2010)

### 3. Technical Features and Socio-Legal Characteristics of Africa's Satellite Constellation

Geospatial products and the air- and space-based platforms from which they are derived are useful in a myriad of ways for all modern states. Information and communications, derived from them are vital for imaging, telecommunications, telebroadcasting and information technology. In recent years microwave remote sensing devices and other meteorological applications have been very useful in monitoring cyclones, rainfall, floods and cold waves, which are regularly occurring phenomena in many developing countries, for example the Bangladesh communication to COPUOUS of 27 October 2009 as quoted in United Nations, General Assembly, Committee on the Peaceful Uses of Outer Space, Questions on the definition and delimitation of outer space: replies from Member States January 2010, A/AC.105/889/Add.5 11 [30]. Satellite technology has applications in medical aid, international healthcare and telemedicine. With satellite link up technology, such as the European Healthcare project, people living in remote areas where health care professionals are unavoidable or unable to leave their homes may receive advanced health care. Medical professionals also discuss cases and tap into specialisations without expensive transfers. Success stories in the area of teleconsultation healthcare have been demonstrated in Cyprus, France, Greece, Czech Republic, Poland and United Kingdom, The Healthcare system uses a communications format known as Digital video broadcasting return Chanel via Satellite (DVB-RCS) which do not depend on a physical cable. See GMES; European Commission, DG enterprise and Industry, EU: Connecting People through satellite-based Telemedicine Connecting People Through satellite-based Telemedicine Solutions: Scenarios and Practical Experiences from the Healthcare project available at (<http://www.epractice.eu/files/media/media1916.pdf>).

Apart from the relatively towering achievements of South Africa and Nigeria, a few other African States have taken a keen interest in space technology in furtherance of their national goals and other commercial and security interests. Earth observation, remote sensing and telecommunications are the



centrepieces of African satellite technological requirements and therefore investments. The technical specifications of Nigeria's stable of satellite acquisition, for instance, betray the country's needs at its stage of development, in 1976, Nigeria declared its space ambition to members of the Economic Commission for Africa and Organization of African Unity during an inter-governmental meeting in Addis-Ababa. In 1988 the National Council of Ministers' approved the establishment of a National Centre for Remote Sensing, to be located at Jos; with a Ground Receiving Station, at Kerang, in Mangu LGA of Plateau State (site of the defunct Aerostat Balloon Project). NASRDA's focus today is in Rocketary and Propulsions, Earth Observations and Space Communications. For more information on NASRDA see its website (<http://nasrda.gov.ng/en/>). Nigeria has taken impressive lead in Sub-Saharan Africa by launching a total of four satellite missions—NIGERIASAT-1, NIGERIASAT-2, NIGCOMSAT-1 and NIGERIASAT-X [31].

#### *Reconstruction of African Territories from Space*

The conclusion that "Border is Fate" [32] is true to the extent that the fate of African peoples are continuously changing with court and tribunal judgments and awards since the end of the colonial era. African territories are very often subject to disputed ownership and are continuously before international tribunals for adjudication, the docket of the International Court of Justice is even as of present still grappling with fresh cases and crises arising out of colonial actions over African territories. A legal challenge to British sovereignty of the Chagos Islands has been instituted by Mauritius based on allegations of coercion leading to the giving away of a large swathe of Mauritius territory before independence. See "*Legal consequences of the separation of the Chagos Archipelago from Mauritius*" in 1965 (Request for Advisory Opinion) available at: <https://www.icj-cij.org/en/case/169>; Owen Bowcott, "Chagos Islands: UK used secret threats to keep Chagos Islands, court hears" *The Guardian* Monday 3 September 2018 available at <https://www.theguardian.com/world/2018/sep/03/mauritius-takes-uk-to-court-over-chagos-islands-sovereignty>. Even in peace time boundary management of vast territories require joint and sometimes separate teams of technical personnel who have to faithfully follow and trace the boundary line through difficult terrain or on maritime zones. Indeed it is widely recognised that European colonialism continues to underlie most territorial disputes in Africa. Recent examples include the Nigeria–Cameroon dispute over the Bakassi Peninsula; the Gabon–Equatorial Guinea dispute over the islands of Mbanié, Cocotiers, and Conga in the Corisco Bay; the Mauritius–United Kingdom dispute over the Chagos Archipelago; and the Comoros–France [33].

With geospatial sciences and space satellite technology, legally significant geographic facts can be determined with exactitudes and relatively cheaply. Legally significant facts and truths increasingly turn on evidence derived from geodesy, remote sensing and other relevant geoscientific ground data. The geospatial sciences have several levels of manifest legal usefulness. Geodesy, the science concerned with the shape of the earth, for instance, has international, regional and of course, national benefits [34]. Thus, the need for geospatial products in Africa is of an urgent and increasing nature. Verification of locations by traditional surveying means is fraught with many limitations. Without space applications traditional surveying is comparatively costlier and fraught with quantitative difficulties. Multiple teams of bilateral surveying and boundary commissions are at work simultaneously across the continent. Surveying vast territories has more than its fair share of dangers. Surveyors are often caught between hostile villagers and communities, security agencies of neighbouring states and wild animals. The prospect of getting irretrievably lost in wild terrain are real and has occurred quite too often, for a particularly harrowing tale of starvation while on a surveying mission see Alistair Macdonald *Mapping the World* [34].

Geospatial products also now afford African states the crucial luxury to reconstruct boundary lines in a way more faithful to impartial geographic and scientific realities. This is particularly important for Africa because much of African territories were drawn up by people who never had any intimate knowledge of the terrain they were delimiting, Thus, African historians like Mohammed Ahmed have rightly concluded that "At both the continental and regional levels, as represented by the African

Union and ECOWAS Commission, African Boundaries inherited at independence have been accepted as *fait accompli*" [35]. Colonial delimitation and demarcation of Africa was deeply flawed in very many ways. As far back as 1890, Lord Salisbury admitted:

"We have been engaged ... in drawing lines upon maps where no white man's feet ever trod; we have been giving away mountains and rivers and lakes to each other but we have only been hindered by the small impediment that we never knew exactly where those mountains and rivers and lakes were" [36].

Thus, the providence of older maps much of which are relied on till date is notably shakeable and weak. Traditional demarcation without the use of geospatial sciences and precisely space imagery and GPS technology was understandably much less reliable. Experts warn that using an old map as a means of relocating disputed boundary markers or lost boundaries would likely give a leeway of up to 25 km on the ground. In other words mapping technology has its inherent difficulties; worse still if the map has no geodetic datum this leeway can be greater by a factor of ten or more, which could be 25 km more or less on the ground. This assessment was given by Dr. Gary Jeffress, Registered Professional Land Surveyor (Texas) and Professor of Geographic Information Science in reaction to queries raised by the author on the International Boundaries Research Unit website "Re Legal Effects of Illustrative maps" available at (<http://osdir.com/ml/culture.discuss.boundary-point/2004-08/msg00225.html>). Not only were previous mapping exercises far from a precise art, but as Botswana successfully advanced in relation to the maps in *Kasikili Sedudu case*, early maps show too little detail or may be too small in scale, to be of value. The World Court has also significantly admitted of colonial maps as follows: "maps merely constitute information which varies in accuracy from case to case; of themselves and by virtue solely of their existence, they cannot constitute a territorial title" [37]. Nigeria also argued in its written submissions to the ICJ in the *Land and Maritime Dispute case*, that it was not unknown for colonial surveyors "to round things up" in order to save themselves from more detailed but difficult work. Brownlie, in his seminal work on African boundaries, noted of the Benin-Niger border as follows: "the precise division of the rivers and thus the allocation of islands, remains the subject of doubt since the relevant French instruments are not sufficiently precise" [38].

Inherited land boundaries notoriously have ambiguous features, whereas space based solutions bring much transparency to the tasks before decision makers. Thus, on mapping and cartographic grounds alone earth observation technology could not have come soon enough [39].

The determination of the African Union to address comprehensively the problems of boundary and frontier determination and demarcation could also not have come too soon as the tensions, skirmishes, Sudan Liberation Army fighters and nomads frequently have deadly skirmishes involving humans and even camels over boundary positions [40] and outright war over boundaries have plagued African states and its peoples, Saïd Djinnit, Commissioner for Peace and Security at the African Union in a speech had reason to note that since African States gained independence, borders inherited from colonisation have been a factor of recurrent conflicts, adding that most of these borders were ill-defined and un-demarcated. AU, "Report of The Meeting: Preventing conflicts, Promoting integration" Preparatory Meeting of Experts on the African Union Border Programme Addis Ababa, Ethiopia Conference of African Ministers (Available at: [http://www.africa-union.org/root/au/Conferences/2007/june/PSC/7/Report\\_final.doc](http://www.africa-union.org/root/au/Conferences/2007/june/PSC/7/Report_final.doc)) [41]. The deployment of modern day tools in the form of satellite imagery and other geodetic data is therefore, an imperative in the quest for ascertainment of legal positions during boundary negotiations and dispute settlement procedures [42–44].

The work to be done is immense. Africa has approximately 28,000 miles of international boundaries. The national boundaries are recognisably of high level of porosity with up to 109 of its international boundaries characterised by permeability. It is significant that experts agree that up to 25% of African international boundaries are completely undemarcated, African international boundaries are 'protected' by about 350 official road crossing points, or one for every 80 miles of boundary [45]. Less than 50% of the world's maritime boundaries have been agreed upon, in Africa, the number is even less than the average in other continents. Africa has 27 mainland coastal states

and maritime delimitation is fraught with ample grounds for dispute. In light of these, it is quite commendable that African States are collectively determined to address their cartographic, earth observation and Remote Sensing (AOCRS) needs and to bring these to bear on the important tasks of delimitation and demarcation of African territories [46,47].

#### 4. Management of Boundary Lines and Conservation of State Boundaries: Case Study of the Cameroon-Nigeria Process

It may be acknowledged that there are few international legally significant events that manage to capture the attention of both the government and the people of independent states like the rendering of a verdict of the International Court of Justice (Hereinafter referred to as the ICJ, the Court or the World Court.). The judgment of 10 October 2002 in the *Land and Maritime dispute Case (Cameroon v. Nigeria)* was the first by the Court in the 21st Century to decide upon a territorial dispute on the African continent. It served as a poignant reminder of the lingering effects of a colonial era fast receding in popular memory [48–50], see particularly para.30. Three notable decisions of the ICJ preceded the Land and Maritime dispute in the new century and each had generated significant interests in their own rights [51–53], many of the Cameroon-Nigeria Mixed Commission and several sub commission documents referred to in this section are held on file by the author. The ongoing attempt to implement this judgment by both states in collaboration with the United Nations very quickly opened up new vistas for understanding the full benefits of earth observation technology to maintenance of state boundaries in modern Africa. The coverage of the implementation process involves international boundaries of about 2000 km. The process has also opened up some criticisms of the severe short comings and limitations of legal and judicial work of the ICJ. This is in relation to the realisation that some of the delimitation may have been without adequate reliance on the aid of geospatial science.

The parties soon discovered that the lack of modern geospatial data can complicate the job of demarcation of international boundaries. The dearth of Geoscientific Ground data apparently complicated matters both at the judicial hearing and implementation stages of the Land and Maritime Boundary case. At the implementation stage of the Court's judgment it was discovered by the parties that there were fundamental discrepancies in the calculations by the Court's cartographers particularly in relation to the maritime sector and that these were apparently part of the Court's evaluation. When Nigeria superimposed the Court's basepoints used in calculating the coastline against the backdrop of actual satellite imagery map, this resulted in those basepoints falling deep into water much against the technicalities of the establishment of national baselines ("Baseline" refers to the line from which the seaward limits of a State's territorial sea and certain other maritime zones of jurisdiction are measured.) The Nigerian team during the negotiations concluded that it was essential in accordance with the principles of maritime delimitation that the median line as prescribed by ICJ, must lie on the low-low waterline (on land), For this assertions Nigeria specifically relied on United Nations Division for Ocean Affairs and the Law of the Sea, *UN Handbook on the Delimitation of Maritime Boundaries* [54], Note may be taken that both Article 3 of the territorial Sea Convention and Article 5 of the LOSC provide in identical words that 'the normal baseline for measuring the breadth of the territorial sea is the normal baseline for measuring the breadth of the territorial sea is the low-water line along the coast as marked on large-scale, charts officially recognised by the coastal State as marked on large-scale charts officially recognised by the coastal State' Churchill and Lowe explain that "[t]he effect of choosing the low-water line, rather than the high-tide line is to push the outer limit of the territorial sea and other zones farther seawards, particularly on coasts where there is an extensive tidal range" [55]. Issues were also raised regarding the effect of substantial erosion on the Nigerian coastline and the effects that should have on the demarcation. Only consistent satellite imagery maintained over the decades could resolve the effects of erosion issue but those were obviously not available and could not be acquired in retrospect. Consequently, the delegation of Nigeria proposed that an independent consultant be appointed to repeat the calculations based on the application of the rule of equidistance, in order to determine the accurate coordinates of the basepoints as well as those of point X and to conduct a ground trothing.

Ground-truthing is common parlance in cartography with significance in meteorology, analysis of aerial photographs, satellite imagery and a range of other remote sensing techniques in which data gathered at a distance is verified through further processes. For instance, a pixel on a satellite image is compared to what is there in reality (at the present time) in order to verify the contents of the pixel on the image. Ground-truthing is basically a validation process to confirm correspondence between places and their abstractions, whether digitally coded or paper based.

#### 4.1. The Role of Geospatial Products in Boundary Demarcation Contracts

Much of the strides made by Nigeria in the Space sector described above happened after the judgment of the World Court. Its satellite infrastructure and has been taking place slowly and piecemeal manner. Thus, there has been very little opportunity to incorporate its growing competence during the implementation stages of the judgment. Other issues that have prevented such desirable justification for Nigeria's investments in space satellites include administrative 'bottle necks,' the disappearance of Nig-CommSAT from space in November, 2008 and the delays in launching of NigSAT-2 initially proposed for 2007 [56]. Perhaps more significantly from an economic point of view, the inability to utilise developing homegrown satellite technological opportunities created the conditions for the prohibitive costs which have become a valid criticism of the Cameroon-Nigeria implementation process. Two surveyors from both countries closely involved in that process persuasively hint at the loss of huge savings by contracting out what could have been done with domestic capabilities. They wrote that, "... the UN cartographic consultant's Specifications and Technical Guide based on 'international standards' made the cost of the demarcation exercise prohibitive" [57].

Typically after states resolve to complete the demarcation of an international boundary a series of commercial geoscientific data based contracts will be awarded. The demarcators would always place reliance on the data acquired and/or retrieved. The Mixed Commission approved the specifications for all the contracts for the demarcation of the boundary and requested that certain key contracts should be announced on the U.N website [58]. The contracts that were announced to international bidders included.

- (a) Contract for Spot 5 Satellite Imagery mapping;
- (b) Contract for GPS Ground survey Control for Spot 5 imagery;
- (c) Contract for Geodetic Datum Stations Emplacement;
- (d) Contract for Quality Assurance of Geodetic Datum Stations;
- (e) Contract for Boundary pillar emplacement;
- (f) Contract for: As-built Survey of Boundary Pillars [59].

The Mixed Commission adopted other assignments for other joint technical teams, including the field verification with the contractor for the imagery of the pillar emplacements shown on the ortho-imagery. Pillar designs were then approved for both the geodetic datum stations and for the final demarcation of the boundary. It was upon these precise mix of scientific products and legal contractual mechanisms that the seventeen yearlong processes for the demarcation of approximately 2000 km of land boundaries between the two African states has proceeded.

#### 4.2. Demarcation of Inaccessible Zones

It is a principle of law that the law must not mandate the doing of the impossible-*Lex non cogit ad impossibilia*. Sometimes a Court's judgment may be easy to interpret yet implementing it may be impossible ab initio or become impossible as things develop. This can occur as it did in the Cameroon-Nigeria process where the attempt to give effect to the delimitation instruments as prescribed by the World Court meant that surveyors will have to traverse inaccessible territories. A clear advantage of space applications in demarcation exercises is their singular advantage in making it possible for demarcators to deal with inaccessible terrain. The boundary between states tend to be



delimited by features like water bodies or treacherous natural features such as dense forests, range of mountain peaks, volcanoes or marshland. As a result verification by traversing the territory for surveys may be impracticable or even impossible.

A recurring feature in the lengthy judgment of the ICJ and therefore, in the Cameroon-Nigeria boundary demarcation project is the feature of watersheds as boundary. Note the occurrence of watersheds in the Judgment Paragraphs 79, 86, 103–112, 116–122, 124, 135–140, 147, 161, 162, 164–167, 168, 170, 174, 179, 183. Indeed it was decided that the demarcation exercise must deal with watershed line for approximately 400 km of the boundary. The *Encyclopaedia of International Boundaries* defines a watershed as “the elevated area separating headstreams that are tributaries to different river systems or basins. Watershed therefore, is the area of land where all of the water that is under it drains off it and goes to the same place [60]. The Mixed Commission soon found out that in many cases the watershed feature referred to in the applicable treaties and the World Court’s judgment are inaccessible or can be accessed only at great cost or danger to personnel. The parties thus, adopted a very modern space science solution in order to find the watershed line.

Three options were identified: (i) manual delineation from existing topographic maps with contour lines; (ii) automatic extraction from a Digital Elevation Model (DEM) data using a software application (ESRI, 2002 (a); and (iii) direct identification in the field. The UN Cartographic section successfully proposed the use of DEM data produced by the Shuttle Radar Topography Mission (SRTM) as the source data for the extraction of watershed line as well as for the ortho-rectification (See Cartographic section, department of Peacekeeping Operations, United Nations, Data and methodology Used in watershed line Extraction for Cameroon-Nigeria Preliminary mapping, 17 January 2005. The SRTM uses imaging radar technology to view the Earth’s surface. The radar signals can see through clouds, but it does not see through thick vegetation canopies and human-made features. It uses a wave length of 5.6 cm which does not penetrate vegetation competently. The shuttle spacecraft emits radar signals that are reflected on the earth surface. Two antennas receive the returning signals. The radar waves are reflected by the ground features, including bare soil, dense vegetation dense and man-made features. The topography of the terrain causes phase difference between the signals received by the two antennas. This phase difference is translated into topographic (elevation) data -Jet Propulsion Laboratory, Jet Propulsion Laboratory, “Shuttle Radar Topographic Mission” California Institute of Technology.) [61]. The Sub Commission on Demarcation selected the option of automatic extraction and specified that the boundary line for watersheds be extracted from “a fully rectified DEM” using “stereo imagery and ground control points” [62]. In the event the UN Cartographic Section was able to produce only limited coverage of stereo imagery over the boundary area that produced the DEM data required according to the parties specifications [63]. In this way GIS and DEM data purchased at considerable cost was eventually deployed to assist other field data gathered during the exercise. As a result the system proved invaluable for places like the extensive summit of the treacherous Alantika Mountains which form a watershed in the north east of the boundary line, The Atlantika Mountains are an extension of the Cameroon line of volcanic mountains, spanning the border between Nigeria and Cameroon. Certain points were however, identified as suitable for helicopter landing for the purpose of verification and construction of boundary pillars, the impressive computer generated imagery wraps the few white clouds around the actual contours of the mountainous watershed so that it does not distort the imagery or the plotting of the boundary line by the software. For those areas that cannot be reached and for which the parties have had to settle for (Digital Elevation Model) DEM watershed line extraction, it may be cynically concluded that modern surveyors continue to give new manifestation to Oppenheim’s depiction of boundaries as “imaginary lines” [64,65].

#### 4.3. Earth Observation and Remote Sensing in the Maritime Sectors

The work of the parties in the maritime sector exposed a current legal problem which will perhaps continue to emerge in these sort of processes. The question is how to deal with maritime maps used for delimitation of territory that were made before geospatial data was available. The positions

derived from satellite navigation systems such as Global Positioning Systems (GPS) are based on World Geodetic System (WGS) 1984 Datum, The WGS 84 may be described as an Earth-centred, Earth-fixed terrestrial reference system and geodetic datum. This system is based on a consistent set of constants and model parameters that describe the Earth's size, shape, and gravity and geomagnetic fields. It is also the standard U.S. Department of Defense definition of a global reference system for geospatial information as well as the reference system for the Global Positioning System (GPS). WGS 84 is indeed compatible with the International Terrestrial Reference System (ITRS) [66]. The differences between satellite derived positions and positions on older charts and maritime maps that states may have inherited as boundary positions from their ex colonisers may be significant to navigation let alone being relied upon as accurate measurement of modern boundaries. The maritime boundaries of Africa were also largely drawn up before the availability of modern space based mapping techniques and before the ubiquitous use of the GIS. In this way the ready availability of geospatial products may open up a new set of controversies in international relations.

A controversy erupted early in the Cameroon-Nigeria negotiations as to how the World Court arrived at the delimitation it decided upon in the maritime sector. This is because the treaties it utilised in the judgment which mentioned features and positions were drawn up prior to the introduction of the GIS System. Thus, how did the Court approved delimitation interface with the GIS based system? Specifically which system did the Court rely on behind doors during its deliberations and while considering its ruling. The judgment itself was silent on its reliance on non-reliance upon any available geospatial data. Indeed it became clear that the maritime coordinates on the available charts were not in terms of WGS 84. The task of conversion was also compounded because a certain crucial Map-Chart 3433 which was relied upon by the Court had no horizontal reference datum. As a result there was no computational way of deriving a correction factor converting the coordinates from the chart to WGS 84. An Expert Determination procedure was incorporated into the negotiations which witnessed the appointment of a former Surveyor General of New Zealand to look into the facts. He concluded that: "If the current coordinates are assumed to be WGS84 coordinates, without any conversion, when they are reproduced on the sea or inlet they will not be at the exact position intended by the Parties or the ICJ . . . " (Report of Bill Robertson annexed to Report of the Third meeting (2005) held on file by author.) Difficult compromises had to be made to resolve the scientific ambiguities which involved establishing new points using GPS receivers.

First the conversion of coordinates to WGS84 datum was achieved through surveying the position of a minimum of 20 identifiable reference points above the surface of the sea on either side of the maritime boundary, which have been previously identified by mutual agreement on the Admiralty Chart 3433 mentioned in the ICJ judgment. Second, where certain features cannot be identified at the location, other physical features above the surface of the sea which appear on the Admiralty Chart 3433 were surveyed to ensure that an adequate number of points had been surveyed for geo-referencing purposes, See Annex III Terms of Reference and Modalities for the Delineation of the Maritime Boundary in Report of the Fifth Meeting (2006). On the basis of these new compromises the parties developed a method for converting the available coordinates to WGS84 [67].

The field methodology for surveying and processing points adopted by the Working Group during its missions and operations are testaments to the utility of contemporary application of geoscientific ground investigation in African boundary demarcation. The precise methodology adopted is presented below and it may indeed be instructive to other teams working on similar delicate assignments in the African continent and elsewhere, See Fieldwork Methodology Annex III –I in Report of the Fifth Meeting (2006):

1. Reference points above the surface of the sea on the 1994 edition of the British Admiralty chart 3433 were to be identified and approved by the parties. The coordinates for these points were to be extracted from chart 3433.



2. The equipment to be used to carry out this field work was to be the equipment already being used by the Joint Technical Team (JTT) for the land boundary field assessment, namely the Trimble Pro XRS GPS equipment.
3. The agreed chart coordinates for the locations to be surveyed (provided from the points selected from Admiralty Chart 3433) were to be uploaded onto the Trimble Pro XRS GPS equipment already configured for WGS84 datum.
4. Using the agreed points as a guideline, the Mission was tasked with using the Trimble Pro XRS GPS equipment to navigate on the sea to the physical features identified from Admiralty Chart 3433.
5. Where the physical feature existed and is accessible, the JTT's task included recording the position using the Trimble Pro XRS GPS equipment (working with sub-meter accuracy) and with the observed position recorded onto the template developed for that purpose.
6. If a physical feature above the surface of the sea exists but the central point is not accessible then four points were observed and recorded on the feature using the Trimble Pro XRS GPS equipment from which the central point corresponding to the feature are then calculated. Each of these observed points and positions were recorded onto a prescribed template.
7. In all cases, twenty (20) epochs were to be used to record the data onto the Trimble Pro XRS GPS equipment and all measurements were in terms of the WGS84 datum in geographical coordinate format.
8. If a physical feature does not exist above the surface of the sea, the Mission's task was to move to the next position provided that a minimum of twenty (20) points were surveyed.
9. If there is a need to supplement the features identified for measurements, that is, if a minimum of twenty (20) physical features/locations are not available, the JTT could agree additional physical features above the surface of the sea and identifiable on the chart which may be surveyed in addition to those physical features listed in the Fieldwork Methodology (An agreed copy of the Admiralty Chart 3433 with physical features was attached as Annex III.).
10. Data collected by the mission were processed using GIS software adopted by the parties for purposes of geo-referencing the British Admiralty Chart 3433 into the WGS84 datum. The maximum geo-referencing errors were by agreement not to be allowed to exceed seven (7) meters. Coordinates of the twenty-one points on the maritime boundary between Cameroon and Nigeria defined in the judgment of the International Court of Justice of 10 October 2002 were extracted digitally from the British Admiralty Chart 3433 and geo-referenced in WGS84 datum.

### 5. Legal and Evidential Implications of Emerging Satellite Imagery of Ancient African Relict Treasures and Features

Africa is the world's oldest continent and her nations, institutions and peoples are humanity's first. Ancient African civilisations are responsible for founding the original logic, structure and method of statecraft for which modern human civilisation is structured. Africa's contributions to human civilisation are indisputable and vast, spanning, for example, the areas of agriculture, arts, government, law, medicine, monotheistic religion and science [68].

Remote sensing activities are one of the core areas of the utilization of outer space science. It is difficult to overestimate the usefulness of this application to commercial and exploitative activities on earth. Such activities have led to the discovery of sites of archaeological value including an ancient Peruvian pyramid [69], ancient canals in the heart of an Arizona City [69], new Egyptian pyramids [70,71] and about 14,000 Mesopotamian settlement sites, which span some 8000 years [72]. One of the most sensational aspects of satellite imagery and remote sensing applications in relation to Africa has been the astonishing discovery of long lost wall features which indeed constitute evidence of pre-existing relict boundaries [73]. Evidence has been emanating from recent satellite imagery and orthorectified imagery as well as archaeological studies that provide overwhelming evidence of other culturally significant heritage sites and features all over Africa. These include magnificent city walls,

mounds and man built ditches as well as other very precise boundary features and markers separating pre-colonial African cities, states and political groups. City walls as archaeological sites add significant tourism value to cities and the discovery of new sites can be of serious economic value to modern states [74–76]. Africa’s current boom in the discovery of walls through earth observation is highlighted by the fact that records now reveal between Lake Chad and the Atlantic Ocean, in West Africa, about 10,000 town and city walls at least 25% of which are on presently deserted sites. This makes it possible to easily tap into the commercial and touristic value of these sites if the governments of Africa and the private sector choose to invest in these discoveries.

It is particularly important to consider the socio-legal aspects of the practice of remote sensing on heritage conservation with respect to the birthplace of mankind. Apart from the conservation and tourism value, relict wall discoveries can be of immense evidential value in law. These include their usefulness in dealing with on-going and future self-determination struggles as well as resolution of international and national boundary disputes. The existence of impressive and significant relics all over Africa arguably indicate pre-existing African indigenous sovereignties which flies in the face of popular assertions that Africa was largely unmanned and undeveloped before relatively recent European colonization. Sovereignty is both a legal and political concept of universal significance across human cultures and with manifestation in time and space. The concept is political in conception and is popularly symbolised by the Leviathan of Hobbes. It implies the supreme authority of a state, which recognises no higher authority in the region. Sovereignty of an independent state, therefore, sums up the essence of statehood, and the power it expresses within a territory is at least equal to but often even greater than the sum of the power symbolised in the person of the sovereign [77,78].

### 5.1. Discovery of Relict Boundaries through Satellite Imagery

The connection between delimitation and demarcation tasks on one hand and archaeological and heritage sites on the other can and often come into sharp focus in Africa as much as elsewhere. This is because heritage sites along with other significant natural features quite often become adapted as marks of boundary alignment. One of the classic rendition of this problem in international relations is to be found however, in the notorious dispute between Cambodia and Thailand over the religious and heritage sites of the Temple of Preah Vihear. This dispute has been adjudicated upon by the ICJ [79]. Despite the existence of a definitive judgment unfortunately, severe problems periodically flare up as a result of religious and cultural implications on the affected population. The *Temple of Preah Vihear case* concerned a boundary conflict between Cambodia and Thailand (formerly known as Siam). The disputed area contained an old temple of great cultural significance. It had been built by the Khmer Peoples, the ancestors of the present Cambodian population, at the high point of their power; although since then the Khmer People have been forced back into smaller areas. The considerations the parties wished the Court to pronounce upon included: to which of the two countries’ history is the temple more related. Despite the Court’s decision in 1962 conflict persist between the parties in relation to the temple and border skirmishes occurred as recent as 2008 [80,81].

Relict boundaries refer to antecedent boundaries which have been abandoned for political purposes but are still evident in the cultural landscape. Relict boundaries manifest themselves in space by, among other features, direct border remains such as border stones, mounds, ancient walls, border roads, clearings, customs houses and watch-towers [82–84]. It is fortunate that evidence emanating from satellite imagery and orthorectified imagery as well as archaeological studies is providing overwhelming evidence of very precise boundary features and markers separating pre-colonial African political groups. Only a handful of the 10,000 walls and relict features discovered all over Africa have been surveyed so far. This portrays immense opportunities for geoscientific ground investigation well into the future. Fulfilling those tasks will be particularly fulfilling both from a scientific and socioeconomic point of view. Both old aerial photographs and other more modern remote-sensing methodologies like Lidar technology, LIDAR—Light Detection and Ranging—is a remote sensing method used to examine the surface of the Earth” [85] continue to offer an opportunity to record

much of this evidence all over Africa. The Kano City walls (a 24 km long, 20 m high perimeter) were considered the most impressive monument in West Africa as of 1903 but that achievement now pales into absolute insignificance in comparison with other recent discoveries of older demarcated boundaries [6].

Of particular note are the following:

- a. The 160 km long Sungbo's Eredo wall;
- b. The fieldwork surveys and inspections that have revealed 1600 km of the 16,000 km long Benin earthwork complex;
- c. The 45 km long Orile Owu walls;
- d. Walls of Old Oyo;
- e. Old Egbe wall and walls completely surrounding pre-European-influence cities of Kwiambana, Old Ningi, Gogoram, Pauwa, Old Rano, Old Sumaila [86–90];
- f. The emerging picture is that since at least the 8th Century AD enormous systems of walls and ditches have been used to demarcate state territorial control in the areas of contemporary Benin and Western Nigeria.

These walls are heritage sites of immense cultural and touristic value and the ignorance of their existence is being removed by rediscoveries through space activities. Eredo for instance represents a system of walls and ditches dug in laterite, a typical African soil consisting of clay and iron oxides. The total length of these fortifications is approximately 160 km. The height difference between the bottom of the ditch and the upper rim of the bank on the inner side can reach 20 m. The diameter of this enormous fortification in a north-south direction is approximately 40 km and in an east-west direction, 35 km. The walls of the ditch are recorded as unusually smooth. The system of walls are thought to encircle the ancient Ijebu state. The total length of the discovered fortifications in this area alone is said to exceed 6000 km [87].

It was not just that Kings of Benin such as Ewuare, Oba (king) Ewuare reigned between 1440–1473. Enjoying full sovereignty, he traded with foreigners including the Portuguese [91] built and maintained secure walls; it is more importantly significant that they maintained their empire very much in the tradition of progressive and sophisticated societies found elsewhere in Asia, Europe and the Americas. It is suggested that further evidence of this can emerge through careful remote sensing investigations of African cities. Quite unbecoming inscriptions of 'otherness' may be found in the writings of older authorities like Hegel, who wrote: "The Negro, exhibits the natural man in his completely wild and untamed state. We must lay aside all thought of reverence and morality—all that we call feeling—if we would rightly comprehend him; there is nothing harmonious with humanity to be found in this type of character [...] They have no knowledge of the immortality of the soul [...] the devouring of human flesh is altogether consonant with the general principles of the African race" [92].

Nothing defeats the idea that Africa was a black hole of underachievement in terms of spatial awareness and technical matters or that it has little cultural heritage sites to offer, more than the discoveries of actual sites through aerial imagery recorded by scientific methods. The promise of the discovery of even more relics and archaeological sites is certainly deserving of further investigation and more investment into earth observation and remote sensing by African states. Through these aerial imagery scholars can retrace and find corroboration and validation for the accounts of some of Europe's first explorers. The Dutch who visited the city of Benin in present day South-Western Nigeria described a highly civilised town with sophisticated spatial lay out and city planning:

The town seems to be very great. When you enter into it, you go into a great broad street, not paved, which seems to be seven or eight times broader than the Warmoes street in Amsterdam .... The king's palace is a collection of buildings which occupy as much space as the town of Harlem and which is enclosed with walls. There are numerous apartments for the Prince's ministers and fine galleries, most of which are as big as those on the Exchange at Amsterdam. They are supported by wooden pillars encased with copper, where their victories are depicted and which are carefully kept very clean.

The town is composed of thirty main streets, very straight and 120 feet wide, apart from an infinity of small intersecting streets. The houses are close to one another, arranged in good order. These people are in no way inferior to the Dutch as regards cleanliness; they wash and scrub their houses so well that they are polished and shining like a looking-glass [93,94].

Similarly the accounts given by British colonial officers of their encounter with Old Ningi debunks the myth of an architecturally undistinguished pre-colonial Africa. The conquest of Old Ningi was described thus:

Old Ningi was a nineteenth century cult settlement opposing Kano, Zaria and Bauchi from its hill fortress base using up to 4000 cavalry. Its mud walls were built on stone-based parapets and presented a complex defence strategy, which the larger kingdoms were unable to breach. It was captured by the British using a local traitor to show a secret way in near the beginning of the 20th Century [87].

A deliberate effort to continue reconstructing and rediscovering the evidence of such African indigenous engineering wonders can and should be systematically embarked upon through the use of the space technology. A policy of investment in this direction is bound to be richly rewarding for African states. Such investment is indeed consistent with the indigenous intellectual curiosity of traditional African societies as detailed studies show us that Africans have long been interested in astronomy, cosmology and cartography, Landscape features have from time immemorial been depicted in Khoisan rock art from the Brandberg, Namibia. They are believed to represent the natural resources of the group's "exploitation space" [95], The *Encyclopaedia Britannica* records that King Njoya of the Bamum Kingdom in Cameroon who reigned c. 1895–1923 CE not only invented a system of writing in 1895 but had a map of the kingdom of Bamum in ink and crayon. Oriented to the west, this map had place-names written in the traditional Mfemfe alphabet. This map was later acquired by a museum in 1937 [96].

## 5.2. Satellite Evidence of Relics and Self Determination

Apart from the possible economic and intellectual benefits that geospatial discoveries may bring there are other significant utilitarian purposes it may serve. For instance, geospatial imagery may provide backing for secessionist or irredentist movements. The ability to show the link between seceding people and their land is often crucial to their struggle. The relationship of people to their monuments, shrines, burial grounds and other items of cultural value may be of crucial value in proving distinctiveness as a people and affinity with the land. Evidence of Satellite imagery may assist in many ways to throw light upon the situation. As a writer correctly explains:

High-resolution satellite imagery can be used for human rights-related documentation, monitoring and advocacy efforts. Imagery is particularly useful for assessing the extent of violent conflict, forced displacement and other human rights concerns in remote, inaccessible or otherwise tightly controlled areas of the world [97].

Theoretically therefore, the discovery of hundreds of kilometres of walled settlement (the Sungbo wall) in Ijebu land may prove significant to the Ijebu people of South-Western Nigeria in many interesting ways. It may be used on the one hand to disprove claims that the erstwhile colonial power Great Britain met a disorganised Ijebuland or that the people ineffectively occupied the land making it *terra nullius*. There may be implications for modern day national politics as well. The same relic feature may also set up a claim by the Ijebus of a right to distinctive existence within present day Nigeria. It is indeed the case that the Ijebus have been clamouring for a separate state within the federation of Nigeria and this relic may be of assistance to their claims. In this scenario the relic boundary of the Ijebu people may be used today to reassert their pre-existing political independence in order to obtain a favourable treatment under inter-temporal laws, Inter temporal law can be broadly described as the branch of law which governs the usage of treaties, codifications and legal acts to the cases and situations which occurred before their creation or entry into force. As eloquently stated in the *Islands of Palmas Arbitration*, (Netherlands v US, 1928) it explains the legal situation that "a juridical fact must be appreciated in the light of the law contemporary with it."

A country that wants to contest a boundary may bring to the attention of the court or arbitrators evidence of the existence of the relict walls in order to show pre-colonial territorial suzerainty of kingdoms which may now be straddling international boundaries. At any rate there is much scope for rigorous multidisciplinary enquiries to incorporate this emerging phenomenon of discovery of relict walls and other archaeological features in imagining and reimagining African territorialisation.

The newly discovered boundary walls may produce the following effects:

- Evidence of international boundary marking between various pre-colonial and sometimes pre-modern African nations and kingdoms.
- Evidence to shore up claims for self-determination by existing separatist groups and peoples.
- Evidence to refute the claim that an area of Africa was *terra nullius*, thus creating the possibility of nullifying the original claim of title to the territory by the pertinent erstwhile colonial power. This is because territories inhabited by tribes or peoples having a social and political organization were not according to inter-temporal law ever treated as *terra nullius* [98].
- Within independent African states the evidence of these relict boundaries may be used to abolish, create and redraw internal boundaries in the course of the nation-building process.
- The discovery of these cultural treasures and features contribute to the much needed evidence of a glorious African past which defeats the pessimism that pervades much of coverage of the continent and its peoples.

National Space agencies such as the NASRDA and the Algeria Space Agency [99] are particularly suited for the task of developing African states competence in this area. In Nigeria for instance, the power to act proactively is located in the function of its space agency to “develop national strategies for the exploitation of the outer space and make these part of the overall national development strategies and implement strategies for promoting private sector participation in the space industry.”

The Department of Strategic Space Applications and Department of International Cooperation as identified empowered in S. 8 (2) of the NASRDA Act could play a more prominent role in studying and articulating Nigeria’s capabilities in the area of identification of relict boundaries and in adopting a more systematic approach to their detection and interpretation.

For those African states with no legislation or national bodies dedicated to space technology their capabilities to act independently is obviously limited. However, given the history of loss of Africa’s archaeological heritage into the hands of the erstwhile colonial powers, south-south cooperation in respect of heritage research ought to be one of the central planks of cooperation within platforms such as CRTEAN and APRSAF.

## 6. Earth Observation, Archaeological Research and Spatial Privacy

Archaeological research via space satellites and remote sensing is very usefully lifting the lid over the mysteries of Africa’s past. The use of remote sensing generally is likely to have increasing value in the management and exploitation of archaeological research. It has a clear role in discovery of heritage sites across a continent that played host to the very beginnings of mankind. Certain questions suggest themselves at this stage of our analysis: Will African states grasp the opportunities of this area of archaeological research through indigenous efforts? Will they do so in collaboration with the advanced space faring states and their private corporations? Indeed in the area of earth observation and remote sensing will they needlessly remain under the situation of absolute reliance upon foreign investment in this area; such as the American Landsat system or the European Spot system? These questions are germane in light of the issues of privacy, security and national sovereignty that are raised by geospatial technology even in Archaeological/Heritage Research?

The right to privacy is one that is commonly recognised in all legal systems. Yet there appears to be a lacunae in relation to the privacy principle with respect to remote sensing over archaeological and heritage sites. We have settled above that invaluable archaeological artefacts and sites may be identified from space. Something as basic as a simple Google Earth searches has produced accurate



identification of important Roman era ceramic artefacts. An Italian computer programmer recently discovered the remains of an ancient Roman Villa in his town after browsing maps and photographs downloaded from the internet site Google Earth. He correctly interpreted curious rectangular shadows he spotted nearby an ancient river as a buried archaeological structure. In this case he alerted the local archaeological museum but it cannot be concluded with certainty that similar course of action will always be adopted by other astute experts from developed countries where there is a higher appreciation of the value of archaeological material much less to expect similar results in poorer regions of the world [98]. This question of archaeological privacy is pertinent given that the history of archaeology has never been free of cloak and dagger practices and that developing states have fallen so often to their artefacts being constructively extracted permanently from their territories. Note the various accounts of treachery in relation to the discovery of Cambodia trail Pichau [100–103]. The developing states of Africa are particularly vulnerable to inadvertent or deliberate surveillance of their archaeological and heritage sites without permission. This has both commercial and security implications to the sovereign states of Africa. Privacy over archaeological treasures and heritage sites may have been lost in a fundamental way to remote sensing capabilities of a few technologically capable states whereas access to the technology is slow in coming to even those developing states that are actually showing interest in space activities. Although, many archaeological sites and monuments are located in inaccessible areas significant numbers also are to be found in cities and urban centres [104]. The use of medium- and high-resolution remotely sensed data of features, water bodies, habitats and vegetation of state territory is necessarily an issue of privacy and sovereignty. Whereas the interests of foreign investigators in Africa is quite high particularly “... in hyper-arid Africa, where collected field data are scarce, the areas to be covered are large and the visibility of certain classes of archaeological evidence is high, since it contrasts with the background barren environment” [105].

Cheng in 2004 gave a description of the impact of remote sensing activities upon modern states which may be considered impressive in its analogical and figurative value. He developed the idea that hitherto a state’s territory is its castle. According to this analogy:

A state’s territory is its castle. No one is allowed to enter it without its permission... although aviation has added an extra dimension to the problem of states in controlling what goes on in their territory, their grip in law and in fact remains unaltered, so much so that from the legal point of view the world resembles a series of immense airtight petroleum storage tanks representing the various national States with their three-dimensional sovereignty... the arrival of the space age was as if the lid on the tank was suddenly ripped off. And, if we can change the image, it was like opening up an ant-hill with all the ants inside scurrying round wondering how to cover themselves and their secrets and stores” [106].

Where remote sensing is conducted by the mutual agreement between states or between private corporations and states there would be little controversy. The legality of such activities would be manifest as long as the activities fall within the express or implied agreement between the pertinent parties. Thus, for instance, the exact geographic position to be remote sensed would usually be identified. The particular features or resources to be searched for may also have been provided for. In this way the body in charge of conducting the remote sensing operations is bound by this agreement and ought not to go beyond it or retain information that is derived in the course of the remote. It is thus suggested that remote sensing contracts over national territory constitutes a kind of contract of agency. In which case the principal is the state acquiring the required data and/or imagery and the agent is the state or corporate body conducting the scientific aspects of the task and owning or operating the requisite satellites. In this manner the normal duties of a commercial agent to his principal ought to apply and in performing his activities a commercial agent must look after the interests of his principal and act dutifully and in good faith [107–113].

In relation to areas within state territory or jurisdictional competence, the prohibition of clandestine gathering of data is irrefutable and the privacy of states is supported by international law and state practice. Clandestine as used here is not exactly the same as illegal but is wider in meaning



to include bad practice and policy of hostile intentions. The general slant of international law is towards protection of the sovereignty and privacy of states. This is further buttressed by the important restrictions in the international regulation of various easements granted to foreign states in areas and zones that expose the territorial state to security concerns. Article 38 of the LOSC (1982) which regulates transit passage in straits used for international navigation includes an important caveat namely—that in relation to research and survey activities during transit passage, foreign ships, including marine scientific research and hydrographic survey ships, may not carry out any research or survey activities without the prior authorization of the States bordering straits. Article 40 which deals with research and survey activities further entrenches an anti-clandestine approach to collection of data by stating that during transit passage, foreign ships, including marine scientific research and hydrographic survey ships, may not carry out any research or survey activities without the prior authorization of the States bordering straits. Relevant state practice may be seen in the reaction of the US to the U2 incident witnessing the flight of US aircraft over Soviet territory and the subsequent downing of the erring aircraft, the US not only apologized for the event but made diplomatic assurances that such reconnaissance aerial flights will no longer be made [106,114].

Remote sensing operations conducted through clandestine means, however, is the new bug bear of international relations. Archaeological spying may just be the new flavour of this age-old problem of International Relations. The problem of clandestine remote sensing may emanate in two basic ways: First and perhaps most significant from the security of the territorial state's point of view is espionage by remote sensing. This problem was first dramatically exposed during the twilight years of the cold war era when a picture emerged in the *Jane's Defence Weekly* in August 1984 and in an edition of the widely circulated UK *Times newspaper* in the same month showing with extraordinary clarity the Soviet shipyard at Nikolaiev on the Black Sea [115]. Inset in the picture was the emerging jigsaw of the construction of the premier Soviet naval 75,000-ton nuclear-powered aircraft. A second way in which clandestine remote sensing is employed is in the form of the gathering of data and images of the natural resources and environment of a territorial state. This includes collation of economically sensitive information about energy resources, hydrocarbon reserves, agriculture, fisheries, forestry, mining, shipping, cartography, wildlife migration patterns, heritage sites and human traffic flows [106,116,117]. Note also the controversies in international space law as to the spatial demarcation boundary plane issue whereby there is no certainty as to where in spatial terms the sovereignty of each state ends. Thus, it is difficult (among other issues) to show where exactly illegality of remote sensing begins.

It is necessary to grapple with the existence of contrary views and interpretations according to which remote sensing is illegal only if violating some specific prohibitions (such as the prohibition to enter foreign airspace without the consent of the relevant state). In short: remote sensing or spying by satellites is not 'illegal' since to sense other countries without their consent and/or even without providing them with derived data is legitimate as long as such states have been given access to data 'on a non-discriminatory basis and on reasonable cost terms' -within the provisions of UN Resolution 41/65 (Principle XII). This particular provision is indeed considered as customary international law. The U.S. as a space power obviously championed the so called "Open Skies" policy according to which there is international availability of remotely sensed data on a non-discriminatory basis. Indeed the UN Remote Sensing Principles (UN Principles) largely follows this policy. It is also important to note the complete absence of protest against the overflight of Sputnik-I and following Soviet space objects [118]. It is however, not incontrovertible that clandestine remote sensing is good policy in international relations. The fact that sensed states have the right to access the primary data, processed data and analysed information on a non-discriminatory basis and on reasonable cost terms is an indication of the instinct of international policy on this sensitive issue.

It must however, be conceded that further arguments have to be to fine-tune the law in this area of space practice. This will be necessary in order to forestall the issue becoming a flashpoint in the occurrence of military tensions and disputes. The situation is indeed, 'an equal opportunity challenge.'

As technological prowess and commercial successes of private entities becomes more democratized, even powerful states are vulnerable. A writer admits this conclusion when he wrote:

“There is a dark side, however. Just as the military will have access to high-resolution commercial imagery, so too will the general public and foreign entities, allies and adversaries alike. Without proper protections, military movement and build-up, the lay-out of military facilities and even the locations of individual pieces of military equipment could be made available to the public eye within a matter of hours. Obviously, this circumstance could have grave consequences for military operations and U.S. national security” [118].

One of the options open to states that are apprehensive of spying over their archaeological and heritage sites from above is that they should adopt domestic laws with extraterritorial effects that make the remote sensing of certain places illegal. This may include the prohibition of dissemination of any unauthorised information derived therefrom. Presumably such laws will apply to offenders as Cheng said “wherever in the world the offences may have been committed” although the ability to enforce jurisdiction will be severely limited if perpetrators do not come within territorial jurisdiction of the offended states [106]. Furthermore the ability of a state to enforce it such cases will inevitably depend on its diplomatic, political and economic clout.

Cheng one of the fathers of modern day international space law himself had noted the limitations provided by the *Lotus case* (1927) to the extent that the case while seemingly allowing states to criminalize acts committed outside territory does so upon the proviso that enforcement may be attempted only when such persons come within their territorial boundaries, Cheng introduced two helpful concepts of enduring importance. *Jurisfaction* he says denotes the normative element of jurisdiction and it represents the powers a state has to adopt valid and binding legal norms and to concretise them with binding effect through its appropriate organs, whether judicial or otherwise. The spheres of validity or operative force of these norms may be realised *ratione loci* (territorial), *ratione instrumenti* (quasi territorial) or *ratione personae* (personal). *Jurisdiction* on the other hand, is the formal element of state jurisdiction and it encompasses the powers a state possesses to, at any place or time, physically perform the acts of making, concretising or enforcing laws. That is it can hold legislative assembly, set up courts or tribunals or even arrest wanted persons. From this point of view, “the validity of jurisdiction presupposes jurisdiction, but it is possible to have jurisdiction without jurisdiction” [119]. Cheng has persuasively argued that; “Military reconnaissance satellites have not only become a fact of international life that states just have to learn to live with but also a vital instrument in the process of arms control and the preservation of international peace” [106].

In a similar manner a view may be taken that aerial/spatial archaeological research without the underlying state’s permission may have become just another manifestation of the shrinking of state sovereignties and a ‘nuisance’ which states must bear. That view however, is certainly not universal. There is therefore, a call to be made to introduce legal certainty in this area of activity. The final position on the matter will, of course, be reliant upon emergent state practice and the opinion of eminent scholars among other sources of law.

African practice and view in this area is arguably consistent with those of most of the developing states. The sheer fact of placement of cadastral authority under ministries of defence such as in Tunisia is arguably an indication of the importance some African states attach to remote sensing activities. The Minister of National Defence has the power of fixing the administrative and financial organization as well the operating modalities of the centre for national cartography and remote sensing. Tunisia Decrees No 75–671 of 25 December 1975 and Decree No 2006–1902 of 10 July 2006, Space Legal Tech, op.cit. Accordingly, even the, legal powers over the fixing of rates of the services to be rendered in Tunisia is granted to the Minister of Defence the National Centre of Cartography and remote sensing Order of the Minister of National Defence of 22 July 2016. See also the following Laws: Law No. 74–100 of 25 December 1974, creation of the Office of Topography and Cadastre, as amended by Law n ° 2009–26 of May 11, 2009; Law No. 88–83 of 11 July 1988, creation of the National Centre for Cartography and remote sensing, as amended by Law No. 2009–24 of May 11, 2009.

There is ample evidence in treaties to indicate that unilateral lifting of the aerial veil of a state without its consent may be seen as hostile, offensive and/or even aggressive conduct in certain instances. A good place to begin the analysis will be the UN Charter. The Charter in Article 74 provides that member states agree that their policy in respect of all territories under their jurisdiction “must be based on the general principle of good neighbourliness, due to account being taken of the interests and well-being of the rest of the world, in social economic and commercial matters.” In this way one would struggle to see how clandestine study of another state’s commercial and economic resources from outer space will fit within the concept of good neighbourliness. Indeed Bin Cheng’s conclusion on the matter is apposite stating that;

“There is no reason why this principle does not apply to data gathering from outer space....Although the import of the principle may not be altogether clear, its relevance to remote sensing is patent, especially in relation to the problems of dissemination and misuse of remote sensing data and information” [106].

In this manner there is nothing about the ‘hi tech’ phenomena of remote sensing activities that ought to disturb the decisions reached on the binding nature of the obligation of good neighbourliness’ and respect for equitable conduct in international relations as may be found in International case law such as the *Trail Smelter Arbitration* (1935) [120], *Corfu Channel case* (Merits) (1949) [121] and the *Fisheries jurisdiction case* [122]. Admittedly it is a difficult proposition to state that specific rules exist under customary international law which completely prohibits archaeological espionage from outer space. States may however be encouraged to institute rules mandating that the result of archaeological research by foreign states and corporations must be freely shared with the underlying state in all circumstances. This may be subject of course to reasonable contributions towards the expenses incurred although such charges ought to be heavily subsidised particularly for developing states.

#### *Disaster Regulation and Assessment of Natural or Human-Induced Threats to Conservation from Space*

Natural or human induced disasters include floods, tsunamis, volcanic eruptions, forest fires, landslides and war damage. It is trite observation as stated by the COPUOS that:

“Space applications related to Earth observation, telecommunications and global navigation can play a vital role in supporting disaster risk reduction, response and recovery efforts, by providing accurate and timely information for decision-makers” [123].

Global navigation satellite systems perform truly global tasks such as contributing to an improved understanding of the relative motion of tectonic plates and to the delivery of humanitarian assistance to areas affected by disasters [124].

The potentials of the geospatial sciences and international space regulation as tools of assessment of natural or human-induced threats to conservation is just beginning to be understood in clearer terms [125–128]. Most of the grave environmental problems facing the world are of international significance and demand coordinated scientific responses often requiring space applications.

The following table culled and collated from information available from a Space Application Matrix developed by the United Nations Office for Space Affairs, shows how earth observation and remote sensing applications have been brought to bear upon many of Africa’s pressing environmental, conservation, health and safety concerns within the last decade [129–133].

Air transportation is central to global economic activities and even the conduct of modern life generally. The reliance of airspace transportation on space based solutions in monitoring natural disasters was dramatically underlined by the events of the natural disaster of volcanic eruption in early 2010. Satellites are included in regional and international monitoring capabilities of volcanic activities and regulatory arrangements [134–139]. The international legal regime of regulation of air transportation was successfully deployed in reducing the severity of this unique natural disaster. Volcanic ash was monitored through space based platforms and the data gathered informed coordination of international legal responses. There was close coordination and communication

between various information providers in fashioning appropriate responses against this disaster and the legal responses were robust and coordinated [140].

Coordination and cooperation between states in an atmosphere of scientific brotherhood will always be key to goal attainment in the area of disaster response and management. From coping with the spread of epidemics and diseases (*Vibrio Cholerae*, malaria, West Nile Virus, tsetse flies and so forth, as shown in Table 2 above) to the monitoring of air quality and global warming space based solutions blended together with international regulation and cooperation is the future of international relations. This was precisely what the drafters of the Outer Space Treaty envisaged when they referred to:

**Table 2.** Geospatial Products, Space Applications and Disaster/Conservation Management over Africa.

Space Activity	Used Sensor	Case Study	Location and Date
Earth Observation and Remote Sensing	IKONOS Landscape	Tracking determinants of the Anopheline Mosquito Larval Habitats in the Western and schistosomiasis control in Kenya	Kenya Highlands 2002
EO & RS	LANDSAT 7 (ETM+)	Landscape Determinants of Anopheline Mosquito Larval Habitats	Western Kenya Highlands
EO, GIS & RS	LANDSAT 7 (ETM+)	Mosquito Larval Habitat Mapping West Nile Virus.	
EO & RS	Meteosat-8 (SEVIRI)	Predicting distribution of tsetse flies using temporal Fourier processed meteorological satellite data.	West Africa
EO & RS	NOAA 15-17 (AVHRR 3)	Detection of <i>Vibrio Cholerae</i> by Indirect Measurement/ Predicting the distribution of tsetse flies in using temporal Fourier processed meteorological satellite data.	West Africa
EO & RS	QuickBird-2	Dynamics and Risk Mapping Rift Valley Fever in a Zone Potentially Occupied by <i>Aedes Vexans</i> :	Senegal 2003–2007
EO & RS	RADARSAT-1	The Use of Radar Remote Sensing for Identifying Environmental Factors Associated with Malaria Risk.	Coastal Kenya
EO & RS	SPOT 5 (HRG)	Dynamics and Risk Rift Valley Fever in a Zone Potentially Occupied by <i>Aedes Vexans</i> .	Senegal 2003
EO & RS	Terra (MODIS)	Vector Borne Disease: Risk Mapping West Nile Virus WNV.	
EO & RS	TRMM (PR)	Dynamics and Risk Mapping: Rift Valley Fever in a Zone Potentially Occupied by <i>Aedes Vexans</i> .	Senegal
EO & RS	TRMM (TMI)	Dynamics and Risk Mapping: Rift Valley Fever in a Zone Potentially Occupied by <i>Aedes Vexans</i> .	Senegal
EO, RS & Damage Assessment Map	QuickBird-2	Application of High-Resolution Optical Satellite Imagery for Post-Earthquake Damage Assessment: The 2003 Boumerdes (Algeria).	Boumerdes (Algeria). 2003
EO, RS & Open Water Pollution Map	SPOT 1,2,3 (HRV)	Spectral Enhancement of the SPOT Imagery Data to Assess Marine Pollution near Port Said, Egypt.	Egypt 2006
GPS Infectious diseases risk map	SATNAV	Schistosomiasis in coastal Kenya. Water sources that the residents use (ponds, spring fed rivers and a stream and manmade open wells and boreholes) entered into a GIS.	Kenya 2000–2004
EO/RS	Aqua (MODIS) EO-1 (ALI) EO-1 (Hyperion) Terra (MODIS)	Volcanic Activity Monitoring The autonomous Model-based Volcano Sensor Web (MSW), based at JPL, proved its worth during a volcanic crisis at Nyamulagira, Congo, in 2006.	Congo 2006
EO-1	MODVOLC thermal detection	Detection and monitoring a carbonatite eruption at Oldoinyo Lengai, Tanzania.	Tanzania 2007

“the great prospects opening up before mankind as a result of man’s entry into outer space . . . Believing that the exploration and use of outer space should be carried on for the benefit of all peoples irrespective of the degree of their economic or scientific development” See the Preamble to the treaty. Article 1 of the Moon Agreement also provides: “The exploration and use of outer space, including the

Moon and other celestial bodies, shall be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development and shall be the province of all mankind [7,11].

It is indeed good international policy that all nations big and small be encouraged towards engagement in geospatial research, earth observation and remote sensing activities. An account shows that: “The fastest growing city in China in economic terms is Shanghai. Since 1996, it has shown an increase in tropospheric nitrogen dioxide of 29%, which is not good news for anyone in China, Europe or the rest of the world.” Part of the solution to this universal concern appears quite interestingly to have come from the unlikely effort of space scientists in Netherlands where the Royal Netherlands Meteorological Institute (KMNI) has developed an integrated information system for monitoring and forecasting tropospheric pollutants over China [141].

Space applications are of crucial value particularly to developing states in conservation and disaster management. This is because operational production, distribution and the effective use of environmental, remote sensing and earth observation data is of enormous benefit to sustainable development in the developing world. The VGT4 Africa project for instance, is but one of the developmental projects that has allowed African states to successfully access satellite technology for vegetation monitoring, food security, early warning crop estimation, livestock modelling and better management of biodiversity [142,143].

The VGT4Africa partners are VITO, JRC-IES and MEDIAS-France. The system has been collecting and communicating data derived from the VEGETATION instruments on board SPOT Satellites to states including countries within the Southern Africa Development Community (SADC), Sudan, Rwanda, Ivory Coast, Kenya, Ethiopia, Senegal, Congo-Brazzaville, Mauritania, The Gambia, Tunisia and the Democratic Republic of Congo.

Africa is of course, home to some of the world’s fastest growing cities and severe challenges to conservation and pollution concerns will emerge in the course of this century; hence the need for more up to date geospatial information. Africa will of course, have to shore up its competences through regional and cooperative arrangements in space but international scientific aid will also be crucial to development. Going it alone for any country will be expensive, wasteful and perhaps even counter-productive. Large scale separate engagement in space activities by potentially 57 independent states of Africa involving hundreds of private enterprises will perhaps be wasteful and may even present unprecedented dangers. The dangers include contributions to environmental pollution, climate change and international conflict. Scientific projections of the effects of space tourism industry alone shows that with a conservative estimate of 1000 suborbital flights per year rubber-burning engine crafts would produce soot that could disrupt the stratosphere and send temperatures soaring at the poles [144]. Joint cooperation in the acquisition and running of geospatial platforms for earth observation and remote sensing ought therefore, to be encouraged among African states.

As earlier on discussed a couple of African Domestic Space Acts lend themselves readily useful for Geospatial, Remote Sensing Disaster Management. In terms of legislative and institutional readiness the Nigerian situation is relatively enviable. The NASRDA Act under Section 11 (1) created certain institutions pertinent to the development of indigenous expertise. Such competences have the potentials of sub regional and regional usefulness if investments are sustained. The particular ‘Development Centres’ created and provided for by law include- the (a) National Centre for Remote Sensing, Jos; (b) Centre for Space Science and Technology Education, Ile Ife; (c) Centre for Satellite Technology Development, Abuja; (e) Centre for Geodesy and Geodynamics, Toro; and the (j) Centre for Basic Space Science and Astronomy, Nsukka. The existence of NASRDA is clearly of value in developing expertise in all the areas of geospatial sciences discussed in this work. Particular relevance lies in the obligations of NASRDA to (a) develop satellite technology for various applications and operationalize indigenous space systems for providing space services and shall be the government agency charged with the responsibility for building and launching satellites; (b) enhance the development and entrenchment of research, development and production tradition in the Agency, so



as to achieve a high output and make the desired impact on national economic and social development; (c) promote the co-ordination of space application programmes, for the purpose of optimizing resources and develop space technologies of direct relevance to national objectives; The work of the Centre for Geodesy and Geodynamics, Toro, in Bauchi State is particularly of value to surveying tasks that would rely on space applications given its mandate to (d) facilitate and sustain the growth in capacity for geodesy surveying and mapping; (e) monitor crustal deformation and subsidence, due to excessive oil and gas exploitation, global mean sea level rise and other related seismic and geodynamic phenomena; (f) implement international agreements with regard to- (i) Satellite Laser Ranging (SLR), (ii) very Long Baseline Interferometry (VLBI), and (iii) Co-operative International Geo-Physical Survey Network.

## 7. Conclusions

The uses and benefits of space technology are myriad and too many to itemise. Earth observation, remote sensing and geoscientific ground investigations specifically are revolutionising the application of scientific method to problem solving and conduct of international relations in Africa. Three of such important areas are (a) boundaries delimitation, demarcation, management and conservation; (b) discovery, protection and monitoring of relict and other archaeological features and heritage sites; (c) Disaster regulation and management of natural and human-induced threats to health and conservation. In all these areas international laws and specifically Space Law is yet to develop an impressive body of jurisprudence and provisions. Yet there is a good number of international legal instruments to which most countries of the world and impressively nearly all African countries are well subscribed to. The benefits to African countries are manifest in many areas but particularly in the areas discussed and highlighted above.

Space applications now provide means of verification of truth and practical solutions to legal problems beyond the wildest imagination and expectations of even 20th Century lawyers, judges, diplomats, statesmen and administrators. Space science thus, enriches lives in fulfilment of much of the dreams of space exploration as envisaged by the drafters of the space treaties. The manifestation of progress in the areas highlighted above within Africa is exactly what UN member states had in mind when they agreed that there are “... great prospects opening up before mankind as a result of man’s entry into outer space” and expressed the belief that “the exploration and use of outer space should be carried on for the benefit of all peoples irrespective of the degree of their economic or scientific development.”

Space science and technology will furthermore unleash tremendous growth in many African states over the next few years and decades. A bottom up approach to the teaching and practice of science and technology in general is required. Education relating to the geospatial sciences will be crucial to solving the future challenges in all the major areas of activities explored in this paper. Africa must therefore, rapidly improve upon the numbers of graduates of space sciences and indeed in space law. Whether a state is complying with international obligations or not will be decided upon through earth observation, remote sensing and geoscientific ground investigations. In May 2018 North Korea’s leader, Kim Jong-un as a show of good faith of his commitment to building “a nuclear-free peaceful world” allowed a select group of journalists from Britain, China, Russia, South Korea and the United States to witness the destruction of a nuclear test site. It was really the emergence of before and after satellite imagery pictures of the test site that granted popular verification of the event. Further Satellite imagery showing the apparent dismantling of facilities at the Sohae satellite launching station, North Korea, emerged on 22 July 2018. These indicate North Korea has begun dismantling key facilities at a site used to develop engines for ballistic missiles in further proof of its denuclearisation policies. Choe Sang-Hun “Destruction of Test Site is viewed by Journalists” *The New York Times International* Friday 25 May 2018, p. A8.; Matthew Pennington, “Satellite images indicate North Korea has begun dismantling key facilities at a site used to develop engines for ballistic missiles” [145,146]. The spread of and extent of ownership of resources around and across state boundaries will be routinely determined via remote sensing just as the evaluation of threats to these reserves will be done on real time basis.



Judges are not geospatial experts and they are not expected to be; however, courts will under their pertinent legal rules of procedure take evidence and/or judicial notice of the basic scientific facts that are adduced before them by experts. There is however, the need for more knowledge and expertise in space science and technology among lawyers and the judicial staff of international organisations. This is because the number of cases that will require knowledge about the geospatial sciences will inexorably increase in the course of this century.

Africa has a rich and noble history of achievements in the arts, science, technology and culture. In order for Africa to properly harness its full potentials in archaeological prospection, manage its boundaries and effectively assess its natural or human-induced threats to conservation, it must invest heavily in procurement of geospatial products. This is best done by African States individually and collectively investing in outer space activities. With the benefit of the emerging satellite imagery the discovery of more of Africa's relict walls, heritage and archaeological sites will continue. Their touristic value can then be systematically secured and exploited.

African states would be wise to act counter intuitively by focusing on outer space research and applications in these areas in order to leap frog aeons of development gap that currently separates it from the more developed states in the world. Africa must resist the temptations of ignoring or abandoning investment in space aspirations and space applications for reasons of scarcity of funds. In a sense in this century all states must realise that truly salvation comes from above. This is why the UN was correct in advancing the principle: "All States should be encouraged to contribute to the United Nations Programme on Space Applications and to other initiatives in the field of international cooperation in accordance with their space capabilities and their participation in the exploration and use of outer space", Declaration on International Cooperation in the Exploration and Use of Outer Space for the Benefit and in the Interest of All States, Taking into Particular Account the Needs of Developing Countries [16].

The increasing severity of natural disasters demands the utilisation of space applications in ways that were previously thought impossible. In 2008 for instance, there were historic levels of natural catastrophes. Chinese victims of the earthquake in the province of Sichuan, the cyclone in Myanmar, and several other natural catastrophes in the first part of the year alone claimed the lives of more than 150,000 people. The previous year had recorded 960 disasters and events which was the largest number in recorded history [147] Note should also be made of the planned framework of the United Nations Platform for Space-based information for Disaster Management and Emergency Response (A/AC.105/929). The COPOUS endorsed the work plan of the United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER) for the biennium 2010–2011 (A/AC.105/937) [148]. Assistance to African states in the areas under review can also be a valid instrument of economic diplomacy. Finally it may be suggested that Africa's development partners ought to explore greater use of economic aid in the form of cooperation in space activities with African states.

Apart from the sheer value of the service renderable to the country through investment in space technology, which will directly and indirectly affect the growth of GDP in African states there are also tariff and other beneficial fees to be made by national governments. The few African states that have invested in this area already establish this point. In Tunisia, the National Center for Cartography and remote sensing approves expenses relating to the realization of the geographical information systems for the benefit of the State, local authorities and institutions and public enterprises for amount fixed at dinars rates for each operation excluding taxes. Under Art. 7 of the Minister of National Defense Order on the National Remote Sensing Center Fees—The National Center for Cartography and remote sensing approves the technical compliance of equipment and materials and charges in part 10% of the amount of equipment excluding taxes presented for approval, for each approval operation. See the Journal Official of the Republic of Tunisia. Tunis, 22 July 2016. Although Nigeria also has modern and elaborate commercial arrangements for use of its satellite facilities by private companies, it is the opinion of this paper that the clear transparency in relation to charges displayed in the pertinent

Tunisian domestic legislation for remote sensing services is missing in the Nigerian NASRDA Act and allied legislation. Although Nigeria also has modern and elaborate commercial legal arrangements for use of its satellite facilities by commercial ventures, the transparency in cost of services found in the Tunisian domestic legislations missing in the Nigerian NASRDA Act. Such as Decrees No 75–671 of 25 December 1975; Decree No 2006–1902 of 10 July 2006 and particularly the Minister of National Defense Order on the National Remote Sensing Center Fees is missing in other African states including those with comparable capacities. See Order of the Minister of National Defense of 22 July 2016, fixing the rates of the services of the National Centre of Cartography and remote sensing. Despite the manifest usefulness of space technology to Africa and its peoples as well as the apparent willingness to exploit these technologies, domestic legal regulation of space related activities in Africa is at this stage rudimentary. Even those African states with regulation in this area need to update their laws to make them fit for purpose in spurring technological and entrepreneurial innovation. What can or must not be done with data legitimately collected from space platforms? What confidentiality rules bind external operators in relation to remote sensing and geoscientific round investigations data? These are just a few of the many questions left unanswered. The trend currently in the few available African domestic legislation is to presume that astronomical observations and satellite operators will always be buying data from governmental sources (e.g., Tunisia and Nigeria -NIGCOMSAT) [149]. Available regulations appear unprepared for privately launched satellites from within the state. With at least one African state –Nigeria planning manned missions into space, regulations will soon be needed on use of planetary resources during space missions. Yet it is South Africa only that makes provisions on personal jurisdiction in space. This is a reflection of the haphazard nature of legislation and the fact that national legislation are not yet expertly aligned with national policies and perhaps even national interests.

This work is in agreement with the groundswell of opinion that Africa needs an African Space Policy Institute, which will among other things champion the cause for capacity building in space policy, promote an African Space Policy and Strategy and conduct appropriate policy research whilst educating decision-makers and various stakeholders in the promotion of Africa's interest [21]. There is a strong requirement for regulation and acquisition of institutional capacity for conducting geospatial operations and investigations for development in Africa. The imperatives are clear -it is important to develop and maintain agencies that have oversight and regulate aspects of outer space exploration and its new applications. The option of not having any domestic regulations at all whilst having signed up liberally to the space treaties is not only insufficient but can be dangerous to the state's legal position as there are important duties to the international community to perform.

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