Evaluating the Potentials of an International Collaboration between Equatorial Nations by Implementing a Constellation of Interferometric Small SAR Satellite Network

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***Abstract*— Abstract— This paper cross examines countries within the Equatorial Region, with the aim of highlighting the setbacks and advantages of exploiting an international collaboration based on sharing resources for implementing a small SAR network. This analysis is unfolded in four stages. The first stage discusses developing nations and their various levels of space capability. Their capability posits a path through five main technological competencies, as follows: 1) owning and operating a satellite; 2) design and building a satellite; 3) having an astronaut; 4) capable of sounding rockets; 5) having the capability to recover biological sounding rockets. The second stage discusses developing nations geographically located between ±10 degrees of the Equator and their specific space capabilities. The results provide information about the similarities and differences in the space technology utilized and the requirements that drove their choice of selection. The third stage is a discussion on the similar issues experienced within the Equatorial Region regarding natural disaster, man-made and environmental disaster, criminal activities, border security and resource monitoring. It also explores the countries' diverse strategies of managing these issues with a view to drawing inference on the effectiveness of these strategies. The fourth stage proposes the use of a constellation of small SAR satellites capable of interferometric operations in a low Earth near-equatorial orbit. A brief description of the orbit constellation and satellite configuration is provided. Then a few attractive application areas for the SAR constellation are highlighted and results on coverage and temporal resolution is presented. Finally, a design value for the data downlink rate and the daily data volume that can potentially be downlinked to selected ground station sites will be presented. This inevitably leads to discussing the benefits of implementing an international collaboration between countries within the Equatorial Region from a technological perspective as a strategy of addressing previously mentioned issues.**

***Index Terms* - SAR Constellation, Interferometry, Equatorial Nations, International Collaboration.**

I. INTRODUCTION

The World Bank is a closely associated group of five developing institutions whose initial mission since its 1944 inception was the International Bank for Reconstruction and Development (IBRD), facilitating the post-war reconstruction and development to the modern-day decree of worldwide poverty alleviation [1-4]. As part of its key priorities, the World Bank provides open data websites which offer free access to widespread indicators about the development in countries around the world. As part of the free data provided, an annual revised classification of the world's economies based on estimates of gross national income (GNI) per capita of the previous year is published on 1st of July. The revised GNI per capita estimates serve as input to the Bank's operational classification of economies, which regulates their lending eligibility [5]. Table I below, is an adopted extra from the World Bank income classifications by GNI per capita:

Table I: World Bank income classification by GNI [5]

Income($)	Group	Economic State
1,035 or less	Low Income	Developing
1,036 - 4,085	Middle Income	Developing
4,086 - 12,615	Upper Income	Developing
12,616 or more	High Income	

The World Bank classifies a developing nation as any nation with a GNI per capita estimate between low-income and middle-income groups. World Bank member states are included as also economies with a population over 30,000. The July 2014 World Bank publication [6] listed 214 global economies. From the list, using the World Bank criterion, 139 nations can be categorised as developing nations. However, changes are experienced yearly; invariably, a major change is when a nation moves from one classification group to another. For the year 2014, only two Kyrgyz Republic and South Sudan experienced a classification change moving from low income to lower middle income group (both income groups separated at a GNI per capita of $4,125).

Another source of statistical data used for classification of economies is the yearly *World Economic Outlook* report published by International Monetary Fund (IMF). The country classification divides the world into two main groups: advanced economies and emerging markets and developing economies. In 2008, data and projections for 183 economies formed the statistical basis of the *World Economic Outlook*. A total of 141 nations were classified as developing and emerging nations by IMF [7], while in IMF's 2009 report, the data and projections for 182 economies showed the number of countries had reduced to 139 nations [8]. IMF's 2011 data and projections for 184 economies for the *World Economic*

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Outlook report showed that the number of developing nations had increased to 150 [9] and by 2012, with an increase in the data and projections of 186 economies, 151 nations were reported as emerging and developing nations [10]. Currently, data and projections for 189 economies form the statistical basis of the 2014 *World Economic Outlook* report published in April listed 153 developing nations [11].

The United Nations (UN) ranks countries largely based on Human Development Index (HDI) values [12]. The four board classifications, which are derived from the quartiles of distributions of component indicators as shown in Table IIII below.

Table II: UN Classification of Countries by HDI [12]

Human Development Index	Cut-off Points
Very high human development	>0.800
High human development	0.700 - 0.799
Medium human development	0.550 - 0.699
Low human development	<0.550

The human development index trend between 1980 and 2013, published in the *United Nations Development Report 2014*, listed 90 countries as having HDI of either medium or low human development [12].

The World Bank, UN and IMF each have a variety of indicators responsible for their classifications. Indicators such as: total export of goods, gross domestic products (GDP) and population. Furthermore, each classification can be further broken down into: operational lending groups, income groups and by region.

Albeit the yearly changes to the economies that constitute each group, there is also a consistency with most countries that constitute the core of each group. A key similarity between most developed nations is their *space capability*. Developed nations like Germany, France and Canada all boost space capabilities at a high level. These countries have been able to adapt space science and technology to improve their various economies. Developed countries have continued to show that space technologies are a key to the modern information and industrial society. Areas such as television reporting and communication around the world, the satellite navigation system in vehicles or precise climate and weather analyses through to emergency mapping and earth system understanding all depend on space technologies.

Conversely, the majority of nations regarded as "developing", continually form the bulk of the yearly reports published by most organisations. Adopting the sub-classification by region used by IMF, TableIII below shows the number of developing nations published in the *World Economic Outlook* April 2014.

Table III: Classification of developing nations by region as presented in the World Economic Outlook April 2014

Region	Quantity
Commonwealth of independent states	12
Emerging and Development Asia	29
Emerging and Development Europe	13
Latin America and the Caribbean	32
Middle East and North Africa	22
Sub-Sahara Africa	45
Total	153

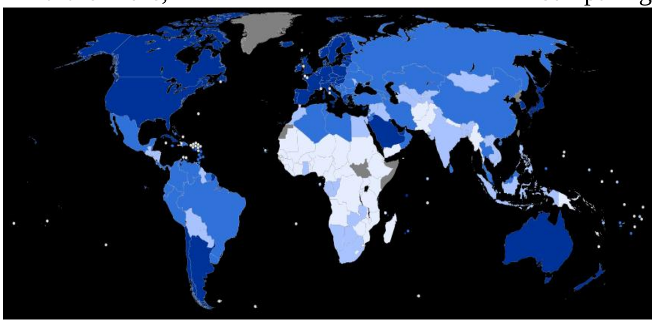
Table IV, however, shows the list of developing nations using the World Bank classification by region.

Table IV: Classification of developing nations by region by World Bank for the year 2014

Region	Quantity
East Asia and Pacific	24
Europe and Central Asia	26
Latin America and the Caribbean	13
South Asia	8
Sub-Sahara Africa	45
Total	139

Although the classification criteria used by each organisation may differ, over 80% of the countries that constitute each group remain the same. In view of both the IMF and World bank classification methods, developing nations constitute over 79% and 72% of worldwide nations respectively (assuming United Nations 193 states).

Furthermore, comparing



Very High High Medium Low No data

United Nations Human Development Index, 2014

Fig 1,

Fig 2 and

Fig 3, there is a clear indication of regions most populated with developing nations.

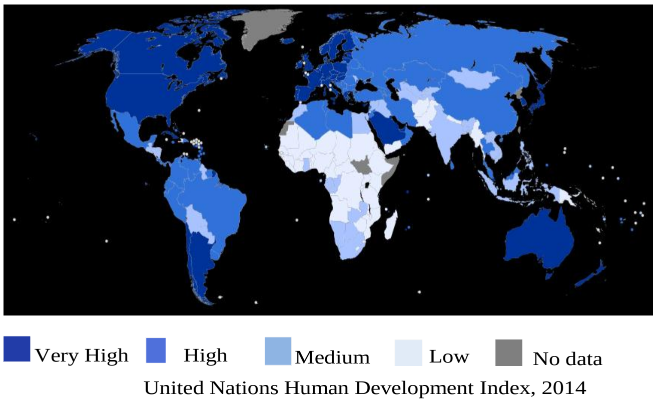


Fig 1: The UN Human Development Index for 2014 [12]

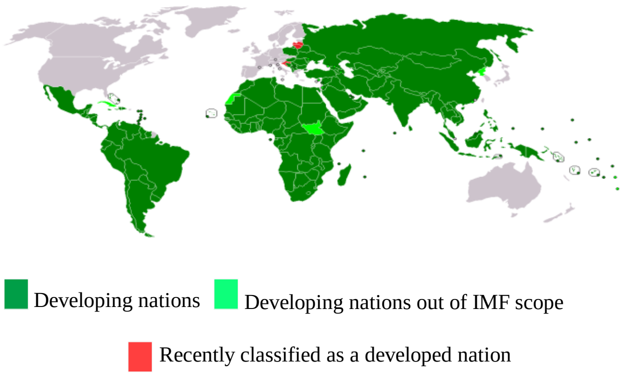


Fig 2: IMF Developing countries Map for 2014 [13]

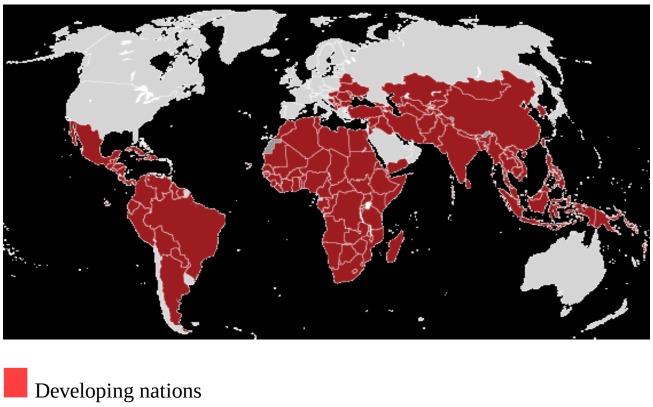


Fig 3: World Bank regional map of developing countries worldwide [14]

All three organisations confirm that most developing nations are located in and around three major continents, namely Asia, South America and Africa. The Regional Outlook report by World Bank for 2014 suggests the progress of developing nations is expect to remain flat after undergoing a decline from the previous year [14]. Furthermore, when viewed from a different perspective, it can be see that countries around the Equator are mostly developing nations.

Hence, by assuming the total of 139 developing nations as provided by the World Bank, this paper sub-classifies developing countries according to geographical latitude. Table V highlights the selection of developing nations according to latitude.

Table V: A selection of developing nations according to geographical latitude

Latitude (Degrees)	Number of Countries
61°N - 90°N	0
31°N - 60°N	43
1°N - 30°N	73
0°	16
1°S - 30°S	23
31°S - 60°S	1
61°S - 90°S	0

From Table V above, it becomes evident that most developing nations are located in low-latitude regions with similar climate conditions. Therefore, by considering only developing nations in low-latitude regions between 30° north and 30° south of the Equator, it can be observed that over 50% of low-latitude developing nations are located on and around the Equator as displayed on TableVI.

Table VI: Number of developing nations within low-latitudes

Latitude (Degrees)	Number of Countries
30°N	12
20°N	35
10°N	37
0°	16
10°S	13
20°S	12
30°S	3

From the 139 developing nations as defined by World Bank, 52 of them are located between latitudes 10° north and 10° south of the Equator as shown on Table VII below.

Table VII: Number of developing nations within the ER

Latitude (degrees)	Number of Countries
0° - 10°N	37
0° - 10°S	16
10°N - 10°S	50 (No repetition)

Therefore, this paper defines the low-latitude geographical region between latitudes 10° north and 10° south of the Equator as the *Equatorial Region* (ER). Furthermore, countries within the ER are regarded as Equatorial Countries. There are 50 Equatorial countries, with 49 of them considered developing nations.

To this end, this work aims to identify the benefits of adopting a collaborative use space mission technology between the equatorial countries, as a means of rapid development.

II. DEVELOPING NATIONS AND LEVELS OF SPACE CAPABILITIES

Space technology and its applications; contribute significantly to the development in developed nations [15]. In 2005, a report by Space Foundation documented a $180 billion contribution from space related activities, to the United States economy; this implying that each dollar spent by NASA, is a catalyst for $10 economic benefit [16].

However, the contribution of space mission technology to the socio-economic development of developing nations is minimal. Assuming 139 developing nations, only 35 of them possess some level or form of space capability. A cross-examination of the various levels of space capabilities of the 24 non-equatorial developing nations is presented on Table VIII. The establishment column specifies the abbreviation/name of the governmental space organisation, and its year of establishment. The column headings 1, 2, 3 and 4 specify the level of space capability of each governmental organisation in the order; astronaut, owner/satellite operator, sounding rocket capabilities and possessing recoverable biological sounding rockets respectively. The cells coloured in "green" is an affirmation regarding the capability to conduct space activities for the indicated space mission activity.

In the context of the driver, responsible for developing nations acquiring some form of space capability, the work of Woods, D [17] extensively addresses the issue. The same work also identified the process of Know-How Technology Transfer (KHTT) agreement between established space companies and the developing nation. The technology transfer modalities, involves various scientist and engineers of the "developing nation", co-located with the members of staff of the established organisation charged with the design and manufacturing of the spacecraft. Under this agreement, it is envisaged that the skills, procedure and technology for designing and manufacturing space systems will be duly transferred.

Table VIII: Non-equatorial developing nations and their levels of space capabilities

Country	Establishment	1	2	3	4
Algeria	ASAl,2002	X	√	X	X
Argentina	CONEA(91)	X	√	√	X
Azerbaijan	AMAKA, 1974	X	√	X	X
Bangladesh	SPARRSO 1980	X	X	X	X
Belarus	2010	X	X	√	X
Bolivia	ABE 2012	X	√	X	X
Bulgaria	STIL BAS 1987	√	√	X	X
China	CNSA, 1993	√	√	√	√
Egypt	EASRT, 1971-94	X	√	X	X
Iran	ISA, 2003	X	√	√	√
Kazakhstan	NSA, 1991	X	√	X	X
Lithuania	LSA, 2007	X	√	X	X
Mexico	AEM, 2010	√	√	X	X
Mongolia	NRSC, 1987	X	X	X	X
Morocco	CRTS, 1989	X	X	X	X
Pakistan	SUPARCO, 1961	X	√	√	X
Romania	ROSA, 1991	√	√	X	X
South Africa	SANSA, 2011	X	X	X	X
Tunisia	CNT, 1998	X	X	X	X
Turkey	TUBITAK, 1985	√	√	X	X
Turkmenistan	2011	X	X	X	X
Ukraine	SSAU, 1996	√	√	√	X
Uzbekistan	USSRA, 2001	X	X	X	X
Vietnam	STI, 2006	X	X	X	X

Only China is currently capable of meeting all four levels of space mission, and Ukraine capable of three levels. Evidently, most developing nations on the Table VIII are satellites owner/operators.

III. EQUATORIAL NATIONS AND THEIR SPACE CAPABILITIES

By the definition of this work, there are 52 *equatorial nations*. From the 139 developing nations worldwide, 51 of them are equatorial nations with the exemption of Singapore. Therefore, approximately 37% of developing nations are also equatorial nations and approximately 99% of equatorial nations are developing nations. A total of 11 equatorial nations possess varying levels of space capabilities as represented in Table IX. Implying just 21% of equatorial states have space capability amongst the developing states within the ER.

Table IX: list of equatorial developing nations and their levels of space capability

Country	Establishment	1	2	3	4
Brazil	AEB, 1994	√	√	√	X
Colombia	CONEA(91)	√	√	X	X
Costa Rica	ACAE, 2010	X	√	X	X
India	ISRO 1969	√	√	√	√
Indonesia	LAPAN, 1964	√	√	√	X
Malaysia	ANGKASA, 2002	√	√	X	X
Nigeria	NASRDA, 1998	X	√	X	X
Peru	CONIDA, 1974	√	X	√	X
Sri Lanka	ISA, 2003	X	√	X	X
Thailand	GISTDA, 2002	X	√	X	X
Venezuela	ABEA, 2008	X	√	X	X

Only India is capable of meeting all four categories of space technology as shown on Table IX. Both Pakistan and Brazil meet three different levels of space capability while the other 8 countries have satellite operating capabilities in common with the exception of Peru.

IV. ISSUES EXPERIENCED WITHIN THE EQUATORIAL REGION

The equatorial states consist of countries mainly from three continents namely: Africa, South America and Asia. Countries within this region experience similar climate conditions, natural and human disasters and have abundance of natural resources. Natural hazard is a natural occurring physical process or phenomena caused by slow or rapid onset events such as geophysical (tsunamis and earthquakes), hydrological (floods and hurricanes), climatological (wild and urban fires), biological (animal and insect plagues) or meteorological (storms). The UN defines natural disaster as: *the consequences of events triggered by natural hazards that overwhelm local response capacity and seriously affect the social and economic development of a region* [18].The horizontal convergence of lower atmosphere complemented by the vertical air current and divergence of the upper atmosphere accompanied by the subsiding upper air current leads to severe weather conditions [19]. In the ER, where towering thunderstorms are frequent, the result is a variety of local climate conditions. The outcome is a yearly occurrence of flood. Flood is associated to the low air pressure center, La Nińa negative Dipole Mode phenomena, and tropical cyclone typified near the Indonesian waters [20]., Recently, over 70% of the Jakarta area in Indonesia was washed away leading to lose of life and properties [19].

Man-made hazards are general associated with technology, and usually occur within or around human settlements. Man-made hazards may include; displace population, complex conflicts environmental degradation, accidents (Industrial and transportation) and pollution. The vast amount of resources within the ER suggests high rates of international commercial activities are conducted via waterways. Natural resources such as minerals and petroleum are shipped from the ER to various parts of the world on a daily basis. To this end, several cases of man-made disasters have been experienced. The lessons learnt from the oil spill event in the Gulf of Mexico, regarded as the "worst US environmental disaster", had over 20 million gallons spilled. This affected both human and aqua-marine life within a 70 mile radius [21 & 22].

Resource management, development and protection for different sectors such as agriculture, petroleum, infrastructure, wildlife as well as territorial integrity are current issues that impede the development of these nations. In Nigeria, it is estimated that between 100,000 and 130,000 barrels per day (bbl/d) of crude oil, worth an estimate of $3billion is stolen via illegal oil bunkering activities of within and around the Gulf of Guinea [23]. The Gulf of Guinea stretches through Central and West Africa is increasingly identified as one of the world's most poorly governed maritime stretches [24]. It has been reported to be used for various forms of nefarious activities such as human trafficking from Senegal to Europe, drug trafficking trans-ship narcotics to South America and finally Nigeria, where oil related crimes have become booming businesses [25].

Border security has been an issue of concern for many nations. The recent activities of cross-border terrorism with the ER are growing. The emergency of the Islamic terrorist group called *Boko Haram* (Western education is a sin) is currently trending worldwide. In June 2014, an estimated 5000 people are reported to have been killed from over 95 attacks [26].

Generally speaking, most developing nations monitor and mitigate both natural and man-made disasters locally by using methods such as; human observation, construction of prone facilities away from areas within high risk, redundancy, having emergency reserve fund, purchasing relevant insurance and the development of operational recovery plans [27].

The use space technology and its application areas, provides a single-most efficient means of addressing all the issues discussed in this section. Moreover, it offers an opportunity to improve education, an avenue to keep pace with the rapid rate of technology development and also provide another access for revenue generation and commerce.

It is to this end, that's the author proposes a *Consortium of Equatorial States for the use of Outer Space for Developing Nations* (CESOS-DN). The proposed mission of CESOS-DN is the implementation and operation of space science and technology for the equatorial states, by the equatorial states, as a means of monitoring and mitigating the issues experience within the ER. Furthermore, CESOS-DN shall act as a platform for promoting technology development, education and commerce locally and internationally.

The successive sections of the work, illustrate a proposed mission that facilitates international cooperative mission between several equatorial states. It demonstrates how each nation can contribute to the successive implementation of a space mission. Furthermore, the mission adopts a low-cost approach using existing methods, and a shared-resources scheme. Results of preliminary and parametric analysis are also presented to buttress the author's vision.

The use of a small synthetic aperture radar (SAR) network consisting of space, ground, launch and human resources from constituents of the proposed CESOS-DN will be required for the unique regional mission.

V. SMALL SAR NETWORK

In view of the approach proposed by NASA's 9th and longest tenured Administrator, Daniel Goldin, who in 1992 announced his vision of "Faster, Better, Cheaper" conventional missions. An approach which limited design and manufacture of space systems to 18 months, with operations limited to three years [28]. This paper adopts the use of small satellites for implementing low-cost mission as indicated by Fig for implementing the space mission objectives.

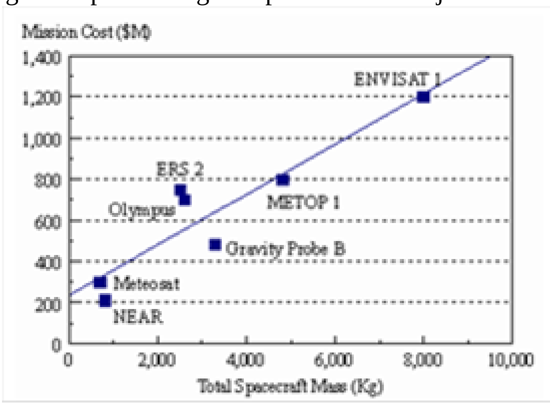


Fig 4: Spacecraft mass vs mission cost [29]

More so, the all-weather capabilities of an active remote sensing payload such as the RADAR, and the desire for a high rate of revisit time over the ER, informed the use of a SAR payload in a circular near equatorial Low Earth Orbit (LEO). This work also assumes that all resources used for the mission are located within the ER.

The small SAR network shall consist of resources provided by members of the proposed CESOS-DN, for the ground, space and launch segments. This resource-sharing approach has the benefit of reducing the cost of space missions for each country, as against individual countries solely embarking on such missions. Furthermore, it mitigates high cost, which has been a key factor to determining nations that partake in space activities. A typical space program costs hundreds of millions of dollars and maybe divided into three phases, with each contributing to the total cost. The phases are: the design and construction of the spacecraft, the launcher and launch program costs, and finally the cost of operating the spacecraft throughout its lifetime [29 & 30].

It is suggested that equatorial nations who already possess the ability to operate satellites form the bulk responsible for the design and manufacture of the space segment through a collaborative training. The suggestion buttresses the work of Wood, D [17], where the author defined a framework for space technology trends for developing nations which indicated the satellite operating nations as having undergone a design and manufacturing training with the established satellite manufacturers that manufactured their respective satellites [31].

To promote continuous access to all spacecraft, it is suggested that the minimum out-of-contact duration for each spacecraft to ground communication, must be less than 30 minutes. In addition, countries without an existing spacecraft but already possess the necessary knowledge and skill for using space acquired data should be considered first as sites for ground segment. Lastly, the criteria of selecting a launch segment location must duly consider its proximity to the ocean

VI SPACE SEGMENT DESIGN AND ANALYSIS

The space segment shall consist of 2 groups of 4 small SAR satellites in formation. Each group is in a different orbital plane as shown on Fig 4. The orange and blue points indicate the locations of each satellite in its orbital plane.

The white boundary is a region selection by latitude. The boundary selected is the ER. Spacecraft within their respective planes are space out by a mean anomaly difference of 90°.

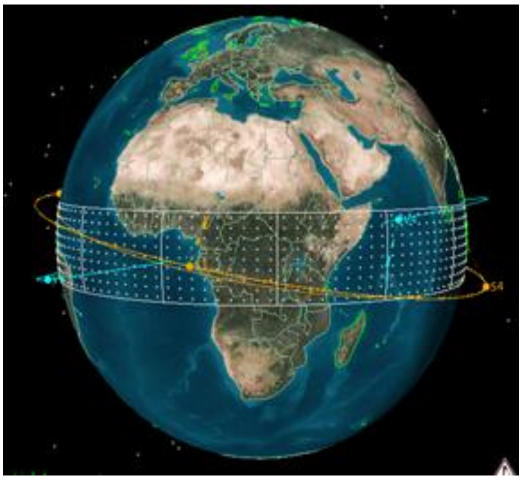


Fig 4: Space segment showing spacecraft in two planes operating over the ER

Fig 5 is shows a polar view of the space segment constellation.

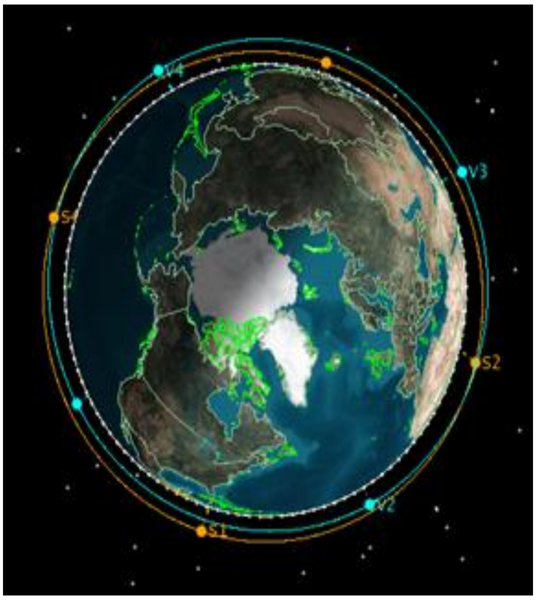


Fig 5: Polar view of the constellation of space segment spacecraft operating over the ER

Error! Reference source not found.X and **Error! Reference source not found.**XI provide the values used for the baseline parametric evaluations for orbital plane "A" and orbital plane "B" respectively. The spacecraft flying in plane "A" (orange coloured plane), are labelled S1, S2, S3 and S4. The spacecraft in plane "B" (blue coloured plane), are labeled V1, V2, V3 and V4. The spacecraft within plane "A" are designed to have a right ascension of ascending node (RAAN) of 0°, while spacecraft in orbit plane B have a RAAN of 180°

Table X: Parametric values for orbital plane A

Orbit Parameters	S1	S2	S3	S4
Altitude (Km)	700	700	700	700
Revs/day	14.57	14.57	14.57	14.57
Inclination (°)	10	10	10	10
Eccentricity (°)	0	0	0	0
Period (mins)	98.79	98.79	98.79	98.79
RAAN (°)	0	0	0	0
M Anomaly (°)	0	90	180	270

The initial collision avoidance implemented is placing all spacecraft in plane B at an altitude of 695 km and allocating an initial mean anomaly of 45°, as against plane A, where the initial mean anomaly is 0°. Subsequently, a 90° mean anomaly spacing between all spacecraft in constellation is enforced.

Table XI: Parametric values for orbital plane B

Orbit Parameters	**V1**	**V2**	**V3**	**V4**
Altitude (Km)	695	695	695	695
Revs/day	14.59	14.59	14.59	14.59
Inclination (°)	10	10	10	10
Eccentricity (°)	0	0	0	0

Period (mins)	98.6	98.68	98.68	98.68
RAAN (°)	180	180	180	180
M Anomaly (°)	45	135	225	315

A 24 hours coverage analysis for the constellation, assuming each small SAR functions in monostatic mode for image acquisition and operating in a standard strip mode of 60km x 60km, provided the results shown on **Error! Reference source not found.**. and Fig 7 below.

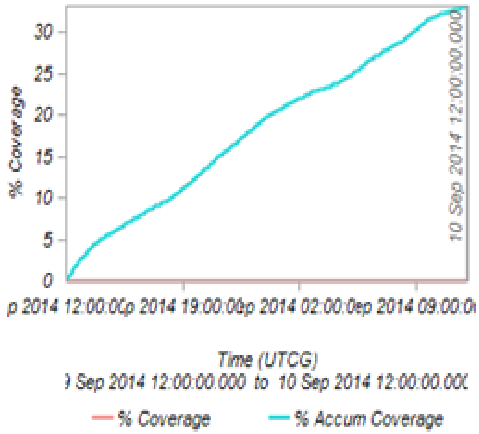


Fig 6: 24 hour coverage analysis graph for satellite in Orbital plane A

Fig. 7, highlights the results of the coverage analysis conducted using all 4 spacecraft in orbit plane A. The graphs show approximately 35% coverage of the ER is achieved over a 24 hours period.

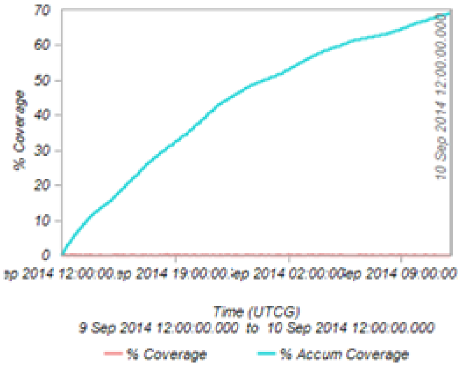


Fig 7: 24 hour coverage analysis for all spacecraft in constellation

From Fig. 8, the coverage is doubled to approximately 70%, when satellites in both orbital planes "A" and "B" are used for coverage analysis.

VII. GROUND SEGMENT DESIGN AND ANALYSIS

By implementing the constraint on the mission, which dictates that all ground segment resources must be located with the ER, and have a minimum of 2 ground segments in each continent (Africa, South America and Asia), to facilitate reduction in out-of-contact periods; the following sites on Table **1**XII are proposed.

Table 1: Proposed ground segment sites within the ER

Country	**City**	**Latitude**	**Longitude**
Brazil	Belem	1°S	43°W
Ecuador	Quito	0.2°S	78.5°W
Brunei	B-S-Begawan	5°N	114°E
Tuvalu	Funafuti	8.5°S	179.2°E
Ghana	Accra	5.55°	0.2°W

Using the locations listed on Table **1**XII, and ensuring minimum elevation angle of 10° for space-to-ground communications, at a downlink rate of 100MBits/s for each spacecraft transmitter, Table **2**XIII provides the daily throughput data from the constellation to each ground segment. Each spacecraft will have average ground station access duration of 14.5 minutes. Hence, 181.3 megabytes of data can be downloaded for each spacecraft in one ground station pass. Furthermore, six ground stations allow for a daily data downlink of 122 gigabytes for all 8 satellites within the space segment constellation.

Table 2: Daily data throughput for SAR constellation

Parameters	**1- sat**	**8 - sats**
Avg # daily pass (rev/day)	14	112
Avg duration of pass (mins)	14.5	116
Downlink rate(MBit/s)	100	100
Data throughput per pass (MBits)	1,450	4,640
Data throughput per pass (MBytes)	181.3	1450
Data throughput per day (GBits)	20.3	162.4
Data throughput per day (GBytes)	2.6	20.3

Fig 8 shows a 2-D view of the proposed ground segment sites listed in Table XI. The white circles around each ground segment site represent the range of the ground station antenna dish, within which communication is established with the spacecraft. **Error! Reference source not found.** is a 3-D polar view of the proposed ground segment locations. The longest out-of-contact period for the mission is 30 minutes. This is experienced when spacecraft is flying between Funafuti and Quito.

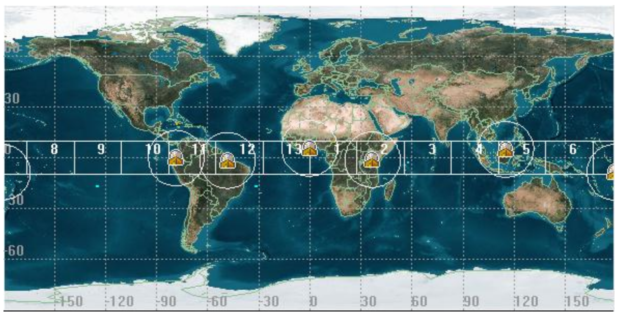


Fig 8: 2-D view of proposed ground segment sites

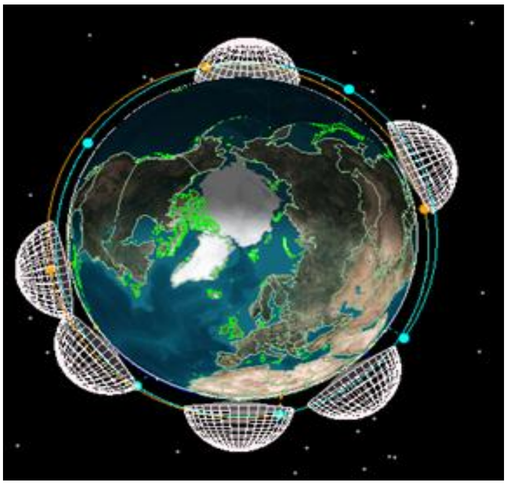


Fig 9: 3-D Polar view of proposed ground segment sites

VIII. LAUNCH SEGMENT AND ANALYSIS

The main selection criteria for locating a suitable launch segment are; the city's proximity to both the Equator and an ocean. The ocean should be located immediately in the western direction of the selected city. **Error! Reference source not found.** is a list of the cities proposed as launch sites based on the aforementioned criteria. The sites are numbered from 1 through 7, beginning with Paramaribo, Brazil in the eastern hemisphere to Tarawa, Kiribati in the western hemisphere.

Table 3: Proposed launch sites with the ER

Country (#)	City	Lat	Long
Brazil (1)	Paramaribo	5.93°N	55.23°W
Brazil (2)	Sao Luis	2.5°S	44.43°W
Somalia (3)	Mogadishu	2.04°S	45.34°E
Philippines (4)	Davao	7.08°N	125.61°E
Solomon Is. (5)	Honiara	9.4°S	159.8 E
M. Islands (6)	Majuro	7.08°N	171.27°E
Kiribati (7)	Tarawa	1.34°N	173.1°E

Fig 10 is a 2-D view showing the various proposed locations for launch sites within the ER. Each location is indicated by an "area target" symbol, which appears as a red marker.

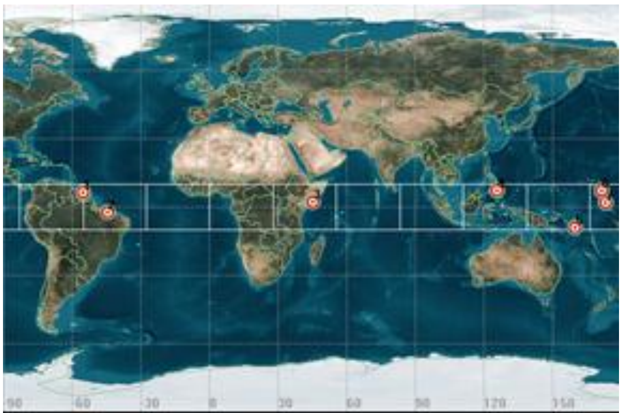


Fig 10: Locations for proposed launch sites with the ER

VIIII. CONCLUSION

This work employed the different classification criteria used by the World Bank, United Nations and International Monetary Fund for identifying the core countries classifies as "developing nations". Although the various organisations provide different numbers of developing nations, it was evident that there are specific countries that constitute developing nations regardless of the selection criteria employed. Over 35% of developing nations are located within and around the Equator. Furthermore, most low-latitude countries experience similar climate conditions, natural disasters and have bountiful natural resources. These informed the author on the need to adopt a new classification criterion for selecting developing nations based on latitude. Therefore, the Equatorial Region is defined as areas within the geographical latitudes 10°N and 10°S.

The paper presented the design results of implementing a network of small SAR satellites. The network consists of a constellation of spacecraft, various locations of ground segments and launch segments with the ER.
The analysis showed the constellation could provide over 20 -gigabytes of valuable data to the equatorial nations daily. These data can be useful for agricultural mapping, border security, disaster monitoring and mitigation, education, technology advancement and demonstration as well as commerce. It also iterated the availability of land resources necessary for locating a ground and launch segment with the ER.

Finally, the work demonstrated the need to constitute a new organisation body consisting of developing nations within the ER. Therefore, the author proposed a *Consortium of Equatorial States for the use of Outer Space for Developing Nations* (CESOS-ND) in other effectively monitor and mitigate natural and man-made disasters, while keep pace with the rapidly developed countries. The work also suggests an improvement in commerce, education, technology and knowledge would be achieved.

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