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Classification of Countries Worldwide according to Satellite Activity Level

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Emerging countries worldwide can benefit technologically, economically, and socially from domestic space-related activities. However, limited resources and lack of know-how prevent many non-space faring nations from initiating space projects, much less building sustainable space or satellite programs. New opportunities exist to overcome these barriers. The number of small satellites launched in the last three years has increased by an order of magnitude, and the market of satellites less than 50kg is projected to grow from $700M USD in 2014 to ∼$2B USD by 2019. This paper gives an overview of space-related activities in various emerging countries and categorizes countries in nine regions worldwide according to level of satellite activity.

Key Words: Capacity Building, Lean Satellite, Small Satellites, Emerging Countries, Space Market

1. Introduction

Sovereign nations are compelled to pursue space activities. Space access and satellite operation offer substantial potential benefits, including but not limited to military advantages, upgraded communication and navigation capabilities, remote sensing intelligence, space science, technological advancement, economic development, and national prestige. [1)- 4)] The global space market is worth over $300B USD annually and has been increasing steadily by ∼7% or more per year. [5)]

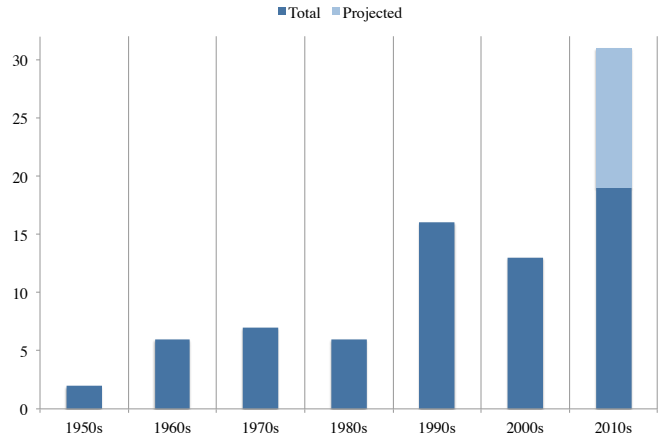

Fig. 1. Number of Countries Achieving First Satellite in Orbit.

However, barriers such as lack of funding, apathetic political support, limited technology, lack of expertise, and underdeveloped human resources inhibit many countries from initiating satellite projects or space programs. Accordingly, space has been traditionally limited to a handful of countries. From 1957 to 1989 the rate of countries achieving their first satellite in orbit was approximately 0.65 countries per year. Based mainly on commercial sales of traditional satellite systems by space countries to non-space countries, [4)] the rate averaged approximately 1.45 countries per year from 1990 to 2009. Yet, the current decade has seen explosive growth in new space actors. As shown in Fig. 1, the number of countries that have achieved or are projected to achieve their first satellite in the 2010s is over 30, meaning a projected average rate of around 3 new countries per year.[i]

Clearly, the barrier to space access is falling. Of the 30 or so new countries that will achieve space in the 2010s, at least 50% of the maiden satellites will have been self-developed by domestic institutions. This is a major departure from the trend in the 1990s and 2000s, when only about 25% of new space countries self-developed their first satellite. Small satellites are driving this lower barrier to space. The number of small satellites launched annually has increased by an order of magnitude since 2011, and the global market for satellites less than 50kg is projected to grow from ∼$700M USD in 2014 to ∼$2B USD by 2019. [7)] Many of these satellites can be categorized as "lean satellites" that employ untraditional risk-taking development approaches to achieve low-cost and fast-delivery with small teams. Utilizing the advantages of lean satellites, emerging countries and institutions can now much more quickly cycle through design, development, launch, and operation.

This report concerns the current level of satellite activity in various nations and regions throughout the world. In Sec. 2 we briefly describe our university-based model for capacity building; in Sec. 3 we report on satellite activity in various regions worldwide, and Sec. 4 gives our conclusions.

2. Space-related Capacity Building Project at Kyutech

Kyushu Institute of Technology (Kyutech) is a Japanese national university (founded 1909) located in the city of Kitakyushu. Since 1993, Kyutech has provided space engineering education in Japanese to undergraduate and graduate students under the Department of Mechanical and Control Engineering. In 2004 Kyutech established a new research center, the Laboratory of Spacecraft Environmental Interaction Engineering (LaSEINE), to study and develop technology to overcome engineering challenges in the space environment. In 2010 a new research division, the Center for Nanosatellite Testing (CeNT) was added to LaSEINE. With the exception of radiation testing, CeNT provides all environmental tests necessary for the

[i] Data compiled from 4) and 6) and author observations

development of satellites and satellite components with size and weight up to 50cmx50cmx50cm and 50kg, respectively. CeNT is staffed by Kyutech professors, researchers, and professionals who have extensive practical and theoretical testing experience, and since its inauguration CeNT has provided environmental tests to over 25 Japanese and international satellites.

Since 2011 Kyutech and United Nations Office for Outer Space Affairs (UNOOSA) have been offering long-term fellowships on nanosatellite technologies to foreign post-graduate students. [8)9)] In 2013 the fellowship programme expanded, and Kyutech established an English-based degree curriculum, the Space Engineering International Course (SEIC), open to both fellowship and non-fellowship Masters and Doctoral students. [10)] Additionally, Kyutech and LaSEINE have been developing the HORYU nanosatellite series since 2006, successfully launched and operated HORYU-II in 2012, [11)12)] and anticipate launching HORYU-IV in fiscal year 2015.

Kyutech's space-related capacity building project took hold in 2013 upon receipt of funding from the Japanese government for 30 post-graduate fellowships dedicated to students from non-space faring nations.[ii] The primary objective of the capacity building project is to educate and train engineers and students from countries with limited space/satellite capacity such that participating individuals are capable of returning the skills and knowledge gained to their home countries or institutions. A full description of Kyutech's capacity building project will be given in a subsequent publication.

3. Satellite Activity Levels in Various Regions

This section concerns satellite activity in various regions worldwide. Observations were gathered primarily from public information and the authors' first-hand experiences and interviews with respective institutions. Descriptions are not considered to be comprehensive with respect to all space or satellite activities in respective countries. Nine distinct regions are considered:

- Africa
- Middle East
- Central/North America
- South America
- Eastern Asia
- Southern Asia
- Southeast Asia
- Eastern Europe
- Oceania

Kyutech has some level of collaboration or association within each region. For the purposes of this report a "country" is a bounded region or geographical area, etc., and is not necessarily a politically recognized state. Country classification is made strictly based on the number of satellites owned or operated by a given country (or institution based in that country) that have reached orbit. The intention is to provide straightforward and easily understood satellite activity level comparisons. Countries are classified as Level 0, Level 1, Level 2, or Level 3 according to the scheme given in Table 1.

[ii] From fellowship regulations "countries without an established substantial capability to develop space technology/launch space objects"

Table 1. Satellite Activity "Levels".

Level 0:	No satellite activity and none planned
Level 1:	First satellite project planned
Level 2:	1 to 4 satellites in orbit
Level 3:	5 or more satellites in orbit

Approximately two-thirds of the world's ~7 billion people lack Internet access, and Internet expansion is slackening. According to consulting firm McKinsey & Co., growth of world-wide Internet users slowed to a compound annual growth rate of 10.4% from 2009 to 2013, down from 15.1% between 2005 and 2008. [13)] Therefore population[iii] as opposed to Gross Domestic Project (GDP) or Human Development Index (HDI) was chosen for the Tables in order to obtain a sense of potential user bases and the sheer scale of humanity living within different "Levels."

3.1. Africa

Of all considered regions Africa has the highest number of Level 0 countries. However, numerous countries are planning satellite projects and have reached Level 1, as shown in Table 2. Still, ~66% of Africa's population lives in a country without space access. In the following sub-sections a brief description is given of satellite activities in African countries that have Kyutech association.

3.1.1. Angola: Level 1

Angola is classified as a Level 1 country due to plans to launch a telecommunications satellite in ~2017. The Angolan National Office for Space Affairs (GGPEN) is responsible for Angolan space interests and activities. GGPEN is under the purview of the Angolan National Telecommunications Office. GGPEN was founded in 2013 after a decision in 2009 by Angola to build a geostationary satellite, ANGOSAT, with Russia. ANGOSAT is scheduled to be completed in 2017. GGPEN will be responsible for ANGOSAT operations and other space projects. GGPEN is hosted at the Institute for Information Technology and Communication (ISUTIC) in Luanda, the most prestigious technical institute in Angola.

3.1.2. DR Congo: Level 1

The Democratic Republic of the Congo (DR Congo) is classified as a Level 1 country due to plans to launch a satellite with the China Great Wall Industry Corporation (CGWIC). To carry out domestic satellite activities DR Congo formed a public company named RENATELSAT approximately four years ago. RENATELSAT is hosted at Radio Television Nationale Congolaise (RTNC) in Kinshasa and is backed by the Congolese Office of Post and Telecommunications (OCPT/SCPT).

3.1.3. Ethiopia: Level 1

Ethiopia is planning a joint cubesat project between the Addis Ababa Institute of Technology (AAiT) and Entoto Observatory and Research Center (EORC). AAiT was established ~60 years ago and functions autonomously from Addis Ababa University. EORC grew out of a private organization, the Ethiopian Space Science Society (ESSS), and officially opened buildings and two dome telescopes in 2014. The cubesat project is currently in preliminary planning phases.

[iii] Population data from 14)

Table 2. Satellite Activity Level and Population of African Nations.

Level 0		Level 1		Level 2		Level 3	
Country	Pop.(M)	Country	Pop.(M)	Country	Pop.(M)	Country	Pop.(M)
Benin	10.60	Angola[K]	22.14	Algeria[K]	39.93	Egypt[K]	83.89
Botswana	2.04	DR Congo[K]	69.36	South Africa	53.14	Nigeria[K]	178.52
Burkina Faso	17.42	Ethiopia[K]	96.51	Mauritius	1.25		
Burundi	10.48	Ghana[K]	26.44	Morocco	33.49		
Cabo Verde	0.50	Kenya[K]	45.55				
Cameroon	22.82	Libya	6.25				
Central African Republic	4.71	Namibia[K]	2.35				
Chad	13.21	Sudan[K]	38.76				
Comoros	0.75	Tunisia	11.12				
Congo	4.56						
Djibouti	0.89						
Equatorial Guinea	0.78						
Eritrea	6.54						
Gabon	1.71						
Gambia	1.91						
Guinea	12.04						
Guinea-Bissau	1.75						
Ivory Coast	20.80						
Lesotho	2.10						
Liberia	4.40						
Madagascar	23.57						
Malawi	16.83						
Mali	15.77						
Mauritania	3.98						
Mozambique	26.47						
Niger	18.53						
Rwanda	12.10						
Sao Tome and Principe	0.20						
Senegal	14.55						
Seychelles	0.09						
Sierra Leone	6.21						
Somalia	10.81						
South Sudan	11.74						
Swaziland	1.27						
Tanzania	50.76						
Togo	6.99						
Uganda	38.84						
Western Sahara	0.59						
Zambia	15.02						
Zimbabwe	14.60						
40 countries	429 M	9 countries	319 M	4 countries	128 M	2 countries	262 M

[K]Kyutech association

3.1.4. Ghana: Level 1

In Ghana there are at least two institutions involved in satellite activities: the Ghana Space Science and Technology Institute (GSSTI) and All Nations University (ANU). GSSTI is a government agency and ANU is a private university. Both are located near Accra. GSSTI is under the purview of the Ghana Ministry of Environment, Science, Technology and Innovation, and hosted by the Ghana Atomic Energy Commission. GSSTI officially opened in May 2012. GSSTI is developing ground station facilities and possibly small satellites.

ANU is home to the Intelligence Space Systems Laboratory (ISSL), which opened in February 2012. ISSL has demonstrated CANSAT and balloon activities and cubesat and ground station projects are underway.

3.1.5. Kenya: Level 1

A Kenyan space agency that will involve satellite projects is in the works, pending political approval. Formation of the space agency is backed by the National Commission for Science, Technology and Innovations (NACOSTI). In the mean-

time space activities are being coordinated by the Ministry of Defence.

3.1.6. Namibia: Level 1

There are no current satellite projects in Namibia but plans exist to initiate a student satellite project at the Polytechnic of Namibia located in Windhoek. Student training is currently being conducted through the French South African Institute of Technology (F'SATI) in South Africa.

3.1.7. Sudan: Level 1

Educational cubesat prototypes named KN-SAT P1 and KN-SAT P2 were built by students and advisors at the University of Khartoum in 2011 and 2012, respectively. As funding permits the University of Khartoum intends to launch the flight model KN-SAT 1, which will be the first Sudanese satellite.

3.1.8. Algeria: Level 2

The first Algeria satellite, ALSAT-1, was developed in conjunction with Surrey Satellite Technology Ltd (SSTL) and launched in 2003 as part of the international Disaster Monitoring Constellation (DMC) led by SSTL. [15] Algeria's second satellite, ALSAT-2A, was launched in 2010. Algerian space activities are conducted by the Algerian Space Agency (ASAL).

3.1.9. Egypt: Level 3

Egypt launched its first satellite, Nilesat 101, in 1998. [4] Nilesat was manufactured by Astrium and operated by the Egyptian satellite company Nilesat. Egypt has since launched four additional satellites (Nilesat 102, Nilesat 201, EgyptSat-1 and EgyptSat-2), leading to its classification as a Level 3 country. The Egyptian Space Program (ESP) has existed within within the National Authority of Remote Sensing and Space Sciences (NARSS) since 1999. ESP is responsible for EgyptSat-1 and EgyptSat-2 and is planning additional satellites. Cubesat activities are being conducted at various universities within Egypt.

3.1.10. Nigeria: Level 3

Nigeria has also launched five satellites, the first in 2003 named NigeriaSat-1, which was built by SSTL under the international DMC project. Nigerian satellite activities are conducted primarily by the National Space Research and Development Agency (NASRDA) and Nigerian Communications Satellite Limited (NIGCOMSAT), established in 2001 and 2006, respectively. NASRDA operated NigeriaSat-1 until end-of-life in 2012 and now operates NigeriaSat-2 and NigeriaSat-X. NIGCOMSAT operated NigComSat-1 until its failure in 2008 and now operates NigComSat-1R.

3.2. Middle East

A slim majority of Middle Eastern countries either have satellites in orbit or are planning their first satellite. Approximately 21% of the regional population lives in a Level 0 country, as shown in Table 3. In the following sub-sections a brief description is given of satellite activities in Middle Eastern countries that have Kyutech association.

3.2.1. Turkey: Level 3

Turkey has launched at least 10 satellites, five to LEO and five to GEO. [6] The GEO satellites are operated by the Turksat Satellite Communications and Cable TV Operations Company (Turksat). The first successful Turksat satellite, Turksat 1B, was developed by Aerospatiale (France) and launched in 1994. Turksat 4A was built by Mitsubishi Electric Corporation (Japan) and launched in 2014. Turksat 4B was also built by Mitsubishi. Turkey is now transitioning GEO satellite development to domestic entities.

The Scientific and Technological Research Council of Turkey (TUBITAK) is involved with LEO satellite development and operation. Additionally, the Istanbul Technical University (ITU) launched a 3U CubeSat, UBAK3USAT, in 2013.

3.2.2. UAE: Level 3

The United Arab Emirates (UAE) has launched at least seven satellites (two to LEO and five to GEO). [6] The two LEO satellites were launched by the Emirates Institution for Advanced Science and Technology (EIAST), three GEO satellites have been launched by Thuraya, and two GEO satellites have been launched by Yahsat. The first satellite, Thuraya 1, was developed by Boeing and launched in 2000. [4] In 2015 UAE opened the Mohammed bin Rashid Space Centre to manage phases of UAE's probe exploration mission to Mars and to contribute to space science and satellite projects. [16] EIAST is coordinating cubesat projects with domestic universities.

3.3. Central/North America

Space access is very limited in Central/North America.[iv] The only country to reach space thus far is Mexico, although Mexico does comprise ~73% of the regional population, as shown in Table 4. In the following sub-sections a brief description is given of satellite activities in Central/North American countries that have Kyutech association.

3.3.1. Costa Rica: Level 1

In conjunction with the Central American Space Association (ACAE), the Costa Rica Institute of Technology (TEC) is designing a 1U CubeSat named DSPACE. DSPACE will transmit carbon values from atmospheric locations. ACAE and TEC are leaders in space efforts in Central America, including the design of an experiment for the International Space Station. TEC also intends to start an official space education program in the near future.

3.3.2. Mexico: Level 3

Mexico has launched at least seven satellites, one to LEO and six to GEO. [6] The first satellite, Morelos I, was ordered from the Hughes Aircraft Corporation and launched to GEO in 1985. [4] More recently, Mexico purchased an end-to-end three-satellite GEO system from Boeing known as MEXSAT. [17] The second satellite launched in 2015. The Mexican Secretariat of Communications and Transportation operates MEXSAT.

The Mexican Space Agency (AEM) was formed in 2010 and at present serves as a facilitator of space and satellite activities. Hardware is not developed or assembled in house. However, multiple cubesat projects are underway at Mexican universities, both with and without AEM's involvement. Cubesat projects are being conceptualized at the National Autonomous University of Mexico Center for High Technology (UNAM CAT) and National Polytechnic Institute Aerospace Development Center (IPN ADC). Another cubesat project named Ulises-1 has passed the prototype phase.

[iv] For purposes of this report the United States and Canada are not considered

Table 3. Satellite Activity Level and Population of Middle Eastern Nations.

Level 0		Level 1		Level 2		Level 3	
Country	Pop.(M)	Country	Pop.(M)	Country	Pop.(M)	Country	Pop.(M)
Cyprus	1.15	Armenia	2.98	Azerbaijan	9.51	Iran	78.47
Georgia	4.32	Bahrain	1.34	Iraq	34.77	Israel	7.82
Kuwait	3.48	Jordan	7.50	Qatar	2.27	Saudi Arabia	29.37
Lebanon	4.97					Turkey^{K}	75.84
Oman	3.93					UAE^{K}	9.45
Palestine	4.44						
Syria	21.99						
Yemen	24.97						
8 countries	69 M	3 countries	12 M	3 countries	47 M	5 countries	201 M

^{K}Kyutech association

Table 4. Satellite Activity Level and Population of Central/North American Nations.

Level 0		Level 1		Level 2		Level 3	
Country	Pop.(M)	Country	Pop.(M)	Country	Pop.(M)	Country	Pop.(M)
Belize	0.34	Costa Rica^{K}	4.94			Mexico^{K}	123.80
El Salvador	6.38	Guatemala	15.86				
Honduras	8.26	Nicaragua	6.17				
Panama	3.93						
4 countries	19 M	3 countries	27 M	0 countries	0 M	1 countries	124 M

^{K}Kyutech association

3.4. South America

In South America there are only two Level 0 countries and only one Level 1 country. Approximately 39% of the regional population lives in Level 2 countries, and ~59% in Level 3 countries, as shown in Table 5. In the following sub-sections a brief description is given of satellite activities in South American countries that have Kyutech association.

3.4.1. Bolivia: Level 2

Bolivia launched its first satellite, Tupac Katari 1 (TKSat 1) in 2013. TKSat 1 is a telecommunications satellite built by CGWIC and operated by the Bolivian Space Agency (ABE). ABE signed a contract with CGWIC in 2010 for satellite development and personnel training. At present ABE is not conducing cubesat activities but a coalition of local students and engineers are working to secure funding for a cubesat project to be hosted by domestic universities.

3.4.2. Colombia: Level 2

Colombia has launched one satellite, a 1U CubeSat named Libertad-1 that was developed at Sergio Arboleda University (SAU) in Bogota starting in 2004. Libertad-1 was launched in 2007. A 3U follow-up satellite, Libertad-2, is currently under development and is projected to be launched in 2016 or 2017. Satellite-related projects are also underway at Universidad Distrital Francisco Jose de Caldas (UD).

Colombia does not have a space agency, although the Colombian Air Force (FAC) is becoming involved with satellite projects. FAC started developing its first satellite in 2012, a 3U CubeSat named FACSAT-1. A private company named Sequoia Space was founded in 2008 and supports many satellite projects in Colombia and South America.

3.4.3. Ecuador: Level 2

Ecuador launched two CubeSats in 2013, named NEE-01 Pegaso and NEE-02 Krysoar, respectively. The Ecuadorian Civil Space Agency (EXA) developed the satellites. EXA was established in 2007 and is a non-profit non-governmental organization. Ecuador does not have an official space agency or program, but the government publicly supports EXA as Ecuador's "civilian space agency." EXA has chosen to develop satellite technology in house as opposed to purchasing satellite systems or technology. This in part led to formation of the Quantum Aerospace Research Institute (QAS) in 2015. QAS is a non-profit non-governmental research institute. QAS intends to host facilities, experiments, etc. related to space and aerospace activities.

3.4.4. Peru: Level 2

Peru has launched four satellites since 2013, all CubeSats: PUCP-Sat 1, POCKET-PUCP, UAPSAT-I, and CHASQUI-I. The satellites were developed at local Peruvian universities. The National Commission for Aerospace Research and Development (CONIDA) acts as Peru's space agency and was formed in 1974 under the Ministry of Defense. In 2014 the Ministry of Defense awarded a contract to Airbus Defence and Space (France) to deliver Peru's first remote sensing satellite. Launch is anticipated in 2016.

Table 5. Satellite Activity Level and Population of South American Nations.

Level 0		Level 1		Level 2		Level 3	
Country	Pop.(M)	Country	Pop.(M)	Country	Pop.(M)	Country	Pop.(M)
Guyana	0.80	Paraguay	6.92	Bolivia^{K}	10.85	Argentina	41.80
Suriname	0.54			Chile	17.77	Brazil^{K}	202.03
				Colombia^{K}	48.93	French Guiana	0.26
				Ecuador^{K}	15.98		
				Peru^{K}	30.77		
				Uruguay	3.42		
				Venezuela^{K}	30.85		
2 countries	1 M	1 countries	7 M	7 countries	159 M	3 countries	244 M

^{K}Kyutech association

3.4.5. Venezuela: Level 2

Venezuela has launched two satellites, to GEO in 2008 and to LEO in 2012. The satellites are named Venesat-1 and VRSS-1, respectively, and are operated by Venezuela's space agency, the Bolivarian Agency for Space Activities (ABAE). Both satellites were developed by CGWIC. China has also trained numerous ABAE engineers. ABAE is building an Assembly, Integration, Test (AIT) and Design center outside of Caracas that is scheduled to open in late 2015. ABAE is coordinating cubesat development (1U to be followed by 3U) with local institutions.

3.4.6. Brazil: Level 3

Brazil has launched at least 15 satellites [6] and is home to a burgeoning space program. Primary space activities are conducted by the Brazilian Space Agency (AEB) and National Institute For Space Research (INPE). Brazil is developing and launching numerous CubeSats. For example, the AESP-14 CubeSat developed by the Technological Institute of Aeronautics (ITA), AEB, and INPE was deployed from JAXA's Kibo module in February 2015.

3.5. Eastern Asia

Four of the six East Asian countries are Level 3, and the remaining two are Level 2 and Level 1, respectively. Approximately 98% of the regional population lives in Level 3 countries, as shown in Table 6. In the following sub-sections a brief description is given of satellite activities in East Asian countries that have Kyutech association (not considering domestic associations within Japan).

3.5.1. Mongolia: Level 1

According to a Mongolian government resolution in 2012, Mongolia plans to launch a remote sensing satellite in 2016 and a communications satellite in 2018. While these dates are optimistic, Mongolia is developing space-related human resources and is anticipated to launch its first satellite this decade. Remote sensing activities have been on-going at the National Remote Sensing Centre (NRSC) since 1991, and CANSAT activities began at the National University of Mongolia (NUM) in 2012. NUM also has a "Space Science" laboratory within its Physics and Electronics Department that may host a satellite project in the near future.

3.5.2. South Korea: Level 3

South Korea has launched at least 18 satellites starting from 1993. [6] The first satellite was named KITSAT-1 and was developed jointly by the Korea Advanced Institute of Science and Technology (KAIST) and SSTL. The Korea Aerospace Research Institute (KARI) is the aeronautics and space agency of South Korea and was founded in 1989. [18] Satrec Initiative (SI) based in Daejeon is a major provider of Earth observation satellites, having delivered over 20 solutions to customers in the Middle East, Asia and Europe. [19] Numerous cubesat activities have been conducted in South Korea since 2006.

3.6. Southern Asia

Four of the eight South Asian countries have space access and the other four do not. However, three of the four countries without space access are Level 1 countries planning their first satellite. The regional population is dominated by India and Pakistan, so nearly 86% of the population resides in Level 3, as shown in Table 7. These eight countries comprise the South Asian Association for Regional Cooperation (SAARC) that was established in 1985. An eloquent overview of SAARC characteristics and space activities can be found in the references. [20] In the following sub-sections a brief description is given of satellite activities in South Asian countries that have Kyutech association.

3.6.1. Bangladesh: Level 1

Bangladesh is planning to launch its first satellite, Bangabandhu-1, to GEO in 2017 or later. However, concerns have been raised regarding the selection of satellite provider and orbital slot. [21] The primary stakeholder will be the Bangladesh Telecommunications Regulatory Commission (BTRC). Additional space activities are conducted at the Bangladesh Space Research and Remote Sensing Organization (SPARRSO), which was established in 1980. Brac University in Dhaka is seeking funding and human resources to launch Bangladesh's first domestically developed satellite.

3.7. Southeast Asia

There is wide disparity in space development in Southeast Asia. Five countries currently lack space access. Of the remaining six countries, five are Level 3 countries having five or more of their own satellites. Approximately 88% of the regional population resides in Level 2 or Level 3, and ~12% in Level 0 or Level 1, as shown in Table 8. In the following sub-sections a brief description is given of satellite activities in Southeast Asian countries that have Kyutech association.

Table 6. Satellite Activity Level and Population of East Asian Nations.

Level 0		Level 1		Level 2		Level 3	
Country	Pop.(M)	Country	Pop.(M)	Country	Pop.(M)	Country	Pop.(M)
		Mongolia[K]	2.88	North Korea	25.03	China	1370.44
						Japan	127.00
						South Korea[K]	49.51
						Taiwan	23.34
0 countries	0 M	1 countries	3 M	1 countries	25 M	4 countries	1570 M

[K]Kyutech association

Table 7. Satellite Activity Level and Population of South Asian Nations.

Level 0		Level 1		Level 2		Level 3	
Country	Pop.(M)	Country	Pop.(M)	Country	Pop.(M)	Country	Pop.(M)
Bhutan	0.77	Bangladesh[K]	158.51	Afghanistan	31.28	India	1267.40
		Maldives	0.35	Sri Lanka	21.45	Pakistan	185.13
		Nepal	28.12				
1 countries	1 M	3 countries	187 M	2 countries	53 M	2 countries	1453 M

[K]Kyutech association

Table 8. Satellite Activity Level and Population of Southeast Asian Nations.

Level 0		Level 1		Level 2		Level 3	
Country	Pop.(M)	Country	Pop.(M)	Country	Pop.(M)	Country	Pop.(M)
Brunei	0.42	Laos	6.89	Philippines[K]	100.10	Indonesia[K]	252.81
Cambodia	15.41	Myanmar	53.72			Malaysia[K]	30.19
Timor-Leste	1.15					Singapore[K]	5.52
						Thailand[K]	67.22
						Vietnam[K]	92.55
3 countries	17 M	2 countries	61 M	1 countries	100 M	5 countries	448 M

[K]Kyutech association

3.7.1. Philippines: Level 2

The Philippines launched its first satellite,[v] Agila 2 (Mabuhay 1), in 1997.[4] Agila 2 was a GEO communications satellite built by Space Systems/Loral (SS/L) and managed by the Mabuhay Philippines Satellite Corporation. A team of Filipino engineers trained at SS/L in California for two years.[23] The Philippines no longer operates Agila 2 or any other satellite.

In 2014 the Filipino Department of Science and Technology (DOST) and Philippine Council for Industry, Energy and Emerging Technology Research and Development (PCIEERD) contracted Tohoku University and Hokkaido University of Japan to build a pair of 50kg remote-sensing microsatellites. The University of Philippines Diliman (UPD) will provide human resources for training in Japan and host elements of the project.

Remote sensing activities are conducted by the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA). A private company named Regulus SpaceTech intends to launch a CubeSat. Efforts to create a Philippine Space Agency are on-going.

[v] The Mabuhay Philippines Satellite Corporation leased an Indonesian GEO satellite in 1996[22]

3.7.2. Indonesia: Level 3

Indonesia has launched at least 13 satellites, the first to GEO in 1976 (satellite built in USA and managed by Indosat).[6] Space activities are managed by the National Institute of Aeronautics and Space (LAPAN). LAPAN was founded in 1963. In 2003 LAPAN and the Technical University of Berlin (TUB) initiated the first Indonesian microsatellite, LAPAN-Tubsat, which was launched in 2007. Multiple follow-up microsatellites have been launched or are under development. Indonesian universities including Institut Teknologi Bandung (ITB) and Telkom University are considering cubesat or nanosatellite projects.

3.7.3. Malaysia: Level 3

Malaysia has launched at least seven satellites, five to GEO and two to LEO.[6] The first satellite, MEASAT 1, was developed by Hughes Space and Communications International (USA), launched to GEO in 1996, and was operated by MEASAT Satellite Systems Sdn. Bhd.[24] Malaysia's first microsatellite, TiungSAT-1, was developed by Astronautic Tech-

nology Sdn Bhd (ATSB) and SSTL and launched in 2000. Malaysia's second microsatellite, RazakSAT-1, was developed by ATSB and Satrec Initiative and launched in 2009.

In 2002 Malaysia established the National Space Agency of Malaysia (ANGKASA) to conduct space operations, space science, and outreach. ANGKASA has installed an AIT facility capable of handling satellites up to 1-ton, has a control ground station, and will manage development of the RazakSAT-2 remote sensing satellite.

ATSB has developed at least two CubeSats. Numerous cubesat and other space activities are underway in Malaysia. The Universiti Kebangsaan Malaysia (UKM) excels in communication technology and antenna design. The Universiti Putra Malaysia (UPM) is developing materials for space applications. The Universiti Teknologi MARA (UiTM) is considering a cubesat project.

3.7.4. Singapore: Level 3

Singapore has launched at least four of its own satellites to LEO, the first in 2011, and two satellites to GEO with Taiwan, the first in 1998. [6] Singapore does not have a dedicated space agency but the government provides funding to universities, industry, and agencies for space/satellite development. The first Singapore-built satellite, the ~120 kg X-Sat, was developed at Nanyang Technological University (NTU). NTU's Satellite Research Center (SaRC) is within the School of Electrical and Electronic Engineering (EEE).

Singapore has also developed and launched CubeSats including Velox-P and Velox-PII. Various CubeSats and other satellites are under development at NTU, the National University of Singapore (NUS), and ST Electronics. NTU and NUS have numerous collaborations with universities, industry, and government agencies.

3.7.5. Thailand: Level 3

Thailand has launched at least two LEO satellites and six GEO satellites, the first named Thaicom 1 to GEO in 1993. [4] Thaicom 1 was developed by Hughes Space and Communications International (USA) and operated by Thaicom PLC, Thailand's sole private satellite operator. Thaicom PLC operates numerous telecommunications satellites, the most recent launched in 2014.

Thailand launched its first microsatellite, TMSat 1, in 1998. TMSat 1 was developed at SSTL with Thai participation. In 2000 the Geo-Informatics and Space Technology Development Agency (GISTDA) was established to collect and utilize satellite data and operate and develop new Thai satellites. In 2008 GISTDA launched THEOS 1, a 700 kg class satellite developed with EADS Astrium. The Ministry of Science and Technology and GISTDA are planning to develop THEOS 2 with another international partner. GISTDA established the "GISTDA Academy" in November 2013 to focus on internal research and development projects, including CubeSats. GISTDA is also planning an AIT facility.

A Thai private group is developing a 1U cubesat named JAISAT-1 (the first Joint Academy of Intelligent Satellites for Amateur Radio in Thailand). King Mongkut's University of Technology North Bangkok (KMUTNB) has initiated a nanosatellite project named KNACKSAT. There also may be cubesat activities at the National Science and Technology Development Agency (NSTDA).

3.7.6. Vietnam: Level 3

Vietnam has launched at least five satellites, the first to GEO in 2008 named VINASAT-1. [4] VINASAT-1 was developed by Lockheed Martin. A second GEO satellite named VINASAT-2 was launched in 2012. A LEO satellite named VNREDSat-1 was developed for Vietnam by EADS Astrium with training of Vietnamese engineers and launched in 2013. [25]

The Vietnam National Space Center (VNSC) was established in 2011 to lead domestic space and satellite activities. VNSC and Japan developed and launched a 1U CubeSat named Pico-Dragon in 2013. FPT University (private university in Hanoi) developed another 1U CubeSat named F-1 that also launched in 2013. In 2011 VNSC signed a contract with NEC Corporation of Japan for two remote sensing satellites, the first to be built in Japan and the second in Vietnam. VNSC is also developing a nanosatellite in parallel that may launch as early as 2016.

3.8. Eastern Europe

Most of Eastern Europe has space access. Six countries have already launched a satellite and the remaining three countries have plans to do so. Approximately 87% of the population resides in Level 2 or Level 3 countries, as shown in Table 9. In the following sub-sections a brief description is given of satellite activities in East European countries that have Kyutech association.

3.8.1. Romania: Level 2

The Romanian Space Agency (ROSA) developed and launched Romania's first satellite in 2012, a 1U CubeSat named Goliat. ROSA was established in 1991 and coordinates national space technology research and activities. The Institute of Space Science in Bucharest is developing two CubeSats, RoBiSAT-1 and RoBiSAT-2, as part of the QB50 Project. [26]

3.8.2. Ukraine: Level 3

The National Space Agency of Ukraine (NSAU) was established in 1992. Ukraine is Eastern Europe's only Level 3 country, as NSAU has designed, built and launched at least six of its own satellites. Ukraine's first satellite, Sich-1, was developed domestically and launched to LEO in 1995. [4] In 2011 NSAU was reorganized into the State Space Agency of Ukraine (SSAU) in an effort to streamline and strengthen space activities. Numerous launch enterprises, scientific institutions, design companies, etc. are under the purview of SSAU. However, the recent cancellation of the decade-long Ukraine-Brazil Cyclone-4 project indicates that struggles may lie ahead for SSAU. [27]

The first Ukrainian cubesat, PolyITAN-1, was developed by the National Technical University of Ukraine (KPI) and launched in 2014. [28] Additional cubesat activities are underway in Ukraine.

3.9. Oceania

Melanesian, Micronesian, and Polynesian countries are not included in this report due to lack of available information. New Zealand and Australia are classified as Level 1 and Level 3 countries, respectively, as shown in Table 10. In the following sub-sections a brief description is given of satellite activities in Oceanic countries that have Kyutech association.

Table 9. Satellite Activity Level and Population of East European Nations.

Level 0		Level 1		Level 2		Level 3	
Country	Pop.(M)	Country	Pop.(M)	Country	Pop.(M)	Country	Pop.(M)
		Czech Republic	10.74	Belarus	9.31	Ukraine[K]	44.94
		Moldova	3.46	Bulgaria	7.17		
		Slovakia	5.45	Hungary	9.93		
				Poland	38.22		
				Romania[K]	21.64		
0 countries	0 M	3 countries	20 M	5 countries	86 M	1 countries	45 M

[K]Kyutech association

Table 10. Satellite Activity Level and Population of select Oceanic Nations.

Level 0		Level 1		Level 2		Level 3	
Country	Pop.(M)	Country	Pop.(M)	Country	Pop.(M)	Country	Pop.(M)
		New Zealand	4.55			Australia[K]	23.63
0 countries	0 M	1 countries	5 M	0 countries	0 M	1 countries	24 M

[K]Kyutech association

3.9.1. Australia: Level 3

Australia has launched at least 15 satellites, five to LEO and 10 to GEO, starting in 1967.[6] However, Australia does not have a dedicated space agency. The majority of Australian Space Research Program funding goes to astronomy and astrophysics. Various cubesat and QB50-Project activities are underway at Australian universities and other entities.

In July 2014 the Australian National University (ANU) officially opened the Advanced Instrumentation and Technology Centre (AITC). AITC is a full-scale comprehensive test facility designed for instrumentation (telescopes, detectors, etc.) but can also be used for satellite testing. AITC is involved with 5 of 14 on-going projects being conducted by the Australian Space Research Program. At present AITC is not developing internal mission payloads or satellites, with the exception of telescope design. However, ANU and AITC are playing an active role in Australia's "satellite utilization policy."

4. Conclusions

In the past five years alone, 19 countries have achieved their first satellite in orbit. By the end of this decade, that number will likely be over 30. Space access has never before been so attainable for new space actors. Small-scale and "lean" satellites have lowered the barrier to space access. As shown in Table 11, maiden satellites launched by new space countries are increasingly of the small-scale/lean type. Not surprisingly, ~50% of maiden satellites launched thus far in the 2010s have been domestically self-developed. In the 1990s and 2000s countries self-developed their first satellite about 25% of the time. (Statistics by Kyutech.)

Table 11. Maiden satellite type by decade.

	1990s	2000s	2010s
Small-scale/lean:	2	3	8
Traditional:	14	10	11

Countries in Africa, the Middle East, Central/North America, South America, Eastern Asia, Southern Asia, Southeast Asia, Eastern Europe and Oceania have been classified as Level 0, Level 1, Level 2 or Level 3 countries according to the number of satellites launched.[vi] Level 0 means no satellite activity, Level 1 means first satellite planned, Level 2 means one to four satellites launched, and Level 3 means five or more satellites launched.

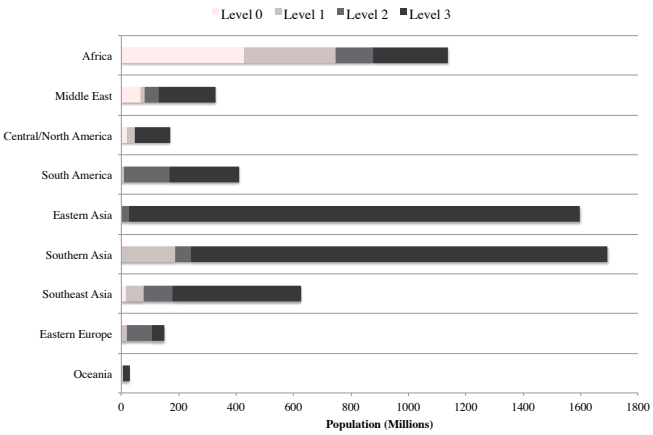

Fig. 2. Population by region according to Satellite Activity Level

In total over the nine regions there are 58 Level 0 countries, 26 Level 1 countries, 23 Level 2 countries, and 24 Level 3 countries. Of the 58 Level 0 countries 40 are in Africa. Note that not all regions in the world were considered nor every country within North America and Oceania. Figure 2 shows the total population for each of the nine considered regions according to Level 0, Level 1, Level 2 and Level 3 classification.

Over 400 million people in Africa live in Level 0 countries. The Middle East and Central/North America have the next highest Level 0 populations, 69 and 19 million, respectively. Over

[vi] "Launched" taken to include owned, leased, operated, developed, and so on

300 million people in Africa and nearly 200 million people in Southern Asia live in Level 1 countries, meaning space access should be achieved in the near future. Of course, practical benefit to the general population may take years or longer to materialize, but the trend is promising. Space faring nations and established space institutions have both for-profit and non-profit incentive to contribute to basic space technology and human resource development that shifts more and more nations from Level 0 and Level 1 to Level 2 and Level 3. Humanity stands to benefit.

A subsequent publication will detail Kyutech's university-based model for space-related capacity building, and discuss advantages and disadvantages of other approaches.

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