Analyzing the Development Paths of Emerging Spacefaring Nations

Opportunities or Challenges for Space Sustainability?

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ACRONYM LIST

ABAE	Bolivarian Agency for Space Activities
AEB	Brazilian Space Agency
ALC	African Leadership Conference on Space Science and Technology for Sustainable Development
APRSAF	Asia-Pacific Regional Space Agency Forum
APSCO	Asia-Pacific Space Cooperation Organization
ARMC	African Resources and Environmental Management Satellite Constellation
CBERS	China-Brazil Earth Resources Satellites
CEA	Space Conference of the Americas
CEV	Venezuelan Space Center
CLA	Alcântara Launch Center
COPUOS	Committee on the Peaceful Uses of Outer Space
CVPR	Venezuelan Center of Remote Sensing
DMC	Disaster Management Constellation
EU	European Union
GEO	Group on Earth Observations
IAC	International Astronautical Congress
INPE	National Institute for Space Research
INSAT	India National Satellite
IRS	Indian Remote Sensing
ISRO	Indian Space Research Organization
JAXA	Japan Aerospace Exploration Agency

LEO	Low-Earth orbit
MEASAT	Malaysia East Asia Satellite
MECB	Brazilian Complete Space Mission
MEXT	Ministry of Education, Culture, Sports, Science and Technology
NASA	National Aeronautics and Space Administration
NASRDA	National Space Research and Development Agency
PNAE	National Program of Space Activities
SAC	Applications Center
SANSA	National Space Agency
SCD	Data Collection Satellites
SpaceX	Space Exploration Technologies
SSTL	Surrey Satellite Technology Ltd
UN	United Nations
VLS-1	Satellite Launch Vehicle
VRC	Village Resource Center

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INTRODUCTION

A domain previously dominated by just two countries now involves more than fifty national space agencies, even as the list of countries setting their sights on space continues to grow. The advent of emerging spacefaring nations, differentiated from established spacefaring nations in terms of both time span and capability of their space activities, has changed the space environment dramatically, with far-reaching economic, political and social implications.

Previous technological and economic barriers to entry are being brought down by factors such as the advent of small satellites and the spread of globalization. While this creates opportunities for emerging space actors, it also raises new security concerns for the entire international space community as the space environment becomes more congested. Unless established and emerging actors agree on what constitutes acceptable behavior in space, their combined activities may threaten the continued use of this shared resource.

With these elements intertwined, stakeholders have begun to engage in discussions over the long-term sustainability of space. Of note are the establishment of the United Nations (UN) Working Group on the Long-Term Sustainability of Space, and inclusion of the topic of space sustainability in the 2010 U.S. National Space Policy. Secure World Foundation founder and President, Cynda Collins Arsenault (2011), described the two key components of space sustainability: "the first is the physical environment, which includes management of space debris, electromagnetic and physical crowding and congestion, and space weather…The second component is the political environment, and includes promoting stability and preventing conflict between nations."

Addressing space sustainability requires international engagement, due to the distinct conditions of the space domain that force interdependences between all space actors. Space debris is a particularly illustrative example, as one actor's decision or negligence that creates fragments in Earth orbit poses long-term threats for all users. Debris can stay in orbit for decades or longer, and even objects smaller than ten centimeters create serious hazards for satellites and human spaceflight missions. This interdependence presents both opportunities and challenges for the advancement of space sustainability by the international community.

In order to stimulate new discussions on this topic, this paper analyzes the driving rationales and major activities of six emerging space actors in three regions of the world: Nigeria and South Africa in Africa, Malaysia and India in Asia-Pacific, and Venezuela and Brazil in South America. At markedly different stages of space development, these countries afford an interesting comparison that provides new considerations relevant to space sustainability.

It is important to note that the emergence of private actors in space has fostered important debates within the context of space sustainability, while the dual-use nature of space technology also presents challenges relevant to this topic. Because of scope limitations, however, discussion will be limited to national, civil space activities.

The paper is organized as follows: Part I discusses the distinct development paths of each nation's space program; Part II puts the previous discussion within a regional context, comparing development paths and identifying shared challenges to explain commonalities and differences within the region; Part III features a case study that draws from the analysis in previous sections to consider the response of emerging space nations to an existing mechanism for addressing space sustainability, the European Union's (EU) draft *Code of Conduct for Outer Space Activities*. The conclusion identifies potential implications to international space sustainability efforts.

PART I: COUNTRY BACKGROUNDS & DEVELOPMENT PATHS

1 <u>Africa Region</u>

Africa is realizing the benefits of space technology to socio-economic development. Several African countries now have national space programs, focused primarily on using satellite applications to address the many challenges facing these developing countries, such as managing scarce resources and providing affordable rural telecommunications. South Africa and Nigeria lead Africa in terms of their space technology capabilities. Over the past decade, both nations have achieved notable milestones in their national space programs. Through international partnerships, Nigeria launched its first satellites and built up domestic capacity; South Africa recently became the only African country to develop local spacecraft manufacturing capabilities.

1.1 Nigeria

1.1.1 Rationale & Major Activities

Nigeria's national space agency, the National Space Research and Development Agency (NASRDA), has the "broad objective to pursue the development and application of space science and technology for the socio-economic benefit of the nation" and the specific mission to "achieve technological competence in the manufacture and launch of satellites by the year 2025" (NASRDA 2010). Its National Space Policy identifies space technology as "an essential tool for its socio-economic development and enhancement of the quality of life of its people" (National Space Policy 2001), and speaks of achieving a "critical mass" of Nigerian space professionals to enable "self-reliance" in using space for national development purposes (National Space Policy 2001). To achieve this, the policy directs government entities to pursue capacity building through international cooperation and calls for increased space-related education at all levels.

Nigeria has taken subsequent steps to fulfill its space policy. Its first satellite, NigeriaSat-1, is a remote sensing microsatellite designed to addresses national development concerns such as resource management and flood-risk mapping (Akinyede and Agbaje 2006). NigeriaSat-1 was built under an agreement with Surrey Satellite Technology Ltd (SSTL), a British company that specializes in small satellite platforms. The contract included a capacity building program to train Nigerian engineers in satellite development and operations (Boroffice 2008).

NigeriaSat-2 is the follow-on remote sensing mission to NigeriaSat-1, also built by SSTL and planned for launch in 2011. As part of NigeriaSat-2's capacity-building program, Nigerian engineers gained hands-on experience at SSTL facilities by developing a training model, NigeriaSat-X. Although not part of the original agreement, the success of NigeriaSat-X led to the decision to launch the training satellite with NigeriaSat-2. Operations will be based in Nigeria, by Nigerian operators, but with backup facilities also at SSTL (D. Wood, Interview with Danielle Wood on African Space Activities 2011). The success of NigeriaSat-X will demonstrate Nigeria's potential for independent space capabilities (Boroffice 2008).

NigcomSat-1 was a communications satellite built by the China Great Wall Corporation, a Chinese state-owned company. NigcomSat-1's services were to include rural mobile telephony, tele-medicine, tele-education, and Internet —all important services for a developing country with a large population and vast geography. Unfortunately, NigcomSat-1 failed in orbit after 18 months, with a replacement being built under insurance coverage for launch in 2012 (Aganaba 2010). Despite this setback, NigcomSat-1's major benefit was a training program for fifty-five Nigerians over two years on communications satellite design and operations (Boroffice 2008).

1.1.2 International Cooperation

Nigeria is striving to establish regional leadership in space as part of its overall science and technology strategy. Accordingly, it participates in the most prominent regional space initiatives, which will be discussed further in Part II. Nigeria also participates in a number of international space-related initiatives, ranging from the UN Committee on the Peaceful Uses of Outer Space (COPUOS) to the Group on Earth Observations (GEO). Through NigeriaSat-1, Nigeria is also a member of the Disaster Management Constellation (DMC), an international collaboration between five countries with SSTL-built satellites to create remote sensing data products for disaster relief and resource management purposes (Boroffice 2008).

1.1.3 Development Path

Capacity building through partnerships with more advanced space actors has been a key feature in Nigeria's space program. This approach appears to be working for Nigeria, in terms of acquiring national satellites for addressing the needs of its people. Indeed, NASRDA and other government entities are reportedly using remote sensing data from NigeriaSat-1 to address a variety of national development challenges (Akinyede and Agbaje 2006). However, Nigeria has yet to develop domestic facilities and industries for indigenous satellite manufacturing and launch. Given the current status of the Nigerian space program, as well as its limited budget, it appears that Nigeria must continue its strategy of using international partnerships to fulfill its space policy, at least in the near term. What space actors Nigeria will partner with in the future is not certain, but its willingness to cooperate with foreign commercial space companies could indicate future trends.

1.2 South Africa

1.2.1 Rationale & Major Activities

South Africa has a long history of space-related activities and the strongest space technology capability in Africa (D. Wood, Summary of Major Space Activities in Africa and Other Developing Regions 2011). Yet, its first National Space Policy was not released until 2009, followed by the launch of its National Space Agency (SANSA) and accompanying National Space Strategy in December 2010. These mechanisms were established to provide much-needed coordination and integration within the already-existing South African space community, in order to maximize the benefits of national space activities to the local population.

South Africa’s space program is primarily oriented toward using satellite applications for national development imperatives. Its National Space Policy recognizes that “space systems have become a cornerstone of the modern information and innovation society” and thus aims to guide the “development and implementation of space science and technology to address South Africa’s development challenges” (South Africa's National Space Policy 2009). A cornerstone of the policy is to foster a domestic space industry, by articulating a clear and progressive path for the nation’s space program, and creating a predictable and stable regulatory environment for its stakeholders (Makapela 2010). Indeed, South Africa’s sustainable development requires that it diversify exports, reduce dependence on other countries for high-tech services, and develop an indigenous community of high-tech professionals (South Africa's National Space Policy 2009).

SANSA is charged with implementing the National Space Strategy, which has the vision “for South Africa to be among the leading nations in the innovative utilization of space science and technology that enhances economic growth and sustainable development in order to improve the quality of life for all” (Munsami 2009). For economic growth, the Strategy encourages the development of a domestic industry capable of exporting complete satellites as well as their subsystems and services. For national development, the Strategy seeks space applications for better decision-making and calls for increased public awareness, partnerships with established and developing space nations, and training and technology transfer programs (Munsami 2009).

Launched in 1999, Sunsat was South Africa's first satellite and Africa's first indigenously built satellite. Rather than a government entity, faculty and students at the University of Stellenbosch built the remote sensing microsatellite; hundreds of students gained experience through the satellite's decade-long development, after which it operated for two years (International Astronautical Congress 2010). In 2000, the developers of Sunsat created a spin-off company called SunSpace, of which the South African government is a majority stakeholder (Martinez, Space Science and Technology in South Africa 2008). SunSpace is the only satellite design and manufacturing company in Africa; it also markets satellite subsystems, consulting services, and training programs with clients in Europe, Asia, and the Middle East.

In 2005, the South African government initiated its first satellite program with the goal of building domestic capacity in executing space missions. To achieve this, the government engaged local companies and institutions: the University of Stellenbosch managed the program, SunSpace was the prime contractor, and the government-established Satellite Applications Center (SAC) was assigned satellite tracking and operations. The resulting remote sensing satellite, Sumbandila, was launched in 2009 and still operates with a high-resolution imaging payload optimized for agricultural applications and environmental management. Although its space program is primarily applications-oriented, the South African government's dedication to fostering a domestic satellite manufacturing industry indicates a balanced approach.

1.2.2 International Cooperation

South Africa's National Space Strategy states that South Africa will pursue partnerships with established and developing space-faring countries, while also strengthening training and technology transfer programs. Thus, South Africa is heavily involved in the region's most prominent regional space initiatives, which will be discussed in more detail in Part II, and is also particularly active in the international space community. Most notably, the country has been selected to host the 62nd International Astronautical Congress (IAC) in 2011, a nod to its advancements in space science and technology and an important opportunity to promote its value to the international space community. South Africa is also an active participant in international space forums. For example, it is not only a member of GEO, but also sits on GEO's Executive Committee with thirteen other nations and serves as the Co-Chair along with the United States, the European Commission, and China.

1.2.3 Development Path

South Africa has never bought a complete satellite from a foreign entity, thereby setting it apart from other African space programs with its indigenous satellite manufacturing capabilities. The government's support of a domestic space industry has been instrumental in fostering these capabilities (Gottschalk 2010). In other areas, South Africa has used capacity building opportunities to capture knowledge exchange and later apply it to national activities. Most notably, South Africa's SAC is an example of a facility that "benefits from the capability to operate satellites even when no national satellite is in orbit. The SAC is able to serve other countries with this capability, and they use these skills at home when they launch indigenous satellites" (D. Wood, The Use of Satellite-Based Technology in Developing Countries 2008).

However, South Africa is not immune to the many challenges facing developing countries seeking to establish national space programs. Launching SANSA and the National Space Strategy has been a long and drawn out process; even after their establishment, inadequate funding, political support and public awareness are slowing the integration and alignment of South African space activities (Makapela 2010). Thus, although South Africa is considering ambitious plans such as independent launch capabilities, its primary focus will likely remain on applications for socio-economic benefit in the near term.

2 Asia-Pacific Region

The Asia-Pacific region boasts a diverse collection of space actors whose capability portfolios largely vary. At one end of the spectrum is India, with indigenous space launch assets and a decades-long track record of satellite design and manufacturing. At the other end is Malaysia, whose first steps in microsatellite design were taken just a few short years ago. An examination of both actors offers an enriched understanding into the emerging nature of the region's space actors. India's aspiration of a space program with soft power projection contrasts strongly with the nascent Malaysian program that seeks technology transfer of the most basic variety. Both countries help characterize the rapidly fluctuating Asia-Pacific space posture.

2.1 India

2.1.1 Rationale & Major Activities

Although India's first development of space capabilities can be traced to the Cold War era, the nation's founding motivation for obtaining space assets was strikingly dissimilar from traditional space actors of that time. India's status as a developing country in the 1960s left the country uninspired to assert itself as a major player in space for the benefit of amassing global influence and prestige (Day 2008). Instead, India's government strongly embraced space activities as a means of addressing the domestic development problems of its population (Day 2008). Thus, the first sixty years of the Indian Space Research Organization (ISRO) were marked by achievement in the use of space applications for Indian society. Design and development of Indian space assets, and more specifically Earth-orbiting satellites, centered on building capacity in remote sensing and telecommunications.

ISRO has used its remote sensing satellite capabilities to offer deep insight into a wide range of Indian resources. The Indian Remote Sensing (IRS) satellite system currently maintains nine satellites in orbit that transmit data directly to nearly 500 Village Resource Centers (VRCs) (Space Technology Enabled Village Resource Centre (VRC) 2007). VRCs connect villagers to IRS data about their geographic region. IRS data is generated for topics of practical relevance to resource management such as the discovery of new sources of clean water, the monitoring of reservoirs and the distribution of clean water to the population (Space Technology Enabled Village Resource Centre (VRC) 2007).

Remote sensing has been a space-based technique with numerous benefits to a developing country like India. Equally important, however, has been India's use of telecommunications satellites in space applications. The India National Satellite (INSAT) program is one of the largest telecommunication satellite programs to serve the Asia-Pacific region, with twenty-four satellites launched over nearly three decades (Geo-Stationary Satellites 2008). INSAT provides services for broadcast television, weather and disaster forecasting, as well as emergency response (Geo-Stationary Satellites 2008). INSAT is the primary communications conduit for VRCs, and the program connects over 305 rural hospitals across the country for tele-medicine and 35,000 classrooms for tele-education (Current Programme 2008).

2.1.2 International Cooperation

India's cooperative space activities can be primarily characterized as technology acquisition and transfer programs. Most of these activities have been bilateral arrangements with former Cold War powers like the United States and the Soviet Union. In addition to these bilateral agreements, India has been a member of COPUOS, and has also been an active participant in the Asia-Pacific Regional Space Agency Forum (APRSAF), but not the Chinese-led Asia-Pacific Space Cooperation Organization (APSCO). Further discussion on Indian choices in regional coordinative participation will be included in Part II.

2.1.3 Development Path

Historically, India's progression as a robust, capable nation in space is rooted in a path that first acquired hardware and technology from more advanced spacefaring nations, and then later developed similar hardware indigenously. India's space launch capability can first be traced to its use of French-, British-, Soviet- and American-built sounding rockets for scientific research in the early 1960s (Speier 2007, 193). Several times throughout the decade, Indian researchers visited the United States to study space launch techniques from the National Aeronautics and Space Administration (NASA) (Speier 2007, 193). Finally in 1980, India launched its first indigenously built space launch vehicle, which carried an Indian satellite into Earth orbit (Haté 2008, 1). It should be noted this first launch vehicle closely resembled the American rocket Indian researchers studied in the 1960s (Speier 2007, 194).

India's transformation to a traditional space power is a narrative that is still being written. Indian space ambition continues to grow and become more sophisticated, with a long-term vision of achieving the ultimate symbolic space activity, human spaceflight. ISRO has received government funding to begin a four-year development program to mature specific technologies such as a crew capsule. If these initial steps prove successful, ISRO plans to solicit the government for further funding to conduct test flights to assess environmental conditions necessary for human flight (Morring 2010). Although ISRO has an official vision of developing a human spaceflight program by 2025 (Space Vision India 2025 2008), it is difficult to determine how the program will advance in the near term. Regardless of what ISRO actually achieves in this realm, the institutional declaration of human spaceflight ambition is perhaps the most telling indicator that India has embraced space capability as a geopolitical asset.

2.2 Malaysia

2.2.1 Rationale & Major Activities

Malaysia is a relative newcomer to the spacefaring community. It would be fair to say that Malaysia is interested in utilizing space for its own national development, but in a far more nuanced fashion than the direct application of satellites for aiding national development. Rather, Malaysia has gone after symbolic activities as well as satellite technology demonstration programs that are meant to bolster the country's scientific and technological prowess. Much of the driving inspiration to engage in space activities fell under former Prime Minister Dr. Mahathir bin Mohamad's vision to modernize and expand Malaysia's economy. The prime minister sought a knowledge-based economy for Malaysia by 2020, and the establishment of a space agency was one of the mechanisms devised to realize this goal (D. Wood, Interview with Danielle Wood on Malaysian Space Activities 2011).

Although Malaysia officially formed the National Space Agency in 2002, the country can trace its first activities in space to the 1996 launch of Malaysia's first satellite, Malaysia East Asia Satellite (MEASAT-1). MEASAT-1 was a commercial communications satellite that was developed to provide Malaysia with a greater communications infrastructure. The satellite was followed up with two more launches, MEASAT-2 in 1996 and MEASAT-3 in 2006.

This first utilization of commercial space assets speaks to Malaysia's general interest in space development. The country has not demonstrated a desire for space capabilities to directly aid national development; instead, Malaysia's leadership is motivated by potential economic investment in the fields of science and technology, gained as a byproduct of inspiring spaceflight activities. This motivation is evident in the organizational make-up of the Malaysia Space Agency. One of the agency's four divisions is devoted to education and outreach, which includes the agency's first major program, the National Planetarium (Our Organization 2011).

2.2.2 International Cooperation

Malaysia has embraced international cooperation for space activities in two ways. First, almost all of its first steps in space have involved bilateral cooperation and acquisition from private companies in Europe and Asia. Malaysia's microsatellite design programs were started through international technology transfer programs; its launch vehicle rides were all acquired through international arrangements with launch providers in the United States, Europe, and Russia, and will continue to do so for the foreseeable future. Second, Malaysia maintains membership in COPUOS and APRSAF, but not the Chinese-led APSCO.

2.2.3 Development Path

The MEASAT Program offered Malaysia its first significant steps in space. The country capitalized on this with the establishment of the Malaysia Space Agency, known in Malay as Angkasa. Angkasa is charged with providing national leadership in education and space science research, in order to realize the vision of "harnessing space as a platform for knowledge generation, wealth creation and societal well-being" (National Space Agency, Angkasa 2011).

In carrying out this vision, Angkasa has devised two microsatellite missions to low Earth orbit. In 2000, Angkasa launched the microsatellite, Tiungsat-1, for Earth observation imaging. The mission was a technical trailblazer because its orbital inclination was nearly equatorial, while most imagery satellites maintain much higher inclinations, often neglecting equatorial regions (D. Wood, Interview with Danielle Wood on Malaysian Space Activities 2011). This was done so the satellite could focus its imagery on Malaysia. Tiungsat-1 was developed through a technology exchange between Angkasa and the British microsatellite manufacturer, SSTL (Wade n.d.), then launched aboard a Russian Proton rocket from Baikonur.

In the summer of 2009, Angkasa launched another microsatellite, Razaksat, but called upon the South Korean company Satellite Technology Research Center for its development (Wade n.d.). This satellite was also used for imaging, and was launched at the Kwajalein Atoll by the Space Exploration Technologies (SpaceX) launch vehicle, Falcon 1 (Smith 2009). Malaysia's path of bilateral acquisition at the outset of their program is similar to many other developing nations that have transitioned to capacity building following initial acquisition.

Remarkably, Malaysia has also participated in human spaceflight. In 2007, the first Malaysian in space was sent to the International Space Station aboard a Soyuz spacecraft (Hassan 2006). The Malaysian was sent to orbit as part of the terms of a fighter jet sale with Russia (Mustafa 2007). The Russians paid for the one-time training and transport of the Malaysian passenger and his back-up crewmember (Mustafa 2007). Not surprisingly, this milestone in Malaysian space history was touted highly as a significant event to encourage a greater interest in science and technology within Malaysia (Hassan 2006).

3 <u>South America Region</u>

Space has been a relatively recent phenomenon for South America, taking off through partnerships with established spacefaring actors. Interests in space have been driven primarily by the alignment of science and technology investments with larger national development strategies. Brazil's intentions mirror those of established space powers in terms of scope, with an interest in showcasing the country as a global power. Alternatively, Venezuela's space program focuses on satellite applications to address societal concerns, emphasizing technology transfer and capacity building. Their experiences glean lessons both on how the South American context has shaped space interests and how each country's priorities impact space efforts in important ways.

3.1 Brazil

3.1.1 Rationale & Major Activities

The largest country in South America has "an evident space vocation" (Monserrat Filho 1995) and has long considered space a natural step to pursuing national and international goals. Begun in the 1960s during the military dictatorship (Harding, 2007), the space program was turned over to civilian hands and in 1994 the Brazilian Space Agency (AEB) was formed. It is organized under the National Program of Space Activities (PNAE), which lays out the space strategy in ten-year increments, and is coordinated by AEB with other relevant institutions. The program has undergone three phases of research, training, basic technological development, and is currently in the commercial phase (Castilho Ceballos 1995).

For Brazil, space is a strategic investment to advance such diverse goals as resource management, economic development, and greater international prestige. The 2005 PNAE explains that it serves "to empower the country to develop and use space technology to solve national problems…benefit Brazilian society…[and] improve the quality of life" (AEB 2005, 13). Space activities are also tied to a strategy to increase Brazil's prestige and standing in the world stage, strengthen the country and secure its independence. Both sets of goals have influenced a broad program, emphasizing applications and launch infrastructure development.

Remote sensing continues to be an important priority and a number of programs have grown in this area. The first satellites developed under the Brazilian Complete Space Mission (MECB), established in 1979, were the SCD-1 and 2 (Data Collection Satellites) remote sensing satellites. Their follow-on program is Brazil's most prominent success in space, the China-Brazil Earth Resources Satellites (CBERS) program, officially begun in 1988. Three CBERS multispectral, high-resolutions satellites have been launched from China, with two more under development. The program purportedly "enabled the development of the most accurate and comprehensive system of deforestation monitoring in the world" (Faleiros 2009).

Securing independent access to space has also been a priority for power projection. One expert described the possession of a launch vehicle as "the critical item for the most important demonstration of a nation's power" (Bartels 2010, 149). It has also been important for commercialization, an activity deemed critical to enable a return on investment. Brazil has built two launch facilities, including the Alcântara Launch Center (CLA), the closest launch pad to the equator in the world. A deal for the launch of Ukraine's Cyclone-4 from the CLA shows some progress in commercialization of the launch facility (Henriques da Silva 2005). However, development of the four-stage Satellite Launch Vehicle (VLS-1), started in the 1980s, has seen three failed prototype launch attempts, with the most recent one ending in tragedy. The 2003 accident, which killed 21 technicians at the CLA, resulted from management and funding issues, a discovery that forced renewed government commitment to the program. A revised timetable plans the first satellite launch to low-Earth orbit (LEO) for 2012 (*Agence France-Presse* 2008).

3.1.2 International Cooperation

In addition to its active involvement in multilateral forums, particularly at the UN level, Brazil has considered international space cooperation as necessary to lower costs and expose Brazilians "to the most sophisticated forms of human knowledge" (Henriques da Silva 2005). Cooperation also increases the transparency and legitimacy of the space program as an advanced, stable and peaceful endeavor. These benefits result from cooperation that is "oriented not just by occasional offers, but by answering national needs…not [just] technical assistance, but joint development" (Monserrat-Filho 1997, 153). Sino-Brazilian cooperation, for example, was spurred by a decision to "reduce the constraint of a policy previously based on a preferential alliance with the United States" (Altimani 2005), a policy shift that was prioritized during President Lula da Silva's administration (2003-2010) as "autonomy through diversification" (Vigevani and Cepaluni 2007). CBERS thus contributed to two goals: diversifying relationships with countries of shared foreign policy principles, and favoring initiatives with developing countries (AEB, PNAE 2005). Consistent with the latter aim, the successful program has been lauded as the first South-South high technology cooperative agreement (Zhao 2005).

3.1.3 Development Path

Brazil's space activities have featured projects enabling technology transfer and cost-saving measures, while bolstering efforts to develop advanced indigenous capabilities. These have allowed the country to gain increased independence and prestige, another success in its policies to harness advanced science and technology for its development.

Future success of the program will depend on the resources allocated. While funding has been more stable since 2003, it is still insufficient. National Institute for Space Research's (INPE) director Gilberto Câmara Neto blamed economic and cultural reasons, arguing that only a "massive investment" in science and technology will enable future prosperity, but that "we must show that there is a real return to society" (Câmara Neto 2010, 114, 117). Yet public support is an open question, largely unknown (Monserrat Filho, Remarks on Brazilian space laws 2005). The absence of "a well-defined vision and mission" that is both recognized and supported by the Brazilian society has been described as a "major cause" of difficulties (Rollemberg 2010, 77). The success of Brazil's space program may depend on how it manages these interrelated issues: resource allocation and public support.

3.2 Venezuela

3.2.1 Rationale & Major Activities

Venezuela's investments in space are part of an initiative to harness science, technology and innovation for economic development within the "Bolivarian socialist revolution" project. The symbolic value of space and the indigenous production of advanced technology has become part of the government's ideological initiatives. Former president of the Venezuelan Space Center (CEV) Nuri Orihuela, said the VeneSat-1 program was breaking the "shackles of technological domination," and was the first of many satellite technology "repossession" programs (TeleSUR 2007). Targeting isolated, low-income communities in the country, it enforces a "democratization" of these allegedly elitist technologies (*El Nacional* 2010; MCTI, Satélite Simón Bolivar: Venezuela sigue en lo alto 2011). Interestingly, while steeped in the ideological rhetoric of the leadership, space activities have responded to concrete national needs.

The foundational phase (2005 – 2007) of a twenty-year-long plan enabled the creation of CEV in 2005, which gave way to the Bolivarian Agency for Space Activities (ABAE) in 2007. The ongoing capacity-building phase (2008 – 2013) includes the VeneSat-1 program, discussed below, development of the first Venezuelan-built satellite, as well as regional projects (Lombardi

2007). A future consolidation phase (2013 – 2023) expects the bolstering of regional activities and continued development of satellites to address regional needs.

The VeneSat-1 program began in 2005 with a $400 million contract under which the China Great Wall Corporation designed, built, tested and launched a geostationary telecommunications satellite, and supplied accessory and ground control systems (Huanxin 2005). The "Simón Bolivar" satellite was launched on December 2008 from the Chinese Xinchang launch base (CANTV 2011). The satellite establishes communication links for basic data and telephony, video, internet, tele-medicine and tele-education services (Acevedo et al. 2010). In addition to these social programs, the government has emphasized the training and education of Venezuelans in satellite manufacture and operation, also included in the deal.

Follow-on efforts have focused on two remote sensing initiatives. The first is the Venezuelan Remote Sensing Center (CVPR); begun in 2001, CVPR will be the country's first remote sensing terminal station, capable of receiving transmissions from the Canadian RADARSAT spacecraft and the American TERRA satellites (IGVSB 2007). Once operational, it will contribute to natural resource management with research in areas such as water and energy (CVPR 2005; IGVSB 2010). Establishment of a remote sensing satellite development facility under agreement with China has also made progress (Daniel 2008). It will be based in Borburata de Carabobo in 2012 (*El Nacional* 2010) and the first satellites, likely to be launched from China in 2013, could serve both civilian and military needs (Daniel 2008). ABAE is undertaking a study to identify needs for such capabilities (MCTI 2011).

3.2.2 International cooperation

Since technology transfer and capacity building are critical goals, international space cooperation is a priority for strengthening capabilities and generating new knowledge (Orihuela

Guevara n.d.). Bilateral engagement has been affected by national policies, emphasizing relationships that strengthen national sovereignty, promote a Latin American community and favor cooperation among developing countries. Consequently, Venezuela's most important partners in space are the emerging powers: China, India, Russia and Brazil. China, in particular, is considered Venezuela's principal strategic ally, which is understandable in the framework of VeneSat-1's success. Not only an example of South-South cooperation, Venezuelan leadership has also framed it as a regional integration tool for expanding social programs and fostering regional cooperation (MCTI 2009; Satélite Simón Bolívar: Venezuela sigue en lo alto n.d.). Also in this vein, Venezuela argues for a regional space policy guided by the principle of space as the common heritage of humanity and the adoption of existing international rules (Becerra 2009).

3.2.3 Development Path

Venezuela's young space program has made significant strides. Although space activities respond to clear national needs, such as facilitating access to previously isolated communities, Venezuelan leadership also uses them as a forum to voice the government's socialist development strategy. This helps explain Venezuela's international space activities, particularly its emphasis on non-traditional partners, on which this burgeoning program will continue to rely.

A remaining issue of concern is the question of public support as the government has been criticized for investing sorely limited funds in space. Officials have said that they are following India's model to advance the country's wellbeing (Daniels 2008) and has argued that $100 million would be saved with VeneSat-1 (Ahorro, soberanía, seguridad y autosustentabilidad n.d.). As the program continues growing, the question of public support could increase the leadership's pressure to emphasize the political and ideological impact of the program to justify considerable and long-term investments in space.

PART II: REGIONAL ANALYSIS

1 Africa Analysis

1.1 Development Paths

The space programs of Nigeria and South Africa have similar near-term priorities and long-term goals; both currently focus on addressing greater socio-economic development needs, while also aiming to obtain indigenous capabilities in space technology and its application to promote regional leadership. Their development paths, however, have had notable differences.

To acquire its satellites, Nigeria used partnerships with foreign companies that also included training programs to build up national capacity in satellite manufacturing and operation. This approach—partnering with more advanced space actors to acquire space hardware as well as build up domestic capabilities—is common for emerging space nations (D. Wood 2010). In contrast, South Africa has used small satellite projects to independently build up basic spacecraft manufacturing capacity. The benefit of this approach is the relatively quick establishment of indigenous capabilities, while the drawback is the possession of less advanced systems, at least initially. Indeed, although Nigeria does not have a domestic spacecraft manufacturing industry like South Africa, it has a more diverse portfolio of spacecraft. South Africa has used capacity building in other areas. Most notably, its SAC has for many years provided telemetry, tracking and command services to foreign satellite users and operators, allowing South Africa to gain expertise in these areas even before having its own satellite.

These similarities and differences in development paths could have implications for regional space activities in Africa. Their common strategic goal of regional leadership in space and Nigeria's relationships with foreign aerospace companies could weaken regional cooperation. Yet, Nigeria and South Africa share similar challenges, discussed below, which will likely encourage these two emerging African space powers to continue to work together.

1.2 Regional Coordination Mechanisms

Although African space projects are typically managed by a single African country or involve non-African partners (D. Wood 2008), two purely intra-African initiatives have recently emerged: the African Resources and Environmental Management Satellite Constellation (ARMC) and the African Leadership Conference on Space Science and Technology for Sustainable Development (ALC). Both receive support from the highest levels of government, which is important for the long-term stability of these initiatives and their ability to enhance regional as well as national space capabilities (Martinez 2011).

1.2.1 African Resources and Environmental Management Satellite Constellation

ARMC is a proposed joint program between Nigeria, South Africa, Algeria and Kenya to build four African-made remote sensing microsatellites (one built by each member country), supported by a coherent ground station architecture (Mohammed 2010). ARMC will address the continent's specific geospatial needs, while also building up African space capabilities (Mostert 2008). Although hardware has yet to be developed, ARMC has achieved the all-important task of bringing together the African countries investing the most in space, with top-down support from their highest levels of government, which is critical for program sustainability (D. Wood 2011).

1.2.2 African Leadership Conference

The ALC is a regional forum where African decision-makers and space professionals can exchange information in a non-technical, high-level manner that emphasizes the benefits of space technology to Africa's sustainable development. Interestingly, although ALC was initiated and driven entirely by Africans, it was largely motivated by the emergence of regional space initiatives in the Asia-Pacific and South America (Martinez 2011).

1.3 Shared Challenges

Nigeria and South Africa are joined by shared challenges that span economic, political, geographic and societal arenas. These shared challenges initially had positive effects on the development of African space activities; a key driver of national and regional space initiatives has been the application of satellites to address the common challenges facing developing countries, in particular managing scarce resources and large populations that are dispersed over vast, under-developed areas. However, the ARMC project highlights how these shared challenges also create difficulties. ARMC countries are spread across the continent, creating logistic and linguistic barriers. They are also key political and economic players in their respective sub regions of Africa, making the project liable to derailment by external factors, such as political and economic instability, both of which are not unfamiliar to Africa (D. Wood 2011).

Public sentiment toward investing limited resources into space projects is another shared challenge. Responses to a BBC online debate on whether space activities should be a priority for developing countries indicated that Africans lacked understanding of how satellites aid socio-economic development (BBC 2003). South Africa, however, appears more proactive than Nigeria when promoting space awareness within its public and government. When adding to these shared challenges the budgetary and technical limitations of emerging spacefaring nations, it appears that Nigeria and South Africa will continue to work together through regional space initiatives, even as their national space program advance. Yet, uncertainty exists due to the young nature of national space programs, which still struggle to find consistent political and public support, as well as regional space bodies, which are just beginning to find their footing.

2 <u>Asia-Pacific Analysis</u>

2.1 Development Path

In a broad sense, India and Malaysia have utilized similar means of initiating their first steps into space, as both nations sought the assistance of established space actors for technology transfer. The differences between India and Malaysia's technology transfer programs lies more with the period in which they were conceived. India's development path to space is one of the most successful implementations of space technology transfer between an established and emerging space actor, but also one of the first such arrangements. Malaysia did not actively engage former Cold War actors for its heritage space technology, but instead sought practical, first-step engagements with microsatellite development companies such as SSTL—an approach common among emerging space powers.

2.2 Regional Coordination Mechanisms

Competition between China and India for economic preeminence, as well as traditional rivalry between Japan and China, has served to delineate between countries in the region that work closely with China in space and those that do not. This demarcation is manifested in the formation of two independent regional cooperation mechanisms. APRSAF, formed in 1993 to enhance Asia-Pacific space activities, is based in Tokyo. Although China has since joined APRSAF, China established another regional coordinative body, APSCO, in 2005 from which Japan and India's space agencies are noticeably absent. Evolution toward a single regional mechanism in the near term is highly unlikely due to aforementioned political issues. Therefore, if space sustainability issues are discussed at a regional level, stakeholders should take into account the existence of two regional space bodies in the Asia-Pacific.

2.2.1 Asia Pacific Regional Space Agency Forum

In 1993, APRSAF was established with the leadership of Japan's Ministry of Education, Culture, Sports, Science and Technology (MEXT) and the Japan Aerospace Exploration Agency (JAXA). APRSAF intended to coordinate Asia-Pacific activities in space to leverage the capabilities of its members for purposes that could otherwise not be accomplished individually. The forum produces no legal obligations but meets annually in a rotation among its member states, which include China, India, Japan, and Malaysia (APRSAF 2011).

APRSAF's participant list has swelled to include nations outside the Asia-Pacific region as well as international organizations, (e.g. the United States, Canada, France, and several United Nations offices). Moreover, not all of its participants are representatives of space agencies, as participants come from a number of universities, private companies, and non-space related government offices. APRSAF's membership now stands at over 30 organizations, and is the largest coordinative body for space activities in Asia-Pacific (APRSAF 2011).

2.2.2 Asia Pacific Space Cooperation Organization

In November 1992, a proposal was put forth by China, Pakistan and Thailand at the Asia-Pacific Workshop on Multilateral Cooperation to institutionalize space cooperation in region; interestingly, this conference took place near the same time as the Asia-Pacific International Space Year Conference, during which APRSAF was formed. The proposal led to the signing of a convention formalizing APSCO in 2005, which now includes nine members (APSCO 2010). The membership requirements of APSCO are far more restrictive than those of APRSAF. Unlike APRSAF, APSCO requires that all of its participants have a geographic connection to the Asia-Pacific region and must be member nations, not international organizations such as the United Nations (APSCO 2010).

2.3 Shared Challenges

The issue of Chinese political alignment in the region is perhaps one of the largest shared challenges for the Indian and Malaysian space programs, but for differing reasons. For India, Chinese cooperation with other countries in the region on space activities means continued Chinese expansion into areas that India would like to lead. With the establishment of APSCO, India lost an appreciable point of influence for binding cooperative leadership in space. Additionally, participation from China, the United States, France, Canada, and the United Nations in APRSAF waters down any potential overarching influence India might have had in this well-known Asia-Pacific body. India never asserted a strong sense of leadership in the region on cooperative space issues, and with the rise of the Chinese program, India could be losing out on opportunities to assert itself as a future leader in the region on space activities.

The Chinese program poses challenges for Malaysia in space issues as well, because it may be forced to make an important decision in the near term on which space power to align with in the region. Although Malaysia has participated in APRSAF, this does not constitute any choice between India and China. As the Malaysian program matures and looks to launch larger satellite payloads in the future, it will be interesting to see if Malaysia will utilize launch vehicle services from India, China, or neither of the two.

3 South America Analysis

The development paths of Brazil and Venezuela expose both deep-rooted similarities, explained below as regional geographic features, and differences with respect to the scope and long-term goals of the programs. Through space, Venezuela seeks to advance its regional integration goals, while Brazil—even as it cooperates with others in the region—is focused on satisfying its own interests as an international power. Consequently, Brazil has emphasized cooperation for cost-savings and indigenous build-up benefits and has pursued a more diverse portfolio of international cooperation. Also in contrast with Venezuela, which emphasizes space as a predominantly governmental endeavor, Brazil is interested in commercialization of space activities. Differences in scope are also indicative of Brazil's interest in a broad and diverse program that is able to pursue, for example, scientific missions for the sake of science.

3.1 Shared Challenges

Because space interests do not arise in a vacuum, understanding the experience of actors requires considering the regional challenges that constrain and motivate their decisions. Two elements should be noted: the geographic setting and the shared economic and political heritage.

Considering the geographic setting clarifies the region's emphasis on remote sensing applications. Such large countries must manage vast territories, with all the opportunities and challenges it entails. The ability to observe, protect and manage these environments serves economic, social and political goals. Utilizing space assets for these concrete objectives has been a feature of even the prestige-oriented Brazilian program, due to the economic challenges that characterize this developing region. Notably, Brazil is no exception when it comes to the need to link investments in science and technology "to economic growth, job creation and technological autonomy" (Dos Santos, e-mail message to author, March 28, 2011).

With limited budgets focused on addressing pressing economic and social issues such as providing basic utilities and medical services, countries in the region face sizeable funding constraints. Where space contributes to social programs like tele-medicine, the link between space and development is easily made, but it becomes harder with those initiatives that do not have immediate practical applications. The Brazilian space program exemplifies this tension, with sets of activities aimed at either national or international goals competing for resources.

This issue is tied to the recurring problem of sustaining public support for the space program, particularly when the understanding of this technology is not widely shared. According to Dos Santos (e-mail message to author, March 28, 2011) the difficulty is "convincing…constituents of the direct link between investing in space and public benefit," a task that "has not yet been tackled." The Venezuelan strategy to address this challenge—tying the program with the political imperatives of the Chavez administration—may prove to be a double-edged sword. Such arguments seem to be on stable ground for the time being, and the success of VeneSat-1 has added momentum to follow-on efforts. Yet it forces the question: what would happen if Venezuela faced a failure of similar proportions to the Alcântara 2003 tragedy? Brazil responded by committing itself more fully to the space program, though recent debates over public support and the lack of a compelling vision suggest the problem is far from over.

As a result of this dynamic, the future stability and growth of space activities in the region is still a question. For both Brazil and Venezuela and emerging spacefaring nations at large, the survival and stability of their space programs may be under constant risk. Unless concerted efforts are made for enhanced public and political awareness of the importance of investing in space science and technology for the attainment of national priorities, the recent push toward space in the region may taper out and remain limited to niche pockets of activity. Shared priorities and a growing awareness of considerable funding constraints may continue to feed high-level discussions of innovative cooperative solutions for space activities.

3.2 Regional Coordination Mechanisms

3.2.1 Space Conference of the Americas

Based on an understanding of the considerations outlined above, the Space Conference of the Americas (CEA) was created in the early 1990s by the UN General Assembly to enhance the use of space applications and build up space capabilities in the region. The VIth CEA took place in 2010 in Pachuca, Mexico, and culminated with the Pachuca Declaration, which supports space activities for “[solving] priority problems…of the societies of the countries of the continent.” More importantly, it links the development of coordination mechanisms for “expanding national capabilities, particularly in countries of South America and the Caribbean that are less advanced in the space field” (Pachuca Declaration 19 November 2010).

The CEA has given voice to those stakeholders that seek the creation of a South American and Caribbean space agency. Some experts argue such an agency could enable the better use of scarce resources in the region, while fostering participation by the greatest number of actors, but there are varying levels of support for the project. Venezuela, for example, has spoken up in support, while Brazil, having the most advanced program, has expressed skepticism, revealing questions over the credence and risk of such a commitment.

Without the backing of the more advanced countries in the region, a regional space agency could prove ineffective. The continued development of the individual space programs may be a prerequisite for coordination efforts to take hold as the stark asymmetry between actors becomes more balanced and the risk of the venture is better distributed. At that point, as commitment to space becomes more tangible in the region, a Latin America and Caribbean space agency may help bolster activities on a regional scale. With national programs on stable ground, a regional space agency would be yet another indicator that space has arrived to stay.

PART III: CASE STUDY ON THE EU CODE OF CONDUCT

This section serves as an exercise in applying the analysis from this paper to an existing mechanism for addressing space sustainability issues: the European Union's draft *Code of Conduct for Outer Space Activities*. The Code outlines acceptable behavior in space, recognizing that the environment's growing use creates security and sustainability concerns that necessitate the establishment of certain 'rules of the road.' The Code also includes consultation mechanisms to enhance transparency and information exchange; it has no enforcement or verification mechanisms, consistent with its purpose to preserve the space environment rather than restrict it.

Although the Code has European origins, its content largely reaffirms existing legal frameworks, declarations and principles for space activities that have already been widely vetted by the international space community. The Code also serves as a basis for consultations with third parties, and invites other nations and space-related organizations to adhere to its contents.

As both South African and Nigerian space programs focus on addressing socio-economic development needs, their attention to space sustainability issues remains limited. Nonetheless, South Africans have actively participated in space sustainability discussions at the international level, for example by chairing the COPUOS working group on the topic. Nigerians attend international space forums that feature discussions on space sustainability, such as recent IAC meetings, indicating that they are staying informed. For the foreseeable future, however, actively addressing space sustainability on national or regional levels will likely take a second seat to the socio-economic development priorities that remain the primary focus of African space programs.

India's interest in space for soft power purposes suggests a willingness to address space sustainability issues, as major space powers are expected to confront such matters. India has already acknowledged the space debris issue, stating that any anti-satellite weapon it constructs will not create fragments in Earth orbit (India has anti-satellite capability: Saraswat 2011). The rationale for Malaysia's space program, along with its engagement in regional and international space organizations, suggests it would also consider the Code. China's stance on the Code may influence its adoption by other space powers in the Asia-Pacific, such as India, though less politically-influenced countries like Malaysia may pay little regard to China's stance.

Brazil and Venezuela have strikingly similar attitudes toward space sustainability issues, with specific concerns over underlying principles and appropriate forums. Both countries have made statements indicating a keen understanding of space sustainability, with one important Brazilian scholar describing it as those steps that allow human space activities to develop in a way that is "not wild, not destructive, not uncontrolled, but orderly, studied, calculated, rational, predictable, preserving natural resources so that these can be used both by those who live today as the future generations" (Monserrat Filho 2009). Attitudes toward these issues also suggest that they would see the voluntary Code as only a first step toward the development of a binding treaty for consideration within COPUOS. Although these similar views may facilitate interaction with South America on further development of the Code, their concerns appear to conflict with those of established space actors and could thus create lasting challenges.

Although these views on the EU *Code of Conduct for Outer Space Activities* appear to vary in their specifics, emerging spacefaring nations seem generally receptive and supportive of the Code. This is encouraging; a primary benefit of the Code is its role as a 'rules of the road' guide for emerging spacefaring nations that are just learning to operate in space. Indeed, by providing consultation mechanisms, rather than enforcement mechanisms, the Code serves as a constructive context through which more established spacefaring nations can help educate these "new drivers on the road" without appearing overbearing (Pace 2011).

PART IV: THE UNITED STATES & EMERGING SPACE NATIONS

An interesting theme emerging from this research was the nature and extent of U.S. cooperation with emerging space nations. The United States has limited its bilateral partnerships with the actors under study, focusing primarily on projects that avoid technology transfer due to U.S. national security concerns. This is in stark contrast to other established space nations, including China and the United Kingdom, which have actively engaged in programs specifically designed to transfer space technologies to emerging space nations.

Technology transfer programs have been an important feature of nascent space programs. Each of the six nations examined in this study used some form of technology transfer program to aid the development of their space capabilities, often serving as the foundation for follow-on efforts.

These programs take a variety of different forms, most notably government-to-government bilateral agreements and commercial contracting. For example, Indian engineers worked with the United States and the Soviet Union during the 1960s to enable its indigenous launch vehicle and satellite capabilities. Malaysia and Nigeria have each partnered with Surrey Satellite Technology to develop their first civil satellites, while Nigeria and Venezuela procured their first communications satellites through the China Great Wall Corporation. Such commercial contracts often include extensive training for local scientists and engineers in areas such as satellite manufacturing and operations.

With the growing proliferation of space capabilities in the post-Cold War era, emerging space actors now have a variety of partnership choices when developing their nascent space capabilities. While China's participation in such partnerships is increasingly clear, the United States has had few technology transfer programs with emerging space nations in the last decade.

In trying to pinpoint the reasons for this vacuum, certain U.S. policies, such as current export controls, discourage, if not outright prevent, U.S. participation in technology transfer programs that have been a hallmark of the development of emerging space actors. The U.S.-Brazilian space relationship, for example, was soured when Brazil demonstrated intentions to develop indigenous launch capability; motivated by nuclear proliferation concerns, the United States put pressure to prevent the initiative. While scientific cooperative activities still continue, the United States has stepped back as a major partner of Brazil's emerging space program.

While these U.S. policies aim to prevent the transfer of sensitive, potentially dual-use space technologies, they also preclude a valuable avenue for the United States to relay space sustainability norms to the increasing number of actors that are just learning to operate in the space environment. Indeed, technology transfer programs do far more than simply move hardware across borders; they also export mature spacecraft design, manufacturing and operational approaches. For instance, in the aftermath of the 2003 Alcântara launch center disaster, Russian experts pinpointed safety at the launch pad as a main concern and have since cooperated with Brazil to bring the facilities up to standard.

Proliferation of best practices and responsible behavior in space can be made possible through these technology transfer programs. By playing a comparatively smaller role in such activities while other countries move forward, the United States is missing a significant opportunity to advance space sustainability in a manner consistent with U.S. policies.

CONCLUSION

As space sustainability issues are relevant to all space actors, their promotion should be addressed on an international level. Part of this requires forging an understanding of the rationale and development paths of all space actors, in particular emerging ones. After analyzing three regions of emerging space activities, this paper has shown that opportunities and challenges exist in engaging these actors for the purposes of promoting space sustainability.

Important similarities have been demonstrated across all three examined regions that provide opportunities for space sustainability advancement. A prime example is the shared need for remote sensing satellites, regardless of any differences in the rationales or development paths of their space programs; these countries now recognize the value of remote sensing satellites to national development, and thus understand the negative repercussions that would occur if these capabilities were lost. For example, a space debris impact resulting in the destruction of an emerging space nation's remote sensing satellite would be a serious setback to development efforts, particularly because these countries often have only one remote sensing satellite and lack the resources to launch a replacement in the near term.

Another important similarity is the persistent reliance on international partnerships. In this diverse environment, cooperation assumes a different form from the Cold-War era, because there are more opportunities for interaction. This provides emerging actors with added freedom to choose from a variety of partners to advance their space programs. Such diversity opens avenues of potential risk, but also creates opportunities for integration between emerging and established actors, particularly in space sustainability discussions. Space activities are no longer isolated; developments in Africa, Latin America or Asia-Pacific are not limited to these emerging regions, but result from complex interactions taking place all over the world.

These emerging actors also share common challenges that threaten their young space programs, such as lack of public awareness and questionable long-term political support. These shared challenges make the space activities of emerging space nations particularly vulnerable to funding cutbacks or cancellations. The need to stay on track in order to avoid exacerbating these risks could drive compliance on space sustainability issues, even in the absence of more traditional mechanisms for enforcement (e.g., binding laws and market forces).

Differences among these emerging space nations equally inform discussions on space sustainability. These countries feature a variety of motivating rationales for participating in space activities, as well as differing technical capabilities, even within each region. These differences must be taken into account when engaging emerging space nations in space sustainability discussions, as they will dictate the specific issues most relevant to their space programs.

Lastly, regional dynamics could also have significant potential to affect space sustainability. The regional space coordination mechanisms examined in this paper illustrate varying degrees of political alignments and operational philosophies: South America has no region-wide space organization, while the Asia-Pacific remains divided between two established entities; Africa is just starting several initiatives in a coherent manner with high-level government support. Unstable political, economic and social environments within these regions also pose challenges to the survival of younger space programs, as well as their ability to take on space sustainability actions. Nonetheless, the universal recognition among all six countries that space is important for national development helps to promote space sustainability. All of these considerations must be taken into account in the promotion of space sustainability measures, in order to ensure the continued and expanded use of a limited resource upon which more actors are becoming increasingly dependent.

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