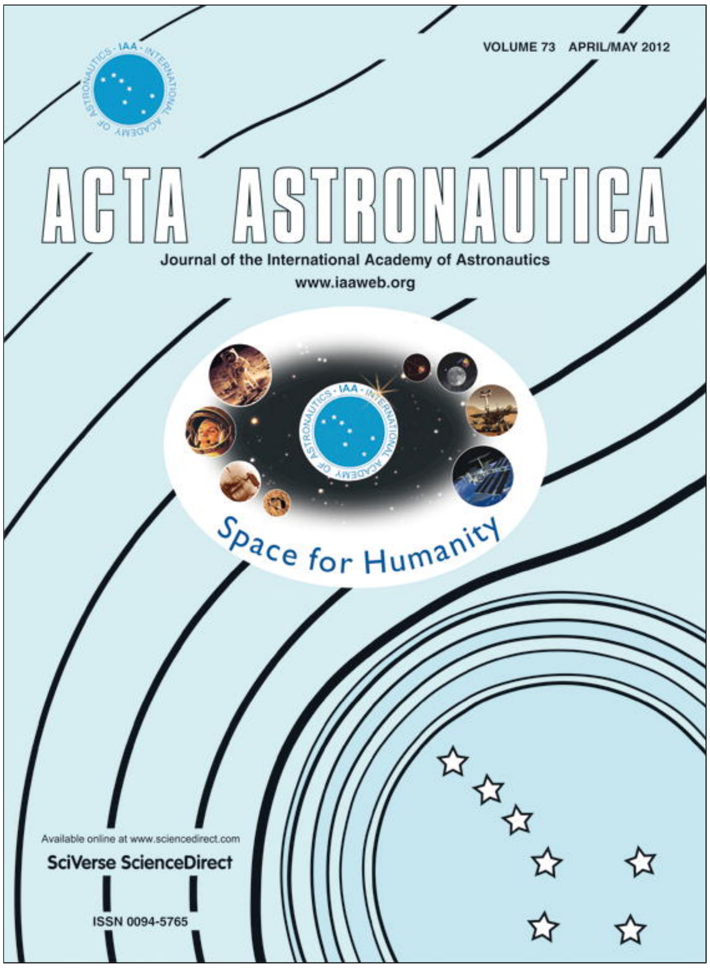
VOLUME 73 APRIL/MAY 2012
ACTA ASTRONAUTICA
Journal of the International Academy of Astronautics
www.iaaweb.org
Space for Humanity
Available online at www.sciencedirect.com
SciVerse ScienceDirect
ISSN 0094-5765

Acta Astronautica 73 (2012) 221–236

Contents lists available at SciVerse ScienceDirect

Acta Astronautica

journal homepage: www.elsevier.com/locate/actaastro

A framework for evaluating national space activity

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ARTICLE INFO

Article history:
Received 21 July 2011
Received in revised form
20 October 2011
Accepted 19 November 2011
Available online 15 December 2011

Keywords:
National space activity
Analytical framework

ABSTRACT

Space technology and resources are used around the world to address societal challenges. Space provides valuable satellite services, unique scientific discoveries, surprising technology applications and new economic opportunities. Many developing countries formally recognize the advantages of space resources and pursue national level activity to harness them. There is limited data or documentation on the space activities of developing countries. Meanwhile, traditional approaches to summarize national space activity do not necessarily capture the types of activity that developing countries pursue in space. This is especially true if they do not have a formal national space program or office. Developing countries pursue national space activity through activities of many types—from national satellite programs to commercial use of satellite services to involvement with international space institutions. This research aims to understand and analyze these trends. This paper introduces two analytical frameworks for evaluating space activity at the national level. The frameworks are specifically designed to capture the activity of countries that have traditionally been less involved in space. They take a broad view of space related activity across multiple societal sectors and disciplines. The discussion explains the approach for using the frameworks as well as illustrative examples of how they can be applied as part of a research process. The first framework is called the Mission and Management Ladders. This framework considers specific space projects within countries and ranks them on "Ladders" that measure technical challenge and managerial autonomy. This first method is at a micro level of analysis. The second framework is called the Space Participation Metric (SPM). The SPM can be used to assign a Space Participation score to countries based on their involvement in various space related activities. This second method uses a macro level of analysis. The authors developed both frameworks as part of a long term research program about the space activities of developing countries. This aspect of the research focuses on harnessing multiple techniques to summarize complex, multi-disciplinary information about global space activity.

1. Introduction

This paper introduces two analytical frameworks for describing national space activity. Both frameworks use qualitative and quantitative approaches to summarize data about space activity, with particular emphasis on the experience of developing countries. The analysis is part of a broader research program by the authors that focuses on understanding and contributing to space activity in developing countries. This research program builds on the authors' training in space technology, policy analysis and social science research. The paper describes the team's approach to summarize and compare national

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doi:10.1016/j.actaastro.2011.11.013

space activity. It includes several illustrative examples of how the frameworks can be applied. The frameworks are one facet of a long term research effort that includes multiple methods for data collection and analysis, such as technical analysis, field interviews and site visits.

It is valuable to analyze space activity among developing countries because space resources have high relevance to national needs in every part of the world. Despite this relevance, space activity among developing countries is poorly documented and publicized. Space technology provides services and opportunities that bring new infrastructure, information and inspiration to citizens around the world. There are five dimensions of space activity that contribute to challenges faced by developing countries. The first dimension is satellite services. In particular satellite communication, remote sensing and navigation systems enable many valuable services in developing countries. Through satellite-based communication there is greater access to telephone, radio, television and internet connections. These media can improvement access to education, health care and government services for underserved or remote populations. Satellite remote sensing can support a disaster management system by providing timely information about dangers such as volcanic eruptions, hurricanes, fires, and famine. Such information can save lives and property. Beyond disaster situations, satellite remote sensing is a valuable tool to promote land management and urban planning. Satellite navigation is useful for facilitating aviation management, precision agriculture and demographic data collection for governments and businesses. The use of satellite-enabled services in developing countries is ubiquitous [1]. Beyond applying satellite services, a second dimension of space activity that contributes to development challenges is in the area of building technological capability. National governments in Africa, Asia, Latin America and the Middle East are currently investing in domestic capability to design, manufacture and operate satellites. They see the process as a strategic to enhancing their national level of technical sophistication while reducing dependence on foreign technical expertise. A third dimension through which space contributes in developing countries is enabling new economic activity. In countries such as Korea, Malaysia and South Africa, domestic satellite programs have led to the formation of new space companies. Fourth, space contributes to development challenges by inspiring new technology applications. There are multiple examples of innovative technical solutions to social challenges, which originated in space research. Research by NASA to investigate food production and water purification for human spaceflight has led to terrestrial products that are being deployed commercial to increase crop yield, maintain food freshness and clean water [2]. Finally, the fifth dimension through which space activity contributes to challenges in developing countries is in the area of building scientific knowledge. By venturing into space, the global community has made immense scientific discoveries. New players in space can achieve local scientific progress with their own space activities. Even with limited resources, it is possible to access and analyze space science data collected on satellite platforms. There are valuable measurements that can be taken using terrestrial sensors that provide insights about the relationship between the earth and sun. Human spaceflight and suborbital operations open the opportunity for scientists all over the world to engage in microgravity research.

Due to the benefits of these five dimensions of space resources, there is an international community of organizations that promote space activity in developing countries, including multilateral organizations such as the United Nations Office of Outer Space Affairs. There is also increasing investment by governments in developing countries to enable national space programs. For example, African countries such as Nigeria, Algeria and South Africa have formal space agencies. Other countries such as Kenya, Egypt and Morocco have national offices that implement space-related projects. Small satellite technology – in particular that based on the CubeSat standard – has also led to an increase in space projects outside the context of formal government programs around the world. There is little systematic research that uses analytical methods to explore the trends in space activity among developing countries. The authors are pursuing a multi-faceted research program that blends approaches from engineering and social science. The goal is to increase understanding of the challenges and opportunities facing emerging space actors in the developing world. This paper emphasizes the aspects of the research that summarize space activity in developing countries using original, analytical frameworks.

In the traditional space community, dominated by the United States, Europe and a few countries in Asia, narrowly defined metrics are used to compare countries based on their national space activity. These metrics tend to be most relevant to countries that are advanced in space technology. Commonly used figures include the number of satellites launched in a country's name, the number of space-related facilities, or the budget of a country's government space agency. Fig. 1 provides visual evidence of the narrow geographical coverage of traditional metrics for national space activity. It shows which countries have reported the launch of at least one satellite in their name to the United Nations [3]. Note that informing the United Nations of a satellite launch is voluntary, thus this list reflects only those countries that have chosen to register their launches. The metric, therefore, does not include all states for which satellites have been launched. The metric is weak because it only shows one dimension of space activity. There are only thirty-one countries shown in this map, out of 195 sovereign countries in the world. The map leads to binary grouping of countries as either registering or not registering a national satellite. Many of the countries that have not registered satellites, however, still have substantial national space activity, which is not captured by such a metric. Thus, the number of satellites launched by a country is not a useful way to compare the national space activities of all the countries in the world. The same conclusion can be drawn from a similar map of the world showing which countries have national space agencies at a particular point in time (see Fig. 8 in Appendix A [19]). A multidimensional measurement of national space

Fig. 1. On this figure, countries that have reported the launch of a national satellite are shaded darkly. (Based on the United Nations Registry of Space Objects, 2009.)

activity is needed to have more complete geographical coverage and to capture non-traditional aspects of space activity.

Several organizations have recognized the need for multi-faceted reports of national space activity with broad geographical coverage. Three examples are reports produced by the Space Foundation, Euroconsult and Futron Corporation. The Space Foundation is a US-based non-profit organization that promotes the benefits of space technology and works to increase awareness about space. Their annual *Space Report* summarizes global space activity along several dimensions, including spending by commercial and government entities on space infrastructure and services [4]. One facet of the report collects information on the budgets of national governments on domestic space programs. The *Space Report* divides this information into two categories. More established space players are highlighted together; in 2011 these include the United States, the European Space Agency, Brazil, Canada, China, France, Germany, India, Israel, Italy, Japan, Russia, South Korea, Spain and the United Kingdom. The report also provides budgetary data for a category they call emerging space countries. In 2011 these include Argentina, Australia, Chile, Indonesia, Malaysia, Mexico, Nigeria, Pakistan, South Africa, Taiwan, Thailand, and Turkey. A second example of attempts to summarize national space activity is the report called *Profiles of Government Space Programs* [5]. It is published by Euroconsult, a for-profit consulting and analysis firm that specializes in space, communication and digital broadcasting. The Euroconsult report for 2011 identifies 60 government space organizations from around the globe and creates profiles that combine quantitative and qualitative information. The report describes each program in terms of economic metrics, organizational descriptions, policy indicators and space activities. The Euroconsult report covers every region; their geographic breakdown includes North America; Latin America; Europe; Russia and Central Asia; the Middle East and Africa; and other Asian countries. A third example of analysis on global space activity is the Space Competitiveness Index (SCI) produced by Futron, a for-profit space consulting firm. The SCI evaluates ten space programs from countries that Futron identifies as leading space participants. The ten programs represent Brazil, Canada, China, Europe, India, Israel, Japan, Russia, South Korea and the United States. For each of the ten programs, the SCI considers 60 quantitative metrics that describe the space activity in terms of three dimensions—namely government, human capital and industry [6].

The reports described above each pursue a specific analysis strategy that aligns with their audience and intended impact. For example, all three reports are particularly effective at describing space activity in countries that have formally defined national or multinational space authorities. These reports also focus primarily on the activity of countries that are more established in space; although effort is made to consider the activities of emerging space players. The authors distinguish the original frameworks presented in this paper from the work described above in three ways. First, the authors' analytical frameworks are specifically designed to capture and summarize space activity for countries from developing regions that have not traditionally been actively involved with space. Second, the national space activity considered by these frameworks includes both formal national space programs as well as other facets of national activity. Thus, countries that have no national space program or office can be readily included and the frameworks have the potential for global coverage. Third, the approaches presented in this paper are not meant to stand alone as quantitative outputs. They are tools that rest on a foundation of multi-method research that draws heavily on social science approaches. The frameworks presented here seek to harness extensive information about complex realities and enable meaningful reflection.

This paper introduces two analytical frameworks for evaluating space activity at the national level. The discussion explains the structure and steps for using the frameworks. There are several examples to demonstrates how the frameworks can be applied to support a broader research program. The first framework is called the Mission and Management

Ladders. This tool considers specific space projects within countries and ranks them on "Ladders" that measure technical or mission-oriented challenge and managerial accomplishment. This first method is at a micro level of analysis; it is most useful for comparisons of countries within a region. The second framework is called the Space Participation Metric (SPM). This analytical approach can be used to assign a Space Participation score to countries based on their involvement in various space related activities. This second method uses a macro level of analysis; it is useful for comparing countries at a global scale. Both frameworks provide a systematic way to compare countries based on their space capabilities and achievements. The authors apply these methods in the context of on-going, multi-method research about the implications of space activity in developing countries. Through this synthetic approach, the insights from the frameworks are effectively interpreted. These methods were initially developed in previous research by the authors [7].

2. Introducing the Mission and Management Ladders

The Mission and Management Ladders are scales created to compare the technical or managerial accomplishments of space activities within countries. The Ladders build on detailed case studies about specific space projects within countries. The Ladders synthesize information from these case studies; they organize qualitative descriptions of case study projects into an analytical summary via three steps. The first step collects examples of space projects to serve as case studies. The second step ranks projects at the appropriate levels within Ladders. The third step summarizes the performance of specific countries in the case study projects. The following section describes the three steps through which the authors analyze country performance using the Mission and Management Ladders. The Ladders provide a generic template that can be reused for diverse analyses. In the next section, several examples are shown in which the framework is applied to countries in Africa. As mentioned above, the first step in using the Ladder framework is to develop a database of representative examples of space-related projects for a given set of countries. In order to be more complete, the approach limits the number of countries under consideration. For example, one analysis may focus on a specific region, such as Africa or Asia. Another strategy might be to choose to compare a set of countries from different regions. A large number of case studies is required in order to achieve a representative sample of the space activities in a country. The number of case studies should be even greater for countries that are more involved with space. Determining when an adequate number of case studies has been reached requires analytical judgment and sensitivity to data saturation. The number of case studies should be high enough to provide examples from all the geographic regions under consideration and draw case data from a variety of sources. In order to provide scope and focus, the authors limit the case studies according to various parameters. For example, case studies may be chosen from a particular time period, from a specific type of space-based technology, or from a particular technology user community. Once the case studies are identified, information about the organizations involved in the projects, the sources of technology and funding as well as the technical implementation of the project are collected. At a minimum, the authors seek to answer the following questions for each space related project or activity: (1) what countries participated in the activity? (2) what organizations within the countries participated? (3) what roles did each participant play? (4) what space-related technology enabled the activity? (5) how was the technology procured? and, (6) what are the sources of funding for the activity? The framework is flexible; it can incorporate other types of information as required. Information to answer these questions may come from books, organizational websites, conference and journal articles, and interviews with project participants, news reports and international meeting reports.

Once the information is gathered to answer these questions, the framework proceeds to the second step. This step ranks the space-related activities on the appropriate level of the various Ladders. There are two major types of Ladders—Mission and Management. "Mission" refers to technology; the Mission Ladders rank projects according to their technical level. "Management" refers to authority and funding; the Management Ladders show the relationships among participants in the projects. In essence, the Mission Ladders show the "What," whereas the Management Ladders describe the "Who." The levels within the Ladders are defined based on the current analysis strategy. For example, the Mission Ladder may rank projects according to technical complexity, scale or maturity. The Management Ladders rank projects according the level of autonomy demonstrated by a country or a group of countries. Within the Mission and Management Ladders, it is possible to specify sub-categories of Ladders that represent different aspects of the project. Management may be broken down to include political authority, technical authority, financial authority or authority over human resources. By breaking the Management Ladder down into these sub-Ladders, different aspects of the projects are emphasized. Step two defines the levels for each ladder and places projects on the appropriate level. This is an iterative process, because levels are defined inductively from the examples in the data. At the end of step two, the various Mission and Management Ladders provide aggregated summaries for all the countries about the distribution of projects with certain profiles. The third step for the Ladder Framework is to summarize the performance of specific countries or groups of countries. One way to summarize is to show the rankings for all the projects in which a given country participates. Another method is to summarize the number of projects in which a country ranks at a relatively high or low level on various Ladders. Step three is also very flexible and can be adapted to answer questions posed by a research customer.

3. Applying the Mission and Management Ladders to Africa

The following section shows how the Mission and Management Ladders are applied to an analysis of satellite-based activities in all African countries.

3.1. Step One: building the database of case studies

This example builds on satellite project case studies—seventy-nine summaries of programs and projects that utilize satellite-based technology in Africa. The case studies are limited to examples from Africa in order to provide scope, but this is appropriate given the diversity among countries in Africa. Each case study involves an operational project using satellite remote sensing, communication or navigation; some case studies use multiple types of satellite services. Data are collected for the satellite project case studies from many sources, including conference proceedings, news articles, journal articles, and organizational websites. The data collection process also includes attending relevant international meetings as well as speaking with experts and practitioners in the field. For each case, a maximum of 19 questions is considered about the technical accomplishments (Mission) and managerial structure (Management) of the project. Approximately one half of the projects use remote sensing technology. Common project goals in this area are water resource management, natural resource management, and food security. In about one third of the project, the main service is satellite communication. Here internet, distance education, radio and television stand out as common uses of satellite services. Almost 20% of the projects involve satellite navigation. This technology is used to collect data for the national census or to support construction and surveying work. The African satellite project case studies provide a rich collection of examples showing how space technology is usefully applied in a developing context. Within the case studies are examples of Africans designing and operating satellites as well as Africans working alongside external partners to apply satellite data to address problems. The case studies are highly detailed. Although the case study process is not completely exhaustive, the data set provides factual examples of space activities in Africa. The large number of case studies provides a representative account of how satellites are used in Africa by including every country several times among the projects and by covering a spectrum of project approaches. The multiple sources of data and insights from practitioners help to ensure the relevance of the data set and to avoid major omissions.

3.2. Step Two: ranking projects on the Mission and Management Ladders

The Mission and Management Ladders are designed in this example to aid in evaluating and comparing the technical capabilities of African countries in the area of satellites. The levels of the Mission Ladder are defined based on the types of technology used in the various projects. Each of the projects is enabled by satellite technology, but to different extents. Whereas some projects involve working directly with the satellite, other projects only interact with the satellite indirectly through services or data. The projects are ranked on the Mission Ladders according to their relationship to the satellite that enabled the project. Fig. 2 above shows a notional chain of activities that are part of a generic satellite project.

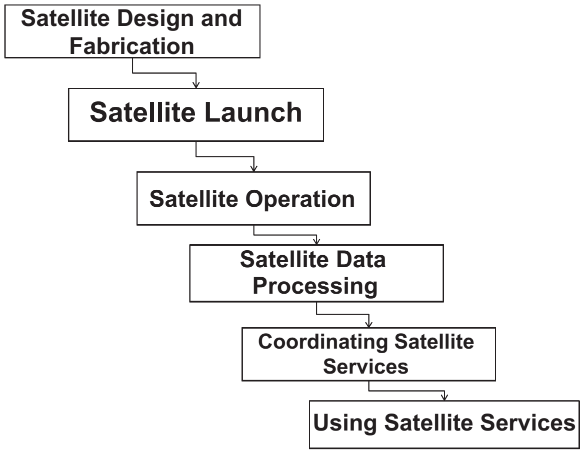

Fig. 2. A Notional Satellite value chain.

Organizations can enter the chain at any of the stages, without having the expertise or resources to participate in higher stages. This chain is the basis for the levels chosen in the Mission Ladders. The specific levels are only included if they occurred in one or more of the African satellite projects.

Two Mission Ladders are used in this example. One shows the technical level for the overall project; this is called the Project Technology Ladder. The second Mission Ladder shows the technical level for the contribution from the African country. This is called the Country Technology Ladder. In some projects, the ranking for the two Ladders is the same. When they are different, the disparity provides valuable information about African technical capabilities. Table 1 below shows the number of projects ranked on each level of the Mission Ladders.

In the case of African satellite projects, the Management Ladder also plays a role in exploring the capability of African countries in the area of satellites. Simply knowing what was done in the project is not enough; it is also important to know who was involved. Many of the African satellite projects are collaborations between African countries and non-African companies or countries. Thus, the roles played by the individual partners are an important aspect of the information contained in the case studies. In this example, the Management Ladder is broken down into three aspects of project authority, as follows: Leadership, Expertise and Financial. In some projects, these management roles are divided among two or three project participants. The key question explored by the Management Ladders is the level of autonomy for African countries in these various areas. The levels of the Management Ladders are chosen to show how projects differ in terms of the geographic source of authority; authority can come from outside Africa, from collaboration between Africans and external partners, from a group of African countries or from one African country.

Table 2 summarizes the Management Ladder levels and projects. They show, for example, that a majority of projects are led by either a single African entity or an external partner. The results of Step Two provide a regional summary of African accomplishments within the case study projects in the area of satellite technology. Step Three considers individual country performance.

Table 1
The Mission Ladders.

Level	Description	Project technology ladder # of projects	Country technology ladder # of projects
A	design, build, operate satellite	**11**	**4**
B	Buy and operate satellite; train in satellite production	**–**	**7**
C	Buy or lease and operate satellite	**9**	**9**
D	Operate others' satellites	**1**	**1**
E	Lease satellite capacity; deliver service	**5**	**5**
F	Operate ground segment; send or receive data	**22**	**22**
G	Process satellite data; create data products	**27**	**11**
H	Use satellite data products	**–**	**16**
I	Participate in regulatory action	**4**	**4**
Total		**79**	**79**

Table 2
The Management Ladders.

Level	Description	Leadership ladder # of projects	Finance ladder # of projects	Expertise ladder # of projects
A	Single African country or organization	**34**	**32**	**19**
B	Non-regional group of African countries or organizations	**1**	**1**	**0**
C	Regional group of African countries or organizations	**4**	**3**	**3**
D	External collaboration, effort from Africa	**2**	**0**	**5**
E	External collaboration, effort from African and external partners	**3**	**14**	**22**
F	External collaboration, effort from external partner	**34**	**28**	**29**
Total		**78**	**78**	**78**

3.3. Step Three: summarizing country performance

Table 3 shows an example of a summary report for one country's performance on the Country Technology Ladder. The results are for Algeria, and the numbers in the far right column show the number of projects for this country at each level of the Ladder. In order to facilitate the summary, the levels of the Country Technology Ladder are divided into projects related to "Satellite Hardware" and "Satellite Services". Satellite hardware projects involve direct access to a spacecraft, while satellite service projects are indirectly enabled by a satellite. Algeria's total performance can be described in three numbers. Out of the seventy-nine case study project, this country participated in a total of eleven projects. Of the eleven, six were satellite hardware projects and five were satellite service projects. Similar summaries can be prepared for all African countries and for each Ladder.

Table 3
Step Three is summarizing a country's performance.

Country technology ladder		
Level	**Activity**	**Algeria's results**
Satellite hardware		
A	Design, build, operate satellite	**1**
B	Buy and operate satellite; train in sat design	**2**
C	Buy/lease and operate satellite	**2**
D	Operate others' satellites	**0**
Satellite services		
E	Lease satellite capacity and distribute service	**0**
F	Operate ground segment to send or receive satellite data	**1**
G	Process satellite data and create data products	**1**
H	Use satellite data products	**1**
I	Participate in regulatory action regarding satellites	**2**
Total projects		**11**
Total Satellite Hardware Projects		**6**
Total Satellite Service Projects		**5**

As Table 3 shows, Algeria pursues activity that harnesses both satellite services and domestic satellites [8]. Algeria's first national satellite project is shown within Level B, which encompasses satellite procurement with training. The Algerian space agency – Agence Spatiale Algerienne (ASAL) – partnered with Surrey Satellite Technology Ltd (SSTL) of the United Kingdom for the AlgeriaSat-1 project. Algerian engineers went to the United Kingdom and trained under SSTL engineers during the satellite development. AlgeriaSat-1 launched in 2002 on a remote sensing mission. ASAL pursued a second project at Level B starting in 2006. Algeria contracted with the firm EADS Astrium for the ALSAT-2A and 2B missions. The two satellites are identical remote sensing spacecraft. One was built by Astrium and launched in 2010. ASAL plans to build ALSAT-2B in local facilities in Algeria. That accomplishment will bring them to Level A in Table 3. The two projects at Level C refer to international collaborations in which Algeria participates. One is the RASCOM pan-African communication satellite, which involves over forty

African countries procuring a satellite from Thales Alenia Space of Europe [9]. The first RASCOM satellite was launched in 2007. After a failure limited its lifetime, it was replaced in 2010. The second project at Level C is the African Resource Management Satellite (ARMS) Constellation. In 2009, Algeria, South Africa, Nigeria, and Kenya signed an agreement to work together to implement ARMS as an earth observation constellation focused on African environmental monitoring. Each country agreed to help develop the constellation and to share data among the team [10]. Table 3 provides a stylized summary of these complex stories of Algeria's satellite projects, with emphasis on difference in technical complexity of the activities. The corresponding Management Ladder would emphasize Algeria's level of autonomy. Table 3 also gives limited examples of Algeria's activity to harness satellite services from foreign satellites. This summary of Algeria's space activities has several characteristics and limitations. It is defined to emphasize the national activity related to satellites and related services. It provides a more complete description of the national satellite projects than the national use of satellite services. This is due to the nature of the data collection process. This type of result points to further research that can uncover additional activity at Levels E through I in Table 3.

The Mission and Management Ladders can also be adapted to explore trends across groups of countries in a region. Fig. 3 shows an example that builds on the same database of seventy-nine case studies used to make Tables 1–3. In this case, the focus is on African countries in the equatorial region. Equatorial countries have several unique geographical opportunities related to space activity. First, the equator provides a preferred location to host facilities for launch and vehicle tracking to the geostationary orbit. Secondly, the interaction between the sun and the earth's magnetic field needs to be observed more from equatorial regions to further global understanding of space weather. In recognition of the potential for equatorial countries to play a unique role in space activity, the International Academy of Astronautics held a 2010 symposium in Abuja, Nigeria that discussed these topics [11]. As a contribution to this on-going discussion, Fig. 3 provides an illustrative analysis of the space-related activity of equatorial African countries. The categories of activities are slightly adapted from those used in Tables 1–3, but the concept is similar. For this analysis, equatorial African countries are defined as those, which are centered between 15° South and 15° North by latitude, according to CIA World Factbook [12]. Thirty-four of the fifty-four African countries are equatorial according to this definition. The equatorial African countries include the following (listed from south to north): Zambia, Malawi, Angola, Comoros, Democratic Republic of the Congo, Tanzania, Seychelles, Burundi, Rwanda, Gabon, Gambia, Republic of Congo, Kenya, Sao Tome and Principe, Uganda, Equatorial Guinea, Cameroon, Central African Republic, Cote d'Ivoire, Ethiopia, Ghana, Togo, South Sudan, Sierra Leone, Benin, Nigeria, Guinea, Djibouti, Guinea-Bissau, Burkina Faso, Senegal, Chad, Eritrea, and Sudan. The figure shows the number of satellite enabled activities pursued by countries from this list. For this presentation, the activities of each country are counted and summed. Thus, if a particular activity involves multiple countries, it will be shown multiple times. The graph thus gives information about activity weighted by level of participation. This initial step shows the predominance of activity on the left side of the graph—which focuses on satellite services. The underlying data for this graph revealed 6 countries that stood out as having high levels of participation compared to their neighbors. Each of these 6 countries was credited with more than ten activities across all five categories in Fig. 3. The high participation equatorial countries in East Africa are Tanzania, Kenya and Uganda. In West Africa the most active equatorial countries are Ghana, Nigeria, and Senegal. While the numbers of activities shown for each country are not absolute, the relative participation of the countries provides a valuable input for further research into space activity among equatorial African countries.

A third example of applying the Mission and Management Ladders is shown in Table 4. Here the framework is adapted to explore the activities of specific countries in more detail. The data in Table 4 is again based on the

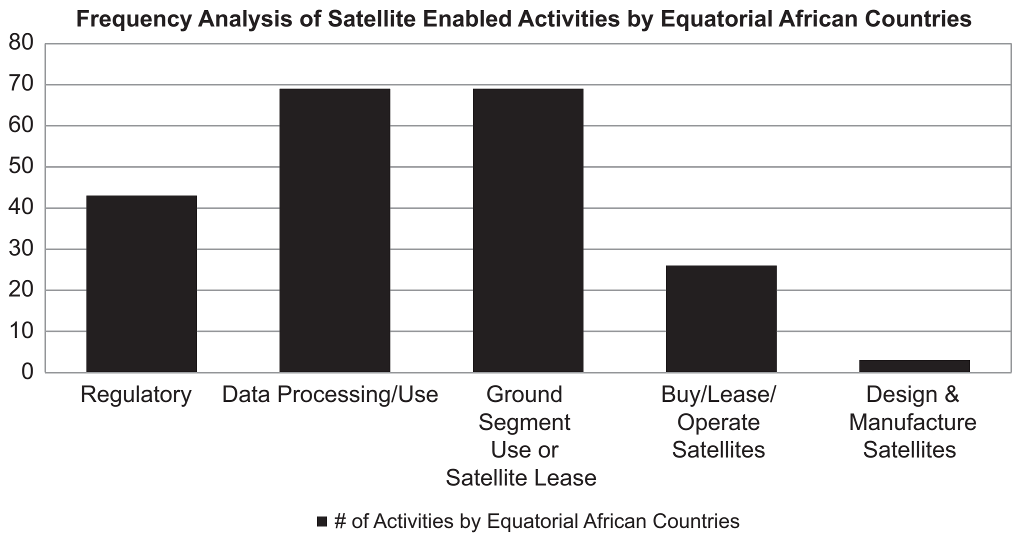

Fig. 3. Example of adapting Mission Ladder framework to investigate space activity among equatorial African countries.

Table 4
Further examples of summarizing country activities.

Country Technology Ladder				
Level	**Activity**	**Nigeria's results**	**South Africa's results**	**Kenya's results**
Satellite infrastructure				
A	Satellite assembly integration and test facilities	**0**	**1**	**0**
B	Satellite design and development facilities	**1**	**3**	**0**
Satellite hardware				
C	Design, build, operate satellite	**0**	**3**	**0**
D	Buy and operate satellite; train in satellite design/build	**4**	**0**	**0**
E	Operate others' satellites	**0**	**1**	**0**
F	Contribute to collaborative satellite project	**3**	**2**	**2**
Satellite services				
G	Lease satellite capacity and distribute service	**3**	**2**	**3**
H	Operate ground segment to send or receive satellite data	**1**	**5**	**8**
I	Process satellite data and create data products	**1**	**1**	**3**
J	Use satellite data products	**1**	**2**	**5**
K	participate in regulatory action regarding satellites	**2**	**2**	**3**
Total projects		**16**	**22**	**24**
Total: satellite infrastructure projects		**1**	**4**	**0**
Total: satellite hardware project		**7**	**6**	**2**
Total: satellite services projects		**8**	**12**	**22**

original database of seventy-nine satellite related case studies. It is update based on extensive field work in Nigeria, South Africa and Kenya. The field work was performed between August and December 2010. During visits of two to six weeks in each country, the authors engaged in interviews, site visits, informal observation and research presentations among the space communities of each country. The meetings involved stakeholders from the government, academic and private sectors. The insights from the field work allow further refinement of the Mission and Management Ladder framework as applied to Nigeria, South Africa and Kenya. Table 4 shows the national summaries on a Country Technology Ladder. In this version, there are three major types of activity—those related to Satellite Services, Satellite Hardware and Satellite Infrastructure. The infrastructure category captures investment in facilities and organizations that have long term capabilities to contribute to local satellite projects. Levels A and B indicate which of the three countries host organizations with facilities for satellite assembly, integration and test or satellite design and development. In South Africa, for example, the newly established South African National Space Agency (SANSA) has taken over a pre-existing satellite test facility that is now known as SANSA Space Engineering [13]. There are also several organizations with facilities and personnel capable of satellite design and technology development—including the University of Stellenbosch, the Cape Peninsula University of Technology and the SunSpace and Information Systems firm. In Nigeria, the Level B result represents the Center for Satellite Technology Development under the National Space Research and Development Agency, which is in the process of establishing facilities for satellite design and development [14]. Kenya is not yet involved with satellite infrastructure. In the category of Satellite Hardware, again Nigeria and South Africa are represented. Nigeria participated in four satellite projects at Level D. In each project, they procured a spacecraft and sent local engineers to the supplier's facility for training. This includes three remote sensing satellites and one communication satellite. South Africa has worked at Level C (Design, Build, and Operate Satellite) in three domestic projects, executed by the three organizations listed represented by Level B. Level E features the South African facility called SANSA Space Operations (formerly the Satellite Applications Center) [15]. This unique facility offers satellite tracking support for external customers. A similar facility is located in Kenya, but it is operated by representatives of Italy [16]. It is not shown on the country technology Ladder which emphasizes the actions of domestic organizations. Level F captures activities in which the three countries join as partners in internationally collaborative satellite projects. All three countries join Algeria in RASCOM and the ARMC, as described above. Nigeria also participates currently in the Disaster Monitoring Constellation, through which members offer both commercial imagery services and humanitarian support during crises. The new Levels defined for Table 4 allow a more involved examination of national space activity. This discussion highlighted key findings from the field work as an example. Future publications will address the outcomes from the field work in more detail.

The three representative analyses shown in this section give an indication of the flexibility, limitations and potential of the Mission and Management Ladder Framework. The framework can be used to summarize large amounts of data and show trends across a region. Tables 1 and 2 give such an example for satellite-related activity in Africa. The same set of data can be reorganized to focus on one specific country, as Table 3 does with Algeria. When moving from the regional level to national level, the data does not give a complete picture in every level of the Table, but inspires potential directions for further research. For example, the Algeria results are more complete in the Satellite Hardware category than the Satellite Services category. Fig. 3 shows how the regional African data can be parsed to understand the behavior of a particular subgroup—such as equatorial African countries. Again, the numbers in the graph do not show absolute behavior, but give an indication of relative behavior. The analysis shows which equatorial countries have comparatively high levels of space activity. Finally, Table 4 shows an example of how the Ladder Framework can be extended for more refined analysis based on field research and interviews. In the examples shown here, the Mission and Management Ladders were used to focus on satellite-related activity. Future work will explore other aspects of space activity, such as ground-based radio and optical astronomy or space education programs.

4. Introducing the Space Participation Metric

The Mission and Management Ladders are useful for making in-depth analysis about a particular region or set of countries. The method is not conducive, however, to a global analysis. It would be prohibitively difficult to build a detailed data set of case studies that is representative for every country in the world. A high level analysis method is needed to compare all countries to each other. This is the purpose of the Space Participation Metric (SPM). Rather than being built on case studies, the SPM builds on a database of lists that describe which countries participate in a variety of space-related activities. This framework assigns a Space Participation score to countries based on their involvement in these activities. As with the Mission and Management Ladders framework, the Space Participation Metric is a flexible method. For each application of the framework, it is designed to emphasize specific aspects of national space activity. There are five steps to build the Space Participation Metric, as follows:

(1) Choose the analysis strategy
(2) Choose the categories of space activities
(3) Choose data sources
(4) Assign country points
(5) Summarize country performance

In the first step toward applying the Space Participation Metric, the authors choose a strategy for the analysis. The question that sparks the analysis will influence each of the following steps. Within the broad goal of comparing the national space activity of countries across the world, there may be different sub-goals. There are also various dimensions along which to consider national space activity. A specific analysis will not capture all the options within each dimension, but the approach tailors the framework to address specific options well. The dimensions of space activity include the sector of the activities, their discipline, their geographic scope and the time scale. The sector dimension refers to the segments of society involved; this dimension is divided among military, civilian, commercial or scientific communities. A second dimension defines the discipline of the space activities, which may includes area such as technology, research, policy, regulation, law, education or institutions. The geographic scope dimension determines which countries are included in the analysis. The fourth dimension – time scale – is important because the nature of national space activity changes quickly. The analysis is valid for a particular point in time, if it is based on time-sensitive data. The results represent a snapshot for the appropriate time. The results of this first step in the SPM framework is an analysis strategy that defines which sectors of space activities to consider, the disciplinary nature of the activities, the geographic scope and time scale. As an example, a potential result from Step One may be a strategy to examine military space activities (sector dimension) that are technical and regulatory (discipline dimension) for Latin American countries (geographic dimension) in the last 15 years (time scale dimension).

After defining the strategy, the second step defines the categories of space activities to include. This decision is directly based on the strategies regarding sector, discipline and geographic scope. The categories reflect a hierarchy of space related activities, which allows for ranking of countries later in the analysis. The categories defined in Step Two are specific examples that further define the general dimensions chosen in Step One. For example, given the analysis strategy defined above to explore military space activities in Latin America, potential categories of space activity might include use of satellite communication services; procurement of satellite communication systems; definition of satellite communication regulation; and investment in satellite navigation infrastructure.

Step Three defines sources of data that show which countries participate in activities within the categories defined in Step Two. Often there are multiple data sources that could be used to convey the same information. Redundant data sources that describe country participation in the same space activity increase can confidence in the accuracy of the analysis, but also increase workload. In such cases, the authors strike a balance between seeking more information and working efficiently. Step Three applies three rules to improve the quality of the analysis. The authors seek data sources that serve as the authoritative list of countries that participate in a particular space-related activity. The data sources must be reputable in their context, although they may contain some errors. Three criteria aid in choosing data sources for space activities, as follows: (1) an exhaustive participation list must be available; (2) the activity must be theoretically available to every country in the world; and (3) there must be a way to associate participation in the activity with specific countries. The data sources chosen in Step Three may not provide the details for every country's participation in the given space categories, but they should at least point out the countries that are most active in each category. Once the data sources are chosen and organized into hierarchical categories, Step Four is straightforward. This step creates a chart in which each country receives credit for the space activities in which it participates.

Step Five determines how to summarize the performance of each country in the selected space activities. The simplest method is to simply count the number of activities that each country claims. In this case, the country's Space Participation score is equal to the total number of space activities. This method has the advantage of being easy to communicate to consumers of the results; it also avoids the need to make any subjective decisions about the relative importance of different space activities. It is possible to choose only space activities that are equally valid examples of national space participation. In such a case, the summed approach is very effective. Sometimes, however, the analysis includes a variety of space activities from a broad disciplinary spectrum and a wide geographic scope. In these cases, it is helpful to create a more complex summary of each country's performance. This approach assigns a weight to space activities of different categories in order to give some activities more importance than others. The authors follow established research methodology to guide this process. A key aspect of Step Five is to communicate clearly about the approach so that readers will understand the strengths and weaknesses of the analysis and interpret it appropriately.

The Space Participation Framework builds on work throughout the international development community to develop Composite Indicators that can capture key aspects of a complex reality using qualitative categories and scores. Based on the methods used in the Composite Indicator community, several options are available for weighting the various space activities. The methods used by researchers in the international development community to build national Composite Indicators are thoroughly explained in the OECD (Organization for Economic Cooperation and Development) *Handbook on Constructing Composite Indicators* [17]. In a similar paper, Freudenberg summarizes the steps required to build a Composite Indicator as follows: (1) develop a theoretical framework on which to base decisions about the indicator, (2) select variables to be combined in building the indicator, (3) standardize or normalize the variables, (4) weight the variables based on quality or importance of data, and (5) test the Composite Indicator for robustness to the methods for standardizing and weighting [18]. The references note that some of these steps require subjective decisions and provide guidance for how to use statistics or sensitivity analysis to apply more rigor to the analysis.

Based on a literature review, this paper applies two examples of methods for weighting Space Participation scores. The first weighting method is based on Cluster Analysis [17]. Cluster Analysis is a method to reduce the dimensionality of data by grouping variables or the objects of measurement into homogenous groups. In this context, it organizes the space activities into groups with similar country participation. Cluster Analysis uses one of several distance metrics to define the similarity of data points. In the case of binary data, the distance between two variables is the number of instances in which these two variables take different values. Thus, the distance between two space activities is the smaller if they have more countries in common that participate in these activities, and the Cluster Analysis groups activities that are similar according to this distance measure. The variant of Cluster Analysis used here makes non-hierarchical groups; it is called *K*-Means because the analyst defines the number of clusters (K). Cluster Analysis is implemented and visualized in software packages such as MATLAB. Once the analysis is run, it is evaluated by looking at the silhouettes of the clusters. There is one silhouette value for each variable. The silhouette value measures how far the points in one cluster are from other clusters. Thus using a value for K that leads to positive silhouette value avoids overlapping clusters. The Cluster Analysis is repeated with different numbers of groups to find the value for K that maximizes the silhouette values. Once a value for K with maximum silhouette values is found, the analysis strategy determines a method to rank the clusters. This may mean, for example, that activities in which fewer countries participate receive a higher ranking. The ranking is translated into a weight on the scores for each country. Using this weight scheme, a country's total SPM score can be calculated as shown in Eq. (1), where N_i is the number of activities in the ith cluster.

$$(1*N_1)+(2*N_2)+\cdots+(K*N_K) \tag{1}$$

The second weighting method is based on the technical level of the space activities. In this method, the space activities are divided into T groups based on their technical level. Each group of activities is weighted by a successive power of 10 (i.e., 10^1, 10^2,..., 10^T), in order to convey the idea that successively higher technical categories are much more complex than previous categories. The is method is attractive because a country's final score contains a simple summary of their performance, due to the fact that the number system uses base ten. A country's SPM score is calculated as in Eq. (2), where N_i is the number of activities in the ith cluster.

$$(10^1*N_1)+(10^2*N_2)+\cdots+(10^T*N_T) \tag{2}$$

The total score shows the number of activities in each category, by the digit in each position. This is true as long as there are fewer than 10 activities in each category. For example, if a country participates in one activity from category 1 and two from category 3, their total score will be calculated as $(1*10^1)+(2*10^3)=2010$. By reading 2010, one can immediately deduce the breakdown of a country's score and the total number of activities. Moreover, one can provide a meaningful summary of a country's performance by simply noting how many significant digits are in their score. In this case, the score shows that the country participated in three activities and that the highest category the country reached was category three. Table 5 summarizes the two weighting methods and their calculation. These represent two of the many ways to complete Step Five of the Space Participation Metric definition process, which is summarizing country performance. The next section provides an example of one application of the Space Participation Metric framework.

5. Using the Space Participation Metric to highlight developing country space activity

In this example, the Space Participation Metric is applied to all sovereign nations in the world, in order to compare their national space activity. Each of the five steps is explained to show how the strategy defined in Step One influences the choices made in later steps.

Table 5
Summary of two SPM weighting methods.

Weighting method	Theoretical basis	SPM calculation N_i is the number of activities in the ith group
1	Cluster analysis	$(1{*}N_1)+(2{*}N_2)+\ldots+(K{*}N_K)$, where K is the number of clusters
2	Technical level of activities	$(10^1{*}N_1)+(10^2{*}N_2)+\ldots+(10^T{*}N_T)$, where T is the number of technical levels

5.1. Step One: choose the analysis strategy

The goal of this instance of Space Participation Metric analysis is to create a scoring system that highlights the space activities of developing countries and has granularity in distinguishing among them. The audience for this version of the Space Participation Metric includes policy makers that are involved with developing countries in internationally collaborative projects. Such policy makers will benefit from data that provides relative comparisons of the space accomplishments of developing countries. This strategy influences choices about dimensions such as sector, discipline and geographic scope. In terms of sector, this analysis focuses on civilian national space activities, with greater emphasis on the government and academic role than the commercial role. The information caters toward governments that may consider working together in the future and highlights their contribution in space. In terms of discipline and geographic scope, both are wide ranging for this analysis. The disciplinary spectrum ranges from activities in space policy to advanced operational space projects. In terms of time scale, the most recent information available will be used where ever possible, and dates will be recorded throughout the analysis.

5.2. Steps Two: choose the categories of space activities

Table 6 shows the categories of space activities used in this analysis. The emphasis is on achieving a wide range of activities in terms of the disciplinary dimension. This helps capture some of the activities in which non-traditional space participants may be involved. The categories are ranked according to technical complexity. At the lowest technical level are the institutional or regulatory activities, in Category 1. At the next level are education and research activities related to space. Categories 3 and 4 demonstrate operational space projects, whereas Category 5 focuses on those countries that have invested in human space flight through launch vehicles or spacecraft. Categories 1, 2, and 3 are particularly relevant to many developing countries as well as more advanced countries that have not traditionally been involved in space. By including these categories, more countries will be represented by the Metric.

5.3. Step Three: choose the data sources

The next step is to find sources that contain lists of countries that participate in these various categories of space activities. Note here that many possible sources can be appropriate. The goal is to choose sources that are available, reputable, exhaustive and frequently updated. Table 7 shows examples of the data sources used in this analysis for each category; a complete list can be found in Table 8 in Appendix A. A total of twenty-one space activities are chosen from the data sources.

Table 6
Categories of space activities for Space Participation Metric definition.

Technology category	Technical category definition
(1) Low	Evidence of membership in international space related society, hosting of space meeting or space-related regulatory action
(2) Medium low	Evidence of space related education, research, or capacity building programs
(3) Medium	Evidence of ground based space hardware
(4) Medium high	Evidence of space hardware or launch facilities
(5) High	Evidence of human rated launch vehicles or spacecraft

5.4. Steps Four and five: assign country points and summarize country performance

Points are assigned to each country in a simple manner. Using a matrix with space activities on the horizontal axis and the countries on the vertical axis, each country receives a one in the column for the space activities in which they have participated. Three methods are used to summarize country performance. First, the unweighted sum of activities for each country is calculated. Second, the scores are calculated using Cluster Analysis, with stronger weight given to more exclusive activities, as explained below. Third, the twenty-one activities are divided into five disciplinary categories; each category is weighted with the appropriate power of ten based on technical complexity. Figs. 4–6 show the results of computing Space Participation Metric scores with the three methods.

Fig. 4 shows the results from the first method for summarizing country performance. There is a noticeable difference between this map and the one shown in Fig. 1 because of the introduction of the multi-faceted metric. Many more countries are included and there is more texture to the information. These results show the performance of countries when their SPM score is equal to the number of activities in which they participate. The colors in the figures are used to highlight three groups of countries. In this unweighted SPM analysis, where each space activity is counted equally, the maximum possible SPM score for each country is twenty one points. In order to divide the countries into three groups, the relative performance of the countries is observed. In this case, the bottom fifty percent of the countries earned less than seven points each. The middle twenty five percent of countries earned between seven and ten points, and the top twenty five percent earned greater than ten points

Table 7
Summary of space activities for weighted SPM definition.

Technology category	Example space activities	Data source
(1) Low	• UN COPOUS Members as of 2009 • Group on Earth Observations Member • Hosted an International Astronautical Congress	• UN COPOUS • Group on Earth Observations • International Astronautical Federation
(2) Medium low	• Participate in United Nations Program on Space Applications • National Space Program	• United Nations Program on Space Applications • *Jane's Space Directory*
(3) Medium	• Domestic Communication Satellite system • International Communication Satellite Earth Stations	• CIA World Fact Book • CIA World Fact Book
(4) Medium high	• Launch Facilities • Launch Vehicle(s)	• *Jane's Space Directory* • *Jane's Space Directory*
(5) High	• Participant in the International Space Station	• NASA

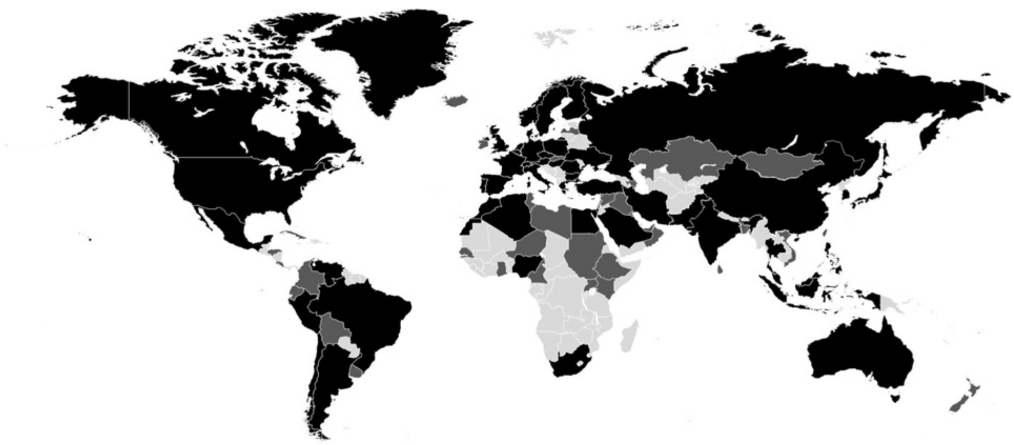

Fig. 4. Summary of country performance using unweighted version of SPM. Each country's score is equal to the number of activities they performed. Black countries are in the top 25% (11–21 activities); dark gray countries are the next 25% (7–10 activities) and the bottom 50% are in light gray (0–6 activities).

each. One weakness is that this analysis applies the same weight to activities from different disciplines. For example, membership in an international organization receives the same importance as operating a satellite. The end result is that there is diversity among developing countries, but the most advanced developing countries appear identical to the most advanced developed countries. This analysis is a useful baseline, but it can be improved as shown below.

Fig. 5 shows the results of calculating each country's SPM score based on Cluster Analysis, with clusters defined around activities. Several values for K are attempted, and the two-cluster solution ($K=2$) maximizes the distance between groups of activities. That is, each of the two clusters of activities maximizes the number of countries in common within the group and different from the other group. This particular analysis divides the set of space activities into two groups based on which countries participated. One cluster contains a group of activities in which many countries participated; the second cluster contains activities achieved by few countries. These clusters show which activities are commonly done and which are rarely done by countries. Rare activities are defined as more exclusive. Double weight is given to rare, exclusive activities in the final score for each country. As summarized in Table 5, the score for each country can be calculated from Eq. (1). Country scores for this example can range between zero and thirty seven. In this case the bottom fifty percent of countries achieved a score between 0 and 8 points. The middle twenty five percent earned from 9 to 17 points; the top twenty five percent of countries scored from 18 to 36 points. These results are useful to understand which countries participate in more of the rare activities, but it does not reveal information about the technical challenge involved in the activities. This map does have the desired granularity among developing countries.

Fig. 6 shows the results of analyzing countries according to their technical accomplishments, based on the categories in Table 6. The colors in the map show the highest technical category reached by each country. The SPM score for each country is calculated using Eq. (2). This method is most useful if the technical aspects of the projects are paramount in the analysis. This graph shows that the majority of countries do not go beyond technical category three; they have ground-based space technology in their country, according to the available sources. Compared to the map

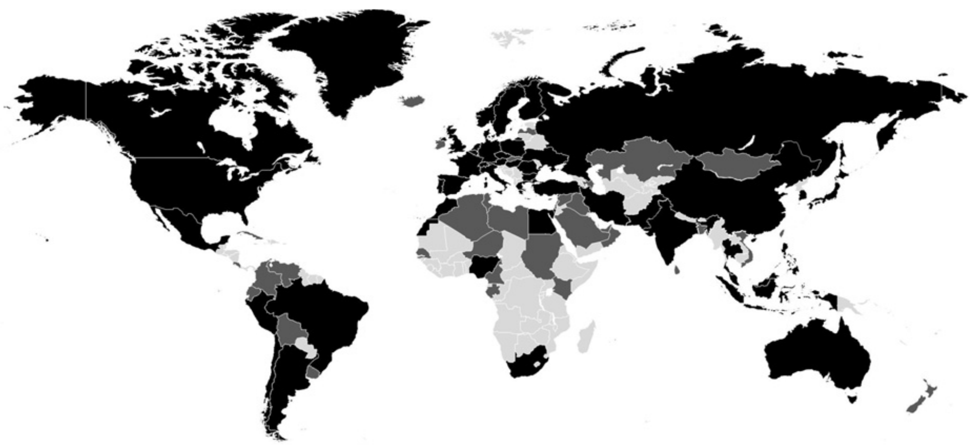

Fig. 5. Summary of country performance using cluster analysis. Black countries are in the top 24% (18–36 points); dark gray countries are the next 25% (9–17 points) and the bottom 50% are in light gray (0 to 8 points).

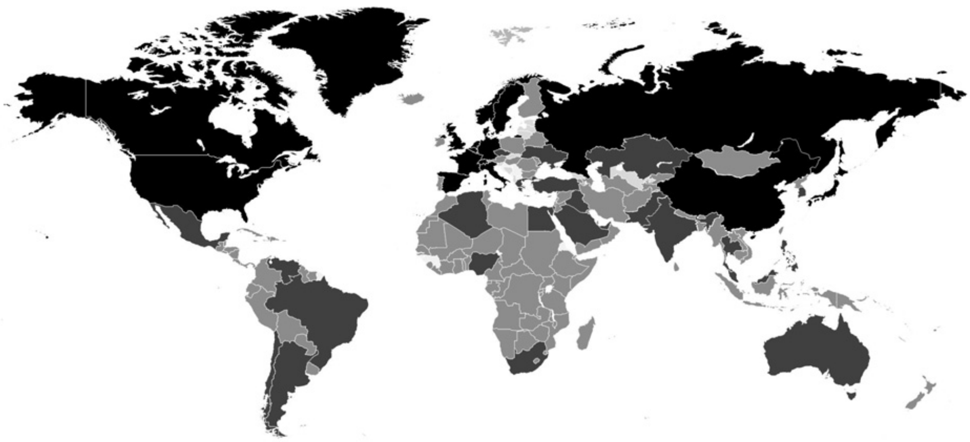

Fig. 6. Summary of country performance using technology-based analysis. Colors show which countries reached the five technology levels. Darker countries scored higher on the five level scale.

in Fig. 5, there is less diversity among developing countries in this view. This map is better suited for comparing developing countries to more advanced countries than for comparing developing countries to each other. The graph in Fig. 7 reinforces this statement.

The graph in Fig. 7 shows the ordered Space Participation Metric scores that are created using the five technical categories. It is shown in log form, so that the score directly reflects the highest technical category achieved by each country. This graph naturally divides countries into three groups. The first group only shows evidence of participating in institutional or educational space activities. They are not noted for having extensive ground-based space hardware, launch facilities or orbiting space hardware. The middle group is where the majority of countries lie. This group is noted in the data sources for having ground-based space hardware such as communication systems or earth observation facilities. The last group circled in Fig. 7 are the darkest countries on the map. They are countries that have demonstrated the use of space hardware, including satellites and launch facilities, or they operate human-rated space craft or launch vehicles. With this summary, it is clear that this method of summarizing country performance is focused on the technical achievements of countries in space activities. It does not emphasize the political or institutional aspects of space participation. For completeness, Fig. 9 is provided in Appendix A. It summarizes the same information as that of Fig. 6, but the countries are divided into three groups instead of 5. This facilitates direct comparison to Figs. 4 and 5.

6. Conclusion

This paper has shown several approaches for performing structured analysis that compares the national space activity of many countries. The approaches described here are flexible; they can be applied to new data with new assumptions as part of the wider program of research by the authors. This new work will lead to new conclusions. Because the outcomes of such work depend heavily on the assumptions of the analyst, it is important that the results be presented with the methods explicitly explained.

The framework known as the Mission and Management Ladders is useful for regional analysis or on a subset of the countries in the world. The Ladders framework uses three steps to organize case study data into analytical summaries of country performance. As an example, these steps are

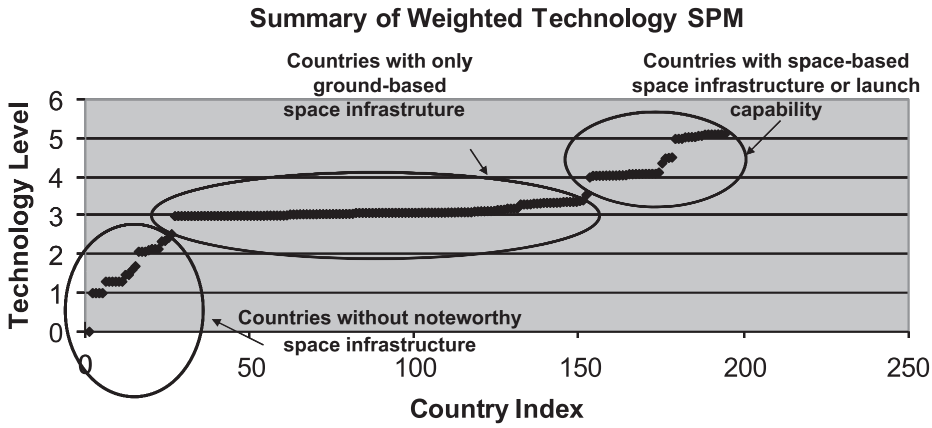

Fig. 7. The Space Participation Metric country scores using five technical categories.

Fig. 8. On this map countries with national space agencies are shaded darkly (Based on Jane's Space Directory as of 2006 [19]).

applied to a database of ninety case studies of African countries. Because the data set is large and all the countries are included, the results represent a summary of both regional and country-based space accomplishments.

The second framework is the Space Participation Metric. This tool is more appropriate for a global rather than a regional analysis of national space activity. It does not rely on detailed case study data; rather it builds on a list of reliable data sources that show which countries participate in various space activities. There are five steps to perform an instance of Space Participation Metric framework. The figures shown in Section 5.4 are used to show that the Space Participation Metric is a tool capable of emphasizing different issues and answering different kinds of questions. In order to interpret it, one must understand the assumptions and strategy that go into the analysis. The results from an SPM analysis do not provide an absolute statement, but rather a starting point to organize the wide variety of information needed for a global analysis of space activity. The SPM can be use for exploratory research, to facilitate dialog and to refine research questions. The strength of the SPM is that it provides a structured process to organize information. This helps the research team to either avoid or acknowledge bias. As an example application, the authors used the SPM metric in response to an initiative by the United Nations Office for Outer Space Affairs (UNOOSA). In 2009, UNOOSA was preparing to initiate the Basic Space Technology Imitative (BSTI) as part of their Program on Space Applications. The BSTI, like other aspects of the Program on Space Applications, is an effort to ensure that all countries receive benefit from space technology and resources. The BSTI is specifically designed to support the efforts of developing countries in small satellite programs. As the UNOOSA team prepared to start the BSTI, the authors performed an SPM analysis in partnership with UNOOSA. They worked together to define a relevant analysis strategy, including categories of space activities and data sources. The goal was to stimulate the thinking of the UNOOSA team about which countries were best positioned to benefit from the Basic Space Technology Initiative. While the analysis did not produce an absolute list of target countries for the initiative, it did expand the team's thinking about how countries can be involved.

This work complements the analysis done by research organizations such as Futron, Euroconsult and the Space Foundation. The audience for this research includes academics, policy analysts and coordinating organizations from both the space and development community. For academics, the benefit of this work is that it connects those focused on space studies to a larger community that tries to describe national characteristics analytically through Composite Indicators. For policy analysts, the benefit of this work is that it summarizes large amounts of information about global space trends that can be carefully used as an input to policy making about issues such as international collaboration or trade policies. For coordinating organizations, such as the United Nations Office of Outer Space Affairs (UNOOSA), this information can help shape outreach programs. The Space Participation Metric and Mission and Management Ladders are flexible, analytical frameworks that provide diverse views of complex social and technical information.

Acknowledgments

The authors would like to acknowledge the United Nations Office for Outer Space Affairs who gave input and feedback about this body of work. Also, we thank Jonathan Wood for technical assistance in preparing the graphics. This research was completed in part thanks to financial support from the NASA's Harriett Jenkins Pre-Doctoral Fellowship, the National Science Foundation's Graduate Research Fellowship, and the National Defense Science and Engineering Graduate Fellowship.

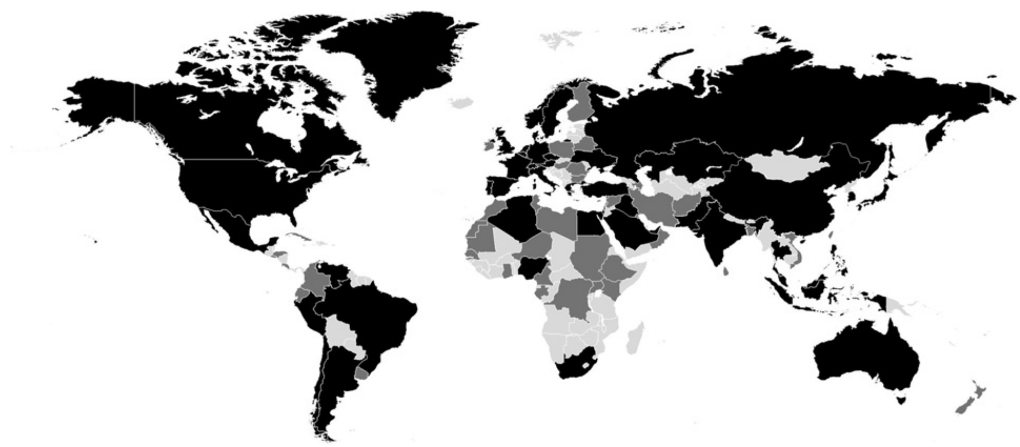

Fig. 9. This figure shows the results of calculating the weighted SPM based on technical achievement and dividing the countries into three groups, rather than the five groups shown in Fig. 6. Black countries are in the top quartile (2360–133,590 points); dark gray countries are the next quartile (1240 –2350 points) and the bottom two quartiles are in light gray (10–1230 points). This figure is provided to show a more direct comparison to the results in Figs. 4 and 5.

Table 8
Complete list of space activities used in SPM definition.

Category	Definition	Space activities
(1) Low	Evidence of membership in international space related society, hosting of space meeting or space-related regulatory action	• U.N. COPOUS Members • Group on Earth Observations Member • Host an International Astronautical Congress Conference • Member of International Mobile Satellite Organization • Member of International Telecommunications Satellite Organization • Member of International Telecommunications Union • Member of International Astronautical Federation • Member of International Astronomical Union • Signed Outer Space Treaty
(2) Medium low	Evidence of space related education, research, or capacity building programs	• Inclusion in American Astronomical Society Directory • National Space Program (according to *Jane's Space Directory)* • Space Institutes or Organizations (according to *Jane's Space Directory)* • Participate in U.N. Program on Space Applications • Report to UNOOSA on nationals space activities or research
(3) Medium	Evidence of ground based space hardware	• Domestic Communication Satellite system • International Communication Satellite Earth Stations • Earth Observation Facilities and Equipment (*Jane's Space Directory)*
(4) Medium high	Evidence of space hardware or launch facilities	• Launch Facilities (*Jane's Space Directory)* • Launch Vehicle(s) (*Jane's Space Directory*) • Appear on UN Launch Registry
(5) High	Evidence of human rated launch vehicles or spacecraft	• Participant in International Space Station or National Human Launch

Appendix A

See Figs. 8 and 9, and Table 8.

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