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How Newcomers Will Participate in Space Exploration

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1. Introduction

Space Exploration, one of the hardest achieved successes of mankind, is defined as all activities geared towards exploration of outer space using either space technology or observations from Earth, though sometimes the latter is not considered as part of space exploration (Logsdon; 2008). In this chapter, we will exclude observations from the Earth or the low Earth orbit (LEO) and scientific LEO missions that explore plasma sphere, which deserve dedicated study, especially because the opportunities cubesats offer to newcomers who want to contribute to space science (Woellert et al., 2010). While exploring our planet from its core to the surface and beyond, space studies has provided good leverage for science, technology and spin-off applications. Since the beginning of the space age, whose onset is generally accepted as the year 1957 when Sputnik-1 was launched, our knowledge about outer space has increased at an accelerating pace, an achievement made possible by developments in space technology. Mankind has succeeded to send satellites, landers, and rovers to other planets and their satellites, built an orbiting space station, analysed samples of other planets' soil, atmosphere and magnetosphere, performed regular launches to various earth orbits, planned regular touristic rides to space and even sent men to the Moon.

The Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, otherwise known as the Outer Space Treaty in short, defines basic principles for use of space. Although the Outer Space Treaty states that "The exploration and use of outer space, including the Moon and other celestial bodies, shall be carried out for the benefit and in the interests of all countries" and has been signed by the majority of the world's nations, as shown in Figure 1, until recently space exploration has actually been a privilege for only the few developed countries who could actually 'touch' the space.

Nevertheless, the number of countries who have initiated space programmes to benefit from space is increasing. Several large countries, like India and China, were early to establish their space programs and have been followed by many others. Although the initial steps are generally small and focus on immediate needs, the programmes eventually involve more scientific content; enabling new nations begin to contribute to the exploration of space, a

trend that can be called “democratization of space”¹. These newcomers, mostly from newly industrialized countries, and Asian nations in particular, are paving the way for intensive space exploration activities.

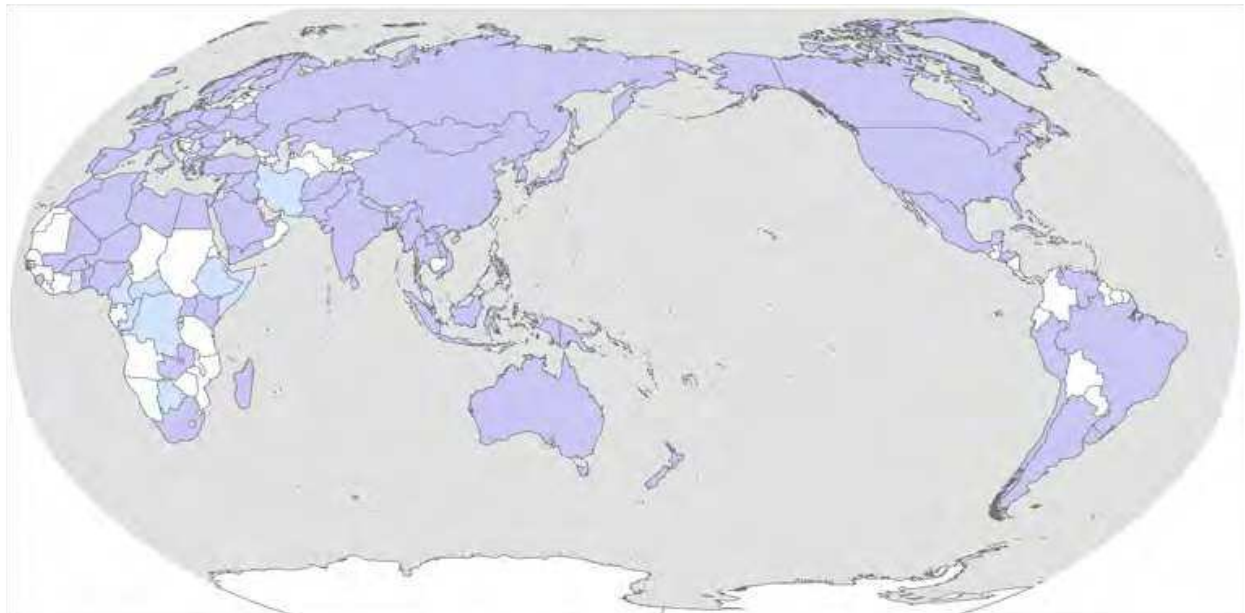


Fig. 1. Outer Space Treaty Signatory States. Blue: signed and ratified, green: signed only.

In this chapter, after a short summary of space exploration, we first try to draw a picture of the democratization of space, i.e. the joining of more nations to the space club. Then, with a focus on space exploration, we discuss possible opportunities and advantages as well as difficulties for the newcomers.

2. A short summary of space exploration

From the very beginning, humanity’s desire to reach celestial objects was reflected in the mythologies of various civilizations. An example from Turkic mythology is the celestial journey of the Shaman to the fifth level of the Sky, Polaris, after sacrificing a white horse. According to their belief, the Moon was on the sixth level where humans could not reach (Gömeç; 1998). However, with Kepler’s laws describing the movement of planets around the Sun and following breathtaking scientific and technological developments, travel to the Moon became a reality during the space age.

Following the end of WWII, the Soviet Union shocked much of the world with its launching of the Sputnik-1 satellite that transmitted periodic pulses and Sputnik-2 satellite carrying a dog as a passenger, launched onboard the modified Russian R-7 ballistic missiles on October 4, 1957 and November 3, 1957, respectively. The US responded immediately with its own launch of the Explorer-1 satellite on January 31, 1958.

¹ The term is generally used to refer the right of individuals to reach orbit in the context of space tourism, however, here we use it for the right of nations to reach orbit and benefit from space in the collective sense.



Fig. 2. A drawing of a shaman's drum depicting the conceptualization of the universe by ancient people. Upper part is the sky. (from Wikimedia, originally from (Anokhin, 1924))

The ensuing Cold War between the US and Soviet Union fuelled a fierce race to achieve tactical and strategic space superiority. Space technology developed from, sending first animals then robotic rovers, probes to the Moon, Mercury, Venus and Mars then finally humans to different targets in space including the Earth's orbit and the Moon. In this short period of about 50 years, even the frontiers of our own solar system were explored after Galileo; plans to send probes beyond Jupiter became part of everyday life and space proved to be an economic, diplomatic and strategic tool for those participating the race. Missile race in the 40's resulted in the Moon race in the 50's, followed by the deep space race in the 60's. The countries who pioneered the space race not only led space exploration but also benefited from the return on investment through the technological spin-offs that later achieved commercial success; and industrial mechanisms that turned into political power. Although these scientific, technical, and financial rewards improved mainly the lives of their own citizens, the increase in the base of knowledge, advances in productive capabilities, expansion of the range of economic activities, and enhancements of geopolitical positioning also served to inspire all of mankind.

2.1 Moon rush

Following the successes of the Sputniks and Explorer-1, the Russian Luna-1 satellite became the first spacecraft to escape Earth's orbit in January 2, 1959. On September 12, 1959, the Russian Luna-2 was launched and impacted on the Moon's surface two days after the launch. Luna-3 was launched in October 4, 1959 and became the first manmade object to reach and photograph the dark side of the Moon while the American Pioneer 1, 2, 3, 5 and 6 satellites failed during their launch towards the Moon. In April 12, 1961, Soviet Russia made an enormous step in the history of space exploration when cosmonaut Yuri Gagarin became the first man to successfully orbit the Earth. Shortly thereafter, American astronaut Alan Shepard completed the first suborbital flight in May 1961. On February 3, 1966, the Russian Luna-9 satellite completed a soft landing on the lunar surface. In the same year, the Luna-10, 11, 12 and 13 successfully reached the Moon orbit and the Luna-13 landed on the Moon's surface.

Between 1966 and 1968, unmanned Apollo-1, 2, 3, 4, 5 and 6 spacecrafts were launched on board of Saturn-1B and Saturn-5 launch vehicles. Manned missions of Apollo started with

Apollo-7 in 1968, which carried a crew of three into the Earth orbit. It was followed by Apollo-8 with a crew of three that completed the world's first manned mission around the Moon between December 21 and 27.

Meanwhile, Soviet Russia was developing “Zond” and a prototype of the spacecraft for manned circumlunar flight flew around the Moon.

Between July 16 and 24, 1969, The astronauts of Apollo-11 landed and walked on the surface of the Moon. They became the first men to walk on a celestial object other than the Earth. After the success of Apollo-11, the USA successfully completed five more Moon expeditions with the Apollo series. After several Russian launch vehicles and sample-return spacecrafts failed to reach the Moon, the Soviet government officially cancelled the N1-L3 program in 1976. Until that date, Russian rovers Lunokhod-1 and 2 landed on the Moon safely in 1970 and 1973, respectively. Following these events, moon rush, turned into deep space rush starting from Mars and Venus.

2.2 Deep space rush

In light of the experiences and developments of the Moon race, Soviet Russia and the United States considered exploration of the inner planets as well. Unsuccessful Mars and Venus probes were launched towards their destinations in the early 1960's. After many disappointments and very expensive trials, for the first time in the history, the American Mariner-4 satellite transmitted 21 images and bountiful scientific data in 1964 at a distance of approximately 10,000 km from Mars. US Mars-1 to Mars-7 and Russian Phobos-1 & 2 were also sent to Mars until 1988, and some of them returned valuable data. The Russians responded with the Venera-3 satellite. The lander penetrated the atmosphere of Venus in 1966, another first time event. Following Venera-3's success, a series of landers, Venera-5 to -16 were sent to Venus until 1983. Exploration of Mars and Venus continues even today, with the US sending two Pioneers to Venus; six more Mariners, two Vikings to the Mars and two Voyagers, three Pioneers to Jupiter until 1978 and many more up to day. Although the space race may seem to have slowed down after the 1980's due to financial reasons, it is unlikely that it will ever end as human interest in space continues to this day with major projects such as the International Space Station.

The technology derived from the Sputnik missions has led to key developments in modern communication, earth observation, meteorology, early warning and scientific satellites that have improved and become the part of everyday life on Earth.

While Soviet Russia and the US were continuously conquering the outer space, the rest of the world seemed reluctant to proceed on the same way and did not join the race for some time. Recently, the investments made by the Asian states in lunar programmes have also increased global interest in the Moon. It is likely that the US, Russia and the European Union will also make significant investments in this direction soon.

2.3 Europe

In 1964, the European Space Research Organization (ESRO) was founded by 10 European nations with the intention of jointly pursuing scientific research in space. ESRO was merged with ELDO (European Launcher Development Organisation) in 1975 to form the

European Space Agency (ESA). In 1970's when Russia and America were flying to Mars and Venus, Europe had just formed its organization devoted to scientific, civilian space applications.

Europeans started developing sounding rockets in 1964, which were followed by several scientific satellite projects in 1968 called ESRO I and ESRO II. After that, Highly Eccentric Orbit Satellite (HEOS) for measurements of plasma, magnetic field and cosmic ray particles and the Thor Delta program for stellar astronomy were started.

The race to the Moon, Venus, Mars and comets did not generate the same interest in Europe as among Russians and Americans during the height of the Cold War. Rather, Europe's long term projects mainly focused on remote sensing, space science, the International Space Station (ISS) and telecommunication. ESA's only mission to the Moon was launched in 2006, 31 years after its establishment.

2.4 Japan

Japan is the first country in Asia to follow the developments in the rest of the world, founding the Institute of Space and Astronautical Science (ISAS) in 1950. The first satellite was launched in 1970 with the indigenous L-4S rocket. In the beginning of its developmental phase, the National Space Development Agency of Japan (NASDA) used a US license to produce rocket engines, which paved the way to the first launch vehicle developed in Japan, the H-II, which was launched in 1994.

The first Japanese missions beyond Earth orbit were launched in 1985 to observe the Halley comet with two observation satellites. The missions were performed together with the Russian and European Space Agencies as part of a joint space exploration program. Japan is also the first Asian country to launch a lunar probe with a satellite called Hiten in 1990. They even sent an orbiter to the Sun in 1991 and sponsored an astronaut mission as part of US Shuttle program in 1992. The first Japanese interplanetary mission, the Mars Orbiter Nozomi (Planet-B), was launched in 1998.

Briefly, Japan invested heavily in exploration of space and space science; astronomy, technology tests, lunar explorations, solar sail research and even sent probes to asteroids and the Moon.

In April 2005, Japan announced ambitious new plans for a manned space programme, including landing on the Moon by 2025. The country now wants to have human presence in space along with unmanned scientific planetary missions and also has ambitions to open a permanent base on the Moon and manned spaceflights around the year 2020.

The Japanese ride to space is supported by their ability to access to space by means of their own indigenous launch vehicle, just like Russia and the US. Sufficient financial support from the government and moral support from society also stimulate Japan's special interest in space. However, it is uncertain today if Japan will continue to invest at the same pace, due to the devastating impact of the Sendai Earthquake and Tsunami in 2011, whose estimated cost is around several hundred billion US \$. Probably, some of the funds, which were allocated for space projects, like other government spending, will be transferred to the recovery of earthquake devastated areas and export oriented Japanese economy.

3. Democratization of space

In the early stage of the space age, almost all space activities were carried out by a small number of developed countries and the USSR. However, an important development in recent years is, as we call it, the democratization of space. Increasingly, nations who want to exploit space for the good of their citizens and to boost national development have stepped into the space technology arena. Some large countries had already initiated their space programs as early as 1950's. China and India comprise the category of newly industrialized countries that represent 37% percent of world population and have made great achievements in the meantime. As of today, these countries have managed to put their own launch vehicles on serial production and even reached the lunar orbit.

Newly industrialized countries like Brazil, South Africa, Turkey, Thailand, Malaysia and some other nations have taken their first steps mostly through relatively low-cost small satellite technology transfer programs and/or by collaborating with nations strong in space technology. For these nations, most of whom are either in the newly industrialized or developing country category, the first priority is generally satisfying immediate needs and achieve a return on investments as soon as possible. The main focus is generally on earth observation, which is an important tool to support development. Countries who can afford to have also invested in telecommunication systems and launch vehicles.

In parallel to space technology investments for immediate needs, efforts in the domain of space science and space exploration have increased as well. China and India have progressed similarly and initiated their space activities in 1950's. Although they have boosted their activities much later than Russia, the US and Europe, since the 1980's, they have become part of the elite club that is paving the way for the future of space exploration to expand scientific knowledge, develop their country's technical capabilities, and provide employment opportunities for valuable human resources in the areas of space technologies and science. With increasing interest in space, more countries are aspiring and will aspire to space exploration activities by the use of space technology following these examples. After summarizing the space programs of China and India, we will review developments in the rest of the world.

3.1 China

Actually, the technological roots of Chinese space studies can be traced back to the late 1950's. As the space race between the two superpowers reached its peak within the context of the Moon race, China did not want to be left behind and initiated its manned space program in 1971. The first manned program was cancelled in 1972 due to financial reasons. The second manned program was launched in 1992 and led to the successful orbital flight of Shenzhou-5 in 2003. Following this flight, China managed to send men into orbit and successfully bring them back to Earth in 2008, thereby becoming the third nation in the world to accomplish that complicated mission. This success encouraged China to make an official declaration about plans for a manned space station and the Chinese Lunar Exploration Program (CLEP).

Current indications are that China will proceed at its own pace; it was officially announced that participation in the ISS is not on the agenda. To achieve successful orbital operations of a Chinese space station, several expensive and slow steps have to be taken, including

construction of dockable space station, extra-vehicular activity trials with space suits, biological, medical, chemical, electronic and electro-mechanical experiments in orbit, and creating a sustainable habitat for the visitors, just like in the ISS.

While the future of ISS is clouded by financial considerations and very small global public interest, China in contrast has expressed self confidence, self reliance, strong determination and future plans for a space station. However, China will most likely conduct fewer and more limited trial missions, unlike the National Aeronautics and Space Administration (NASA) and Russian space agency (Roscosmos) did in the past, to cut costs. Recently in 2011, the world's largest launch vehicle construction facility opened in China and one of the products will be the Chang Zheng-5 heavy lift launch vehicle, which is supposed to be capable of delivering 25 tons to low earth orbit (LEO) beginning of 2014. Once heavy lift capability is achieved, space transportation for landers, rovers and travel of Taikonauts (Chinese version of the term astronaut) from the space station to the Moon, Mars and beyond is theoretically achievable with sustained cash flow.

The outcome of this investment in space will be very useful in many different areas, such as financial, moral and especially political and geopolitical positioning for China.

The start-up of the Chinese space exploration program is Chinese Lunar Exploration Program (CLEP). The Chang'e program is part of CLEP and currently consists of two orbiter spacecrafts that were launched in October 2007 and October 2010, respectively. These satellites have provided data about possible future landing sites and mapped the surface of the Moon. Although key elements of the first satellite were mainly developed and funded by China, international support came from ESA by providing the necessary deep space network for Chang'e missions in return for Chang'e-1 data. Due to the political reasons, China could not benefit from the US Deep Space Network distributed all over the world, which would have enabled continuous communication with spacecraft and accomplishment of Telemetry, Tracking and Control (TT&C) tasks. Thus, the only option for CLEP was to rely on ESA's network. Meanwhile, China upgraded its own TT&C network, which was originally designed for manned space missions, and managed Chang'e-2 mission without any foreign support, thereby achieving independence. Presumably, we hope to assume China will share its valuable sources through regional, international or bi-lateral cooperation with other nations for space exploration.

For the Mars program, China cooperated with the Russian Federation; however, the Russian partners couldn't perform the launch in 2009 when Mars was relatively close to the Earth, so the most favourable launch window was missed due to the delay in the Phobos-Grunt project. This opportunity could have been evaluated as one of the best joint interplanetary outer space explorations had it succeeded. However, the willingness and close cooperation between these two giant states is an emerging and encouraging opportunity for the others, especially those who want to participate in outer space exploration and share the cost of development and launch.

3.2 India

Following the successful launch of Sputnik-1 in 1957, the Indian National Committee for Space Research was founded in 1962, later evolving into the Indian Space Research Organization (ISRO) in 1969.

Following the same development patterns of Japan and China, India invested in earth observation, communication, meteorology, scientific and outer space exploration programs (e.g., the Moon) and formulated its own launch vehicle program to guarantee the access to Earth's orbit. While the space program was formulated with little foreign consultancy and support, the lunar program, Chandrayaan, was supported by international institutions and several countries. Chandrayaan-1 was launched in 2008 and is one of the best and so far, one of the most successful international outer space exploration programs, even though the mission ended earlier than expected. Bulgaria, the United Kingdom, Sweden, Canada, ESA and the United States participated in the mission, contributing various payloads and flew onboard the spacecraft free of charge. Recently, ISRO allocated funds for Chandrayaan-2 & 3 that includes lunar lander and rover segments. Although NASA and ESA would like to participate this project as well, Chandrayaan-2 will mainly be performed with Russian support and estimated launch dates are after 2013 and 2015, respectively. Another key aspect of Chandrayaan-1 is that 11 different instruments, designed by different organizations, worked well and with each other on a single satellite platform. This represents a tremendous achievement in terms of gathering different organizations and technologies under the same umbrella on board a single satellite platform and enabled them to benefit from the same technological standards on a totally non-commercial space mission.

According to Indian officials, the main drive behind the lunar exploration program is to expand scientific knowledge, develop the country's technical capabilities, and provide working opportunities for valuable human resources in the areas of space technologies and science, which are the *crème de la crème* of the Indian nation.

The Indian Lunar Exploration program has included international cooperation from the beginning and will hopefully continue to do so in the upcoming Chandrayaan missions as well. Invitation to these types of prestigious cooperation programs could well serve as an appetizer for newcomers in the future. Additionally, India aims to demonstrate independent human spaceflight after 2020.

Although totally initiated and funded by the Indian Government to promote development, the program has many accomplishments, including the development of a home grown launch vehicle and indigenous satellite platform, boosting scientific interest, technological capability and public and institutional the awareness about the Moon within India. Moreover, providing a free-ride for international contributors has marked the Chandrayaan-1 initiative itself as one of the best and most successful opportunities to discover outer space together with other nations. It is the most international lunar spacecraft ever designed.

3.3 Others

Futron Corporation released the 2010 Space Competitiveness Index in which countries are ranked according to their space competitiveness, which was measured using a method developed by the company. The top 10 Countries (Europe being considered as one entity) and their ranks are reported as follows (Futron, 2011):

The first six countries have already been discussed up to this point. Three other countries that can be considered as newcomers are shortly introduced in following sub-sections.

Country	Rank
USA	1
Europe	2
Russia	3
Japan	4
China	5
India	6
Israel	7
South Korea	8
Canada	9
Brazil	10

Table 1. Top 10 in Futron’s Space Technology Capacity Index.

3.3.1 Israel

Despite being the geographically smallest country among other newcomers, Israel reached its indigenous launch capabilities much earlier than many of the countries mentioned in this chapter. This success is based on its ballistic missile program in 1980’s, and the help of a very strong local defence industry. Although recently many scientific applications have been developed, mainly by scientists originating from the Ukraine and Russian Federation, the main scope of the Israeli space program is defence needs and the country has no restrictions to use export licensed space products.

Due to geographic constraints, Israel is planning to launch its rockets from aircraft, similar to Indonesia and thereby avoid drop zone problems. Israel also cooperates with ESA via EU 7th Framework Programme (FP7) programs, Ukraine, the Russian Federation and also generally with the US.

3.3.2 South Korea

The South Korean Aerospace Research Institute, KARI, was founded in 1989 and so far has invested in earth observation, meteorology, communication and ocean monitoring satellites, launch vehicles and human space flight. Today a lunar lander prototype is ready and KARI would like to realize its lunar exploration program until 2025, following the successful qualification of the KSLV (Korean Space Launch Vehicle) rocket, many other spacecraft technologies, and procurement of necessary funds.

3.3.3 Brazil

The Brazilian space program, initiated in 1961, is primarily launch vehicle oriented. After several sounding rocket trials, a collaboration agreement with China was signed in 1988 resulting in the China-Brazil Earth Resources Satellite program (CBERS). So far, three satellites have been launched and two more are on the way. Brazil has also signed cooperation agreements with Canada, ESA, NASA, Russia, Ukraine and France and is also looking for partnership opportunities with Israel. The country has owned the Alcântara Launch Centre since 1982, and has collaboration programs with Ukraine based on the Cyclone-4 launch vehicle.

South Korea and Brazil clearly show promise as future players in space exploration, thanks to the political support from their governments, financial capabilities of their economies, and promising launch vehicles for independent access to Earth's orbit.

However, countries aspiring for space are not limited to the list given above. Many countries are already operating satellites, as shown in Figure 3. Some countries who are not contented with being the final users and operators of space systems created by a few industrialized countries, and who have a certain economic, demographic and technological capacity, have already initiated space programs to create their own space industry. The problem of establishing basic space technology capabilities with limited budgets and creating a sustainable, sound industry that can at least fulfil domestic needs is already well addressed in the literature (Leloglu & Kocaoglan, 2008; Jason et al., 2010; Waswa and Juma, 2012), so we do not discuss this topic in this study. The activities of some newcomers, namely South Africa, Thailand, Malaysia and Indonesia, which are in the category of newly industrialized countries, and some other countries are summarized as follows.

3.3.4 Taiwan

Taiwan is one of the more interesting examples with its Formosat satellite program and desire to develop its own indigenous launch vehicle. Unlike mainland China, they have no problem in procuring western products. The main aim of Taiwanese National Space Organization is to establish national self-reliant satellite technology. Taiwan, being technologically and financially more advanced than most of the newcomers with an export oriented economy, aims to develop local space technology infrastructure as well as to employ competitive resources that would favour Taiwan's space application industries for future international space markets. This would in turn benefit the development of space technology for basic daily needs, increase the breadth of scientific applications, and keep valuable human resources inside Taiwan, thereby increasing competitiveness and added value for domestic high technology industries such as telecommunications, nanotechnology, electronics and defence.

Due to the political balance in South East Asia, Taiwan generally allies with the United States and Europe, rather than pursue regional cooperation, and thus faces no obstacles inhibiting it from benefiting from International Traffic in Arms Regulations (ITAR) restricted US space technologies and launching its satellites via US military launch vehicles like Minotaur, Athena and Taurus. In this way, Taiwan has solved generic "procurement of export licensed qualified components" and "arrangement of launch campaign" problems.

3.3.5 South Africa

South Africa launched its first indigenous satellite, Sumbandilasat, in 2009, which continues to operate successfully. Future plans include establishing a space agency, and investing in launch vehicles and earth observation satellites. Although external funding for future projects is uncertain, South Africa aims to pursue its space-based goals with maximum local contribution and governmental support.

3.3.6 Turkey

Turkey started benefitting from space technologies in early 1990's by communication satellites. Towards the end of 1990, the country signed know-how and technology transfer agreement with the same source of Algeria and Nigeria. As a result, the first earth observation satellite, BiLSAT is launched in 2003.

So far, Turkey procured six more communication satellites, one earth observation satellite and also manufactured two more earth observation satellites at its own premises in the capital city, Ankara. One of the indigenously developed satellites, RASAT, was launched in August 2011. Among several space industry companies, TUBITAK UZAY, as an ambitious newcomer, is planning space exploration projects in the medium term in parallel to the National Space Research Program adopted by Supreme Council for Science and Technology in 2005 (TÜBİTAK, 2005).

In the meantime, some necessary capabilities are acquired; an on-board computer that can be used in interplanetary missions was developed. Some other hardware that can survive high radiation environment, including communication and power modules and vital software packages are in the process of development and project for establishing infrastructure and development environment for electric propulsion is being conducted. Hall Effect thrusters are being developed in parallel. An international project was also launched with Middle East Technical University and Ukrainian institutions.

TUBITAK UZAY also takes part in several EU FP7 projects and has submitted various projects with foreign partners. The European Cooperation for Space Standardization (ECSS) and Consultative Committee for Space Data Systems (CCSDS) standards and various established industry practices are followed to facilitate future international cooperation.

3.3.7 Thailand

Apart from the experiences of Thaicom in telecommunication satellites, Thailand's Remote Sensing Centre (GISTDA) ordered the first earth observation satellite, Theos, from France in 2004. Today, Theos still operates successfully to serve the daily imagery needs. In addition to five telecommunication satellites and one earth observation satellite, Thai universities have invested in Ka-band transponder development studies and several balloon experiments to observe the ionosphere both indigenously and in cooperation with the other South Asian nations participating in the Asia Pacific Space Cooperation Organization (APSCO) and Asia Pacific Regional Space Agency Forum (APRSAF) initiatives.

3.3.8 Malaysia

Malaysia is an interesting case as it established its space agency relatively recently in 2002 and has invested in human spaceflight, purely for prestige and public awareness. The first Malaysian astronaut visited the ISS under the Angkasawan program in 2007.

The satellite experience of Malaysia started with a small technology transfer project and continued with complicated and operational Razaksat satellite project, which is a technology transfer from South Korea. The satellite was launched in 2009. Similar to Thailand and many other countries, Malaysia has invested heavily in commercial telecommunication satellites. The local telecommunication satellite operator has procured three satellites, similar to

Thailand, to serve communication applications and benefit from the financial return. Malaysia is an active member of APRSAF and collaborates not only with other nations in this organization on space technologies, but also works together with the Russian Federation on suborbital launch vehicle technologies.

3.3.9 Indonesia

Indonesia established the Indonesian National Aeronautics and Space Institute (LAPAN) in 1964 and has invested mainly in launch vehicle technologies with the help of the Russian Space Agency, and in the Palapa and Telkom telecommunication satellites, similar to its South Asian neighbours. Indonesian satellite development activities were initiated with the help and on-the-job training from Berlin Technical University and resulted in the development of two LAPAN mini satellites. The country signed a collaboration agreement with Ukraine in 2008 to study launch vehicle technologies. Additionally, Russia and Indonesia signed a commercial agreement that resulted in the construction of air-launch infrastructure on one of the islands in the Indian Ocean, one commercial communication satellite, and manufacturing of one other by Russia. LAPAN is currently indigenously developing a launch vehicle that is capable of delivering 100+ kg satellites to low earth orbit and two mini remote sensing & Automatic Identification of Ships (AIS) satellites in the 70 kg class.

3.3.10 Algeria

Similar to other countries, Algeria embarked on its space adventure via a technology transfer program from the Western Europe. Successful satellite design, test and operation experience of Alsat-1 satellite resulted in the construction of a satellite assembly integration and test (AI&T) facility in Oran city and the advanced Alsat-2A satellite, designed by a European company. After these technology and know-how transfer projects, Algeria is now developing its third satellite Alsat-2B at its own AI&T facility with its own personnel, and will be the third country in Africa to reach and benefit from space technologies, following South Africa and Nigeria.

3.3.11 Nigeria

Nigerian Space Agency launched its second and third remote sensing satellites together in August 2011; Nigeria ordered two more telecommunication satellites for commercial use with turn-key contract.

3.3.12 Egypt

Egypt was fortunate to have benefitted from a technology transfer program from Ukraine before the recent political depression and operates the Egypt-1 earth observation satellite.

3.3.13 Pakistan

Pakistan started with a technology transfer program from the United Kingdom and is now working with China for both turnkey telecommunication and earth observation satellite programs. Additionally, the Pakistan Space Agency is developing its own systems

for testing on board the Chinese-made Paksat-1R communication satellite launched on August 2011.

3.3.14 Iran

Iran is developing its space technology mostly with the local resources. The country's launch vehicle program currently employs technologies enabling orbital distances of about 260 km and capable of carrying payloads in the 30 kg class. Although announcements about human spaceflight may not be realized in the foreseeable future, it is clear that Iran achieves more because of the embargo by developing applications and technologies with its own sources, rather than relying on technology transfer programs as other nations have done.

3.3.15 Vietnam

Vietnam is about to join the "Others" soon, with its two remote sensing satellites from France and Belgium, and a second telecommunication satellite from the US, currently on assembly.

Clearly, these latecomers are highly motivated and possess modest funding schemes mainly for "space for improving daily life" applications. Participation of the pioneers' space race with their local contribution will be valuable nationally and also encourage the rest of the world to join in this prestigious but very expensive work.

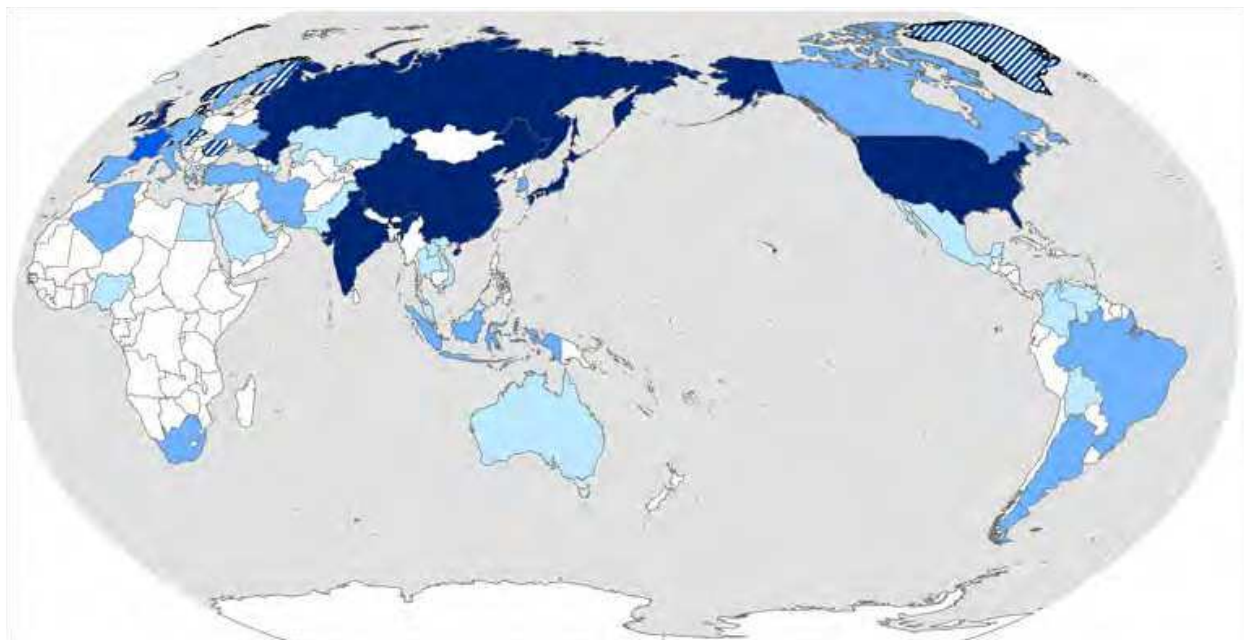


Fig. 3. Satellite operating nations. Dark blue: LEO, GEO and outer space, blue: LEO only (excluding cubesats), light blue: countries operating turnkey satellites systems

4. Newcomers in space exploration

In this section, we first visit the prerequisites of an ambitious program for space exploration. Then we discuss the major difficulties that an aspiring nation will face. Some advantages that the newcomers will enjoy are the subject of the following sub-section. Finally, we

discuss some possible ways that these nations can contribute to space exploration with examples in the next section.

4.1 Prerequisites

Of course, certain prerequisites exist for the contribution of a nation to space exploration. The basic capabilities of space technology, including the infrastructure, like clean rooms and environmental testing chambers, human resources, basic know-how of design, assembly and test facilities, are musts. The newcomers that are the subject of this work are assumed to have already reached that level.

Another important prerequisite is the existence of strong universities and research institutes that can support scientific missions. This requirement is closely related to the science and technology policies and the R&D expenditures of the country, as well as strong GDP levels.

Per the Science Citation Index, many of the newly industrialized and developing countries are getting stronger and investing more to support their scientific and academic basis, which will be the main source of space science and technology studies.

According to a report published by the Royal Society in London (The Royal Society, 2011), China has acquired a second place ranking in the number of articles published in international science journals, and has already overtaken the UK. By 2020 China is positioned to take the leading position from the US. While the top 10 is still dominated by the major Western powers and Japan, who are producing high quality publications and attracting researchers to their world class universities and research institutes, their share of published research papers is falling and China, Brazil and India are coming up fast. While Western EU Countries and Japan produced 59 percent of all spending on science globally, their dominant position is nevertheless slipping against the newcomers.

The Royal Society report also states that China improved from sixth place in 1999-2003 (4.4 percent of the total) to second place behind the US over the years 2004-2008 (10.2 percent of the total), thus overtaking Japan. Newcomers like Iran and Turkey are also making dramatic progress. Turkey's improved scientific performance has been almost as dramatic as China's. The country increased its investment in research and development nearly six-fold between 1995 and 2007, and during the same period, the number of researchers increased by 43 percent.

The fact that the newcomers that have successful space programs are at the same time the countries whose share of scientific publications is increasing is not a coincidence. To summarize, achieving a strong scientific background relies on strong government funding for R&D and a sustainable budget for the universities. Newcomers lacking in a strong scientific and technological basis will have little chance to achieve success.

Key driving forces for the sustainability of space activities in the long term include, political will, public support, competitive pressure from neighbouring countries (Taiwan, Japan and Iran examples), in addition to basic capabilities and a strong scientific background. If we consider the emerging countries mentioned in the previous section, creation of public support shall be supported with providing employment opportunities for the new generation, supporting scientific opportunities for universities and institutes, answering daily needs like disaster management, remote sensing, telecommunication,

commercialization of developed technologies and funding spinoffs to step forward for industrialization.

Organizational capabilities are also important to succeed in space programs. An effective and efficient organization that can be kept out of daily political melee should coordinate all the efforts.

4.2 Difficulties

Although the world has seen an increase in space technologies and applications so far, many developing and newly industrialized countries have been facing several problems including “inadequate information, high cost, difficulty of accessing the data, no involvement of end users, sustainability of transferred technologies and lack of commercialization of space activities” (Noichim, 2008), limited availability of highly reliable, high performance, electrical, electronic and electro-mechanical components to trade restriction imposed by export licenses, agreements safe guarding technology, and US International Traffic in Arms Regulations (ITAR) and other countries’ export licenses, technology safe guard agreements and dependency on other nations for launch campaigns. These generic and common problems are the basic hurdles in the race to space of newcomers. In this subsection, we summarize the most important obstacles to for space exploration missions for newcomers.

4.2.1 Access to space

Access to space is one of the major problems for newcomers to achieve orbital success. There is no doubt that certain countries may develop state of the art tools, payloads and spacecrafts, but only limited number of them are able to reach the orbit with their own will and abilities. Russia, the US and France are the main actors in this field and they inspired Asian nations, starting from India, China, Japan and South Korea in the area of space exploration. The first three have already reached sustainable, self reliant and self sufficient launch vehicle development programs to guarantee the access to space. However, the highly elliptical orbits necessary for outer space explorations may require more than the available capabilities of low earth orbit launch. Figure 4 summarizes the countries with the orbital launch capabilities, whose launch vehicles confirmed to reach orbit.

The experience of South Korea is a good example of difficulties of obtaining this capability. South Korea’s Korean Space Launch Vehicle (KSLV) program was initiated with the cooperation of the Russian Federation and South Korea in 2004 as a part of a turn-key contract for the delivery of first stage engine of a launch vehicle, launch site and necessary services. South Korea contributed to the program with the second stage of the launch vehicle and test satellites. The KSLV is the first carrier rocket that made its maiden flight from Naro Space Centre in South Korea in 2009, followed by a second flight in 2010. Both flights dramatically ended up in failure and resulted in the loss of two technology demonstration satellites, moral, public support, motivation and public financing.

Today, Asian nations like Indonesia, Taiwan, Iran and Malaysia have sounding rockets or low earth orbit launch vehicle programs. Although Indonesia works with Ukraine and Russia while Malaysia works with Japan and Russia, there is a long way to go before these rockets serve space exploration missions.

Hence, most of the newcomers are dependent on launch vehicles from other countries. Dedicated launches for these missions are very costly and shared launches for the required peculiar orbits are very difficult to arrange and manage.

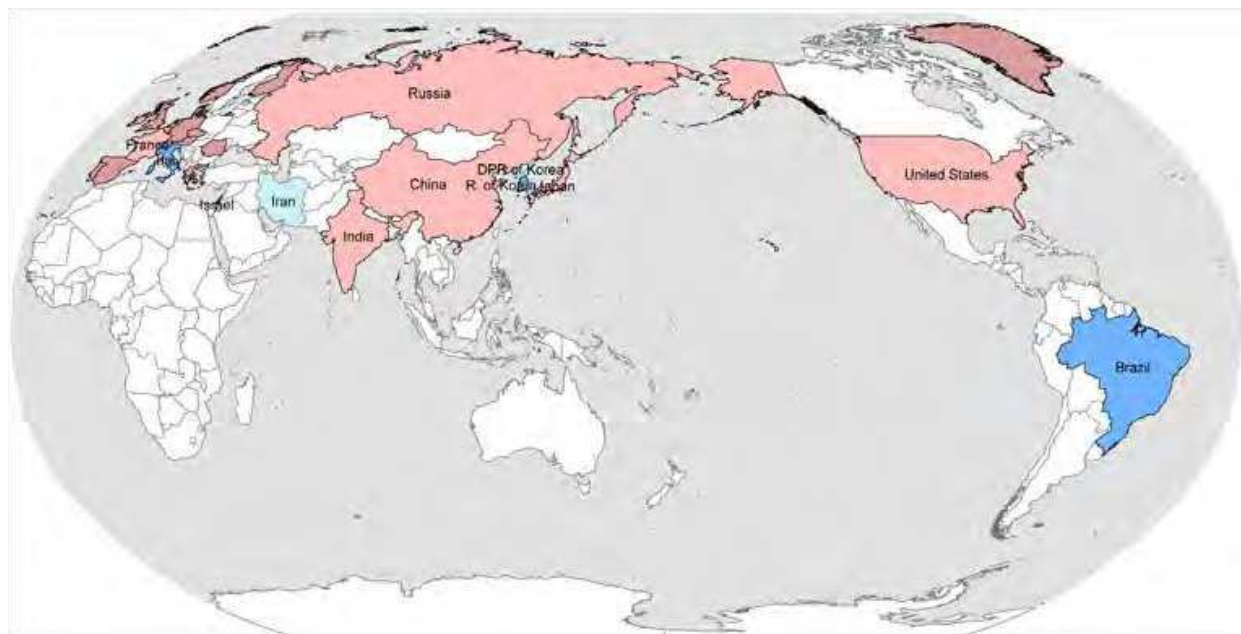


Fig. 4. Space Launch Capability. Pink: countries capable of launch technologies, Dark red: ESA, light blue: Countries with limited launch capability, blue: Countries thought to be very close to performing the first successful launch.

4.2.1.1 Important orbits for space exploration missions

The elliptical orbit is the primary way to access the Moon, Mars and beyond as they can provide escape from earth's gravity field. Orbits have different classifications from geostationary earth orbit (GEO) to geostationary transfer orbit (GTO), from Medium Earth Orbit (MEO) to Moon Transfer Orbit (MTO) or Earth-Moon Transfer Orbit (EMTO).

Low Earth orbit (LEO) is geocentric orbits ranging in altitude from 0–2,000 km and is the suitable orbit altitude for remote sensing satellites, suborbital launches, mobile communications, zero-g and biological experiments. LEO access is relatively more common than the others and number of LEO launch rockets and the number of countries who could achieve LEO access is more common.

Geostationary orbit (GEO) is the orbit around Earth matching Earth's sidereal rotation period. All geostationary orbits have a semi-major axis of 42,164 km. And this orbit is suitable for geostationary communications for TV, radio, telephone signals and meteorology applications while geostationary transfer orbit (GTO) is used for transferring communication satellites from LEO to GEO. GTO is an elliptic orbit where the perigee is at the altitude of a Low Earth Orbit (LEO) and the apogee at the altitude of a geostationary orbit. GEO launch vehicle is relatively limited than LEO launch vehicle and countries who could achieve this success are; US, Russia, China, France and India.

There are other certain orbit types that are used for outer space exploration. High Earth orbit (HEO) is the geocentric orbit above the altitude of geosynchronous orbit 3,786 km and

suitable for escape manoeuvre via apogee kick engine and provides launch to solar system destinations except the Moon. They are also used for satellite radio applications by the US and communication purposes by Russia during cold war-era. HEO access is harder to achieve due to several cutting edge technologies onboard the launch vehicle and so far only Russia, US and Japan managed to launch satellites to HEO orbits.

To be able to reach the Moon, Moon Transfer Orbit (MTO-Hohmann transfer orbit) is generally used. In orbital mechanics, the Hohmann transfer orbit is an elliptical orbit used to transfer between two (typically coplanar) circular orbits. The orbital maneuver to perform the Hohmann transfer uses two engine impulses which, under standard assumptions, move a spacecraft in and out of the transfer orbit. This maneuver was named after Walter Hohmann, the German scientist. MTO orbit is achieved by Indian, Russian, Japanese, Chinese and US launch vehicles so far.

4.2.1.2 On board propulsion for space exploration

On-board propulsion is required to make necessary manoeuvres from the initial orbits for space exploration missions. Interplanetary travel requires new propulsion systems and new ways of generating power (Czysz, 2006). Although nuclear energy could be an alternative and unique way to discover our solar system and beyond, only Russia and the US have achieved this technology so far. This is a definitely limiting factor for newcomers wishing to pursue exploration of Mars and beyond. To be able to design satellites reasonably small to fit in launch vehicles, I_{sp} , the specific impulse, must at least double. However, a limiting factor for using chemical sources starts at this point and they do not permit benefitting from commonly used cold gas propulsion or hydrazine systems to be employed on board, as these chemical sources will finish much earlier than providing necessary thrust.

For outer space transportation, the ultimate alternative could be ion propulsion or Hall Effect thrust, which is a mature and qualified technology. This technology is safe, peaceful and easily be accessible for at least some of the newcomers and attracts the way for outer space exploration.

However, another major problem is maintaining the temperature of the satellite battery and other subsystems as the spacecraft grows increasingly distant from the Sun and the heating effect of the sunlight to approach other space objects like Mars. It is clear that a simple way will have to be discovered by scientists to solve this problem so that reliance on nuclear reactors for propulsion is terminated. Otherwise, all nations will remain dependent on the nuclear superpowers, which is another limiting factor for newcomers to pursue outer space exploration.

4.2.2 Funding

The next obstacle is the difficulty to convince politicians to allocate sufficient funds for space exploration. The funding of costly projects like telecommunication satellites, high-resolution earth observation satellites, or launchers is easier to justify on economic, strategic or security-related grounds. Although space exploration projects can be defended for their technological returns in the long run, spill-over effects, reversing brain-drain and promoting science, and their positive psychological effects on the public, securing the necessary funds is not easy. Most space exploration missions are extremely costly, for example, NASA's

recent mission to Jupiter costed 1.1 billion US dollars. Most newcomers have difficulty in fronting that kind of expenditure. Even the Indian Space Agency, ISRO, who has had tremendous success in their space programs, is having difficulty to defend budget allocation for future Chandrayaan programs.

4.2.3 Dependency

Another basic problem for newcomers seems to be the dependency on other nations for specialized spacecraft technologies, such as radiation tolerance, propulsion technologies for complicated orbital manoeuvres, geographic distribution of ground stations networks, launchers, and the employment of international standards that are different than national ones. Unfortunately, many of these technologies are protected by national or well known international safeguards. Once a qualified space technology is protected and distribution is limited, newcomers are compelled to depend on other components, which may be less reliable or result in reduced performance, thereby slowing progress and increasing the risk in newly designed spacecraft.

4.2.4 Advantages

Although the space industry cannot be considered to be labour-intensive, the cost of recruiting the necessary high-skilled staff is an important component of space program costs. In developing and newly-industrialized countries, the labour costs of the engineers, scientists and other technical people are considerably lower compared to equivalent workers in developed countries.

In (Leloglu, 2009), the advantages of latecomers in space technologies have been discussed in detail. To summarize, some of the advantages are the ability to exploit literature published based on the difficultly-acquired experience of others; the accessibility of space equipment from various suppliers, which facilitates integration of space systems; a rich spectrum of technology transfer options; and developments in nano- and micro-satellites that enable the acquisition of basic capabilities with relatively modest resources.

5. Opportunities for space exploration

The most important mechanism for overcoming difficulties encountered along the way to realizing space exploration missions is international cooperation. Countries may share the costs and risks of expensive and ambitious projects. Partners may also benefit from complementary capabilities and geographic distribution of available ground stations. Another advantage pointed out by Petroni et al. (Petroni et al., 2010) is that collaboration enriches the capabilities of both sides by “exchange of knowledge and skills”. Even the big space powers collaborate on several aspects of space explorations. For example, China and Russia worked together to explore Mars via the Phobos-Grunt program. While Russian Phobos Grunt is supposed to go to Mars, it would also provide a launch and transportation opportunity for the Chinese Mars orbiter Yinghuo-1. However, the satellite failed to leave Earth’s orbit after launch.

Another mechanism for cooperation in space is the joint collaboration between a newcomer and an experienced agency. Taiwanese Formosat satellite project is a good example of this kind of cooperation. Formosat-1 and 2 spacecrafts and their payloads were developed jointly by the Taiwanese National Space Organization (NSPO), US and European suppliers

and launched by US launch vehicles in 1999 and 2004, respectively. Formosat-3, aka, COSMIC (Constellation Observing System for Meteorology, Ionosphere, and Climate) was launched in 2006 and consisted of six spacecrafts. Taiwanese and US agencies not only shared the cost but also shared the data gathered from these ionospheric research satellites. On this project, Taiwan has mainly focused on payload development and benefitted from reliable, qualified US launch vehicles and the widely distributed US ground station network. Although only one of the satellites remains active today, the technology that Taiwanese institutions developed and hands on experience for NSPO employees paved the way for the Formosat-5 program, involving joint Taiwan-Canada-Japan collaboration and also resulted in an efficient use of resources.

The cooperation between ESA and other countries is another example. ESA has relationships with non-European countries such as Argentina, Brazil, China, Japan, India, Canada, US and Russia. Argentina is different from the others with respect to its space capabilities, however, the country benefits from its geographical location and supports ESA's future deep space missions to Mars and beyond. In return, ESA provides joint training courses for Argentinean students in various areas.

The EU Framework Programs is another example. The 7th Framework Program (2007 - 2013) is open to non-EU countries such as Turkey, Israel, Switzerland, Norway, Iceland, Liechtenstein, Croatia, Macedonia, Serbia, Albania, Montenegro, Bosnia & Herzegovina and the Faroe Islands. The FP7 Space Work Programme covers areas like "Space Exploration" and "RTD for Strengthening Space Foundations" (European Union, 2006). If these countries could succeed in becoming partners to space projects, in theory they would also be able to jointly develop key technologies. However, in practicality, it is not easy to take part in such projects due to the requirements of space heritage for products and compatibility with mainly ESA driven international standards such as The European Cooperation for Space Standardization (ECSS) and Consultative Committee for Space Data Systems (CCSDS).

Regional cooperation is another type of cooperation for which ESA is a very bright example. Two such initiatives in Asia are the APRSAF led by Japan and APSCO led by China. In these cases, at least one nation possesses launch vehicle capability and existing distributed ground station networks are needed.

Another example is International Space Exploration Coordination Group (ISECG) formed by 14 space agencies, namely Italian, French, Chinese, Canadian, Australian, US, UK, German, European, Indian, Japanese, Korean, Ukrainian and Russian space agencies in 2007. ISECG aims to formalize the vision for future robotic and human space exploration to solar system destinations, starting from the Moon and Mars, based on voluntary work approach and exchange information regarding the named space agencies' interests, plans and activities in space exploration with their "The Global Exploration Strategy: The Framework for Coordination" approach. ISECG is a good model for newcomers to pursue the way ahead for joint outer space exploration and be part of the coordination, basically to eliminate the duplication in this area.

On the other hand, regardless of the composition or existence of partners, there are technological solutions that can reduce costs or increase launch options. An important revolutionary mission is SMART-1, an ESA-funded satellite developed by the Swedish

Space Corporation. Using the French-made Hall effect thruster, the satellite could reach lunar orbit in more than one year from its initial geostationary transfer orbit. The Hall Effect thruster is in fact relatively old technology and has been in use since the 1960's in Russia. Although this technology is generally used in geostationary telecommunication satellites for station keeping manoeuvres, Smart-1 is one of the first examples of using the Hall Effect thrusters out of a geostationary earth orbit. Smart-1 has about 80 kg on board xenon and has managed to reach a total of 3.9 km/s ΔV in 5000 hours of operation. The spacecraft has demonstrated a cheaper, safer (with respect to hydrazine propulsion) version of space exploration by means of non-conventional propulsion technologies. Some standards designed for deep space communication that enable the reliable transfer for large amounts of satellite data over a very limited-bandwidth communication link by CCSDS, an international organization were also successfully qualified by Smart-1 and enabled future deep space missions to transmit larger volume of data back to earth from a distance of thousands and millions of kilometres away. In the final analysis, this mission provided very valuable experience to ESA and paved the way for the future, long, relatively cheap and safer missions to the Moon, Mars and beyond. The equipment qualified on board Smart-1, such as infrared and X-ray instruments, were also used in Indian lunar mission, Chandrayaan-1. Also, this mission enabled ESA to sign cooperation agreements with China, India, Japan, Russia and NASA regarding joint lunar programs.

Another groundbreaking and extraordinary example of a relatively low-cost space exploration mission to Mars was Beagle-2. The Mars Express Orbiter carried Beagle-2 to the orbit of Mars. Although the mission failed, it had the possibility of success due to strong support from ESA by means of ground stations, NASA by allowing a co-passenger on the mothership Mars Express, and Russian Space Agency with launch service support. Again, international collaboration was the only feasible way for this kind of space exploration mission. This was facilitated by a consortium set up by the project management office, and included universities and industry. After the development phase started, a European defence and space conglomerate took over the responsibility for managing the entire program. Thereafter, one of the most outstanding financial support campaigns was organized in which British pop music artists and painters were called upon to increase the awareness of the project in the public, mainstream media, and schools. In fact, the beacon signal of the spacecraft was composed by a British pop music band and several subsystems, including the cameras, were polished by a British painter to attract the attention of mainstream media. Given the enormous public support, the main ground control station was kept open to public to show where the funds had been used. Although the mission failed at the end, the Beagle-2 was used in several science fiction movies to strengthen the image that the spacecraft actually reached the planet Mars. Nevertheless, the Beagle-2 project continues to serve as a valuable example for how support from popular artists can be used to increase public awareness. For the first time, financial donations from ordinary citizens of all ages, wealth, and occupation were used to fund a space project, and as such Beagle-2 will always remain a unique project development success story.

In keeping with the low cost theme of the mission, the control software was the first of its type deployed on a laptop and several on board systems, which were not designed and manufactured with space qualification criteria, procured from the industry; similarly, mass spectrometer was provided by University of Leicester and University of Aberdeen.

These examples show that innovative solutions can be possible for the purpose of space exploration missions with limited resources. Newcomers can find novel creative solutions to realize their missions by optimizing their capabilities and cooperation opportunities. Moreover, cube-satellites and small satellites provide low-cost experimenting opportunities for scientific instruments, solar sails, formation flight technologies, tether tests and similar technologies.

As indicated by Petroni et al., to create an innovative mission to decrease the costs or increase the reliability, one important path that needs attention is to transfer technologies from non-space sectors and from the universities. (Petroni et al., 2010)

Another crucial way to communalize outer space exploration is to benefit from distributed, common ground stations and communication systems that are designed according to CCSDS protocols and standards to collectivize different systems can work in harmony and communicate with each other, especially on deep space missions, where spacecraft is seen commonly on the other side of the earth and throughout the day, forcing owners to use deep space ground stations owned by other countries.

For example, integration of Chinese, Indian, Russian, European and US Deep Space Networks via CCSDS standards could facilitate the achievement of distributed and sustainable outer space exploration, benefitting all mankind and eliminating duplication of individual efforts and unnecessary spending.

6. Conclusion

Space exploration has been a privilege for a few developed countries during most of the space age; however, as more nations get involved, space is becoming increasingly democratized. This has been made possible by technological developments as well as political changes at the global level. As the space programmes of nations new to space race advance, investments in space science and space exploration have increased, and, as a result, even more countries are getting involved. Although these new nations can benefit from the latecomer's advantages, they still need to overcome many obstacles to be able to contribute meaningfully to space exploration. There is a strong relationship between national science and technology policies, and advancement in space science and technology. Hence, investment in R&D backed by sound policies is a must for a successful program. Newcomers also need to seek international cooperation with strong space agencies and/or peers to share risks, costs and create synergy. Rather than imitating the missions of pioneers, they may try to find novel innovative solutions enabled by new technologies and an increasing number of international players and missions. Finally, aspiring nations should prepare for the future by following a sound but flexible plan.

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The all-encompassing term Space Science was coined to describe all of the various fields of research in science: Physics and astronomy, aerospace engineering and spacecraft technologies, advanced computing and radio communication systems, that are concerned with the study of the Universe, and generally means either excluding the Earth or outside of the Earth's atmosphere. This special volume on Space Science was built throughout a scientifically rigorous selection process of each contributed chapter. Its structure drives the reader into a fascinating journey starting from the surface of our planet to reach a boundary where something lurks at the edge of the observable, light-emitting Universe, presenting four Sections running over a timely review on space exploration and the role being played by newcomer nations, an overview on Earth's early evolution during its long ancient ice age, a reanalysis of some aspects of satellites and planetary dynamics, to end up with intriguing discussions on recent advances in physics of cosmic microwave background radiation and cosmology.

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