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*Review Article*

# Space Activities and the Simultaneous Development of the Economy in Türkiye

Nedim SÖZBİR [a], Murat BULUT [b,*], Şenol GÜLGÖNÜL [c], Lokman KUZU [d,e], Osman DUR [f],

[a] *Rector, Düzce University, Düzce, TÜRKİYE*
[b] *Department of Mechanical Engineering, Faculty of Engineering, Düzce University, Düzce,, TÜRKİYE*
[c] *Electrical and Electronics Engineering, Faculty of Engineering, Ostim Technical University, Ankara,, TÜRKİYE*
[d] *Electrical and Electronics Engineering, Faculty of Engineering, Karabuk University, Karabuk, TÜRKİYE*
[e] *Turkish Space Agency, Ankara, TÜRKİYE*
[f] *Advanced Technologies, Graduate School of Natural and Applied Sciences, Gazi University, Ankara, TÜRKİYE*
* *Corresponding author e-mail: muratbulut@duzce.edu.tr*
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## ABSTRACT

As space technologies have become an integral part of our daily lives, they have profoundly influenced the course of human civilization since 1957. These technologies have provided humanity with many remarkable insights. Therefore, they have an important role in modern society. Satellite technology is not only vital for military and defence but also for civil applications such as transportation, communication, disaster management, agriculture planning, land, and urban planning. These applications make the space sector an engine of economic growth having advanced and the state-of-the art technology. Technological advances in space continuously benefit the citizens of developed countries. The space economy is defined as all the actions and resources that produce value and benefit to people through exploration, research, knowledge, management, and utility of space. Through satellite communications, navigation systems, earth observation missions, space science and technology research, employment is created, economic growth is achieved, and many industries become more competitive in worldwide economic market. Spinoff companies are born from space activities. In 1994, the Türkiye had its first communication satellite TURKSAT 1B built by Aerospatiale; thus, Türkiye entered the space field being an operator in its region. After millennium, the Turkish space industry has ramped-up by developing its dedicated communication and observation satellites, and their subsystems and creating a launcher system for microsatellites. Türkiye is now developing space technology more comprehensively. This article describes recent developments of space activities and future work in Türkiye. In the article, the strategies in other countries in space technologies are also discussed and suggestions are made for space technology education, development of space economy and regulation of space activities for Türkiye.

***Anahtar Kelimeler:*** *Space technology, space capability, space economy, TÜRKSAT, Türkiye*

# Türkiye'de Uzay Faaliyetleri ve Ekonominin Eş Zamanlı Gelişimi

## Öz

Uzay teknolojileri günlük hayatımızın ayrılmaz bir parçası haline gelirken, 1957'den bu yana insan uygarlığının seyrini derinden etkilemiştir. Bu teknolojiler, insanlığa birçok önemli içgörü sağlamıştır. Bu nedenle, modern

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toplumda önemli bir role sahiptirler. Uydu teknolojisi sadece askeri ve savunma için değil, aynı zamanda ulaşım, iletişim, afet yönetimi, tarım planlaması, arazi ve şehir planlaması gibi sivil uygulamalar için de hayati öneme sahiptir. Bu uygulamalar, uzay sektörünü gelişmiş ve ileri teknolojiye sahip ekonomik büyümenin öncüsü haline getirmektedir. Uzaydaki teknolojik gelişmeler sürekli olarak gelişmiş ülke vatandaşlarına fayda sağlamaktadır. Uzay ekonomisi, keşif, araştırma, bilgi, yönetim ve mekan kullanımı yoluyla insanlara fayda sağlayan ve değer üreten tüm eylemler ve kaynaklar olarak tanımlanır. Uydu iletişimi, navigasyon sistemleri, yer gözlem görevleri, uzay bilimi ve teknoloji araştırmaları yoluyla istihdam yaratılır, ekonomik büyüme sağlanır ve birçok endüstri dünya çapındaki ekonomik pazarda daha rekabetçi hale gelir. Yan şirketler uzay faaliyetlerinden doğar. 1994 yılında Türkiye, Aerospatiale tarafından inşa edilen ilk haberleşme uydusu TURKSAT 1B'ye sahip oldu. Böylece Türkiye bölgesinde operatör olarak uzay sahasına girdi. Milenyumdan sonra, Türk uzay endüstrisi, özel iletişim ve gözlem uydularını ve bunların alt sistemlerini geliştirerek ve mikro uydu için bir fırlatma sistemi oluşturarak hız kazandı. Türkiye artık uzay teknolojisini daha kapsamlı bir şekilde geliştiriyor. Bu makale, Türkiye'deki uzay faaliyetleri ve gelecekteki çalışmalarla ilgili son gelişmeleri açıklamaktadır. Makalede, uzay teknolojilerinde diğer ülkelerdeki stratejileri de tartışılarak Türkiye için uzay teknolojileri eğitimi, uzay ekonomisinin gelişimi ve uzay faaliyetlerinin regülasyonu ile ilgili önerilerde bulunulmaktadır.

***Keywords:*** *Uzay teknolojisi, uzay kabiliyeti, uzay ekonomisi, TÜRKSAT, Türkiye*

# I. INTRODUCTION

Thousands of years ago, people were curious about space and began to wonder about its origins. Many philosophers have observed our solar system and helped shape our current perception of the universe since beginning of the life. They made discoveries and established theories, changing our understanding the universe significantly. After thousands of years dedicated to developing an understanding of the solar system and the universe, scientists went beyond the boundaries of earth and explored space via current technology and engineering [1].

The U.S. space exploration projects commenced in 1954 starting with the Orbiter Project put forward by the armed forces. The project planned to send a satellite into space using the ballistic missile called Redstone, used by the US army. It was rejected by the U.S. president, Eisenhower, because using military technology in a scientific project could be misinterpreted. Therefore, it was decided to develop a launch via a civil program. However, in 1957, after the Soviet Union successfully sent the Sputnik-1 and Sputnik-2 satellites into space, the Orbiter Project had to be revived. Not to fall behind in the space race, the USA gave the ballistic missile agency, within the army, the task of updating the Jupiter rocket, which was produced for military purposes, to carry a satellite into space. A large amount of funds was allocated to national space agencies in the U.S. because there was a huge competition between Russia and the U.S., throughout the Cold War. However, in the 1970s, as the Space Race decelerated and the space market decreased, less funds were allocated to NASA. In response, NASA began exploring and later prioritizing support of markets in the private sector, and then collaborating with private firms on space research. The European Space Agency (ESA) also gave research funds to the private sector. At last, the private space sector was given credence, because it had a high probability for producing revenue and the ability to activate other sectors. Entrepreneurs and private investors have increased in the space sector [1]. Many countries have developed space policies and technologies to grow their national economies. They have shared space technologies in other countries and developed space technology and the economy as well [2-18].

Many scientists and researchers have investigated the economic effects of satellite technology and the industry, new opportunities in space, scientific benefits of space economy, space technology development, spinoffs, benefits of space technology, and space market, etc. [19-30]. The global space economy has grown to be a significant size, with many companies and varied products. Furthermore, the global space economy has become one of the most significant contributors to the global economy, reaching 350 billion dollars in 2017, and is expected to reach 1.1 trillion dollars by 2040 [1].

Today, there is a new space race. Hundreds of satellites are launched into Earth's orbit every year for purposes ranging from communications and the internet to environmental monitoring and border security. In total, almost 6,000 satellites are circling Earth and that number is increasing. The Union of Concerned Scientists (UCS) indicated that 2,666 operational satellites were rotating around the Earth in April of 2020. Of these, only 1,327 satellites belong to the United States. China, the US's closest follower, has only 363 satellites. Satellites are an important part of our modern world, allowing GPS use, the internet access, and the Earth studies. In addition, 1,007 satellites are used for communication services, 446 are used for observing the Earth and 97 are used for navigation/GPS purposes. The purpose and number of commercial satellites is shown in Table 1. In the next ten years, Euroconsult (2019) estimated that 990 satellites would be put into orbit annually. From 2009 to 2018, 2,298 satellites were launched while from 2019 to 2028, 9,935 satellites will be launched. As we compare those periods, the number of satellites in space will increase 332%, meaning that by 2028, there could be 15,000 satellites in orbit. As of now, the number of satellites in space has increased 600% since 2012 from 994 to approximately 6,000 [31].

***Table 1.*** *Purpose and number of commercial satellites [31].*

| Commercial Satellites by Purpose | Number of Satellites |
|---|---|
| Communications | 1,007 |
| Earth Observation | 446 |
| Navigation / GPS | 97 |
| Tech Demonstration & Development | 87 |
| Other | 9 |
| All Commercial Satellites (including combination) | 1,646 |

The new space race is continuing as SpaceX is planning the Starlink constellation of 12,000 satellites and Amazon also is proposing a constellation. Greater than 50% global operational satellites are put in orbit for commercial use with approximately 61% providing communication for satellite TV and global internet, and 27% providing Earth Observation such as environmental monitoring and border security. Though most commercial satellites are used for communications or Earth Observation purposess, they can also serve multiple purposes. Of all the Earth’s operational satellites, government and civil satellites make up 21%, while military satellites make up 13%. SpaceX is used for missions to the International Space Station (ISS) and the biggest operator of commercial satellites. Part of Space X’s mission is to increase navigation potential and provide worldwide internet from space using 358 satellites launched since April 2020, 22% of all operationing satellites in the world. From August to September 2020, it further launched an additional 175 satellites. Greater than 50% of all functioning satellites are for commercial purposes. With growing constellations and new market entrants, space operators have set their sights on mass connectivity, analytics, and earth monitoring. The satellite operators and satellite numbers of the company is shown in Table 2. Following several launches conducted in summer, SpaceX had sent off enough satellites to encourage the beta version of Starlink, a satellite-based internet service. The new space race also involves small satellites such as cubesats, microsats, and nanosats. With its flock of small EO satellites, Planet Labs now has more than 150 satellites in operation (however, in April 2020, the number exceeded 250). Amazon is also getting ready for space as demonstrated by the approval to dispatch and manage an internet constellation of 3,236 satellites in July of 2020 by the US Federal Communications Commission (FCC) [31].

***Table 2.*** *Satellite operators and satellite number of the company [31].*

| Satellite Owner/Operator | Number of Satellites | Country of Operator/Owner |
|---|---|---|
| SpaceX | 358 | USA |
| Planet Labs, Inc. | 246 | USA |
| Spire Global Inc. | 89 | USA |
| Iridium Communications, Inc. | 78 | USA |

| | | |
|---|---|---|
| OneWeb Satellites | 74 | United Kingdom |
| SES S.A. | 51 | Luxembourg |
| Intelsat S.A. | 51 | USA |
| ORBCOMM Inc. | 35 | USA |
| DoD/US Air Force | 33 | USA |
| EUTELSAT Americas | 33 | Multinational |
| TÜRKSAT | 5 | Türkiye |

The United States, China, and Russia have the greatest number of operationing satellites worldwide. The U.S. and Russia began the space race throughout the 1950s and 1960s. The U.S. manages nearly 1,308 satellites, about 50% of all worldwide satellites, as of April 2020, while China operates approximately 356 satellites. Russia has the third most satellites, 167, while the UK has 138 and Japan has 78 satellites in operation. All others in the world total 627 as of April 2020. Satellites from the US, Russia, China, The UK, and Japan dominate earth's orbit today, collectively, operating approximately 76% of all satellites. International collaboration today allows for ease in launching satellites and space-based science. SpaceX will likely reduce launch costs up to US$6 million per flight, because of the reusable rockets, and in effect, there will be an increase in satellite production in the near future [31].

The US Commerce Department aides in the success of the U.S. space economy in several ways; it studies economic trends in the commercial space market and encourages commercial financing and insurance for the space sector. In 2020, 352,000 jobs were created or saved as a result of $21.6 billion in NASA funding. The US Government began seeking the well-being of the public, through investing in practical outcomes via the space programs. Scientific and socio-economic benefits to society continue today through space travel and space exploration. NASA's budget for 2020 was $22.6 billion, 0.48 % of the $4.7 trillion the United States planned to spend in 2020. Overall, the U.S. NASA budget has been close to US$650 billion [32].

In this paper, Turkish space technology, space economy, and economic benefits of Turkish space activities were investigated.

# II. SPACE TECHNOLOGIES AND ITS BENEFITS TO THE WORLD

Space systems have seriously affected modern society more than ever. The economic development of space systems is on the rise because they are increasingly important in satellite technology for navigation, communications, meteorology, and Earth observation. These days, space technologies are also a source for economic growth in agriculture planning, disaster management, medicine, land monitoring, transportation, and urban planning [33]. Public and private investors around the globe are also attracted to the space sector because of the potential for innovative sources of economic development.

Space technology has strategic importance in the world. The space industry has grown steadily recently. The global space sector encompasses a state-of-the-art technology niche with a complex composition, employing more than 900,000 people worldwide in 2013, including public administration (space agencies, space departments in civil and defence-related organizations), the space manufacturing industry (building rockets, satellites, ground systems), direct suppliers to the industry (components), and the wider space services sector (mainly commercial satellite telecommunications). However, people employed by universities and research institutions are not accounted for in these numbers, and they make up a large portion of the R&D, because they receive public contracts and initiate much of the space sector’s research [33]. Today, the space sector is rapidly developing in the world, employing approximately 1,000,000 people. In Türkiye, approximately 1,000 people are employed in the space sector and it includes public administration, manufacturing, suppliers, and service sectors. Space technology research activities, its impact on a growing nation and its society requires understanding space capability, activities, and applications.

Because satellite technology is used in navigation, communications, meterology, and earth observation, space systems are vital for the function of today's society, their strategic order, and their economic growth. Space technology influences agriculture planning, disaster management, medicine, land monitoring, transportation, and urban planning. Because there is an abundance of applications of space technology, there are many opportunities for economic growth within this sector. Even with the recent economic crisis, there have been ample funds for global space programs compared to other sectors, despite space programs frequently having a stigma of being expensive.

Space activities have an important impact on everyday life and society such as GPS on mobile phones. Other well-known uses of space technology include use in telecommunications and National Security. Space activities have provided societal benefits such as bringing communication and education to inaccessible areas, and information and entertainment to large numbers of people. Economic impacts can be categorized in many forms: cost savings, new products, dynamic savings, new values, lower costs for environmental management, health, social services, outcomes, and national economic growth [33].

Satellite manufacturing, launch services, ground stations, and related equipment make up commercial space infrastructure and related industries. Commercial space products and services include, satellite broadcasting, communication, earth observation, geolocation, and global navigation equipment and services. Global navigation equipment a services is one of the space industry's fastest- growing sectors. Design, assembly, and integration of spacecraft systems are dispatched to governmental or commercial users and include: telecommunications and earth observation satellites, launchers, and human-rated capsules. There are four groups of people that encompass the space sector. The first group, carries out the design, assembly, integration, and manufacture of major subsystems, such as satellite structures, propulsion subsystem, power subsystem, and payloads. The second group manufacturers equipment that is assembled in major subsystems. The third and fourth groups produce components and subassemblies that, specialize in the production of specific electronic, electrical and electromechanical components, and materials [33].

The space sector has adopted the "upstream" and "downstream", the same business terms that are used by other industries. Upstream occurs when objects are sent into space and when space is explored. Downstream work occurs when the research and technology gained from upstream is applied to a number of different sectors [34,35]. Fig. 1 shows the space value chain concept [35].

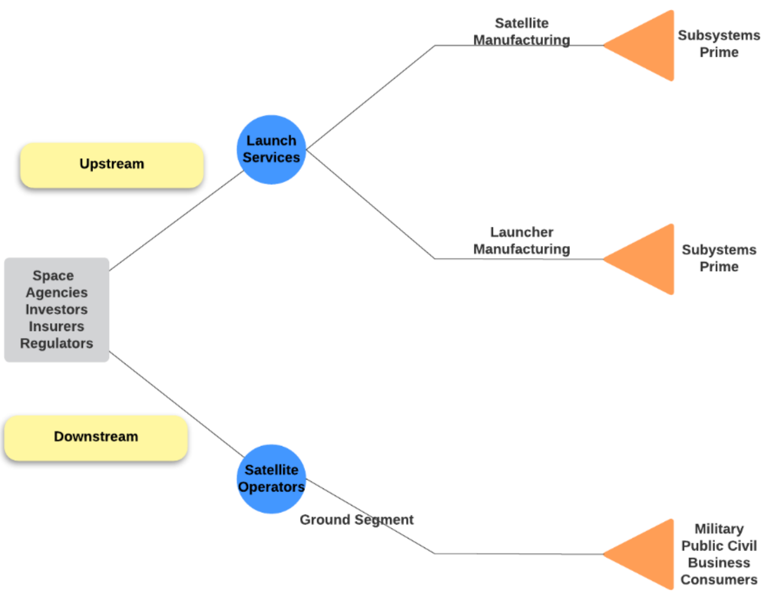

***Figure 1.*** *The space value chain concept [35].*

Government agencies and commercial firms are supplied infrastructure by the satellite industry, which flows from upstream to downstream to the end-users, along the value chain. Space-based services that rely on satellite technology are delivered along the satellite value chain, and includes diverse stakeholders at five stages of the chain [35]: The first level contains government agencies that provide funding for space technology research and development for their sole use or use in conjuction with partners. Most government-funded R&D projects are rare and are only found in a few countries. The second stage includes the space industry (upstream), or those individulas who design and manufacture space systems and their launch vehicles. The third group is the satellite operators who own the satellite systems and market their capacities to the service providers (downstream). The service providers deliver communications, navigation, and geographic formation services to the end-users by incorporating the satellite signal into multiple solutions. The fourth level contains the ground segment and terminal suppliers, who design and deliver a plethora of software and equipment geared toward managing satellite infrastructure and accessing services by the users. Customers also can be found along the value chain. The last group are from governmental (civil/military) or commercial (business or customer) sectors who do not request the satellite technology. Rather, they are interested in solutions geared towards their needs. For example, they might request better communications, navigation, or geographic information services.

Because of scientific and technological innovations, space applications are more accessible and can cultivate social and economic growth especially for developing countries. In fact, there is gradual increase in countries from both the private and public sectors involved in international space activities due to te increased importance of and the various domains affected by space applications in every day life. Finally, the space value chain creates socio-economic impacts from space investments [33].

The organization and scope of work of the space agencies can differ across various countries but a well-coordinated national space activity is important. Governments have direct, concrete, and significant involvement in space activities. On the other hand, the private sector may not be as involved in space activities due to the high costs, the long time to obtain a reasonable return on investment and high risk. Governments may support space activities in many ways including providing funds to finance the research, coordinating researchers and the development of the tasks, implementing policies, creating regulation and laws that allow space development and sustainability, international collaborating, and monitoring of market and development. Only Space agency can build an efficient collaboration. A partnership between industry, government and university is created by establishing the ideal situation that accommodates both space-related industry needs and encourages space-based research. The Space Agency establishes the main goals and specific objectives based on its national program and strategies. The Space Agency priorities focus on national priorities, driving industry growth, creating jobs, developing policies, and laws, international relations, developing national skills and space expertise, following an educational path, and university programs [33].

# III. SPACE ECONOMY IN THE WORLD

Space economy is the use of all activities and resources while creating value and benefits for people amid exploration, researching, understanding, management, and use of space. In space manufacturing, satellite operations and other consumer activities have been the central activities of the space industry have been derived from governmental research and development. Space-related outcomes include all public and private factors from the development, provision, and use of scientific information from space-based products, services, and space research. The main parts of the space economy include in manufacturing, services from satellite operator and consumer services. The space manufacturing supply chain includes many different individuals involved in the production of space systems and relies on institutional civil and military funding. The space economy has become important for high-tech innovation, commercial opportunities, and strategic purposes [33].

Recently, there has been a boom in the space that has been driven by topics related to climate change, security, and telecoms. For example, there is a growing relationship between space and climate change, increased capital formation, mitigating orbital debris, space and security and telecoms a near-term focus [36,37].

Many economists and experts have predicted that the size of the space economy will be approximately $3 trillion in the next couple of decades which will stimulate economic growth and will be driven by space products and services including: launch vehicles, ground systems, new capabilities, businesses. These also include other products, and services from space technologies and spinoffs from space programs [1].

Fig. 2 shows an overview of the 2016 value chain for a commercial satellite. Fig. 2 includes commercially active companies with greater than or equal to one operating satellite or satellite developed, and are satellites at least 50 kg. There are 30 space industry companies (as integrators) having $ 4.9 billion economy in total where as 50 satellite operators generate $14 billion. There are 10 launcher companies with $2.5 billion market. The remaining 5000 other companies shares $250 billion of the commercial satellite value chain [35]. The main segments of the space economy are satellite services and ground equipment. The latest research indicates that the U.S. government is the largest worldwide investor in space programs, while China, Russia, France, and Japan follow in descending order. The U.S. spent $40.9 billion or 58 percent of the world market on space programs in 2018 which was, down from 75 percent of the world market in the early 2000s. China's $5.8 billion budget is the second largest in the world, using these funds to commercialize and internationalize its space sector. Russia's budget has been depleted significantly since 2013, while France has the highest national budget, overtaking Japan with the fourth-largest government - funded program in 2018 [36-39].

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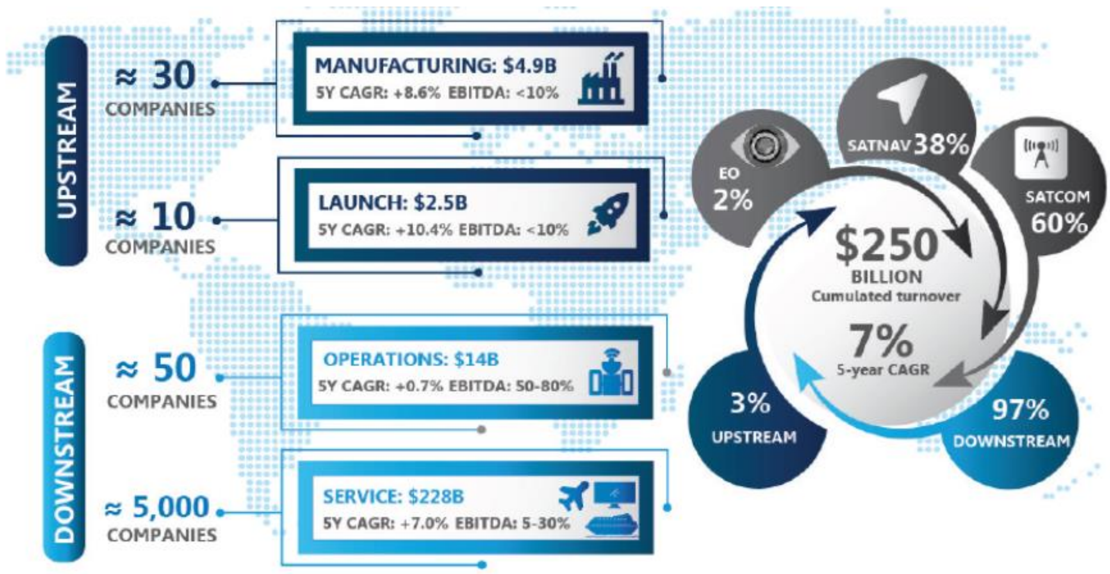


***Figure 2.*** *Overview of the commercial satellite value chain in 2016 [35].*

Fig. 3 shows the commercial satellite revenues in 2018. The industry company (satellite manufacturing) economies are $ 4 billion. The satellite operator economies are $14 billion. The launcher company economies are $1.4 billion. Ground economies are $ 3 billion. Services economies are $276 billion. Upstream is $8 billion, downstream is $290 billion and total revenues are 298 billion in 2018 [38].

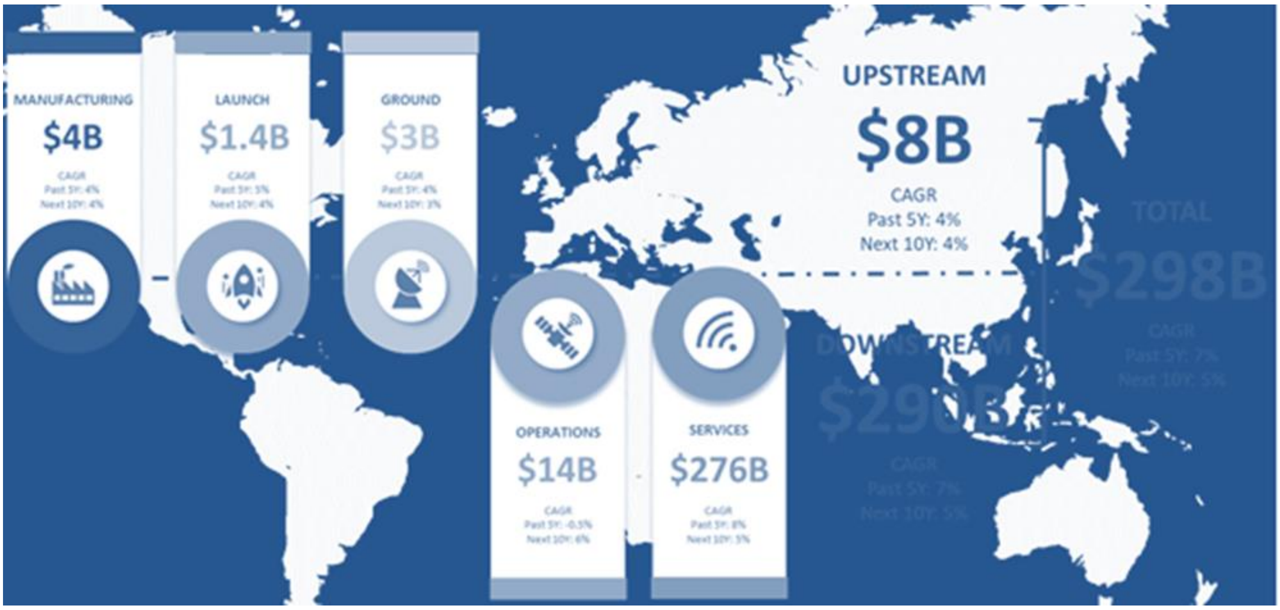


***Figure 3.*** *Commercial Satellite Revenues in 2018 [38].*

The space economy was worth $385 billion in 2020, having total commercial space revenues over $310 billion [39]. Government spending remains unaffected, despite the Covid-19 global pandemic impacting some parts of the commercial space market. In fact, Euroconsult estimates that the consolidated space economy was a record $385 billion in 2020; this include both government space and commercial space investments. Compared with 2019's $319 billion revenues, commercial revenues in 2020 were $315 billion, a 2% decrease. This decline in revenue was partially a result of the Covid-19 pandemic that affected particular commercial markets, such as satellite communication sub-segments markets with high mobility including aero, maritime, offshore oil and gas. Other factors also contributed to the downward trend in commercial revenue in 2020. For example, video-related revenues continued their pre-pandemic decrease in 2020. Government space budgets also added $70 billion to these commercial revenues in 2020 (not counting government payments toward commercial services, because they were considered commercial revenues), 10% higher than in 2019. Government space investment were not impacted, because 2020 budgets were established before the pandemic. However, it remains to be seen how these large government space investments post-pandemic will be affected [39]. Fig. 4 shows Space Economy in 2020.

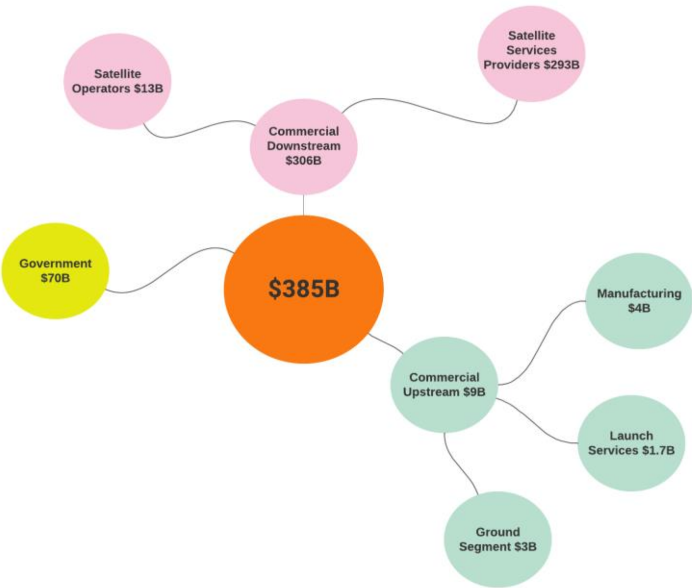

*Figure 4. Space economy in 2020 [39].*

Fig. 5 shows commercial satellite value chains during 15-year evolution. Over the next decade, the commercial space value chain will see a gradual increase, to $485 billion by 2028. The upstream segment, encompassing commercial revenues from manufacturing, launch, and ground equipment is predicted to grow to $11 billion in 2028, from $8 billion in 2018. This is at a growth rate of 4% per year. The downstream segment, was valued at $290 billion in 2018 and encompassed commercial operations and satellite services, which included satellite navigation. It is predicted to increase 5% percent per year to reach $474 billion in 2028 [38].

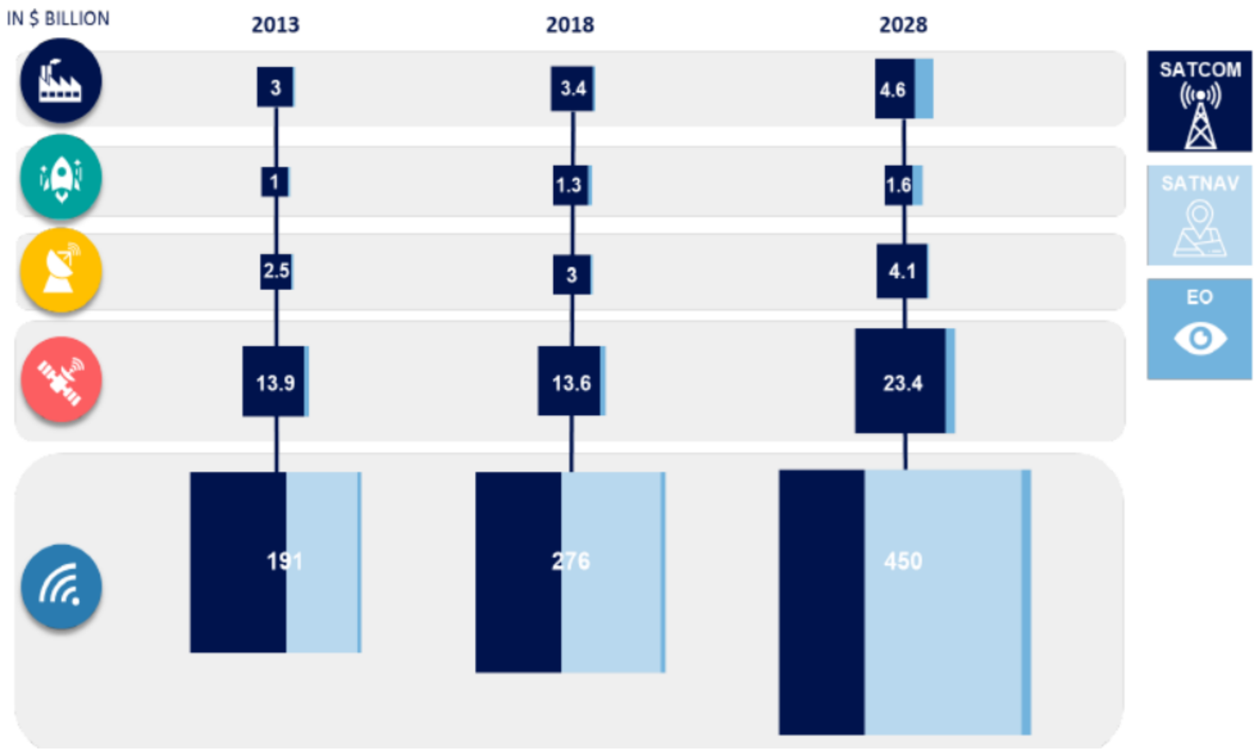


***Figure 5.** The commercial satellite value chains 15-year evolution [39].*

In the beginning of a decade-long growth cycle, total world payments for global government budgets are forecasted to reach $84.6 billion by 2025 form $70.9 billion in 2018. The Euroconsult report presents relevant information on investment priorities according to regions, and it emphasizes this information for space programs in 86 countries. Trusted by hundreds of organizations worldwide, it analyses seven topics areas for each country include: Earth observation, satellite navigation, space science and exploration, space security, communications, launch vehicles, and manned spaceflight. Countries with government spending on space programs greater than $200 Million in 2018 can be seen in Fig. 6 and Table 3 that show the United States allocates the toward its space budget. The latest research indicates the U.S. government is the largest worldwide investor in space programs, while China, Russia, France, and Japan follow in descending order. The U.S. budget spent $40.9 billion or 58 percent of the world market on space programs in 2018 which was below 75 percent of the global market that was observed in the right after the year 2000. China's $5.83 billion budget is the second largest in the world, using these funds to commercialize and internationalize its space program. Russia's budget has been depleted significantly since 2013, while France has the highest national budget, overtaking Japan with the fourth-largest government-funded program in 2018 [36-39]. In 2018, Russia had a budget of US$4.2 billion, France had a budget of US$3.2 billion, Japan had a budget of US$3.1 billion and Germany had a budget of US$2.2 billion on space programs. Global government space budgets are currently in the beginning of a decade-long growth cycle with total world spending forecasted to increase $84.6 billion by 2025 from $70.9 billion in 2018 [35, 38, 40, 41]. More government satellites were launched and more governments took part in launching in 2018. Two new precedents were set in 2018; more government satellites were launched and more governments took part in launching. The Euroconsult report predicts that an average of 150 government satellites will be put into orbit each year for the next 10 years [41].

Fig. 7 shows the government's annual space program spending from 2003 to 2018, and indicates that the United States allocated the most funds toward their space budget among all countries, while China and Russia allocated the next highest budget to their budgets [41].

According to the Euroconsult report, in 2018, 18 countries spent as much as $200 million on space-related activities, including those related to satellites to exploration. Although the U.S. continues to spend the most on space activities, other nations are increasing their budgets. For example, the investment firm space Angels noted that China's government spending on space activities has increased 349% over 15 years, with a total of $22.3 billion being invested in 476 private space companies since 2009 [41].

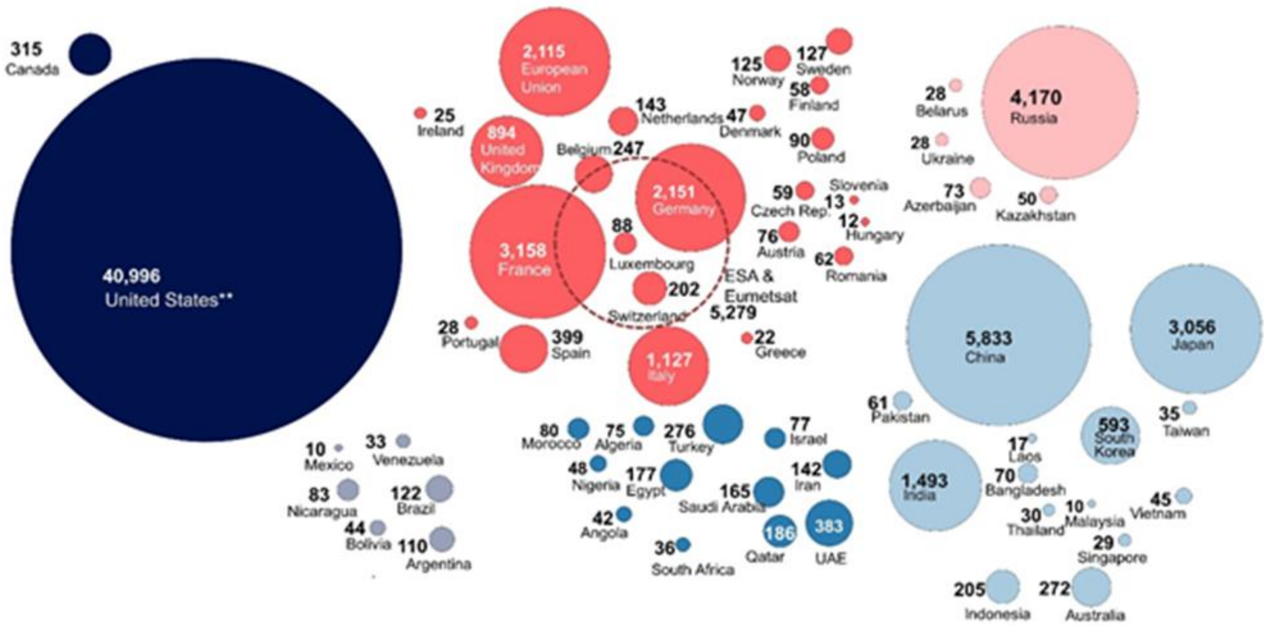


*__Figure 6.__ World government expenditures for space programs in 2018 [40].*

*__Table 3.__ Government spending on space programs in 2018 [41].*

| | Countries | Budgets (US$) |
|---|---|---|
| 1 | USA | 41.0 billion |
| 2 | China | 5.8 billion |
| 3 | Russian | 4.2 billion |
| 4 | France | 3.2 billion |
| 5 | Japan | 3.1 billion |
| 6 | Germany | 2.2 billion |
| 7 | European Union | 2.1 billion |
| 8 | India | 1.5 billion |
| 9 | Italy | 1.1 billion |
| 10 | United Kingdom | 894 million |
| 11 | South Korea | 593 million |
| 12 | Spain | 399 million |

| | | |
|---|---|---|
| 13 | United Arab Emirates | 383 million |
| 14 | Canada | 315 million |
| 15 | Türkiye | 276 million |
| 16 | Australia | 272 million |
| 17 | Belgium | 247 million |
| 18 | Indonesia | 205 million |
| 19 | Switzerland | 202 million |


***Figure 7.*** *Government annual space program spending (adjusted for inflation) [41].*

Ten drivers of the new space ecosystem are satellite launchings, satellite internet, deep space exploration, lunar landing, earth observation, asteroid mining, space debris, space tourism, space research, and manufacturing. The satellite launching industry is one of the largest subsectors and focuses on technology and infrastructure with the hope of sending satellites to near space and low Earth orbit. Satellite Internet firms concentrate on enhanced connectivity using low Earth orbit satellites, wireless broadband, optical communications, and other technologies. Deep space exploration firms establish cutting-edge missions to transport people and supplies to the moon, the surface of Mars, and elsewhere. Lunar landing companies build products and develop infrastructure for missions to Earth's moon. Earth observation firms develop imagining, tracking, and analytics technology for monitoring the weather, climate, maritime data, GPS technology. Asteroid mining disruptors are improving technologies that extract water, rare minerals, and metals from near-Earth asteroids. Space debris firms track and analyze anthropogenic objects orbiting in the atmosphere; such debris needs to be monitored for fear that it could collide with satellites and spacecraft or land on earth. Space tourism firms are exploring possible space trips for private citizens, space explorers, space adventure programs. Space research groups are dedicated to space and space technology research, exploration, and education. Finally, large manufacturing is a sub-segment of the worldwide space economy that designs and develops spacecraft, hardware, propulsion systems, engines, and other technology [36,37,39].

In 2016, the Ground Equipment economy was $113b (33.33%), the Consumer TV economy was $98b (28.91%), the Government economy was $84b (24.78%) and all other economics were $44b (12.98%). In 2040, the Consumer Broadband economy was $95b, (9.02%,) the Consumer TV economy was $117b, (11.11%), the Government economy was $181b, (17.19%), the Internet economy was $412b, (39.13%), the Ground Equipment economy was $196b, (18.61%) and all other economies were $52b, (4.94%). By 2030, the new space economy will result in many benefits. For instance, there will be more advanced technology, as we live life more sustainably beyond Earth. In another example, we will improve Earth observations that assist in protecting and preserving life on Earth. Finally, there will be new jobs, companies, and opportunities as a result of the new space economy. The global space industry is forecasted to be worth more than $1 trillion by 2040, which is an increase from about $350 billion in 2016 [36,37]. The global space economy will triple from US$329 billion in 2016 to $1.1 trillion in 2040

[36,37,40]. Today, the global space economy is roughly a $400B economy, of which about 80% is commercial activity.

# IV. SPACE ACTIVITIES IN TÜRKİYE

Türkiye's early consideration of space activities dates back to the 1990s [42]. Türkiye has designed, assembled and tested the capabilities of space products. Türkiye produces and operates communication satellites, earth observation satellites, scientific micro, and nanosatellites. The Turkish space sector is relatively small. Türkiye's top universities, government organizations, and companies are providing support to these projects. TÜRKSAT R&D Department under the Ministry of Transportation and Infrastructure, TÜBİTAK Space Technologies Research Institute (TÜBİTAK SPACE), TÜBİTAK Marmara Research Center (MAM) TÜBİTAK RUTE, and TÜBİTAK UME under the ministry of Science and Technology, and commercial companies such as Turkish Aerospace Industries, Inc. (Turkish Aerospace), ASELSAN, STM, and CTech, have a solid role in the Turkish space sector. The space economy is estimated to be above 270 million USD in Türkiye. Türkiye is in a good position to leverage existing fortes and investments in space-related activities, and therefore, to benefit the national economy while encouraging innovation. Over the past 10 years, Türkiye has increased potential in the space economy as it has developed its necessary assets and technologies and gained knowledge. Türkiye has shown its capability in many space sectors such as observation satellites, communication satellites, services, and products. Moreover, expanding space activities in Türkiye allow for several valuable contributions to daily life and the national economy, which is demonstrated in the following detailed list of benefits that would be gained from a space program: satellite manufacturing (communications, earth observation, micro, and nanosatellites) and satellites replacement (old with new), increased national economic growth, improved safety, and security in Türkiye, significant innovation opportunities, ensure space capabilities in the future, launching of systems for microsatellites, developed ground systems, and refined operation satellites (communication and observation).

TÜBİTAK SPACE plays a critical role in the Turkish Space Industry. TÜBİTAK SPACE is focused on space technologies and leads several R&D projects for satellite design and manufacturing such as BİLSAT, RASAT, GÖKTÜRK-2, İMECE, and TÜRKSAT 6A. TÜBİTAK SPACE has a clean room with class 10,000, an environmental test facility that can be used for vibration, thermal vacuum, and thermal cycle tests, some other laboratories such as reliability and hall effect propulsion laboratory, and a ground station works at VHF-UHF, S and X bands [43].

In 2001, BİLSAT Earth Observation Microsatellite Project started under the framework of an agreement between SSTL (Surrey Satellite Technology Limited, UK) and TÜBİTAK SPACE. The goal of the BİLSAT project was to initiate, develop and support small satellite technologies in Türkiye and this was carried out in cooperation with SSTL. After the infrastructure for the design was established, there was an increase in small satellites production. Then, a ground station was set-up and Türkiye's inaugural remote sensing satellite, called "BİLSAT," was produced and launched. The designing, manufacturing, testing, and launching phases of BİLSAT were conducted in collaboration between Turkish and SSTL engineers. GEZGİN, and ÇOBAN, two payloads of the satellite in Türkiye, were devised and produced by TÜBİTAK SPACE staff and integrated into BİLSAT. It was launched from Russia on September 27th, 2003, and it was Türkiye's inaugural Earth Observation Satellite. Its resolution is 12 m PAN and 26.7 m RGB. Its total mass is 129 kg and had an altitude of 686 km [44].

RASAT is Türkiye's second earth observation satellite, following BİLSAT of TÜBİTAK SPACE which is a high-resolution optical imaging system and has new modules that were developed by Turkish engineers. RASAT is the first Earth-observation satellite conceived of and produced in Türkiye, has a total mass is 94 kg and an altitude of 687 km. Its resolution is 7.5 m PAN and 15 m RGB. Attitude Control is 3-axis stabilized control. Swath Width is 30 km. Mission Duration is 3 years. Payloads are a new generation flight computer (BİLGE) with a X-Band Transmitter Module (TREX) and a real-time image processing module (GEZGİN-2). It was launched on August 17, 2011 [43].

İMECE is an Earth observation satellite designed and developed by TÜBİTAK SPACE. İMECE program consists of two main project which are İMECE satellite subsystems development project and İMECE satellite platform development project. İMECE satellite subsystem development project was started in 2013 with funding from the Presidency of Strategy and Budget in coordination with the Presidency of Defence Industries. İMECE satellite platform development project was started in 2017 with funding under TÜBİTAK 1007 Programme [44]. İMECE has a total mass is 800 kg and an altitude of 680 km. Its resolution is 0.99 m PAN and 3.96 m MSI. It has an image area of 13.9 km × 16.2 km. Mission Duration is 5 years. It was launched on April 15, 2023. İMECE is shown in Fig. 8.

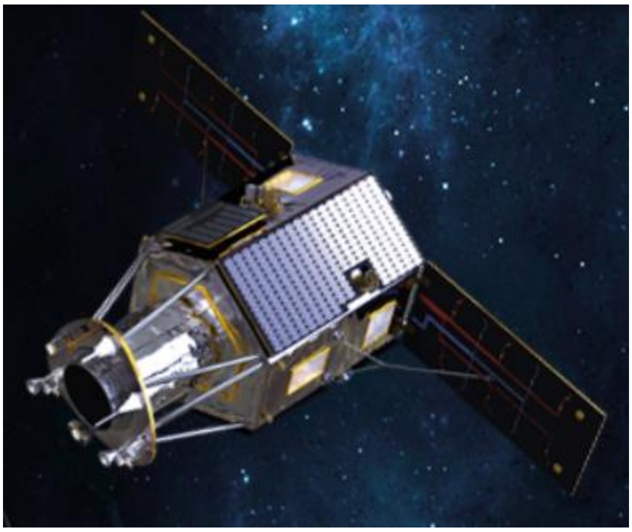

***Figure 8.*** *İMECE satellite developed by TÜBİTAK Space [43].*

GÖKTÜRK-2 has provided the satellite imaging for the Turkish Armed Forces and other governmental institutions and organizations. Through its development, GÖKTÜRK-2 afforded the opportunity to cultivate human expertise and to develop technology and infrastructure in the field of space. The satellite is 686 km from the ground, is set in the sun-synchronous orbit and can take images from any point in the world. The satellite takes a turn around the earth every 98 minutes and every turn passes once in the North and South polar regions. TÜBİTAK SPACE and Turkish Aerospace Industries Inc. created GÖKTÜRK-2 and it was launched in 2012 from China. Its resolution is 2.5 m PAN and 5 m MSI. Its total mass is 409 kg, and its lifespan is 5 years. The satellite's on-board computer and software were produced by Turkish engineers in Türkiye. TÜBİTAK SPACE and The Turkish Aerospace have gained the capability to design and build Earth Observing Satellites [44]. It was launched on December 18, 2012.

Table 4 shows main actors in main space and satellite projects in Türkiye from 1994-2023. BİLSAT, RASAT, GÖKTÜRK-2, and İMECE observation satellites were developed by TÜBİTAK SPACE. TÜRKSAT 6A is being developed by TÜBİTAK SPACE, Turkish Aerospace, ASELSAN and CTECH. Fig. 9 show satellite and indigenous satellite subsystems developed by TÜBİTAK SPACE. Fig. 10 shows BİLSAT, RASAT, and GÖKTÜRK-2 observation satellites specifications.

The GÖKTÜRK-1 program (satellite and AIT center) was coordinated by the Turkish Under Secretariat for Defence Industries. Telespazio was involved in this program, as the prime contractor who built the satellite. Thales Alenia Space (TAS) and other local industrial partners including Turkish Aerospace, ASELSAN, TÜBİTAK BİLGEM, Roketsan, and TR Technology were also involved. GÖKTÜRK-1 satellite was launched from Kourou, in French Guiana in 2016. The Turkish Aerospace established an AIT Center with the Investment of the Republic of Türkiye Undersecretariat for Defence Industries (SSB) and Ministry of Transport and Infrastructure and TÜRKSAT, and it is operated by Turkish Aerospace. This state-of-the-art AIT center enables assembly, integration, and test activities of more than one satellite up to 5 tons simultaneously, using a 3.800 $m^2$ ISO 8 grade cleanroom and specific ground support equipment [43].

***Table 4.*** *Main actors in main space and satellite projects in Türkiye from 1994-2023.*

| **Projects** | **Type** | **Dates** | **Main actors** |
|---|---|---|---|
| TÜRKSAT 1A | GEO Communication Satellite | Launch: 24 Jnauary 1994 | Türksat A.Ş. |
| TÜRKSAT 1B | GEO Communication Satellite | Launch: 11 August 1994 | Türksat A.Ş. |
| TÜRKSAT 1C | GEO Communication Satellite | Launch: 9 July 1996 | Türksat A.Ş. |
| TÜRKSAT 2A | GEO Communication Satellite | Launch: 10 January 2001 | Türksat A.Ş. |
| BILSAT | Remote Sensing LEO Satellite | Launch: 27 September 2003 | TÜBİTAK Space |
| TÜRKSAT 3A | In orbit GEO Communication Satellite | Launch: 13 June 2008 | Türksat A.Ş. |
| RASAT | Earth Observation LEO Satellite | Launch: 17 August 2011 | TÜBİTAK Space |
| GÖKTÜRK 2 | Earth Observation and Reconnaissance LEO Satellite | Launch: 18 December 2012 | TÜBİTAK Space, the Ministry of Defence (SSB) |
| TÜRKSAT 4A | In orbit GEO Communication Satellite | Launch: 15 February 2014 | Türksat A.Ş. |
| TÜRKSAT 4B | In orbit GEO Communication Satellite | Launch: 16 September 2015 | Türksat A.Ş. |
| GÖKTÜRK 1 | High Resolution Earth Observation and Reconnaissance LEO Satellite | Launch: 5 December 2016 | The Ministry of Defence (SSB) |
| TÜRKSAT 5A | In orbit GEO Communication Satellite | Launch: 8 January 2021 | Türksat A.Ş. |
| TÜRKSAT 5B | In orbit GEO Communication Satellite | Launch: 19 December 2021 | Türksat A.Ş. |
| AIT Center | Satellite Assembly Integration and Test Center | One part of Göktürk 1 project, opened on May 21, 2015 | The Ministry of Defence (SSB), Türksat A.Ş. |
| Regional Positioning and Timing System Satellites | Navigation Satellites (LE/MEO or GEO) | In feasibility study phase | The Ministry of Defence (SSB) |
| GÖKTÜRK 3 | High Resolution Earth Observation and Reconnaissance LEO Satellite with SAR Payload | Contract Date: 08 May 2013 | The Ministry of Defence (SSB) |
| Space Launch System Project | Space Launch System | Contract Date: 17 July 2013 | The Ministry of Defence (SSB) |

| | | | |
|---|---|---|---|
| TÜRKSAT 6A | Planned GEO Communication Satellite | Projected Started: 15 December 2014 | TÜBİTAK Space, Türksat A.Ş. Ministry of Transport and Infrastructure |
| IMECE | High-resolution observation satellite | Launch: 15 April 2023 | TÜBİTAK Space, the Ministry of Defence (SSB) |

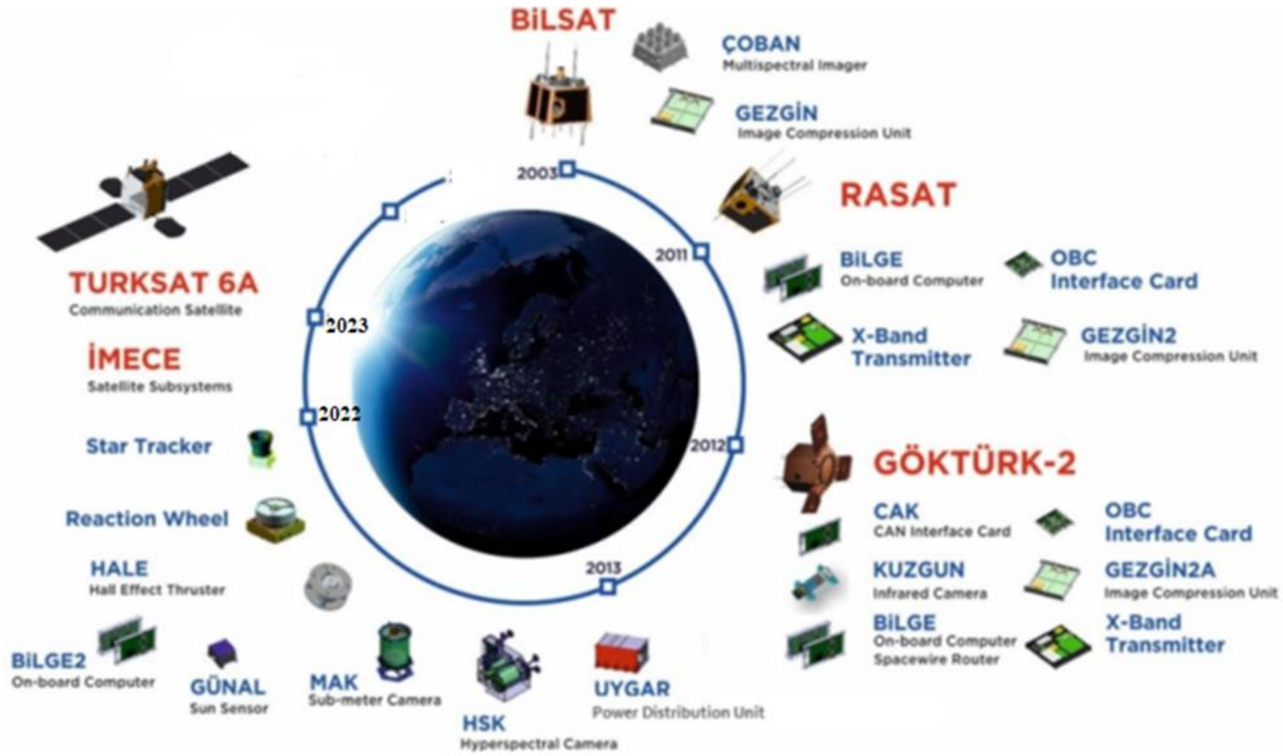


***Figure 9.*** *Satellite and indigenous satellite subsystems developed by TÜBİTAK Space between 2003 and 2023 [43].*

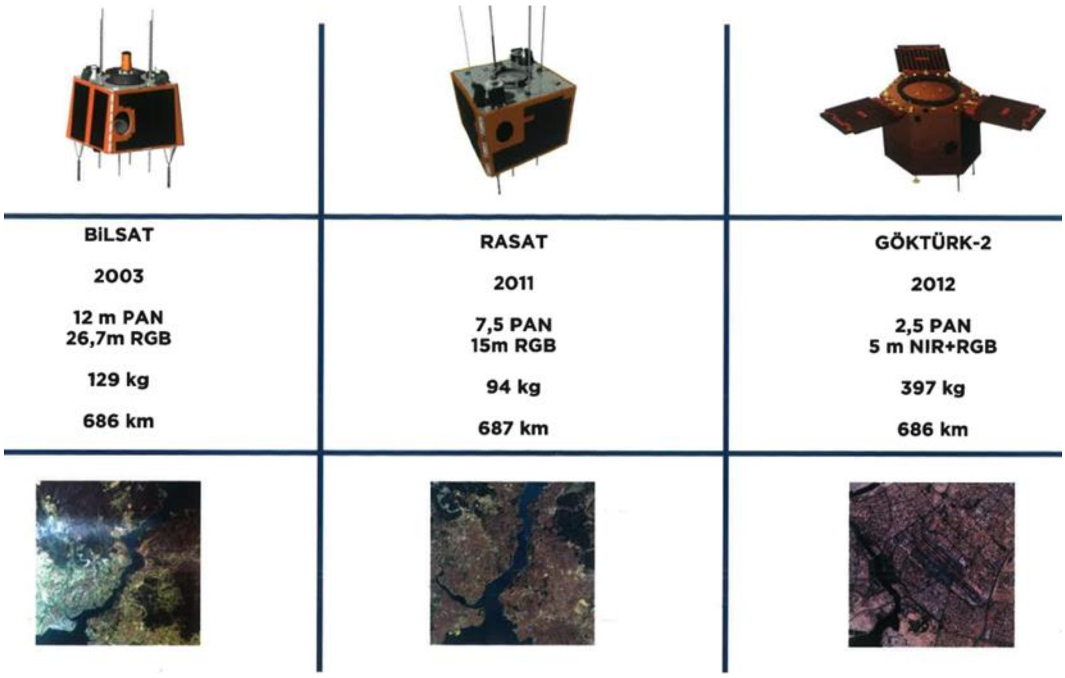


***Figure 10.*** *BİLSAT, RASAT and GÖKTÜRK-2 observation satellites developed by TÜBİTAK SPACE [43].*

Turkish Aerospace Space Systems Assembly, Integration and Test (AIT) Center (Uzay Sistemleri Entegrasyon ve Test Merkezi, USET), started running on May 21, 2015. Turkish Aerospace Industries, Inc. is located in Ankara on a 4 million $m^2$ area of land with an industrial facility of over 296,000 $m^2$. The AIT center has a vibration test system (VTS), an acoustic test system (ATS), a mass properties measurement system, a compact antenna test range (CATR) test system, an EMI/EMC test system and a Thermal Vacuum Chamber (TVAC) test system. VTS maximum load capacity is 8000 kg and maximum force is 289 kN sine, 266 kN random, and 578 kN shock. The frequency range is from 5 to 2,000 Hz. ATS maximum, the sound pressure level is 156 dB. The frequency range is from 25 to 10,000 Hz. Mass Properties Measurement System range is from 50 to 9000 kg. Mass measurement is up to 5850 kg. Device Under Test (DUT) positioner capacity of CATR is 6000 kg. The frequency range is from 1 GHz to 200 GHz. Electric field attenuation is from 1 to 40 GHz. Measurements capabilities are Co-polar / cross-polar radiation pattern, gain, end to end test. TVAC is Ø6.2 m x L7.0 m (horizontal). The vacuum level is 10-6 mbar, Shroud temperature is -180 ± 5 °C (via LN2) [45]. In September 2019, the partly state-owned Turkish Aerospace Industries Inc. (Turkish Aerospace) and Argentine provincial state-owned INVAP officially agreed to co-developed a geostationary satellite [46].

In January 2013 at the meeting of the Defense Industry Executive Committee (SSİK) it was decided to start the procedures for the preliminary plan of Türkiye's first military satellite with RADAR synthetic aperture (SAR) [47]. The partners of the project include the Turkish Aerospace Industries the support of the TÜBİTAK Research Institute of Space Technologies and the private company Aselsan, TÜBİTAK Space’s recent innovation include the İMECE Satellite Subsystems Development Project and İMECE Satellite Platform Development Project. İMECE is based on the information and expertise acquired in the BİLSAT, RASAT, and GÖKTÜRK-2 Projects, and is set to satisfy future sub-meter resolution needs of Türkiye as well as to build related infrastructure and capability domestically. İMECE Satellite Subsystems Development Project was started in 2013 with funding from The Ministry of Development in coordination with the Minister of Defence. This project is composed of several sub-systems such as Electro-Optical Satellite Camera, Communication System, Star Tracker, Sun Sensor, Hall Effect Thruster System, Reaction Wheel, Payload Data Storage, Compression and Formatting Unit, and Next Generation On-board Computer. İMECE Satellite Platform Development Project was started in 2017 with funding from TÜBİTAK [43].

For many years, TÜBİTAK SPACE has been contributing to European Commission FP7 projects including the P2-ROTECT (Prediction, Protection & Reduction of Orbital Exposure to Collision Threats), which aims to arm future space missions with ideas on how to limit space debris. TÜBİTAK SPACE also has played role in the project by enhancing mission safet and sustainability by integrating Space Situational Awareness services (like collision avoidance, space weather prediction, etc.) into general spacecraft operations [48-51].

TÜBİTAK Marmara Research Center (MAM) houses the İMECE observation satellite subsystems project, which is developing a space-qualified solar panel. In this project, new generation (perovskite and organic) photovoltaic technologies are being researched and application-specific solar panels are being developed. TÜBİTAK Rail Transport Technologies Institute (RUTE) houses the İMECE observation satellite subsystems project in which a space-qualified lithium-ion battery is being developed. TÜBİTAK National Metrology Institute (UME) contains the İMECE observation satellite subsystems project in which a space-qualified torque rod and magnetometer is being developed.

Türkiye has bought seven communication satellites since 1994 and two communication satellites in production and plan to be launched in 2021. Türkiye launched its first satellite in 1994 (TÜRKSAT 1A and TÜRKSAT 1B) followed by two others in 1996 (TÜRKSAT 1C) and 2001 (TÜRKSAT 2A). TÜRKSAT 3A, 4A, and 4B were launched in 2008, 2014, and 2015, respectively. TÜRKSAT 1A, TÜRKSAT 1B, TÜRKSAT 1C, TÜRKSAT 2A, and TÜRKSAT 3A were manufactured by Thales Alenia Space (formerly Alcatel Alenia Space). TÜRKSAT 1A, TÜRKSAT 1B and TÜRKSAT 1C belongs to the Spacebus 2000 family. TÜRKSAT 1A was lost in 1994 due to launch failure. TÜRKSAT 2A and TÜRKSAT 3A belong to the Spacebus 3000 family. TÜRKSAT 4A and 4B were manufactured by Mitsubishi Electric Corporation (Japan). TÜRKSAT 4A and TÜRKSAT 4B EMC belong to the DS2000 family. Türkiye signed an agreement with Airbus for the production of TÜRKSAT 5A and TÜRKSAT 5B communication satellites in 2017. TÜRKSAT 5A was launched on January 8, 2021, with Falcon 9 in the USA, while TÜRKSAT 5B is prepared to launch in 2021. All communication satellites have been operated by TÜRKSAT, which is a satellite operating company of the Turkish government.
TÜRKSAT 6A is Türkiye's inaugural communication satellite project that supports programs that develop technologies and encourage production. The Project has been funded by TÜBİTAK and the Ministry of Transportation, Maritime, and Communication. After in orbit tests, TÜRKSATwill be the end-user and future the owner of the satellite. TÜBİTAK Space, the main contractor of the TÜRKSAT 6A project, partnered with Turkish Aerospace, ASELSAN, and CTECH, to combine their expertise and capability in space technologies accumulated over years, and contribute their expertise learned from the RASAT, GÖKTÜRK-2 and IMECE projects. The TÜRKSAT 6A Project started in December 2014 with on-ground delivery in 60 months. The Republic of Türkiye, Ministry of Transport, and TÜRKSAT and TÜBİTAK contributed to the financial budget for the program. TAI is responsible for satellite structural, thermal control, chemical propulsion subsystems, harness, and mechanical ground support equipment. The assembly, integration, and test (AIT) activities will take place at the Turkish Aerospace's facilities in Ankara. ASELSAN is developing a communication satellite payload and Ctech is developing Telecommand and Telemetry subsystems. Other than the Flight Model, Engineering Model for the ground tests and development will also be produced as part of the project. The satellite with a total mass of more than 4 tonnes, including propellant will be placed into the orbit of 42ºE. There are 16 active and 4 redundant Ku-Band transponders which cover Europe, the Northern coast of Africa, the Middle East, India, and Indonesia, in addition to Türkiye. As a result of the project, equipment produced in Türkiye will set a precedent that will constitute a solid baseline for Türkiye's future space projects. The service life is more than 15 years, and dry mass is almost 1700 kg. The total mass is almost 4200 kg, and power generation is almost 8 kW at EOL.

The number of CubeSats launched since ITUpSAT-1 was launched in 2009. Table 5 shows the list of CubeSats by developed and launched by Türkiye.

*__Table 5.__ The list of CubeSats by developed and launched by Türkiye [52].*

| Mission Name | Organisation | Type | Launch date | Mission description |
|---|---|---|---|---|
| ITUpSAT-1 | İTU | 1U | 23.09.2009 | Educational space systems engineering and CMOS camera |
| TURKSAT-3USAT | İTU | 3U | 26.04.2013 | Main payload in linear transponder operating in VHF/UHF |
| BeEagleSat (TR01) | İTU HHO GUMUSH SABANCI UN | 2U | 18.04.2017 | Part of QB50 to study lower termosphere |
| HavelSat (TR02) | İTU HAVELSAN GUMUSH | 2U | 18.04.2017 | Part of QB50 to study lower termosphere |
| UBAKUSAT | İTU | 3U | 02.04.2018 | Amateur radio communications and telemetry transmission |
| ASELSAT | İTU ASELSAN | 3U | 24.01.2021 | Earth observation mission with X-band downlink system |
| Connecta T1.1 | Plan-S | 3U | 25.05.2022 | Demo satellites for end-to-end solutions for global IoT services |
| Connecta T1.2 | Plan-S | 3U | 03.01.2023 | Demo satellites for end-to-end solutions for global IoT services |
| AKUP | TÜBİTAK SPACE | 3U | 15.04.2023 | Educational training and capacity building in space technlogy development |
| KILICSAT | ASELSAN GUMUSH | 3U | 15.04.2023 | Demonstrate locally made LNA module in space and AIS transceiver |
| Connecta T2.1 | Plan-S | 6U | 15.04.2023 | Demo satellites for end-to-end solutions for global IoT services |
| n-ART One | GUMUSH | 3U | not launched | Test&Demonstration Satelllite n-ART Bus |
| PIRI-SAT | ITU | 6U | not launched | Modular 6U platform for hosted payloads to provide free platform and launch for payload developers without the burden of finding a satellite/launch. Experimental AIS demonstration. |

ITUpSAT-1 is the first pico-satellite that was developed by İstanbul Technical University (İTU) in Türkiye. TÜRKSAT-3USAT was a LEO communication triple unit CubeSat that was built jointly by ITU and TÜRKSAT and launched in 2013. TÜRKSAT-3USAT program advances educational, scientific, and technological interests, and will full support and funds coming from the TÜRKSAT, A.S. Company. İstanbul Technical University's the Space Systems Design and Test Laboratory (SSDTL) (İTU) was used for building and testing the TÜRKSAT-3USAT. TÜRKSAT-3USAT's payload contain an amateur band VHF/UHF transponder (for use in voice communication), and its primary structure uses ISIS 3-Unit CubeSat platform as the generic modular having a total volume of 10×10×34 cm3. Included in TÜRKSAT-3USAT's subsystems are a thermal control subsystem, a command and data handling subsystem, a mechanical structure, a power subsystem, a payload subsystem, and a communication subsystem. The subsystems and the payloads can be found in its the upper, middle, and lower stacks. TÜRKSAT-3USAT was created with maximum possible redundancy, which means that every subsystem has a backup with complementary design. TÜRKSAT-3USAT has two onboard computers, two transponder modules, two electric power systems, and two beacons and modems, and its entire structure is shown in Fig. 11 [53-59].

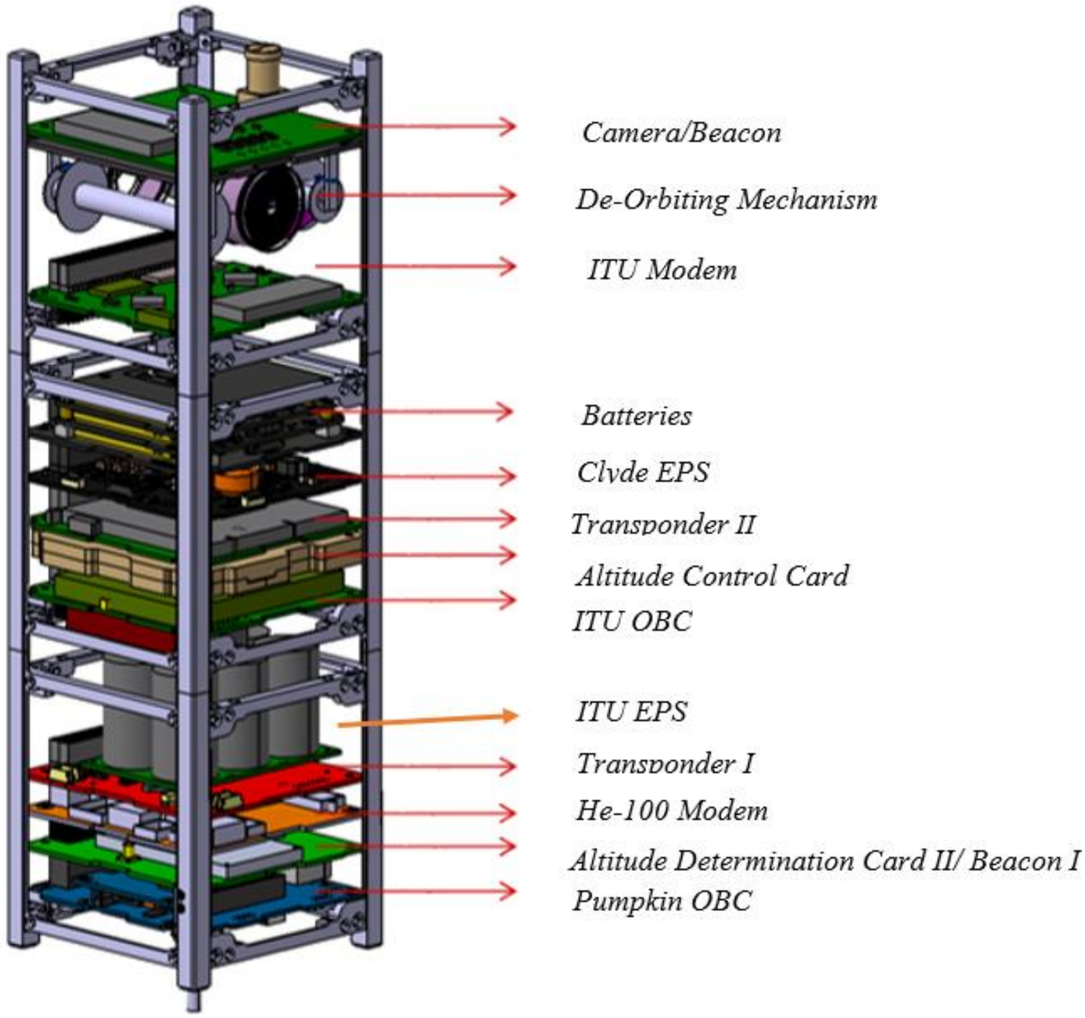


***Figure 11.*** *TÜRKSAT-3USAT and its subsystems [55-59].*

TÜRKSAT started a model satellite competition in 2016, with 3 teams and 18 people. This competition is open to Turkish and International universities, attracted increasing attention each year. There were approximately 114 applications in 2022. After completing the Qualification Review (QR) phase, in 2023, 15 finalist teams are selected. The model satellites of these teams were launched with rockets designed specifically for the competition. The TÜRKSAT Model Satellite competition statistics from 2016 until 2023 are given in Table 6.

***Table 6.*** *TÜRKSAT satellite model competition between 2016 and 2023.*

| Years | Number of Applications | QR Phase | Number of Flying |
|---|---|---|---|
| **2016** | 8 | 4 | 3 |
| **2017** | 25 | 13 | 11 |
| **2018** | 34 | 22 | 20 |
| **2019** | 95 | 33 | 32 |
| **2020** | 149 | 46 | 23 |
| **2021** | 109 | 66 | 20 |
| **2022** | 111 | 53 | 20 |
| **2023** | 114 | 57 | 15 |

There are 18 space engineering departments in Turkish Universities with 606 student's quotas. Fig. 12 shows number of master and PhD thesis in Astronomy and Space Sciences in Türkiye from 2010 to 2022. There is an increasing trend at number of master and PhD thesis in Space Technologies.

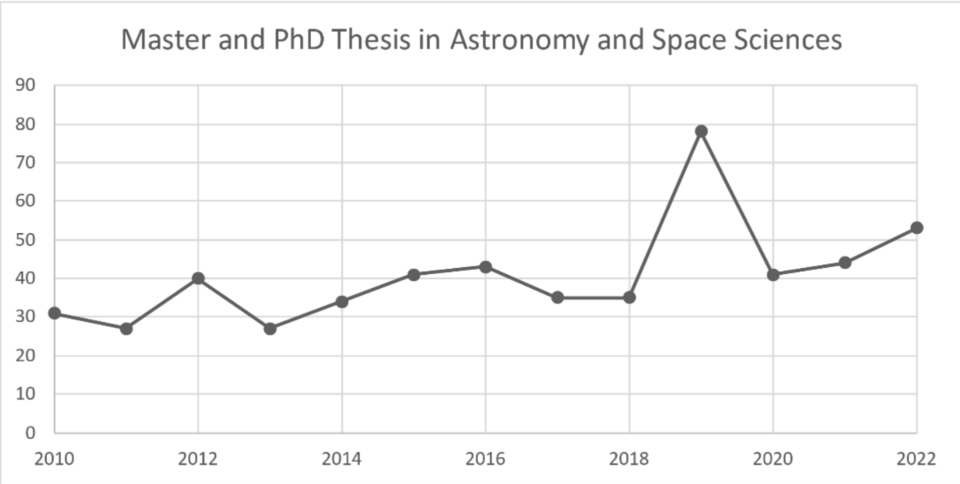


***Figure 12.*** *Number of master and PhD thesis in satellite technologies in Türkiye from 2010 to 2022.*

LAGARİ, developed by Engineering Technology Consultancy (STM), is a micro-class, high-resolution Earth observation satellite that will be launched in Low Earth Orbit (LEO), and will be the first of its kind in Türkiye. LAGARİ will be the first constellation satellite to deliver imagery for use in general mapping, forestry, agricultural, disaster monitoring, near-real-time tactical field applications. The satellite also will contain the latest electro-optical camera system that has capabilities for PAN and multispectral spot/strip imaging. LAGARİ Main Properties are high - resolution imaging, lightweight and compact satellite structure, high accuracy attitude determination, and positioning, 3-axis attitude control, body-mounted highly efficient solar panels, Lithium-Ferrite (Li-Fe) battery technology, and S-Band and X-Band links for communication with the ground. Its lifetime is 2 years. It has a Sun-synchronous orbit and will be launched at end of 2021. Automatic Identification System Application on Nano-Satellite Platform Project which is a 6U-sized nanosatellite platform PİRİSAT, will be developed by STM and will be the first application of the space-based Automatic Identification System (AIS) in Türkiye. PİRİSAT is the first national satellite of a future constellation that will provide AIS data in Türkiye. In addition to the main AIS mission, the platform will also be used to gain space heritage for various experimental payloads which will be developed by national institutes and companies. PİRİSAT nanosatellite platform to be developed, will be a reliable, time and cost-effective commercial platform that can be used for solidifying sound space-ready qualification of the products that are already developed or under developed in Türkiye. LAGARİ and PİRİSAT satellites are shown in Fig. 13 [60].

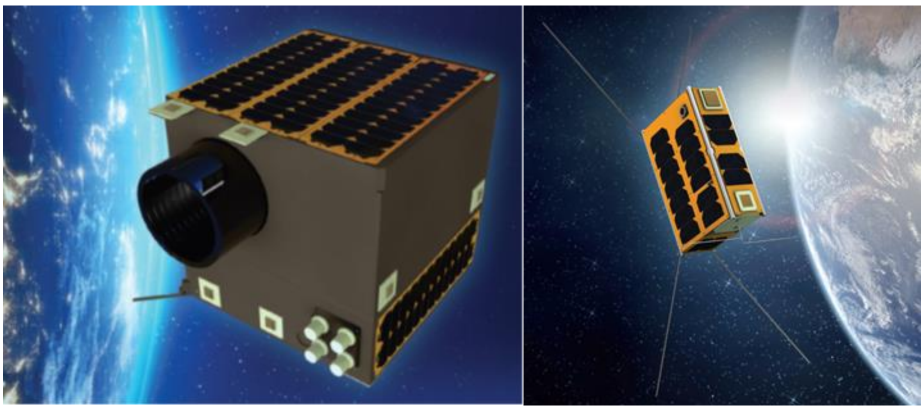

***Figure 13.*** *LAGARİ (left) and PİRİSAT (right) satellites [60].*

The Eastern Anatolia Observatory (DAG) project has been an important investment in Türkiye. at the project is on Atatürk University Campus in Erzurum city of Türkiye. In the scope of the project, an observatory building with a telescope, dome, buildings, and infrastructure were established in the first phase between 2012-2019. In the second phase, called the ODA project, which occurred between 2016-2019, purchasing, design, construction, and construction of an optical laboratory were completed. In the third phase, named AKS project, which occurred between 2018-2020, space satellite equipment were gathered, including a 4 m telescope with its enclosure, and all infrastructure and civil work and the mirror coating system were put in place on mountain (altitude 3170 m). When the DAG project is completed, it is expected to have a great international impact and the facility will be “the world's third important gateway to space. An observatory with a diameter of 50 cm was established in the Türksat campus to monitor geostationary communication satellites. Using Türksat observatory, Türksat satellites were observed optically for the first time and formed the infrastructure for many scientific studies. [61, 62]

Studies on satellite navigation systems started with distribution of atomic clock through TÜRKSAT satellites. A satellite based GNSS augmentation system developed using Türksat satellites Ku-band frequency. Finally, a regional navigation system using TÜRKSAT satellites has also been developed [63-66].

A model satellite competition has been held every year for university students since 2016 [64]. This competition ensures that university students learn the satellite production phases and increases their interest in satellite technologies.

Türkiye Space Agency (TUA) was established on December 13, 2019, and has been awaited especially by those in the aviation and space industry sector. Established as an institution with administrative and financial autonomy with a special budget by decree, TUA’s primary tasks are to prepare and follow-up on the National Space Program, determine medium and long-term strategies in the field of aviation and space, represent and coordinate with international organizations, research on space preparation and support development of (R&D) projects.

Türkiye’s National Space Programme was announced on February 9, 2021. This program covers vision, strategies, targets, and projects of Türkiye’s national space policy. The space program (Turkish Space Agency, 2021) has a “Moon Mission”, which is sending a Moon rover that was produced using domestic technological capabilities, to the Moon surface, and gaining experience in launching technologies and deep space systems. Significant progress has been made in Türkiye's first Lunar Mission (AYAP-1). An agreement was signed between the Swedish Space Physics Institute (IRF) and TÜBİTAK Space for the Lunar Neutral Telescope (LNT) scientific payload on July 5, 2022 [44]. AYAP-1 will collect data on neutral particles from the Moon's surface. In February 2021, National Space Program was explained and it is said that in 2021, Türkiye is planning heavy landing on the moon with an international cooperation and, in 2028, soft landing on the Moon with national rocket [67]. The national and indigenous hybrid rocket developed by DeltaV a subsidiary of the Presidency of Defence Industries with mission to moon was fired for the first time on 25 June 2021 [68]. Through the second main projects in the program, Türkiye is seeking to establish a regional positioning and timing system, obtain independent positioning and timing skills and increase the positioning and timing precision for our country and all countries in the region. The third project is called “Access to Space and Space Port”, which is developing critical technologies and establishing a launching facility infrastructure. Ankara has tried to push for a domestic launch capability project [46]. Roketsan and the Turkish Presidency of Defense Industries (SSB) agreed in 2008 to develop a Satellite Launch System (MSLS) to LEO that will allow the country to gain independent access to space [69]. Up till now, Türkiye has relied on developed nations including the United States, Russia and members of the European Union, to launch her satellites.

The other projects of the space program are entitled: Turkish Astronaut and Scientific Mission, Space Weather Research, Observation and Tracking of Space Objects from Earth, Forming Space Industry Ecosystem, Increasing Awareness in Space and Developing Human Resources and finally Space

Technology Development Zone. As part of the national space program, Türkiye officially started the process of sending the citizen to the International Space Station. The Turkish astronaut is expected to embark on the journey in 2023.

# V. SATELLITE TECHNOLOGY TRANSFER PROGRAMS

In Türkiye, space companies and research agencies more frequently are considering technology transfer opportunities. The noticeable characteristics of technology transfer are, at present, mainly concerned with [70]:

- creating new technology and making it available;
- increasing information about what is available; and
- facilitating transactions between supplies and potential users.

BILSAT, TÜRKSAT 3A, TÜRKSAT 4A, TÜRKSAT 4B, TÜRKSAT 5A, TÜRKSAT 5B and GÖKTÜRK-1 (with AIT center project) projects contained technology transfer programs within the main procurement contract.

The BILSAT Know-How Transfer and Training (KHTT) team comprises a core group of 8 young engineers with strong backgrounds in mechanical, electrical and electronic engineering. Complementing the activities of this SSTL-based team are 4 MSc students conducting research at the Surrey Space Centre and a number of academic staff and technicians at TÜBİTAK-Bilten in Ankara. The core team engineers, upon completing their academic lecture programme, immediately became involved in the development work on BILSAT [71,72]. The second satellite built by using the technology transferred in the development process of BILSAT is RASAT [73].

During the production of TÜRKSAT 3A, TÜRKSAT started the first satellite technology transfer programs. Sixteen people attended technology transfer programs which were organized in France. Within the TÜRKSAT-3A project, a domestic communication satellite design project, namely TUSAT was started. TUSAT communication satellite design (Preliminary Design Review (PDR level)) was completed 2012. Several outputs such as reports, papers, patents have been completed that highlight the development of communication satellite design, through the work at AIT center. TUSAT preliminary design became a baseline for TÜRKSAT-6A and many engineers of TUSAT project transferred into TÜRKSAT-6A project.

Within the scope of the TÜRKSAT 4A and TÜRKSAT 4B projects, TÜRKSAT carried out the second phase of satellite technology transfer called, “Direct Participation Program”, with 16 engineers attending the program in Japan. For the TÜRKSAT 5A and TÜRKSAT 5B projects, 12 people have been receiving training under the third technology transfer training programs by Airbus and IAS in France since 2018. Three technology transfer programs were promoted by TÜRKSAT and the Presidency of Defence Industries (SSB) to design, assemble and test skills of communication and observation satellites, operation of the AIT center. These programs are determinants of developing spacecraft technology in Türkiye.

GÖKTÜRK-1, with AIT, carried out technology transfer programs. GÖKTÜRK-1 is an Earth Observation Satellite developed by Thales Alenia Space-France with the Direct Participation (DP) of Turkish companies which are Turkish Aerospace and ROKETSAN. DP is a work model where the DP companies participate to all activities in the scope of the work package description while the responsibility of the activities belongs to the Subcontractor [74].

# VI. SPACE ECONOMY IN TÜRKİYE

Opportunities in space industries could be summarised as the need for improvement in manufacturing communication and observation satellites through national means and exporting those products and services developed to other countries while also providing improvements in infrastructure [73]. It could be stated that space exploration would have great impacts on the economy if it is planned in the "right" way, so public agencies would play critical roles within the mission-oriented policies. Dede and Akcay [73] define the strategic management of space technologies as an important phase in the capacity building efforts of the nation. Özalp [42] also underlies that the initial initiatives led by TUBITAK have an understanding of defining science and technology goals that would affect social life. In this regard, strategies and policies to support space science, life science, and earth sciences could be included in mission-oriented policies.

Satellite communication services reached $135 million yearly revenues in 2018 [75] in Türkiye, excluding TV Platform Services. TV platform services had $ 51.5 million yearly revenues in Türkiye. We can assume that US$ 186.5 million for satellite services from direct revenues were created by three TÜRKSAT satellites, TÜRKSAT-3A, TÜRKSAT-4A, and TÜRKSAT-4B. The estimated investment for these three satellites is US$ 771 million in total. By assuming 15 years of lifetime, US$ 51.4 million yearly satellite investment created triple revenues of US$ 186.5 million. This means that every $ 1 yearly investment in satellite creates $ 3.6 yearly revenue, which is smaller compared to the UK's 1 to 6 direct return ratio for space telecommunication investment and NASA's general 6-9 rate of return ratio.

All of these studies and space projects, described above, play a very important role in accelerating Türkiye's role in global space programs [76]. Türkiye spent US$ 276 million on its space programs in 2018. USA, China, Russian, France, Japan, and Germany spent $41 billion, $5.8 billion, $4.2 billion, $3.2 billion, $3.1 billion, and $2.2 billion respectively on space programs. The space program budget of Türkiye was the fifteenth largest in the world, in 2018. Space program budget is increasing every year.

# IV. CONCLUSIONS

The Turkish government spent US $ 276 million on space programs in 2018. The space sector uses state-of-the art technology and employs approximately 1,000,000 people in the world today. Currently, around 1000 engineers and scientists work in the space sector of Türkiye where the program gives credence not only to designing, analysing, and testing the satellites but also to manufacturing high-value-added equipment in Türkiye. However, the number of people working in space sector should increase and more manufacturing of value-added equipment should be conducted. Commercialization of space technology and research in communication, earth observation, and navigation systems is also important for the sustainability of economic development. TÜRKSAT plays an important role in commercialization of communication satellite technologies. Similarly, Türkiye's state-owned observation satellites outputs need to be commercialized by TÜRKSAT or other commercial companies. The Turkish space industry is growing steadily. Türkiye is now among fifteen countries in the world which is spending generously on the space program. The global space economy is roughly $400 billion now and is expected to grow all over the world. The rate of return in space investment is as low as 3.6 in Türkiye compared to values of the UK and the USA. This situation motivates Türkiye to enrich value-added space services such as Earth observation and navigation, in addition to direct services of TV broadcasting and data communication. Satellite TV services through TÜRKSAT satellites are saturated and reached 578 due to influencing growth of internet broadcasting such as Youtube, Netflix, BluTV etc.

Technology transfer has especially benefited from the development of satellite technologies in Türkiye, especially in BILSAT, TÜRKSAT 3A, 4A, 4B, 5A, 5B, GÖKTÜRK-1 projects. This practice of Türkiye can be an example for developing countries.

Supporting spinoff companies in the development of satellite subsystems and equipment, it will support the faster development of space technologies (CTECH example in TÜRKSAT 6A project, Gumush Aerospace Inc. from cubesat projects). Satellite operations and services are very profitable compared to satellite manufacturing and launching. On the other hand, Satellite manufacturing and launching are strategic need support of government funds.

Türkiye's participation to ESA will catalyse development space technologies. Similarly, participation and collaboration to other space related international organizations will ease the finance of space projects and will provide a job opportunity to Turkish space engineers in addition to limited space sector of Türkiye.

Finally, when compared to international space technology companies (Eutelsat, SES, SpaceX etc), entrance of Türkiye's key space companies (TÜRKSAT and Turkish Aerospace) to the Turkish stock market (BIST) will provide necessary finance for future projects and will strengthen their institutional structures.

This study shows that the rate of return value of investments in the space economy is low compared to other countries and the added value should be increased. In addition to classical TV broadcasting and data communication, observation satellites, positioning systems, "Internet of Things" IOT applications reveal the need to bring into the economy. It is clear that for the development of the space economy, space activities should cease to be limited to the state and become an area in which the private sector plays a role.

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