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MASTER THESIS

Turkish Space Technology

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ΕΘΝΙΚΟ ΚΑΙ ΚΑΠΟΔΙΣΤΡΙΑΚΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΑΘΗΝΩΝ

ΣΧΟΛΗ ΘΕΤΙΚΩΝ ΕΠΙΣΤΗΜΩΝ

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ΤΜΗΜΑ ΦΥΣΙΚΗΣ

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ΔΙΑΤΜΗΜΑΤΙΚΟ ΠΡΟΓΡΑΜΜΑ ΜΕΤΑΠΤΥΧΙΑΚΩΝ ΣΠΟΥΔΩΝ

"ΔΙΑΣΤΗΜΙΚΕΣ ΤΕΧΝΟΛΟΓΙΕΣ, ΕΦΑΡΜΟΓΕΣ και ΥΠΗΡΕΣΙΕΣ"
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Στέργιος Γ. Μανταρλής

Επιβλέπων: Αλέξανδρος Κολοβός, Αναπληρωτής Καθηγητής

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INTRODUCTION

Space technology is considered to be the technology that is based on natural sciences, developed originally on earth and is designed to exploit space by countries that possess it in all its aspects (political, military, economic and environmental) - as well as a means of promoting international peace, security and stability[1]. Space is anything at an altitude of at least 100 km (the scientifically known as Karman Line), although some set the space line at 80 km. Space technology mainly includes rocket launches, satellites, space stations and spacecrafts that orbit around the earth or travel to other planets. Space flights can be manned or unmanned.

Space technology is utilized in a wide range of applications. The most well-known application in most parts of the world is telecommunication services. Nowadays we have reached the point where telecommunications satellites cover the whole earth, some of them even competing with each other, offering direct communication of excellent quality from end to end. Satellite telecommunication services are slowly transforming and taking on the role of data transfer. In the past, the high demand for data transfer, mainly initiated by internet traffic, pushed much of the world to invest in underground optical fiber infrastructure. Nowadays, with global satellite coverage, the cost for such an endeavor would have been significantly lower.

Satellite internet meets the requirements for high quality direct-to-home connection without the need to install a terrestrial network. Whether satellite internet will prevail completely or will be able to cover only the central nodes remains to be seen in the future. What is certain is that the widespread use of fiber optics will be reduced thanks to the reduction of costs offered by satellite connection between remote areas.

Other very important applications of space technology are Earth observation services. Intelligence, Surveillance, Reconnaissance applications began as crucial military applications. These applications give the ability to monitor the facilities and critical infrastructure of any country, without having to be concerned about crossing borders or acquiring a flight license.

Earth observation is also important for maritime applications. It can provide answers to questions pertaining to ship tracking, maritime traffic congestion and optimal route planning. Even for unusual questions such as whether there are groundwater streams that can slow down or speed up a ship, satellites are able to provide optimal solutions.

In addition to maritime applications, numerous agricultural applications are in use, which offer great assistance on land cultivation process to increase production, as well as applications for sustainable forestry. Remote sensing is used for mapping the distribution of forest ecosystems as a whole and global fluctuation in plant productivity in relation to season.

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[1] Boutros-Ghali, Boutros, International cooperation in space for security enhancement, Space Policy Volume 10, Issue 4, November 1994, Pages 265-276, ISSN 0265-9646, https://doi.org/10.1016/0265-9646(94)90003-5., (https://www.sciencedirect.com/science/article/pii/0265964694900035), Διεθνής Συνεργασία στο Διάστημα: Δραστηριότητες για Ενίσχυση της Ασφάλειας στην Μετα-Ψυχροπολεμική Εποχή. Αναφορά του Γενικού Γραμματέα ΟΗΕ. Μετάφραση στα Ελληνικά: Αλέξανδρος Κολοβός, Εθνικό Κέντρο Διαστημικών Ερευνών, 1994. https://bit.ly/3A4bitb

These applications are only a small sample of the applications that already exist. The potential for novel applications is also high since space technology could cater to the needs of various fields.

From all the aforementioned, we can draw the conclusion that space applications as a whole have two common features.

Firstly, space technology holds a comparative advantage: There are no corresponding terrestrial technologies that can compete with space applications on such a large scale, due to the fact that space technologies are applied at very high altitudes where there are no obstacles, such as mountains or sea or borders, that obstruct communication or exchange of information between two points, as long as there is visual contact with the sky.

Secondly, space technology development requires an inconceivably high amount of investment until a technology matures and bears fruit. Even projects on the lower end of the financial scale such as microsatellites require a few tens of millions to develop the satellites, train the staff, carry out the necessary tests, build the ground station and in the end launch the satellite and put it into orbit.

Because of the high cost investment required and the unique advantages that space technology holds, space applications that were chosen to be developed were funded exclusively by governments and supported by the state budget. This used to be the common policy until the age of New Space[2]. The nature of the projects (military, research, exploration etc.) and the utility of their applications was dictated by each country's space policy. There are countries such as India that are particularly focused on space exploration; on the other hand, there are countries, such as Turkey, which are particularly focused on military applications.

Because space technology requires large government funds, each country's Space Policy is of particular importance. Decisions such as whether to develop a system for identifying potential external military threats or intercom systems for the military or land farming systems are decisions that completely differentiate the entire design of a space program along with the candidates involved in the development and operation of space technology. In addition, the high cost and complexity of space technologies pose a strong incentive for countries to cooperate in this area, and Turkey is a classic example in the field of international cooperation.

This dissertation will study the space technology that Turkey has chosen to develop. We will present how space technology started and what choices the country made regarding the technologies developed. How these technologies are funded. How current technology influences future decisions and why Turkey considers it important to be technologically independent of third countries avoiding outsourcing.

[2] New Space, is considered the modern era of space technology where for the first time in history there are private companies, e.g. SpaceX and Blue Origin, which develop their own technologies and applications for space.

ABSTRACT

Modern Turkish space technology and the successful results of Turkey's space policy have come after a series of developments in many different fields. It started with the reform of the state administration and its decision-making process. From the 1960s, Turkey began planning its central sectors over a five-year period. Central planning included specific procedures to be implemented in various fields and from the beginning, there was a special mention of the development of space technology in Turkey.

Starting from that early planning and as the process of reforming the central administration matured, and the involvement of the Turkish Air Force, we reached a major change in 2018, in the year that took place the change of the Turkey constitution that finalized the political form of the state decision-making bodies. Thus, in 2018 the Turkish Space Agency (TUA), which is responsible for the implementation of the Turkish space program, officially started operating. In addition, the Presidency of Defense Systems (SSB) was established which has great autonomy, its own budget and plays a central role in the development of Turkey's space programs. Respectively, the appropriate legislative framework was established under the Law 3238/1985 to facilitate the procurement of government expenditures, which includes the space expenditures.

What stands out from the first moment in every design of Turkey's space program is the acquisition of ever-increasing technological autonomy. The required autonomy is obtained through the domestic design and production of satellite systems in whole or in part. When domestic production is not possible, international partnerships are made with companies from other countries in order to transfer expertise to Turkey, with the intent gain the required autonomy in the future. Following this policy of acquiring expertise and outsourcing when needed, Turkey has managed to develop its domestic industry by financing Turkish companies which have grown in number each one having developed its own technology and final products.

As for the needs that Turkey's space program meet and what drives space technology development, the answer lies in the great demands of the Turkish Armed Forces. Major space projects that were developed for this purpose include military earth observations and reconnaissance satellites; these projects are driven by the insurmountable need to improve the clarity and resolution of images taken from earth. Moreover, the largest space project underway is the extremely expensive satellite navigation system, with which Turkey will gain relative autonomy from third-party systems. It also keep improving its current hybrid rockets for space access as well as a rocket launch base.

In addition to military applications, Turkish telecommunications satellites operated by Türksat A.S. have a three-decade history with five generations of telecommunications satellites in space. Three generations are currently in orbit and the design for the next generation satellites has already begun.

This dissertation also reports and analyzes all major and minor projects related to the Turkish Space Program, such as ground-based satellite systems, telecommunications satellites, large military earth observation satellites, the many microsatellite programs and their future applications.

Furthermore, we will take a look at the government bodies that play a central role in shaping Turkish space technology, such as the Tubitak Uzay Institute of Space Technology, the Defense Industry Executive Committee (SSIK) and the Presidency of Defense Industries (SSB).

Of particular importance in the space industry sector on this thesis are presented. The most important companies that have developed and manufactured space technology are the following: Roketsan, Havelsan Co., Aselsan, Gumush, Turkish Aerospace Industries – (TUI), GsatCom and STM.

It is worth mentioning the development of public and private bodies, which could not have come without the change in the education system and in particular in the training and specialization of staff in specific space issues. For this reason, we present the work of two such organizations: the Technical University of Istanbul, which provides comprehensive training and has developed many successful microsatellite programs, as well as the Turkish Air Force Academy, which has its own internal space studies program.

As a first introductory conclusion, which we will see in more detail in the following chapters, we conclude the existence of a set of organizations, committees, universities, space competitions, industries and even electronic journals, which are self-feedback and that their staff works for development of Turkish space technology with the support and guidance of the central government.

SUBJECT AREA: Turkish Space Technology, space policy

KEYWORDS: Turkish space technology, defense, satellite, Turkey, Turksat, Gokturk

ΠΕΡΙΛΗΨΗ

Η σύγχρονη Τουρκική διαστημική τεχνολογία και τα επιτυχημένα αποτελέσματα της διαστημικής πολιτικής της προήλθαν μετά από μία σειρά εξελίξεων σε πολλούς διαφορετικούς τομείς. Ξεκίνησε αρχικά με την αναμόρφωση της κεντρικής διοίκησης και του τρόπου λήψεως των αποφάσεων της. Από την δεκαετία του 1960, η Τουρκία ξεκίνησε να προγραμματίζει τους κεντρικούς τομείς της σε βάθος πενταετίας. Ο κεντρικός προγραμματισμός περιελάμβανε συγκεκριμένες διαδικασίες που έπρεπε να υλοποιηθούν σε διάφορους τομείς και από την αρχή είχε γίνει ξεχωριστή μνεία για την ανάπτυξη της διαστημικής τεχνολογίας στην Τουρκία.

Ξεκινώντας από εκείνον τον πρώιμο προγραμματισμό και καθώς ωρίμαζε η διαδικασία αναμόρφωσης της κεντρικής διοίκησης και τον ρόλο της Τουρκικής Πολεμικής Αεροπορίας, φτάσαμε στην πρόσφατη μεγάλη αλλαγή του 2018, όπου μαζί με την αλλαγή του πολιτεύματος οριστικοποιήθηκε η μορφή που θα έχουν τα κεντρικά όργανα αποφάσεων. Έτσι, το 2018 ξεκίνησε επίσημα η λειτουργία της Τουρκικής Διαστημικής Υπηρεσίας (TUA), η οποία είναι υπεύθυνη για την υλοποίηση του διαστημικού προγράμματος της Τουρκίας. Επίσης, δημιουργήθηκε η Προεδρία Αμυντικών Βιομηχανιών (SSB), η οποία διαθέτει μεγάλη αυτονομία, δικό της προϋπολογισμό και διαδραματίζει κεντρικό ρόλο στην εξέλιξη των διαστημικών προγραμμάτων της Τουρκίας. Αντίστοιχα, δημιουργήθηκε το κατάλληλο νομοθετικό πλαίσιο με τον Ν.3238/1985 για την διευκόλυνση των προμηθειών των κυβερνητικών δαπανών, στον οποίο εντάσσονται οι διαστημικές δαπάνες.

Αυτό που ξεχωρίζει από την πρώτη στιγμή σε κάθε σχεδιασμό του προγράμματος της Τουρκίας είναι η στόχευση για απόκτηση συνεχώς όλο και μεγαλύτερης τεχνολογικής αυτονομίας. Η ζητούμενη αυτονομία αποκτάται μέσω της εγχώριας σχεδίασης και της παραγωγής δορυφορικών συστημάτων στο σύνολό τους ή μερικώς. Όταν δεν είναι εφικτή η εγχώρια παραγωγή, γίνονται διεθνείς συμπράξεις με εταιρείες άλλων χωρών για μεταφορά τεχνογνωσίας στην Τουρκία, ώστε στο μέλλον να αποκτηθεί η ζητούμενη αυτονομία. Ακολουθώντας αυτή τη πολιτική απόκτησης τεχνογνωσίας και προμηθειών, η Τουρκία κατάφερε να αναπτύξει την εγχώρια βιομηχανία της, χρηματοδοτώντας Τουρκικές εταιρείες, οι οποίες έχουν αυξηθεί σε αριθμό και η κάθε μία έχει αναπτύξει την δική της τεχνολογία και τελικά προϊόντα.

Ως προς τις ανάγκες που ικανοποιεί το διαστημικό πρόγραμμα της Τουρκίας και αυτό που οδηγεί την ανάπτυξη του είναι οι μεγάλες απαιτήσεις που έχουν οι Τουρκικές ένοπλες δυνάμεις. Μεγάλα διαστημικά έργα που έχουν υλοποιηθεί για αυτό το σκοπό είναι οι στρατιωτικοί δορυφόροι παρατήρησης και αναγνώρισης γης, στους οποίους υπάρχει η αδήριτη ανάγκη να γίνονται συνεχώς καλύτεροι με μεγαλύτερη ευκρίνεια και ακρίβεια. Επιπλέον, το μεγαλύτερο διαστημικό έργο που βρίσκεται σε εξέλιξη είναι το εξαιρετικά δαπανηρό δορυφορικό σύστημα πλοήγησης, με το οποίο η Τουρκία θα αποκτήσει σχετική αυτονομία, παύοντας να είναι εξαρτημένη από συστήματα πλοήγησης τρίτων (πχ από το αμερικανικό GPS). Επίσης, κατασκευάζει υβριδικούς πυραύλους για πρόσβαση στο διάστημα καθώς και βάση εκτόξευσης πυραύλων.

Πέρα από τις στρατιωτικές εφαρμογές, οι τηλεπικοινωνιακοί δορυφόροι της Τουρκίας, που τους διαχειρίζεται η εταιρεία Türksat A.S., έχουν μία ιδιαίτερα πετυχημένη ιστορία τριών δεκαετιών με πέντε γενιές τηλεπικοινωνιακών δορυφόρων στο διάστημα. Αυτή τη στιγμή βρίσκονται σε τροχιά τρεις γενιές ενώ έχει ήδη ξεκινήσει ο προγραμματισμός και κατασκευή της επόμενης γενιάς.

ΘΕΜΑΤΙΚΗ ΠΕΡΙΟΧΗ: Τουρκική διαστημική τεχνολογία, διαστημική πολιτική.

ΛΕΞΕΙΣ ΚΛΕΙΔΙΑ: τουρκική διαστημική τεχνολογία, άμυνα, διάστημα, δορυφόρος

Σε αυτούς που τα όνειρα τους, δεν τους αφήνουν να ησυχάσουν.

ΕΥΧΑΡΙΣΤΙΕΣ

Θα ήθελα να ευχαριστήσω τον επιβλέποντα Αναπληρωτή Καθηγητή κ. Κολοβό για την εμπιστοσύνη που μου έδειξε να αναπτύξω το συγκεκριμένο θέμα σε επίπεδο διπλωματικής για πρώτη φορά στην Ελληνική βιβλιογραφία καθώς και για την συνεχή επικοινωνία και βοήθεια που είχα όταν την χρειάστηκα.

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PREFACE

The Turkish Space Policy and its consequent space development program, which implements the Policy in question, has been around for three decades, since the early 1990s. Turkey set off to a dynamic start with two geostatic satellites and a mishap (the first satellite was destroyed shortly after being launched) (Türksat 1A, 1994, ch. 2.2), but nevertheless carried on with several space projects in various fields, each one of them designed with regards to the goal that ought to be achieved. Nowadays, the country has a robust medium-sized aerospace industry, with a number of international collaborations[3] and a formal planning of future programs reaching up the year 2034, which has the approval of the highest government state bodies.

This dissertation begins with a description of the factors that shaped Turkey's Space Policy, such as the change in administration culture and the role of the armed forces in shaping the industry. In the course of this dissertation, it will be made evident that these factors have matured and managed to stay up to date with their contemporary developments and requirements. Next, we will describe the special public bodies and supreme councils that were founded and how they shape the evolution of Space Policy. We will also take a look at the companies that have been developed and are participating in the space program, as well as the many projects that have been completed and are related to space.

At a first glance, the general characteristics and “trends” that characterize the Space Policy and the related technological development of Turkey are the following:

The acquisition of ever-increasing technological autonomy from third countries, a feature that is emphasized in every program design. Autonomy is acquired through domestic design and production of satellite systems in whole or in part, and when domestic production is not possible, international partnerships are made for the transfer of expertise to Turkey in order to obtain the required autonomy for the future projects. The country’s first satellites were built in this fashion, until Turkey's domestic industry could build its own satellites along with ground-based systems.

Secondly, the great demands of the Turkish Armed Forces, which largely determine the technological development of Turkey. Projects that have been implemented for this purpose are the military earth reconnaissance satellites, where there is a constant need for images with greater resolution and accuracy. Turkey is also developing a national and costly satellite navigation system for its armed forces to become independent of US GPS.

Thirdly, the effort for autonomous access to space through the creation of rocket launchers, inside Turkey so as to place satellites primarily in low orbit but also outside Turkey for access to space in higher orbits.

Fourth, it is used as an influence tool in Turkish politics, both for domestic consumption inside Turkey and to improve the brand image abroad.

Fifth, it has a presence in every thematic unit related to space.

[3] Turkey Working on 30 Space Projects, Discussed Cooperation with 20 States – Official, 04/12/2020, https://www.urdupoint.com/en/technology/turkey-working-on-30-space-projects-discusse-1104721.html

Sixth, there is a set of organizations, committees, universities, industries and even e-journals, which closely interact with each other and under the guidance of the central government work for and contribute towards the development of Turkish space technology.

This shows that Turkey's Space Policy is a key pillar of growth and promotion, in which the President of the Republic of Turkey, Recep Tayyip Erdoğan[4], often plays a leading role and with a total budget that to date (2021) is estimated to have exceeded two billions dollars.

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[4] Turkey, Ukraine seeking broader space cooperation, 14/12/2020, Available: https://www.defensenews.com/space/2020/12/14/turkey-ukraine-seeking-broader-space-cooperation/

1 SPACE TECHNOLOGY, HOW ITS EVOLUTION COMMENCED AND HOW IT IS SHAPING IN THE CONTEXT OF CURRENT TIME.

In the first chapter, we will see what is so special about the services that space technology offers to the human daily life. In addition, why satellites can improve the security and defense needs of each country and why it has been given so much importance by countries with high GDP. How Turkey took its first steps, what global factors affect it and how space relates to security of itself.

1.1 What does space offer? What is its comparative advantage?

Space geopolitics is a field of competition among countries who own the relevant technology that began το exist from the late 1950s [1] [2]. The importance of space technology is shown by the fact that space increasingly affects our lives, on a daily basis, and this is the main reason that financially strong countries with high GDP have been investing in the space sector for decades. How important the geopolitics of space is depends on the existing possibilities offered by space technology and the potential prospects that are open to development in the future. A typical example of such a perspective is the possibilities of satellite remote sensing for real-time military information, i.e. the ability to know exactly what there is in a desired geographical location, something that has not yet been fully achieved. The benefits of this perspective have prompted almost all major powerful nations to develop their own monitoring system by their own means, with investments continuing until their technology evolves to the point of achieving picture in real time.

Comparing the level of investment in space technology of powerful countries, the United States remains the main player in space, but still faces challenges for its future supremacy primarily from China, and secondarily from Russia [3]. Russia remains the second most capable military space force, next to the United States. China is rapidly emerging as a major space power and has already stood out, having a very broad space program that includes manned flights, missions to Mars and the Moon, commercial, scientific and military capabilities. There are also indications that China is developing a space weapons program. Europe, although somewhat lagging behind as a whole, has a variety of space technologies from civilian and military satellites and several military applications [1].

Space technology has many unique advantages for the counties that own it [3]. These advantages lure countries, including Turkey, to develop themselves or purchase space technology, paying for its high cost, its high-risk environment and the need for endless support that is required. In the past, the use of space technology was prohibitive due to its inconceivable cost. That has changed since the 1990s, when economies of scale for space have improved by reducing costs to the benefit of smaller countries. Thus, among the space programs of the richest developed countries, an impressive number of smaller countries (which may exceed one hundred nowadays) have been added, especially in the last decade, with active space programs supported by their state budget.

Regarding the advantages of owning space technology and developing space programs, in addition to the prestige it offers to the country that owns them and how each government benefits in the polls because of them, the possibilities and the benefits obtained are the prerogative of space. The telecommunications capabilities offered by space are impressive, making it possible to communicate between any point on earth without requiring visual contact or geographical proximity between them [9].

Furthermore, space offers direct observation of the earth from above, something that can be used for military, agricultural, weather, etc. applications. There is plenty of solar energy from the sun and the prevailing conditions are unique to scientific research. These advantages are desirable for many countries in world including Turkey as well. Turkey has shown that it strives to have the most advanced technology available, developing its own domestic space technology and improving its own systems. This is something that will benefit Turkey in its military objectives, which is considered of highly importance for the country [9].

The development of the space program is a key policy for Turkey [1], in particular for military applications. Space technology increase the effectiveness of the Turkish Armed Forces. The specialized requirements of the Armed Forces promote research in space technology, while at the same time the knowledge resulting from the research in turn enhances and upgrades its military applications, which make use of the advantages of space technology to a greater degree.

As for the comparative advantages for the Turkish Armed Forces offered by the technologies based on space, these are [4]: First, they provide more capabilities due to the high altitude they are in relation to the ground. Consequently, the ground surveillance area increases as the height of a satellite's orbit increases, although the payload (whether for remote sensing or communications) remains the same.

Second, a satellite can pass over restricted terrestrial areas, a feature especially useful when a flight by plane or other means of remote sensing is not possible within the politically sensitive and sovereign airspace of another country. The satellite can pass over any ground on earth, regardless of borders, inaccessible terrain, does not require flight plans and is not subject to other restraints. This particular comparative advantage is unparalleled by any other system and extremely useful for security-related missions [9].

1.2 Turkish Space Technology, how did it start and what factors shaped it?

“One day, humankind will walk in the sky without airplanes, visit planets and, maybe, send us news from the moon… Our duty is to ensure that we are not left far behind the West”[5]

Mustafa Kemal Atatürk spoke these words in 1936 during his visits to the Eskisehir Aviation Regiment.

Before the launch of the Space Policy in the neighboring country, the reform of the economic policy, in particular of the central administration and the way of decision-making, preceded [5]. Thus, the basic foundations and the goals that had to be achieved in the state budget were reformed, which is the main pillar of prosperity of each country on which the subsequent development would be based. We are in the aftermath of World War II, where central economic planning became particularly popular because of the Soviet Union. The Turkish Republic formally adopted it in 1960 under the title "State Planning Agency". In this way, by planning the basic economic activities and setting goals each time over a five-year period, the foundations were laid for the stabilization of the Turkish economy. Consequently, the public administration began to implement a plan of actions and goals, the observance of which was considered the right path.

[5] Sait Yilmaz, 4 August 2016, Space and Turkey, Open Journal of Political Science, Vol. 6 No.3.

1.3 How the first steps in space were taken

In the first planning of the "State Planning Organization" that took place, the goal was set to found the "Scientific and Technological Research Council of Turkey" (Türkiye Bilimsel ve Teknolojik Araştırma Kurumu,TÜBİTAK[6] in Turkish), which was finally established and started operating in 1963 [5]. It was an independent council with the aim of organizing a five-year theoretical and applied research in the natural sciences, with the ultimate goal of achieving predetermined and very specific goals.

From the early years of its establishment, TÜBİTAK set up in-house units to assist it in formulating a policy agenda for coordinating actions in the natural sciences and applied research. The first unit created was the "Scientific Policy Unit". However, for a long time, about 30 years, the unit took no initiative on creating a specific action agenda, and thus, the unit closed in 1984. It was replaced by the "Department of Science, Technology and Innovation Policy" founded in 1993, which carried on the unit's activities under the supervision of TÜBİTAK [5].

Turkey's space activities first entered the government's agenda in the 1990s, specifically in a document of the Supreme Council of Science and Technology[7] (SCST), titled "Turkish Science and Technology Policy, 1993-2003" [5] [6], which took effect in 1993 and contains the following in free translation:

Taking into account the progress of Science and Technology in the world and the potential Turkey has in order to achieve its ultimate goals, the issues we need to focus on are the ones that affect almost all sectors of the economy and all sectors of the economy. in our lives, these issues are:

- Informatics (a combination of computers, microelectronics, communication technologies)
- Advanced technology materials
- Biotechnology
- Nuclear technology
- Space technology

The need to give special priority to the development of know-how in the aforementioned sciences, first through universities and later through companies, was emphasized. TÜBİTAK was designated by the SCST as the body responsible for setting the policy to

[6] Official page: TÜBİTAK, https://www.tubitak.gov.tr/en.

[7] The Supreme Council for Science and Technology (SCST) was established on 4 October 1983 [2]. His duties are: implementation of Turkish scientific policy, assisting the government in defining long-term technology policies, setting goals, elaborating plans and programs, outsourcing public institutions, seeking cooperation with private institutions, elaborating required laws and regulations, providing human resources for research , implementation of measures for the establishment of research centers, definition of research fields and provision of coordination services. The SCST is headed by the Prime Minister and consists of all the ministries and organizations interested in science and technology.

be followed in the issues of space technology. The study of coordination of space activities in Turkey began officially with the declaration of the State Planning Agency on 22 June 1990, along with the establishment of the Space Science and Technology Committee (UBITEK) under the auspices of TUBITAK[8] [6]. From 1990 to 1995, UBITEK performed studies in space applications, especially targeting projects in fields like remote sensing, space science, astronomy and astrophysics.

A meeting was held on 15 October 1993 [6] among related institutions and public bodies interested in space technology, and a study was initiated to form national space policy. Following the identification of space (along with defense and aeronautics), a number of specific plans and studies were prepared. These included a draft bill prepared by TUBITAK for the establishment of a National Aeronautics and Space Studies Council[9].

The draft was submitted to the Prime Ministry through a statement dated 28 April 1998 of the Ministry of State to which TUBITAK is responsible. During the SCST meeting held on 20 December 1999, TUBITAK was nominated to initiate studies gathering all relevant parties in order to prepare a national policy in the field of space science and technologies[10]. In this context, a draft document entitled [7]: ‘‘The general framework for Turkey’s national space policy’’ was submitted to the views of related institutions, parts of this text are quoted from various open sources.

1.4 The role of the Turkish Air Force (TAF)

From 2000 onwards, things became more specific as the main role of the Turkish Air Force (TAF, Turkish: Türk Hava Kuvvetleri) became valid and in charge. In 2000 in particular, the White Book of the Turkish Ministry of Defense stated that the TAF is responsible for "developing attack, defense, reconnaissance and early warning capabilities in space"[11].

A year later in 2001, the Turkish National Security Council (TSA) approved for the first time the establishment of the Turkish Space Agency (TSA). The proposal was made by consensus by TÜBİTAK in coordination with the Turkish Armed Forces, the Ministry of Defense and the Ministry of Transport, Shipping and Communications [6].

Although the decision clarified this national body would be subordinate to the Prime Minister, a subsequent government decision entrusted its management to the Turkish Air

[8] TUBITAK, 1993, Turkish science and technology policy (1993-2003), Supreme Council for Science and Technology, 2. Meeting, Ankara.

[9] TUBITAK, 1998, Assessments regarding progresses and decisions, Supreme Council for Science and Technology 4.Meeting - June 1998, SCST, Ankara

[10] TUBITAK, 2007, Assessments regarding progresses and decisions, Supreme Council for Science and Technology 15.Meeting e March 2007, SCST, Ankara

[11] Turkey Moves towards Setting up Costly Space Programs, Turkish daily News, May 30, 2001.

Force[12]. The TAF undertook the national effort to coordinate space activities and to promote the establishment of central space agency.

At the same time, importance was attached to the relevant research in space issues. The preparation for the adoption of the "National Space Research Program" was made in 2003 with the document "Vision 2023"[13]. Some consider this paper to be Turkey's "Space Strategy".

In 2004, research on Space issues was one of the 4 national priorities and was marked as a “privileged topic” under the supervision of the Prime Minister.

On March 10, 2005, the Supreme Council of Science and Technology decided that TÜBİTAK should prepare the national roadmap for space for the next 10 years. Being part of this effort, the central bodies has increased funding for space research, focusing in particular on the Armed Forces Information, Surveillance and Reconnaissance (ISR) capabilities.

The Turkish Space Agency (TUA) took its current form in 2018 with Presidential Decree no. 23[14]. It is headquartered in Ankara and report to the Ministry of Science and Technology. According to its statutes, the organization is responsible for the preparation and execution of the "National Space Program" which is determined by the President of Turkey.

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[12] Cihan Ercan, İzzet Kale, Historical space steps of Turkey: It is high time to establish the Turkish space agency, Acta Astronautica 130 (2017) 67–74.

[13] Ozcan Saritas, Erol Taymaz & Turgut Tumer, Vision 2023: Turkey’s National Technology Foresight Program – a contextualist description and analysis, http://www.inovasyon.org/pdf/ET.Vision2023.pdf, Duygu Halim, Tunc Medeni, A Comparative Strategic Analysis Of Space Technologies: Developing A Roadmap For Turkey, International Journal Of Ebusiness And Egovernment Studies Vol 4, No 2, 2012 Issn:2146-0744(Online), ttp://www.sobiad.org/ejournals/journal_ijebeg/arhieves/2012_2/duygu_halim.pdf, Tugrul Daim, Nuri Basoglu, Orhan Dursun, Ozcan Saritas, Pisek Gerdsri, (2009), A comprehensive review of Turkish technology foresight project, Foresight, Vol. 11 Issue: 1, pp.21-42, https://doi.org/10.1108/14636680910936422

[14] The policy type of Turkey is presidential republic thus all state decisions have the signature of its President

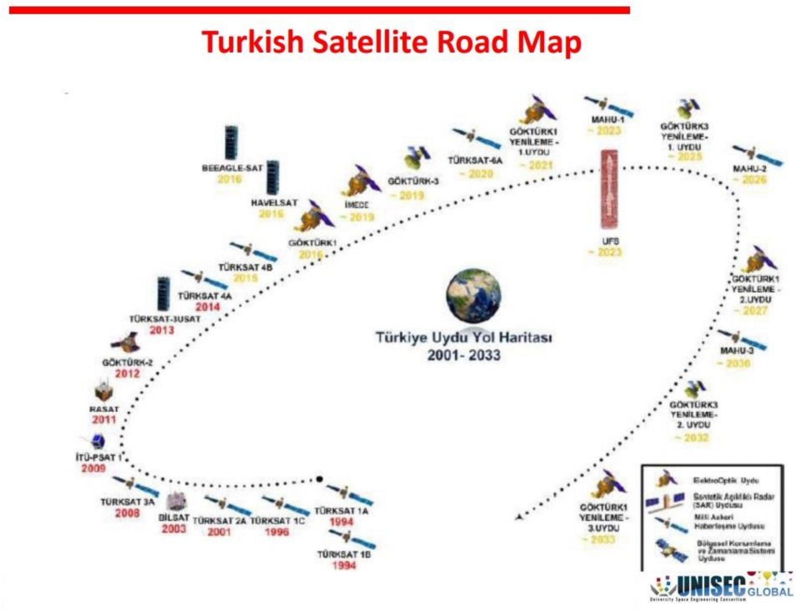

Image 1 Long-term planning of satellites that to be launched into orbit

1.5 Factors that influence the shaping of Turkish space policy

"PEACE AT HOME, PEACE IN THE WORLD"

THE VISION OF FOREIGN POLICY OF KEMAL ATATÜRK [15]

A characteristic of the Turkish scientific community, and in our case the space-related one, is that there are still references to the guidelines given by Kemal Ataturk almost a century ago and these guidelines continue to shape to some extent the crucial decisions that are made even today.

Keeping "peace at home, peace in the world" appears as a fundamental approach in Turkey's foreign policy[16]. This saying might be one of the reasons that Turkey has decided to focus on defense research activities, especially after 2004. The central government bodies increased the resources and budgets for research and development to strengthen Turkey's capacity to develop its space infrastructure.

Emphasis was placed on the areas of electro-optics and synthetic aperture systems (SARs), space-based remote sensing systems, ground-based systems and subsystems for information retrieval, ground-based reconnaissance and surveillance, navigation systems, positioning systems, and in recent years great effort is made for autonomous access to space [8].

Turkey's geography favors the development of space technology [1]. Its location at the crossroads of three continents is geostrategically sensitive and it would be extremely useful for the country to be able to constantly monitor what is happening throughout its

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[15] Republic of Turkey, Ministry of Foreign Affairs, "Turkish Foreign Policy During Ataturk's Era", Accessed 17 June 2021, Available: https://www.mfa.gov.tr/turkish-foreign-policy-during-ataturks-era.en.mfa

[16] The recent conflicts in Syria, Georgia, Libya and ongoing tensions with Greece show that they perceive peace at home and in the world differently.

territory. For this reason, observation from space was considered as a primary field that must be developed in order for the country to acquire the ability to know what exists primarily in its territory but also outside its borders. Turkey, with the means at its disposal, aims to establish an independent domestic space technology, strengthening its defense industry and research institutes. Demand for space based applications such as satellite navigation, communications and ground observation is constantly increasing on the part of Turkey.

Furthermore, Turkey follows a joint policy on security and defense. Following the tendency of large nations to make decisions for the further development of their domestic capabilities and meeting their own needs, Turkey recognize that it is necessary to support and preserve policies for the development of systems and technologies based on national priorities within the country, in the medium and long term [9].

For the aforementioned reasons, the Supreme Council for Science and Technology [1] decided on September 8 2004 to reduce its reliance on external sources by supporting defense projects in research and development, allocating sufficient and continuous resources[17] to Turkey's domestic industry. However, a further important reason for this choice was the embargo on arms sales imposed in 1974 by the United States on Turkey after the invasion of Cyprus. Although the embargo was put to an end in 1978, Turkey has learned an important lesson on the significance of autonomy.

Regarding the needs the Turkish space program meets, apart from telecommunications applications, which constitute a big part of the space industry, there are agricultural and shipping applications. However, demand for space technology originate from the needs of the Turkish Armed Forces, which are the largest and more demanding customer in these matters to date. We could say that the development of Turkey's space program, especially large-scale projects, is based solely on the requirements of the armed forces, with an emphasis on those of the Turkish Air Force.

The military procurement related to space is made under a special regime, as we will see in more detail later on. The "Undersecretariat for Defence Industries " (note: renamed "Presidency of Defense Industries" after the change of government in 2018) plays a significant role, which aims to modernize the Turkish industry and reports directly to the President of Turkey. The "Ministry of Defense Industries" came into force in 1985 with three main objectives: 1) Meeting of domestic needs, 2) Reduction of costs and 3) application of state-of-the-art technology [9].

1.6 Turkish policy on the acquisition and supply of Turkish Defense Systems.

Most countries around the world want to have their own defense industries, albeit this involve some serious hedges between a country's resources. The primary reason for the development of a state's domestic defense industry, in several cases, is due to the relationship of the defense industry with the independence of the state [9]. That is, the more military needs a state satisfies by its own means, the more self-sufficient it is, and so it has more independence from third countries. Achieving the defense independence of a state, which Turkey has set as its primary goal, requires valuable resources. The aim is to allocate the available resources in the best way to achieve this goal [10].

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[17] Continuous flow is emphasized to ensure that a company will not risk of running out business if there are no projects for some time.

The purpose of this chapter is to outline the policy of procuring defense systems, which is followed by Turkey. The main focus of the chapter is on decision-making in the defense industry (which contains a very large part of the space program) and how this policy affects the development of domestic industry. It also includes the description of law 3238/1985 that is related to the facilitation of the defense systems acquisition policy.

1.7 Policy for the acquisition of defense systems of Turkey

The policy for the acquisition of defense systems is defined as the goal setting that determines the course and means used by a government to acquire goods and services related to the defense of the state. Acquisition policy requires cooperation between the government and the industry.

Turkey's acquisition policy can be described from the decision of the state central bodies and means used for acquiring final products and services. The objective of this policy is to develop a financially healthy domestic defense industry that meet the government needs. The means that are utilized to bolster this objective can be recorded as industry policy, export policy, R&D policy, and offset policy [9]. E.g. The military satellite GOKTURK-1, photographed the ship EVERGREEN in March 2021 when it was stuck in the Suez Canal with a very high-resolution photo. This capability, so far from Turkey, so far from Turkey, is not directly related to Turkey's military defense needs but more to the demonstration of its capabilities.

The sub-policies and means used to support defense acquisition policy can be divided into smaller categories as follows [12] [9]:

- Development of domestic industry policy, by financing domestic industries to develop domestic technology and final products.
- Export policy, manufacturing military material that can be exported to friendly countries.
- Policy for research and development in new academic areas.
- Hedging policy, between military products from external suppliers or by financing domestic companies to develop technology.

Different institutions with distinct roles and responsibilities participate in the process of acquiring defense systems, which include [9]:

- The Council of Ministers chooses the general strategy,
- Defense Industry High Coordination Board is responsible for directing orders,
- The Defense Industry Executive Committee is responsible for choice making,
- The Turkish General Staff is responsible for general requirements,
- The MND (Ministry of National Defense) and Undersecretariat for Defense Industries are responsible for execution, industrialization, procurement, export, and financial assistance.
- The Defense Industry Audit Board is responsible for auditing and control

- Universities, research centers, and companies are responsible for design, production, manufacturing, and R&D.

1.7.1 Law 3238/1985

In the past, Turkey had faced problems maintaining its defense systems because of the absence of the domestic defense industry. Until 1985 when law No. 3238 was established [9], there had not been any serious attempt to develop a domestic industry. Until then, the state held the right solely of the defense industry and private companies were not allowed to enter the defense market. In 1985 under Law no. 3238 the Undersecretariat of Defense Industries was established. This statute introduced new standards to the defense market, the basic concepts of which were as follows:[18]

- To make maximum use of Turkey's existing industrial capabilities and potential,
- To provide direction and assistance to new investments that contain high technology,
- To incorporate foreign technologies and to render possible contributions by foreign capital,
- To encourage research & development activities.

The main targets of this law were to create a modern sound defense industry, utilizing productive regulatory components and steady cash streams to the defense industry. As a result, domestic suppliers began to meet the country's defense needs to the maximum extent possible.

Furthermore, this law established "the Defense Industry Executive Committee" and "the Defense Industry Support Fund".

1.7.2 Resolution Number 23378

Resolution Number 23378 is considered the foremost critical record to shape the acquisition of modern defense systems in Turkey. In this document, the objectives and sub-policies that must be followed are clearly defined. The Defense Industry Policy and Strategy Document (TDIPS-Türk Savunma Sanayii Politikası ve Stratejisi) was given approval by the Council of Ministers in 1998. The overarching goal of this resolution is to meet the needs of the Turkish Armed Forces (TAF) to the greatest extent possible using national and domestic resources. [9].

1.8 Space and Security, a different perspective.

Space and security are closely related [12] [8]. Nowadays, space is an intrinsic component of security and military strategy and it is becoming an increasingly important infrastructure for C4ISR strategic systems (Command, Control, Communications, Computers (C4) Intelligence, Surveillance and Reconnaissance (ISR)). Nevertheless, space technology is vulnerable to new space threats. In this chapter we will examine the

[18] Mehmet Simsek and Pakphum Phairotchananan, A Comparison Of Transparency In The Defense Procurement Processes Of Turkey And Thailand, Naval Postgraduate School, March 2014, https://apps.dtic.mil/sti/pdfs/ADA607927.pdf

current and future role that space will have in Turkish politics, defense and security, and we will see how Turkey intends to deal with threats to its space infrastructure.

A key principle of space technology in defense applications is to increase the security of a country. Turkey's space systems, like any other country, must be able to function properly safely and without threats that could disrupt their operation. Gradually, it became clear that space security assumes the security of space systems themselves, and so the issue of space security entered the international dialogue. Space security begins with the security of space itself, in other words space security [6].

Every country that has made big investments in space has shown a corresponding interest in protecting its infrastructure. Likewise, Turkey has shown similar interest at potential threats to space infrastructure that can be both terrorist acts and actions that are difficult to predict, such as space debris [6].

1.8.1 The need for space to improve a state's security and defense policy: protection of critical infrastructure.

Today, we live in the age of new space, and space is more competitive and useful than ever before. By effectively and efficiently utilizing the existing capabilities of space, satellites provide a force multiplier[19] to the governments and states that own them. It is thus clear that, in contrast to the old outdated approaches, a primarily precautionary approach to threats will help provide better and broader security, particularly in the aftermath of the spread of global terrorism[20], and that the fight against terrorism is not the only threat to critical space infrastructure [12].

The critical space infrastructure according to NATO[21] is analyzed in the following five main categories [12]:

- Position, Timing, Navigation (Position, Time, Navigation-PTN) and speed.
- Information, Surveillance and Recognition (ISR)
- Early warning and risk assessment systems.
- Satellite communications (SATCOM)
- Environmental monitoring.

The number of space-based military operations is constantly increasing. Space has a special place in Turkey's security and military policy. The number of important space programs, which include low-, medium-, and geostationary satellites, demonstrates

[19] J.W. Canaday, Space Technology: Force Multiplier or False Sense of Security, 1994. accessed 18 April 2021, Available: http://www.dtic.mil/dtic/tr/fulltext/u2/a279726.pdf

[20] Turkish texts when referring to terrorism usually refer to the PKK, Anadolu Agency, accessed 18 April 2021. Available: https://www.aa.com.tr/en/turkey/turkey-nabs-senior-pkk-terrorist-reveals-terror-plans/2176350, Anadolu Agency, accessed 18 april 2021. avaivalble: https://www.aa.com.tr/en/middle-east/anadolu-agency-video-shows-pkk-terror-camps-in-n-iraq/2005354

[21] NCIA NATO, D. Allen, P. Bartolomasi, R. Essad, T. Kreitmair, L. Patten, et al., “Space Support to NATO Operations: NATO Dependencies on Space (Revised), No Single NATO Operation without Space”, 2015.

Turkey's reliance on space for security and defense. Since the first Türksat 1B satellite was deployed in 1994, Turkey's PTN, C4ISR, SATCOM, and monitoring assets have become increasingly reliant on satellites.

1.8.2 Critical services of the Turkish space program

Data from space are an essential and necessary part of Turkey's security and defense [12]. Most of the data: "for the weather", "communications", "location navigation and timing", "information, surveillance and identification", "mapping and early warning", are provided via satellites. But the growing dependence on space makes them vulnerable. Many SBA (space-based applications) for space security require the security of data from space and satellites and space applications must be considered secure from external agents.

Space Based Applications (SBA) are essentially no longer an option but a necessity for most countries in order to be able to support security and defense. The type of threats has changed and the conceptual methods of security need to be reconsidered in an effort to keep up with modern data. Today's space technology is a crucial and basic need for international security [12].

As mentioned earlier and as we will see in more detail below, Turkey relies on space for its security and defense needs. It has been on Turkey's strategic agenda for the last 30 years with the aim of becoming a major regional player in the space arena [12].

1.8.3 Dependence on space, implications for international politics.

Space is a valuable tool for Turkey's civil defense and security purposes. Satellites make a significant contribution to security with key benefits of flexible, cheaper and global near-real-time land cover capability. However, as satellites' use and capabilities expand, they become targets of human attacks and unforeseen natural calamities [12].

The human factors that threaten critical space installations can be terrorism. Terrorism is not a new phenomenon and it has a global impact. Terrorists achieve their goals by causing fear, raising media awareness, and with the help of the media or social networks, they can convey the message of their actions whenever they occur on a global scale. Thus, a small catastrophe in a space system may cause chain reactions with unpredictable consequences [12].

Also, periods of war are a threat to the critical infrastructure of space. Satellites must be resilient to a war environment and the services they provide must continue to be reliable. Reliable in the sense that they will continue to operate in a war environment with protection from potential threats to disruption of their operation, but also in the sense that the services provided will continue to be deemed reliable without raising the issue of questioning the information provided. As a typical example, the data from the navigation satellites (GPS) should be correct. This requires ensuring the security of telecommunications between earth and satellite, from any possible interference even under extreme events such as nuclear war [12].

Besides these anthropogenic threats, the natural environment of space itself poses a threat to satellites. Solar storms have occurred in the past, each time with a different intensity. A high-intensity solar storm has devastating effects on satellites, but protection from low-intensity solar storms, which occur more frequently, must be foreseen to protect the critical infrastructure. Space debris is also a very important threat to satellites and the orbit that is most affected is the low orbit due to the fact that space debris tends to accumulate on the low earth orbit [12].

All of the foregoing demonstrate that diverse threats, changing requirements, and increasing dangers necessitate new means of approaching defense and security requirements. As a result, satellites, one of a country's most significant infrastructures, should be safeguarded, particularly those infrastructures related to military and the proper operation of the country's services. [12].

International cooperation on space security is the way to go for Turkey. The author's personal opinion is that Turkey will seek to participate in any international or multilateral effort for the security and protection of space. Especially since it has invested heavily in space and intends to continue to do so, we will see Turkey take space security initiatives.

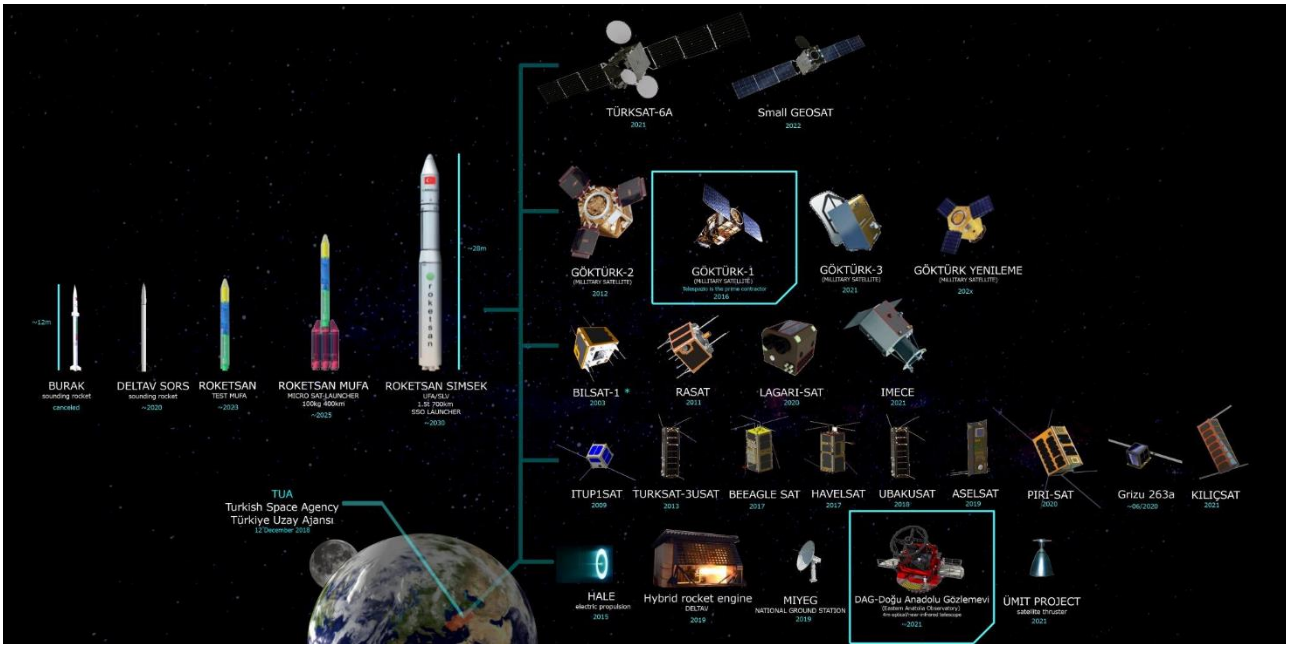

Image 2 Turkey's space program with its latest developments[22]

[22] Source: https://twitter.com/miguyan2000/status/1346564291139399684

2 TURKEY'S TELECOMMUNICATIONS SATELLITES

Turkey's space program began with the acquisition of its first telecommunications satellites by the French private company "Aérospatiale Company" in the early 1990s. A total of five generations of satellites have been developed and placed into orbit. Each generation followed a general plan of improvement and meeting new requirements [13]. The first generations had been developed with international partnerships, one main issue that was always highlighted on the contracts was the transfer of expertise to Turkey. In this way, Turkey reached the point where the sixth and last generation of Türksat Satellite is being built exclusively in Turkey, at the premises of the TUSAŞ at the Space Systems Assembly Integration and Test (AIT) Center.

In the following subchapters we will see the evolution of telecommunications satellites along with its international partnerships and the main company that manages them.

2.1 Satellite program of Türksat A.Ş.

The Turkish satellite communications company, (Turkish: Türksat Uydu Haberleşme Kablo TV ve İşletme A.Ş, Türksat A.Ş.)[23] is the country's responsible company for telecommunications satellites. It operates as a stated-owned company and its responsibilities are the following [2]:

1) Within the scope of national sovereignty, manages the rights to satellite orbital positions, as well as their management and operation..

2) It has its own satellites and can delegate the operation of satellite systems on behalf of the organization (this reference is emphasized in particular to provide the system's services to the armed forces when required).

3) To build the necessary communication and data transmission infrastructure that will be carried out via satellites, which will belong to national or international bodies.

4) Performs satellite platform functions.

5) Carry out relevant business activities.

It was established in 1990 and the headquarters are situated at Gölbaşı, Ankara Province. During the reorganization and privatization of Turkish Telecommunications (türkish: Telekom A.Ş.) in early 2004, the satellite communications and operations department was given a privileged status because satellite services were considered a crucial key to Turkey's security and therefore the newly formed Türksat A.Ş. was not permitted to be privatized [2]. Officially, Türksat A.Ş. launched on 22 July 2004 "to provide satellite communication services ", which had previously been carried out on behest of Türk Telekom A.Ş. Despite the fact that Türksat A.Ş. was a new company, its experience dates back to 1994, when the satellite Türksat 1B was successfully launched and began its space mission.

[23] Türksat A.Ş., Accessed 15 April 2021, https://www.turksat.com.tr/en

Türksat A.Ş. already has extensive experience on operating five generations of telecommunications satellites while the design and construction of the sixth generation has already begun.

2.2 The first generation of telecommunications satellites

Türksat 1A

The first attempt to access space from Turkey made with the Türksat 1A satellite, which launched by the Ariane 4 rocket from the Centre Spatial Guyanais in Kourou, French Guiana, on January 24, in 1994. Because of the launcher malfunction, the satellite burst 12 minutes after launch.

Türksat 1B

Following the destruction of the Türksat 1A, the Türksat 1B was smoothly launched on August 11, in 1994. The Türksat 1B was placed into its final orbit and operation on 10 October, in 1994, following initial orbital tests. Turkey, Central Europe, and Central Asia were all covered by the Türksat 1B satellite. Television and radio broadcasting, data transmission, and telephony were all provided by Türksat 1B. Although it is considered technologically obsolete nowadays, for the decade it operated it met the technological needs. It completed its mission in 2006[24].

Türksat 1C

After the failure of the launch of Türksat 1A, the French company Aérospatiale Company began construction on a new satellite under new insurance terms of the agreement, which required the satellite to be placed in orbit and fully operational. In comparison to the Türksat 1A, the area of the Türksat 1C has been expanded by two large zones, which differs from the coverage areas of the Türksat 1B. The Türksat 1C was designed to cover Turkey in its western part along with a part of Eastern Europe, while it covered Turkey and Central Asia in the east, it provided a direct link between Europe and Central Asia. Its mission ended in 2010.

2.3 The second generation of telecommunications satellites Türksat 2A

Türksat A.Ş. continued to make progress achieving higher standards for new multi-channel satellites with bigger coverage and backup capabilities. To provide customers with a larger coverage area and to remain competitive with other satellite operators, the new satellite was positioned in the same optimal spot as the Türksat 1C satellite. Türk Telekom entered into a partnership with Aérospatiale, EurasiaSat, that was responsible for the purchase of a new gen satellite called Türksat 2A (Because of the consortium also written: Eurasiasat 1).

The Türksat 2A became fully operational on 1 February 2001, at the same position as the Türksat 1C. The geographical areas it covered were: Europe and Turkey to the west,

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[24] Gunter Krebs, "Türksat 1A, 1B, 1C", accessed 15 April 2021, Available: https://space.skyrocket.de/doc_sdat/turksat-1.htm

Balkan Peninsula, Turkey, part of Asia including the Middle East, Russia and Pakistan to the east. He had the ability to serve these areas at the same time.[25]

The mission ended in September 2016.

2.4 The third generation of telecommunications satellites Türksat 3A

The Türksat 3A satellite, which covers Turkey, Europe, the Middle East, North Africa, and Central Asia, provides even more advanced telecommunications as well as live television offerings than previous satellites. Thales Alenia Space built it and it was launched by Arianespace from Guiana Space Centre in Kourou, French Guiana on 12 June 2008.

Equipped with interchangeable transponders, the Türksat 3A can act as a connection between Europe and Asia. Coverage of Turkey through Türksat 3A is specifically designed to provide much more efficient bandwidth applications as well as VSAT services, providing customers with low-cost up-link systems. The satellite has been in service since 12/06/2008.[26]

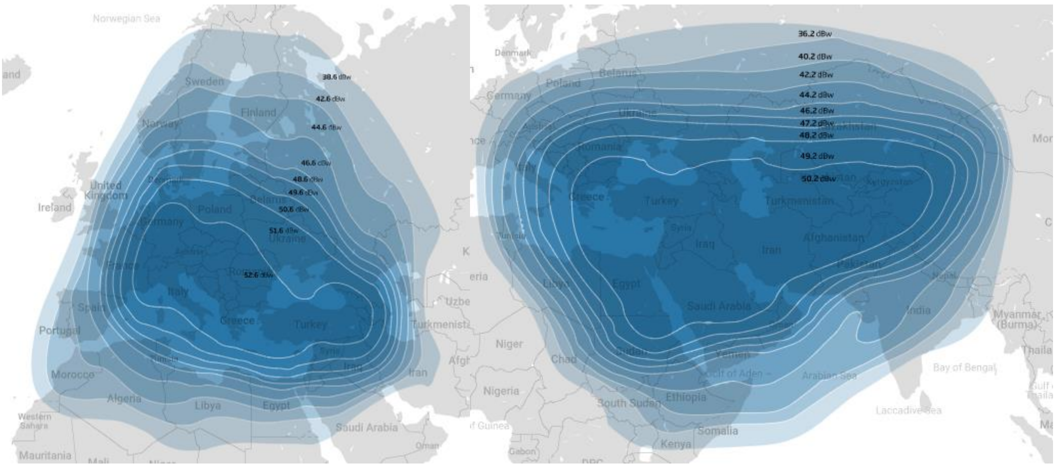

Image 3 The coverage area of Türksat 3A in western and eastern canal

2.5 The fourth generation of telecommunications satellites Türksat 4A και Türksat 4B

The Türksat 4A and Türksat 4B satellites were constructed by the Japanese company Mitsubishi Electric MELCO. Both satellites have specifications with a minimum lifespan of 15 years, allowing Türksat A.Ş to offer telecommunications and live TV services throughout Turkey, as well as in Europe, Central Asia, the Middle East and Africa. The Türksat 4A was placed into orbit at 42 degrees east longitude, after a short period of three months at 50 degrees, provides high-power live TV channels. Turkish engineers were trained in the facilities of MELCO in Japan.

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[25] Gunter Krebs, "Eurasia 1 (Türksat 2A)", accessed 15 April 2021, Available: https://space.skyrocket.de/doc_sdat/eurasiasat-1.htm

[26] Gunter Krebs, "Türksat 3A", accessed 15 April 2021, Available: https://space.skyrocket.de/doc_sdat/turksat-3a.htm

Both the Türksat 4A and the Türksat 4B were launched from the Baikonur Cosmodrome in 2014[27].

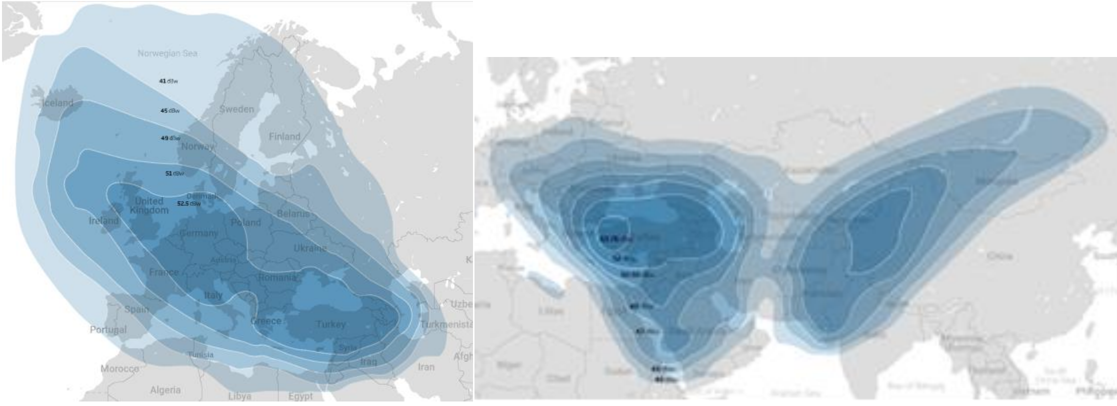

Image 4 The coverage area of Turksat 4A on the west channel and Turksat 4B and its east channel

2.6 The fifth generation of telecommunications satellites Türksat 5A και Türksat 5B

Turkey's 5th generation telecommunications satellites were built by Airbus Defense and Space[28]. Türksat 5A will provide coverage in Turkey, the Middle East, Europe, North Africa, and South Africa. The launch weight will be 3,500 kg, with an electric power of 12 kW. The Türksat 5A satellite will be launched in January 2021 [14].

The Türksat 5B satellite, which will operate at 42 ° east longitude, will operate in Ku and Ka zones. With HTS (High Performance Satellite) capacity, it will provide capacity over 50 Gbps and cover much of the Middle East and Africa. The nominal launch weight will be 4500 kg and the electric power will be 15 kW. It is planned to be launched in the summer of 2021 [14].

The satellites were built at Airbus facilities in the United Kingdom and France with the contribution of Turkish engineers. The two satellites are also based on Airbus' Eurostar E3000 "electric lift" technology, which uses electric propulsion to put them back in orbit and is considered to be the most advanced system in its class.

The contract for the construction and launch of the two satellites is about $ 500 million. The participating Turkish companies are Aselsan and the Turkish Aerospace Industries (TAI). The two satellites are expected to have a lifespan of 30 years and will be launched by SpaceX[29] [15].

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[27] Gunter Kreb, "Türksat 4A", accessed 15 April 2021, Available: https://space.skyrocket.de/doc_sdat/turksat-4a.htm

[28] C4Defence, "Airbus to Produce TurkSat 5A and Turksat 5B ComSat", 09 November 17, accessed 15 April 2021, https://www.c4defence.com/en/airbus-to-produce-turksat-5aturksat-5b-comsat/

[29] Daily Sabah, "In long-awaited launch, Turkey to send Türksat 5A satellite into orbit Monday night", 30 December 2020, accessed 15 May 2021, Available: https://www.dailysabah.com/business/tech/in-long-awaited-launch-turkey-to-send-turksat-5a-satellite-into-orbit-monday-night

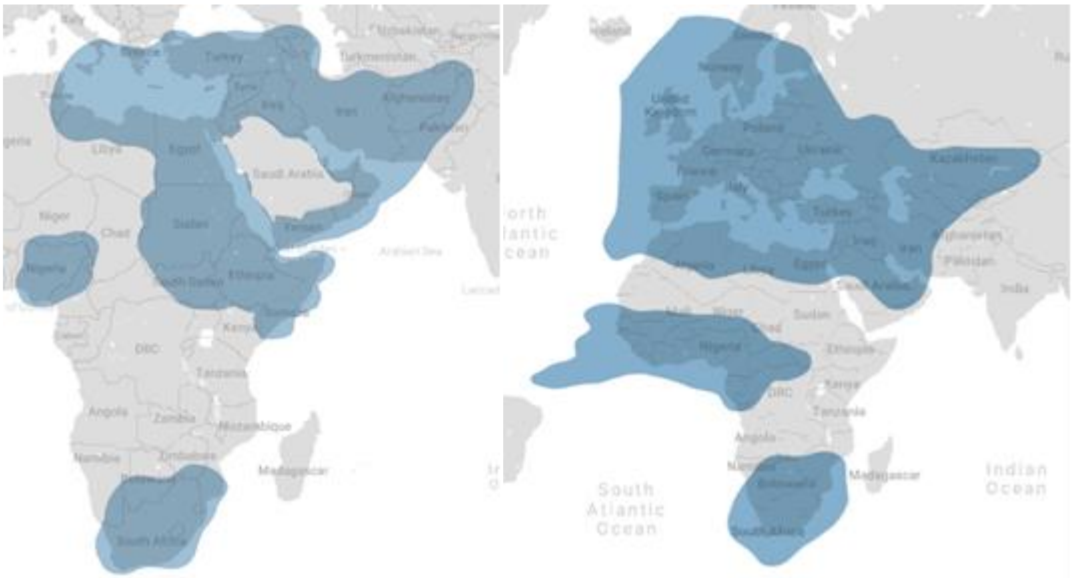

Image 5 Coverage area of Türksat 5A on the west channel and Türksat 5B on the spotbeams channel (ka)

It is worth mentioning that while this thesis is being written, Greek and Armenian organizations in the US are trying to cancel the launch of the Türksat 5B[30]. According to both organizations, the State Department has imposed CAATSA 231 sanctions on both the Turkish Defense Industry and senior Turkish officials.[31] Both organizations claim that the Türksat 5B satellite is clearly used for military purposes and is therefore linked to the Turkish Defense Industry.

2.7 The sixth generation of telecommunications satellites

In 2014, Türksat A.Ş. ordered the Türksat 6A satellite from the Turkish Aerospace Industries (TAI). It is Turkey's first geostationary communications satellite, designed and built entirely in the country, it was expected to be completed by 2020[32]. The project is part of a general plan of Turkey to use its own technology and not be dependent on foreign technology suppliers. [16] [17].

The assembly, completion and testing activities of the Türksat 6A satellite are carried out at the "Space Systems Assembly Integration and Test Center" (AIT) at the Turkish Aerospace Industry in Ankara in cooperation with Aselsan and TÜBİTAK Uzay. The

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[30] Καθημερινή, "Φρένο στην εκτόξευση του Turksat 5B βάζουν οι ελληνικές και αρμένικες οργανώσεις στις ΗΠΑ",14 April 2021, accessed 15 April 2021, Available: https: //www.kathimerini.gr/life/technology/561331162/freno-stin-ektoxeysi-toy-turksat-5b-vazoyn-oi-ellinikes-kai-armenikes-organoseis-stis-ipa/

[31] MICHAEL R. POMPEO, SECRETARY OF STATE, The United States Sanctions Turkey Under CAATSA 231, PRESS STATEMENT, DECEMBER 14, 2020, https://2017-2021.state.gov/the-united-states-sanctions-turkey-under-caatsa-231/index.html

[32] Daily Sabah, "Turkey's first domestic satellite set to be completed in 2020", 02 November 2017, accessed 17 June 2021, Available: https://www.dailysabah.com/technology/2017/11/02/turkeys-first-domestic-satellite-set-to-be-completed-in-2020

satellite is planned to be geostated at 42 ° for the services of Türksat A.Ş and its final payload will be over 4 tons.

TÜRKSAT 6A will offer extensive capabilities for high and secure data transfer applications with 20 Ku-Band transponders that can be used simultaneously.

Once launched, the satellite will cover Europe, Turkey and India and will have a lifespan of 16 years[33].

2.8 Plans for the future

For the coming years, it is planned to build the seventh generation Türksat, as well as satellites to be put at low-earth-orbit for communications needs. The military satellite MAHU (Milli Askeri HaberleĢme Uydusu), [34] which will have transponders in UHF and EHF and will probably be part of Türksat 7.

Turkish Aerospace Industries (TAI) are working on a lighter geostatic satellite, mainly for political-commercial and secondarily for military purposes. Its design plans include launching it from a Turkish rocket.

Turkey already has low-earth-orbit satellites and in cooperation with the satellites that will be put at medium-earth-orbit they will establish communication between them in order to achieve faster data transmission.

[33] Hatice İspir , “Deneyim, kabiliyet, koordinasyon: TÜRKSAT 6A 2022’de uzayda”, 11 Mar 2021, accessed 14/07/2021, available: https://www.defenceturk.net/deneyim-kabiliyet-koordinasyon-turksat-6a-2022de-uzayda

[34] “An Overview of the Ongoing Space Platform and System Projects in Turkey”, vol.13 Issue 92, Year 2019, accessed 17 June 2021, Available: https://www.defenceturkey.com/en/content/an-overview-of-the-ongoing-space-platform-and-system-projects-in-turkey-3538

3 SPACE-BASED EARTH OBSERVATION TECHNOLOGIES

Remote sensing is a way of collecting information about various objects, using instruments that do not come into direct contact with these objects. Satellite remote sensing are the applications of this method that is used in space via satellites. There are many Earth observation remote sensing satellites with different characteristics, which produce a variety of satellite data for use in many applications. In addition to the scientific community, remote sensing satellites are widely used in intelligence services, military operations, disaster monitoring, agriculture, shipping, infrastructure design and monitoring, and more. The great advantage of space-based application is that they provide information from areas that are inaccessible or even in areas that are not normally allowed access. For example, military installations in foreign countries.

In this section, we will see that Turkey began the first steps in satellite remote sensing, what kind of applications developed and future remote sensing capabilities that it wants to develop.

3.1 BilSAT-1

Turkey, in the 1990s, as a newcomer country which was seeking a way to enter the field of space technology, needed a strategy to fill the technological gap with the most advanced countries. For that reason, a committee that was set up for this purpose at the offices of "TÜBİTAK BİLTEN"[35], decided to start a microsatellite program, with the aim of acquiring the necessary skills, through the transfer of know-how and expertise from abroad, so that Turkey could acquire the ability to design, manufacture and testing of its own microsatellites. The reason why a small observation platform, weighing 140 kg, was specially chosen was the relatively small budget required, the shorter development cycle compared to the larger satellites and the capabilities that this technology seemed to have [18].

Thus, TÜBİTAK BİLTEN conducted an international tender that was won by Surrey Satellite Technologies Limited (SSTL), a UK-based company owned by the University of Surrey, in March 1999 [19]. The know-how transfer project started in August 2001 and was completed with the launch of the BiLSAT satellite and put in its final orbit. Launched on September 27, 2003 in sun-synchronous orbit, from Plesetsk Cosmodrome, Russia and the contract cost $14 million.

BILSAT-1 which was part of SSTL's Disaster Monitoring Constellation (DMC) system, was shut down in 2006 due to battery cells failure [20].

The following actions were implemented within the project [21]:

- Design, construction and launch of the BiLSAT-1 satellite
- Basic space infrastructure, including a ground station, is being built.
- The delivery of a separate model of the satellite along with the ground equipment delivered to the customer.

[35] Prior to May 2006, TUBITAK-UZAY referred to as TUBITAK-BILTEN

- The necessary transfer of know-how that was also in the terms of the contract.

Since the BiLSAT project was a know-how transfer project, it is useful to look at the know-how transfer method, what were the conditions for its success and how much the BiLSAT project contributed to transfer know-how and expertise from abroad to Turkey.

The significant advantage of the project was the experience of the organization that implemented it, Surrey Satellite Technologies Limited (SSTL), in terms of know-how and the ability to transfer this know-how. After all, as mentioned above, SSTL had a direct relationship with the University of Surrey [18].

The technology transfer department of the project covered the following:

- Introductory courses for the team,
- On-site training in the satellite design team,
- Provision of scholarships for postgraduate and doctoral studies,
- Construction and testing of the satellite by the same team that received the training and finally its delivery to TÜBİTAK UZAY
- Limited license of hardware and software on BiLSAT satellite and related documentation,
- Construction of infrastructure including ground station, clean room and test equipment
- Payload development

Image 6 The BilSat satellite before leaving the clean room

3.2 RASAT

O RASAT[36] is the second earth observation satellite Turkey after BiLSAT-1, and the first developed and manufactured in Turkey by Turkish engineers. Funded by the State Planning Organization (DPT) and implemented in the TUBITAC UZAY facilities [22]. The project's initial budget was between $ 12 million and $ 14 million, not including launch costs. The project started in 2004 and the satellite was launched in August 2011, at the Dombarovsky Cosmodrome in Russia. The orbit is sun-synchronous and the BilSAT-1 is located at an altitude 685 km and having a period of 98.8 minutes.

No external cooperation or consultant agreement was signed for the construction of the project. Such an agreement could speed up the construction process, but TUBITAK UZAY[37] preferred to do it alone to solve the problems that would arise. Except for the solar panels and the imaging system which were not yet available in Turkey, all the other parts were made in Turkey with the experience gained by BiLSAT.

The RASAT is a high-resolution optical imaging system (sample of the capabilities shown in the figure), provided by a South Korean company, named: Satrec Initiative. The spatial resolution is 7.5m at panchromatic band nd 15 m at multispectral band. [22]

It was put into orbit on August 17, 2011 and while the lifespan of the system was three years, it is still in service[38]. Its ground station is located in Ankara at the premises of Tubitak Uzay [22] [23].

The purpose of the RASAT program was to further improve the experience and skills acquired by the BiLSAT-1 program, as well as to further improve the technical infrastructure required for the assembly, integration and testing of small satellites in Turkey without the contribution of foreign consultants or associates.

The objectives of the RASAT mission can be summarized as follows:

1. Take pictures in the form of stripes

2. Take stereoscopic images of Turkey,

3. Take pictures anywhere in the world,

4. Gaining experience with the payloads of a satellite and how it behaves in space.

On January 24, 2014, the GEOPORTAL project (Geoportal is the parent of the project of RASAT) got the certification CMMI maturity of Level 3. The Integrated Level 3 Capability Maturity Model for Development (Capability Maturity Model Integration for Development) is considered the most widespread certification process in the world. An appraisal at maturity level 3 indicates the organization is performing at a "defined" level. At this level,

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[36] TUBATIK UZAY, “Rasat”, accessed 17 June 2021, Available: https://uzay.tubitak.gov.tr/en/uydu-uzay/rasat

[37] Prior to May 2006, TUBITAK-UZAY was referred to as TUBITAK-BILTEN.

[38] TUBATIK UZAY, “Our RASAT Satellite: 7 years in orbit”, accessed 17 June 2021, Available:https://uzay.tubitak.gov.tr/en/haber/our-rasat-satellite-7-years-orbit

processes are well characterized and understood, and are described in standards, procedures, tools, and methods.

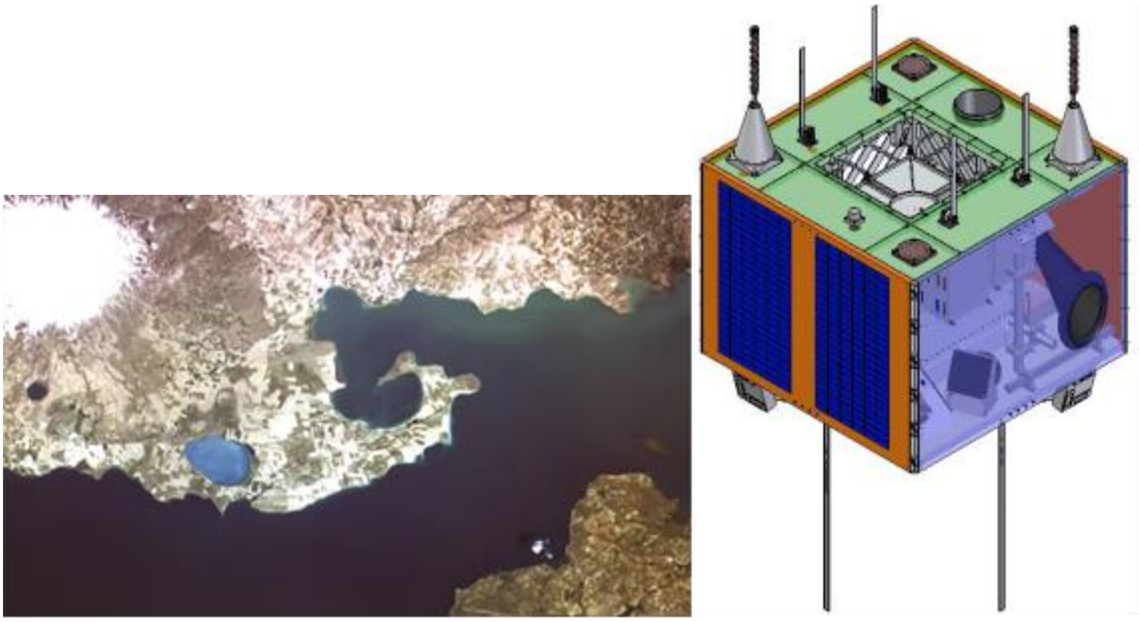

Image 7 Photo taken by RASAT satellite and RASAT CAD model

3.3 Gokturk-1[39]

The GOKTURK-1 satellite was launched from the Kourou space base in New Guinea on December 5, 2016 atop on ArianeSpace's Vega rocket. The cost of the project was 250 million euros. The GOKTURK-1 was launched into a sun-synchronous orbit at a height of 700 kilometers [24].

The contract for the construction of GOKTURK-1 was signed on 13 July 2009 between the Turkish Ministry of Defense, the Undersecretariat of Defense Industries and the French TELESPAZIO which was the main contractor and entered into force on 19 July 2009. Its construction, as well as parts of it are made from the major European aerospace industries (Telespazio and Thales Alenia Space), with the assistance of Turkish industries such as the Turkish Aerospace Industries (TAI), Aselsan and the scientific and technological support of TUBITAK's council. The project was funded and supervised during its construction by the Turkish Ministry of Defense.

The primary objective of GOKTURK-1[40] satellite was to provide high-resolution images for military purposes from anywhere in the world, without regard to geography. Secondary objective of the satellite system was to support applications beyond the military purposes, such as forest observation systems, monitoring of arbitrary construction, detection of damage as soon as possible after natural disasters, annual detection of plant production and finally the production of geographical maps. In support of the project, a ground satellite station was built that provides the opportunity for future cooperation and

[39] Gokturk means Heavenly Turks or Blue Turks, whom were a nomadic people living in the interior of Asia. The first signs of his life date from the 5th century AD.

[40] Leonardo Company, "Gokturk", accessed 17 June 2021, Available: https://www.leonardocompany.com/en/products/gokturk

coordination of several satellites simultaneously in order to receive better measurements from space. The contract signed in 2009 with the Italian Telespazio includes the development of satellite capacity in Turkey as well as the contribution to the construction of a space systems assembly, integration and testing center (USET), at a cost of 110 million dollars.

Regarding the discrete spatial abilities, the satellite has sensors that can take images with very high resolution (70 cm black / panchromatic and colorful 2.5 meters) and has a life expectancy of seven years. The clarity is such that it allows the recognition (recognition) of 85% of the objects of military interest, while in terms of the most difficult identification (description) has a success rate of 70%. Despite its high definition, it fails to distinguish the model of a car or whether a person is a man or a woman. The satellite image data is transmitted to the terrestrial segment via S-band and X-band connectors, and uses encryption developed by TUBITAK. It can also provide images of the Earth in bad weather and at night using an infrared sensor, but with medium sharpness. The total weight of the satellite is 1060 kg.

The Göktürk-1 is considered to be technological similar to the corresponding French civilian-military Pleiades 1A and 1B launched in 2011 and 2012 respectively. As the latter trace their orbits, the earth continues to rotate beneath them (sun-synchronous orbit), so they do not see the same area over and over again. Each one has a return period over the same point every 2 - approximately 2.5 days.

The launch date of Göktürk-1Y, which will replace the Göktürk-1 satellite, has been postponed from 2024 to 2026.[41]

3.3.1 Delay in delivery of the satellite due to claims from Israel.

Israel has asked French company Thales Group, one of Telespazio's shareholders, to limit the satellite’s image capture capabilities. Israel feared that the high-resolution images that can be taken by Göktürk-1 on its territory could fall into the wrong hands. Israel, which supplied some of the critical electro-optical components of the high-tech satellite system to the Thales Group, has demanded that Gokturk-1 not be able to capture images while it is over its territory[42].

Turkey, after being informed of Israel's objections, asked the Thales Group contractor to prove that the satellite can capture images from any desired location, including Israel. The French manufacturer initially rejected the request, but later was forced to accept it, after the Turkish government threatened to suspend payments of the project.

[41] “Göktürk-3 ve Göktürk-1Y uydularının fırlatma tarihine erteleme”, 30 Μαΐου 2021,accesed: 07 July 2021, available: https://m5dergi.com/savunma-haberleri/gokturk-3-ve-gokturk-1y-uydularinin-firlatma-tarihine-erteleme/

[42] EMRE SONCAN, “Ankara-Paris arasında 'Göktürk-1 savaşı”,27 Απριλίου 2012, Accessed 30 June 2021, Available:https://web.archive.org/web/20130127201133/http://zaman.com.tr/gundem/ankara-paris-arasinda-gokturk-1-savasi/2033462.html

3.3.2 Gokturk-1: a demonstration of capabilities

A small international demonstration of the high capabilities of Gokturk-1 took place on two occasions: The first test image received in 2016 and the second test image was during the case of the Suez Canal in 2021.

Image 8 First test image from the GOKTURK-1 satellite[43]

The biggest demonstration of Turkey's space technology capabilities took place on the Suez Canal on the EVERGREEN cargo ship, which at the time had sparked global interest.

[43] http://www.byegm.gov.tr/english/agenda/first-test-images-of-the-gokturk-1-satellite/109312

Image 9 Satellite image from the GOKTURK-1 satellite of the merchant ship EVERGREEN that was stuck in the Suez Canal in March 2021.

On Monday, March 29, 2021, after a six-day blockade of the Suez Canal, the large cargo ship Evergreen withdrew from the shores and shallow canals of the Suez Canal. The obstruction of the channel was a small maritime disaster, where the ship remained intact, but it had a huge impact on world trade.

While the "struggle" of the excavator, the dredger and the tug on the end of exclusion made headlines in the international press, another "race" took place in the space area. An effort to provide rescue teams and the international media with high-resolution images from space. Started as a serious effort to project the "big picture" of ship blockade and traffic congestion at both ends of the canal, but it soon became a means of competing for geographic imaging capabilities by government and commercial remote sensing organizations. Turkey posted a picture (Image 9), which was one of the cleanest image presented at the time and in fact did show its space capabilities on the world stage with a five-year-old satellite[44].

3.4 Gokturk-2

The satellite GOKTURK-2[45] is Turkey's second earth observation satellite after RASAT and the first of the GOKTURK series that was placed into orbit in 2007 (same year with RASAT).

[44] Remco Timmermans, "Space Race over the Suez Canal",31 Mars 2021, accessed 17 June 2021, available: https://www.groundstation.space/space-race-over-the-suez-canal/

[45] TUBITAK UZAY, "GÖKTÜRK-2", accessed 07 July 2021, available: https://uzay.tubitak.gov.tr/en/uydu-uzay/gokturk-2

The project was funded by the Turkish Scientific and Technological Research Council (TÜBİTAK). The cooperation agreement for the development of the GOKTURK-2 satellite was signed on 13 April 2007 (before GOKTURK-1) among the Turkish Ministry of National Defense, the TÜBİTAK Institute of Space Technologies (TÜBİTAK UZAY) and the Turkish Aerospace Industries [26].

The objectives of the GOKTURK-2 project, in addition to the manufacture and launch of the satellite, was the further development of the technologically qualified human resources in Turkey and the improvement of the infrastructure for space, such as satellite systems to meet the needs for Earth observation needs of public institutions and organizations.

It is equipped with technology developed mainly in Turkey. Constructed by 80 percent hardware technology from Turkey and 100% software developed in Turkey, the satellite provides high-resolution imagery of 2.5m resolution at panchromatic, 10m at multispectral, 10 m at multispectral VNIR and 20 m SWIR band. GOKTURK-2 transmitts images taken from around the world to Air Force Command Ahlatlıbel Ground Station. Regarding its telecommunications characteristics, it has three receivers and S band transmitters. It weighs 409 kg and it had a lifespan of 5 years but it is still in orbit. [27] [28]

GOKTURK-2 satellite pre-shipment tests were completed at the premises of the Turkish Aerospace Companies (TAI). The satellite was launched by the Jiuquan Launch Area 4, China. GOKTURK-2 was launched on December 18, 2012. The first signal from the satellite, which was put into orbit after 12 minutes and received after 86 minutes. The launch cost was 20 million euros. GOKTURK-2 is on a sun-synchronous orbit at an altitude of 686 km.

Image 10 The Gokturk-2 satellite

3.5 Gokturk-3

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 Turkey's first military satellite with RADAR synthetic aperture (SAR). The partners of the project include the Turkish Aerospace Industries (TAI), the support of the TUBITAK Research Institute of Space Technologies and the private company Aselsan, [29].

The purpose of this small satellite is, as the two previous ones, to provide high-resolution images from anywhere in the world. The peculiarity is that the SAR sensor can take pictures day and night and under any weather conditions to meet the special requirements of the Turkish Armed Forces.

Following the technical studies carried out in this direction, the discussions for the specifications were completed and the pre-planning agreement for the GOKTURK-3 satellite system development project (phase 1) was signed between SSB and the Turkish Aerospace Industry in May 2013. The final design product of phase 1 of the project was completed in May 2016. Phase II of the project covers the insurance procedures of the satellite launch and satellite development. However, it seems that significant challenges came up, since the launch of the GOKTURK-3 satellite is delayed and is expected between 2025-2028.

Image 11 The Gokturk-3 satellite as expected to be in space with SAR

3.6 The renewal of the satellite Göktürk, Göktürk Yenileme

Turkey plans to replace the Göktürk-1 satellite in 2025 according to the initial plan. Further technical information is not known or has not yet been disclosed. In the original design there is a requirement to have even better resolution and to pass through the same point more often than the previous ones, so it will be at a lower altitude. It is expected to be designed and built in Turkey by Turkish companies [30].

3.7 Imece: The first earth observation satellite made entirely in Turkey

The first Turkish Earth observation satellite, to be built entirely in Turkey with a very high resolution of less than one meter, is to be completed in 2021[46]. Its development and construction takes place at the "Space Technology Design, Construction and Control Center" (USET) and despite the difficulties due to Covid-19, it is estimated that its construction continued smoothly. The satellite, which will be named Imece, will meet the needs for high-resolution images for civilian and military purposes. The software as well as the satellite material were manufactured by Turkish companies.

The IMECE program consists of two main projects [31]:

1) The design and development of satellite subsystems that make up the IMECE satellite, launched in 2013. It is funded by the Ministry of Development, coordinator of the project is the Ministry of Defense. The project consists of various subsystems such as Electro-Optical Satellite Camera, Communication System, Star Tracker, Sun Sensor, Hall

[46] Goksel Yildirim, “1st Turkish-made observation satellite to launch in 2021”, 04 June 2020, accessed 17 June 2021, available: https://www.aa.com.tr/en/science-technology/1st-turkish-made-observation-satellite-to-launch-in-2021/1864719#

Effect Thruster System, Reaction Wheel, Payload Data Storage, Compression and Formatting Unit and Next Generation Onboard Computer.

2) Development project of the IMECE earth satellite station together with all the relevant sub-projects which started in 2017. It is financed by TUBITAK.

Based on the experience and know-how gained from the BİLSAT, RASAT and GÖKTÜRK-2 projects, IMECE is expected to meet future remote sensing needs for images with a resolution of less than one meter, as well as to build the relevant infrastructure required by domestic technology [32].

It is expected to be launched in 2022.

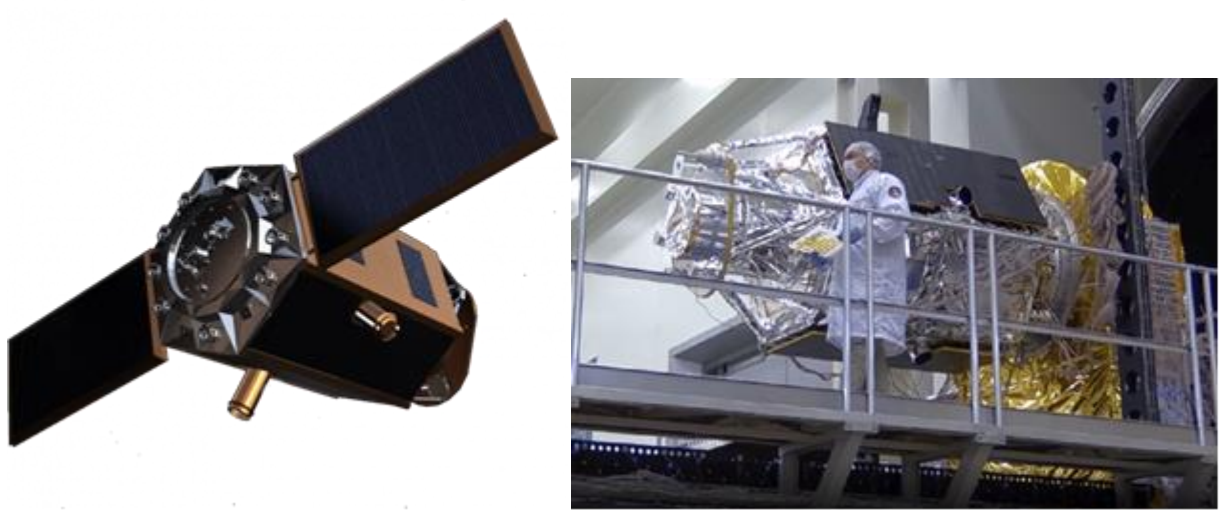

Image 12 The IMECE satellite and its construction site[47].

[47] Souce: https://defencehub.live/threads/imece-recon-satellite.927/, accessed 05 August 2021

4 GROUND STATION CENTERS

The ground station or earth terminal is a terrestrial radio station designed for telecommunications with satellites or spacecraft. Space ground station is the workhorse for all satellites[48].

Space ground systems consists of central terrestrial computer systems that are necessary for the proper operation of a satellite in orbit, these computer systems include: mission control center, ground network and remote infrastructure. These components work together for the management of satellite, payload and telemetry. Remote infrastructure includes terrestrial terminals, which can be satellite dishes communicating with the satellite or simply data receiving terminals.

According to the Delft University of Technology, space ground systems contribute over 5% of the total cost of the entire space system.

In this chapter, we will take a look at the space ground station of BilSat's control center and at the control center of the Technical University of Istanbul. More terrestrial control centers exist, however information about them is limited.

4.1 Bilsat's terrestrial control center

The Bilsat satellite system had its own terrestrial remote sensing control center at the Tubitak-Bilten offices in Ankara. The station was equipped with a) satellite tracking system, b) satellite course control c) reception and decoding of telemetry data and d) data storage [19].

Image 13 The Bilsat ground system during its assembly

[48] **Shannon Terry,** What are Space Ground Systems, accessed 18 July 2021, available: https://ai-solutions.com/newsroom/about-us/news-multimedia/what-are-space-ground-systems/

4.2 Istanbul Technical University, Satellite Communication and Remote Sensing Center (ITU-CSCRS)[49]

The Satellite Communication and Remote Sensing Center of the Technical University of Turkey was funded by the Central Planning Organisation (DPT) in 1996. Construction was completed by 2000 and it became fully operational after test audits in 2002. The center has five satellite dishes and the necessary technology in both hardware and software to operate as a fully integrated satellite station for remote sensing and data reception.

The purpose of the ITU-CSCRS is to develop operational capabilities in satellite remote sensing and satellite telecommunications to meet Turkey's scientific and operational needs. Due to its strategic location, it can cover almost all geographic area of Europe, North Africa, the Arabian peninsula and a very large part of western Asia.

Being fully operational 24/7 and with a large coverage area (radius of approximately 3000 km), the ITU-CSCRS is extremely suitable for supporting applications related to earth surveillance, environmental monitoring, agriculture and natural disasters. The center has 2.4m and 4.6m diameter VSAT antennas to receive data from Ku band communication satellites, 13 m diameter remote sensing antenna and up to 3000 km diameter coverage area with X-band remote sensing satellites reception capabilities.

The largest ongoing research project in terms of cost is the "National Agricultural Yield and Monitoring System" funded by the Turkish government (Project budget: 6 million euros).

The main objective of this project is the monitoring of agricultural land and the development of a system based on Geographic Information Systems (GIS), statistical data and field data for estimating crop yields. Some results of this project are:

- Crop forecast for different types of crops.
- Live and continuous reporting system for different crops.
- Report crop damage and loss after any event.
- Early warning of climate change and agricultural diseases.
- Decision support system based on the report on agricultural management.

[49] UHUZAM, “İTÜ - Uydu Haberleşme ve Uzaktan Algılama UYG-AR Merkezi”, Accessed 17 April 2021, available: https://web.cscrs.itu.edu.tr/

Image 14 The ITU-CSCRS building[50]

Image 15 ITU-CSRS coverage area

[50] Source: https://www.cscrs.itu.edu.tr/, accessed: 05 August 2021.

5 TURKEY'S MICROSATELLITE PROGRAMS

Microsatellites has been the field that Turkey's scientific community has focused on in recent years. This is evident from the numerous scientific publications regarding the subject as well as the various research satellites set in orbit by public and private bodies of the country [34].

Microsatellites' capabilities have grown significantly as a result of recent advancements in space technology. Private and public agencies, as well as military organizations are interested in microsatellite applications as their cost is much lower compared to larger space systems. Microsatellites provide technology that is similar to larger systems and, more importantly, can be produced much more quickly than bigger satellites due to their less complicated system. Their main competitive advantage is their ability to develop and exploit new technologies quickly [35].

In this chapter, and before we present the rest of Turkey's satellite systems, it is appropriate to describe programs related to the development of microsatellites by public and private organizations in Turkey, in the two sectors we have already analyzed, telecommunications and earth observation.

5.1 The High Resolution Earth Observation microsatellite - LAGARI

LAGARİ[51] is a high-resolution earth observation microsatellite developed by STM and Berlin Space Technologies that will be placed into low earth orbit. It is the first satellite, from a constellation of microsatellites that will follow, with the purpose to provide images that will be used in applications such as: mapping, forestry, agriculture, natural disaster monitoring, in near real time. According to the manufacturing company STM, it is equipped with the most modern electro-optical camera system and has the ability to display spot / strip PAN and multispectral images [36].

Its technical specifications show that it will provide global coverage between 80ºN and 80ºL., daily coverage of the region of Turkey with at least 50 photos and a lifespan of two years. Its orbit will be sun synchronous, so it will always have its mirrors facing the sun to have the necessary power supply for its operation.

Its technical characteristics are the following:

- High resolution images
- Light and compact satellite construction
- High precision determination of stop and geographical location control
- 3-axis stop control
- High level solar panels
- Lithium-ferrite battery technology (Li-Fe)
- S-Band and X-Band links for terrestrial communication

[51] Gunter Space Page, accessed 18 July 2021, available: https://space.skyrocket.de/doc_sdat/lagari.htm

- Weight of 70 kilograms.

The project also includes a cooperation agreement with Berlin Space Technologies GmbH and the satellite will be launched with the PSLV rocket of the Indian Antrix Corporation Limited. The launch was scheduled for 2020.

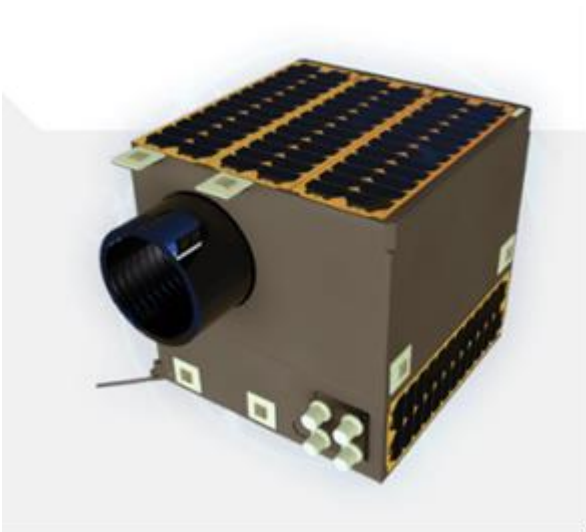

Image 16 The model and logo of the LAGARI satellite

The satellite was named after Lagari Hasan ÇELEBİ (17th century, Constantinople), who according to a unique report[52], was launched on a rocket with the help of 60 kg of gunpowder in 1633.

5.2 6U microsatellite with automatic identification system - PIRISAT

The PIRISAT project, which is being developed by STM, has as its main objective the implementation of the "Automatic Identification System" (AIS) on small satellites. Ships equipped with an AIS receiver will be able to transmit detailed information such as identity, dialing code, coordinates, route, speed, size, destination port, and estimated time of arrival in this manner. This technology aims to make ship navigation safer while also allowing shipping authorities to monitor ships for improved maritime traffic information. [66].

An important feature of PIRISAT is that future electronic components and experimental products developed by universities and companies can be integrated into the satellite and operated in real space conditions. As a result, the PIRISAT project will help to advance space technology.

PIRISAT has a maximum weight of 10 kilograms, which is the limit for the 6U standard (10cm x 20cm x 35cm), and will be able to carry an additional 4 kg of payload. It will provide global coverage between 80oN and 80oL. Its orbit will be sun synchronous, so it will always have its mirrors facing the sun so that it does not face any issue with power supply. Its lifespan is set to be at least one year of life, it has no propulsion system of its own and its mass is 10 kg. It will be able to carry 2U microsatellites with a mass of 4 kg.

[52] Lagâri Hasan Çelebi, accessed 07 July 2021, available: https://owiki.org/wiki/Lag%C3%A2ri_Hasan_%C3%87elebi

- Technical characteristics:
- 3-axis stop control
- UHF-Band communication
- S-Band communication
- Providing available space for experimental loads

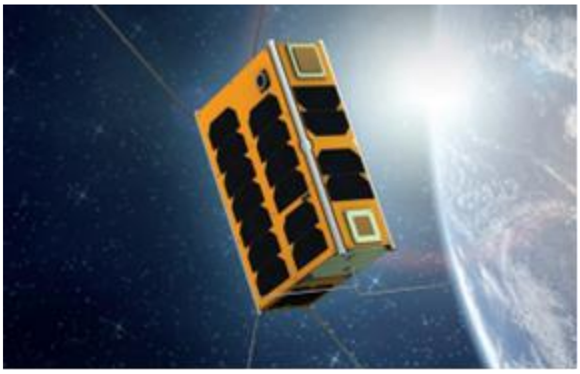

Image 17 The logo and the model of the PIRISAT satellite

The satellite was planned to be sent into space in 2020.

It was named after the Kurd Piri Reis (1470 Gallipoli - 1554 Cairo), who went down in history as a cartographer and Admiral of the Ottoman Navy.

5.3 ITUpSAT1 satellite

The ITUpSAT1 (Istanbul Technical University picoSatellite-1) satellite is a pico-sized microsatellite built in the "Aeronautics and Astronautics" department at Istanbul Technical University. The reason it is worth looking at this particular satellite in this dissertation is to demonstrate the importance that Turkey attaches to its education system in terms of the direction of space studies. ITUpSAT1 was launched on September 23, 2009 and was the first Turkish student satellite to orbit the earth. It was originally designed to have a lifespan of 6 months, but is still in orbit (according to N2YO.COM[53] website) in a sun synchronous orbit at an altitude of 720 km. It has the dimensions of a cube with an edge of 10 centimeters and its mass is 0.990 kg [38] [39].

The purpose of the satellite was to provide a real educational environment to students. The primary mission of ITS-pSat-1 was to test the performance of a passive stability system consisting of a magnet that aligns the satellite depending on the Earth's magnetic field with an error of about 15 degrees, according to measurements made in the simulations. The secondary goal was to take photos with a simple lens in 640 × 480 pixel resolution[54].

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[53] The position of ITUpSAT1 satellite can be located on the website : N2YO.COM," ITUPSAT 1" accessed 17 June 2021, available: https://www.n2yo.com/satellite/?s=35935

[54] Alcetron, "ITUpSAT1", 28 March 2018, Accessed 30 June 2021, Available: https://alchetron.com/ITUpSAT1

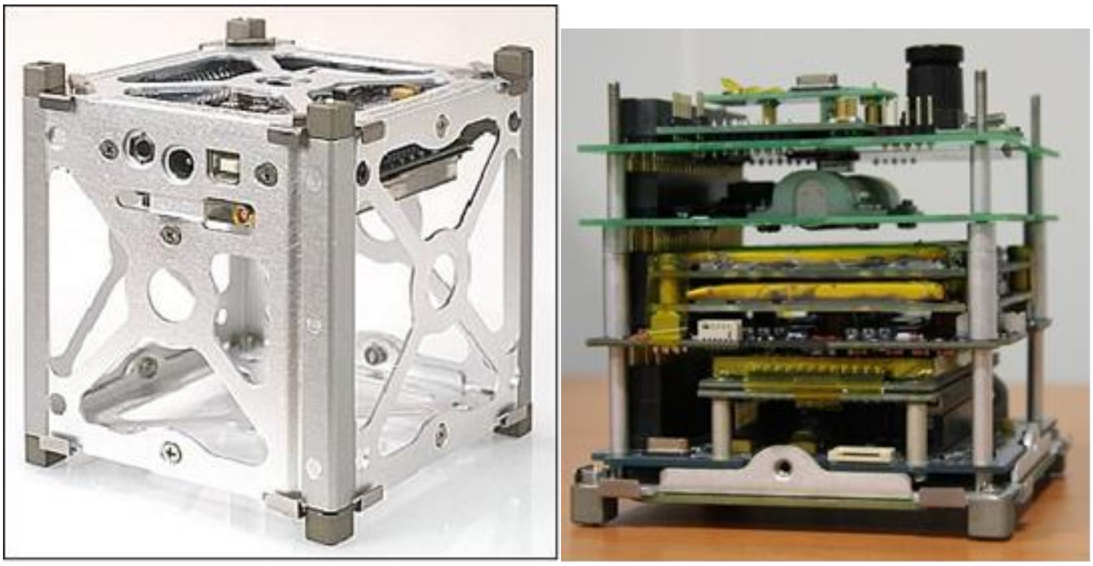

Image 18 The chassis and interior of the ITUpSat1 satellite. (image credit: Pumpkin Inc. and ITU)

5.4 TURKSAT-3USAT satellite

The Turkish Amateur Satellite Technology Organization (TAMSAT), the Türksat A.Ş, and the Technical University of Istanbul collaborated on the development of TURKSAT-3USAT, a telecommunications nanosatellite [40].

Its construction began after the signing of a cooperation agreement between the stakeholders in September 2010 and its development was based on the experience left by the ITUpSAT1 satellite. It was launched into orbit on April 26, 2013. The TurkSat-3USat was launched into a low-altitude, sun-synchronous orbit at a height of 645 kilometers. It passes over Turkey two to three times per day. The lifespan was expected to be at least three years, but according to the website N2YO.COM[55] is still in operation [40].

The housing of TurkSat-3USat was manufactured by Innovative Solutions in Space[56] based in Delft, Netherlands. It has dimensions of 3U, i.e. it is 10 x 10 cm wide and 34 cm high, its mass is about 4 kg.

The payload of the satellite, a linear transponder with a built-in computer, was designed at the RF Electronic Laboratory of Istanbul Technical University. TurkSat-3USat supports amateur radio frequency bands for SSB and CW communication.

Solar panels, lithium polymer batteries, and capacitors provide the necessary power. The satellite can be stabilized using a passive magnetic stop control system (as in ITUpSAT1) with lag bars. Lens on the satellite gives occasional snapshots of the earth. All subsystems have been developed with the maximum possible redundancy, so that in case of failure they have a backup system with the same architecture [41] [42].

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[55] N2YO.COM," TURKSAT-3USAT" accessed 17 June 2021, available: https://www.n2yo.com/?s=23132&live=1

[56] ISISPACE, accessed 17 June 2021, available: https://www.isispace.nl/

After completing its mission, the satellite has a system for abandoning orbit and returning to Earth in accordance with the applicable microsatellite standard and United Nations regulations.

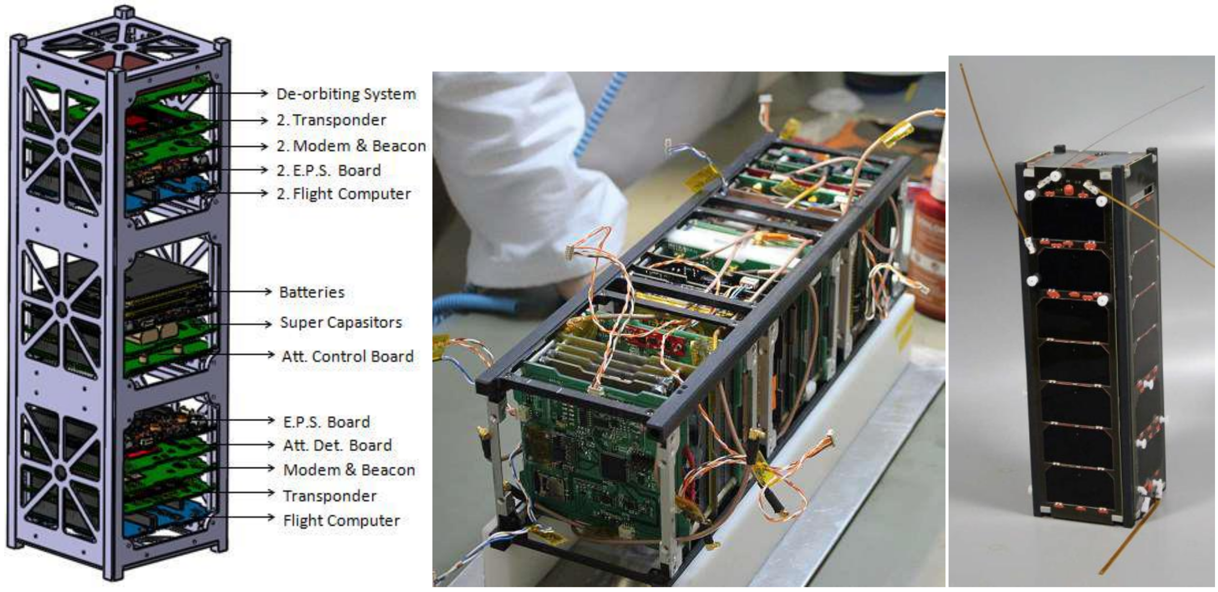

Image 19 The subsystems of the TurkSat 3USAT satellite and its housing for space. (image credit: ITU)

5.5 BeEagleSat and HAVELSAT scientific satellites

QB50 is a network of microsatellites developed by public and private entities around the world, with the Von Karman[57] Institute (Rhode-Saint-Genèse) in Belgium as the overall coordinator. It was funded under the European Research Program FP7. The purpose of the QB50[58] was to create 50 satellites, although 36 were eventually built to make in-situ multi-point, low-temperature measurements. The von Karman Institute described the satellites as “string-of-pearls”. They were built mainly by universities and to a lesser extent by private companies around the world and had as their primary objective to perform scientific data measurements in the widely unexplored lower temperature region[59]. 28 microsatellites were launched in May 2017 by the International Space Station in orbit at 380 km and 8 by the Indian Space Agency with the PSLV rocket.

The goal of the QB50 project is to conduct atmospheric research in the lower atmosphere, at an altitude of 200-380 km, which is the least explored layer of the atmosphere. To explore this area in the past, they had flown in very elliptical orbits (about 200 km periphery, 3000 km apogee). Experiments were performed with point and field measurements, but the time devoted to the area of interest was a few tens of minutes. In contrast, project QB50 will provide on-site multi-point measurements for a period of months, instead of minutes [44].

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[57] Von Karman Institute for fluid dynamics, accessed 17 June 2021, available: https://www.vki.ac.be/

[58] QB50, accessed 14 June 2021, available: www.qb50.eu

[59] The temperature is at an altitude of 80 to 90 km, it is below the line of the interval that starts from 90 km and (according to others from 100 km). It is called a thermosphere because it has temperatures that reach up to 2,500oC and we know very little about this layer of the earth.

Turkey participated with two satellites, BeEagleSat and Havelsat, and was considered the most advanced small satellite system developed by Turkish space technology to date.

BeEagleSat is 2U in size, like all QB50 satellites. Istanbul Technical University (UTEB, UNISEC-TR), the Turkish Air Force Academy (TurAFA) and two smaller Turkish start-ups collaborated to build BeEagleSat. Sabanci University also provided a CdZnTe-based semiconductor X-ray detector and related electronic reading data. In terms of payload for QB50, the satellite carries a multi-link Langmuir Detector (mNLP) and samples the density of electrons around it [45] [46].

HAVELSAT is 2U CubeSat in size. It was manufactured jointly by HAVELSAN and the Istanbul Technical University. The payload of HAVELSAT is a radio software (Software Degined Radio, SDR) for communication. The satellite also has the ability to perform small-scale image processing. HAVELSAT also carries a Langmuir Multi-Needle Detector (mNLP) and samples the electron density of the space around it.

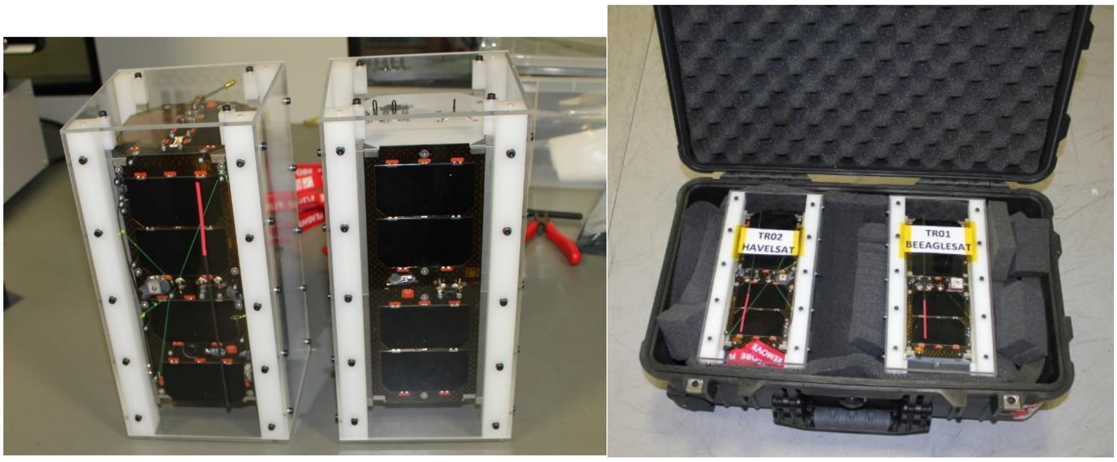

Image 20 On the left the BeEagleSat and on the right the Havelsat, externally showing the solar installations and being in their final position before being launched. (image credit: ITU)

5.6 UBAKUSAT (UBAK-3U-SAT) satellite

The UBAKUSAT satellite was developed in collaboration with a Japanese institutions and the Technical University of Istanbul. It was launched by SpaceX with the Falcon-9 rocket and launched into orbit by the I.S.S. in May 2018 [49]. On September 8, 2016, Istanbul University and the Japanese Government signed a contract for the development and launch of UBAKUSAT in Ankara.

UBAKUSAT is referred to as a nanosatellite[60] but its final size is 3U. It was built by students of the School of Aeronautics and Astronautics of the Technical University of Istanbul, in the Laboratory of Space Systems Design and Testing (SSDTL). The Turkish Ministries of Transport, Communication, and Shipping provided technical assistance in collaboration with the Japan Aerospace and Exploration Service and the Kyushu Institute of Technology. The satellite is equipped with an amateur radio and a linear transponder.

[60] Nanosatellites weigh between 1 and 10 kg and are smaller than microsatellites. In microsatellites the size is measured in U units. 1U has a cube size with dimensions 10x10x10 cm.

The linear transponder on UBAKUSAT is similar to that on the TURKSAT-3USAT satellite, which was launched on April 26, 2013 [80].

It also has satellite earth remote sensing and voice communication systems for amateur radio stations all over the world. The TAMSAT Simplesat is a test design in the form of a card that allows researchers to test the accuracy of measuring radiation from space. It is the second satellite built by Istanbul University students.

On February 23, 2018, it was handed over to officials from the Japan Aerospace Exploration Agency at the Tsukuba Space Center in Ibaraki. The satellite was then put through a series of tests at the space center to simulate the conditions it will face in space.

Its development cost is estimated at $ 100.000. The launch cost is estimated at $ 250.000 and was covered by the Japanese Government.

Image 21 Delivery ceremony UBAKUSAT, Tsukuba, JAXA, Japan (picture Tsukuba, JAXA), (image credit: ITU)

5.7 ASELSAT - high resolution microsatellite

The Turkish company ASELSAN started the construction of the ASELSAT satellite in order to gain valuable experience in microsatellites and use its own technology in low-earth orbit space. The company used its own x-band transmitter and put it in orbit to see what results it would have in space. The ASELSAT satellite's mission was to capture images and transmit them to a ground station using an X-Band transmitter [51].

The X-Band micro-transmitter designed specifically for ASELSAT by ASELSAN sends visual data to the ground station, which is processed on the satellite before being sent to the ground. The camera used is also made by ASELSAN and can take photos at 30m GSD. The satellite's secondary payload has a radiation meter that collects low-orbit statistics for future satellite missions [52].

The "preliminary design review" phase of the Project was completed in 2018, and production and assembly of ASELSAT 3U began in May 2019. The “Information and

Communication Technology Authority" granted Aselsan a license to test the ASELSAT 3U Cube Sat in February 2019. The ASELSAT 3U satellite was launched into space by SpaceX on January 24, 2021, and was placed in a 500 km heliosynchronous orbit.

Under the ASELSAT 3U Development Program, the Department of Aerospace Engineering of the Technical University of Istanbul (ITU) and the Department of Engineering of Atılım University worked as subcontractors.

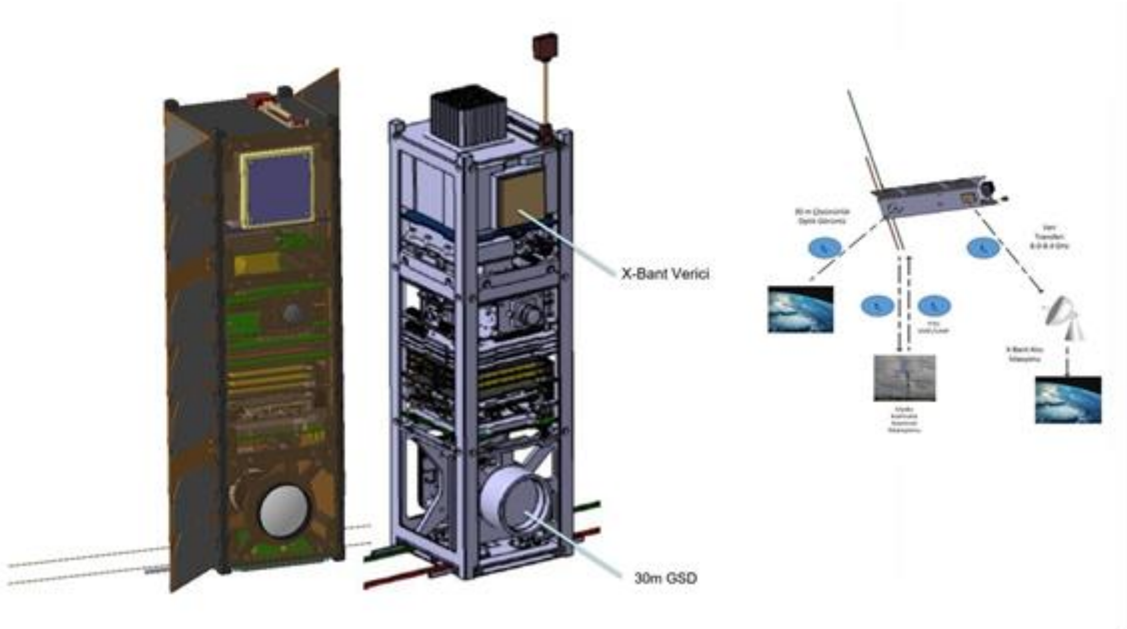

Image 22 the ASELSAT 3U satellite with X-Band transmitter (image: ASELSAN)

5.8 The Grizu-263 team

Grizu-263 is a student team founded in 2016 at Zonguldak Bülent Ecevit University to take part in the CanSat[61] competition, which is considered the most famous satellite design, construction and launch competition in the world. The team has gone to the finals held in America four times in a row. Also in 2019, the Grizu-263 team took first place in Turkey in the TURKSAT Competitive Satellite Model organized as part of TEKNOFEST in Turkey [53].

In addition to these successes, the team set up a ground station at Zonguldak Bülent Ecevit University to receive data from low-orbit satellites [54].

The team's contribution to the design and construction of Turkey's first pocket satellite is significant, with project title: Grizu-263A and dimensions 5x5x5 cm. It was launched on January 14, 2021 by SpaceX from Cape Canaveral and was put into orbit at an altitude of 525 km in sun-synchronous orbit [55].

5.9 Scientific Proposals for a microsatellite program

The Turkish Armed Forces are preoccupied with microsatellites for space applications. The extraordinary advantages of speed and cost of implementation of microsatellites

[61] CanSat Competition, accessed 10 June 2021, available: www.cansatcompetition.com

have turned Turkey to intensifying research and development to use these systems for military use. Applications such as intelligence collection, surveillance and reconnaissance (ISR), remote communications, high-resolution land surveillance and environmental disaster monitoring missions can be implemented with excellent results using microsatellites [81].

A space solution, which would include the addition of satellite telecommunications channels, would fill in the gaps in the Turkish Armed Forces' existing capabilities, providing regular advantages [82].

This chapter will describe an interesting solution, found by research and which has been proposed for military communications using constellations of microsatellites. A low-orbit telecommunications microsatellite formation could provide Turkish Armed Forces with continuous communication coverage over Turkish territory, the Black Sea, the Aegean Sea, and the Mediterranean Sea, particularly over Turkey's mountainous east and surrounding seas. A constellation of this type is thought to be capable of improving communication capabilities for NATO forces and units operating in the region [82].

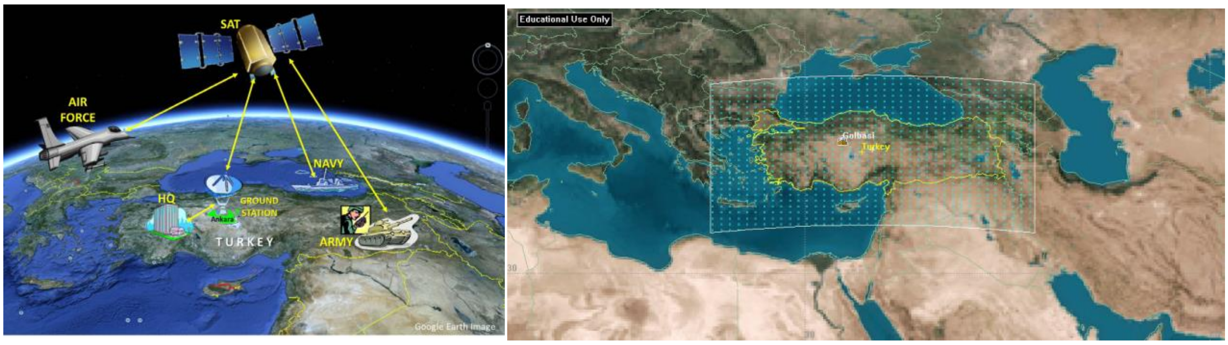

Image 23 Microsatellite system, how the coverage area could work [82].

5.9.1 Telecommunications microsatellites for military applications, operation and general technical characteristics

Satellite formation can be used to transmit communication signals received from one unit or platform from one area to another unit or platform in another area. For example, an aircraft (manned or unmanned) flying over the Mediterranean will be able to send data to the satellite, which will then transmit this data to the operations center in Turkey's interior. A ship in the Black Sea communicating with an aircraft flying over the Aegean is another example. The effectiveness of the formation's communications via satellites is directly proportional to their technical ability to communicate with the Turkish Armed Forces' existing communication devices via air, sea, and land [82].

The headquarters (HQ) is located near the town of Golbasi where the headquarters of Türksat is also located, in order to enable better decisions regarding the allocation of resources of all satellite systems and the determination of the priority of use. The headquarters will house representatives from all the services that use the system. The priority of using the system will be decided according to how "urgent the requests are" and their relation to national security. The mission of this space system is to provide efficient, reliable and continuous communication capability at ultra high frequency (UHF, 300 MHz-3 GHz), voice and data communication capability over Turkey and the surrounding areas, the Black Sea, the sea of Marmara, the Aegean Sea and the Mediterranean Sea for serving of the Turkish Armed Forces [82].

The Turkish Air Force Headquarters will be responsible for frequency allocation and guidance of satellite operations, including telemetry, guidance and control of microsatellites. TÜBİTAK UZAY academic staff and METU Middle East University can assist the Air Force in operating the microsatellite system. A network of microsatellites will form a cluster in low orbit around the earth. The microsatellites will have the same technical characteristics, but different orbits to provide 24/7 coverage of the area as shown in image 33. The formation follows the Walker Delta design. The satellites are evenly distributed in different orbital planes with the same inclination. It is estimated that between 10 and 50 satellites are required to cover Turkey and the surrounding area, depending on operational requirements [82].

Each microsatellite in the constellation will have the same technical specifications as the others. These capabilities are dictated according to the current communication devices (terminals) that potential users already have, in order to communicate with all facilities, units and platforms of the Turkish Armed Forces. The satellites will also be able to interface to ensure that ground users stay connected when the satellite in use goes out of range until the next one arrives and connects. This process between satellites is necessary so that user service is not interrupted each time a satellite goes out of range. Each satellite should contain multiple transponders, with point beam antennae turned to the Earth and the interconnection antennae between satellites should point to each of the three adjacent satellites (assuming there are two levels) to allow interconnection for real-time transmission of voice services and data [82].

6 AUTONOMOUS ACCESS TO SPACE

Space technology is an integral part of our daily lives. Telecommunications, meteorology and navigation services are invisible but essential utilities that we use on a daily basis, and they solely depend on the use of satellites. In this respect, it is a major economic, defense and scientific interest of each country that owns and manufactures its own satellites to have autonomous access to space at any time, without depending on other organizations to put its satellites in orbit.

Turkey has set a key goal of achieving autonomous space access by initially building the infrastructure needed within the country. Missions for placing satellites in low orbit can be served by the domestic facilities in Turkey. However, missions that need to place satellites in geostationary orbit or even on other planets, such as the Moon, which is also a long-term target for Turkey, are best served by launch sites near the equator. That is why Turkey is seeking to establish a rocket base in a friendly country near the equator.

In this chapter, we will take a look at the development and construction of missile launch systems, both inside and outside Turkey.

6.1 Satellite Launch System: Uydu Fırlatma Sistemi

The Satellite Launch System (Turkish: Uydu Fırlatma Sistemi)[62], abbreviated UFS, is a project with the main objectives of autonomous space access from Turkish territory, the further development and improvement of space technology and the independence of Turkey from third-party suppliers. This includes the technical support and viability of the existing satellite systems.

The contract for the construction of the project was signed in 2013 between the Presidency of Defence Industries (SSB) and Roketsan for the needs of the Turkish Air Force. Its main parts are the creation of a spaceport, the development of satellite rockets and the creation of remote ground stations[63]. According to planning, the space base that will be built will have the ability to orbit microsatellites up to 100 kg at an altitude of 500 to 700 km. The project is expected to be completed in 2025.

It is worth mentioning that the company Roketsan, in parallel with the aforementioned projects, is also developing a ballistic missile program. Its main features are a range of 2500 km and a payload of 500 kg[64].

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[62] Roketsan, “Micro-Satellite Launching System”, accessed 17 June 2021, available: https://www.roketsan.com.tr/en/product/micro-satellite-launching-system/

[63] Hurriyet daily news, “Innovation key to breakthrough in Turkish defense industry”, 17 December 2013, accessed 17 June 2021, available: https://www.hurriyetdailynews.com/innovation-key-to-breakthrough-in-turkish-defense-industry-59680

[64] Burak Bekdil, “Does Turkey really need long-range missiles?”, 07 February 2014, accessed 17 June 2021,available:https://www.al-monitor.com/pulse/originals/2014/02/turkey-missiles-needed.html#ixzz51S3bllx6

6.1.1 Where are satellites launched from?

So far, all launch tests have been carried out at the test center in Sinop province[65], which is the northernmost part of Turkey and borders the Black Sea. A very important fact to note is that the rockets that have been tested are divided into stages and due to the high altitude a rocket must reach, the first stages of the rocket that detach during the launch of the rocket end up in the sea. However, due to the geographical location of Turkey, such launches are only possible for sun synchronous orbits. In case other orbits are to be tested, a different launch location must be selected and candidate areas are the Aegean or southeastern Turkey.

Image 24 Simulation of the launch site and the platform (source: Roketsan)

6.2 Space Base in Somalia

Turkey has announced its plans to build a rocket launch site in Somalia in February 2021[66]. The cost of the facility is estimated at $ 350 million and is part of Turkey's overall plan for autonomous space access, totalling over $ 1 billion in cost.

In this context, two phases have been planned: The first is planned for 2023, in which the first mission to the Moon will be sent with the hybrid rocket developed by Turkey. After being placed in orbit around the moon, the rocket will perform an abnormal landing.

[65] Daily Sabah, Turkey successfully tests hybrid rocket engine for moon mission, 11 April 2021, accessed 04 August 2021, available: https://www.dailysabah.com/business/tech/turkey-successfully-tests-hybrid-rocket-engine-for-moon-mission

[66] Daily Sabah, “Turkey to build spaceport in Somalia as part of $1B space program”, 19 February 2021, accessed 17 June 2021, available: https://www.dailysabah.com/business/tech/turkey-to-build-spaceport-in-somalia-as-part-of-1b-space-program

In the second phase, planned for 2028, the next mission to the moon is planned and a smooth landing will take place by space shuttle. The purpose is to carry out scientific research on the natural sciences.

The two phases are directly connected to the Somali base, which is an ideal location for rocket launches with space as their final destination. Somalia is located on the equator where the centrifugal force of the earth during its rotation is the maximum possible. Somalia also has Turkey's largest military base outside its borders since 2011, which can guarantee the security of its space airport[67].

On June 16, 2021, the President of the Turkish Space Agency (TUA), at the International Space Exploration Conference in St. Petersburg, Russia, stated that Turkey intends to send a rover[68] to the moon in 2028-29 to collect scientific data from the planet's surface. The mission will be using Turkish missiles and most likely the launch will take place in the Somali base.

[67] Ragip Soylu, “REVEALED: Turkey plans spaceport in Somalia for $1bn moon mission”, 18 February 2021, accessed 17 June 2021,available: https://www.middleeasteye.net/news/turkey-space-programme-somalia-base-cost-revealed

[68] Καθημερινή, “Τουρκία: Σχεδιάζει να στείλει ρόβερ στη Σελήνη έως το 2030”, 19 Ιουνίου 2021, Accessed: 20 Ιουνίου 2021, Available: https://www.kathimerini.gr/world/561405709/toyrkia-schediazei-na-steilei-rover-sti-selini-eos-to-2030/

7 REFERENCE SATELLITE PROGRAMS AND APPLICATIONS IN THE FIELD OF NAVIGATION AND POSITION TRACKING

7.1 Reference system: Tusaga-Aktif

Turkey, like most other advanced countries in the world, uses the US GPS system for navigation. For increased accuracy, however, it uses differential GPS (abbr. dGPS) which is an improved version of GPS. Tusaga-Aktif[69] is an implementation of dGPS which has 146 GNSS stations that improve the accuracy of the system. Tusaga-Aktif uses predefined base stations, which receive GPS signals and transmit the necessary corrections. Thus, moving terminal equipped with dGPS receivers know their instantaneous position at all times with precision of less than 1 meter [56] [13].

Image 25 The TUSAGA - AKTIF with its 146 reference stations that are synchronized with the remote and the satellites.

Turkey, as a member of the European Space Agency (ESA), also participates in the Ranging and Integrity Monitoring Station program (EGNOS RIMS)[70]. EGNOS RIMS complements GPS by increasing the reliability and accuracy of location data.

7.2 Regional Positioning and Timing System (RPTS)

7.2.1 Applications and existing implementations of R.P.T.S.

Positioning systems are three-dimensional measurement systems that use radio waves from a constellation of satellites orbiting the Earth. They include a satellite navigation system, usually served by more than 4 satellites simultaneously, designed to provide instant information such as location, speed and time almost anywhere in the world at any time. RPTS systems are used in many fields such as unmanned systems, missiles, commercial and military aviation. The United States NAVSTAR / GPS Global Positioning System and the Russian Global Navigation Satellite System (GNSS) have the required reliability and are used by various countries. Similarly, GALILEO is the European GNSS

[69] Tusaga-aktif, "Türkiye Ulusal Sabit GNSS Ağı - Aktif", accessed 17 June 2021, available: https://www.tusaga-aktif.gov.tr/

[70] D.Brocard, T.Maier, C.Busquet, "EGNOS Ranging and Integrity Monitoring Stations (RIMS)", accessed 17 June 2021, available: https://www.fig.net/resources/proceedings/fig_proceedings/fig2011/papers/ts05c/ts05c_bakici_kisa_5255.pdf

program developed by the European Space Agency (ESA) and the European Union (EU) for global urban coverage. GALILEO aims to provide global, highly accurate location information and functionality between GPS and GLONASS [58] [13].

Other countries that are developing their own global GNSS system are China with BEIDOU, India with IRNSS, and Japan in cooperation with Oceania with QZSS. Due to the necessary technology, most countries are aiming for independence. However, this is a big problem for developing or non-space countries due to the high cost of the systems [58].

7.2.2 Advantages of an independent R.P.T.S. for Turkey

Turkey has set a goal to become completely independent of the American GPS and rely on its own reporting and timing system[71], so as not to be affected by any deliberate shutdown during a period of military operations. In addition, through its own RPTS, it will eliminate cases of "fraud" in military operations that could change the course of its GPS-based missiles. Finally, even when there are electronic interferences in the GPS signals used by the opposing forces, the Turkish Armed Forces should not be affected by this [58] [59].

In this way, the country will be able to have its own timing and positioning system when its armed forces need it (in time of peace or operations) and not risk being dependent on external systems that can be deactivated in times of conflict. Experts in Turkey say this move will minimize the risk of "disruption" or "deception" in military operations. Especially since all military platforms with missiles and ammunition use the American or third country GPS, no one can guarantee whether another country's navigation system will work in critical operations or in a war environment when there is conflict of interests involved. How much can different countries such as the USA, Russia, Europe or China be trusted in the future that they will not disconnect the system when their interests are affected? [58]

Another aspect of the project is even more important. It is extremely valuable for the Turkish Armed Forces to be certain of the authenticity of the coordinates given to them. How will they destroy a critical target at a critical moment when the navigation system they are using displays distorted values? [58]

For the reasons stated above, this program is of great military importance to the Turkish Armed Forces and occurs as stage number 3 in the new Space program announced by President Erdogan in 2021[72].

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[71] Veronica Magan, “Turkey Plans to Increase Investment in Satellite Communications”, 03 April 2013, accessed: 17 June 2021, available: https://www.satellitetoday.com/uncategorized/2013/04/03/turkey-plans-to-increase-investment-in-satellite-communications/

[72] Turkey unveils National Space Program including 2023 moon mission, 9 FEB 2021, TRTWORLD https://www.trtworld.com/turkey/turkey-unveils-national-space-program-including-2023-moon-mission-44025

Image 26 The ten points of development of the Turkish Space Program as presented by the President of Turkey

7.2.3 The Turkish Regional Positioning and Timing System (BKZS)

The project has started to be developed by the Turkish company "Defence Technologies and Engineering Inc (STM)" . The project is currently in its first phase, its current title in Turkish is: "Bölgesel Konumlama ve Zamanlama Sistemi" (BKZS) and its initial goal is to launch 5 reconnaissance and tracking satellites in the coming years. The BKZS satellite array will also work with the existing Tusaga-Aktif system [58].

Previous studies have concluded that in order to improve DOP (Declaration Of Performance) accuracy by RNSS systems, it is necessary to increase the number of satellites. Considering the cost of one satellite is estimated at about 350 million dollars, the cost to build a basic eight-satellite BKZS architecture is estimated between 2 to 2,5 billion dollars. This includes the start-up cost and the ground segment and was compared to the cost of similar projects. The annual operating cost of such a system is expected to be about 150 million dollars. Even so, since the system will not initially have the necessary accuracy and timing to be sufficient, Turkey is obliged to continue cooperating with GPS, GLONASS and GALILEO, and satellite navigation receivers must be compatible with these systems [59] [60].

Image 27 The Turkish Regional Positioning and Timing System (BKZS) [73]

[73] Source: https://www.defenceturk.net/milli-uzay-programina-genel-bir-bakis

8 TURKISH GOVERNMENT AGENCIES INVOLVED IN RESOURCE ALLOCATION AND DECISION-MAKING FOR SPACE POLICY

8.1 Institute of Space Technologies - TÜBITAK Uzay

TÜBİTAK Uzay[74] (Turkish: Teknolojileri Araştırma Enstitüsü, Greek: TÜBİTAK Ινστιτούτο Διαστημικών Τεχνολογιών) was founded in 1985, following the signing of a cooperation protocol between the Middle East Technical University and the Scientific and Technological Research Council of Turkey (TÜBİTAK), which aimed to set up a state-funded research institute.

TUBITAK UZAY specializes in space technologies and everything else associated with them, such as electronics, satellite communications, space observation, satellite remote sensing, following the latest technological developments. The institute takes initiatives and participates in research and development projects, aiming to play a leading role in the Turkish space research community, helping Turkish industry solve technical problems and investing in the development of new products in its fields of specialization.

TÜBİTAK Uzay puts particular emphasis on the development of design know-how, engineering and validation of microsatellites by the Turkish space program, while concluding international collaborations in this field.

The HALE program, which we will see below, is considered one of the most successful projects it has completed.

8.1.1 The HALE program

For the completion of the Hall Effect Thruster Development Project (HALE), TÜBİTAK Uzay built a fully equipped facility for research and development on thrusters. The establishment was built on the premises of TÜBİTAK UZAY with the financial support of the Turkish Ministry of Development. The project aimed for the potential electronic thrusters that would result from the research to be able to meet the space needs of Turkish missions in the short and long term. [61] [62]

The HALE project establishment had the required space simulators and diagnostic tools for the complete design, construction and testing of electrical thrusters. In addition, with the technical background obtained during the project, the mechanical model Hall-effect thruster (HET) was developed, with a power of 1.5 kW. The HET produced a nominal thrust of 70 mN and had a specific impulse at 1500. The first prototypes of other system parts, including Propellant Feeding, Cathode, Power Processing and Control Units, were also designed and manufactured.

The HALE project was a strategic, technological, commercial and critical investment for Turkey, taking into account the increasing needs of the domestic and international market for electric propulsion systems for future missions. Through the HALE project, Turkey hopes to develop its own reliable propulsion systems while reducing its dependence on foreign technological sources.

[74] TUBITAK UZAY, accessed 16 June 2021, available: https://uzay.tubitak.gov.tr/en/kurumsal/about-us

The project was completed two years after its initial planning in 2018 having achieved all its initial goals.

Image 28 The HALE facilities and the HET model (source[75])

8.2 Defense Industry Executive Committee - SSIK

The Defense Industry Executive Committee (SSIK)[76] is the primary decision-making body for critical defense industry issues and major defense system procurement decisions. The Prime Minister chairs this committee, which also includes the Ministers of Interior, National Defense, and the Commander of the Turkish Armed Forces. SSIK ratified by Law No. 3238/2018 [9].

8.3 Defense Industries Presidency - (SSB) Former Ministry of Defense Industries - (SSM)

The primary goal and purpose of the Defense Industry Presidency (SSB) [77] is to implement the decisions of the Defense Industry Executive Committee. To accomplish this goal, the SSB is given a special legal foundation, a separate budget, and financial resources.

It was established in 1985 as the Office for the Management of Development and Support of the Defense Industry (SaGeB), administratively belonging to the Ministry of National Defense. The tasks of the SaGeB were to define policies related to the creation of industrial infrastructure on defense systems. SaGeB was upgraded as Undersecretary of Defense Industries in 1989.

SSM changed management in 2017 and is now under the Presidency of the Republic and was renamed the Presidency of Defense Industries (SSB) in July 2018.

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[75] HALE, accessed: 04 August 2021, available: https://uzay.tubitak.gov.tr/en/uydu-uzay/hale

[76] DEFENCE INDUSTRY EXECUTIVE COMMITTEE (SSIK) , accessed: 17 June 2021, available: https://www.ssb.gov.tr/WebSite/contentlist.aspx?PageID=40&LangID=2

[77] "Undersecretariat for Defence Industries (SSM)", accessed 17 June 2021, available: https://www.ssb.gov.tr/WebSite/contentlist.aspx?PageID=39&LangID=2

Its missions and responsibilities are as follows:

- Implement the Defense Industry Executive Committee's decisions,
- Reorganizes the existing Turkish industry to meet the needs of the defense industry,
- Plan the production of modern weapons and equipment in both private and public sector companies,
- Assists in the research and development of modern weapons and equipment, as well as the construction of prototypes, and has a high degree of financial flexibility,
- Coordinates export and countervailing trade issues related to defense industrial products.
- Plan the production of required modern weapons and equipment by the private or the public sector.
- Support new private, public or joint investments on condition of openness when necessary.
- Ensure that implementation deficiencies are resolved by the relevant organizations and companies.

The Defense Industries Presidency carries out multibillion-dollar projects and its procurement strategy favors domestic production. It has the highest priority in the projects it finances and in space policy planning.

8.4 Defense Industry Support Fund

The Defense Industry Support Fund is the only funding source available to the Defense Industries Presidency (SSB) in order for it to carry out its mission. What distinguishes this fund is its high degree of flexibility and lack of bureaucracy in its structure. It has an ongoing cash flow and complete and independent control [78] [9].

This fund's primary source of revenue is corporate tax quotas, fees, and levies imposed on alcoholic and tobacco products, as well as all forms of gambling and betting, lotteries, and so on [9].

8.5 Turkish Space Agency - TUA

The Turkish Space Agency (Türkiye Uzay Ajans 1998, abbreviated TUA) was established informally in 1998. Later, in 2001, the Turkish Air Force was appointed to coordinate a national effort for space activities and make specific recommendations for a permanent central organization. With the participation of other relevant government agencies, a draft law was prepared for the official establishment of the Turkish Space Agency. Thus, the operation of TUA was approved for the first time by the Turkish National Security Council in 2001 after the TUBITAK report prepared jointly by the Turkish Armed Forces, the

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[78] Ismet Akca, "Military-Economic Structure in Turkey", TESEV, accessed 1 July 2021, available: https://www.files.ethz.ch/isn/120118/gsr-2-eng.pdf

Ministry of Defense and the Ministry of Transport, Maritime Affairs and Communication [2].

Its current form, the Turkish Space Agency[79] was established in December 2018 by Presidential Decree no[80] 23. Its headquarters are in Ankara, and it is part of the Ministry of Science and Technology. Its mission is to develop strategic plans for aerospace science and technology that include medium- and long-term goals, key principles and approaches, goals and priorities, performance measures, methods to be used, and resource allocation [63].

The Turkish Space Agency is a legal entity and has its own budget with administrative and financial autonomy. According to its statutes, the organization is responsible for the preparation and implementation of the "National Space Program" which is determined by the President of Turkey. The Board of Directors of the Turkish Space Agency has seven members, including the president and is the highest decision-making body. The term of office of the members of the Board of Directors outside the Chairman is three years [64] [65].

The presentation of the "National Space Program" was made by the President of the Turkish Republic in February 2021.

8.5.1 The main tasks and responsibilities of the organization

The main tasks and responsibilities of the Turkish Space Agency are:

- To plan and carry out the National Space Program in accordance with the policies established by the country's President.
- Prepare strategic plans that include medium and long-term goals, key principles and approaches, goals and priorities, performance criteria for goals, methods for achieving them, and resource allocation for sciences, space, and aviation technologies.
- The growth of a competitive aerospace and aerospace industry, as well as the expansion of the use of space and aeronautical technologies in accordance with societal prosperity and national interests.
- The advancement of scientific and technological infrastructure, as well as human resources, in the fields of space and aeronautical technologies.
- Increased capacity and capabilities, as well as the acquisition of facilities and technologies that will allow independent access to space.
- The advancement of scientific and technological infrastructure, as well as human resources, in the fields of space and aeronautical technologies.
- Plans, projects and research projects to ensure that all finished products, technologies, systems, systems, equipment, space and aircraft-related tools,

[79] Turkish Space Agency- TUA, accessed 15 June 2021, available: https://tua.gov.tr/en

[80] The Constitution of Turkey is a presidential republic and all state decisions are signed by the President.

including satellites, launch systems and launch systems, aviations, simulators and space platforms are developed, integrated, and tested.

- Organization and monitoring of various activities, including ground space systems, such as design, analysis, production, testing, operation and completion of space and aircraft construction.
- To support astronomy and space science research and to coordinate national projects.
- Develop international partnerships.
- Supporting research for technology development of monitoring and measuring systems.
- To create and distribute apps linked to science of space, technology and aviation, to work on finance, law, business administration, marketing and the like.

A brief presentation of the projects of which the TUA participated as a partner or as a coordinator.

8.5.2 Improved X-ray synchronization and multimetry - eXTP

Full title in English Enchanced X-Ray Timing and Polarimetry (eXTP)[81]. It is a scientific mission designed to study the state of matter under extreme conditions of density, gravity and magnetism. Primary objectives are to determine the equation of state of matter at hypernuclear density, to measure the effects of QED in a highly magnetized environment, and to scientifically study the gradual increase in gravity. The systems to be studied include isolated and binary neutron stars, strong magnetic field systems such as magnets, stellar masses and supermassive black holes. [66] [67]

Turkey will contribute to the Wide Field Monitor (WFM) under European Space Agency, in coordination with Sabancı University and TUBİTAK UZAY, and develop the application of the system.

The international consortium behind eXTP includes the Chinese Academy of Sciences and Universities, the European Space Agency and other major institutions with international partners.

8.5.3 Map of Cosmic Radiation of Turkey - KORAH

The coordinator of the project is the Turkish Space Agency in cooperation with Istanbul Technical University, the General Directorate of State Airports Authority of Turkey and the General Directorate of Civil Aviation of Turkey. The aim is to draw a map of Turkey's cosmic radiation. The purpose is to measure the exposure of cosmic rays to passengers traveling by airplane. Special test flights will take place at different altitudes and different routes to measure the amounts of proton (p), electron (e), neutron (n), alpha (a), beta (b), gamma radiation (c), the cosmic rays UV and X. The obtained data will be used for the

[81] eXTP, accessed: 17 June 2021, available: https://tua.gov.tr/en/project/extp-1

modeling of the national cosmic radiation model as well as in the preparation of the national cosmic radiation network. The map will be used for space and aeronautical purposes[82].

8.5.4 Certification of atomic clock for space use - UTAS-R

The National Institute of Metrology TÜBİTAK (UME)[83] designed and built the first domestic Rubidium-based atomic clock to be used for navigation satellites. The National Institute of Metrology and the Turkish Space Agency have signed a collaboration protocol to certify that the atomic clock is suitable for space activities. The certification of the atomic clock will take place in real conditions in space environment [68].

Optical atomic clocks will increase the accuracy of Turkey's time scale by 100 times. The use of optical clocks will pave the way for a redefinition of seconds and other constants in physics, as well as other concepts such as navigation, better communications, electronic signatures, relativistic geodesy of new generation RADAR systems, quantum computers and other applications.

The project is of the utmost importance and priority for Turkey because atomic clocks are a key feature of navigation satellites and Turkey has made it a priority to acquire its own navigation system.

[82] TUA, "KORAH Turkey's cosmic Radiation Map", Accessed May 2021, Available: https://tua.gov.tr/en/project/korah-1

[83] TUA, "UTAS-R", accessed: 19 July 2021, available: https://tua.gov.tr/en/project/utas-r-1

9 TURKISH COMPANIES THAT ARE ENGAGED IN SPACE INDUSTRY

9.1 Roketsan

Roketsan (Turkish: Roket Sanayii ve Ticaret A.S) is one of the largest companies in the defense industry, based in Ankara.It was established on June 14, 1988 by decision of the Defense Industry Executive Committee (SSİK) with the aim of "Establishing a leading institution in the country for the design, development and construction of missiles". The shareholders of the company include TAF by 55.5%, Aselsan by 15%, MKEK[84] by 10% and HAVELSAN 4.5% [69].

Important space-related projects undertaken by Roketsan include the construction of the Satellite Launch System (Turkish: Uydu Fırlatma Sistemi) and the Roketsan Research Center (Turkish: Roketsan Uydu Fırlatma, Uzay Sistemleri ve İleri Teknolojiler Araştırma Merkezi) [70] [71].

Image 29 The Micro-Satellite Launching System (MSLS) (source: roketsan)

Roketsan has been involved in the development of missiles for the Turkish Air Force. The information available about the missiles is limited because they are considered classified.

Led by Roketsan, a team of technicians developed a two-stage rocket called the Teknoloji Platformu (TP). The first stage of TP used solid fuel and had a diameter of 0.6 m. The second stage used liquid fuel. That was the reason why they characterized the rocket as a hybrid. Three missiles were built with the codes: TP 02-1, TP 02-2 and TP 02-3. The TP 02-3 was Turkey's first rocket to reach an altitude of 130 km and exceed 100 km, which is considered the space line.

[84] MAKİNA ve KİMYA ENDÜSTRİSİ KURUMU, accessed: 5 June 2021, available: https://www.mkek.gov.tr/tr/

The evolution of the Teknoloji Platformu rocket was named BURAK and was ROKETSAN's first experimental high-altitude rocket. It had initial specifications to be able to reach an altitude of 150 to 300 km. Its launch was done by a self-propelled mobile launch unit attached to another vehicle. The project was eventually abandoned and its overall design revised.

The ROKETSAN MUFA and ROKETSAN SIMSEK rockets were originally designed to be deployed with solid fuel and be completed in 2023 and 2025. But due to delays in their development compared to the original programming, they are likely to eventually evolve into hybrid rockets with a combination of solid and liquid fuels. The DELTA-V company is expected to significantly contribute to this target.

Finally, ROKETSAN is developing the Micro Satellite Launch System (MUFS) rocket launcher, which is designed to place 100-kilogram microsatellites on orbits up to 400 kilometers. With a possible launch date of 2025, the company is working on propulsion systems, with solid fuels, liquid fuels and hybrids[85].

9.2 HAVELSAN Co.

HAVELSAN[86] is a Turkish software company with a business presence in the fields of defense and information technology. Its headquarters are located in Ankara, Turkey and the offices are located throughout Turkey and internationally. Havelsan is mainly involved in C4ISR, naval fighting systems, ego-government applications, IT, surveillance and recognition systems, information management systems, simulation and training systems, logistics and security systems, power systems.

Havelsan was founded by the Turkish Air Force Foundation (TUAF) in 1982 as a Turkish company called Havelsan-Aydin to provide maintenance for the Turkish Air Force's high-tech RADARs.

Havelsan was established by the Turkish Air Force Foundation (TUAF) in 1982 to maintain the high-tech RADARs of the Turkish Air Force as a Turkish corporation called Havelsan-Aydin.

The company has been designated as the "House of Informatics and Systems of Turkey" to emphasize its important role in the operation of Turkey's defense systems. Havelsan develops vital defense systems such as management systems, Turkish security systems and C4ISR.

The development of the HAVELSAT and the HAVELSAN KASK satellites was undertaken by HAVELSAN.

9.2.1 The HAVELSAN KASK system

HAVELSAN KASK is a GNSS protection system. The military and civilian navigation platforms need accurate location information to know where the users are located and

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[85] “Savunma Sanayii Başkanı Prof. Dr. İsmail Demir: Türkiye uzayı gördü”, (20 June 2020), accessed 08 July 2021, available: https://m5dergi.com/dergi/savunma-sanayii-baskani-prof-dr-ismail-demir-turkiye-uzayi-gordu/

[86] Havelsan, accessed 4 June 2021, available: https://www.havelsan.com.tr/

based on this can calculate their routes correctly. Global Navigation Satellite Systems (GNSS) are provided by satellites at an altitude of about 20,000 km. GNSS terrestrial navigation systems are receivers that provide location information after processing signals received from satellites.

It is very easy for GNSS receivers to provide incorrect location information, either when these signals are blocked by third-party devices or because the signals on the earth's surface are very weak. Blocking or false data generators can be easily fabricated and have already been used in several cases.

HAVELSAN KASK ensures that satellite signals can be analyzed and that location information (latitude and longitude) can be generated correctly when blocked, by detecting the interfering antenna when present and correcting position accuracy.

HAVELSAN KASK provides protection against jammer signals by detecting the direction of the jammer using special mechanisms. HAVELSAN KASK is compatible with the existing GNSS system of Turkey's system and can be adapted to the future GNSS.

Image 30 The HAVELSAN KASK device (source: Havelsan)

9.3 Aselsan A.Ş.

Aselsan (Turkish acronym: Askeri Elektronik Sanayi), is a Turkish defense company based in Ankara, Turkey. Its main areas are research, development and manufacture of advanced military products for air, land and maritime capabilities. Aselsan is one of the most important contractors of the Turkish Armed Forces [72].

It was founded in 1975 by the Turkish Army Foundation, which owns 74.20% of the shares, while the remaining 25.80% of ASELSAN shares are traded on the Istanbul Stock Exchange.

The ASELSAN spends on average 7% of its annual turnover in research and development activities, financed by its own resources. Its personnel is characterized as highly qualified engineers, outperformed the number of 7,000 employees.

For its military and privately held customers in Turkey and abroad, ASELSAN designs, develops and produces advanced electronic systems. The firm is based in Macunköy, Ankara. ASELSAN has subsidiaries across Azerbaijan, the United Arab Emirates, Kazakhstan, Saudi Arabia and South Africa.

According to the field of activity, ASELSAN is divided into five business sectors:

- Business Communications and Information Sector,
- Microelectronics, guidance and electro-optics sector,
- RADAR and electronic warfare systems,
- Defense technology systems sector,
- Transport, Security, Energy and Automation Systems Sector.

ASELSAN inaugurated its new “Radar, Electronic Warfare and Technology Center” (Turkish: ASELSAN Radar ve Elektronik Harp Teknoloji Merkezi)[87] in the Gölbaşı district of Ankara on March 16, 2015. Its construction took three years and the cost was 157 million dollars. The facility covers a surface area of 75,000 km2. The center has 776 engineers, 261 technical personnel and more than 200 support personnel.

The technology park focuses on research and development to support RADAR, RADAR for fighter jets, long distance aviation defense monitoring, electronic warfare systems as well as antennas, microwave power units, and Turkish Army support software (army, navy, air force).

9.3.1 Aselsan Space Technologies

ASELSAN has in its history the construction of telecommunication satellites, surveillance and reconnaissance satellites for both military and commercial frequency bands. It has experience at designing and manufacturing innovative solutions for Turkey’s national purposes in the areas of the payload, board for satellites and for space ground systems.

Also, Aselsan has the necessary electrical, electronic and mechanical equipment to provide system design and production, integrated ground system design, subsystem and equipment design, satellite payload design, final production, integration and testing services (including orbital testing).

It commercially has a variety of space systems, the most important of which are:

Land Platform Satellite Communication Terminals:

- Manpack Satellite communication Terminal:
- Flyway satellite communication terminal.
- Portable satellite communication terminal.
- Vehicle communication terminal.

Naval Platform Satellite Communication System.

[87] Radar ve Elektronik Harp Teknoloji Merkezi , accessed: 19 July 2021, available: https://www.aselsan.com.tr/tr/basin-odasi/haber-detay/aselsan-radar-ve-elektronik-harp-teknoloji-merkezi-acildi

- AcroSAT Shipborne Satellite Communication Terminal
- Submarine Satellite Communication Terminal

Air Platform Satellite Communication System.

- Airborne Satellite Communication Terminal

Network control stations

- Surveillance & Reconnaissance Satellite Ground Stations
- Network Control Station

Surveillance and Reconnaissance Satellite subsystems and equipment

- Synthetic Aperture Radar (SAR) Satellite Systems

Earth images are collected during day or night in all weather conditions via a SAR payload

- Development of numerous Cubesat projects

Communications satellites payloads:

- EHF-Band

To fulfill the requirements on extremely high frequency and being reliable against electronic warfare, ASELSAN develops on-board processing EHF payload for geosynchronous communication satellites.

- Ku-Band

Ku-Band Receiver – (comprising Low Noise Amplifier and Frequency Downconverter)

Payload equipment:

- Payload interface unit.

Payload Interface Unit (PIU) is the on-board equipment used for relaying telecommands received from on-board computer to the Ku-band and X-band equipment respecting to the equipment interface. PIU is also tasked for collecting telemetries from the Ku-band and X-Band Payload equipment and sending them to on-board computer.

- Ku-Band Receiver

Ku-Band receiver is tasked for amplification of the received uplink signal and downconversion to the downlink frequency band.

- Ku-Band INET

Ku-band INET is responsible of multiplexing Ku-band uplink signal respecting the channel frequency bands and also INET is responsible of channel switching at the input stage

- Ku-Band ONET

Ku-Band ONET is used for multiplexing and switching of downlink channels

- Ku-Band Turkey Antenna

Ku-Band Turkey Antenna is a shaped beam Gregorian Satellite Antenna used for receiving Ku-band uplink signals sent from Turkey coverage area. Turkey Antenna is also responsible of transmission of downlink signal to the Turkey coverage area.

Payload services:

Having high technology investments and qualified personnel, ASELSAN conducts payload and payload equipment design & production, payload integration as well as space qualified card and module production. Moreover, ASELSAN performs various tests including EMI/EMC, environmental, in-orbit test support and Thermal Vacuum Chamber tests

It has two vacuum thermal chambers, with a diameter of 2200x2500 cm and 1000x700 cm respectively, have been constructed in order to test the payloads in space conditions.

The chambers are in a clean space. ASELSAN has two clean rooms, one of which is in the assembly, completion and testing room (AIT) with an area of 500 square meters. compliance meters with a class of 100,000 and the other is a room for the construction and certification of equipment of 600 square meters with an order of 10,000.

Other payload services provided are:

• Design and production of hardware with space specifications.

• Design & Production of Electronic and Mechanical Equipment for ground stations.

• Assembly, completion and testing of payload (X-band, Ku-Band, EHF-Band, etc.).

• Environmental Analysis (Thermal, Shock, Vibration and Radiation).

• Environmental tests (Thermal, shock and vibration).

• EMI / EMC tests (compliance with MIL-STD-461E / F).

• Thermal vacuum space test (TVC).

• Orbit test.

Compliance with ISO

For the category 100,000 (ISO 8), 500 m2 clean room.

For the category 10,000 (ISO 7) & 1,000 (ISO 6), a total of 600 m2 clean room.

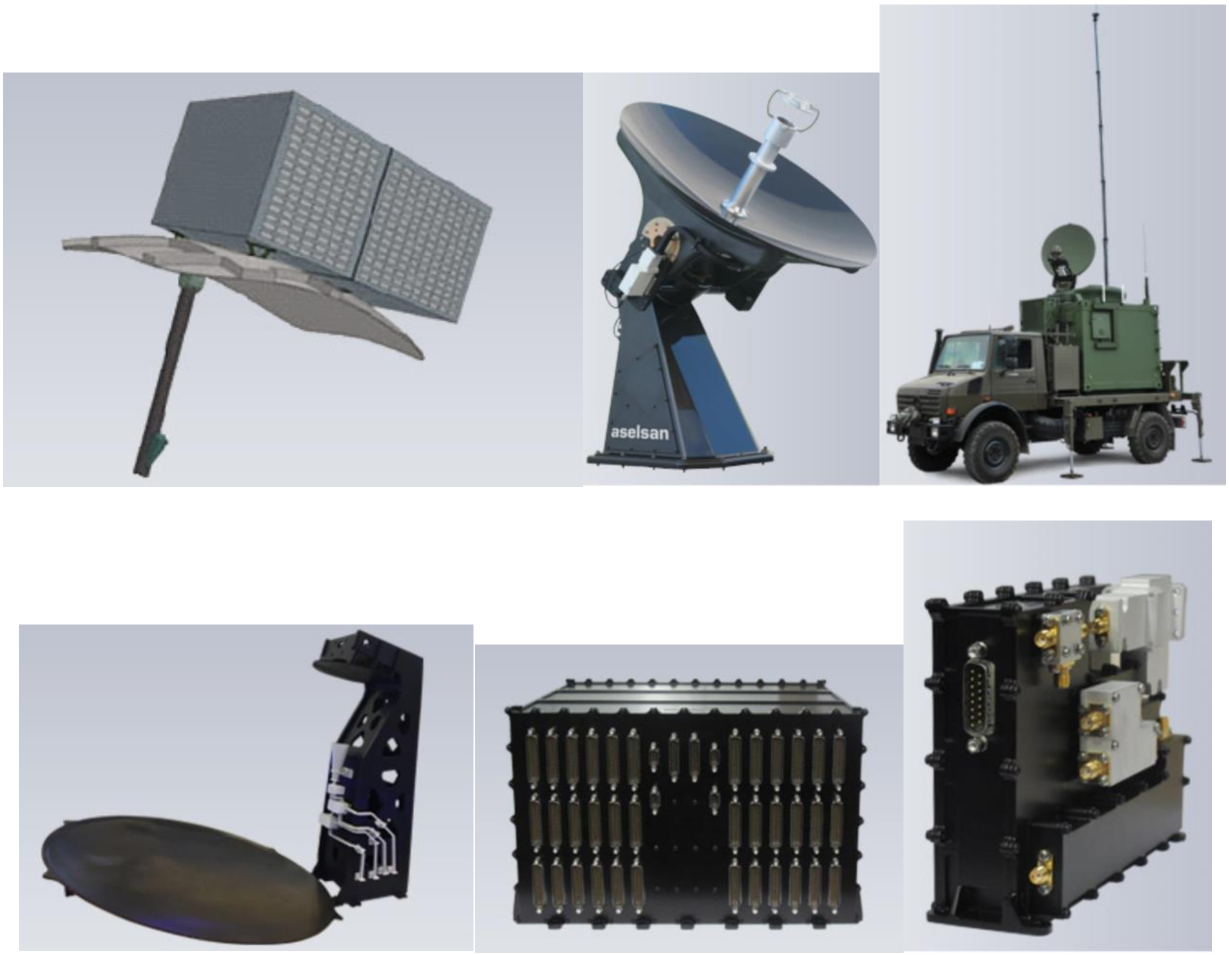

Image 31 Space technologies provided by ASELSAN. From top left to bottom right we see 1) SAR Satellite, 2) Satellite communication terminal for ships, 3) Satellite communication terminal for mobile vehicles, 4) Turkish Ku-Band Receiver, 5) Payload Interface Unit (source: Aselsan)

9.4 GUMUSH Aerospace & Defense Ltd.

Gümüş Uzay Savunma Havacılık Ltd. (GUMUSH Aerospace & Defense)[88] was established in 2012 and is the first company in Turkey and the Middle East specializing in manufacturing microsatellites sized pico and nano (mainly CanSat and CubeSat) for academic and commercial purposes. The company has the full support of the Presidency of the Republic of Turkey and the Ministry of Science, Industry and Technology.

GUMUSH has a sophisticated research and development center for satellite subsystems and provides cost-effective, reliable subsystems for nanosatellites.

Provides:

- Satellite design (Pico, nano & micro) for military, academic and commercial uses.
- Microsatellite subsystem design (EPS, OBC / OBDH, T&TC, ADCS, Thermal, etc.).

[88] Gumush, accessed 1 July 2021, available: https://gumush.com.tr/about

- Advisory and training services on satellite systems and projects.
- Thermal, structural analyzes and tests.
- Satellite launch services.
- Construction of solar panels for all satellites depending on its mission and orbit.
- Track design.
- Design of communication and ground stations.
- Rocket design

He participated[89] in the 3USAT project, which involved the construction of a 3U satellite. At the project he had the role of project manager, and the purpose of the satellite was to transmit data by voice in low earth orbit.

He also participated in the BEAGLE and HAVELSAT project, which carried out in the framework of the European research program FP7 in collaboration with three universities in Turkey and the company ErTEK space technology.

Another project of the company is the NART-BUS. NART-BUS is nanosatellite system includes Structure, Antennas for UHF-VHF & S-Band SDR, OBComms, ThermalControl, EPS, Solar Panels and ADCS. It is cost effective solution for technology demostration and space test. The project is supported by TUBITAK.

9.5 Turkish Aerospace Industries – TUSAŞ

TUI (Turkish: Türk Havacılık ve Uzay Sanayi A.Ş., TUSAŞ)[90] is the center of the development, design, construction and support of aerospace systems in Turkey. Founded in 1973, it is based in Ankara and employs over 1,500 engineers. The total area of its facilities is 5.000.000 square meters of which 186.000 square meters are closed. The company's modern aircraft manufacture facility located at Akıncı Air Base.

His space projects include the military satellites Gokturk-1, Gokturk-2, Gokturk-3 and Gokturk-1Y, which will replace Gokturk-1. It manufactures the telecommunications satellite TURKSAT 6A and a fully electric satellite (as we will see later).

Revenue in 2019 was $ 2.26 billion. Holders of TUI are the Turkish Armed Forces with 54.49%, the Presidency of Defence Industries (SSM) with 45.45% and the Turkish Aeronautical Union with 0.06%.

[89] Gumush, accessed 6 June 2021, available: https://gumush.com.tr/project/

[90] TUSAS, accessed 1 July, available: https://www.tusas.com/en

9.5.1 Space Systems Assembly Integration and Test (AIT) Center - Uzay Sistemleri, Entegrasyon ve Test Merkezi - USET).

The Space Systems Assembly Integration and Test (AIT) Center[91] is designed to serve for assembly & integration activities, functional performance test and environmental test to be conducted all space systems for earth observation, communication and similar featured satellites until they are ready for launch activities.

It is located in Ankara, Turkey and the contract for its construction was made through the Presidency of Defense Industries (SSB) for the Ministry of Transport and Infrastructure. As part of Göktürk-1 the center began to be set up in 2009 for domestic satellite construction and certification testing, from the first design to the start-up phase.

The arrangement was the outcome of a 2010 agreement between the Turkish Ministry of National Defense and Telespazio. It is spatially located within the territory of the Turkish aerospace industry, in the province of Kazan in the province of Ankara. The cost of the installation is estimated at US $ 100 million[92]. The official inauguration of the facility took place on May 21, 2015 in the presence of President Recep Tayyip Erdogan.

The center has the following facilities:

- Satellite assembly
- Environmental tests
- Thermal vacuum tests
- Installation testing for solar cells
- Testing of vibration
- Mass property measurement
- Testing Acoustic, and
- Preparation M.L.I.

91 TUSAS ,"UZAY SİSTEMLERİ ENTEGRASYON VE TEST MERKEZİ", accessed 10 June 2021, available: https://www.tusas.com/urun/uzay-sistemleri-entegrasyon-ve-test-merkezi

92 Haber Giriş, "Türkiye'nin uydu merkezi tamamlandı", accessed 10 June 2021, available: https://www.hurriyet.com.tr/teknoloji/turkiyenin-uydu-merkezi-tamamlandi-27662450

Image 32 Photos from inside the center where the various checks are made (source: TUSAŞ)

9.6 GSATCOM Company

In December 2018, the President of Turkey Recep Tayyip Erdogan and the President of Argentina Mauritius Makri during official meetings at G20 meeting, announced the start of their cooperation in space and the creation of the company GSATCOM[93]. The newly established company, which will benefit from the technology developed and offered by the two countries together, has the main goal to build small geostatic satellites to meet the needs of their countries but also for export to third countries. The participating

[93] Gsatcom, accessed 10 June 2021, available: https://www.gsatcom.com/

domestic companies are the Argentine company INVAP and from the Turkish side the Turkish Aerospace Industries. It was decided GSATCOM to be headquartered in Ankara.

The Argentine company INVAP hold a remarkable course in space. It has participated in the construction of two telecommunications satellites in collaboration with Thales Alenia Space, the Arsat-1 launched in 2014 and the Arsat-2 launched in 2015. In addition, it has built the Saocom-1A and Saocom-1B which were launched in 2018 and 2020 respectively and both are earth observation satellites.

GSATCOM will manufacture high-performance satellites with payloads of 500 to 2000 kg, 1.5 to 7.5 watts of satellite power and 50Gbps connection speeds [74].

The partnership began with the agreement of the construction of a geostationary satellite for the needs of Turkey and the construction of three more low-orbit satellites without being known for which country or space agency they are made. According to the original design, the target of the company is to build a satellite within 20 to 24 months and to be able to deliver two satellites a year.

The great advantage of the design of satellite is the adaptation of the characteristics of the design to the individual needs of the customer and the market and to the business opportunities that appear in each orbit. The construction of the satellites will be flexible and can be adapted to the needs, the power required, the geographical location and the transmission beam.

The advantages they will offer are [75]:

- Digital flexible payload tailored to the needs.
- High performance satellites. Multi-link architecture to reuse available bandwidth for better use of available spectrum.
- Full electric propulsion.
- Load power: 1.5 to 7.5 kW
- Launch mass: 500 kg to 2000 kg
- Multi-start compatibility while in orbit
- Antenna plate 74 cm to 120 cm
- Included but not limited to Ka, Ku, C band support X and UHF.

The possibility of multiple starts is an important advantage, because the satellite will be able to change its orbit.

Shortened integration time and in-house availability of basic subsystems and components allow the vertical integration strategy that reduces the total cost of overall system, ensures delivery time and allows customers to have fast and competitive responses to immediate market opportunities.

9.7 DeltaV A.Ş

DeltaV Space Technologies Inc. was founded in 2017 based in Istanbul. Its purpose is to develop the hybrid rocket with which Turkey will be able to go to the moon. According to the Daily Sabah[94], hybrid rocket engines provide a significant launch cost advantage over other rocket engines in the space industry.

DeltaV Space Technologies works exclusively on the research and development of chemical rockets that can be used in advanced space applications, include a) advanced launch systems, b) advanced stage rocket engines and c) spacecraft propulsion systems [78] [77].

Although the official website of the company has been under construction for a long time: http://deltav.com.tr/, the Daily Sabah newspaper published in April 2021 a successful test carried out by DeltaV in the Sile area of Istanbul. In the test, a vertical test was performed to trigger the hybrid sound rocket propulsion system [79].

Image 33 The firing test of the Turkish hybrid rocket engine takes place in Sile, Istanbul, on April 11, 2021.

9.8 Defense Technology and Trade Engineering Company - STM

STM[95] (Turkish: Savunma Teknolojileri Mühendislik ve Ticaret A.Ş), is a Defense Technology and Trade Engineering company that was founded in 1991 by the Defence Industry Executive Committee (SSIK). It provides the following services: project

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[94] Daily Sabah, 28 February 2021, accessed 16 June 2021, available: https://www.dailysabah.com/business/tech/turkish-firm-to-develop-hybrid-rocket-tech-for-2023-moon-mission

[95] STM, accessed 16 June, available: https://www.stm.com.tr/

management, engineering of systems, transfer of technology, scientific and logistical support and consulting services. STM is ruled by a five-member Board of Directors, headed by its Chairperson. The firm operates in three key divisions: 1) engineering, 2) development of technology and 3) consulting.

STM pays great attention to its export, since 2018 is in the top100 list of DefenceNews[96] based on the exports of defense equipment. Its goal is to become a global leader in world market of defense expenses. Within the framework of Vision 2023 established by the Presidency, STM aims to continue to grow by increasing its exports and join the 50 largest companies within the next five years. Aiming to become a global player by developing projects that can compete internationally, STM will focus on future investments in the following areas: underwater and unmanned vehicles, cyber security and artificial intelligence. STM seeks cooperation and builds new partnerships with friendly and allied countries of Turkey, providing consulting services, support and training to build the necessary development infrastructure.

Important projects that have been developed and related to space are: The PiriSat satellite and the LAGARI satellite. Below we will take a look at the two computer systems Microsatpro and Nanosatpro.

9.8.1 MICROSATPRO

The Space Qualified Processor Unit (MICROSATPRO)[97] is a high-performance, on-board computer (OBC) built to suit to microsatellite space missions.

MICROSATPRO is resistant to harsh space conditions, has a high fault tolerance, offers high reliability and high processor power. It is designed to operate in low orbit and is designed to remain in that orbit for at least five years.

Image 34 The Microsatpro system that seems to fit the technical specifications for a microsatellite chassis. (source: STM)

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[96] DefenceNews, “Top 100 for 2020” accessed 16 June, available: https://people.defensenews.com/top-100/

[97] STM “Microsatpro Space Qualified Processor Unit”, accessed 16 June 2021, available: https://www.stm.com.tr/en/our-solutions/command-and-control/microsatpro-2713

9.8.2 NANOSATPRO

NANOSATPRO[98] (Nano Satellite Processor Unit), is a technology similar to MICROSATRO, but for smaller satellites and lower performance due to its smaller size. Its service life in operating lifespan is 2 years at low orbit.

9.8.3 Mission Planning Software

It is computer software[99] designed to operate in a web environment and plans the mission of a satellite system with one or more satellites, according to the constraints and resources and calculates the required parameters.

Features:

- Automatic programming without user intervention
- Ability image requests through the application map
- Feasibility Analysis import image request using satellite dynamics and image geometry
- Satellite power and memory management
- Support for different types of imaging applications:
- Better optimization GSD and Pitch Angle

[98] STM "NANOSATPRO Space Qualified Processor Unit", accessed 16 June 2021, available: https://www.stm.com.tr/en/our-solutions/command-and-control/nanosatpro-2718

[99] STM "Mission Planning Software", accessed 16 June 2021, available: https://www.stm.com.tr/en/our-solutions/satellite-and-aerospace/mission-planning-software

10 DISTINGUISHED SPACE TECHNOLOGY STUDIES AT MILITARY SCHOOLS AND UNIVERSITIES.

The importance that Turkey has given to the development of its own space technology and investing in the training of its personnel is evident from the space studies curricula that have been integrated in military academies as well as from the curriculum provided by the Technical University of Istanbul.

10.1 Turkish Air Force Academy

The Turkish Air Force Academy[100] (TuAFA) (Turkish: Hava Harp Okulu) is a four-year military academy, located in the city of Istanbul. It is part of the National Defense University of Turkey and its graduates pursue a career as executives in the Turkish Air Force.

The department of "Aviation Engineering and Space" is one of the four total departments of the academy. The aim of the department is to train prospective pilot officers with aviation / aerospace knowledge and skills.

The school also releases the electronic Journal of Aeronautics and Space Technologies[101], which is published biannually since 2013. It is written entirely in English and contains scientific and academic articles. It is distributed free.

10.2 Hezarfen Institute of Aeronautics and Space Technologies (ASTIN)

The National Defense University of Turkey was founded in 2016 and the Hezarfen Institute of Aeronautics and Space Technologies[102] (ASTIN) is part of it. It started operating in 2001 under the title "Hezarfen Institute of Aeronautics and Space Technologies (ASTIN)". The institute offers postgraduate studies and conducts scientific research in applications and scientific fields of study related to Turkish defense.

In 2001 the institute began to provide postgraduate programs in Aeronautical Engineering and from 2003-2004 began to provide studies in space technology.

The institute has a satellite monitoring laboratory[103]. It had previously worked on the QB50 project. It is now focusing on the development of satellite clusters in orbit (Satellite Cluster). The satellites weigh less than 50 kg and are in low orbit at 200 km. The purpose of the project is to provide ancillary assistance to operations of the Armed Forces. The Technical University of Istanbul also participates in the development of the project.

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[100] Milli Savunma Universitesi Hava Harp Okulu, accessed 10 June 2021, available: http://www.hho.edu.tr/

[101] Journal of Aeronautics and Space Technologies, accessed 10 June 2021, available: http://www.jast.hho.edu.tr/index.php/JAST/about

[102] National defense University, HEZARFEN, Aeronautics and Space Technologies Institute, accessed 10 June 2021, available: http://www.hezarfen.msu.edu.tr/en/index.php

[103] Accessed 10 June 2021, available:http://www.hezarfen.msu.edu.tr/en/page-lab2.php

10.3 Turkish Amateur Satellite Technologies Association - TAMSAT[104]

The Amateur Satellite Technology Association (Turkish: Amatör Uydu Teknolojileri Derneği) aims to provide research, development, implementation and training services related to the design, production and operation of amateur and scientific satellite systems in Turkey. It also organizes training seminars to increase the number of young people involved in space technology and provides its services free of charge to amateur radio and related users for amateur and scientific use.

Its aim is to help Turkish young people and radio amateurs create their own satellite systems, provide them with alternative devices, provide legal advice and guide them to use satellite systems that operate in accordance with the laws and regulations.

10.4 Space Systems Design and Test Laboratory - USTTL

The “Space Systems Design and Testing Laboratory”[105], (Turkish: Uzay Sistemleri Tasarım ve Test Laboratuvarı) belongs to the School of Space Engineering of the Technical University of Turkey. Its purpose is the study and development of microsatellites.

The laboratory employs electricians, electronics, telecommunications engineers, physical engineers and space engineers, from undergraduate, postgraduate to doctoral students.

Its facilities contain:

- Clean room (class 1000) with a total area of 25 square meters. The room contains a thermal vacuum chamber, in which pressure and temperature controls are performed.

- Thermal vacuum inside the clean room serves to simulate the vacuum and the ambient temperature that a spacecraft receives when exposed to space. Tests are performed at very low pressure levels (10-5 Pascal), the temperature scenarios that are created help to analyze the strength, resistance and endurance limits of the tested model.

- The system is used for vibration tests achieving the minimum acceptance levels received by a satellite, which simulate the dynamic loads during the launch phase. The laboratory is also used for various industrial projects providing testing facilities. Its shaking table capabilities allow for testing of models up to 300 kg.

- The LPKF ProtoMat® S100 circuit board designer enables the design and production of prototype space electronic systems with specific properties. The device is used to configure the board used for passive satellite position control and the payload board consisting of a camera and sensors. It is also used for original boards and construction applications of all other electronic components for different projects and purposes.

- The Laboratory enables the design and verification of high-resolution microwave imaging systems, the development of digital electromagnetic methods and applications,

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[104] TAMSAT- Amator Uydu Teknolojileri Dernegi, accessed 10 June 2021, available: http://www.tamsat.org.tr/

[105] USTTL, accessed 10 June 2021, available: https://usttl.itu.edu.tr/

electromagnetic compatibility testing (EMC) for industrial applications, antenna design and testing. The laboratory also has facilities and know-how in microwave imaging experiments (tomography), EMI-EMC tests, antenna measurement tests and active-passive microwave circuit tests. The facilities of the Electromagnetic Diagnostics and Measurement Laboratory consist of non-reflective space, vector network analyzer (10MHz-40GHz), EMC analyzer (100Hz-26.5GHz), 4-channel digital oscilloscope, 3 signal sources, 4 reference horn antenna, rotary panel system grading kit, fiber optic cables and adapters, HFSS packaged software and high performance computers.

- The Objet Eden 500V printer is used to create industrial prototype samples under design and are to be manufactured. The device allows the rapid production of a prototype in 3 dimensions and therefore contributes to the process of product design and development.

The laboratory has built several successful microsatellites including a) ITUPSAT1, b) TURKSAT-3USAT, c) HAVELSAT, d) BeEagleSAT, e) UBAKUSAT.

11 PRESENT, FUTURE AND SUSTAINABILITY OF TURKISH SPACE POLICY: SWOT ANALYSIS

Given the difficulty and effort required by such a complex long-term project as the Turkish space program along with the policy that supports it, we will present a SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis shortly before closing this dissertation. The purpose of this analysis is to identify the strengths and weaknesses, opportunities and threats of a project. In our case, we will try to give a clear picture of the present, the future and the sustainability of Turkey 's space policy and space program [82].

11.1 Strengths

The presence of space technology on the country's government agenda and therefore the government's support for the space program are the most important strengths of space policy. The demand for space technology, formed by the Armed Forces of the country and remaining stable in the long run, and the supply from the domestic space industry are interrelated. This ensures the activity and expansion of the industry, and the technological development of the projects to be implemented, two more strong points of the space policy. The know-how that results from successful projects is another benefit and a secondary strength, as well as the transfer of knowledge from the involvement of Turkish engineers in foreign projects or partnerships [82].

Another secondary strength of space policy is the adequacy of knowledge, know-how and infrastructure (supported by the state) of the domestic space industry. The consequence of sufficient knowledge in the industry is its transfer to the academic institutions, with the final recipient being the up-and-coming student engineers. The access of universities to the existing infrastructure, as well as the connection between education and industry are two more strong points [82].

11.2 Weaknesses

Space projects have high costs and require interdisciplinary collaboration, while at the same time resources (material, financial and human) are finite. The probability of success of the projects is directly affected by the strategic planning that has preceded. The most important weakness of space policy is the failure of projects due to poor strategic planning. Given the shortage of trained human resources, the other important weakness is the lack of new people entering the scientific workforce. Projects tend to be based on the practices of specific individuals in each scientific field and no emphasis is placed on their documentation, which is itself a secondary weakness.

Besides human resources, lack of domestic infrastructure for launching satellites is another weak point. The total cost of the projects increases as equipment transfer to bases abroad is required. In addition to the lack of infrastructure, the precarious viability of the projects and the teams working on them is another weak point. When this is not ensured, the expansion of the domestic scientific workforce is being limited [82].

11.3 Opportunities

As the number of space-based applications grows, the space program's greatest opportunity is to build and export earth observation and telecommunications satellites to countries that do not have advanced space technology. The capital that flows in the domestic industry, together with the state subsidy, strengthens its activities and paves the way for innovations, either through partnerships or autonomously.

Moreover, the economies of scale brought about by microsatellites and their use in applications of various scientific fields give the country the opportunity to gain further experience in space projects at a lower cost as well as the possibility of exporting these projects [82].

11.4 Threats

Space projects by their nature involve a great risk, as they combine high cost and constant effort by interdisciplinary human resources. The negative economic impact on the Turkish space industry and on human resources resulting from possible technical failures in (future) projects poses a major threat to space policy [82].

The know-how and infrastructure of the domestic industry have indeed matured, but are not yet able to fully meet the technological requirements of the projects. Because of this, it is necessary to procure material from abroad. Thus, in addition to the economic consequences, the viability of the projects is threatened. Domestic research and development seeks to improve the state of technology supply, but due to the time required to produce results, there is a risk that the country will lag behind technological developments [82].

Strengths	Weaknesses	Opportunities	Threats
Commitment and support of the government	Lack of coordination in space/satellite planning process and roadmap implementation	The need for communication and imaging satellite projects to be developed with indigenous means	Technical failures that could be faced during the project processes
Having the will to meet the needs of demand and supply sides with domestic resources	Absence of an institution responsible for carrying out cooperation at international level and for conducting national space policies and activities	The opportunity of acquiring markets in countries that have close relations with Turkey and/or don't yet have an advanced space industry	Procurement of the existing needs for space/satellite systems from abroad
Know-how and motivation brought about by successful satellite projects	Lack of expertise in the area of space	New business spin-offs through public funding designated for space/satellite projects	A dramatic increase in the existing disparity in space studies between Turkey and other countries
Financial resources and funding in this area	Lack of institutional memory and documentation infrastructure due to overdependence on persons in the implementation of projects	Establishment of international cooperation with foreign companies, institutions and organizations	Equipment necessary for developing units being subject to regulations such as ITAR (International Traffic in Arms Regulations),

			not being able to obtain sub-components
Designation of space technologies as a priority technology field	Absence of domestic satellite launching infrastructure	The steady increase in the use of space technologies for civilian and military purposes	High costs involved in projects and infrastructure investments
Experience in original design and development	Inability to ensure sustainability of both the projects and the teams working at these projects	The momentum brought about to the industry by the positive trend of country's economic indicators	Absence of metrics for measuring efficiency and productivity to make inter-project assessment in allocating financial resources
Having an infrastructure specially built for space/satellite projects	Inadequate level of production capacity for space/satellite systems	The cooperation opportunities with foreign companies and/or countries owing to the current global economic environment	Appointing persons under-qualified in terms of technical know-how and vision as project managers
The know-how and experience in satellite operation	Inadequacy in qualified and recorded technical space components	The presence of newly opened academic space departments	Destructive innovation by foreign companies at the overwhelming scale blocking healthy competition for national companies
The know-how in basic sciences and conducting R&D projects at universities	Inability to establish a full-fledged cooperation between university and industry	The growing importance of small satellites and the opportunity to gain project experience with relatively limited budget	Failing to exploit the qualified human resources in the following projects
Increasing volume of projects in recent years by the supplier industry and by engineering firms with prospects for development	Inadequate level of companies' innovation capabilities	A fertile ground provided by space studies for inventions in various fields (i.e. health, medicine, transport, public security etc.)	
Having an advanced system of education in mechanical and electrical-electronics engineering	Lack of know-how due to absence of manufacturing experience	Ongoing studies for the development of space launching capability	
Technology-savvy young population with increasing level of education	Established tradition of cooperation not being sufficiently developed	Interdisciplinary nature of space studies	
	The low number of research and application		

	centres in the area of space technologies
	Duplication of infrastructure and uneven distribution of technological expertise in the industry
	Absence of a well-defined policy and inter-agency coordination in the technology transfer projects in space studies
	Lack of education, science and technology policies in space studies

Figure 1 SWOT of Turkish Space Policy [82]

12 CONCLUSION

In the course of this dissertation, we made extensive reference to the different aspects of Turkey's space policy. We presented the historical development of the space program in parallel with the political, legislative and administrative structural changes that founded it and contributed to its effective organization and continuity over time. **The first conclusion is that Turkey has a rich experience in the field of space**. The significant technological steps and benefits that Turkey has gained from its involvement with space technology confirm the overall value and success of the whole project.

The aerospace industry and public research organizations have been more or less involved in the development and construction of 15 satellites of all types and sizes, which successive governments in Ankara have successfully launched since the beginning of the 21st century. The country has managed to develop a domestic space defense industry that is largely independent of external suppliers, while the know-how and industry projects are up to date with (or sometimes keep pace with) the international technological developments in space and incorporate edge technologies.

The country's academic institutions are closely following developments and adapting curricula and the level of knowledge provided to prepare the scientific workforce that will staff the positions in the future and meet the needs proposed by space policy. Finally, we must not fail to mention the plethora of organizations and institutions, each with its own specific responsibilities, which take on the task of making important decisions and planning the space program.

We must emphasize, perhaps to the superlative degree, the role of central planning in the country's Space Policy. At the heart of central planning is the state and the policy it chooses to pursue in order to realize its space vision. Since the Turkish economy is far from free, it is a vital requirement for any initiative related to the space program that it obtains state approval and central planning support. This, after all, was the plan from the beginning of space policy (since its adoption was also an initiative of the state itself). **The second conclusion is that a condition for the development of a robust Satellite Program is that the state recognizes the importance of the role of Space at the highest possible level.**

With exclusive state initiative in the beginning, until the legal and administrative framework had been established and the basic infrastructure had been built, the synergy of state and private initiative supervened. As a result of this synergy, the space defense industry developed rapidly and expanded its activities into various applications, largely under the auspices of its largest client and financier, the Armed Forces. Thus, the **third conclusion is that satellites have become essential tools for multiplying the power of the Armed Forces** in the various armed conflicts in which they are involved. With their satellite systems, they can and do decisively enhance functions such as Administration and Control, telecommunications and information. It was therefore decided that a large national defense aerospace industry should be created to support this effort. It should not be overlooked, however, that the involvement of the defense industry of European countries such as France and Italy was also important in the formation of the Turkish defense aerospace industry.

In the development of the space defense industry and the acquisition of know-how, the correct planning of the space program, which took place in individual phases, played an important role. The various roadmaps that began to be published in the early 1990s are indicative of this. The selection of feasible goals and projects that could be implemented by the domestic industry (in part or in full) brought the know-how, while the long-term planning of space projects gave direction to research and development. The favorable environment and the continuous demand for space technology from the domestic economy pushed the academic institutions in turn to adapt to technological developments and to ensure their contribution to knowledge and scientific faculty.

Finally, the financial security surrounding the development of the space program deserves special mention. The country follows the model of direct financing through the state budget. The whole endeavor would have failed if the consistent funding of the space defense industry and research, and as a consequence the long-term continuity of the industry, had not been secured.

Appendix A: The President of Turkey presents the national space program

On February 9, 2021[106], the President of the Republic of Turkey Recep Tayyip Erdoğan presented the Turkish space program in Ankara. The Turkish Space Agency (TUA) is responsible for the implementation of the program and in the presentation of the program it was stressed that the country aims to make the first contact with the Moon and send a Turkish citizen into space.

The most important goals of the program that were set are:

- The first and most important goal is considered to be the first contact with the moon in the year 2023, which also coincides with the celebration of the 100th anniversary of the Turkish Republic. Then a Turkish hybrid rocket will be launched that will reach the moon. In the next stage, in 2028, there will be a landing on the moon and research in the natural sciences will be conducted.
- The creation of new high spec satellites, able to compete with international satellites.
- The creation of the national Regional Positioning and Timing System (BKZS) with the goal to become independent of US GPS.
- Creating a national space launch base for access to space.
- Development of Turkish space technology in space by investing in space weather and meteorology.
- Acquisition of astronomical observations by observing them from the earth.
- Further development of the space industry in Turkey.
- Creating space technology development zones, so that Turkey becomes a country that can produce all space technology subsystems that are commercially competitive.
- The further improvement of study programs for undergraduate and postgraduate education in space and aerospace.
- Sending the first Turkish citizen in space to conduct scientific research.

[106] Tuba Sahin and Ali Murat Alhas, Anadolu Agency, “Turkey unveils national space program”, 09 February 2021, accessed 10 June 2021, available: https://www.aa.com.tr/en/science-technology/turkey-unveils-national-space-program/2139378

Image 35 The program of the Space Agency as presented by the President of the Turkish Republic

Appendix B: Suggestions for further research

This research was conducted until the summer of 2021 using data extracted from hitherto available sources. Through this research, new questions which are worth researching in the future arise. Questions such as:

The microsatellite program to be developed by Turkey, in which several studies have already been done on proposals that are presented in this dissertation. The questions that arise are what will be their final mission and their final form? Furthemore, will they be used for telecommunications alone, or will they also have cameras for images and video? On which orbit will the satellites be? It will certainly be at the low earth orbit, but how many satellites will it take to have continuous 24 hour coverage? The author's opinion is that since the Turkish industry already has tried and tested solutions in cameras for low-orbit satellites, the microsatellites developed in the future will be equipped with them. In this case, the system will greatly upgrade Turkey's surveillance and reconnaissance capabilities and will be complementary to the GokTurk-1 satellite. The only difference being that the array of microsatellites will cover only Turkey and nearby areas, unlike GokTurk-1 which can cover the whole earth.

The "Regional Positioning and Timing System (BKZS)" developed by Turkey is a costly project, with high development and maintenance costs. The satellites that will be in orbit must each have an individual atomic clock. The atomic clock is necessary to achieve as accurately as possible a reflection of terrestrial time in space. Any distortion in time leads to wrong measurements and therefore to wrong signals on earth. Turkey believes in its ability to develop, implement and maintain such a system. It is worth studying in the future how close the country has come towards implementing the system, plus how accurate and reliable the system will be.

The hybrid rockets that Turkey is developing to reach the Moon. Although there is not much data yet in this area, it is worth studying how far they have come. What has been achieved? Also, hybrid missiles can easily be converted into ballistic missiles, which raises new security issues in the surrounding area.

These are just some of the questions worth researching in the future. I hope that this dissertation will be the basis for further research.

Appendix C: Telecommunication satellites

Telecommunications satellites			
Name	Turksat 1A	Turksat 1B	Turksat 1C
Launch date	24/1/1994	10/10/1994	9/7/1996
Date of end of service	exploded after launch	2006	2010
Manufacturer	Aérospatiale Company	Aérospatiale Company	Aérospatiale Company
Launch site	Guiana Space Centre	Guiana Space Centre	Guiana Space Centre
Orbit	geostationary orbit	geostationary orbit	geostationary orbit
Cost	315 million. $	300 million $	-
Name	Turksat 2A		
Launch date	10/1/2001		
Date of end of service	2016		
Manufacturer	Aérospatiale		
Launch site	Guiana Space Centre		
Orbit	geostationary orbit		
Cost	300 million $		
Name	Turksat 3A		
Launch date	12/6/2008		
Date of end of service	in service		
Manufacturer	Thales Alenia Space		
Launch site	Guiana Space Centre		
Orbit	geostationary orbit		
Cost	200 million $		
Name	Turksat 4A	Turksat 4B	
Launch date	14/2/2014	16/10/2015	
Date of end of service	in service	in service	
Manufacturer	Mitsubishi Electric MELCO.	Mitsubishi Electric MELCO.	
Launch site	Baikonur Cosmodrome	Baikonur Cosmodrome	
Orbit	geostationary orbit	geostationary orbit	
Cost	140 million $	571 million $	
Name	Turksat 5A	Turksat 5B	
Launch date	8/1/2021	-	
Manufacturer	Airbus Defense and Space	Airbus Defense and Space	
Launch site	Cape Canaveral	Cape Canaveral	
Orbit	geostationary orbit	geostationary orbit	
Cost	500 million $ both of them		

Figure 2 Telecommunication satellites

Costs are indicative.

Appendix D: Earth observation satellites

	Earth observation satellites		
Name	BILSAT-1		RASAT
Launch date	27/9/2003		17/8/2011
Date of end of service	1/9/2006		in service
Manufacturer	TÜBİTAK UZAY		TÜBİTAK UZAY
Launch site	Plesetsk cosmodrome		Dombarovsky Air Base
Orbit	Sun-synchronous		Sun-synchronous
Cost	14 million $		10 million $
Name	Gokturk-1		Gokturk-2
Launch date	5/12/2016		18/12/2012
Date of end of service	in service		in service
Manufacturer	Telespazio,TUSAS, ASELSAN		TUSAS, TUBITAK UZAY
Launch site	Guiana Space Centre		Jiuquan
Orbit	Sun-synchronous		Sun-synchronous
Cost	250 million $		-

Figure 3 Earth observation satellites

Costs are indicative.

TABLE OF TERMINOLOGY

Acronyms	English term	Greek term
A.D.C.S.	Attitude Determination And Control System	Σύστημα Προσδιορισμού Θέσης και Ελέγχου
B.L.O.S.	Beyond Line of Sight	Πέρα από το οπτικό πεδίο
C.4I.S.R.	Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance	Εντολή, Ελεγχος, Διαβιβάσεις, Υπολογιστές, Πληροφορίες, Επιτήρηση, Αναγνώριση
G.N.S.S.	Global Navigation Satellite System	Παγκόσμιο δορυφορικό σύστημα πλοήγησης
G.P.S.	Global Positioning System	Παγκόσμιο Σύστημα Τοποθεσίας
P.T.N.	Private Telecommunications Network	Ιδιωτικό δίκτυο τηλεπικοινωνίας
I.S.R.	Intelligence, Surveillance and Reconnaissance	Πληροφορίες, Παρακολούθηση και Αναγνώριση
R.N.S.S.	Regional Navigation Satellite System	Περιφερειακό δορυφορικό σύστημα πλοήγησης
R.P.T.S.	Regional Positioning and Timing System	Περιφερειακό σύστημα εντοπισμού θέσης και χρονισμού
S.A.R.	Synthetic Aperture Radar	RADAR συνθετικού διαφράγματος
SAT.COM	Satellite Communication	Δορυφορικές Τηλεπικοινωνίες
S.B.A.	Space Based Applications	Εφαρμογές στηριζόμενες στο διάστημα
S.W.O.T.	Strengths, Weaknesses, Opportunities, Threats	Δυνατά σημεία, Αδύναμα σημεία, Ευκαιρίες, Απειλές

LIST OF TURKISH ABBREVIATIONS

Acronyms	Turkish Term	English term
BKZS	Bölgesel Konumlama ve Zamanlama Sistemi	Regional Positioning and Timing System
DPT	Devlet Planlama Teşkilatı	State Planning Organization. SPO
ITU-CSCRS	İTÜ Uydu Haberleşmesi ve Uzaktan Algılama Merkezi	ITU - Satellite Communication and Remote Sensing Center
SSB	Savunma Sanayii Başkanlığı	Presidency of Defense Industries
SSIK	Savunma Sanayii İcra Komitesi	DEFENCE INDUSTRY EXECUTIVE COMMITTEE
STM	Savunma Teknolojileri Mühendislik ve Ticaret A.Ş	Defense Technologies Engineering and Trade Inc.
TAMSAT	Amatör Uydu Teknolojileri Derneği	Amateur Satellite Technologies Association
TUSAŞ	Türk Havacılık ve Uzay Sanayi A.Ş.	Turkish Aerospace Industries Inc., TAI
TSK	Türk Silahlı Kuvvetleri	Turkish Armed Forces, TAF

TUA	Türkiye Uzay Ajansı	Turkish Space Agency, TSA
HHO	Hava Harp Okulu	Air Force Academy, TuAFA
TÜBİTAK	Türkiye Bilimsel ve Teknolojik Araştırma Kurumu	Scientific and Technological Research Council of Turkey
TÜBİTAK-UZAY	TÜBİTAK Uzay Teknolojileri Araştırma Enstitüsü	TÜBİTAK Space Technologies Research Institute
UFS	Uydu Fırlatma Sistemi	Satellite Launch System
USET	Uzay Sistemleri, Entegrasyon ve Test Merkezi	Turkish Space Systems, Integration and Test Centre
USTTL	Uzay Sistemleri Tasarım ve Test Laboratuvarı	Space Systems Design and Test Laboratory
UTEB (UNISEC-TR)	Union of Turkish Space Universities	Union of Turkish Space Universities
TAMSAT	Amatör Uydu Teknolojileri Derneği	Amateur Satellite Technologies Association
Türksat	Türksat Uydu Haberleşme Kablo TV ve İşletme A.Ş	Türksat Satellite Communication Cable TV and Management Inc.

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