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The Future and Importance of Establishing Space and Satellite Engineering In Turkey

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----------ABSTRACT----------
In this study, the future and importance of the establishing space and satellite engineering in Turkey are analyzed in various points of view with the help of former studies, comprehensive research, and inspection of the system. In this manner, firstly space and satellite technologies and importance of these technologies are defined and emphasized. Then, space and satellite technologies in Turkey and the world are compared technically by looking at the curriculum of the universities of the world and Turkey. This comparison is between universities which have space and satellite engineering around Turkey and the world, shows necessities to have this kind of departments in universities. Finally, Turkey's plans for space and satellite technologies are inspected, in this part, history, substructure, vision, and strategy with 2023 strategy plans are investigated apparently by investigating national research program, institutes and public corporations which are related to space and satellite engineering. Results are tabulated with tables to show the importance of giving attention to space and satellite engineering education in universities.

Keywords:*Space Engineering, Engineering Education, Satellite and Space Education Curriculum, Turkey's 2023 plan*

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I. INTRODUCTION

1.1 What isSpace and Satellite Technology?

The fields of space and satellite engineering and technological sciences are increasing in quality and quantity day by day all over the world. Countries have to follow, implement and adapt these developments on the subject of these technologies to follow economic empowerments. In our era, it is a necessity to follow the rapidly developing technology and to produce new technologies by inquisitive, curious, numerical thinking individuals who can introduce several approaches to problem-solving. In this case, space and satellite technologies include designing, launching, orbiting, and beneficial data transfer of space vehicles, which serve all kinds of purposes, such as communication, defense, navigation, astronomy. Examples include rockets, space shuttles, probes, artificial satellites, planets, and various means of being brought to the surface of satellites. In this manner, space technologies which relate to usage of space can be defined as[1] ;

- Space Vehicles Construction Technologies
- Space Vehicles Guidance and Control Technologies
- Satellite Production Technologies
- Location and Orientation Technologies
- Satellite Communication Technologies
- Satellite Detection and Observation Technologies
- Space Vehicle Launch and Ground Control Technologies
- Living and Production (Microgravity) Technologies
- Aerospace Technologies
- Space and Terrestrial Space Technology
- New Technology Areas of Space Applications
- Space Operations Management and Information Systems Technologies

II. SPACE AND SATELLITE TECHNOLOGIES IN THE WORLD AND TURKEY

Today, space and satellite technologies are used in many areas such as aircraft and defense systems for transportation, security, communication, agriculture, energy, and astronomy. Especially since 2000, space studies have progressed with a sharp increasing speed and become a field of competition in world age. Countries such as Italy, Germany, France, and England, Russia, China, Japan, India, Canada, Brazil, and the USA in particular, constitute the sources of space studies of these countries in the area approaching 200 billion dollars[2]. The studies firstly based on observation and surveillance of the outside of the world but recently aimed at studying human space flights and detailed planets to make a habitat for peoples. Considering the problems of the world such as global warming, crowded population, shortage of food and clean water, this idea is essential and critical for the next generations of the world. In addition to that, with the advance telecommunication systems, smart phones, video conferences, etc. satellite technologies have become much more important day by day, in the communication manner.

At the beginning of 90's, studies on space and satellite engineering started with a high acceleration in the world [3]. After Sputnik, the first human-made satellite, and same pioneering works, between 1990-1999, satellite making progresses become more common in the world. The competition between countries related to space and satellite technologies is started because of that situation. In figure 1, road map and history are seen that with the name of improvements. For instance, Eutelsat is a satellite which provides a live broadcast and Yahsat modems, is a computer data network supplier, are substantial improvements to ease daily life.

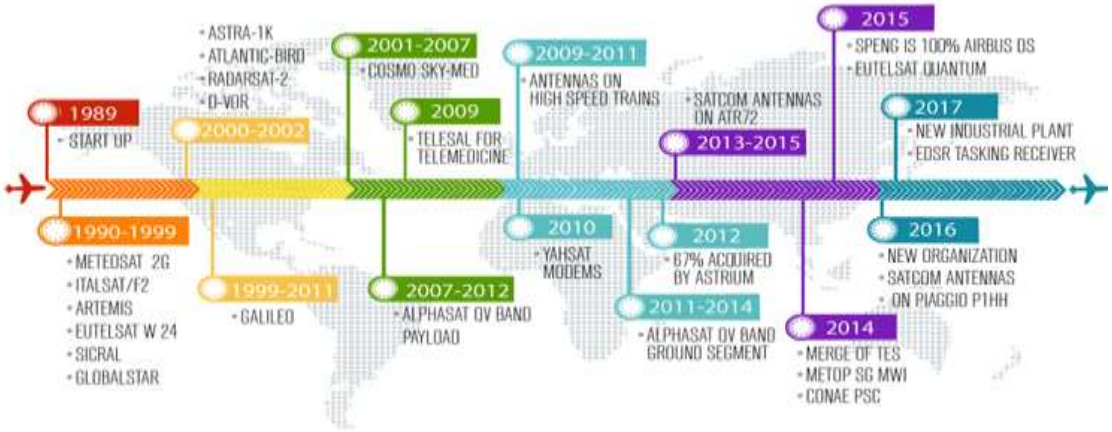

Figure 1. Space and Satellite Engineering Progress in the world (courtesy of www.space.it)

However, there is a significant shortage of qualified engineers for space and satellite technology in the world. Because of this situation, an importance of educating skilled engineers is sharply increased, and there is a need for university department related to this subject. For Instance, in 7 Billion populated worlds, there is only nearly 700.000 employee who is working on this issue and the share of this employment total can be shown in figure 2 [1]. In figure 2, it can be seen clearly that Turkey have contributions to direct European Aerospace and Defense Industry Employment, but it is not enough for becoming a significant contributor to this sector. This area is become more important by quantity and quality by giving enough attentions to educate space and satellite engineers by establishing related departments in the national universities.

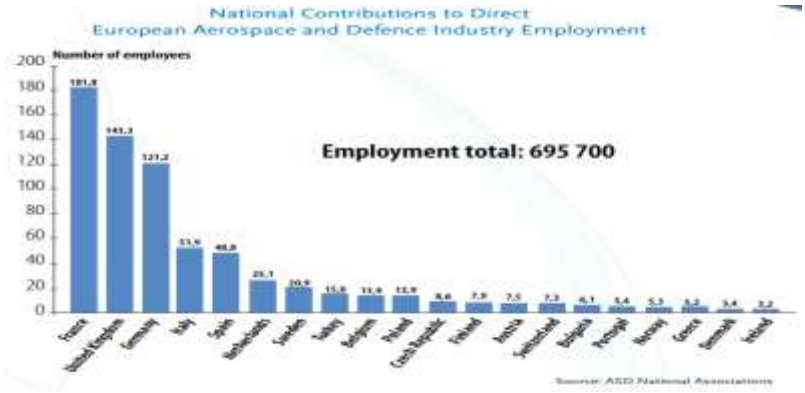

Figure 2. Total employment *of Aerospace and Defence Industry (2013)*

On the other hand, Turkey can also be considered as a developing country in the field of space technology [4]. Starting from the 1980s, studies initially started with state-controlled and military purchasing methods, then expanded to serve civilian purposes as well. With the beginning of the 2000s, a new effort has developed with the TÜBITAK initiatives, and the private sector has started to get profit by investing in this field with government encouragement. Because of Turkey's geostrategic position, it becomes vital that having control of observation and communication possibility. Today, space technology capabilities in Turkey are satellite design for imaging, production and imaging purposes, and communication satellites which store data in operation. Up to now, Turkey has four communications and one earth observation research consulate satellites which are supplied from abroad. On the other hand, studies about the ability to launch the satellite continue with great interest.

The development of space and satellite technology creates a necessity to become more educated in university and academic staff manner to pursue more rigorous work to improve the quality of undergraduate or graduate education in space and satellite engineering. Therefore, Turkey should focus the subject of space and satellite engineering education with investments to the universities and academic staffs.

III. Education of Space Engineering

3.1. Space and Satellite Engineering Education in the World

With an increasing competition about space and satellite technology in the world, investments in space and satellite engineering have sharply increased. The primary target of the space and satellite engineering is trying to improve space technology by training the qualified engineers on this subject. Teaching aims and techniques in space engineering highly focus on preparing students to undertake duties as members of multidisciplinary teams in institutions where the profession of space engineering is practiced and to prepare students to achieve effective verbal and written communication skills to understand the global, social and cultural effects of professional and ethical responsibilities and engineering. As a result, the main idea is converting students to engineers who will be able to use engineering to contribute to the development of today's and future space and satellite technologies. Top and pioneer universities in the world on this subjects are Massachusetts Institute of Technology Department of Aeronautics and Astronautics (AeroAstro), University of Southern California- Department of Astronautical Engineering, University of Stanford- Department of Aeronautics and Astronautics and University of Southampton- Department of Aeronautics & Astronautics have a significant impact on this engineering. These universities give an excellent opportunity to learn space engineering such as aerodynamics, astronautics, dynamics, mechanics of materials, fluids engineering, heat transfer and propulsion along with a wider appreciation of the economic, legal and environmental issues associated with spacecraft operations, space exploration, air and space-based telecommunication industries, teaching, research, military service, and many related technology-intensive fields. In addition to that, students learn to apply this fundamental knowledge to conduct laboratory experiments and aerospace system design problems. In this work, the courses which are planned and designed to give this knowledge to this universities are presented in a table as a result of comprehensive research.

3.2 Space and Satellite Engineering in Turkey

Last five years, Turkey has a considerable progress on the education of space and satellite engineering. With the help of government investments loads of university established in this sector. The best universities of the Turkey are Middle East Technical University, and Istanbul Technical University is a pioneer of this engineering in Turkey. The aerospace engineering department of Middle East Technical University and Space engineering department of Istanbul Technical University has a big influence on this technology in Turkey. After these universities, some university in Turkey established the related department to find a solution for qualified engineers in this subject. Astronomy and space sciences departments are founded in Ankara University, Ege University, Erciyes University, İstanbul University. Aerospace engineering departments are founded in İzmir Economy University, Aeronautics, and Space Engineering departments are founded, On Dokuz Mayıs University and Gaziantep University. In recently, Space Sciences and Technologies is founded in Akdeniz University and Space and Satellite Engineering departments are established in Konya Necmettin Erbakan University. The information about total student quota, total student number of placement, graduated student numbers, the order of last placement student in university entrance exam and number of faculty members with titles are tabulated in Table 1,2,3.

	Aerospace Engineering		Aeronautics and Astronautics Engineering	
University				
	Middle East Technical University	İzmir Economy University	On DokuzMayıs University	Gaziantep University
Total Quota	88	30	41	31

Total Student Number Of Placement	88	30	41	31
Graduate Number				
2014	65	-	-	-
2015	76	-	-	-
2016	68	-	-	-
Turkey Order Of Last Placement	8,506	67,808	54,578	60,643
Number of Faculty Members and Titles				
Professor	6	3	1	-
Associate Professor	3	1	2	-
Assistant Professor	8	1	10	6

Table 1. Aerospace, Aeronautics and Astronautics departments in Turkey

	Astronomy And Space Sciences			
University				
	Ankara University	Ege University	Erciyes University	Istanbul University
Total Quota	31	31	31	77
Total Student Number Of Placement	31	31	11	77
Graduate Number				
2014	33	24	19	35
2015	24	31	15	39
2016	14	28	9	23
Turkey Order Of Last Placement	275,698	277,215	297,059	277,686
Number of Faculty Members and Titles				
Professor	3	10	1	7
Associate Professor	2	2	1	3
Assistant Professor	5	3	6	6

Table 2. Astronomy and space sciences departments in Turkey

	Space Sciences and Technologies	Space Engineering	Space and Satellite Sciences
University			
	Akdeniz University	Istanbul Technical University	Konya Necmettin Erbakan University
Total Quota	31	62	-
Total Student Number Of Placement	31	62	-
Graduate Number			
2014	-	50	-
2015	-	51	-
2016	5	42	-
Turkey Order Of Last Placement	258,852	19,503	-
Number of Faculty Members and Titles			
Professor	3	5	-

Associate Professor	5	2	1
Assistant Professor	4	6	4

Table 3. Space Sciences and Technologies and Space and Satellite Engineering departments in Turkey

It is clearly seen from tables; graduate student number is increased with decreasing acceleration year by year. Moreover to that, some faculty members are not sufficient to give proper education to the students and in newly established universities there is a lack of faculty members which is a great problem for this engineerings. On the other hand, it can also be seen in the tables there is a demand for these engineerings from students at every year because total student quota is equal to total student number of placement, so it will be a beneficial thing to establish new university departments. Additionally, these establishments are vital to training qualified academic members to prevent the lack of faculty members.

In education, course selection and content of the course is very important for quality of space and satellite engineering. In order to do it correctly, there should be comprehensive research on the subject of course and content of course. As mentioned, top and pioneer universities in the world on this subjects are Massachusetts Institute of Technology(MIT) Department of Aeronautics and Astronautics, University of Southern California(USC)- Department of Astronautical Engineering, University of Stanford(STANFORD)- Department of Aeronautics and Astronautics and University of Southampton(SOTON)- Department of Aeronautics & Astronautics. The aerospace engineering department of Middle East Technical University(METU) and Space Engineering department of Istanbul Technical University(ITU) can be included as top universities in the world, especially Middle East Technical University with an ABET accreditation which is a common accreditation document to determine the quality of the university. We can divide these courses into three main group as space and satellite engineering basic sciences courses, main courses of space and satellite engineering and laboratory and tutorial courses. In Table 4, 5 and 6 are tabulated clearly with course name, lecture hours and university name labels.

Courses	**Hour(per weekly semester)**					
	METU	İTÜ	SOTON*	USC**	STANFORD	MIT
1. Basic Sciences Courses						
General Chemistry I	3	3		4	4	4
Mathematics I	3	5	55	5	5	4
Physics I	3	3		3	5	4
Linear Algebra		3			5	4
Mathematics II	4	5	55	5	5	4
Physics II	3	3		3	5	4
Differential Equations	4	4			4	5
Mathematics III	3		48	4	5	
Mathematics of Physics and Engineering I			48	3		
Physics III: Optics and Modern Physics				3		
Probability and Statics For Engineers					4	3
Calc. & Vector Analysis	3				4	

Table 4: Space and Satellite Engineering Basic Sciences Course

Space and satellite engineering main courses are very vital for space and satellite engineering educations to teach important subject of the space and satellite to students. The basic sciences courses are mostly same for each university with minor differencesbecause these are basic and fundamental courses in engineerings to teach basic technical knowledge.

Courses	**Hour(per week or semester)**					
	METU	İTÜ	SOTON*	USC**	STANFORD	MIT
2. Space and Satellite Engineering Main Courses						
Intro. to Space Eng. & Ethics	2	2	48	3	3	
Statics	3	3		3		
Dynamics	3	3		3	4	5
Materials Science	3	3	36	3	4	5
Strength of Materials I	4	3	35	3	3	
Fundamentals of Electric. Eng.	3	3				
Fluid Mechanics	4	5	42		4	5
Numerical Methods	3	3				
Strength of Materials II		3			4	

Thermodynamics	4	3	36	4	3	5
Thermodynamics II				3		
Aerodynamics	3	4	36		3	4
Aerodynamics 2	3		36		3	
Design of Machine Elements		3	36	3		
Aerospace Structures	5	3			3	5
Heat Transfer	3	3	36		3	
Aerospace Control		3	33			
Compressible Aerodynamics		3				
Orbital Mechanics		3				
Attitude Determination & Ctrl.		3				
Propulsion Systems	3	3	36	4	3	4
Space Environment		3	33	4		4
Space Environment II				2		4
Spacecraft Design and Communications		3	36		3	
Design and computing in Aerospace Engineering			45			5
Aircraft Operations and Flight Mechanics	3		40			
Electrical and Electronics Systems			42			
Electrical and Electronics Systems2			42			
Design and computing 2			45			
Aircraft Operations and Flight Mechanics 2			40		4	
Computing Methods in Engineering	3					5
Applied Elasticity	3					
Propulsion Systems II	3					4
Flight Mechanics	3		32			4
System Dynamics	3				3	
Acoustic and Mehanical Vibrations	3				3	
Principles of Production Engineering	2		24			
Thermofluids 2			42		3	
Advanced Thermal Systems					5	
Control Systems					4	5
Structural Mechanics						4
Principles of Autonomy and Decision Making						4

Table 5: Space and Satellite Engineering Main Courses

Main courses space and satellite engineering are common mainly but there are some courses must be in the curriculum. Courses which are used at least 5 of 6 university are Intro. to Space Eng. & Ethics, Dynamics, Materials Science, Strength of Materials I, Fluid Mechanics,Thermodynamics,Aerodynamics,Propulsion Systems and must be used in curriculum.Courses which are used 3 of 6 university are Statics, Aerodynamics 2, Design of Machine Elements, Aerospace Structures, Heat Transfer, Space Environment, Spacecraft Design and Communications and Flight Mechanics should be used in curriculum. Although these main courses are approximately similar, there are some different courses that are used by only one or two university. In my opinion, these lectures should be given in last semester as an elective course and there should be options to choose to become more expertise about it. For example, University of Stanford has a system like this.

Courses	**Hour(per week or semester)**					
	METU	İTÜ	SOTON*	USC**	STANFORD	MIT
3. Laboratory and Tutorial Courses						
General Chemistry I Lab	2	2			3	3
Physics I Lab	2	2			3	3
Mathematics I	2				3	3
Mathematics II	2					
Int to Comp and Inf Systems		2	26		3	
Computer Aided Drafting		3		4		
Physics II Lab	2	2			3	3
Intr to Sci&Eng Comp (C)		4		3		
Measurement Techniques		3				
Experimental Engineering		3				

Graduation Project		6		4		
Spacecraft Systems Design		4	26	4	3	
Mechoptronics Laboratory I				2		
Mechoptronics Laboratory 2				2		
Linear Control Systems I				4	3	3
Aerodynamics	2		12		3	2
Aerodynamics 2	2					
Propulsion Systems	2				3	2
Principles of Production Engineering	2					
Orthopaedic Biomechanics			30			
Optimisation			56			
Aircraft Design			56			4
Finite Element Analysis					3	
Analysis of structures					3	4
Introductory Digital Systems Laboratory						4
Real-Time Systems and Software						4
Communication Systems and Networks						4
Robotics: Science and Systems						4
Experimental Projects I						4
Space Systems Development						4

Table 6: Space and Satellite Engineering Laboratory and Tutorial Courses

It can be seen that the laboratory and tutorial sessions of these basic science courses are vitally important to give a good infrastructure to the students so there must be lab sessions for these lectures. In addition to this basic science courses labs, there should be some other laboratory lectures to show students the illustration of theoretical knowledge.

AA-2. Depth Area: Four Courses Required, Two From Each of Two Areas			Fluids and CFD		
Dynamics and Controls			AA 200	Applied Aerodynamics	3
ENGR 105	Feedback Control Design	3	AA 201A	Fundamentals of Acoustics	3
ENGR 205	Introduction to Control Design Techniques	3	AA 210A	Fundamentals of Compressible Flow	3
AA 203	Introduction to Optimal Control and Dynamic Optimization	3	AA 214A/CME 207	Numerical Methods in Engineering and Applied Sciences	3
AA 222	Introduction to Multidisciplinary Design Optimization	3-4	AA 283	Aircraft and Rocket Propulsion	3
AA 242A	Classical Dynamics	3	ME 131B	Fluid Mechanics: Compressible Flow and Turbomachinery	4
AA 271A	Dynamics and Control of Spacecraft and Aircraft	3	ME 140	Advanced Thermal Systems	5
Systems Design			Structures		
AA 236A	Spacecraft Design	3-5	AA 240A	Analysis of Structures	3
AA 236B	Spacecraft Design Laboratory	3-5	AA 240B	Analysis of Structures	3
AA 241A	Introduction to Aircraft Design, Synthesis, and Analysis	3	AA 256	Mechanics of Composites	3
AA 241B	Introduction to Aircraft Design, Synthesis, and Analysis	3	AA 280	Smart Structures	3
AA 284B	Propulsion System Design Laboratory	3	ME 335A	Finite Element Analysis	3

Figure 3: Space and Satellite Engineering Last Year Optional Courses [8]

AA-1. Engineering Electives: Two Courses Required			
AA 250	Nanomaterials for Aerospace	EE 108	Digital System Design
ENGR 240	Introduction to Micro and Nano Electromechanical Systems	EE 180	Digital Systems Architecture
ME 210	Introduction to Mechatronics	ENERGY 121	Fundamentals of Multiphase Flow
ME 220	Introduction to Sensors	ENERGY 191	Optimization of Energy Systems
ME 227	Vehicle Dynamics and Control	ENERGY 226	Thermal Recovery Methods
ME 250	Internal Combustion Engines	MATSCI 155	Nanomaterials Synthesis
ME 257	Turbine and Internal Combustion Engines	MATSCI 156	Solar Cells, Fuel Cells, and Batteries: Materials for the Energy
ME 260	Fuel Cell Science and Technology	MATSCI 197	Rate Processes in Materials
ME 324	Precision Engineering	MATSCI 198	Mechanical Properties of Materials
ME 331A	Advanced Dynamics & Computation	PHYSICS 100	Introduction to Observational Astrophysics
ME 331B	Advanced Dynamics, Simulation & Control	ME 348	Experimental Stress Analysis
ME 345	Fatigue Design and Analysis	CHEMENG 140	Micro and Nanoscale Fabrication Engineering
EE 102A	Signal Processing and Linear Systems I	CS 107	Computer Organization and Systems

Figure 4: Space and Satellite Engineering Last Year elective Courses[8]

Last year elective courses are the most important part of the engineering education because with the help of these courses students become more experienced in the desired area. The sample of these last elective courses, can be seen in figure 3 and 4, are taken from Stanford University Department of Aeronautics and Astronautics. There are very interesting courses in various areas.

IV. CONTRIBUTIONS OF SPACE AND SATELLITE ENGINEERING EDUCATION TO TURKEY'S TECHNOLOGY

Turkey's plans for Space and satellite technologies

Space and satellite technologies infrastructure in Turkey, with the understanding of the key importance of space technology and its strategic value, has been documented in the "Turkish Science and Technology Policy: 1993-2003"[4]. With this document, space technology has been described as one of the priority areas of work that affects all sectors and all areas of life. In this document, precautions for creating monetary resources, a human power source, increasing the share of private institutions in R & D expenditures about satellite and space technologies and increasing public awareness has been discussed. Turkey has six active satellites, three of which are communications (TÜRKSAT 3A, TÜRKSAT 4A, TÜRKSAT 4B), and three observations (GÖKTÜRK-1, GÖKTÜRK-2, and RASAT). The three communication satellites (TÜRKSAT 1B, TÜRKSAT 1C, TÜRKSAT 2A) and observation satellite (BİLSAT) previously sent to space and had completed their lives. In addition to that, the Turkish government will continue to invest in the field of satellite technologies, plans to produce services with local satellites until the end of 2019, TÜRKSAT 5A and TÜRKSAT 5B. In addition to that, TÜRKSAT 6A is planned for launching a new generation telecommunication satellite in 2020.

Turkish National Space Research Program

The approval of the National Space Research Program (UUAP), prepared by the contributions of relevant experts and organizations, at 10 March 2005 is one of the most important steps of Turkey considering space technologies.[5] The main aims of this program are to take all necessary measures for the National Space Research Program to be implemented as a long-term and sustainable state policy and to initiate the studies to start Turkey's membership in the European Space Agency immediately with the effort of TÜBITAK.

Vision 2023 Strategy Document

The Vision 2023 Strategy Document creates a strategic road map for technology and science policies scientific to make Turkey an important member of the international community by providing important technologies of the future and will guarantee future tomorrows.[4] The main aims of this program are to be able to design a satellite and improve the ability to send vehicles in the distance to be able to develop critical weapons, ammunition and protection systems and technologies to develop and produce NBC (nuclear, biological, chemical) detection systems.

Private and public organizations in the field of space and satellite technologies in Turkey

- Turkish Aerospace Industries Inc. (TAI/TEI)
- TÜBITAK-SPACE
- HAVELSAN
- ASELSAN
- ROKETSAN
- TÜBITAK-SAGE
- TÜRKSAT
- BilUzay (Bilkent University Space Technology Research Center)
- Defense Industry Manufacturers Association (SASAD)
- Turkish Aeronautical Association (THK)
- Turkish Airlines (THY)

V. CONCLUSION

Investing the area of space and satellite technologies is significant action in a space era of the world to save the future of the country itself and the world because of the problems of the world such as global warming, crowded population, shortage of food and clean water and lack of communication. It is obvious that the improvement of the technology of the space and satellite depends on the quality of the qualified scientists and engineers in this area. In this sense, governments should be a focus on the education on this subject to train well-qualified engineers. In the world, there is sharply increasing attention in this subject with the last 20 years. In Turkey, this attention is highly enhanced in last five years by establishing new university departments to train engineers on this subject. The Turkish government has a well-planned vision to have great technology in space and satellite engineering, and these plans highly depend on the education side of this engineerings. It is a good development to establish new departments in this area but it is crucially important that the course and course content plans of these departments should be well-organized. In order to organize these, planners should be a focus on the top universities in the world on this subject such as Massachusetts Institute of Technology, University of Southern California, University of Stanford. To sum up, Turkey will have a great future on space and satellite technologies by focusing the education part with a great organization by conducting extensive research.

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