The Eurasia Proceedings of
Educational & Social Sciences (EPESS)
ISSN: 2587-1730

The Eurasia Proceedings of Educational & Social Sciences (EPESS), 2019

Volume 14 Pages 13-17

ICEMST 2019: International Conference on Education in Mathematics, Science and Technology

Aerospace Systems Science and Engineering Program: A Novel Integrated Approach

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Abstract: A recent report on the global road map for 2015-2025 commissioned by COSPAR and ILWS emphasized the growing appreciation that the environmental conditions that we call space weather impact the technological infrastructure that powers the coupled economies around the world (Carolus, 2015). Since space borne theoretical and practical problems are complicated enough, an up to date science and engineering curricula may need to be considered to cope with such cases. The program/curricula is meant to combine basic sciences, space sciences and technology under a system engineering umbrella. In short, the objective of this program is to produce graduates who will be capable of tackling space programs with deep confidence in an integrated and interdisciplinary manner. In other words, the graduates will be able to take care of these problems from a broad-wide spectrum including for example, space sciences, such as space weather on one side, and very specific technological problems, such as space debris on the other side. So, in this paper we propose an engineering education program.

Keywords: Engineering education, Space science, System engineering, Curriculum

Introduction and Historical Background

The space sciences and technology have been developed by the very few leading countries in the world (Fortescue, 1995). The rest of the countries including the ones who are well advanced in employing the space technologies are following the pre-existing developments most of the time. Therefore, for such countries to narrow the gap at least in relevant education and training aspects, some specifically designed curricula and programs must be developed. Such a need has been our main motivation in proposing a program/curricula to serve the purpose (Y. Tulunay, 2009) (Tulunay, 2008). (Tulunay, 2001).

The 50th anniversary of Space Age in 2007 and the beginning of the International Heliophysical Year with its activities are among the other motivations leading to this work (Y. Tulunay E. T., 2009), (Agency, 2009) (International Heliophysical Year Website, 2009), (CORDIS, 2009).

Systems engineering deals with the complex technical and non-technical engineering systems in terms of input and output variables (Fortescue, 1995).The required outputs for specified inputs are considered and required functional blocks and interrelationships between them are specified by considering the "design", "implementation" and "operation" of the system. Therefore, a systems engineer sees and comprehends the whole of the system. Designs of the blocks themselves are carried out by the scientists and engineers of the associated fields (Muller, 2018) (Erik Hollnagel, 2005).

- Selection and peer-review under responsibility of the Organizing Committee of the Conference

"Design specification", "test" and "validation" requirements are considered during design, implementation and operation phases. The "test" phase answers the question: whether the product is right. In other words whether it satisfies the design requirements. The "validation" phase answers the question: Whether it is the right product. In other words whether it works satisfactorily to perform the required function.

In this overview, the first version of a novel program that we propose the title to be "*Aerospace Systems Science and Engineering*" (ASSE) is introduced. In establishing such a program for Turkish educational system, we have studied similar programs of the American and European Universities.

In this novel, comprehensive Aerospace System Science and Engineering Program, we have combined two approaches: *(i)* the space systems engineering programs of well-known American Universities (e.g. MIT) and *(ii)* as our original contribution, the dimension of the science and engineering of the Near Earth Space (MIT, 2018). (Missouri University, 2018)

Aerospace System Science and Engineering (ASSE) Program

What is Aerospace Systems Science and Engineering (ASSE) Domain?

In analogy to system engineering, ASSE is the process of designing, developing and verifying a space system as an integrated system able to fulfill the objectives of a mission within acceptable technical and programmatic frames within a reference frame of Near Earth Space (NES).

The step-by-step design process is guided by considering what a space system seeks to achieve. Among the many issues of interest the followings are some typical and common examples: What orbit will the mission need as a consequence? What kind of instruments and how large a payload? What will be the payload's optimum operating temperature, and how much power will it require? How stable and steerable does the spacecraft platform have to be? What kind of communications infrastructure and associated ground segment will the mission need? Which launcher will be best suited to deliver it into space? What are the impacts of NES on these subsystems?

There can be many potential solutions to each question so ASSE is as much an art as a science, with trade-offs made between the different options in terms of performance, risk, cost, reliability and turnaround time, among other factors. The design team includes experts on the various technical and scientific disciplines involved to advise on their integration into the overall design.

At the end of these feasibility and preliminary design studies – known as "Phase A" studies – a baseline space system plan is in existence, defining necessary elements and including initial programmatic estimates. Follow-up "Phase B" studies turn the preliminary design into a full system design which can then be developed further.

Among the most important factors in deciding whether to proceed to further stage is a mission's likely cost. The process of putting accurate price tag onto space projects is an associated discipline within, in general Systems Engineering and in particular, ASSE domain called "Cost Engineering".

To demonstrate how prospective graduates of this program can utilize the knowledge, skills and know-how gained to promote the science and society nationally and internationally, there will be two case studies given.

Aerospace Systems Science and Engineering Education

Education in ASSE is often seen as an extension to the regular engineering courses, reflecting the industry attitude that engineering students need a foundational background in one of the traditional engineering disciplines (e.g. mechanical engineering, industrial engineering, computer engineering, and electrical engineering) plus practical, real-world experience in order to be effective as systems engineers. In fact, undergraduate university programs in systems engineering are rare.

Aerospace Systems Science and Engineering is a broad term used to encompass all the disciplines needed in the design and fabrication of projects which must operate in the Near Earth Space (NES) environment, an education program on ASSE must be equipped with a NES education dimension.

In the present day society, there is a vital need for setting up education and outreach activities in the Space Weather field for creating a healthy environment for the proper development of Space Weather markets along with the fundamental and applied research activities. The Space Weather, concretely, must provide value added services for the end user that has to be the driving motivation. Last, but not the least, a portal financial support for the Space Weather service providers is the formation of the competent human resources. Sufficient financial support for the Space Weather service providers is required for the information of competent teaching (scientific and technical personnel) and, hence, for research and education in the subject.

The basic users of a Space Weather Education Program may be summarized as in the following areas: communications, satellite operations, power grids, manned spaceflight, navigation, etc. Scientific and technological developments are achieved as the results of research, observations, models and education. Forecasting and warning services use the technology developed and disseminates the results to the basic users mentioned above. Comments of users are returned back to the education program via feedback mechanisms. Thus, the quality and efficiency of the education system are sustained at satisfactory levels.

The vision of ASSE Program is to comprehend and design aerospace systems which can make optimal use of the Near Earth Space environment both from the ethical, economical and political and environmental viewpoints.

The mission of ASSE Program is to provide an interdisciplinary education and training to comprehend the aerospace systems and to provide capability for graduates to be able to design, construct and operate them for present and future needs.

General Layout of ASSE Curriculum

It is proposed that the candidates for Bachelor of Science degree in ASSE (Aerospace System Science and Engineering) must complete a program consists of

(1) Must courses: mathematics; physics; chemistry; English; computer programming; space physics seminar; thermodynamics and statistical mechanics; molecular gas dynamics; operational methods in engineering; optional non-technical elective courses such as language; history (a total of 55 credit hour; up to the level of 7th semester)

(2) Related technical core courses: engineering graphics; basic concepts in material science (a total of 6 credit hour; up to the level of 5th semester)

(3) Aerospace system science courses: introduction to space sciences; performance of aircraft and spacecraft; deterministic models in operational research; Probability and Random Variables; Dynamics; Signals and Systems; Physical Mechanics I; Aircraft and Spacecraft Structures; Aerodynamics; Aircraft and Spacecraft Propulsion (AEROSP); Electromagnetic Theory; Flight Dynamics and Control; Digital Systems Design; System Dynamics (a total of 47 credit hour; starting at the level of 2nd semester)

(4) Aerospace systems engineering courses: Introduction to Systems Engineering; Aero Eng. Seminar; Aerospace Eng. Lab I; Methods and Instrumentation; Simulation Modeling; Aerospace Eng. Lab II; Engineering Systems Analysis (a total of 20 credit hour; starting at the level of 1st semester)

(5) Elective courses: technical electives are added up to at least 18 credits of the ASSE coded courses; at least 6 credits of non-ASSE coded courses; at least one 3 credits of free elective course (a total of 21 credit hour; starting at the level of 6th semester)

(6) Summarizing the ASSE undergraduate program is constructed on 149 credit hours, 8 semesters

This sample schedule may be an example of one leading to graduation in eight terms. Technical electives are to be designated first by an academic committee in general and then the technical electives can be selected if approved by an academic adviser. Technical electives must be chosen between mathematics of science division courses; ASSE courses; and graduate seminar courses.

To facilitate a road-map for those graduates of the ASSE who would like to pursue a graduate education in Near Earth Space Science and Technology the following scheme is proposed. The program could be used as reference and illustration purposes.

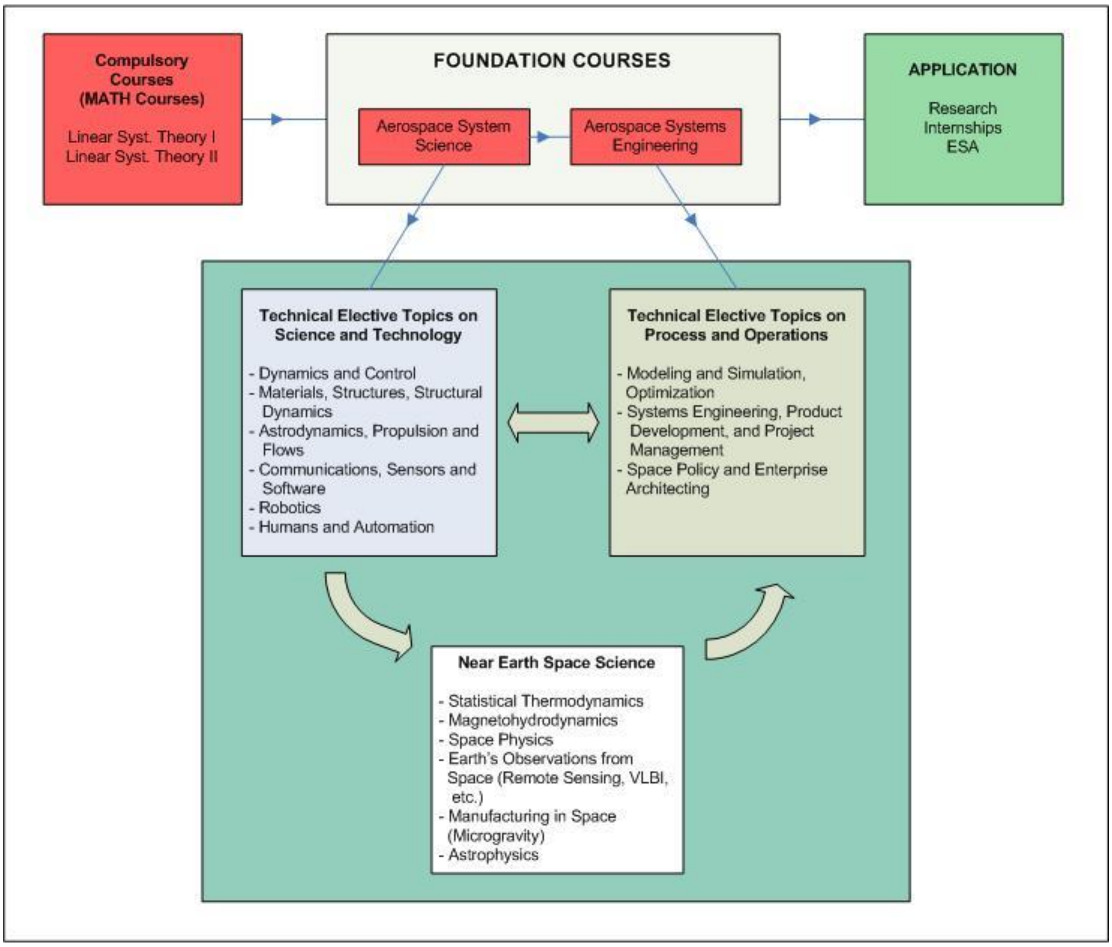

Figure 1. Block diagram of aerospace systems science and engineering program

Figure 1. Illustrates the block diagram of the Aerospace Systems Science and Engineering Program (ASSE). As illustrated in this figure, the ASSE Program consists of four main domains. The *foundation courses* domain, in turn, consists of two sub-domains of the Aerospace Systems Science and Aerospace Systems Engineering.

Conclusion

As stated in the introduction part, the required theoretical background, relevant skills and know-how for preparing and executing the space projects are provided herewith for the educational systems.

The innovations and technological developments on the Near Earth Space science and engineering have not been reflected as major applications in practice as an integrated approach in many countries who have been buying and employing space technologies for a long time. For example, the Near Earth Space concept has been created in some of the curricula of some of the Turkish Universities. In addition, the university activities in this field are neither documented nor systematic. Under the current circumstances in the international and national levels we have taken initiative to propose a contemporary educational program. The proposed program bears the title of "***Aerospace Systems Science and Engineering***" (**ASSE**). In establishing such a program, we have studied similar programs of the leading international universities.

In this novel, comprehensive Aerospace System Science and Engineering Program, we have combined two approaches: *(i)* the space systems engineering programs of well-known American Universities (e.g. MIT) and *(ii)* as our original contribution, the dimension of the science and engineering of the Near Earth Space.

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