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Aerospace engineering training: universities experience

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Abstract. Contemporary professional working in aerospace engineering must have a set of soft and hard skills. The experience gained in universities shows that training of a competent professional is impossible without an employer involved in this process. The paper provides an analysis of missions, tasks and experience of aerospace professionals and identifies the present and future roles, missions and required skills of a highly qualified specialist in aerospace engineering. This analysis can be used to design a master's program aiming at providing students with the required knowledge, know-how and attitudes needed to succeed as professionals in industrial companies.

1 Introduction

According to the U.S. Department of Labor, Bureau of Labor Statistics, aerospace engineers are expected to have 10 percent growth in employment between 2006 and 2016, about as fast as the average for all occupations.

Aerospace engineers develop new technologies for use in aviation, defense systems, and space exploration, often specializing in areas such as structural design, guidance, navigation and control, instrumentation and communication, or production methods. They often use computer-aided design (CAD) software, robotics, and lasers and advanced electronic optics. They also may specialize in a particular type of aerospace product, such as commercial transports, military fighter jets, helicopters, spacecraft, or missiles and rockets. Aerospace engineers may be experts in aerodynamics, thermodynamics, celestial mechanics, propulsion, acoustics, or guidance and control systems [1].

The aerospace industry is a high-tech industry, which plays an important role in ensuring the national security of the country. The dynamics of the social-economic development of society has led to the necessity of changes in education. Today, the industry needs the specialists who are able to solve complex engineering problems, to meet the future requirements of aerospace projects, to provide the selection of optimal solutions with high technical and economical effect and to take into account long-term forecasts of the impact of technology on the environment.

2 Change in the approach to training specialists

Training for Aerospace Engineering in the late 20th and early 21st century in Russia faced certain stagnation turned into a recession. This was due to the fact that businesses in this area survived rather than evolved since state orders significantly decreased, and the companies were not interested in

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recruiting young competent professionals. The rise of the industry initiated an interest of employers in competent college graduates; therefore, much attention was paid to the quality of training future engineers. The education standards FSES 3 and FSES 3+ were introduced, according to which the employer and the student became equally involved in the educational activity. Employers became aware of the need to be involved in training of future professionals.

The current state of the aerospace industry generates demand for qualified engineers capable of comprehensive combining various activities, able to solve complex engineering problems, to provide a choice of optimal solutions with high technical and economic effect, to match the foresight requirements of aerospace projects and to take into account long-term forecasts of the impact of technology on the environment and life and activities of both society and man. The formation of engineering competence of the future specialist, task-oriented mastering of graduates in innovative engineering activities, raising the level of social and personal responsibility for the results of professional activities aimed at sustainable development [2] and «green engineering» are becoming of particular importance to ensure the competitiveness of university graduates.

Quality management of engineering education is a strategic objective of engineering education in Russia. It can be provided by the universities (most of which are accredited by ABET) which confirm that the quality of training of technical college graduates for innovation activities depends on many factors: the quality of the educational program; human and scientific potential involved in the educational process; students (including the quality of applicants training); logistical and methodological support; organization of project activities, etc.); educational technologies.

Training of future engineers (including those for space industry) requires practice-oriented training (in accordance with the employer's order) using problem-oriented projects, and it is to be related to real production.

3 Aerospace soft and hard skills requirements

In order to design an educational curriculum in our university, we have to answer two main questions: what knowledge and competences are needed? What does industry expect from such graduates?

It is essential that the professional competence should be integrative and holistic, being the product of vocational training as a whole. As part of the modern paradigm of the education competency, basic methodological approaches to form competences of future engineers are systemic, personality and activity approaches.

Systematic approach allows development of a consistent methodology for formation of the communicative competence based on the activities and functions of the modern engineer. Person-oriented approach provides favorable conditions for self-development of the creative potential of individual and student-centered teaching technologies. Activity approach, in which education and training are based on social experience, focuses on the interaction with the social environment. The efficiency of formation of communicative competence of the future engineer can be enhanced by active learning methods: problem-based lectures and seminars, case-studies, educational and professional simulation games, search techniques, training sessions, group discussions, etc. These methods are specifically encouraging for active mental and practical activities of students thus contributing to the development of their competencies [3]. Table 1 shows the integrative professional competencies of engineers according to Rozhkova's opinion.

Third and fourth year bachelor degree students and first year master degree students, INDT TPU, program "Instrument making" were given an assignment to write an essay "Ideal aerospace engineering training". The students coped better with the description of soft and hard skills the graduates require to possess after graduation than with their proposal of the learning process for formation of these competencies. It should be noted that most of the students wrote that communication competencies and organizational skills are crucial for specialists in this area. Only a quarter of the students wrote that representatives of enterprises should be involved in the educational process. The most often share the idea that lectures should be delivered, on the one hand, by the teacher experienced in the field and, on the other hand, by the teacher who possesses all the necessary modern teaching tools, including advanced training. The majority of students believe that increase in the time practical training in the production will have a positive effect on the quality of training. Some of the students suggested a one-year internship (practice) in the enterprise. According to the students, a good basic knowledge of fundamental disciplines such as mathematics and physics plays an important role. In addition, the respondents note that only highly motivated students who are ready to learn independently and outside the university environment can become competitive specialists. The students expect the university to create an educational environment, including modern laboratories and information environment, and implementation of the best practices of Russian and foreign universities.

Table 1. Professional competences of engineers.

Abilities (skills)	Content of competences
Planning and organization	Accuracy, punctuality, control, planning
Leadership skills	Activity, leadership, colleagues respect
The ability to analytical thinking	Analysis, information search
Cooperation	Confidence, sociability
Teamwork	Ability to cooperate, emotional support
Focus on success	Perseverance, following the quality standards
Perception of innovation	Flexibility, initiative
Professional skills	Tutorship, professionalism, self-development
Motivation	Positive attitude to work, energy
Corporate spirit	Loyalty, promotion of corporate values, following the corporative standards
Stress resistance	Attitude towards failures, work under pressure, emotional stability
Independence	Independent opinion, confidence
Oral communication	Oral literate speech, persuasion skills
Writing skills	Informative presentation, literate written speech
Creativity	Ideas generation

4 Experience of Russian and foreign universities

The experience of Russian universities in training of specialists in the field of research development, development of space systems, devices, etc. is implemented in the following forms:

- base department (at the Department of Space Research and Aerophysics MIPT and JSC "Russian Space Systems")
- implementation of educational programs (Department of Space Device Engineering and Innovation Technologies SFU, design and construction of space systems and unmanned spacecraft in the Institute of Radio-Engineering and Telecommunications, Kazan National Research Technical University; ITMO University – for optical and space instrument making, Tomsk State University, specialists in "Design and construction of industrial space systems").

- New educational programs (Moscow State University of Mechanical Engineering (MAMI) in Modern Astronautics);
- fulfilment of master's theses in the JSC "Gazprom Space Systems' (TSU);
- target training of specialists(Russian State Technological University named after Tsiolkovsky (RSTU – MATI) and Moscow Aviation Institute National Research University (MAI);
- scientific internship in enterprises engaged in design, manufacture and operation of space equipment;
- research conducted within the bachelor’s degree program, scientific work fulfilled within epymaster’s degree program;
- lectures delivered by leading scientists and specialists (including astronauts);
- scientific and practical conferences and workshops;
- participation of employers in meetings of the State Examination Board;
- introduction of the Project Activity Module (MAI, as an example).
- Virtual Design Bureau.

TPU has gained experience in creating a virtual space bureau where students work. The first practice-oriented result was opening of the Mission Control Center. In addition, professionals from the aerospace industry are actively involved in the design of master's and bachelor's degree practice-oriented programs; a joint master's program for the space industry is implemented. Starting from the 3rd year, students take an internship at the enterprises of Roskosmos, and its employees deliver lectures at the university.

In addition, the program of the University development should focus on recruitment and scientific and innovative support of the aircraft, missile and space industries, and other high-tech sectors of the economy.

The analysis of international experience shows that the discussion of the strategy of training experts is to be adopted at state level. As an example, an international aerospace school, where Russian cosmonauts and leading specialists of the Cosmonaut Training Centre named after Yu. A. Gagarin deliver lectures, is organized in Tashkent (Uzbekistan).

The overseas abroad are also actively developing programs to train professionals. Michigan AERO (U-M Aerospace Engineering Department) of the University of Michigan support students’ activity for projects in space areas. The training process makes each student, from the freshmen to the graduate, feel part of a strategically important project. The student employed can take a position in the company or lab outside the university, such as NASA, Langley; be involved in the research project or independent study with an Aero faculty member, for credit or pay; take a position as a grader for an Aero class; take a work-study position in Aero [4].

The School of Aeronautics and Astronautics, through Purdue University's Engineering Professional Education program, is offering graduate level courses in aerospace engineering so that students can earn non-thesis MS degrees in Aeronautics and Astronautics entirely via distance learning courses.

Bristol university courses are accredited by the Royal Aeronautical Society. In Southampton, a Space Systems Engineering Course is going to be offered [5].

In addition to Russian forms of training specialists, it is recommended to implement the following measures to enhance practice-oriented engineering training:

- ability to take part in international satellite design competition;
- SEDS (Students for Exploration and Development of Space);
- creation of infrastructure to support student projects (including that intended for development of technology entrepreneurship);
- appointment of AeroFaculty Advisors in the university;
- student chapter of the Institute of Aeronautics and Astronautics;
- development of e-learning (including master degree programs).

According to the survey conducted by N.A. Onishchenko among 440 students of the Aerospace Institute, Orenburg State University, and Kazan National Research Technical University[6], more than

170 students indicate a need for closer integration of theory and practice, 87% of the respondents believe that they will need time to adapt to the workplace irrespective of the high level of training. More than 170 students point out a lack of curriculum interdisciplinary modules and lack of relation to their future profession.

In addition, there is a contradiction between the requirements to the quality of training indicated by employers and insufficient involvement of the enterprises in the design, implementation and assessment of educational programs.

Thus, to improve practice-oriented training, it is necessary:

1. to allocate resources to design innovative educational programs.
2. to provide flexibility, interdisciplinarity and logistics of training modules;
3. to implement network forms for organization of the educational process;
4. to develop strategic cooperation with schools and businesses;
5. to improve the quality of training in fundamental disciplines;
6. to create a career guidance system (starting with primary school);
7. to ensure implementation of space-related research;
8. tointroducepracticalcoursepapersandcreativeprojectsonspacesubjects (offering a wide range of problems and tasks);
9. to solve specific problems of the space industry within the training modules;
10. to introduce modules of technology entrepreneurship;
11. to establish interactive exhibitions and museums with real exhibits, to use prototyping and 3-D modeling equipment in the classroom.

In addition, some changes must be carried out in terms of Human resources: management of educational programs by experts with practical experience, representatives of companies involved in assessment of competencies of the graduates completing these educational programs, transition from the curatorial support to tutors for project activities [7-19].

5 Conclusion

Engineering training in the space area should be the topic of discussion at national level. Only a systematic approach of experts (from classes in children's organizations to the University) with active involvement of enterprises will ensure the results in scientific and engineering solutions of fundamental and applied problems. The activities for development of practice-oriented training proposed as a result of the analysis of the experience of universities (Russian and foreign) will form the environment for regeneration of engineering thinking competencies, soft skills and hard skills in the space sector to train competent professionals.

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