Czech space technology “know-how” entering the International Space Station

Marek Šimčák

European Polytechnic Institute Kunovice
Osvobozeni 699, 686 04 Kunovice
Tel. +420 572 549 018, fax +420 572 549 018, simcak@edukomplex.cz

Abstract: *Nowadays, at the beginning of the second decade of the 21st century we are the witnesses of a remarkable development in many technological branches. No doubt to say that just the Space technologies belong to the most dynamic ones having an increasing impact on the functioning of the present world in a substantive way. Space technologies are becoming a natural component of many sectors of human activities. This paper is focused on presenting an extraordinary success of the Czech space electronics industry that opens a door to the International Space Station (ISS) which is often considered as the most challenging technical project of the human being ever. At present, sophisticated computations and design activities of a space electronic module called European Laser Timing instrument (ELT) are running under responsibility of a team of Czech researchers and engineers. This instrument will form an integral part of the ACES payload to be operating in the Columbus science laboratory, the Europe’s key contribution to the ISS. It is my great pleasure to present here also the fact that the European Polytechnic Institute has become an active player within the Czech space educational activities. Within a framework of a new course called “Electronics in the space devices” established in 2010 the first student team project “Introduction to the ISS systems” was made.*

Keywords: *International Space Station (ISS), European Space Agency (ESA), Atomic Clock Ensemble in Space (ACES), European Laser Timing instrument (ELT)*

1. INTRODUCTION

The International Space Station (see Figure 1) is a unique, orbiting research laboratory that has been designed and built-up in the frame of the worldwide peaceful technology co-operation. The main ISS partners are United States, Russia, European countries associated in ESA, Japan and Canada. This international co-operation is considered as the largest partnerships in the history of science. Since the first module of the ISS was launched in 1998, the Station has circled the globe 16 times per day at 28 000 km/h speed at an altitude of about 370 km, covering a distance equivalent to the Moon and back daily. Once complete, the Station will be as long as a football field, and will have as much living space as a five-bedroom house.

The key contribution of Europe is the multipurpose science laboratory called Columbus. This is a place where scientists can send experiments to be carried out in weightless conditions and where major technological and science achievements are made. This participation is also a great stimulus for European industry performing the development and manufacturing of cutting-edge space systems and hardware.

It is great to say that prototype development activities of the first real Czech space hardware intended for the ISS have been started not later then just one year after completion of the Czech formal memberships in ESA. That time the concrete Contract between EADS Astrium, the leading ESA prime contractor and the Czech Space Research Centre (CSRC), the Czech private engineering company, was officially signed. Entering this challenging project was possible based on satisfying all the strict criteria of the evaluation process supervised by the ESA experts.

2. PRESENT ACTIVITY OF THE CZECH REPUBLIC IN ESA

The Czech Republic became the 18th member state of the European Space Agency (ESA) on the 14th November 2008. This moment can be considered as one of the most important milestones waving the long way to the new visionary achievements of the Czech space technologies and industry in the near and distant future. Accessing to the ESA convention was not an easy process covering not only the PECS transition programme (2005-2008). It must be mentioned also extensive background in space science and technology based on substantial participation in the Inter-cosmos programme and also the strong interest of the recent Czech governments.

The country does not have a National space agency yet, but it has been proposed and recommended in the strategic document called “Czech Space Plan” recently approved by the Czech government. At present, several Czech official institutions and authorities are active in the whole complex of the national space activities. Main responsibility is delegated upon the Ministry of Transport co-operating together with the Ministry of Education, Youth and Sports, the Czech Space Office and the Czech Space Alliance. The Czech Space Office (CSO) is an official contacting point especially for the academic issues, science, education, and research activities while the Czech Space Alliance (CSA) represents great majority of the active space industry.

The Czech Space Alliance plays a key role to the success of the country in ESA. It is an industrial association of the Czech space companies with proven skills while some of them have more then 15 years' track record in space including ESA. The alliance was established in 2006 under the auspice of CzechTrade, the export promotion agency of the Ministry of Industry and Trade. Among the main alliance goals it could be mentioned especially representation and promotion the interest of the space industry to the national decision makers and stakeholders, the national and international media, co-operation with the ministries and all the other official entities supporting space activities in formulation of the space policy and creation of suitable conditions for the growth of the Czech space industry. Moreover, it is also important to present the skills of the CSA's members at international events helping them to develop business relationships with potential partners inside ESA and other space subjects.

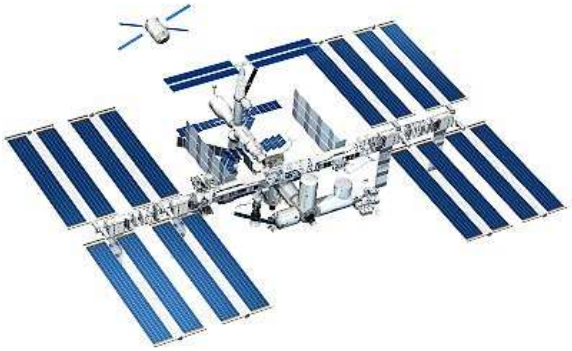

Figure no.1: International Space Station, © ESA

3. EUROPEAN SPACE AGENCY

ESA is an international organization of 18 member states, including the Czech Republic, which can be called as a gateway to space. More then 2000 people try to fulfill the main ESA's mission which is to shape the development of Europe's space capability and ensure that investment in space continues to deliver benefits to the citizens of Europe and the world. The basic act of ESA is the Convention for its establishment, signed on 30th May 1975, in Paris. By coordinating the financial and intellectual resources of its members, it can undertake programmes and activities far beyond the scope of any single European country. ESA's budget for 2010 is almost €4000 million. ESA operates on the basis of geographical return, i.e. it invests in each member state, through industrial contracts for space programmes, an amount more or less equivalent to each country's contribution.

Among the other, the main ESA's domains are for example science and robotic exploration for space discovery, the Earth observation, microgravity research, satellite navigation, telecommunication & integrated applications, innovative technology for everyday life, launchers industry, and human spaceflight. All these activities are performed in several ESA centers, as follows:

- ESA's headquarters are in Paris, France;
- EAC, the European Astronauts Centre in Cologne, Germany;
- ESAC, the European Space Astronomy Centre, in Villanueva de la Canada, Madrid, Spain;
- ESOC, the European Space Operations Centre in Darmstadt, Germany;
- ESRIN, the ESA centre for Earth Observation, in Frascati, near Rome, Italy;
- ESTEC, the European Space Research and Technology Centre, Noordwijk, the Netherlands.

A new ESA centre has opened in the United Kingdom, at Harwell, Oxfordshire. ESA also has liaison offices in Belgium, USA and Russia; a launch base in French Guiana and ground/tracking stations in various parts of the world.

Within the context of the European space business, ESA is in charge of managing all the procedures to attribute and place the contracts through the procedure "Invitation-To-Tender" called also the ITT system, up to the final approval of contracts given to specific industry entities. As for the Czech Republic, in 2009 ESA announced its historically first call for proposal titled AO6052. The second call has just been opened under the title AO6647. Nowadays all the Czech companies having any ambitions to enter the European space business are busy to make their best proposals to ESA.

4. ESA CONTRIBUTION TO THE INTERNATIONAL SPACE STATION

The ISS can be characterized also as a versatile permanently inhabited research institute in Low Earth Orbit enabling a large observation platform in outer space for scientific research and applications. It also serves as a test centre to facilitate introduction of new technologies. This permanently human occupied outpost in outer space should also serve as a stepping stone for further space exploration. Once completed, the ISS will have the following parameters:

- Dimensions: width=108 m, length=74 m, height=45 m
- Pressurized volume: 1 200 m^3
- Total mass at completion: ~450 000 kg

- Orbital altitude: 370-460 km
- Orbital velocity: 7.7-7.6 km/s (~27 500 km/h)

The first launch became reality on the 20th November 1998. The launch vehicles connecting the Earth with the ISS are provided by 4 of the 5 participating partners (ESA: Ariane-5 launcher, Japan: H-IIA launcher, Russia: Proton and Soyuz launchers, USA: Space Shuttle).

As already mentioned, the key contribution of Europe is the Columbus module (see Figure 2). This research laboratory is permanently attached to the ISS and provides internal payload accommodation for experiments in the field of multidisciplinary research into material science, fluid physics and life science. In addition, an external payload facility hosts experiments and applications in the field of space science, Earth observation and technology. The Columbus module is characterized with the following parameters:

- Dimensions: length: 6 871 mm, largest diameter: 4 477 mm
- Total internal volume: 75 m^3
- Payload mass: 2 500 kg
- Launch mass: 12 775 kg
- Supported crew: 3 persons
- Cabin temperature: 16° and 27°C

There is a lot of flight hardware in Columbus, for example: Biolab, Fluid Science Laboratory, European Physiology Module, European Drawer Rack, European Transport Carrier, Data and mission computers Command/Measurement Units, High-rate multiplexer, Mass Memory Unit, Video Cameras and many other scientific instruments.

Figure no.2: Columbus module, © ESA

5. CZECH PARTICIPATION AT THE ESA's MISSION CALLED "ACES"

The whole ISS including the Columbus module is in the permanent development to increase its benefit for the complex human being applications. Among many others currently running projects, development of the Atomic Clock Ensemble in Space (ACES) is one of the exciting challenges of the present time. The ACES is an ESA mission in fundamental physics based on the performances of a new generation of atomic clocks operated in the microgravity environment of the ISS.

The ACES payload accommodates two atomic clocks called PHARAO (a primary frequency standard based on samples of laser cooled cesium atoms developed by CNES) and SHM (an active hydrogen maser for space applications developed by Spectra time under ESA contract). The performances of the two clocks are combined together to generate an onboard timescale with the short-term stability of SHM and the long-term stability and accuracy of the cesium clock PHARAO. Finally, it will provide precise orbit determination of the ACES clocks. One of the main objectives of the ACES mission consists in maintaining a stable and accurate onboard timescale which will be used to perform space-to-ground as well as ground-to-ground comparisons of atomic frequency standards.

The ACES clock signal will be transferred on ground by a time and frequency transfer link in the microwave domain (MWL). MWL compares the ACES frequency reference to ground clocks worldwide distributed, enabling fundamental physics tests and applications in different areas of research. ACES will test a new generation of atomic clocks using laser-cooled atoms. Comparisons between distant clocks both space-to-ground and ground-to-ground will be performed worldwide with unprecedented resolution. These comparisons will be used to perform precision tests of the special and general theory of relativity. In addition, ACES will demonstrate a new type of 'relativistic geodesy' which, based on a precision measurement of the Einstein's gravitational red-shift, will resolve differences in the Earth gravitational potential at the level of tens of centimeters. ACES will also contribute to the improvement of the global navigation satellite systems (GNSS) and to their future evolutions; it will perform time transfer and ranging experiments by laser light; it will exploit the GNSS signal for reflectometry measurements and contribute to the monitoring of the Earth atmosphere through radio-occultation experiments.

The European Laser Timing instrument (ELT) is one of the subsystems of the ACES (see Figures 3 and 4). The ELT will extend the ACES operational capabilities for an additional time and frequency link in the optical domain. It will be an optical link between the ACES payload and established Satellite Laser Ranging (SLR) stations providing (1) two-way laser ranging and (2) one-way laser ranging to be able to perform a space-to-ground time transfer via ELT with a time error below 48ps (23ps as target performance).

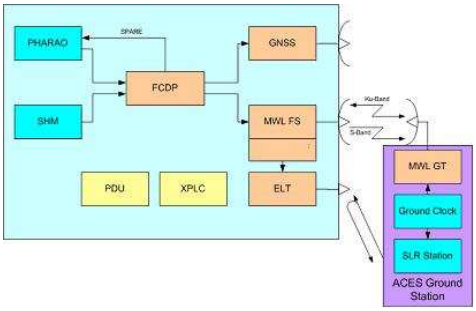

Figure no.3: ELT Instrument

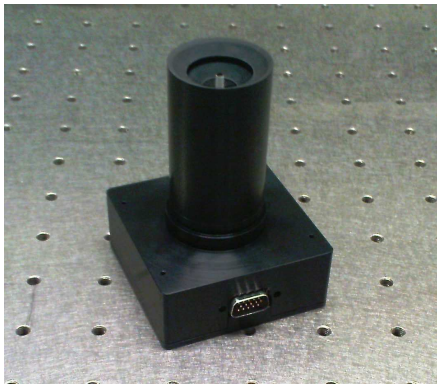

Figure no.4: ELT Instrument

It is an exciting fact that the ELT instrument was designed at the Czech Technical University and the prototype is coming through the development phase in cooperation with the CSRC Company. Once completed, this instrument will be installed at the Columbus External Payload Facility called CEPF (see Figure 5).

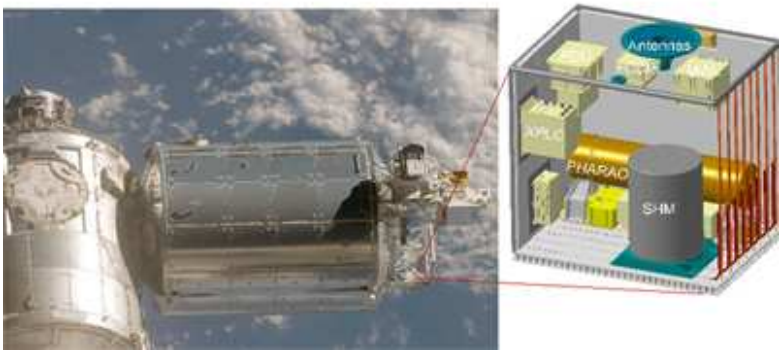

Figure no.5: ACES Payload installation at the CEPF of Columbus , © ESA

6. EPI AND ITS SPACE EDUCATIONAL ACTIVITES

At present, it is obvious that the "Space Age" is entering also into the Czech education area. Except both the famous traditional state universities, the Czech Technical University and the Brno University of Technology, we can see significant activities coming from the private university sector too. The European Polytechnic Institute is most probably the first Czech private educational centre where the space technologies have been introduced to the students. A new course called "Electronics in the space devices" has been established since 2010. During the opening period the main emphasis was put on the various topics related to the space activities. For example, it can be mentioned the basic space terminology, the Czech Republic as a new ESA member state and its role in the space technologies in the past, at present and in the near future, introduction to the Czech space hardware, the USA and Russian space competition history, the main technical requirements to the hardware operating in the space, brief summary of the main space physics rules, the main Czech space authorities, the ESA introduction and its business calls to the Czech industry, and the International Space Station. The ISS, its history, development, internal structure and its functionality was the topic of the first student team project performed in the frame of this new space-related course.

7. CONCLUSIONS

Main aim of this paper was to present a new growing phenomenon within the international space activities which is an emphatic entrance of the Czech space technology "know-how" into the European space business including the most challenging international space project ever, called the ISS. To make the positive meaning of this national activity underlined, the main aspects, priorities, and the key players of the European and international space were introduced. The ACES / ELT project with the Czech participation was presented in more detail. Finally, the first steps of the European Polytechnic Institute towards the strategic and rapidly growing space technologies were described.

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