PROSPECTS FOR COOPERATION OF THE TECHNICAL UNIVERSITY OF MOLDOVA WITH ROMANIAN SPACE AGENCY IN THE FIELD OF SPACE TECHNOLOGIES

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1. THE PREMISES OF COOPERATION

The rapid development of space technologies requires new paradigms of cooperation at regional and international scale in the field. The complex evolution of space technologies favours the expansion of research and innovation partnerships within educational and commercial projects attracting youth, accelerating also the dissemination of related technologies in the socio-economic, scientific and social environment.

For Moldovan researchers the research centres from Romania are the most valuable and accessible institutional structures able to develop partnerships for cooperation in the field of space technologies. These aspects of cooperation were discussed during the meeting in Bucharest on 2 April 2015 between PhD, DHC Marius-Ioan Piso - President of the Romanian Space Agency (ROSA) with the Academician Gh. Duca - President of the Academy of Sciences (ASM), Academician I. Bostan - Director of the National Centre of Space Technologies (CNTS), Technical University of Moldova (TUM), Academician I. Tighineanu - First Deputy Chairman of ASM.

The cooperation with the Romanian Space Agency is also of interest to the Republic of Moldova in terms of exchange of experience in the field of satellite technologies, Romania having launched into space its first satellite "Goliat" on 13 February 2012.

2. ROSA – ON THE TOP OF THE NATIONAL SPACE PROGRAMME

The Romanian Space Agency (ROSA) is the national and international coordinator of the activities of Romania in the field of space technologies. It has the statute of a public institution, is financed wholly from own revenues, being subordinated to the National Authority for Scientific Research and Innovation (A.N.C.S.I.) of the Ministry of National Education and Scientific Research [2-4]. The research directions coordinated by ROSA are focused on [4]:

- coordinating national research programs and space applications;
- promoting the development of Romania in the space field;
- representing the Romanian Government in international cooperation programs;
- research oriented on space issues.

As a coordinator of the national research programs and space applications, ROSA develops and coordinates the implementation of the National Space Program. Depending on its objectives, ROSA is authorized to establish research and development centres. As the representative of the Government, the Romanian Space Agency establishes cooperation agreements with international organizations such as the European Space Agency (ESA) and the Committee on Space Research (COSPAR) and bilateral agreements of cooperation at Romanian Government level. Together with the Ministry of Foreign Affairs, ROSA represents Romania at the meetings of the United Nations Committee on the Peaceful Uses of Outer Space and its subcommittees. ROSA coordinates the space activity of scientific and industrial communities, which include over 120 institutions, companies and businesses [4].

One of the most representative institutions, the **Institute of Space Sciences (ISS)** in Bucharest, has played a key role in Romania's accession to the ESA. Another mission of ISS refers to popularizing the research and development fields of ESA in Romania. ISS coordinates a wide range of research and development directions of which the following are worth mentioning [3]:

- Theoretical Physics and Mathematical Physics;
- High Energy Physics and Astrophysics;
- Astroparticle Physics and Cosmology;
- Microgravity, Space Dynamics and Nanosatellits;

- Solar-terrestrial interactions, magnetosphere physics and magnetosphere, solar wind and ionosphere-thermosphere coupling;
- Fundamental dynamic processes in collisionless plasmas; relationship to astrophysical and laboratory plasmas;
- Planetary and interplanetary disturbances and hazard in connection with space weather and electromagnetic phenomena associated with terrestrial tectonics;
- Development of experiments and equipment embarked on cosmic vehicles, in-flight calibration and associated software tools development;
- Advanced analysis and numerical simulation techniques with application to satellite data and images treatment; advanced methods for time series analysis;
- Distributed and Parallel Computing for Space and Ground-based Research and Applications;
- Human Performance and Space Biophysics, Biology and Medicine studies and experiments in benefit of Human Spaceflight and for societal terrestrial spin-off;
- Space Technologies Applications for Humans and Communitarian Health and Safety in critical situations on Earth;
- Systems Engineering and Knowledge Management applied to space-related activities.

Many of the directions mentioned are promoted within the **University Politehnica of Bucharest (UPB)**. The Research Centre for Aeronautics and Space was established in 2001 within UPB, which became an important component in space research. The Centre's mission is to maintain a balance between theoretical and applied investigations in the field of space technologies, with the objectives as follows:

- Development of scientific and practical cooperation with the involvement of SMEs, research institutes, university centres within distinct projects;
- Providing support to industrial units on exploiting new space technologies, improvement of human research potential in the field;
- Stimulation and development of research cooperation within the European Union initiatives.

Another institutional structure, the **Centre for Research and Advanced Studies (ASRC)**, develops theoretical and applied research projects in a variety of scientific and technological fields. ASRC tends to develop and apply innovative solutions in various areas of expertise through a multidisciplinary approach in order to solve problems arising from the social, industrial and ecological environments. ASRC can develop and analyse mathematical models, numerical methods and solutions, complex algorithms and innovative software tools for programming and visualization, as well as for the validation and substantiation of the results of various tests. ASRC areas of interest include fluid dynamics, geophysics, environment, structural analysis, biomathematics, telemedicine, virtual reality, space dynamics, artificial intelligence etc. ASRC has experience in initiating and promoting national and international projects and programs in the fields of Space, Aeronautics, Computer Science and Information Technology, Security.

Aerospace area is represented by **S.C. Aerostar S.A. (ASTAR)**, which has accumulated extensive experience with regard to repairing and modernization of military aircraft, production of light aircraft, hydraulic equipment for aviation and electronic equipment. In the field of GNSS - INS, ASTAR has gained experience in areas such as:

- development of hardware / software for GNSS-INS equipment;
- GPS and INS equipment integration in avionics;
- GPS / GALILEO equipment testing etc.

The Research, Development and Innovation Programme Space Technology and Advanced Research – STAR, for the period 2012-2019 [5], is the tool by which the Ministry of National Education - National Authority for Scientific Research (ANCS) ensures, through ROSA, a great support at national level to the implementation of the Agreement between Romania and the European Space Agency (ESA). The activities of many national programmes have been carried out under STAR [4-8]: CD-I AEROSPACE, CD-I SECURITY, CEEX, CORINT, INFOSOC, AMTRANS, AGRAL, RELANSIN, PNCDI-I/II, including international joint programmes with the European Space Agency (ESA), the United Nations Organization, organizational programmes in Food and Agriculture, PHARE Programme (1), bilateral and multilateral cooperation etc.

3. DEVELOPMENT OF SATELLITE TECHNOLOGIES IN THE REPUBLIC OF MOLDOVA

The starting of the project [1] in 2009 on developing the first Satellite of the Republic of Moldova has stimulated the initiation and development of a range of research and design activities in the field of satellite technologies. Given the funding opportunities of the project from the

State Budget, previously negotiated within the Supreme Council for Science and Technological Development of the ASM, and given the outlook of co-financing from extra budgetary sources, it was decided to develop a satellite with a mass of 10-12 kg, classified according to the European Scale as typo dimension - Microsatellite (MS).

The topic of the activities carried out in the period that followed was projected on three distinct directions:

The first direction - refers to the research, design and manufacture of microsatellite functional components related to its scientific purpose and objectives [1, 9]. The research and design activities devoted to the development of microsatellite on-board subsystems were based on the a priori concept adopted, including on the use of standardized functional COTS components available (Commercial Off The Shelf components) assembled on modular principle. This approach to the process of MS developing meets a number of advantages, including reduced costs and time to perform the MS research-assembly cycle, increased functional reliability of on-board subsystems and of the MS as a whole, simplified procedures and techniques of experimental testing and so on.

However, the theme of the activities included a wide spectrum of scientific research, experimental and construction-technological works, largely interdisciplinary, including at the junction of areas. Due to the achievement of the approved MS design concept based on the use of some functional COTS components (standardized, parametrically unified), their selection was based on an extensive study of ensuring the parametric compatibility, taking into account the mass limitations, dimension, accessibility and acquisition availability etc. Numerous undergraduate, postgraduate and doctoral students from different specialties and faculties were involved in the research and design process, thus ensuring the project an inter- and multidisciplinary educational character.

The second direction includes actions related to the establishment of the National Centre of Space Technologies (CNTS), with a network of interconnected ground stations so that:

- to ensure upward and downward connections of the MS during its flight, with ground infrastructure (especially when it is in the visible area of the Republic of Moldova);
- to ensure the determination, orientation and attitude control of the MS during orbit flight so that when entering into the visible area of the Republic of Moldova it is correctly oriented to capture images (the axis of the scanner lens to look in the nadir);
- to ensure the reception of satellite signals for their further processing;
- to allow the tracking and dialogue with foreign weather satellites etc.

CNTS establishment with a network of ground stations in the Republic of Moldova will open opportunities for expanding international cooperation and involving teams of researchers from the local academic community as partners in European projects in the field of space technology. But the main importance and purpose of such an infrastructure will be to ensure monitoring the MS flight after its release in the outer space.

The third direction of the research carried out relates to achieving the specific objectives with regard to remote sensing of the earth surface and providing various scientific and socio-economic space services as well as image capture of the land area of the territory of Moldova, prevention of flooding risks by determining the evolution of river hydrological status, monitoring the ecological status of forests, plantations and agricultural land, solving of various weather problems etc.

MS objectives bear an exclusive civil character, and the MS on-board subsystems developed using components purchased through non-disclosure commitments shall not be passed to third parties.

4. THE NATIONAL CENTRE OF SPACE TECHNOLOGIES (NSTC), THE REPUBLIC OF MOLDOVA

The first steps in researching engaged on projects in the field of satellite technologies have been taken with the launch of the State Programme *Capitalization of renewable energy resources in the conditions of Republic of Moldova and developing the Moldovan Satellite* - approved in 2009 for financing from the State Budget (coordinator Acad. I. Bostan) [1]. The programme provides for the development of the first satellite of the Republic of Moldova with four distinct projects in the field of developing satellite technologies (project leaders PhD, assoc.prof. Secrieru N., PhD, assoc.prof. V. Blaj, acad. V. Canter, acad. I. Bostan [1, 9].

To develop the research capacities, along with the formation in 2009 of scientific teams with some research and design experience in the field of satellite technologies, a comprehensive plan for the design and construction of the technical and material infrastructure was designed and implemented in 2009-2012 that aims at achieving the scientific goals and objectives of the satellite.

Figure 1. Laboratory of on-board subsystems for nano and microsatellites, NSTC, TUM.

***Figure* 2.** Laboratory of the Microsatellite assembly, NSTC, TUM.

Thus, in 2009 started the establishment of the National Centre of Space Technologies, which was formalized by TUM's Senate Decision no. 6 of 31.01.2012 with the following structure:

4.1. Laboratory of on-board subsystems for nano and microsatellites (SBNMS)

BNMS laboratory specializes in the research and development activities of on-board subsystems, including: the scanner for image capturing; MS electricity supply system by converting PV to solar energy; MS determination, orientation and attitude control systems in orbit flight; equipment for data reception and transmission; on-board computer, etc. The elaborations of MS on-board components are carried out based on alternatives, providing undergraduate, postgraduate and doctoral students with fairness of decision and competitive freedom of creation. Thus, based on alternative principles it is ensured the competition for ideas and innovative technical solutions of the teams of young researchers involved in educational projects of research and development of MS on-board subsystems.

Along with the elaborations made in the original variant [1, 9], research teams, based on case studies, propose variants of on-board COTS (commercial) components available together with compatibility, mass, dimension, and cost analyses, including the insurance of the interchangeability and reliability of the MS as a whole. SBNMS laboratory is equipped with modern computers, computer aided design stations applying modern design software in 3D and comparative analyses, including computer simulations of technological processes (Figure 1).

4.2. Laboratory of data and image processing (PDI)

PDI Laboratory is intended to familiarize undergraduate, postgraduate and doctoral students

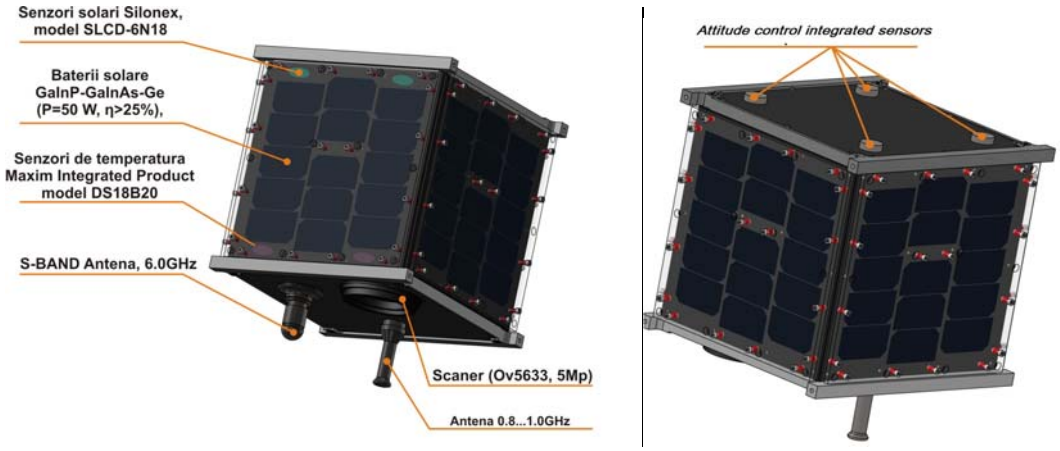


***Figure* 3.** The general view of the Microsatellite, developed at the Technical University of Moldova, Chişinău.

and young teachers with modern methods and techniques of data image and processing from the satellite, dissemination of processing results in different applications and fields. Within the research conducted in the PDI laboratory a special role is assigned to the study of processing peculiarities of satellite images jeopardized by geometric and radiometric distortions, as well as modern processing methods and techniques.

Figure 1 shows a post of geometric and frequency processing of satellite captured images.

4.3. Laboratory of on-board subsystems and MS assembly and testing (AEMS)

AEMS laboratory is endowed with equipment for the assembly of precision mechanics and electronic equipment for measurement (figure 2). figure 3 presents the general view of the MS developed at the Technical University of Moldova. The PV panels of the MS (figure 3) were designed at NSTC and manufactured using the photovoltaic cell GalnP-GalnAS-Ge (P = 50W, η> 25%) resistant to cosmic radiation. SILONEX Solar Sensors of SLCD-6N18 model, Temperature sensors Maxim Integrated Product of DS18B20 model, which are compatible with the MS attitude determination subsystem of MAI-200 model, are mounted in the PV panels.

At the same time, a Simulator (figure 4) is mounted in the AEMS in an isolated space, on a fixed foundation, for the experimental research in laboratory conditions of the MS kinematics and dynamics with sphere-space motion with a fixed point, which reproduces the rotary motion of the satellite around three axes of the orbital reference system. The Simulator also allows experimental research of the intervention of on-board systems on the MS orientation on the orbit, including the determination and calibration of physical efforts of the intervention developed by the two on-board systems [9] on the stability and dynamics of MS repositioning on the axes of the orbital coordinates system. The Simulator allows the experimental research of the MS in laboratory conditions and in vacuum medium of up to 10^{-6} bars (12 μm Hg).

Figure 4. The simulator with the Microsatellite mounted in the external gyroscope, NSTC, TUM.

The Simulator's nest with external gyroscope (figure 5) allows the MS rotation around the 0x, 0Y, and 0z axes in relation to the mobile coordinates system. The nest is equipped with two actuator drivers in order to communicate the MS the nutation motion with an angle of $\theta = 16°$ and precession motion at $\varphi = 360$ °. The planet gear carrier nest allows the study of MS kinematics and dynamics under the action of two MS on-board intervention systems, namely magneto torchers driven by the Earth's magnetic field and the inertial mechanism with three flywheels.

The original Simulator was designed within NSTC, TUM, and manufactured at factories in Chisinau.

4.4. Telemetry communications station (SCT)

The station is endowed with specialized equipment to ensure upward and downward linkages of the MS in orbit flight with the ground

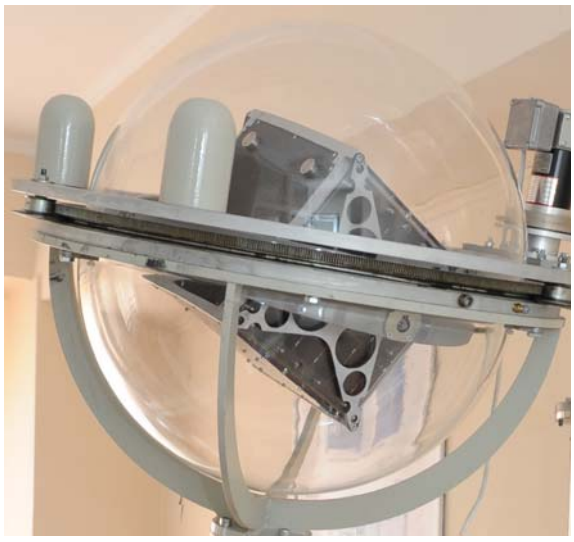


Figure 5. The Microsatellite mounted in the vacuumed planet gear carrier nest with spherical motion, NSTC, TUM.

infrastructure (figure 6). It is connected to a set of telemetry antennas and to the parabolic antenna with mixed purpose (figure 7) [1]. The telemetry

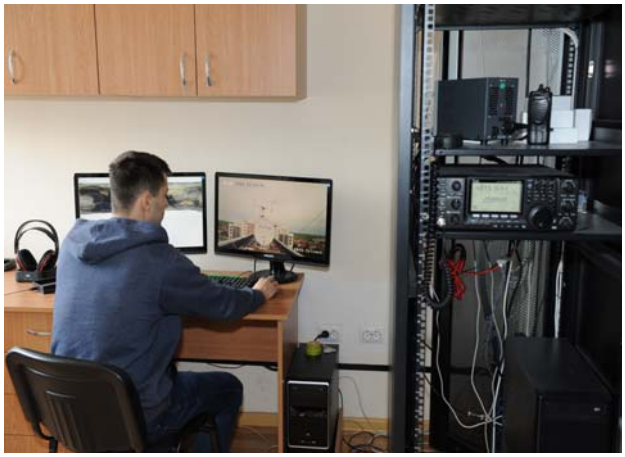


Figure 6. Laboratory of Telemetry Communications, NSTC, TUM.

Figure 7. The set of telemetry and parabolic antennas.

antennas and the parabolic antenna shown in Figure 7 are able to orient on two axes towards the MS in orbit flight through the actuator drivers of Rotor BIG-RAS HR model.

4.5. The design and manufacture platform

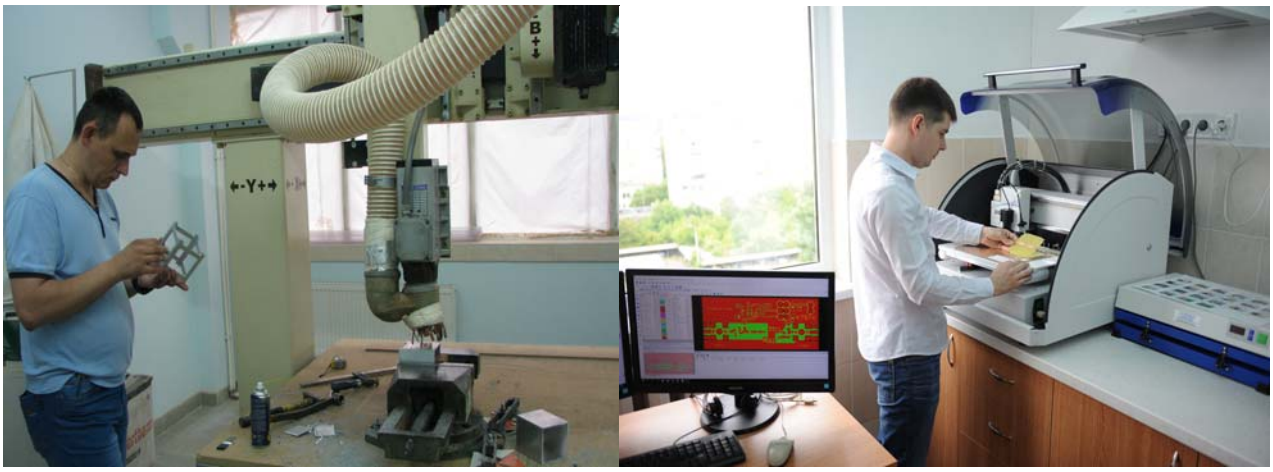
An autonomous design and manufacturing platform of components of the MS on-board subsystems affiliated to the CNTS. It is endowed with advanced stations of computer-aided design, computer simulation of the kinematic and dynamic processes of the MS in the stages of design, experimentation and in the prospect of MS launching. In the design process of functional components of the MS, to simulate the influence of cosmic perturbations on the MS positioning on the orbit, there were used softs like Solid Work, Catia, ANSYS, ABAQUS etc. The manufacture of the components of the MS basic functional subsystems is performed at the Centre of Advanced Technologies "*Etalon*", which is endowed with modern equipment, for example, machine tools of Motion Master TB-105 model having heads with 3 and 5 degrees of mobility, operated with the numerical control Fagor 8055M by applying the software SPUTH CAM and ASPIRE VECTRIC. For the manufacture of the plaques with printed wiring, the design and manufacturing platform is

Figure 8. 3D design platform, TUM.

endowed with equipment of LPKF-S103 model operating under the command of Soft Circuit PRO.

Figure 8 shows a computer-aided design and computer simulation station of the MS kinematics and dynamics at the stage of design, testing and commissioning; figure 9a - manufacturing of the components of the MS on-board subsystems at the Centre of Advanced Technologies "Etalon", and figure 9b – computer-aided design station for the prototyping of the plaques with printed wiring of the electronic modules.

NSTC is directly connected to the **Centre of Excellence and Communications of TUM**, endowed with extensive infrastructure for hosting a powerful network "Claud computing", which includes laboratories of research, design and simulation of informative, including satellite, communications systems. A successful collaboration was established with IBM, Romania, through workshops conformed to IBM Academic Initiative regarding the familiarization with design technologies like Model Drivon Systems developed with IBM Rational Rhapsody ILOG OPL-Operations Research.



a) b)

***Figure* 9,a,b.** Manufacturing of the components of the Microsatellite's on-board subsystems, TUM.

SBNMS, PDI, AEMS and SCT laboratories are structures integrated in the NSTC, and the platform of design and manufacturing of the components of the MS on-board subsystems is affiliated as an autonomous structure with self-financing.

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