Technical University of Moldova Institute of Electronic Engineering and Industrial Technologies of Academy of Sciences of Moldova

REPORT

on aerospatial activities in programme's framework

"Exploitation of renewable energy resources in conditions of the Republic of Moldova and development of Moldavian Microsatellite"

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1. Introduction

The remote sensing of Earth from space appears to be an advanced industry and the number of users that utilize images from space is constantly growing. The agrarian sector of the national economy is the most important for Republic of Moldova. The countries which occupy leading positions in agricultural production regularly monitor the state of cultured vegetables, fruits and berries with the help of satellites. However, the high cost of space photography does not allow farmers in Republic of Moldova to purchase space photos from countries and corporations that have active satellites on the orbit. Therefore, the own satellite would provide solutions for both existing and other important problems of the national economy. The offered project corresponds to the national priorities related to the electronic data processing for cadastral use; landslides forecast; predicting of the formation and movement of hail clouds; monitoring land lots; ecological monitoring of forests and aquatic evolution of rivers and lakes, flood damages (fig. 1), hydrological services and others.

Fig. 1. Flood damage of Nester river (July 2008)

Certainly, the microsatellites offer valuable missions with current and emerging technologies, for all fields of science and applications, for technology demonstrations and for education and training. It is important for the developing countries, such as Republic of Moldova and other countries emerging in the space technology, which can then have access to space missions, applications and spin-off technologies. Together with the reduced development times, the inherent reduction of launch costs offered by the reduced size and mass of the spacecraft and their more manageable proportions, small satellites become attractive ways to develop and establish a national expertise in space technology.

Current results of our scientific teams in the realization of the aerospatial ”Moldavian Microsatellite” programme are presented in the report.

2. General objectives of the project

Till now there were no own concerns related to the integral development of space flight devices in Republic of Moldova. However, some industrial enterprises and research teams have participated in various research and development works of aircraft units in cooperation with

various institutions of the former USSR. In some Moldavian enterprises and departments of the Technical University of Moldova certain researches have been conducted in the development of: control and manipulation of objects based on microprocessors, radio and telecommunications systems, system for processing and encoding information, which are directly related to cosmic issues or can be attached to it. The Research Laboratory of the Department of Theory of Mechanisms and Machine Bodies at the Technical University of Moldova was involved in the implementation of the present project. It carried out researches on the development of systems of orientation and control driving mechanism for the cosmic apparatus on the base of high-accuracy planetary transmissions. Within the Faculty of Power Engineering at the Technical University of Moldova there have been also carried out a series of works and research projects in the development of: systems of solar energy conversion into electrical energy, sources of static power converters, which are directly related to the use of solar energy for supplying electrical equipments on the board of artificial satellites. There were also concerns in this field at other departments of the Technical University of Moldova - "Construction and Production of Electronic equipment", Telecommunications" such as: control and manipulation of objects based on microprocessors, telecommunication systems, processing systems and information encoding, which are directly related to the cosmic issues or can be attached to it.

The project objectives are the development of micro satellite in order to analyze orbit parameters, make improvements in the satellite control, test the on-board computer (research algorithms to determinate the satellite orientation and stabilization; realization of control algorithms of the satellite system status); testing the base components of the computer; and, finally, research the technologies of Earth observation for obtaining information about the land surface of Republic of Moldova, in particular.

Certainly, the demonstration of technology is an obvious application for microsatellites, which are an attractive and low-cost means of demonstrating, verifying and evaluating new technologies or services in a realistic orbital environment and within acceptable risks. One of the main objectives of this project is also to conduct, encourage and promote the R&D space technology and industry development in Republic of Moldova.

3. Organization of the "Moldavian Microsatellite" programme

Today, in many technical universities of the world, in their elaboration and design laboratories researches on the development of microsatellites are carried out. Some universities have already successfully launched satellites on the orbit and with their help solve scientific and educational problems. For example, world leaders in the field of microsatellites are considered

universities in the USA: Utah, Stanford, Arizona, Colorado, universities in Russia, Technical University of Berlin, universities in Australia, Israel, South Korea, etc.

The programme "Exploitation of renewable energy resources in conditions of Republic of Moldova and development of the "Moldavian Microsatellite" was launched in January 2009. The Centre for aerospatial research at the Technical University of Moldova was set up. The following faculties of TUM have been involved in the programme: Radio electronics and Telecommunication; Power Engineering; Machine Building; Informatics, Microelectronics and

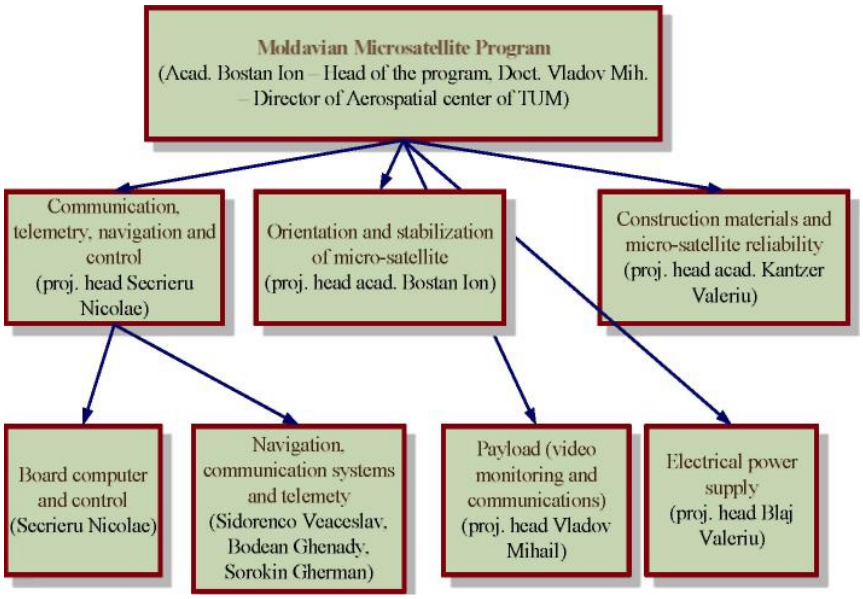

Fig. 2. Organization diagram of the "Moldavian Microsatellite" programme

Computer Science, and also the Academy of Sciences. Therefore, the project realization requires close cooperation with a number of enterprises from Republic of Moldova, the most important being "ComelPro","Topaz", etc. The organization diagram is shown in fig. 2. It includes the following projects:

- Board systems of navigation and control;
- Telemetry and telecommunications;
- Payload (video monitoring and communications);
- Electrical power supply;

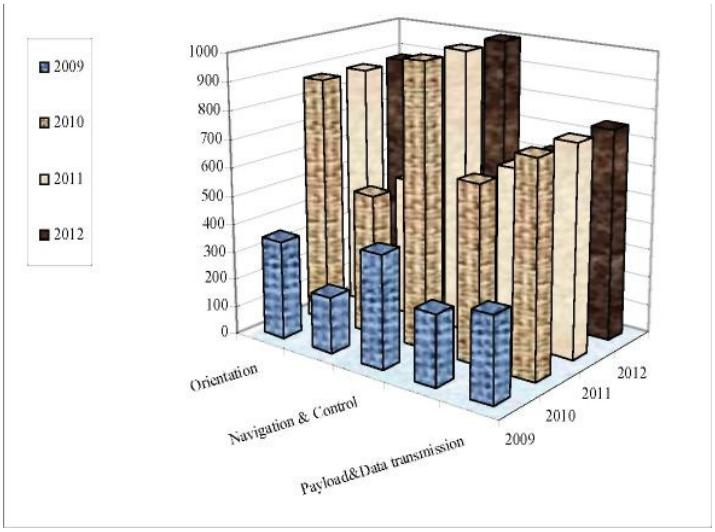

Fig. 3. Distribution of state financing for the whole programme

- Orientation and stabilization of the microsatellite;
- Construction materials and microsatellite reliability. Projects of microsatellites developing require complex and intensive research and they are

quite expensive, as a rule. Usually, such kinds of projects are financed by the state. It constitutes about 1500 thousands of MDL. This programme is planned for the period 2009 – 2012. The distribution of the state financing for the whole programme is shown in fig. 3.

4. Microsatellite control and navigation

The navigation system has the following objectives: to ensure radio communication with microsatellites in two bands of radio carrier frequencies in both directions; to control the work of a multi-spectral scanner from the orders given from the terrestrial station and from the on-board computer; navigation, on the bases of the navigation satellites GPS and GLONASS in any combination. This project is provided by a team from the Faculty of Radioelectronics and Telecommunications from TUM under the leadership of the associated professor Secrieru Nicolae.

The onboard computer was designed to control the power and the satellite's multispectral scanner, to ensure monitoring and control systems' functioning, to maintain thermal regime, to ensure measurements of telemetry system interactions, to supply with power all the systems of the microsatellite, to ensure communication with the non-oriented microsatellite or which has orientation problems.

Taking into consideration the conditions in the outer space at a considerable distance from the earth station, we have concentrated the forces to solve the following design and development problems:

- microprocessor platform of the board computer and the ground station;
- operating system of the onboard computer;
- computer software applied to the onboard computer,
- the components for schema-technical design;
- transmission/reception devices to communicate with the micro satellite;
- methods for communication with the onboard computer;
- the monitoring block and control of energy supply;
- the orbit correction control unit;
- the electronic encryption keys monitoring unit.

For the realisation of the proposed project during this year we have undertaken a number of researches and design works, as well as prototyping some units for processing and modelling the navigation and control system. The results include:

- electric principle diagram of the onboard computer, which includes basic devices;
- automatics and communication modems;
- operating programs for the microcontrollers for the onboard computer;
- electrical schemes of the emission-reception devices;
- electrical schemes of the telemetric system;
- the operating model of the satellite navigation system;
- the operating model of the command system of the satellite.

5. The electricity power supply of the microsatellite

The power supply system of the satellite is intended for the generation, storage, distribution and regulation of electricity in all phases of the satellite operation on the orbit under cyclic programs. This project is undertaken by a team from the Faculty of Power Engineering from TUM under the leadership of the associated professor Blaj Valeriy. The supply system that was designed consists of the following elements:

- Primary source of electricity, which are onboard solar batteries;
- accumulator batteries;
- controller of battery charging;
- regulation and distribution of electricity on the board. The source of the power supply unit is the solar batteries, which convert solar energy into electricity in the phases of orbit solar lighting and recharges the batteries. The power supply system ensures the necessary power consistently for all systems on the board. The energy captured from the solar batteries provides power to all on board systems in the phases with solar lighting and recharge the batteries. Solar batteries and accumulators must be able to operate both separately and simultaneously. Electricity voltages are transmitted directly to those systems and devices from the board. Other systems with high and special requirements will be powered by own converters of DC-DC type.

The analysis of other variants of satellites allows us to give priority to solar batteries GaAs or GaAs/Ge, which provide a quite high conversion efficiency of the solar energy into electricity (around 18 - 28%), batteries and accumulators can be Ni-Cd or Ni-Mn. In the previous researches there have been developed a number of systems of autonomous electric power supply based on photovoltaic panels with different power converters for anti-hail service stations and

water pumping for irrigation. It was decided to solve some technical and design problems for working conditions in the space, such as:

- selection of solar panels and accumulators;
- sub-system for loading accumulators;
- sources of individual supply;
- monitoring system of voltages and currents;
- communication sub-systems between the supply and central processor. At the base of this

project realization there are some previous theoretical and applied results already obtained:

- in the project “System of autonomous electric power supply to consumers post anti-ice using solar energy”;
- in the project “Development and implementation of small irrigation system using solar energy”;
- in the project “Electrical generators for renewable energy sources”;
- using the experience of a long-term research in the field and the scientific potential of the research teams who are concerned with the development of new systems to supply electricity from renewable sources, as well as static power converters used in adjustable electromechanical systems, automatic and controlled by microprocessors, acquisition and processing of information systems. Simultaneously, a whole series of devices developed by the Institute of Electronic

Engineering and Industrial Technologies of AS RM (IIETI) was adapted in this project in terms of digital signal processing and the experience can serve as a basis for the implementation of a number of items for the collection and processing data from spatial digital devices. Thus, technical solutions have been proposed, it was carried out the design and execution of mock demonstrational elements for stabilized voltage converter correlated with the selection of the satellite solar battery panels. There have been established the constructive ways of schema-technical operating performance in extreme conditions. They laid down the design and engineering features of the full device.

6. Microsatellite orientation and stabilization

This project is carried out by a team from the Faculty of Machine Building from TUM under the leadership of the academician Bostan Ion and professor Dulgheru Valeriu. The project envisages the design of conceptual diagram of the control, orientation and regulation mechanism based on the using of systems for attitude control (solar transducers, magnetometer) and for the

realization of orientation motions (rectangular electromagnetic coils, pitch flywheel); design of control, orientation and regulation system for satellite flying trajectory (SDOSM) based on the interaction with the magnetic field of the Earth; design, research and simulation of SDOSM parts: magnetometer, solar transducer, mechanism for rectangular orientation with three degrees of liberty correlated isochronously with the three parts of the magnetic induction vector; mechanism of operational orientation with pitch flywheel; inertial mechanism for passive operation and regulation of flight; determination of functional characteristics of SDOSM parts; modelling of orientation-regulation system functioning.

The operating mechanisms, often used in space devices so far, are harmonic and planetary transmissions. To achieve high transmission ratios of slow movements and a tendency to use high-speed electric motors planetary transmissions are embedded in several steps. This ensures the obtaining of a report of transmission up to 5500. However this significantly raises the costs and reduces system reliability in its entirety. Another class of mechanical transmissions used in the electromechanical modules are harmonic transmissions, which provide a bearing capacity and a rather high kinematical precision, which is provided by a multiplicity of high gear (in gear participate simultaneously up to 40% pairs of teeth), a high transmission (up to 350 in one step), the opportunity to operate in watertight spaces. Since the harmonic construction of the transmission includes a flexible element (deformable cog wheel) reliability is reduced and the

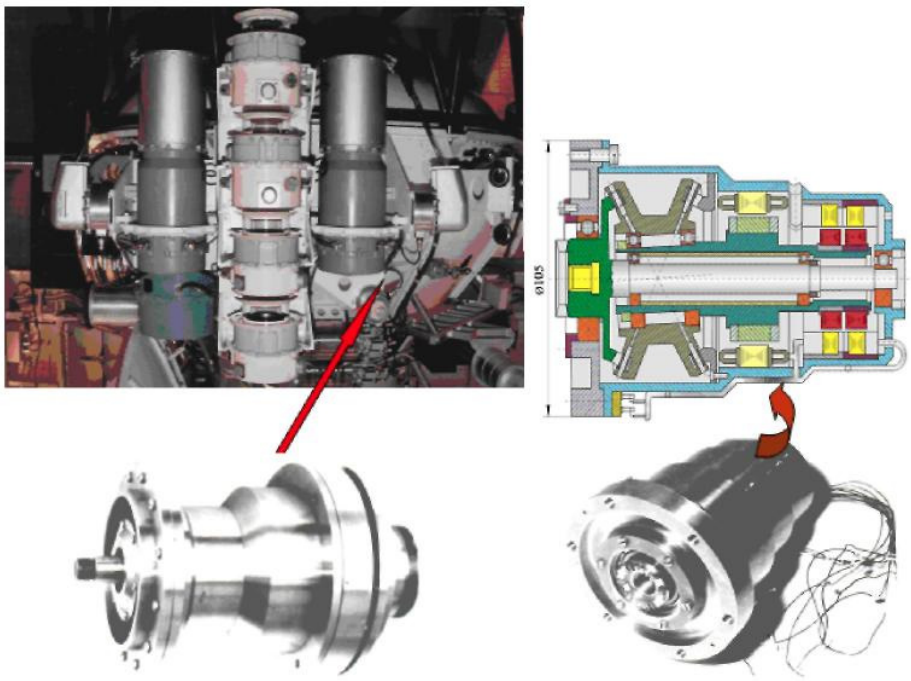

Fig. 4. The mechanism of precession action of the electronic module from the electro high precession

duration of operation is low.

A particular interest for this class of planetary transmission mechanisms presents high accuracy transmissions, developed at the “Department of Theory of Mechanisms and Machine Bodies" of the TUM. Planetary high-accuracy transmissions possess bearing capacity and high kinematical accuracy that are provided by a high gear multiplicity (within the gear there participate up to 100% pairs of teeth), a high transmission report (up to 5000 in a single step) and the possibility of operating in space watertight. Since the construction of a high accuracy transmission does not include flexible elements it has high reliability and high operating duration.

The research team of the department of “Theory of Mechanisms and Machine Bodies" from the Technical University of Moldova, involved in the implementation of this project, has experience of various researches on developing separate systems of driving mechanisms for the orientation and management of devices based on cosmic planetary transmissions of high-precession such as:

- the driving mechanism for space flight device made at the order of the Special Design Bureau of the Institute of Cosmic Research of the former USSR, Moscow;
- the precessional driving mechanism of the electro high-accuracy VEGA-6 space station electronic module made at the order of "COMET" (Moscow);
- the driving mechanism of the space flight device developed at the order of a company from Krasnoyarsk, Russia.

These proposed electromechanical modules present special constructions with high-accuracy planetary transmission and with the formation of special transducers for precise positioning of the space flight apparatus or of the basic units. To reduce production costs and weight, and increase the efficient operation under insufficient lubrication, the authors have developed two modules with electromechanical high-accuracy gears and sliding bearings made of plastic. These modules have electromechanical constructive simplicity, satisfactory performance compared with the planetary transmission and harmonic dimensions, low weight and a low production cost.

7. Earth observations, video monitoring and telecommunications

Remote Earth observations from satellites and distribution of the remote-sensing data should help to solve very important problems, for instance, to slow the depletion of natural resources. Therefore, this project is the central project of aerospatial “Moldavian Microsatellite” programme. This project is provided under the supervision of Vladov Mihail, director of the

Centre for Space Research of the Technical University of Moldova and director of "ComelPro" enterprise.

The system of video monitoring and telecommunications of microsatellite was developed to ensure exploring Earth remote area. It was decided that the system must be endowed with multi-spectral scanner, which allows research of the land surfaces in the visible and infrared ranges. The system of video monitoring and telecommunications should provide a telemetric control of the satellite, a telemetry transmission of information to the Terrestrial Command Item and data acquisition. It is proposed to develop the radio communication with satellite in two directions on two-range radio carrier frequencies, for instance, of 400 MHz (L - range) and 2257 MHz - (S - range). The system of video monitoring and telecommunications should ensure continuous operation on the orbit for at least some years in the vacuum, radiation and high temperature. During the work on the orbit, the system will suffer from mechanical overloading, vibration and impact blows. Most components of the system have been designed and the assembling procedure will come in the near future.

Certainly, remote sensing with portable ground stations and low-cost space systems has an important role. A key feature of the space system is direct down-linking to numerous small ground stations, excluding the need for a centralized processing and distribution system. The advantages are real-time access to observations, smaller databases and ease of information distribution, even in areas not well served by communications systems. This point of view is included in the designing of this system.

8. Construction materials and microsatellite reliability

The project „Development of materials, structures (including nanotechnologies) and electronic devices for operation in extreme cosmic conditions" is provided under the leadership of academician Kantzer Valery, Institute of Electronic Engineering and Industrial Technologies (IIETI) of AS RM. The major objective of this project is:

- Research and development of new materials and elements of spatial devices and terrestrial station building blocks of MS;
- Design and implementation of verification stands in extreme elements apparatus MS;
- Development and adaptation of developing materials and devices of IIETI, previously performed for other uses, for spatial devices, connected to technical requirements and operating in extreme cosmic conditions.

This project aims at developing many aspects. First, there are a series of works previously performed in IIETI, including some related to missile equipment and cosmic technology. It can be also mentioned the important aspect of a profile of the institute, concerning the investigations

of materials properties at cryogenic and ultra low temperatures. Another aspect is part of the wide range of IIETI concerns in electronic devices and sensors, including the collection and processing of digital information.

Fig. 5 High level pressure sensors.

Among some elaborations made during the years at IIETI and issues pertaining to the project it is necessary to mention the design and development of:

- structures of thermoelectric pyrometry measuring thermal radiation;
- microsystems for thermoelectric refrigeration;
- instruments and control systems and vacuum-metric measure of ultra-high vacuum;
- sensitive elements and detection systems for infra-low frequency mechanical waves for security and surveillance systems;
- structures and developing tenzoresistive pressure and temperature Polyfunctional transducers with a wide range of temperatures and pressures;
- implementation of spatial microsensors;
- instruments and apparatus for rapid process control;
- implementation of control systems;
- solid lasers in the near infrared;
- laser telemetry;
- mass spectrometry;
- autonomous sources of energy, stabilizers, etc.. for use in energy, including solar cells;
- implementation of transducer for monitoring of plants and environment.

Fig.6. Vacuum parameter control device

Fig. 7. Vacuum parameter measurement device.

The images of sensors and measuring devices of high pressure and vacuum are shown in the fig. 5-7. The developed device - a vacuum quantity surveyor presents a measuring complex in which we enter a block of three converters and digital measurement. Converters, the operating principle

of which is based on pressure dependence of elastic membrane strain of air thermo-conductivity are designed to convert air pressure into electrical signals.

Among the recent elaborations may be mentioned the creation of the testing laboratory of the active component of anti-hail missiles with the equipment that simulates the conditions in the atmosphere. Some illustrations of this laboratory

aerodynamic tube are shown in fig. 8.

Fig. 8. The aerodynamic (fragment) tube
with data acquisition system.

Recently it was proposed a new system in infrared remote sensing and field TeraHertz. The way in which the system finds its application in the multispectral scanner of the satellite apparatus is illustrated in fig. 9.

Thus the basis of the performed work can be used for the spatial device of Moldavian Satellite programme:

- Vacuum metrics control systems and measuring ultra-high vacuum;
- Wide-range pressure and temperature Polyfunctional transducers;
- Thermoelectric refrigeration Microsystems;
- Far infrared array detectors.

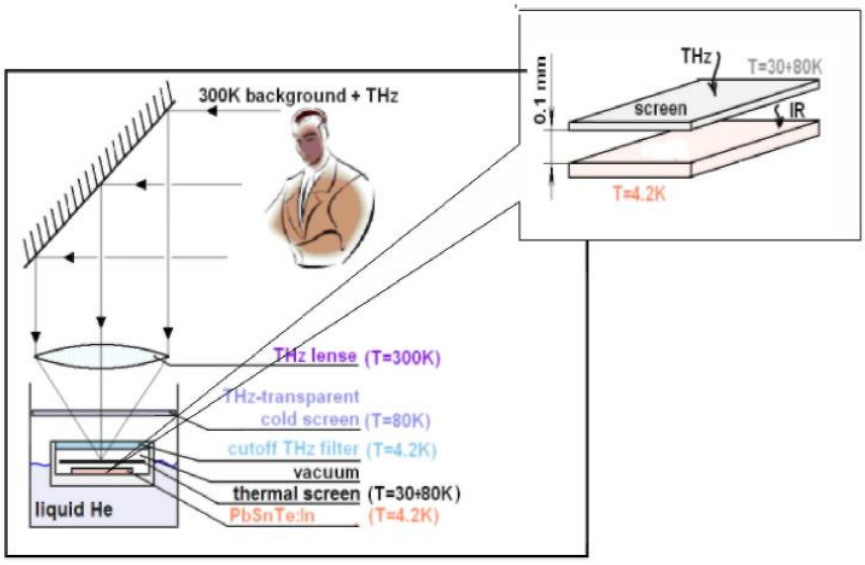

Fig. 9. Scanning and detection in the far infrared spectrum with TeraHertz frequency

9. Arguments for carrying out investigations in the programme

The presented programme will contribute to the development of youth and renewal of student scientific and industrial potential of the Republic of Moldova; it will create a connection between students and laboratories for the production and industrial domains; attract young inventors; create new jobs; preserve the intellectual potential of the country; develop scientific and technical directions of the national economy in the Republic of Moldova; contribute to the professional orientation of pre-university graduates.

Besides the educational, scientific and technical problems this programme will allow to resolve a number of concrete problems of the national economy of the Republic of Moldova: to realize the territory monitoring in order to measure soil moisture; to estimate cultivated agricultural land; to monitor and evaluate the degree of the crop maturation; to perform various cadastral works; to monitor roads; to monitor forests, rivers and lakes; to determine the extent of the river's overflow, to set the danger of ice clouds appearance; to obtain photo and video information for the country districts of interest, etc.

10. The scientific results, forms of implementation and the beneficiaries

The scientific, technical and instructive potential of the country and its world authority is determined by the possibility of realization of advanced technology and science-intensive projects. That is why the realization of a complex project, such as the launching of a space craft with a command and on-board navigation system and the land control system, will help to increase the authority of Republic of Moldova on the international arena. The economic aspects of realizing such a complex project is very difficult to estimate. Monitoring the territory of Republic of Moldova will permit in the future to:

- obtain images with high-accuracy that will provide cadastral works;
- receive information about the cultivated agricultural lands (land area treated, and the degree of ripening of agricultural production, the quantity of harvest, setting the level of soil humidity);
- conduct environmental monitoring of regions;
- monitor movements and transports of goods on the territory of the republic;
- oversee the processes of formation of clouds with the threat of hail and security services against hail.

At present the cost of providing these types of services on the world market arrives at values of up to several thousands of USD. This instructive-educational project will help develop

professional customs for students; will ensure continuous contact between science and the manufacturing industrial domains; it will also increase the interest of youth creativity and will allow creating new jobs, preserve the country's intellectual potential and will be based on new scientific and technical fields in Moldavian agriculture. It will contribute to the guidance of graduates of pre-university educational institutions.

11. International cooperation in the framework of aerospace problems

At the current realization phase of the programme and its subsequent development is provided the establishment of cooperation relations with several universities in the EU, Germany, Romania, the Ukraine and Russia etc., where similar projects have been performed.

Actually, there is the following cooperation in the framework of this programme. The active participation of our collaborators in the regional and international conferences, meeting is one of priority activities. Recently, our delegation: academician Ion Bostan, professors Dulgheru Valeriu, Secrieru Nicolae and Bostan Viorel participated in the CRAS 2009 conference in Bucharest, Romania. Besides this conference's works, we had several meetings with other delegations. For instance, Academician Ion Bostan, Head of the Moldavian aerospatial programme has discussed with Chris de Cooker, Head of the ESA International Relations Department about future cooperation and involving in the ESA aerospatial programs. Academician Ion Bostan and Marius-Ioan Piso, director of ROSA – Romanian Space Agency and University "Polytehnica" of Bucharest have discussed about an agreement of bilateral cooperation and promoting international relations in the field of high technologies. The main areas of cooperation include the development of small satellites and ground control systems of satellites.

Fig. 22. The session of CRAS 2009 conference.

It was established that we have the similar needs at regional level that demand some new solutions. For instance, we are ready to coordinate the satellite

programs to address our specific needs and other developing areas that require special capabilities related to sensor parameters, such as specific spectral bands, spatial resolution, time resolution, cost of image, autonomy and investment level in ground equipment, and the expertise required for their utilization. Another field of cooperation will be the exchange of experience in image data collection and processing for monitoring of flood damages in our region and for the agricultural applications.

Our representative, Secrieru Nicolae, Head of the project "Board systems of navigation, control, telemetry and telecommunications" made a report about Moldavian aerospatial program at the symposium "Wissenschaftliches Kommunikations und Sicherheittskolloqium 2009" at University of Siegen, Germany. To improve our experience in telecommunications, these problems have been discussed with Professor Doctor Karl Cristoph Ruland, Head of Institute for data communications systems from the University of Siegen (Germany). It was decided to cooperate on the common theme „Orientation and stabilization methods on capturing images from long distances associated with real time coding, compression, protection and transmission". This theme is rather actual, because an important role in telecommunications and data processing is played by application of research/monitoring methods on captured images, but the high cost of images from space does not allow all users to benefit from these results to explore the land surface in agriculture, geodesy and cadastre, ecology and environmental monitoring. Good image quality can be achieved with objective lens with a big focal distance and with a high-resolution, which are installed on large aircrafts (satellites, orbital stations, aircrafts), but afterwards the cost of these images increases. Another situation is the case of small aircrafts on which high-quality objective lens can not be installed. This, however, lowers the quality of images if the problem would be treated traditionally. Important factors affecting the quality of images are not only lens parameters, but the dynamics of aircraft movement, lack of stability, object orientation, that results in essential distortion of captured images. Often, to get a result it is required to repeat the operations, which is not always possible.

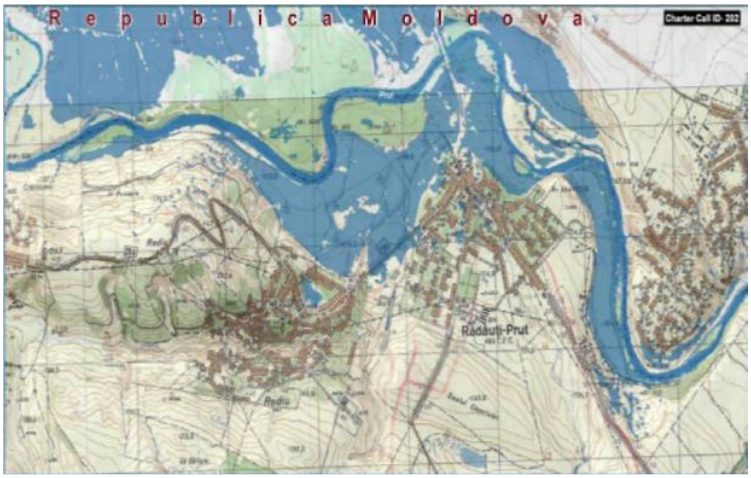

Fig. 4. Flood damage of Prut river (July 2008)*

* TerraSAR-X/topo image, http://Romanian Space Agency (ROSA).mht

It is proposed to solve complexly the problem of capturing images using light aircrafts, applying new technologies, methods and processes of orientation and stabilization of the aircraft, simultaneously capturing images, and compressing, codifying and transmitting data in real time to the recipient. This will increase the quality and will reduce the total cost of images. As a result, images will be obtained without distortion, with a much smaller volume, coded in order to protect them and sent to recipients.

Another representative of our team, Vladov Mihail, director of the Centre for Space Research of the Technical University of Moldova, Head of the project "Earth observations, video monitoring and communications", participated with a report at the conference "Scientific and technical centre of spatial missiles" in Samara, Russia, concluded an agreement of cooperation. The protocol of intention on scientific and educational cooperation in the field of aerospace activities between Samara State University and the Technical University of Moldova includes:

1. Implementation of joint research and development work in the aerospace field.
2. Participation in the development and implementation of joint projects in the field of scientific-educational small satellite, including remote sensing of the earth.
3. Contribution of inter-university exchange students and university teachers to integrate into the international educational space.
4. Joint participation in organizing and conducting conferences and seminars on topics of interest to both parties.

Also, there is an agreement between our Centre for Space Research of the Technical University of Moldova and the Institute for Space Research, Bulgarian Academy of Sciences concerning bilateral cooperation and promoting of international relations in the field of high technologies. The main areas of cooperation include the development of small satellites and ground control systems of satellites.

Conclusion

Although the program "Moldavian Satellite" is at an early stage, a number of promising results have been obtained for the successful implementation of this programme. We hope that this instructive-educational programme will help develop professional skills of the students; will ensure continuous contact between science and the manufacturing industrial domains; it will also increase the interest of youth creativity and will allow creating new jobs, preserve the country's intellectual potential and will constitute a basis for new scientific and technical fields.