Examples for reusability of concepts and development results
from project to project

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ABSTRACT

The Hungarian research institute, KFKI Research Institute for Particle and Nuclear Physics (KFKI RMKI) is a permanent participant of international space research mission in the last three decades. The most memorable missions the research group of the institute participated in were the VEGA, Phobos, SPECTR-X-GAMMA, Cassini and the Rosetta.

During the years, the research group accumulated a lot of experience appreciated by the international science community in the field of designing, manufacturing and testing on-board electronic devices for spacecrafts, on-board computers, data acquisition systems and their ground support equipment.

As a result of the accumulated experience, KFKI RMKI now is participating in the Obstanovka project and in the BepiColombo mission. For which KFKI RMKI is developing the hardware and the software of the on-board data acquisition system for the Obstanovka project and the electric ground support equipment (EGSE) of the Planetary Ion Camera (PICAM) experiment to be mounted on the Mercury Planetary Orbiter (MPO) of the BepiColombo mission.

Concerning to the space missions, the development phase is long and the development itself is a costly and resource hungry activity. Thus, it has key importance to find a way to decrease expenses appearing during the development phase. But whatever method is applied, it must not decrease reliability of devices resulted by the development process.

One of the most premising ways allowing us to reach the goals is increasing reusability is of the methods and the components have already been applied in the earlier project.

The presentation tends to describes the questions of the development process of a small sized embedded real time Linux system configuration which was applied with success in devices of EGSE prepared for the Aspera experiment of the Venus Express, and planned also to be applied in the on board data acquisition system of the Obstanovka and in the EGSE of the PICAM experiment of the BepiColombo mission.

The research and development group accumulated its knowledge with a day-by-day work during its more than quarter century long existence. At the very early times, knowledge capturing and documentation process was based on paper. However it was

dramatically changed at the beginning of decade of nineteenth, when the extremely rapid expansion of usage of personal computers was started in Hungary. Up to that time even the research institutes and universities had problems to obtain good quality computers applicable for research and design.

Nowadays external sources of scientific and technical information can be reached using the Internet, and the communication between the members of the research group is done on the intranet of the Institute. The internal websites give option to share the information between the members of our group and also with our cooperative partners abroad.

With the help of the Hungarian Ministry of Informatics and Communications and the Hungarian Academy of Sciences, KFKI RMKI started a research and development project in 2003 with the aim of studying the knowledge management methods of long duration space research projects and to develop an information system providing a base for saving and use the knowledge gathered. Now the system is operable and will be extended with the number of documents created during the projects of the last three decades. All the information can be searched and accessed fast.

However, key problems are still remained. Recognizing reusability of knowledge gathered during the projects of the past still based on human intelligence, in other words, on the experience of our colleagues, and their capacity to identify the common requirements and the eventual useful common solutions applied in the past and applicable in the future.

Background information

In order to make problems, research targets and results more understandable, it seems to be useful to provide some background information.

From the end of the Second World War till the end of 1980’s, Hungary belonged to the Soviet Union’s zone of interest. At the end of 1980’s as the result of social and economic changes in the countries of the so-called Eastern Block, the communist power crashed in Hungary. During the last two decades, as the result of a series of permanent changes, the country established stable political democracy and market economy. This was crowned by entering the European Union on May 1, 2004.

And now, several statistical data: the country’s population is about 10 million and, according to the Hungarian Central Statistical Office the GDP per capita was 6782 € in 2002 which is 53 % of the average value in the European Union. Concerning all the sciences, the share of expenses spent on R+D was 0,94 % of the GDP in the last two years.

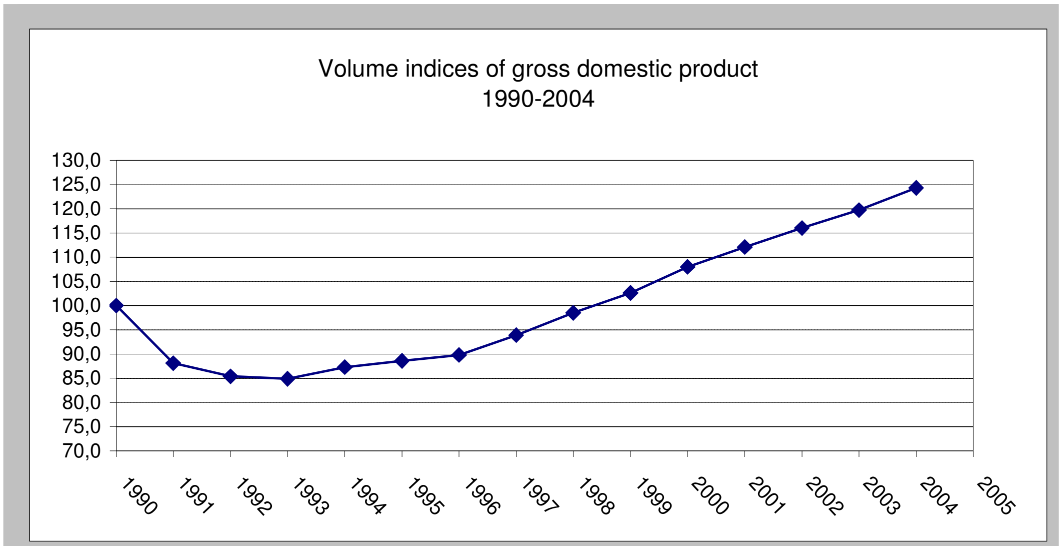


Figure 1

As shown [**Figure 1**], the Hungarian GDP fell about 15% in the first two years after 1990 and stayed at 85 ~ 90% of the 1990 base till 1994. The first signs of strengthening the economy were shown in 1994. The growing of economy was only 2,4% in 1994 and 1,2 ~ 1,3% in the next two years. Then the rate of growing increased up to 4 ~ 5% between 1996 and 2004.

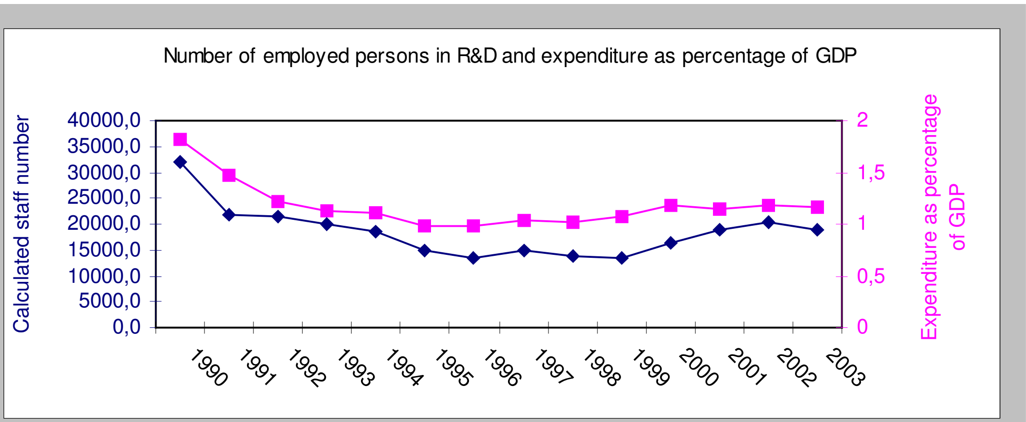


Figure 2

The [**Figure 2**] indicates that in accordance with the behavior of the GDP, the resources spent for research and development and also the number of researchers fell down as well.

It is worth to note that while the deep fly of the GDP immediately resulted in the decrease of resources and staff number (in Hungary, 1990-92 was the period of reorganization and downsizing of research institutes), but the increase of the GDP was followed by these parameters only with some delay and minor values. This was the result of a change in the structure of economy and also in the degree of importance of R&D in the economic policy.

The question is obvious: why are these facts interesting from the point of view of a KM?

In such a strong economic shock that struck Hungary in the first half of the years 1990, research groups, institutes and university cathedras were deceasing. There were researchers who stayed at their institutes, some others went abroad into countries with more stable economy, and there were some who went to work in the developing industry.

The diagram [Figure 2] shows that the decrease of number of staff continued even in the starting phase of 1994 and the strengthening phase of 1996 of the GDP growing. The experience and the knowledge of researchers changing their working place were not immediately lost at the level of the whole society but the economic exploitation of this knowledge took another direction. The leave of researchers for another working place means immediate loss for a research project and this risk should be calculated with as a natural factor.

The situation of space research in Hungary

The total Hungarian space budget is about two million euros. The country's space research activities are co-coordinated by a governmental organization, in English it called as the Hungarian Space Office (HSO).

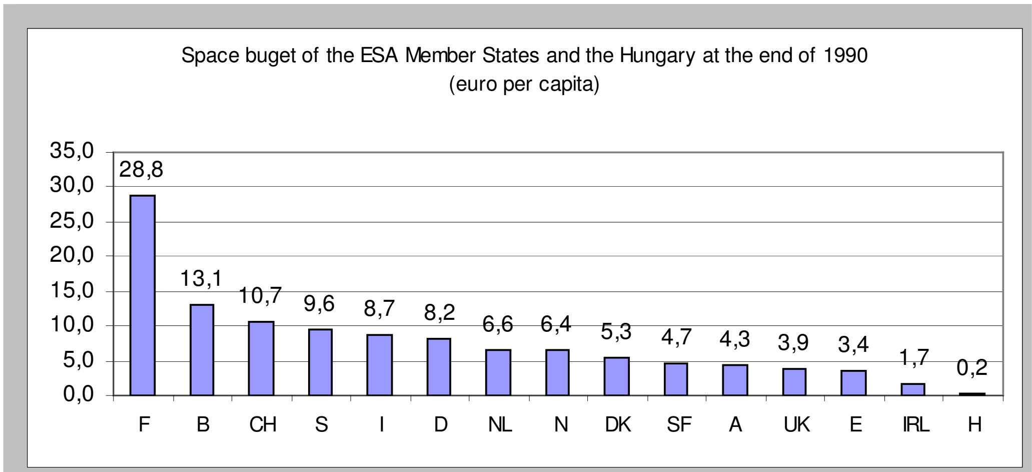


Figure 3

According to HSO's latest reports, research is conducted today in about 25 scientific institutes, the number of space researchers is about 300 and so the average group size is about 10.

[**Figure 3**] displays here the Space budget of the ESA Member States and the Hungary at the end of 1990. It clarifies clearly the country's power in space research.

However space related expenses are not too high, the space research itself is quite popular in Hungary. There are country wide well-known societies, as Hungarian

Aeronautical Society and Hungarian Chapter of the Mars Society who are working on to deepen this popularity; and the latest news related width space research are presented to the grand public by the high quality on-line newspaper called Űrvilág, accessible on the net at www.urvilag.hu.

Research Institute for Particle and Nuclear Physics

KFKI Research Institute for Particle and Nuclear Physics (KFKI RMKI) that is research institute of the Hungarian Academy of Sciences was a permanent participant of international space research mission in the last three decades. But, space research is only one of the fields of activities of the institute. The main areas are Experimental Particle Physics, Theoretical Physics, Nuclear Physics, Space Physics, Plasma Physics and Biophysics.

The contribution to the space missions was started at the beginning of the decade of eighties. Major projects of the past were VEGA, Phobos, Mars'96, Rover, SPECTR-X GAMMA, Cassini, Rosetta, and Venus Express. The currently running one is Obstanovka and there is a tentative to participate in BepiColombo.

The reputation archived by the institute in the international science community with its high quality contribution and its high quality devices becomes extremely important at the current situation as Hungary expressed its intention to join to European space Agency.

Acquired competences

KFKI RMKI's contribution to these projects might be mentioned in later sections, but at this point, it is the time to express that the first experiences in a successful space project, which was the Vega Mission to Comet Halley, determined the evolution path for KFKI RMKI's in space research for the future.

During the projects, the research group accumulated a lot of experience in the field of designing, manufacturing and testing on-board electronic devices for spacecrafts, on-board computers, data acquisition systems and their ground support equipment. Culture of development and co-operation was created and preserved in spite of the difficulties of nineties.

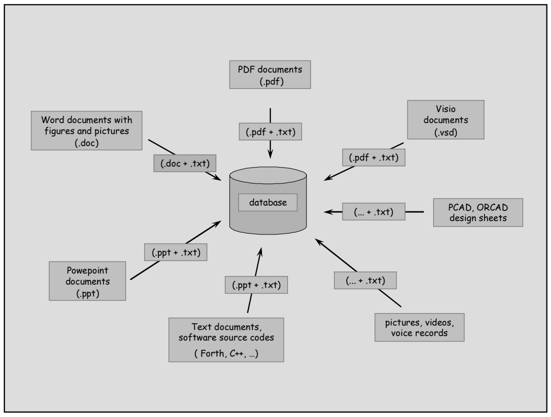
KFKI RMKI became specialist for fault-tolerant on-board computers and also for electrical ground support equipments, both in design and in manufacturing level. High reliability equipment needs high reliability software. The related software usually also was prepared by the specialists of the institute.

What competences were acquired? Personal skills: language and negotiation skills; knowing of importance of planning and budgeting; capacity for continuous knowledge extension and preservation; capabilities for research, design, development, and verification, as this work expects speaking foreigner languages at discussion level, and also reading and creating documents, standards, reports and protocols.

There are also other types of skills. These are the skills appearing at corporate level.

Such a corporate level skill are the capacity for executing thermo-vacuum, and vibration tests, manufacturing mechanical components for the devices, like metal boxes and consoles. These corporate level skills need acquisition and application expensive equipments.

Knowledge preservation tentatives



During the years the staff changed, the capacities evolved. Most of the peoples who participated in the first projects left the institute. Some of them went for ever. Younger ones went for working abroad or for the business, and older ones are retired. From the nineties up to now, business presented and presents a significant attractive force for the highly qualified peoples.

When the staff evolved, knowledge transfer was based partly on documents previously were written, but major role was played in this process by the option transferring the knowledge throw personal contact during the work.

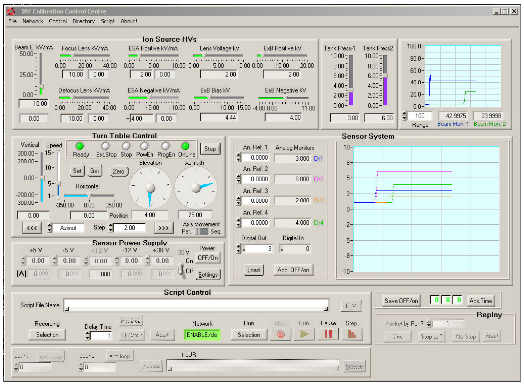
Long duration space projects often expect knowledge preservation and transfer without personal interaction, as there is no option to meet the original source of the knowledge. In these cases documents play major role, and knowledge has to be reconstructed from documents. After recognizing this, a database was set up for the documents created by the team members during development phase of the Rosetta Mission. These documents were indexed and became searchable. Later this database will be expanded with the documents of future projects.

Evolution of capabilities

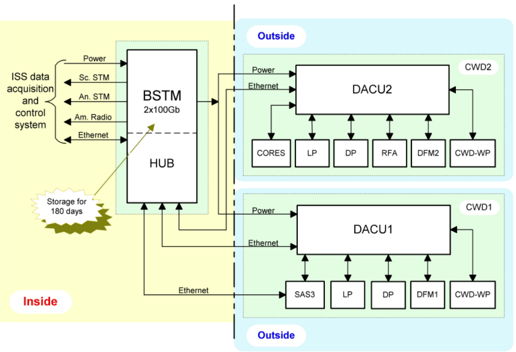
Technical skills could become obsolete very fast; this is the case especially in electronics and computer science.

In KFKI RMKI, at the time of participation in its first space projects, the electronic design was based on components and integrated circuits. Circuit and mechanical design was made by hand on paper sheet. Documentation was not created electronically, but on paper. Then the world changed. Nowadays data acquisition devices and EGSEs are often built up from card level. Design documents are created electronically. Each of the researchers has its PC. PCs are connected to 100Mbit local area network and to the Internet. Machines are furnished with the appropriate software tools. Mechanical and electronic design is done using these tools. Information is shared via the network, and could be searched on the Internet.

Software design and development is also computer aided, now. The formerly once so much characteristic assembly development was changed to higher-level languages; character consoles to graphics user interfaces. Complexity is rapidly growing. It requires application complex development tools, high-level library components, and complete verified solutions; otherwise the development tasks cannot be fulfilled in time.



Recently, a standard widely spread real-time multitasking operation system was applied in the last two projects. A small sized embedded real time Linux system configuration was applied with success in devices of EGSE prepared for the Aspera experiment of the Venus Express. This system is planned to be applied in the on board data acquisition system of the Obstanovka and in the EGSE of the PICAM experiment of the BepiColombo mission.



Applying a free and reliable software component, useable under GNU or similar licenses, gives option to decrease the cost and the time of a development project. Concerning to the space missions, the development phase is long and the development itself is a costly and resource hungry activity. Thus, it has key importance to find a way to decrease expenses appearing during the development phase. But whatever method is applied, it must not decrease reliability of devices resulted by the development process.

One of the most premising ways allowing us to reach the goals is increasing reusability is of methods and library components have already been applied in the earlier project.
In space research related software development KFKI RMKI assured its capacities. The applied standard and the followed methods allow positioning the development activity at least to the second level of CMM model, successes are repeatable. Processes are co-coordinated by disciplines. Elements of project management are applied to track cost and schedule. There are predefined quality requirements in each project. Configuration management tools are applied. The quality based on defined processes and assured by test procedures and operation.

Common solutions in the latest projects

KFKI RMKI latest contributions to the space research are the calibration system for Aspera 4 experiment of the Venus Express Mission and the data acquisition system of the Obstanovka experiment. These systems were realized with application of similar solutions, based on competences recently acquired by the development group.

Common points:

- Standard purchasable processor and compatible add-ons cards were applied
- The same operating systems were embedded in both systems
- Embedded application programs were created based on same technology
- Communication between the computers of the systems were realized using TCP/IP protocol over the Ethernet connection
- Embedded systems mounted into similar standard boxes
- Graphical user interfaces were created using the same technology

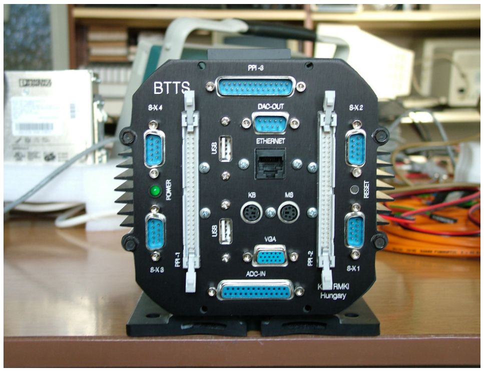
Differences:

- Unique interface cards and standalone boxed devices were manufactured to fulfill special requirements.
- Unique embedded application software had to be created for each of the embedded devices
- Unique graphical user interfaces were implemented

These common solutions allowed running the two development processes parallel without using extra human resources. Problems related with the areas being in intersection of these projects should have been solved only once and the solutions could have been applied in the other project without delay.

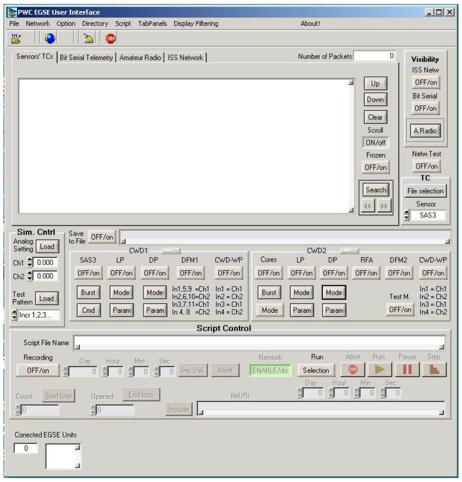
Following figures indicate the similarity of the components of systems. Devices have similar shape. Same standard cards are applied in them, too.

BSTM, DACU1 and DACU2 of Obstanovka

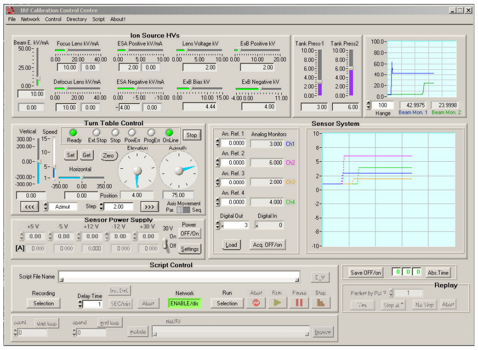


BTTS of Aspera calibration system

User interfaces built up using same development tool and the same graphical library.



User interface of Obstanovka EGSE



User interface of Aspera calibration system

Future

When an opportunity appears to participate in a mission, it always reinitiates the work. We expect continuing our contribution to the currently running and to the future missions and hope that Hungarian experts will be available for the future missions as citizens of an ESA member country.

The next challenge is for us the designing and the manufacturing the electric ground support equipment (EGSE) of the Planetary Ion Camera (PICAM) experiment to be mounted on the Mercury Planetary Orbiter (MPO) of the BepiColombo mission.

We expect to keep the same quality of work and results in the future that have already been reached in the past.

KFKI RMKI's contribution to space projects - Overview

Vega Mission to Comet Halley

The Vega mission comprised two identical spacecraft, Vega-1 and Vega-2. The name of the mission VEGA is formed from the Russian words Venera (Venus) and Gallei (Halley). The mission was headed by the USSR with a number of other countries within the framework of Intercosmos. Each Vega spacecraft comprised a Halley flyby probe and a Venus descent module.

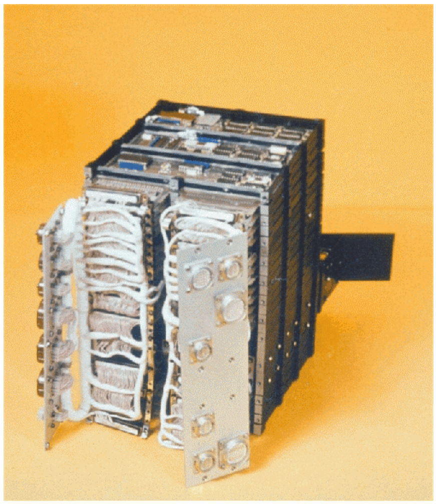
The two spacecraft were launched by Proton rockets from the Baikonur cosmodrome on 15 and 21 December 1984, respectively. On 11 and 15 June 1985, the two spacecraft successfully delivered the balloons into the Venusian atmosphere. After Venus gravity assist flyby the two spacecrafts encountered comet Halley on 6 and 9 March 1986, respectively.

The Vega spacecraft weighted about 4.5 t at launch, it was three-axis stabilized with a wingspan. It carried 14 experiments, among them a TV system (TVS) for tracking and imaging the inner coma and the comet nucleus.

Imaging the comet during the flyby at relative velocity close to 80 km/s from a three-axis stabilized spacecraft required a steerable platform. This platform had a mass of 82 kg and carried 64 kg of payload. The telemetry system consisted of a high-data-rate channel of 65 536 b/s and a low-data-rate channel of 3 072 b/s. The high-data-rate channel was used for real-time scientific data transmission only, while the housekeeping data were transmitted via low-data-rate channel. Scientific data could also be stored on-board on a magnetic tape recorder with 5 Mbit capacities and subsequently transferred to the telemetry.

Contribution to the Vega mission

Imaging Television System (TVS) for the Vega spacecraft



The TVS of the Vega 1 and Vega 2 observed the comet Halley in 1986. It was placed on a pointing platform, and consisted of a narrow-angle camera, a wide-angle camera, and a digital processor unit (DPU). The DPU had two computers. One of them controlled the imaging, maintained communication with the Earth (download information and process the uplink commands). The task of the second computer was to recognize the comet and to track it by controlling the platform motion. This was the first time in the history of space research that real-time autonomous control was realized through onboard picture processing. The most sensitive and critical components of both computers (memory, clock generator) had warm redundancy. In addition, the DPU contained back-up systems for the tracking and for the communication functions.

They were designed on different technological bases for the same function, so that any systematic error in the design or manufacture could affect only the subsystem in question, but not the functionality of the whole system.

Optical parts of the TVS were built partly by French and partly by Russian scientist. The TVS transmitted 1500 images to the Earth, the nucleus of Halley's Comet was observed for the first time in history. Its shape, surface features and activity mechanism were derived. Cometary nuclei are considered to belong to the oldest, most primitive population of solar system bodies, thus their investigation contributes to understanding the formation of the solar system.

TÜNDE instrument

The TÜNDE energetic particle experiment was designed and built by KFKI RMKI. The instrument measured the ions from Halley Comet, to determinate their energy distribution between 20 keV and 650 keV. Additionally it performed continuous measurements of the cosmic ray radiation of the Sun between 3 MeV and 13 MeV of charged particles.

Phobos mission

In 1988 two space probes (Phobos-1 and Phobos-2) were launched towards Mars planet. As a planetary mission, the Phobos Soviet space probe is devoted to studying the planet Mars and its vicinity, along with its natural satellite Phobos that gave the expedition its name, but also the Sun and the interplanetary environment. At the time of the Phobos encounter, should separate a small lander.

Contribution to the Phobos mission

Phobos Lander Central Data Acquisition and Control System (CDACS)

The CDACS was planned to control all of the small spacecraft (lander) scientific experiments and the service system. The system has a fault tolerant architecture: a single error does not cause degradation in operation, in the case of multiple errors some degradation could arise, certain experiments would be ended but the functionality of the lander would be kept on. The central processor unit contains two 8-bit microprocessors, the three independent memory data flows are united in the majority logic. The circuit works even if one of the memories is not functional, on the other hand the majority logic circuits can be switched over to multiplexers by commands and data can be read from the selected memory unit. Another protection method is the using of two alternately write protected areas in the memory, in which the basic system status information is saved periodically. This protected system information can be used in case of failure, when the processor overswitch happens. In this system the clock unit is four times active (warm) reserved, and the other units of the system (interfaces) have passive (cold) redundancy.

The lander was due to soft touch down on the surface of Phobos but unfortunately the carrying spacecraft itself failed just before the initiation of landing.

Phobos ESTER plasmaphysical experiment

In the ESTER Charged Particle Complex three slightly different experiments were grouped together, simultaneous data processing and operation mode control for all three experiments were carried out by a specialized 8-bit onboard computer (so-called DPU-B).

Due to safety, weight and power restrictions, it had a simple, basic structure, pursuing reliability through massive engineering overhead rather than extensive redundancy. Still, redundant solutions were applied at all the sensitive points: triple redundant system clock, system ROM and RAM (controlled by majority logic) and switchable three mass memory banks for scientific data. Hardware watchdog helped to supervise software deviations, and a battery operated RAM containing basic operation mode data eliminated the need for uplinking long, time consuming commands in case of re-initialization during flight. The DPU communicated with the scientific experiments through galvanically isolated serial lines (optocoupled), thus allowing for switching off the experiments independently in case of a fatal error.

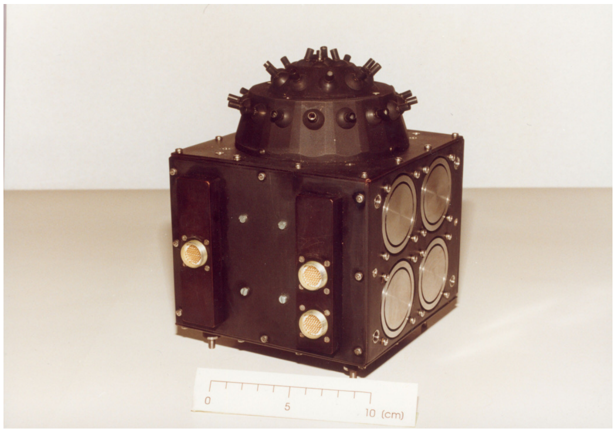
The data obtained have provided many important scientific results: new regions of the magnetosphere have been discovered in the environment of Mars and an intensive ion-outflow of planetary origin in the tailward direction was detected. Evidence for turbulence and heating and small- structure was seen in the planet’s heath. Perhaps the most important results are related to the tail region, were a strong outflow of planetary ions and hot component of the electrons was detected. No previous Mars probe with such good plasma physical and magnetic field instrumentation penetrated the shadow cone of Mars before. The comparison of these results with those obtained by NASA's Pioneer Venus Orbiter enabled us to reveal simulates and differences between the magnetosphere of Mars and Venus.

Mars-96 Mission

The Mars-96 space probe was planed to be launched at 16 November 1996 for studying the environment and the surface of Mars. Due to our field of interest we were particularly interested in examining interaction between the planet and solar wind. The Mars-96 launch was unsuccessful. Spacecraft fell down to Pacific Ocean after a few hours.

We had been participating in completing three different experiments, which could be realized with relatively low financial effort using our wide experience in this field we gained before. The first equipment (MAREMF) studies the distribution of electrons around Mars, the magnetic field of Mars and the interaction between electrons and magnetic field. The MARIPROB experiment will be examining the parameters of ionosphere of the planet, while the third experiment (SLED-2) the high energy particles of the environment of Mars.

Contribution to the Mars-96 Mission



In case of the MAREMF and MARIPROB experiments our task is the development and manufacture of the Electrical Ground Support Equipment (EGSE). The EGSE provides checking of the given scientific equipment during Autonomous, System (integration) and Complex Tests and gives the possibility of a quick look at the data during tests or flight. Due to this, the EGSE remains in function continuously after launch, to provide quick process of scientific or housekeeping data during flight.

The EGSE has the following main functions:

1. Simulation of the onboard signals of the Mars 96 Space Probe (The Morion-S system, that is, ControlCommandWords, Onboard Time, Telemetry Signals and Power Lines)
2. Coding and archiving of acquired data
3. Evaluating of the experiment functionality based on the acquired data
4. Process and visualization of the scientific data

The tasks listed above need certain computing capability, so the core of the system is a general purpose computer, extended by the necessary special-purpose interface units. For low-budget reasons this system core is an IBM PC or compatible, and it is extended by the following interface units to form an EGSE:

1. Control Command Word (CCW) simulator
2. OnBoard Time code simulator
3. Digital Telemetry simulator
4. Analog Telemetry simulator
5. On/Off Switch Relay Command simulator
6. Power System Simulator
7. Data-Distribution interface

The operating software is based on a custom-designed real-time quasi-multitask Operation System written in Turbo Pascal. In this system Tasks are serviced in three levels:

1. The most frequent event is data acquisition through Direct Memory Access - this method consumes the least processor time
2. Real Time system control&timing and asynchronous service of Operator commands through Interrupts, which method causes the least slip in service time
3. Data processing and displaying runs in the background.

For the two experiments (MAREMF and MARIPROB) altogether four fully implemented EGSE systems are needed, these are basically similar. The only difference between them is in the connection cables and operating software.

For SLED-2 experiment the development of the on-board Operation System is our task. We also have here tasks in the design of the experiments and in the preparations for the scientific data evaluation. Our contribution to this project was the implementation of the system software, which we had developed for our previous projects. The repeated utilization of it helped us to keep the costs at a minimal level.

Spectrum X-ray Gamma mission

The project is an international astrophysical project. The Russian space probe originally planned to be launched on a Proton rocket from Baikonour in 1998. But the mission is in a serious, ten years long delay. Instruments prepared before the mid nineties became obsolete. It means, mission will not be realized in its originally planned form. But scientific objectives are still on stage. There is a tentative for a launch in 2011 with redesign instruments. The scientific objective: astronomical observations beyond the atmosphere of the Earth, in particular in the until now less observed X-ray and Gamma range.

The scientific objects of the project are the following:

1. observation of known and unidentified as well as discovery of new gamma sources
2. study of the environment of compact objects, neutron stars and gamma eruptions
3. study of the physical circumstances in the centre of the Galaxy
4. look for remnants of Supernova outbursts, explosions
5. study of interactions between cosmic ray and interstellar gas
6. study of not thermal radiation of galaxy masses
7. observation of active galaxy nucleus in gamma range
8. study of X-ray Quasars
9. study of the origin of cosmic X-ray background radiation

On the spacecraft there will be numerous, in various energy range functioning, scientific experiments as the contribution of numerous research centers in different countries, such as Russia, USA, Great Britain, France, Denmark, Germany, Italy, Finland, Israel.

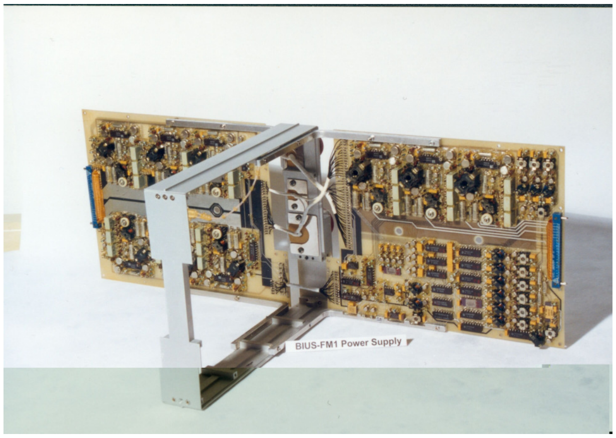
Our activity covers the design and manufacture of the central data acquisition on-board computer (BIUS) and of its Electrical Ground Support Equipment as well as the evaluation of the gained science data. The design of BIUS is an attractive task both from technical and technological point of view. It must be an up-to-date design with extremely high reliability figures due to the expected high life time. The correct operation of the BIUS is of decisive importance, because almost all of the scientific experiments will be controlled by the BIUS and the collected science data will be passed over to the Earth through BIUS.

The total weight of the spacecraft will be over 4000 kg, and will be revolving around the Earth on a high-apogee orbit (1000-200000 km) with the expected life time of five years. The scientific payload (mass cca. 2.5 tons) will be composed of the following experiments:

1. HEPC, LEPC X-ray telescope with the focal length of 8 m in the range of 0.2-10 keV (Russia-Denmark)
2. JET-X grazing incidence telescope with the focal length of 4 m, high angular resolution in the range of 10-15 keV (Great Britain)
3. MART-LIME coded mask telescope (Italy-Russia)
4. SODART coded mask telescope in the hard X-ray range (Russia)
5. SXRP X-ray polarimeter (USA)
6. MOXE (USA)
7. SIXA (Finland)
8. TAUVEX (Israel)
9. DIOGENE (France)

The project will provide a unique experiment complex. A tremendously large collecting area of the mirrors of X-ray telescopes, a wide energy range from 0.02 to 100 keV, an ability to make X-ray images with a resolution from 10 seconds of arc to 2 minutes of arc over a wide field of view, to make X-ray spectroscopic measurements, open up a unique possibility of employing observatories in the interest of cosmology.

Contribution to the Spectrum-X-Ray-Gamma Mission



The on-board data acquisition and control computer (BIUS) is being developed in our institute. The BIUS will be connected to the other units of the spacecraft, such as other service systems and scientific experiments. In order to avoid malfunction due to any kind of erroneous operation of the external experiments the BIUS has redundant modular construction in one hand, on the other hand the external units and the modules of the BIUS are

connected together on reserved, galvanically isolated, serial buses. On the above figure there are redundant secondary power converter units. The control and change of information is taking place on these links.
Basic activities of it are the following:

1. collecting science and technical data from the experiments and storing it onto the on-board magnetic tape
2. preprocessing of science data and passing it to the Earth over radio link
3. controlling scientific experiments according to a predefined cyclogram or the uplinked Earth commands

The BIUS is composed of different, self functioning modules having their own power supplies and the possibility of switching on/off independently of each other. The other advantage of modularity is that by implementing a standard protocol for data exchange it makes possible to work out various, flexible reservation methods. The need for a continuous operation, the extreme environmental circumstances (most dangerous of them is radiation) and the expected life-time (over 3 years) necessitates to triplicate every module of the BIUS.
We decided to apply cold reservation. The activation of reserved modules may be initiated from the Earth while the radio uplink is functioning. Since every single module is connected to the same link, overswitching from one module to another one does not need any extra hardware.
Since the functioning of radio link is not continuous, it is possible to operate BIUS in warm reserved mode in critical time intervals. In this case more processor modules are working at the same time, one of them as active, while the other ones as listener and as such they can take the active role over the module has just gone wrong. For this purpose the processor modules are connected to an internal serial bus in order to be able to test each other. Systematic exchange of critical parameters and regular test procedures running in the background ensure that change of active processor does not cause any loss of data and the functioning seems to be continuous looking from the external experiments.
Every single module can be connected to an external computer on the serial bus without dismounting of BIUS. During ground tests it makes the localization of errors easier. The BIUS is composed of the following modules:

1. Processor modules
2. Earth command and on-board time code receivers
3. Scientific telemetry interfaces (1 Mbit/sec)
4. Service telemetry interfaces (16 kbit/sec)
5. Power supply and analogue telemetry units

The processor module uses 80C86 type processor its memory is organized 16 bits wide. The memory is built up with PROM, EEPROM and RAM components. The clock generators of processor modules have component-level redundancy. The memory has error-checking and correcting circuits. This, at the price of the slightly increased memory-size requirement, stores information in Hamming-coded format, and with the help of this method is able to correct smaller errors (1 bit/word), or signaling more faulty bits.
The computer, due to the built-in component and module-level redundancy, in spite of its gradual degradation, is able to keep the system in a working condition.

The software is a real-time multitasking operation system, parts of it performing the tasks of both system functions and scientific experiments. The kernel of the operation system (supervisor) is written in assembly language in order to increase speed. We have solved the problem of application of high-level programming language C, written originally to IBM-PC, to our IBM-PC-independent architecture on-board computer, this way making the Turbo-C development-kit possible to use for developing the tasks. To support the software development for the computer missing human/machine connection, we made a solution including both hardware and software elements, by which, connected to the so called technological connector of the computer, we can control the running of programs, can stop it, and can check or change parameters. The technological model of the ground support equipment we have finalized the supervisor, the terminal task, the slow and fast telemetry task, and on-board time task.

The electrical ground support equipment is an IBM-PC based test system, in which special interface cards simulate the space probe's electrical signals. The system includes the following individually developed circuit cards:

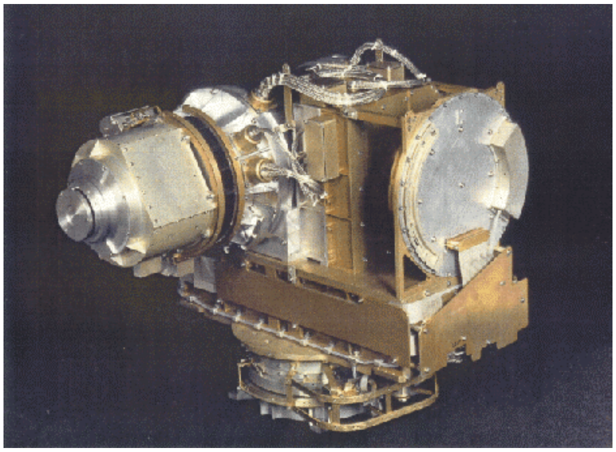
1. on-board bus simulator
2. analogue telemetry and relay command simulator
3. coded command and on-board time
4. fast telemetry simulator
5. slow telemetry simulator
6. inner bus simulator ("processor bus")

The operating software of the EGSE has been written partly in Borland C++. The software is menu-driven, window oriented, quasi-real time, interactive. The control commands are unpitied through the keyboard then are sent to Coded-Command and time simulator card by programmed (polled) method, and again now by hardware method they are sent to the on-board system. Receiving of fast telemetry signals are organized as a background job (direct memory access).

Cassini Mission

On October 6, 1997, the Cassini spacecraft was launched from Cape Canaveral using a Titan IV Centaur launch vehicle. The Cassini weighing more than 5000 kg (5.5 tons) at launch, the spacecraft was too heavy to be injected into a direct trajectory to Saturn. A boost from the Titan IV/Centaur and several planetary gravity assists were needed for Cassini to arrive with sufficient propellant to brake down into orbit around Saturn.

Contribution to the Cassini mission



The CASSINI space probe is for studying Saturn and the interplanetary region. This research work started in late 1990; NASA accepted two proposals, submitted with the participation of groups from our institute. This paved the way to joining in the scientific data interpretation by providing ground support equipment for the magnetometer (MAG) and a charged particle detector (CAPS) for the spacecraft. The objective of these experiments was to observe charged particles and the magnetic field in the magnetosphere of Saturn and in the neighbourhood of Titan. It should be stressed that one technical development, the EGSE, provides the opportunity to participate in more than one experiment. The work relating to the onboard software of both experiments has also been commenced. KFKI RMKI is responsible for developing the EGSE and some of the onboard software for the Cassini Plasma Spectrometer (CAPS) as well as for the magnetometer (MAG). The EGSE consists of a PC and a Sun workstation as nodes of an Ethernet network, and comprises a combination of software and hardware components to provide:

1. instrument interfaces for simulation of spacecraft control subsystems and acquiring housekeeping and science data by Mil-Std-1553B serial bus,
2. power and pyro subsystem simulation,
3. temperature acquisition subsystem simulator,
4. user interfaces for monitoring, logging and manipulating the data and control transactions associated to CAPS on the spacecraft onboard network,
5. gateway functions between a TCP/IP type local network and the Mil-Std-1553B serial bus for controlling the test sequence and data display from a remote station (Sun) and gathering data on a magnetic tape back-up system,
6. calibration mechanism to correlate science data and calibration parametric data, etc.

The special dedicated interface PC cards (Spacecraft simulators) and windows oriented software for Sun and PC are in the development by KFKI RMKI to fulfill these previous requirements.

Rosetta Mission

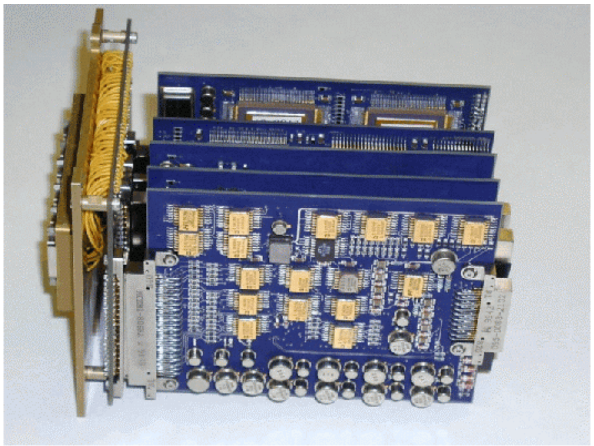
Rosetta is the third cornerstone mission of the ESA long term scientific program Horizon 2000 and launched in 2004. 03. 02. with an Ariane 5 Launcher.

The mission is dedicated to the in-situ study of a comet for at least one year. After one year delaying when the original target was lost according to orbit properties of Wirtaanen, the new target is the Churjumov-Gerasimenko comet which is reachable new target.

Contribution to the Rosetta

The Command and Data Management System (CDMS), which is the on-board computer of the Rosetta lander, named Philae was designed by our department at KFKI-RMKI in cooperation with a small Hungarian company (SGF Ltd.).

The CDMS hardware and consists of the following functional units:



- Data Processing Unit (DPU)
- Emergency Telecommand Decoder (ETCD)
- Oscillators
- Real-Time Clock (RTC)
- Instrument/Subsystem Central Interface Unit (CIU)
- Mass Memory (MM)
- Power Switches / Housekeeping

All functional blocks within the CDMS with the exception of the Emergency Telecommand Decoder (ETCD) are double-redundant. Once, at a given moment, one of the DPUs is considered to be the primary one, the current DPU in-charge. This is the one, which is in charge of performing all control functions on the Lander. The alternate DPU is referred as the current secondary one.

All of the connected peripherals are also redundant. The current DPU in-charge can choose to communicate either with the main or redundant counterpart of the peripheral units.

The CDMS On-board Software (OBSW) is written in Forth, by taking advantage of some of the specific properties of the Harris RTX-2010 processor the CDMS hardware is based on.

The major OBSW components are

- ♦ Boot Program and DPU Redundancy Control
- ♦ Task Scheduler & Operating System
- ♦ Application Tasks

Following a processor reset (either power-on or a sort of SW reset) SW control will be passed to the entry of Boot Program. The Boot Program is a sequential code and will be running out of PROM, excluding of its interruption in any way. After performing basic initialization procedures (ie.: memory-test and configuration, SW composition of new patches, DPU redundancy control) SW control flow will be passed over to the Task Scheduler & Operating System.

The real OBSW is composed of the Operating System and the Application Tasks. The Operating System is a multitasking SW running environment with real-time capabilities. It is a sort of dispatcher in charge of ensuring "parallel" run of Application Task by distributing processor run-time among them. In addition, it provides so called system services for the Application Tasks. System services are standardized means (routines) thru which all the resources of the CDMS system (HW and SW) get accessible.

Since the multitasking mechanism of the OBSW has been realized by means of the built-in shared-stack structure of the microprocessor, the maximal number of Application Tasks at a time is 8.

Obstanovka

Obstanovka experiment is being prepared by an international space research team. The participants are from 7 countries, Bulgaria, Hungary, Poland, Russia, Sweden, Ukraine and United Kingdom. The project is co-coordinated by Russian Space Research Institute, tending to investigate the influence of the factors of space whether weather on the state of the middle-latitude and equatorial ionosphere. It has 12 instruments. Obstanovka will be mounted to board Russian Segment of the International Space Station (RS ISS).

The scientific purposes are the followings:

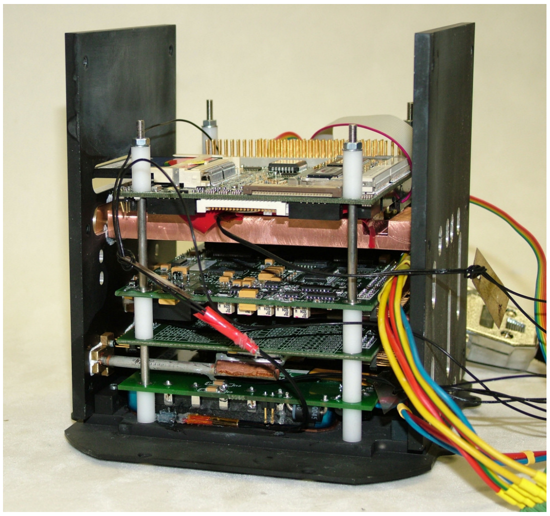
- Geophysical studies of the plasma-wave processes, connected with the manifestation in the ionosphere it is solar-magnetospherically-ionospherically-atmospheric-terrestrial connections.
- The ecological monitoring of the low-frequency electromagnetic radiations of anthropogenic nature and connected with the global catastrophes.
- Studying plasma-wave conditions in zone near to super big spacecraft.
- The coordinated ground observations on the influence of electromagnetic disturbances on the technogenic structures and the living organisms.

The “Obstanovka-1st stage” will be carried out to provide a databank of electromagnetic fields and of plasma-wave processes occurring in the ISS near-surface zone (NSZ) to account for the influences of the plasma component factors of near-Earth space (NES), including influence of an artificial origin.
The "Obstanovka" experiment also enters into the Program of the space education, realized on RS ISS. For education purpose, the part of the physical parameters, measured by the PWC, will be transferred to Schools.

Contribution to the Obstanovka

The data acquisition system developed by KFKI RMKI consisted of three processor units. There units are called BSTM, DACU1 and DACU2. The central unit is the BSTM (Block of Storage of Telemetry Information Unit) is mounted to the interior of ISS, where the astronauts live, and it will communicate with DACU1 and DACU2 units (Data Acquisition and Control Unit, that are fixed to the outer surface of the wall of ISS. The communication will be realized using TCP/IP over Ethernet. The detectors are connected directly to the DACU1 and DACU2 units. DACU1 and DACU2 collect the data from the experiments and transfer it to BSTM. Regarding to the scientific data the BSTM is double. It writes the data to its local mass data storage and transfers certain packages to the telemetry, according to the reserved telemetry quote of the experiments. The volume of scientific data produced by the experiments fluctuates, but in general, the integrate volume of data overruns the total telemetry capacity reserved for whole Obstanovka experiment. This fact explains the necessity of application of local mass data storage in BSTM. Scientific data written to this storage are transferred to the Earth by astronauts, when the staff is changed according to the schedule.

Each of BSTM, DACU1, DACU2 contain Intel Pentium compatible processor card corresponding to PC/104-Plus standard. The communication between the board of ISS and BSTM and between BSTM and DACU units is realized on a 10 Mhz Ethernet bus. This type of communication is applied between the SAS experiment and the BSTM. All three embedded processors units are controlled by real-time Linux operation system. The size of the available operative memory is 128 Mbyte. The operation system and the application program are stored on a 128 Mbyte flash disk. The generated heat in DACU1 and DACU2 computers are conducted out a passive heat conductors as shown on the figure.



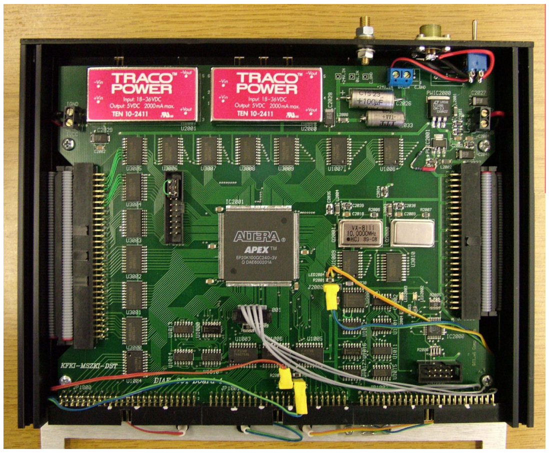
The electrical ground support equipment (EGSE) developed by a small Hungarian company (SGF Ltd.). The EGSE consists of a portable unit and a standard PC. The portable unit function is to simulation the space station electrical interfaces signal level. This function realized with an embedded processor and with dedicated hardware units. The communication between embedded processor and PC is realized on Ethernet network. The PC has a graphical user interface to control the Obstanovka system and to visualize the measured information, the so called science and house-keeping telemetry packets.

Venus Express

The VenusExpress is the first adventure of ESA for investigation of Venus. The main components of MarsExpress are used by VenusExpress.

Contribution to Venus Express

KFKI RMKI participates in ASPERA-4 (Analyzer of Space Plasma and EneRgetic Atoms) experiment. The task of the institute is to promote the calibration of ASPERA-4. The calibration is indispensable to the exact evaluation of the measurements being performed by the experiment at the Venus. It was necessary to implement an automatic calibration system at particle accelerator of the Institutet för rymdfphysik (IRF) in Kiruna. The implemented system serves for calibration of detectors of ASPERA-4 experiment by an ion source. The automatic calibration system speeds up the calibration process, and also makes it reproducible.



The calibration system consisted of three embedded computers BTTS, HVAM, HVDS and a portable computer supplying the graphical user interface for the researchers. The embedded systems based on PC/104 type processor cards. The communication between them is realized on TCP/IP protocol on optical fiber. The implementation of optical fiber connection prevents the propagation any of high voltage isolation failure. The above picture shows one of the high voltage measurement units. This type of communication is applied between the BTTS and the portable computer, too. The PC/104 type processor cards are controlled by real-time Linux operation system, while a windows system is running on the portable computer.

BepiColombo

KFKI RMKI tasks to develop the low voltage power supply of the Planetary Ion Camera (PICAM) experiment to be mounted on the Mercury Planetary Orbiter (MPO) of the ESA's BepiColombo mission. The PICAM is part of the SERENA (Search for Exospheric Refilling and Emitted Natural Abundances) instrument. The SERENA consists of four spectrometers: ELENA (Emitted Low-Energy Neutral Atoms), STROFINO (STart from a ROtating Field mass spectrOmeter), MIPPA (Miniature IOn Precipitation Analyser) and PICAM. SGF Ltd. develops the electrical ground support equipment for the PICAM experiment. This system is planned be prepared using the standards and methods were followed and applied in elaboration of Aspera calibration system and the data acquisition system of Obstanovka experiment.

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Further information sources

Obstanovka	www.iki.rssi.ru/obstanovka
Hungarian Space Office	www.hso.hu
KFKI RMKI	www.rmki.kfki.hu
Rosetta	www.esa.int/Rosetta
Aspera-4	www.irf.se/aspera-4
Cassini	www.nasa.gov/mission_pages/cassini/main