History of Rocketry and Astronautics

Proceedings of the Forty-Fourth History Symposium of the International Academy of Astronautics

Prague, Czech Republic, 2010

Kerrie Dougherty, Volume Editor

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AAS History Series, Volume 41

A Supplement to Advances in the Astronautical Sciences

IAA History Symposia, Volume 30

AAS Publications Office
P.O. Box 28130
San Diego, California 92198

Affiliated with the American Association for the Advancement of Science
Member of the International Astronautical Federation

First Printing 2014

ISSN 0730-3564

ISBN 978-0-87703-607-4 (Hard Cover Plus DVD)
ISBN 978-0-87703-608-1 (Soft Cover Plus DVD)

Published for the American Astronautical Society
by Univelt, Incorporated, P.O. Box 28130, San Diego, California 92198
Web Site: http://www.univelt.com

Printed and Bound in the U.S.A.

Chapter 23

Solar Physics Space Research in the Czech Republic*

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Abstract

Solar physics has a long tradition in the Czech Republic (Czechoslovakia before 1993), which began shortly after World War II. Ground-based observations in optical, and also in radio regions, made at the Ondřejov Observatory during the 1950s and 1960s gained international reputation. Acceptance of an offer to participate in space observations within the (then) Soviet Intercosmos program was a logical extension, commencing at the end of the 1960s.

This short survey of the following space activities describes briefly many projects where Czechoslovak instrumentation was used for X-ray observations of the Sun. Later on, when the Czech Republic was created from Czechoslovakia and the Intercosmos program vanished, new contacts with U.S. scientists enabled the continuation of some solar space observations from a U.S. satellite. Even though the Czech Republic's economic and industrial reconstruction after 1990 led to a partial freeze in space activities, developments in this century have turned in a promising direction and the Czech Republic became a new European Space Agency (ESA) member in 2008. Now, the country is involved in the ESA science program and participates in the ambitious Solar Orbiter project.

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* Presented at the Forty-Fourth History Symposium of the International Academy of Astronautics, 27 September – 1 October, 2010, Prague, Czech Republic. Paper IAC-10-E4.4.05.

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Introduction

When the first rocket after World War II carried a scientific instrument above Earth's atmosphere, astrophysics (including solar physics) acquired an extremely powerful tool for obtaining new results and new knowledge about the universe, which were unattainable earlier. Therefore, it is understandable that the foundation of the Council for International Cooperation for the Exploration of the Cosmos (Intercosmos), on 30 May 1966, was welcomed, even by the scientists of the former Czechoslovakia, which was at that time part of the "empire" of the Soviet Union. Particularly for researchers in solar physics and geophysics (who had a very high international reputation in these two fields), observations from space would enable them to keep pace with the "western world." For this reason, Czechoslovaks very quickly became the most active participants in this cooperative program, which included not only Eastern European countries, but also Austria, India, France, and Sweden.

Intercosmos 1

The largest astronomical and astrophysical institute in Czechoslovakia, situated in Ondřejov, was part of the Czechoslovak Academy of Sciences, and its largest department was the Department of Solar Physics. Observations in optical and radio regions focused on active processes in the solar atmosphere, especially solar flares, and were well-known in the community. The newly open offer to build instruments and observe from space could not be rejected and, after detailed discussions among Ondřejov scientists, it was decided to build an X-ray monitor that would register the evolution over time of solar X-ray emissions in the soft X-ray region.

Czech scientists and technicians had absolutely no experience in this field and had to learn everything from scratch. A close collaboration among scientists at the Ondřejov Astronomical Institute and a group of technicians at the Tesla Electronic Research Institute was established, and the two groups began to cooperate. The initial result of this cooperation was the first Czechoslovak instrument launched on board the Intercosmos 1 satellite in 1969. This very simple instrument observed integral soft X-rays from the Sun. However, it had poor temporal resolution, limited by the Soviet telemetry system, in which data was transmitted to Earth and registered in analog form on film. Nevertheless, it worked for a few months, yielded some data, and the group began to learn how to make better and more sophisticated instruments.

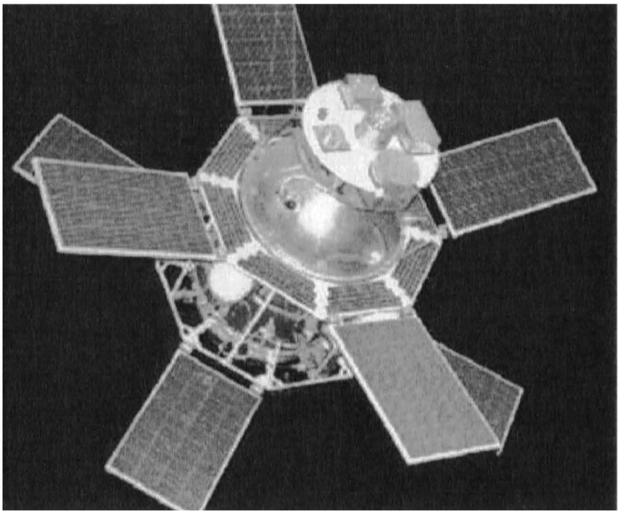

Figure 23–1: The Intercosmos 1 (IK-1) satellite with its scientific payload, including the Czechoslovak soft X-ray monitor.

Intercosmos 4 and Intercosmos 7

Immediately after that first launch, a new version of the instrument was under development, and this time its goal was not only to observe the soft X-ray emissions from the Sun, but also hard X-rays, up to 100 keV. A scintillation detector (a combination of a NaI crystal and a photomultiplier, both of which were made in Czechoslovakia) was added to a gas proportional counter. A parallel telemetry system, which enabled scientists to transmit data from their instruments in real time during a few short transits of the satellite over Ondřejov, was also part of the payload. They could receive short bursts of data a few times a day directly at the institute and thus check the actual situation of the instrument, which was launched on board Intercosmos 4 (IK-4) in 1970.

The main advantage of the Intercosmos program was full freedom in scientific instrument development and manufacture, provided that it complied with the dimension, weight, energy consumption, and telemetry requirements that were allocated to each instrument at the beginning of each project. Of course, all the scientific instruments had to "survive" prescribed mechanical and electrical tests. Another advantage was relatively frequent launches. On the other hand, scientists had to accept the short lifetime of the satellites, poor pointing accuracy, very poor telemetry capacity, and a complicated and mostly delayed data transfer to Czechoslovakia. Until the Intercosmos 7 (IK-7) project, all telemetry data was stored on film. Therefore, reading the data was labor intensive and not very precise. The Intercosmos 7 satellite was launched in 1972 and carried a nearly identical instrument to that flown on Intercosmos 4.

Intercosmos 11

Scientists at the Astronomical Institute, together with the Tesla technicians, continued with the improvement and development of their solar X-ray spectrometer, and the next generation of the instrument was launched on board the Intercosmos 11 (IK-11) satellite in 1974. In this new instrument, the observed energy band was extended further into the soft X-ray region and the proportional counters were continuously calibrated in-flight.

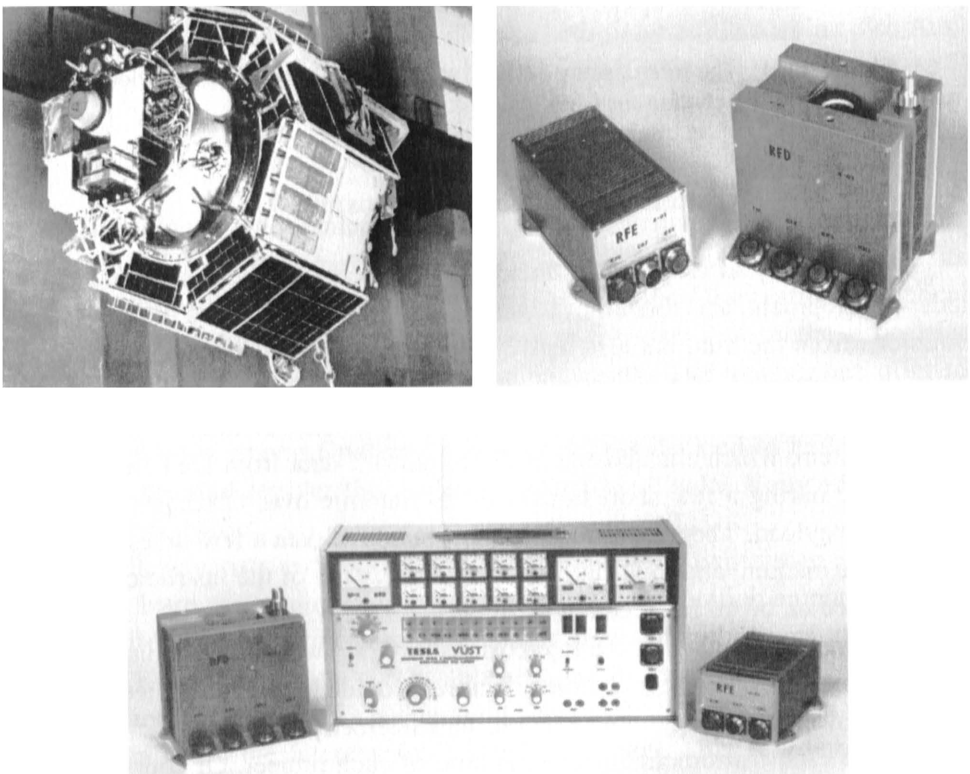

Figure 23–2: Intercosmos 11 satellite and the Czech X-ray spectrometer, including the ground-based preflight testing instrument.

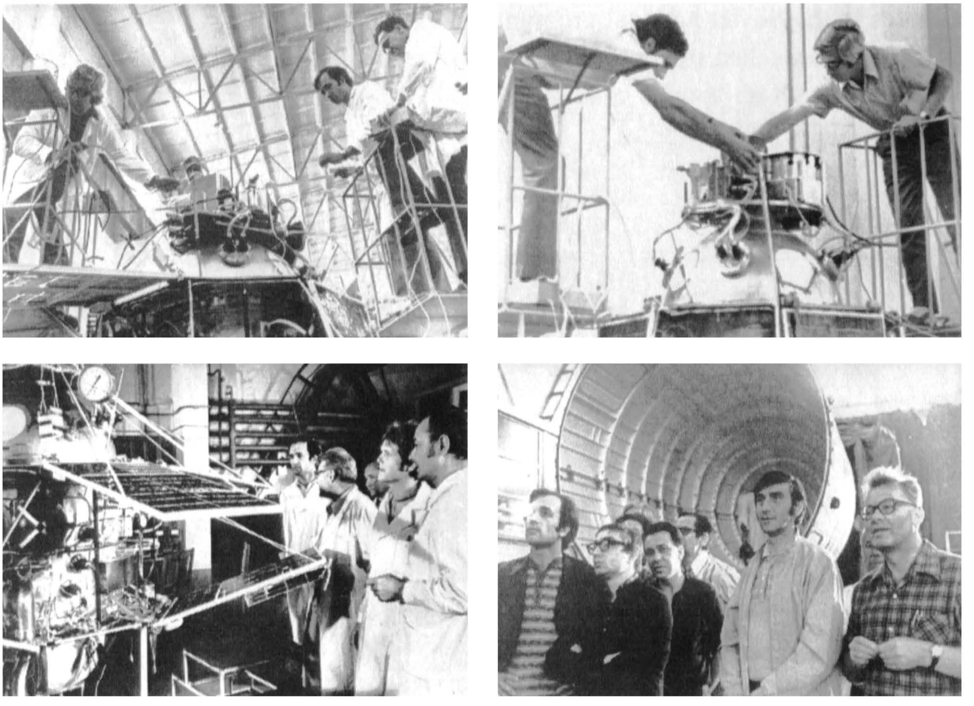

Figure 23–3: Integration and testing of the scientific payload in the integration hall at the Kapustin Yar launch center. In the four pictures, the complete Czech team, led by Dr. Boris Valniček (together with Dr. František Fárnik, Dr. Igor Zacharov, Engineer Bohuslav Komárek, Engineer Jiři Ullrich, and Jaroslav Soral) is shown, together with a German colleague, Dr. Bernd Stark.

Involvement with the Prognoz Program

Two years later, in 1975, a nearly identical X-ray spectrometer was launched on board the Intercosmos 16 (IK-16) satellite. This was the last Intercosmos-type satellite to carry a Czechoslovak solar instrument. While the quality of the satellites, including their telemetry capacity, had been improving from launch to launch, in comparison to U.S. technology the parameters (such as lifespan, pointing accuracy, low orbit, and low telemetry capacity) made solar observation very inefficient. It was impossible to achieve better temporal resolution, as, due to the pointing system, only whole-disk observations were possible; also, due to orbital parameters, only 30 percent of the orbit time could be used for X-ray registration.

Nevertheless, the quality of the Czech instruments and the extended participation of Czechoslovak technicians and scientists in the Intercosmos program enabled an invitation to put Czech X-ray monitors on board the Prognoz-type satellites in the Soviet national program. The Prognoz satellite weighed almost a ton and was launched by the Molniya-M rocket from Baikonur into a very elongated orbit, with an apogee of about 200,000 km and a perigee of about 1,000 km. This enabled uninterrupted solar observation for about 95 hours, with a gap of about 6 hours each orbit.

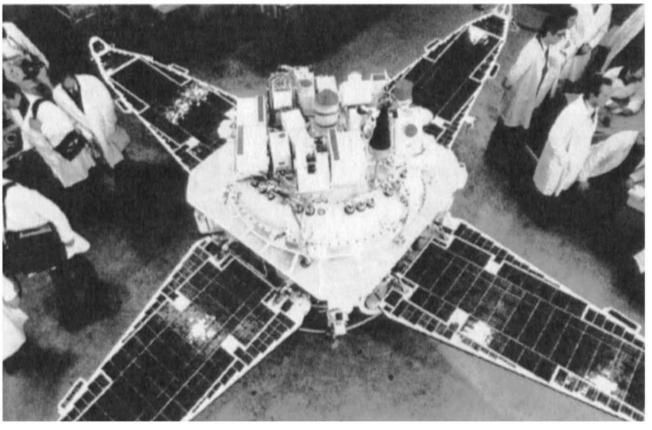
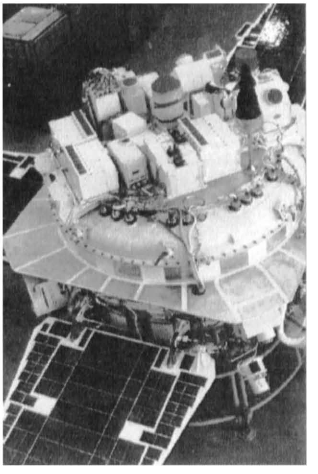

Figure 23–4: A Prognoz-type satellite and its scientific payload.

The first Czech X-ray spectrometer was flown on the Prognoz 5 satellite in 1976. It had two X-ray detectors—a scintillation detector for the energy region between 6 and 100 keV, subdivided into five energy bands, and a proportional counter for the energy region between 2 and 8 keV. This instrument enabled the study of the temporal development of the integral solar emission, with a medium time-resolution (10 sec), together with its basic spectral characteristics. Because of practically uninterrupted observations, nearly all solar X-ray events were registered during the lifetime of each satellite, which was between six months and a year. The X-ray monitoring of the Sun continued on board Prognoz 6 (1977), Prognoz 7 (1978), and, with some updating of the instrument, on board Prognoz 8 (1980), Prognoz 9 (1983), and Prognoz 10 (1985).

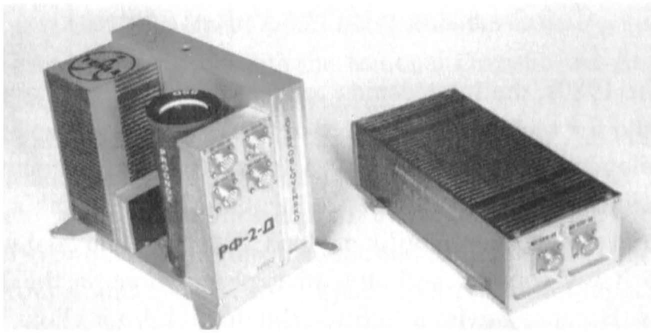

Figure 23–5: X-ray spectrometer for the Prognoz-type satellite series.

The Soviet Phobos Mission

During the 1980s, the Soviet Union planned, and was developing, a planetary mission to the Martian moon Phobos. The Czechs were invited to put a soft X-ray monitor on board each of the two probes. The two heavy spacecraft (more than 6 tons with their orbit insertion hardware attached) were launched in July 1988 by a Proton-K rocket. The Czech instrument consisted of five in-flight calibrated proportional counters, registering integrated soft X-ray emissions for the whole solar disk in two energy bands, 2–4 and 4–8 keV. The Phobos 2 spacecraft reached Mars on schedule; solar monitoring was carried out during the 200-day long flight from Earth to Mars. Unfortunately, the Phobos 1 spacecraft was lost shortly after launch, due to a controller failure, and Phobos 2 did not complete its observations of that moon due to a technical failure while in orbit around Mars. Nevertheless, the solar X-ray observations were successful and enabled the first stereo observations of the Sun, when complemented with the U.S. geostationary satellite observing solar X-rays in the same energy bands.

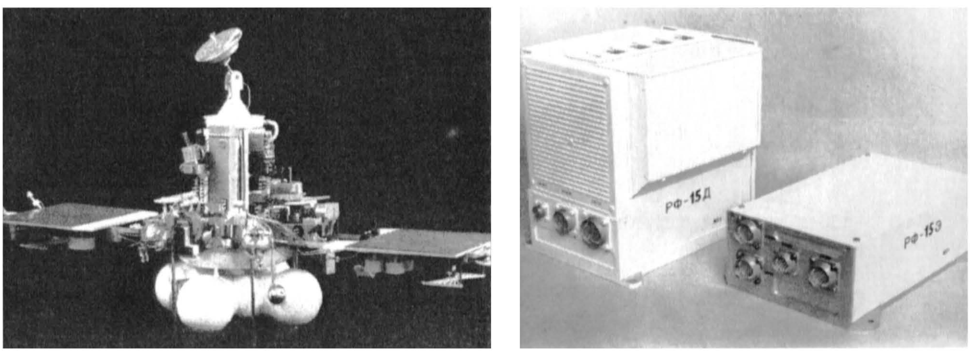

Figure 23–6: The Phobos 2 spacecraft and the Czech instruments for solar soft X-ray monitoring.

Collaboration with the United States

During the 1980s, the Intercosmos collaboration began to have severe difficulties—mainly for technical and organizational reasons. The Soviet Union planned to develop and launch a rather big solar observatory, to compete with the U.S. Solar Maximum Mission (SMM) satellite, and Czechoslovakia promised to build a substantial part of the scientific payload. This time, the goal was to obtain images of hard X-ray sources, and also other observations in the X and XUV spectral regions. Because Soviet satellite technology did not allow very precise pointing and scanning of the solar disk, Czech scientists and technicians had to develop a scanning platform that could point the instruments to a selected region and/or scan that selected region as the satellite was held steady, while roughly pointed at the Sun's center, with a stability and precision not previously reached.. The scientific payload, including the platform, was developed and technological tests were underway, when the Soviet Union canceled the whole project because the technicians were unable to build the satellite with the requested pointing stability. All projects became further and further delayed.

From 1988, the scientists from the Astronomical Institute established close scientific collaboration with scientists from the Space Environment Laboratory (SEL) in Boulder, Colorado. One of the tasks of the Laboratory is to provide soft X-ray monitoring of the Sun from on board the Geostationary Operational Environmental Satellites (GOES). They have had long lasting, uninterrupted observations (now from 12 satellites), which became the standard basic information on solar activity.

The observing instruments were (and still are) registering the solar flux in two energy bands, which were practically identical with the energy bands of the Czech instruments on board the Prognoz satellites and Phobos spacecraft, but the instruments were (and still are) using different types of detectors. The main goal of the cooperation was to compare the fluxes observed by the two basically different instruments and to check their calibration. It was proven that the differences between the GOES and Prognoz-type X-ray monitor data were very minor. Another scientific goal was to analyze data registered by the Phobos and GOES instruments, which saw the Sun from different angles. This stereoscopic effect enabled the study of the vertical structure of solar flares situated close to the solar limb.

After 1989, when the political situation in Czechoslovakia (now the Czech Republic) was fundamentally changed, cooperation with Western countries became fully open. U.S. colleagues suggested the use of one of the Czech hard X-ray spectrometers on the next U.S. solar satellite launch: the initial idea was to add it to the next GOES payload, which carried a soft X-ray monitor only. However, after a lengthy discussion with the National Oceanic and Atmospheric Administration (NOAA), this idea was rejected.

New opportunities appeared in the form of the U.S. Air Force Space Test Program. Partners submitted a proposal to launch the Czech hard X-ray monitor on board one of the test satellites and, on the second attempt, the proposal was accepted in 1996. Scientists from the Astronomical Institute, together with the technicians from a small private firm, Space Devices from Prague, started to develop a new, more sophisticated instrument—a hard X-ray spectrometer with a very high temporal resolution. The very friendly and successful cooperation among the Czech team and the technicians at the Sandia National Labs in New Mexico was crowned with success in March 2000, when the new Czech instrument, the Hard X-ray Spectrometer (HXRS), was launched on board the U.S. Air Force Multispectral Thermal Imager (MTI) satellite by a Taurus rocket from Vandenberg Air Force Base. HXRS operated successfully until February 2003, and its data, documenting the hard X-ray spectra of hundreds of solar flares, was transmitted via the internet to the Ondřejov Observatory with a delay of only a few hours.

Figure 23–7: The MTI satellite, prepared for its integration with the Taurus rocket, and the Hard X-ray Spectrometer.

Conclusion: ESA Membership and the Future

During the 1990s, and especially after the year 2000, the Czech Republic expressed its wish to become a full member of the European Space Agency (ESA). The previous history of scientific space research, and also the technological level of Czech space industry, was a good ground for supporting membership. In 2004, an agreement on cooperation between ESA and the Czech Republic, under the name of Program for European Co-operating States (PECS), was signed and a close collaboration started to grow. Extended activity and good results from joint projects led to full membership being officially accepted in November 2008. This membership opens new opportunities for Czech scientists to participate in large, ambitious scientific missions in a broad international cooperation, that is, in missions that are too expensive to be carried out by a small country alone. Of course, the Astronomical Institute is fully involved in the preparation of the next solar mission in the ESA Science Program, Solar Orbiter.[*] It is believed that, based on previous solar space research experience, the Czech Republic will be a good partner in this very ambitious mission.

[*] **Editor's note:** Solar Orbiter is currently planned for launch in July 2017.