

Polish Academy of Sciences Committee on Space Research



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Space Research in Poland

Report to COSPAR 2008

Second edition

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Editors: Jan Błęcki and Barbara Popielawska

Cover: An example of a calibrated RESIK spectrum of solar X-ray radiation. This spectrum was accumulated over the entire February 22, 2003 flare that took place around 09:30 UT. Several spectral bands are marked selected to study the absolute abundance of indicated elements.

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Foreword

This is the report to COSPAR on Polish space research and space application projects covering period 2003–2007. The Report was prepared by the Committee on Space Research of the Polish Academy of Sciences. The authors of the contributions to this Report are the chairpersons of four commissions of the Committee: Space Physics, Satellite Geodesy, Remote Sensing, and Astronautics and Space Technology. The report describes scientific activity in space physics, in space applications for planetary geodesy and remote sensing, and the activity in the field of astronautics and space technologies.



In 2007 we commemorated the 50th anniversary of Sputnik-1 launch. The conference "Space for Humans – 50 years and beyond" was organized at Warsaw University of Technology hosting representatives of ESA, NASA and RSA. (Photo: The "Future of space exploration" contest – children from Warsaw schools, with NASA astronaut Shannon W. Lucid and ESA astronaut Jean-Pierre Haigneré; ©ESA).

It was also the year of 30th anniversary of Space Research Center of the Polish Academy of Sciences (SRC PAS), the key actor in most space related activities in Poland. In 2007, on April 27 Polish government signed the European Cooperating State Agreement with the European Space Agency. Within a year, on 28 April 2008, Poland finally reinforced its relations with ESA by signing the Plan for European Cooperating State Charter. The first call for PECS projects opened in 2007 by ESA was met with great interest of Polish research institutions and commercial enterprises. This success opened new perspectives. Experts from the Committee on Space Research were invited to advise the government on shaping the national space policy by participation in the Commission on Outer Space Exploitation of the Ministry of Science and Higher Education, by serving as advisors on space applications and technology to public authorities, and cooperating with the Parliamentary Group on Outer Space. The foresight project "The assessment of the perspectives and potential benefits from space technologies development in Poland" financed by European structural funds was performed in SRC, accompanied by promotional activity like organization of Warsaw Space Days or Warsaw Science Picnic, public events with exhibitions and demonstrations.

Perspectives for further development of space activity in Poland are good for more than 200 young engineers that took part in the astronautics and space technology courses at Warsaw and Wrocław Universities of Technology. The way is pawed for young generation to enter the modern world space market and use it for the benefit of Poland.

SPACE PHYSICS

Compiled by Barbara Popielawska

Polish participation in space missions

Mars-Express



The ESA cornerstone mission Mars-Express was launched on June 02, 2003 and entered Martian orbit on December 25, 2003. One of the instruments aboard is the Planetary Fourier Spectrometer (PFS), covering wavelengths from 1.2 to 45 microns in the infrared range (corresponding to 250 to 8200 cm⁻¹ wavenumbers), with spectral resolution equal 2 cm⁻¹.

SRC PAS participated in PFS hardware building and in science program definition for this Italy-led experiment. The experiment is successful and is delivering a lot of new data on the chemical composition and physical structure of the surface and atmosphere of Mars. During years 2003–2007 Polish scientists and engineers were co-authors of more than 30 articles in refereed international and national scientific journals and conference proceedings, presenting results from Mars-Express mission and related theoretical modeling of Martian atmospheric spectra.

Rosetta



The European Space Agency's space probe Rosetta destined to reach comet 67P/Churyumov-Gerasimenko in 2014 was successfully launched on March 02, 2004. One of the instruments aboard the probe's lander is the SRC PASbuilt penetrator MUPUS with a deploying and hammering device, designed to study physical parameters of the nucleus surface and sub-surface layers. During the Cruise Phase Operation # 0 at the end of March 2005 the penetrator was turned on for 4 minutes and tested, showing its nominal on-flight

performance. Theoretical studies of dynamics of comets, modeling of cometary spectra, laboratory and numerical experiments of penetration process are undertaken in SRC PAS with the aim to help the Rosetta's data analysis in the future. Results are published in scientific articles as enumerated below.

Venus-Express



The most recent ESA's planetary mission Venus-Express was launched on November 09, 2005. It carries the SRC-constructed power supply unit and the scannerwhich of the infrared PFS spectrometer for Venus atmosphere investigation. (Actually, PFS scanner does not function properly, but still there are hopes to fix it.) Polish scientists

cooperate also in data analysis from VIRTIS experiment on Venus Express.

Cassini-Huygens



Year 2005 began with a historic ESA Huygens probe's landing on Titan, on 14 January. The THP (<u>TH</u>ermal Conductivity <u>Probe</u>) sensors of Surface Science Package, constructed in SRC PAS in cooperation with Rutherford Appleton Laboratory and University of Kent, survived landing and operated on Titan's surface until radio communication with lander was lost. THP operated also throughout

the descent in the Titan atmosphere. First results were reported on COSPAR 2006 conference. Data quality was very good. Thermal conductivity determination during the descent agrees with that for the molecular nitrogen, the main component of Titan's atmosphere.

Publications related to planetary and cometary missions:

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Integral

Polish participation in ESA's Integral mission (launched on November 17, 2002) is



very fruitful scientifically. Integral it is the orbital gamma-ray observatory, most sensitive ever launched. Polish astronomers recently proposed and tested the new method of data analysis with the use of double detector layer design of the IBIS instrument on-board INTEGRAL, making possible to observe powerful gamma-ray bursts even if they fall outside the telescope's main field of view. A powerful

gamma-ray burst, GRB 030406, occurred on 6 April 2003 and lasted around 65 seconds. At the time, INTEGRAL was pointed 36.9° away from the direction of the burst. Dr Radoslaw Marcinkowski from Space Research Center PAS and his colleagues have reconstructed an image of the event using the radiation that passed through the side of INTEGRAL's imaging telescope [Marcinkowski et al., 2006]. This new method may increase significantly the number of registered hard (E_{peak} of several MeV) long-duration GRB events. Analysis of Integral data in Poland is performed in several institutes, in SRC PAS, Nicolaus Copernicus Astronomical Center PAS in Warsaw and Torun and in Astronomical Observatory of Warsaw University. Polish observations with Integral include the following findings:

- Gamma-ray bursts, soft γ -ray repeaters, X-ray flashes, including discovery of a giant flare from the soft gamma-ray repeater SGR 1806-20 (J. Borkowski);

- Accreting X-ray pulsars OAO1657-41 (γ -ray tomography of a B supergiant), 4U1626-67 (M. Denis, T. Bulik, R. Marcinkowski);.

- Rotation-powered pulsar PSR B0540-69 (A.Słowikowska, J. Borkowski);

- BL Lacertae object S5 0716+714 (M. Sikora).

Black-hole binary GRS 1758-258; active galaxy NGC 4151 (P. Lubiński, A. Zdziarski);

- Black-hole binaries Cyg X-1, Cyg X-3, GRS 1915+105, IGR J17464-3213, 1E 1740.7-2942, IGR J17091-3624; quasars 3C 273, 3C 111; a sample of active galactic

nuclei; a sample of neutron-star low-mass X-ray binaries, in particular Serpens X-1, X-ray bursters, the LMC region (A. Zdziarski);

- IBAS – the real-time Integral Burst Alert System have been organized for GRB detection (J. Borkowski).

In total, in the years 2003–2007 more than 120 publications on Integral data-based results in refereed journals and international conference proceedings have been published with Polish co-authorship.

Refereed publications from Integral with Polish contribution:

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Coronas-F



One of Polish specialities in the experimental space physics is the solar X-ray spectrometry. Two Polish instruments aboard the Russian solar physics mission Coronas-F (July 31/2001 to December 06/2005), the Bragg crystal spectrometers Resik (built by SRC PAS, Solar Physics Branch, in cooperation with IZMIRAN,

NRL/USA, MSSL and RAL/UK) and Diogeness (SRC PAS and IZMIRAN), were designed to record the solar flares' X-ray spectra to study plasma properties in active regions. Diogeness and Resik, operating in the 3-7 Å X-ray spectral range, have detected multiple spectral lines in the emission of most intensive solar flares ever observed. Diogeness has observed for the first time the evolution of spectra in vicinity of He-like ions of Si XIII, S XV and Ca XIX with high resolution. This has been possible for the entire duration of the X5.3 class flare of 25 August 2001. Thanks to a special arrangement of the scanning crystals in so-called X-ray Dopplerometer configuration, absolute blue-shifts of all emission lines have been observed allowing for estimates of absolute value of the hot plasma radial velocity component. The X-Ray spectrometer Resik has measured hundreds of thousands of spectra in the unexplored range between 3.3 Å and 6.1 Å. Tens of new spectral lines has been identified by investigating the variations of spectral shapes emitted by plasma of different temperature. Thanks to the high sensitivity of the instrument, weak lines from K and Cl have been observed and absolute abundances of these elements in the corona have been

determined for the first time. Coronas-F X-ray data were also used to cross-calibrate X-ray instruments on NASA and JAXA missions and in cooperative studies of solar activity.

Coronas-Photon

A prototype of a new narrow-band soft X-ray spectrophotometer SphinX was designed and built in SRC PAS. This instrument is accepted to fly aboard the new Russian satellite Coronas-Photon, scheduled for launch in 2009. SphinX will measure solar Xray spectra in the range 0_12 keV, with a resolution of 300 eV. Measured spectra will be used to determine the composition of coronal plasma for elements between Mg and Ni. For the first time the measurement's absolute accuracy will be better than 5%. A similar instrument named STIX is considered to be built with SRC team participation for the Solar Orbiter mission (launch planned in 2015).

Polish contribution to solar physics data analysis:

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Interball-Aurora



Continuation of data analysis from Polish radiospectrometer Polrad aboard Interball-Aurora satellite has provided new series of interesting results. It was shown that bursts of auroral kilometric radiation (AKR) observed with the Polrad radiospectrograph at low frequencies (20 - 100 kHz), called "dot-AKR" (from their dynamic spectra which remind dots), occur in the expansion phase of magnetospheric substorms. These observations suggest that electrons emitting bursts of low-frequency AKR are accelerated in the plasma cavities at radial distances of 2 to 3 Earth's radii in parallel electric fields of kinetic Alfvén waves. Statistical investigations of Polrad data indicate occurrence of plasma cavities also in a higher region at radial distances of 4 to 5 Earth's radii. Here, electrons are also accelerated by parallel electric fields of dispersive Alfvén waves. Cases of periodic AKR pulsations at a frequency range of Pc 5 (1 to 4 mHz) occurring simultaneously with field line resonances (FLR) identified from IMAGE, the ground magnetometer chain, confirm role played by the Alfvén waves in the electron acceleration and generation of this radiation [Hanasz et al., 2006]. Dynamic spectra of the polarization parameters of AKR have been determined in the plane orthogonal to the source direction, based on corrected measurements in the three orthogonal antenna planes of the Polrad triaxial polarimeter [Panchenko, 2004]. Directivity of the AKR emission has been investigated using the AKR spectra provided by Polrad. Cases of filled and partially filled emission cones as well as smaller emission cones embedded inside the main cone were found. Anisotropic AKR beams as thin as 10°, and sometimes even narrower, are consistent with the model [Schreiber, 2005].

Interpretation and modeling of data from magnetospheric missions like Prognoz-8, Interball-Tail, Magion-4, Interball-Aurora, Polar and Cluster were continued during 2003–2007 with the following published results:

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Demeter



DEMETER (Detection of Electro-Magnetic Emissions Transmitted from Earthquake Regions) it is the first project in the Myriade microsatellite series of CNES. DEMETER was launched on July 29, 2004. It carries the SRC-built power supply and control module for all scientific instruments aboard. SRC PAS participated also in software

building for DEMETER data processing. The main task of the mission is to investigate the ionospheric plasma and the Earth's electromagnetic field field perturbations caused by the geotectonic activity. First results have been already published in a Special Issue of Planetary and Space Science in 2006 and in Proceedings of the DÉMÉTER International Symposium (CNES, Toulouse, June14–16, 2006), where examples of unusual ionospheric observations made by DEMETER over seismic regions are shown.

Kompass-2



In 2006, a new series Russian satellite KOMPASS-2 (Complex Orbital Magneto-Plasma Autonomous Small Satellite) was successfully launched on May 26. The goal of the mission is to detect, register and explain the anomalous physical phenomena in lithosphere, atmosphere,

ionosphere and magnetosphere of the Earth which accompany catastrophic events such

as earthquakes, tropical cyclones, tornados, etc., as well as strong magnetic storms. Polish contribution to the mission was the radio frequency analyser RFA (in cooperation with IRF Uppsala and IZMIRAN) designed to carry out local wave measurements using high frequency spectrometry. RFA registers electric component of the plasma emissions in the 100 kHz-15 MHz frequency band. In spite of initial problems with activation of the scientific payload, the instruments were finally turned on and first data have been obtained.

Apex and Coronas



Analysis of data from LEO satellites with Polish instruments provided following new results: examination of wave spectra from the APEX and CORONAS satellites showed that quasi permanent banded structure with characteristics expected for upper hybrid emission occurs below the local plasma frequency for $f_n/f_c > 2$ (f_n -

plasma frequency, f_c - electron gyrofrequency). The spectral content of this structure is related to input circuit resonance and satellite plasma interaction. Strong emissions in the frequency range of fast magnetosonic mode were used as an indicator of wave activity within extended, shallow auroral cavity characterized by weak changes of local plasma frequency in the interval $f_n \sim (1.3 f_c, 1.6 f_c)$. The divers, multi banded and broadband spectral structures extending from f_c well beyond the upper hybrid band were found and have been assigned to electromagnetic emissions of the auroral plasma. Observations pertain to very high magnetic activity.

Interpretation and modeling of ionospheric phenomena to build physical basis for space weather prediction was also carried on, in the frame of COST programs (European Cooperation in the field of Scientific and Technical Research).

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Herschel



SRC PAS participates in design and manufacture of the biggest Herschel mission's instrument – HIFI – Heterodyne Instrument for Far Infrared, lead by prof. Thijs de Graauw from SRON-Groningen. The consortium of Max Planck Institute fuer Radioastronomie from Bonn, Jet Propulsion Laboratory from Pasadena, COM DEV from Toronto and

SRC PAS had to deliver the HIFI Local Oscillator Subsystem - the programmable source of 600 to 2000 GHz frequencies. SRC is responsible for delivery of main Local Oscillator (LO) controller - HLCU block. In 2004 year the final set of qualification tests of HLCU Qualification Model (QM) was successfully performed. The Delta Critical Design Review (CDR) of HIFI Local Oscillator Subsystem, including final approval of HLCU design, has been formally passed. HLCU QM block was successfully integrated with the rest of HIFI QM in SRON, Groeningen. As a result of a year-long intensive works with participation of SRC staff in Bonn, Germany, the new approach of implemented. The proper controlling the LO Subsystem has been agreed and modifications of HLCU software were tested. The engineering model of "LCU-LSU Interface Board", the HLCU Simulator and the software used for HLSU commanding have been tested and delivered to COM DEV in Canada. After CDR approval, the production of HLCU flight and spare models started. The full set of technical documentation of HLCU flight model and flight spare model has been prepared. The first flight PCB's have been manufactured.

Scientists from the Nicolaus Copernicus Astronomical Center (NCAC) PAS are in the international scientific teams for realization of astrophysical scientific programs. The three Guaranteed Time Key Projects in which scientists from NCAC are involved include: 1) PRISMAS : PRobing InterStellar Molecules with Absorption line Studies; 2) HIFISTARS: The physical and chemical properties of circumstellar environments around evolved stars; and 3) The HEXGAL (Herschel EXtraGALactic) Key Project: Physical and Chemical Conditions of the ISM in Galactic Nuclei.

Scientists from SRC PAS are in the international team that works on the Guaranteed Time Key Project entitled "Water and Related Chemistry in the Solar System", devoted to studies of planetary and cometary atmospheres. Studying water in the solar system bodies will provide key information about their formation and evolution.

BepiColombo

The new infrared spectrometer MPO-MERTIS for ESA/JAXA Bepi Colombo mission is recently in the SRC PAS's engineering workshop, the instrument built in cooperation with Germany (University Münster and DLR, Germany). In the frame of the project "The pointing system for orienting the measurement direction of the MERTIS spectrometer of the Bepi Colombo mission for spectral measurements of the Mercury surface and calibration" following tasks have been performed: the laboratory model was designed and manufactured; functional and thermal tests were carried out using EGSE developed for this model; based on test results a new development model was designed and is under manufacturing.

Obstanovka and ASIM on the International Space Station

Obstanovka experiment:

The aim of Obstanovka experiment aboard ISS is to monitor and diagnose the electromagnetic radiation and plasma properties around the station, simultaneously at two different points. This will enable to develop a theory of interaction of the surrounding plasma with the station and will serve for application purposes in space technology. To achieve these goals the Plasma Wave Complex (PWC) was constructed by the scientific groups from Bulgaria, Hungary, Poland, Russia, Sweden, UK and Ukraine. The Radio Frequency Analyzer (RFA) has been developed jointly by SRC PAS and IRF in Uppsala. New digital technology of this instrument creates excellent possibility for monitoring and diagnosis of EM emissions in space and time domain.

ASIM experiment:

In the ASIM/Columbus/ISS project SRC PAS collaborates with the University of Bergen and the University of Valencia in building the Miniature X-ray and γ -ray Sensor. SRC is responsible for instrument's Power Supply Unit (High- and Low Voltage) and autonomous (FPGA based) Housekeeping System. The project is actually in phase B – the first documents of requirements and specifications were delivered to ESA in 2007. The design and manufacturing of the prototypes have been already started.

Chandrayaan-1



In the frame of India/ESA Chandrayaan Project to the Moon, the infrared spectrometer SIR-2 has been designed and manufactured in MPS/Lindau, University of Bergen, and SRC PAS. The SRC team was responsible for the delivery of the 10 W Power Supply Unit, the Programmable Current Source for the IR detector cooler, and the electronic Housekeeping System. The flight model of SRC blocks was integrated with the rest of flight electronics in Lindau. The complete set of environmental tests was successfully performed by the SIR-2 consortium, in Spring 2007. Full instrument was delivered to Bangalore in India and has passed all tests. The integration of the payload and the satellite passed smoothly. Chandrayaan-1 was launched on October 22, 2008 and entered the lunar orbit as planned on November 08. SIR-2 was commissioned successfully on November 19. The instrument was switched

on and sent back housekeeping data indicating normal functionality. Science observations were started successfully on 20 November.

UNAMSATMAI

Engineers from SRC PAS are involved in building the radiospectrometer for the Mexican-Russian new series nanosatellite which is planned for launch in 2009 and will carry the plasma and wave instruments (produced in cooperation with Sweden).

NASA IBEX

Theoretical studies and numerical simulations were undertaken in SRC PAS for the NASA IBEX (Interstelar Boundary Explorer) mission and the long-term envisioned ESA HEX (Heliospheric Explorer) project. Ulysses data were used to the study solar wind non-linear dynamics and turbulence, and SWAN/SOHO observations to infer the latitudinal anisotropy of the solar wind and its variations with the phase of solar activity cycle. Polish researchers participated in a multi-national, cross-experiment effort coordinated by the International Space Science Institute in Bern, Switzerland, and devoted to establish the velocity vector of the Sun with respect to the Local Cloud of interstellar gas and the temperature of this cloud, the key parameters for heliospheric physics. About 80 scientific reports were published in 2003–2007 by Polish researchers in the field of heliosphere physics, in which SRC PAS is one of the leading groups in the world.

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2. SATELLITE GEODESY

Compiled by Stanisław Oszczak and Stanisław Schillak

Introduction

This part of the Polish National Report on Satellite Geodesy is the report of works on advanced space techniques performed in Poland in a period from 2003 to first half od 2008. The activity of the Polish institutions in the field of satellite geodesy and navigation are concentrated on the several main tasks:

- global and regional GPS and SLR measurements in the frame of International GNSS Service (IGS), International Laser Ranging Service (ILRS), International Earth Rotation and Reference Systems Service (IERS), and the European Reference Frame Permanent Network (EPN),
- Polish Active Geodetic Control ASG-EUPOS,
- modeling of ionosphere and troposphere,
- practical utilization of space techniques in local geodesy,
- application of the Global Navigation Satellite System (GNSS) in overland, maritime and air navigation,
- time service for Galileo.

These activities were conducted mainly at the following research centers listed below:

- Institute of Geodesy and Geoinformatics, Wrocław University of Environmental and Life Sciences;
- Department of Mining Geodesy and Environmental Engineering, AGH University of Science and Technology in Cracow;
- Department of Planetary Geodesy, Space Research Centre of the Polish Academy of Sciences (SRC PAS) in Warsaw;
- Institute of Geodesy, University of Warmia and Mazury in Olsztyn;
- Department of Satellite Geodesy and Navigation, University of Warmia and Mazury in Olsztyn;
- Institute of Geodesy and Cartography in Warsaw;
- Institute of Geodesy and Geodetic Astronomy, Warsaw University of Technology;
- Polish Naval Academy in Gdynia;
- Gdynia Maritime University;
- Maritime University of Szczecin;
- Polish Air Force Academy in Dęblin.

This Report was compiled from information reported in a period from 2003 to 2008 by the correspondents from Polish institutions dealing with different use of satellite navigation systems and corresponding scientific research and experimental development. The bibliography of related works is given in the references.

Satellite Laser Ranging

The Satellite Laser Ranging station in Astrogeodynamic Observatory of the Space Research Centre, Polish Academy of Sciences at Borowiec (ILRS 7811) collected, produced and delivered during 2003–2008 over 70000 normal points to the scientific user community, tracking almost 5000 successful passes of 27 satellites in the framework of the International Laser Ranging Service (ILRS) and EUROLAS Consortium. The data quality in the form of an average single shot RMS, normal points RMS, and Analysis Center orbital RMS-fit were equal to 20 mm, 4 mm and 14 mm, respectively. Data acquired at Borowiec SLR station supported scientific missions of SLR satellites and were used for orbit calculations by majority of Analysis Centers.



The Satellite Laser Ranging station in Borowiec near Poznan.

The important upgrading of the Borowiec SLR system was executed in 2007–2008. It consisted in, in particular, setting new optical parts in transmitting and receiving channels, the installation of a new MCP-PMT detector and a new gating system, the implementation of the Consolidated Laser Ranging Prediction Format (CPF) and modernization of the software (Kucharski, 2006). Ability to reach high orbiting satellites (GIOVE-A, GPS, GLONASS, ETALON) was an effect of such an upgrading. The detailed analysis of the SLR error sources were presented in the several papers and presentations (Schillak, 2004, 2005). The determination of spin parameters of the several SLR satellites on the base of the data of kilohertz laser ranging in Graz has been done (Kucharski *et al.*, 2007, Kirchner *et al.*, 2008).

The determination and analysis of the station coordinates was continued in the Borowiec Observatory. The positions and velocities of the Borowiec SLR station (Schillak, 2004) and the coordinates of all SLR stations in a period from 1993.0 to 2004.0 were determined (Schillak and Wnuk, 2004, Schillak and Michałek, 2006). Two real position displacements in horizontal plane as result of the earthquake were detected; for station Tateyama (Schillak *et al.*, 2006), and station Arequipa (Schillak and Wnuk, 2003). The station positions stabilities were used for quality control of the SLR stations (Schillak, 2005). The comparison between two reference frames, ITRF2000 and ITRF2005 was presented (Schillak, 2008). The differences of the station positions and velocities between SLR and GPS techniques were estimated (Schillak and Lehmann, 2008). Determination of the Low Earth Orbit (LEO) satellite orbits and calculation of the station coordinates from the data

of LEO satellites were the next tasks in the field of orbital analysis. The orbital RMS-fit determined from the LEO satellites Starlette and Stella for 10 days arcs was lower than 2 cm, the station coordinates calculated from those orbits were comparable with LAGEOS data (Lejba *et al.*, 2007).

Active GNSS Station Network in Poland

Permanent GPS stations of IGS and EUREF network operate in Poland since 1993. Recently 6 permanent GPS stations, i.e. Borowa Góra (BOGI), Borowiec (BOR1), Józefoslaw (JOZE, JOZ2), Lamkówko (LAMA), Wrocław (WROC) operate in Poland within the IGS network (Tab. 1), among them two Reference IGS Frame stations BOR1 and JOZE. The EUREF Permanent Network (EPN) include 15 IGS and Polish ASG-EUPOS stations (Fig. 2).

Permanent GPS stations in Poland together with such stations in Europe were the basis of networks that are used for both the research and the practical use in geodesy, surveying, precise navigation, environmental projects, etc. (Kryński *et al.* 2003, 2004, 2005, 2006). Data from these stations are transferred via internet to the Local Data Bank for Central Europe at Graz, Austria and to the Regional Data Bank at Frankfurt/Main, Germany.

The permanent GPS/GLONASS station "Wroclaw" has been included since 2003 to IGS global network and its data are used for determination of the following IGS products: final and rapid GPS orbits and clocks, final ionosphere models, and GLONASS orbits. The team from Wrocław University of Environmental and Life Sciences participated in the Special Project "Time Series for Geokinematics" – studies on connection of local geodynamic networks with the EUREF permanent network and the correlation between velocities and station's location (Bosy *et al.*, 2003; Cacoń *et al.*, 2003; Cacoń *et al.*, 2004; Kontny 2004).

The European Geostationary Navigation Overlay Service (EGNOS) station in Space Research Centre in Warsaw continued measurements as one of the 34 Ranging and Integrity Monitoring Stations (RIMS) in Europe.

Data from 60 permanent GPS stations of EPN are processed on daily basis at the EUREF Local Analysis Centre of Warsaw University of Technology (WUT EUREF LAC). WUT EUREF LAC as one of 16 local European analysis centres provides parameters for local and global model of the ionosphere and conducts works on determination of water vapour content in the troposphere.

4 char Station ID	Domes Number	Location / Institution	Receiver / Antenna	Started operating	Meteo / Rec. device	Data transfer blocks	Additional observations	
		Borowa Gora	Javad JPS		Yes	24 h	Ground water	
BOGI	12207M003	Inst. of Geodesy	Eurocard	06MAY2003	06MAY2003 LAB- EL	LAB-	- 24 II 1h	level
		and Cartography	ASH700936C_M			EL		Astrometry

Table 1. Permanent IGS GPS stations in Poland (2008).

4 char Station ID	Domes Number	Location / Institution	Receiver / Antenna	Started operating	Meteo / Rec. device	Data transfer blocks	Additional observations
			SNOW		Poland		Gravity GPS/GLONASS
BOR1	12205M002	Borowiec Space Research Centre, PAS	Rogue SNR-8000 Trimble NetRS AOAD/M_T	01JAN1994 08JUL2007	Yes Skye Instrum ents Ltd	24 h 1h	SLR GPS/GLONASS Time Service
JOZE	12204M001	Jozefoslaw Inst. of Geodesy and Geod. Astr., WUT	Trimble 4000SSE TRM14532.00	03AUG1993	Yes LAB- EL Poland NAVI Ltd. Poland	24 h 1h	Ground water level Astrometry Gravity tidal GPS
JOZ2	12204M002	Jozefoslaw Inst. of Geodesy and Geod. Astr., WUT	Ashtech Z18 ASH701941.B SNOW	02JAN2002	Yes LAB- EL Poland NAVI Ltd. Poland	24 h 1h	Ground water level Astrometry Gravity tidal GPS/GLONASS
LAMA	12209M001	Lamkowko Inst. of Geodesy, UWM	Ashtech ZXII3 ASH700936F_C SNOW	01DEC1994	Yes LAB- EL Poland	24 h	Gravity GPS
WROC	12217M001	Wroclaw University of Environmental and Life Sciences	Ashtech Z18 ASH700936D_M	28NOV1996	Yes LAB- EL Poland	24 h 1h	Ground water level GPS/GLONASS

Since 1995 two permanent reference DGPS stations, Dziwnow and Rozewie (Table 1) are distributing RTCM corrections *via* mediumwave radio broadcasting. They are located on the Southern Baltic seashore. The central station in Gdynia, controlling Dziwnow and Rozewie DGPS stations, operates at the Maritime Office.

Table 2. DGPS stations in the Southern Baltic seashore.

Station	Geographie	Nominal range	ERP	
Name	coordinates	Official data (in Nm)	True data (in Nm)	(W)
Dziwnow	54°01' N, 14°44' E	90	55	Dziwnow
Rozewie	54°49' N 18°20' E	90	100	Rozewie

Polish Active Geodetic Control – ASG-PL and ASG-EUPOS

A sub-network of the ASG-PL, Polish Active Control, with a processing centre was established by the end of 2002 in Upper Silesia as a pilot project of

governmental and local (regional Silesian) authorities (Góral, Jasiurkowski, 2005; Krynski *et al.*, 2003, 2004, 2005). In February 2003 it has reached a preliminary operational stage. It became fully operational in December 2003. The map of this network is given in Fig. 1. The network consists of 6 permanent stations (two of them: KATO and ZYWI have been accepted in 2003 as EPN stations) and is recently linked to EPN (BOGI, BOGO, BOR1, JOZ3, JOZE, KRAW, LAMA, LAM6, WROC) stations and six other permanently operating GPS stations (CBKA, GDAN, INS1, POZN, WLAD, KWBB) that provide GPS data at 5 s sampling rate.



Figure 1. Polish Active Control Network ASG-PL (2003-2007).

Observations were acquired at 1 sec sampling rate and stored in the RINEX2 format. Data of each station, downsampled to 5 s rate are transferred in hourly blocks via Frame Relay transmission using POLPAK network to the ASG-PL Processing Centre in Katowice. The receivers at ASG-PL stations can also generate the RTK corrections in the RTCM v.2.1 format.

Some improvements of the processing module used by the ASG-PL Processing Centre in Katowice worked out by the SRC PAS were implemented. They consist in the modification of evaluation method of ionospheric and tropospheric corrections using close EPN stations beyond the Polish territory, the improvement in checking procedure by comparison with the independent calculation using different set of reference points, some changes in the algorithm for selection of reference points taking into account the geometry of the solution and the quality of observations, and developing the procedure for control compatibility of observations with requirements of the ASG-PL. The continuation of the ASG-PL is the ASG-EUPOS network started from 1 May 2008. 98 permanent GPS stations in Poland are operational in 2008 (Fig. 2), 1600 users are registered (as of 17 July 2008). The Processing Centre provides GPS solutions for the network stations on daily basis. It also provides a continuous service for the users *via* internet.

The European Project EUPOS (*European Position Determination System*) consists in establishment of about 430 multifunctional satellite reference stations in Central and Eastern Europe. Fourteen European countries participate in the project. The project include the existing or developed infrastructure in participating countries. The system will use the standard signal of the European system Galileo as the basis, as soon as it is available, and then will be optional for GPS and GLONASS.



Figure 2. Polish ASG-EUPOS stations.

The network of reference stations provide a signal for both the positioning of geodetic control points and for land, air and marine navigation. Several levels of

positioning accuracy is offered. The project was consulted with the representatives of European Commission, Brussels, at the EU INTERREG IIIC East Joint Technical Secretariat, Vienna, Austria, and at the UN Office of Outer Space Affairs (OSA), Vienna and got positive assessments and supports.

In December 2004, a proposal was submitted to the Polish Ministry of Science and Information Technology with the request for financial support from the programme ERDF (European Regional Development Found). The establishment of the Polish reference network ASG – EUPOS started in 2008. The Surveyor General has been authorised by the Minister of Infrastructure to coordinate all actions related to establishment of the ASG – EUPOS system in Poland and to cooperate with other countries on integration of the system with the European positioning system EUPOS.

Activity within the EUREF-IP Project

Józefoslaw, Kraków, Wrocław and Borowa Góra stations (Kryński *et al.*, 2004, 2005), took part in the EUREF IP pilot project (Tab. 3). In the AGH University of Science and Technology in Cracow the broadcaster was established in January 2005.

Location	Appr. lat. [deg]	Appr. long. [deg]	RTCM message types (update rate [s])	Bitrate [bits/s]	Site log File
Krakow	50.01	19.92	1(1),3(30),16(60),18(1),19(1),22(60)	1900	KRAW
Jozefoslaw	52.10	21.03	1(1),3(60),18(1),19(1),22(60),31(1)	1200	JOZ2
Borowa Gora	52.48	21.04	1(1),3(60),18(1),19(1),22(60),31(1)	1200	BOGI
Wroclaw	51.11	17.06	1(1),3(30),9(1),18(1),19(1)	6000	WROC 0

Table 3. Characteristics of Polish stations participating in the EUREF IP pilot project.

Some practical test with RTK and DGPS survey using the IP technology and mobile phone data transfer were conducted at the Institute of Geodesy and Geodetic Astronomy of the Warsaw University of Technology (Rogowski et al., 2004), at the Institute of Geodesy and Cartography in Warsaw (Cisak et al., 2004) as well as at the Dept. Satellite Geodesy and Navigation of the University of Warmia and Mazury.

The system of GPRS Tele-transmission for DGPS/RTK Station Network in Warmia and Mazury region, developed at the Dept. Satellite Geodesy and Navigation of the University of Warmia and Mazury consists of a network of GPS reference stations connected to the system's main server using IPSEC tunnels. The system's server collects data from all existing GPS reference stations, manages data and distributes them to mobile users in real time. Distribution of corrections is possible using different GSM operators in Poland, which makes the system fully independent. Each mobile receiver is connected to the main system server via GSM network and has pre-defined primary GPS reference station. In the case of failure of primary reference station the server detects an emergency and automatically switches the user to another nearest GPS station. Each GPS reference station in the network can be remotely controlled from arbitrary place all over the world. The system is fully compatible with all GPS receivers having RTCM option. The only need for a user is the GPRS modem with an active SIM card dedicated to server application (Oszczak B., 2005).

The RTCM Client software has been developed in the Institute of Geodesy and Geodetic Astronomy of the Warsaw University of Technology. The software provides a stable work and is easy to operate for the client. It operates at the moment in MS Windows environment (Rogowski et al., 2004).

The location of two EPN stations BOGI and JOZ2 taking part in the EUREF-IP pilot project is extremely suitable to provide the RTK corrections at any place of the capital of Poland with sub-decimetre accuracy. Studies on precise point positioning in the urban area using two NTRIP servers of EPN stations BOGI and JOZ2 were performed in the Institute of Geodesy and Cartography (Cisak et al., 2005).



Figure 3. The system of GPRS Tele-transmission for DGPS/RTK Station Network.

GPS Positioning of Moving Objects

Many applications of GPS positioning were tested in the Dept. of Satellite Geodesy and Navigation of the University of Warmia and Mazury in Olsztyn. They include the accuracy estimation of aircraft, airplane, boat, car and pedestrian trajectory with GPS methods. The analyses cover such GPS methods as: OTF post-processing mode, RTK, DGPS in real time/post processing and stand alone mode (Ciećko, Oszczak S., 2003; Popielarczyk 2005b; Uradzinski, 2004). Other experiments concern navigation and positioning of a moving vehicle with the use of GPS satellite system and the corrections from EGNOS satellites. Tests were performed in cooperation of University of Warmia and Mazury in Olsztyn, Poland; University of Trieste, Italy and Air Force Academy in Kosice, Slovakia (Oszczak S., *et al.*, 2003; Ciećko *et al.*, 2003b).

Many experiences of moving objects were gained from real-time GPS car monitoring during the European Rally Championships. In cooperation with rally teams special GPS/GPRS safety boxes were designed and made. Monitoring of all 7 rally stages with GPS receivers and method of calibrations of the maps were presented. (Oszczak B. et al., 2006).

In order to analyse the accuracy of two techniques of aircraft position determination, the radar and GPS/EGNOS satellite systems, during the en-route and approach phase of flight the experiments were carried out. The results obtained with the above methods were compared, which led to a conclusion that GPS receivers can be regarded as the primary navigation instruments (Grzegorzewski *et al.*, 2004; Oszczak S., 2006).

Troposphere and ionosphere studies

New algorithms and software for determination of tropospheric refraction were developed in the Academy of Metallurgy and Mining in Cracow. The proposed methodology does not require information on meteorological conditions in survey points. It has been indicated that the method is particularly effective for GPS projects in mountainous areas. The analysis of GPS data burdened with multi-track effect was carried out (Krankowski *et al.*, 2005).

In the Institute of Geodesy of the University of Warmia and Mazury in Olsztyn scientists are investigating the features of pre-earthquake ionospheric anomalies in the total electron content (TEC) data obtained on the basis of regular GPS observations from the IGS network. For the analysis of the ionospheric effects of the 26 December 2004 Indonesian earthquake, global TEC maps were used. The possible influence is discussed of the earthquake preparation processes on the main low-latitude ionosphere peculiarity – the equatorial anomaly. Analysis of TEC maps has shown that modification of the equatorial anomaly occurred a few days before the earthquake (Krankowski *et al.*, 2006).

The research on ionospheric delay to determine Total Electron Content (TEC) and to investigate the influence of TEC changes on the precision of positioning started in the University of Warmia and Mazurty in Olsztyn in 1995. The TEC can be obtained on the basis of the simultaneous two frequency observations at the

level of precision of $(2-3)*10^{16}$ el./m². GPS observations from IGS and EUREFF stations were used. Changes of TEC are monitored in many directions since the GPS solution requires at least 4 GPS satellites to be simultaneously observed. The study carried out at the minimum of solar activity shows that two frequency GPS observations are useful for monitoring periodical (daily and seasonal) changes of TEC and for monitoring TEC at solar storms periods. It turned out that during ionospheric disturbance periods at middle latitudes the TEC could rise three times over its normal value even at the minimum of solar activity. Changes of conditions in the ionosphere affect the propagation along the path between the satellite and the receiver. Related error in positioning can reach up to 0.5 m or more.

GPS observations carried out 1995–1997 at the permanent IGS stations Borowiec, Jozefoslaw and Lamkówko were used to create regional TEC model over Poland. The model is valid at the minimum of solar activity. The local ionosphere models over three mentioned IGS stations were used as the bases of the model. Daily changes of TEC were shown as expansion of Fourier series in function of local time and seasonal changes in function of the month. The model was checked by calculating the TEC value by back extrapolation. Differences amounted to 15– 40% depending on the month. The obtained discrepancies were interpreted as the result of long period changes of TEC that were not included in the model.

Other GNSS applications

The team of the Dept. of Satellite Geodesy and Navigation of the University of Warmia and Mazury in Olsztyn were involved in the application of DGPS/GPRS satellite navigation and hydrographic systems for monitoring and safety sailing on Great Mazurian Lakes (Popielarczyk, Oszczak S., 2003; Popielarczyk 2000a, 2000b). They had developed integrated technology of bathymetry surveying, which makes possible navigation of the small hydrographic boat along the pre-defined profiles, examination of bottom shape, computation of water volume, elaboration of bathymetric charts and monitoring of dangerous shallow places. For the developed Integrated Bathymetric System a number of professional equipment units is used like: the DGPS/RTK/GPRS receivers, EA 501P Simrad single frequency digital echo sounder, SportScan side scan sonar and special GPS/CAD software.

They were involved in development of GPS positioning methods for the calibration of satellite images (Bakula and Oszczak S., 2003), in the accuracy and efficiency aspects of DGPS and RTK method in hard observational conditions (Bakula 2003, 2004, Bakula, Oszczak S., 2006; Ciećko *et al.*, 2003a) and the use of VRS and ASG-PL Network (Bakula, 2006).

The University of Warmia and Mazury itself takes part in the project of practical application of EGNOS and Galileo systems in agriculture entitled "Introduction and Promotion of GNSS in Agriculture" (acronym FieldFact), a project financed by the European 6th Framework Program.

The team from the Faculty of Mining Surveying and Environmental Engineering of AGH University of Science and Technology in Cracow makes investigations on application of newest technology of satellite measurements in realization of geodetic tasks.

A new system developed by University of Warmia and Mazury in Olsztyn for creation of Digital Terrain Model is based on GPS and GSM/GPRS technology. Precise RTK method is used for real time determination of horizontal and vertical coordinates of the points used in the model (Ciećko *et al.*, 2006a, 2006b).

The main goals of experiments performed in Pompeia's archeological site were as follows: a) establishment of GPS control point network on the streets of this ancient city; b) examination of GPS/RTK OTF method with different types of receivers and teletransmission lines; c) examination of EGNOS (ESTB) performance and positioning accuracy (Manzoni G., *et al.*, 2004). These experiments were conducted jointly by the teams of Italian Universities in Trieste, Napoli Seconda, Salerno, Catania, Cagliari, Pisa and Padova and the team of the Dept. of Satellite Geodesy and Navigation of the University of Warmia and Mazury in Olsztyn.

To enhance the accuracy of the height anomaly in southern Baltic, altimetryderived, sea-borne and airborne gravity anomalies were used as well as the terrain data. The results of different modelling methods were compared with each other, as well as with existing gravimetric and GPS-levelling quasigeoid models (Jarmołowski 2005a, 2005b). (See also other papers on sea altimetry: Kierulf et al. (2008), Niedzielski and Kosek (2005); Niedzielski and Kosek (2008)).

The system of four permanent stations in the northern part of Poland was build and the teletransmission of data via GSM/GPRS for RTK and DGPS survey using the IP technology and mobile phone data transfer were developed and implemented to practice at the Dept. of Satellite Geodesy and Navigation (Oszczak B. 2005; Ciećko *et al.*, 2006a, 2006b).

The works in satellite navigation were concentrated on the realization of the several tasks: Telecommunications Research Institute performed the accurate measurements of the way by the special GPS car on the accuracy level of 1 meter. Gdynia Maritime University is applying geodesy satellite technologies in navigation, hydrography and marine traffic engineering. The research is focused on precise navigation in restricted waters and hydrographic surveys in waterways. The University of Warmia and Mazury and the Air Force Academy in Dęblin built the tool of control of airplane traffic by GPS and EGNOS systems, especially in the landing phase.

Time service for Galileo

The activity of the Time and Frequency Laboratory of the Astrogeodynamic Observatory of the Space Research Centre at Borowiec concentrated on time system for Galileo and development of technologies for time and frequency measurements. All these activities will support the Galileo program. The infrastructure of the Borowiec Time and Frequency Laboratory has recently been upgraded to two cesium frequency standards, two hydrogen masers, Galileo receiver and two-way method of time comparison. The time comparison with several time laboratories by two-way method (geostationary satellite) was on the level of 200 picoseconds. The Borowiec Time and Frequency Laboratory participate in three Galileo projects: "Precise Time Facility", "Galileo Time Service Provider Prototype" and "Harrison".

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4.REMOTE SENSING

Compiled by Jan Olędzki

Remote sensing activity in Poland concentrated in several academicdidactic-and-research centres. It covered several fields. Basic research activities and staff education were carried out at universities and technical universities.

At the time of the reporting period, four doctoral theses were completed at the University of Warsaw, at the Faculty of Geography and Regional Studies, Department of Geoinformatics and Remote Sensing. The subjects covered were as follows: <u>B. Zagajewski</u> – Application of Geoinformatics in the Research of Abiotic Environment Components Influence upon Positioning of Vegetation in the National Park of Narew and in its Close Surrounding (Zastosowanie geoinformacji w badaniach wpływu abiotycznych komponentów środowiska na rozmieszczenie roślinności w Narwiańskim Parku Narodowym i jego otulinie); B. Błach-Woś – Changes in Terrain Cover in Chosen Gminas of the Beskid Mountains in the Second Half of the XX Century basing on the Analysis of Air Images (Zmiany pokrycia terenu w wybranych gminach Beskidów w drugiej połowie XX w. na podstawie analizy zdjęć lotniczych); M. Krówczyńska – Using Spectral and Structural Characteristics of Objects Reproduced on Satellite Images in Land Exploitation Mapping (Wykorzystanie spektralnych i strukturalnych cech obiektów odwzorowanych na zdjęciach satelitarnych w kartowaniu użytkowania ziemi); D. Ziółkowski – Environmental Conditions for Effectiveness of Radar Interferometry in the Research of Mass Movements in Mountain Areas (Srodowiskowe uwarunkowania efektywności interferometrii radarowej w badaniach ruchów masowych w terenach górskich); M. Sobczak – Hyperspectral Method of Alpine Vegetation Research and Mapping (Hiperspektralna metoda badania i kartowania roślinności wysokogórskiej).

At present, a PhD research is carried out and two subsequent doctoral theses are under way. Also two habilitation dissertations are being prepared referring to hyperspectral methods in the research of the environment and in the field of remote sensing research of forests in Poland. 36 master theses and 33 baccalaureate papers were also accomplished in this period.

Department of Geoinformatics and Remote Sensing of Warsaw University is a leading academic centre in Poland carrying out research within the scope of hyperspectral methods, cooperating with such German research centres as Humboldt State University and German Space Agency (DLR). The Department also specializes in applying aerial and satellite images in the research of environment structure and its transformations. It is also a coordinator of research on land exploitation for the Integrated Monitoring of Natural Environment exploiting the data from Base Stations operating within the framework of State Monitoring of the Environment. Also works are carried out on applying remote sensing in research of forest areas and on methods of making geomorphological maps using aerial and satellite remote sensing and systems of geographical information.

The Department of Geoinformatics and Remote Sensing of Warsaw University in 2005 was entrusted with organization of the 4th Workshop SIGIS (Special Interest Group Imaging Spectroscopy) EARSeL "*New Quality in Environmental Studies*" which took place at the University of Warsaw on 26–29 April 2005. This was a convention of specialists in hyperspectral techniques (within the framework of European Association of Remote Sensing Laboratories EARSeL). Within the course of the convention 16 thematic (87 papers delivered) and 3 poster sessions (40 posters) took place, 6 key lectures were delivered (keynote talks). Subjects raised were as follows: new algorithms of data processing; new sensors for obtaining hyperspectral data (ground, aerial and satellite instruments) and the outcome of their operation; calibration methods and techniques of image registration equipment and measuring instruments; application of techniques and hyperspectral methods in the environment studies.

In the course of two additional round table meetings: *EnMAP* (new European hyperspectral environmental satellite) and *Mining & Environment*, directions of development of hyperspectral techniques were defined in the perspective of the next 5 years.

Warsaw University of Technology educates specialists within the scope of remote sensing in the **Institute of Photogrametry and Remote Sensing, the Laboratory of Remote Sensing and Systems of Spatial Information**. Doctoral theses have been undertaken here by five persons. Also, the research in methodical aspects of remote sensing is carried out (object classification, methods of atmospheric correction of CHRIS/PROBA data, geometrical correction of high resolution satellite images), and practical application of remote sensing: research of waters of the Mazurian lakes, marking out agricultural and environmental indicators, creating topographical data bases, and other applications. Two doctoral thesis were also completed: J. Pluto-Kossakowska – Analysis of SPOT Satellite Images Processing and Interpretation Methods from the Point of View of the Needs of the Soils Information System; E. Pilich-Blaquiere – Application of Satellite Images of Very High Spatial Resolution for Description of Diversified Structure Agricultural Areas.

Remote sensing team of the Warsaw University of Technology arranged exhibitions on the Days of Remote Sensing twice, in 2003 and 2006, entitled "Remote Sensing — Science or Art?" and took part in the Festival of Science in 2003 delivering its presentation entitled "Satellite Images in Service for Society".

At the Adam Mickiewicz University of Poznan education of specialists and research works are carried out by two entities: the Department of Environmental Planning and Photointerpretation and the Department of Soil Science and Remote Sensing of Soils at the Institute of Physical Geography and Environmental Planning of the Faculty of Geographical and Geological Sciences. Also, the doctoral thesis was completed here by Gulzat Kokoeva entitled: *Interpretation of Saline Soils of the Czuj Valley in Kirgistan via Multispectral Landsat and Terra-Aster Satellite Images.*

At the University of Gdansk, within the Faculty of Oceanography and Geography, the Dept. of Physical Oceanography operates the Laboratory of Remote Sensing and Spatial Analysis. During 2003–2006, within the scope of remote sensing the following projects were carried out there:

- 1. Analyses of Solar Radiation Energy Inflow and of the Distribution of Temperatures on the Surface of the Baltic Sea Basing on Satellite Data.
- 2. Impact of River Suspensions upon Optical Characteristics of Water Zones of Direct Impact of the Vistula River Suspensions in the Gdansk Bay.
- 3. Characteristic Features of Spatial Diversification of the Quality of South Baltic Waters Basing on the Analysis Of "The Sea Colour".

These 3 projects were carried on in cooperation with the Institute of Oceanology of the Polish Academy of Sciences in Sopot. Employees of the Laboratory participated in many academic conferences where they presented the results of works in the field of remote sensing: Baltic Sea Science Congress 2003, Helsinki, 23–28.08.2003; European Aerosol Conference, Budapest, Hungary, 6–10 September 2004; Clouds Transmission Retrieval Over the Baltic by Use of Meteosat Data, Ocean Optics XVII, Fremantle, Western Australia, 25-29, 2004; Fifth Workshop on Luminescence & Photosynthesis of Marine Phytoplankton, Sopot-Krokowa 21-25 November 2005; ICES-IOC-SCOR Working Group on GEOHAB Implementation in the Baltic, 5-7 April 2006, Gdynia; local conferences like Polish Symposium of Geoinformation "Geoinformation an Integrated Tool for Spatial Research", Wroclaw-Polanica Zdroj, 15-17 September, 2003; Second Working Debate "Examination and Working out of a System of Satellite Monitouring of the Baltic Ecosystem", Mogilny 22-26.09.2003; Polish Scientific Conference: "Water Blooming - Monitoring and Control of Dangers", Gdynia, 20-21.04.2004; the conference summing up the PBZ-KBN 056/P04/2001 project Research and Working out of a System of Satellite Monitoring of Baltic Ecosystem, Sopot-Krokowa (22–25.11.2005).

At the **University of Szczecin**, the Department of Remote Sensing and Marine Cartography of the Faculty of Natural Sciences deals with remote sensing. The research subject matter of the Institution refers mainly to analysis of circulation systems of the coastal zone with the use of aerial and satellite images; remote sensing analysis of surface currents and of southern upwelling of the Baltic sea; remote sensing analysis of morphodynamics of the coastal zone, remote sensing multispectral research of the environment of Pomorze Zachodnie.

At the AGH University of Science and Technology in Krakow, remote sensing activity is concentrated in the Dept. of Geoinformatics, Photogrammetry and Environment Remote Sensing, and covered works connected with the

enhancement of the didactic process by elaborating new handbooks or monographies. Basic research was also carried out in the subjects as follows: remote sensing monitoring of the environment in the area of saline diapirs with the use of satellite images; analysis of usefulness of multispectral aerial images for photogrametric inventory of spatial structures in the stand of trees; hyperspectral remote sensing in the research of soil degradation; obtaining a numerical model of topographical surface based on the altitude data originating from the aerial laser scanner; examination of temperature distribution of the surface of the terrain with the use of thermovision images. Four doctoral theses have been recently defended at the Department: U. Marmol – Filtration of Altitude Data Originating from the Aerial Laser Scanner; T. Pirowski – Assessment of Usability of Integration Methods of Remote Sensing Images Obtained with the Use of Various Sensors; W. Drzewiecki – Landscape-and-Ecological Analysis of the Mode of Terrain Exploitation with the Use of Geographical Information Systems and Remote Sensing Data; S. Mikrut – Impact of Scanning and JPEG Compression upon Detecting Linear and Point Objects on Digital Images.

At the University of Silesia two academic units deal with remote sensing. These are: Laboratory for Collection and Interpretation of Satellite Images at the Dept. of Climatology and Laboratory for Environment Remote Sensing at the Dept. of Geomorphology, both within the Faculty of Earth Sciences. The Laboratory for Collection and Interpretation of Satellite Images is equipped with the satellite station SKYCEIVER WIN - HRPT system of the Swiss company TECNAVIA. Basic scope of operations of the station covers archiving of NOAA satellite data transmissions in the raw data format and the MODIS radiometer data (of Terra and Aqua satellites,) on CD-ROM and DVD magnetic carriers what enables their use in the future by the employees and students of the University of Silesia, and also by all interested users, in the frame of mutual cooperation. Works on implementation of collection of satellite data retransmitted in the EUMETCast system within the EUMETSAT organization are going on, too. Accessible archive data are used in research projects in the scope of satellite climatology. Up to now, basing on them several master theses originated (dynamics of changes of snowy cover in Poland, thermology of urban isles of heat of chosen cities in Poland, dynamics of cyclonal structures over Europe, occurrence of cellular and wave cloud cover in the chosen parts of Europe) and two doctoral theses (spatial structure of weather elements over the alpine areas of Europe and extent of arctic aerial masses advections in Europe). Activity of the study focuses upon analyses of dynamic changes of chosen weather elements over the alpine areas of Europe basing on satellite data with reference to ground data. This especially refers to the area of the Carpathian Mountains, where at present analysed are temporal and spatial distribution of wavy cloud covers since the beginning of XXI century. Results of works are presented at local and international conferences. One PhD thesis was accomplished here in 2005: A. Widawski – Spatial Structure of Chosen Weather Elements in the Alps and the *Carpathians in the Light of NOAA and METEOSAT Satellite Information.*

Separate remote sensing academic-and-didactic entities operate also at the **University of Warmia and Mazury** in Olsztyn – Department of Photogrammetry and Remote Sensing at the Faculty of Geodesy and Land Management, specializing among others in thermovision; at the **Jagiellonian University** in Krakow – Department of Geographical Information Systems, Cartography and Remote Sensing of the Institute of Geography and Spatial Management, dealing with application of remote sensing in natural sciences and running didactic classes in remote sensing and photointerpretation on the basic level; at the **Nicolaus Copernicus University** in Torun – Department of Cartography, Remote Sensing and GIS of the Institute of Geography.

Department of Forest Ecology of the Forestry Faculty at the University of Agriculture in Krakow and Institution for Spatial Information Systems and Forest Geodesy of the Faculty of Forestry of Warsaw University of Life Sciences (WULS – SGGW) also deal with the subject matters of photogrammetry and photointerpretation in forestry economy.

In the Institute of Geography and Spatial Organization of the Polish Academy of Sciences, the doctoral thesis was completed in 2006 dealing with issues of remote sensing within the scope of basic research. The defended thesis of <u>Pawel Prokop</u> was entitled *Degradation of Natural Environment of the Southern* Slope of the Meghalaya Upland in India (with the application of GIS and methods of remote sensing).

In Poland four entities address practical aspects of remote sensing:

- 1. Institute of Geodesy and Cartography (IGiK) Department of Remote Sensing which carried out research projects as follows: working out the models of growth and development of corn in Poland with the application of data obtained via remote sensing; working out a method of obtaining image information for the needs of drawing up detailed maps of land exploitation; analysis of conditions for distinguishing crops reproduced on microwave satellite images as the basis for drawing up maps of terrain exploitation; assessment of usability of images produced by ASAR and MERIS, a new generation of image radiometers, for the examination of moistening of marshy areas; working out methods for specifying changes in land exploitation based on analysis of multi-temporal high resolution satellite images. Institute of Geodesy and Cartography was the organizer of the 26th EARSeL international symposium in 2006.
- 2. Space Research Center of the Polish Academy of Sciences (SRC PAS) carried out construction works of remote sensing instruments for planetary ESA missions Mars Express (PFS) and Venus Express and within the course of doctoral studies several theses on using remote sensing in research of the environment of Mars have been defended. Recently, work is underway in SRC PAS on a similar instrument Mertis for ESA BepiColombo mission to Mercury, built in a cooperation with the University of Münster. In the scope of remote sensing research and development activity, SRC PAS is also involved

in the European space application program GMES – Global Monitoring for Environment and Security. In 2003, SRC PAS was awarded with a 6^{th} FP Specific Support Action "GMES Poland" and played a role of the focal point of the GMES activities in the new member states. Lessons learned in this project have resulted in invitations to a number of other European initiatives, mainly in the 6^{th} and 7^{th} FP:

- TANGO project to develop, integrate, demonstrate and promote new satellite telecom services for GMES
- LIMES security-related project, in which SRC manages Land Border Monitoring activity
- ASTRO+ (Security) integrating space technologies into security operations in the framework of 7th Framework Program. SRC organized field demonstration near Warsaw
- GEOLAND-2 big European project to develop GMES operational services on land monitoring; SRC manages seasonal and annual monitoring core service
- G-MOSAIC a pilot GMES service on security; SRC is involved in monitoring migrations routes from Africa to Europe
- PEARL a project dedicated to developing a port monitoring system that employs satellite observations, airborne data and in-situ measurements. The PEARL project is a model example of Polish involvement in European Union research programs. This STREP-type project was won by a consortium of six European partners led by Spanish company ATOS. When the project was prepared SRC has not yet acquired the expertise on operational use of space technology as it has got now. Therefore it has been charged with the task of dissemination the result of the project and to prepare the plan of exploitation of the developed system. In this role SRC gained an opportunity to learn how the complex technological application system is developed, tested and implemented in close contact with potential end users. In the future projects, SRC and Polish industry should benefit from the PEARL experience.
- 3. Institute of Land Reclamation and Grassland Farming Dept. of Regional Studies for Development of Rural Areas, which among others deals with the perfection of methods of computer processing of data from satellite and aerial imaging instruments.
- 4. Institute of Meteorology and Water Management (IMGW). In 2003–2007, in its Center of Satellite Teledetection in Krakow a number of works were performed on the system of collection, processing and distribution of data recorded from the system of meteorological satellites. At present, collected data (directly from satellites or indirectly via the EUMETCast satellite system) are from geostationary satellites METEOSAT-6, 7(0°), 8 (3.4° W) and 9 (0°), GOES-E (75° W) GOES-W (135° W), MTSAT-1R (140° E), METEOSAT-5 (63° E), METEOSAT-7 (57° E since October 2006); from circumpolar satellites NOAA-12, 14, 15, 16, 17 and 18; from Chinese satellite Feng Yun 1D, and

from the satellite METOP-1. As a result of carried out research and development works, IMGW operationally uses many new products of satellite data processing. Within the framework of EUMETSAT licence activities, in 2003–2007 licences were granted to collect data from the METEOSAT system to recipients using the data for educational purposes and for research projects. Currently, apart from IMGW eight other institutions possess licences and collects data from METEOSAT European meteorological satellites. Poland will become a full Member State of EUMETSAT in 2009 after having been a Cooperating State since January 2000. As a Member State, Poland will participate fully in EUMETSAT data and products for official duty use, and its industry will be able to bid for contracts. Poland will participate in all EUMETSAT mandatory programmes.

Among commercial remote sensing companies, a vital place in Polish remote sensing take the following firms:

GEOSYSTEMS Polska, which is the geoinformatic company acting on the market since June 1995. It specializes in operationally applied geographical imaging of terrain for the needs connected with the creation and use of geographical information Systems (GIS). Since its origin GEOSYSTEMS Polska was the authorized distributor and technological partner of the world leading producer of image processing systems – ERDAS. Inc. This role has been still fulfilled after taking the company over by the corporation LEICA GEOSYSTEMS GIS AND MAPPING DIVISION in 2001. GEOSYSTEMS Polska is also a distributor of satellite data from satellites: SPOT, Landsat, KVR-1000, IRS, and of RADARSAT Inc. products in Poland. The company accomplishes research, development, and implementation works and realizes pilot projects within the scope of applications of telegeoinformatics. It also deals with propagating knowledge and technology of GIS among interdisciplinary user circles (technical advisory, expertises, consultations, training, etc.).

SCOR S.A. The Company was registered in 2004 as a Satellite Centre for Regional Operations (Satelitarne Centrum Operacji Regionalnych S.A.). It is the operator of Polish ROC station (Regional Operation Center). The task of Company is programming in the contracted term the Earth imaging satellites, such as IKONOS, IRS, Radarsat. The Company has the ability to process obtained images to the form of an orthophotomap and to perform analyses of differences on images originating from various sources. In the future it is also aimed to service an archive containing all data collected. SCOR is the most modern European remote sensing company offering its customers geographic data, and products based on satellite imagery. SCOR owns and operates the most modern and sophisticated satellite ground station in Europe. Its capability serves the national demand for very high

resolution imagery intended for national security, homeland defence, emergency responding, environmental monitoring, spatial planning, and many other purposes. In addition to operating Satellite Ground Station, SCOR is a leader on Polish market in photogrammetry and advanced image processing and analysing. **SCOR** offers a large spectrum of imagery products derived from different satellite and airborne sensors.

In Poland, two social organizations dealing with remote sensing exist. These are The **Polskie Towarzystwo Fotogrametrii i Teledetekcji** (Polish Society of Photogrammetry and Remote Sensing) and **Klub Teledetekcji** (Remote Sensing Club) being the division of the **Polskie Towarzystwo Geograficzne** (Polish Geographical Society). These organizations arrange the cyclic scientific conferences devoted to remote sensing issues, independently or together with other scientific societies.

There are three Polish magazines serving the local science community within the scope of remote sensing:

- 1. **TELEDETEKCJA SRODOWISKA** in 2003–2007 six volumes appeared (33 38), including three monographies, recently the book *Geographical Regions of Poland* by J. R. Olędzki. Polish Geographical Society is the publisher. In the remaining volumes 27 articles were published.
- 2. Articles on remote sensing subject matter are also published in the magazine *ARCHIWUM FOTOGRAMETRII, KARTOGRAFII I TELEDETEKCJI*, whose publisher is the Polish Society of Photogrametry and Remote Sensing, in cooperation with the Club of Remote Sensing of the Polish Geographical Society and the Society of Polish Carthographers.
- 3. Remote sensing issues have also their columns in the magazine *GEOINFORMATICA POLONICA*. Within 2003–2007 four volumes appeared in which 14 articles were published on remote sensing issues which constitutes 45% of the total number of published articles.

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4. ASTRONAUTICS AND SPACE TECHNOLOGIES

Compiled by Józef Modelski

During the last five years, the main aims of the Commission of Astronautics and Space Technologies were connected with the investigation and development of new technologies and perspectives in consolidating the position of space techniques in the market of modern telecommunications. Another very important element of Commission's work was the education of a new scientific personnel working in the field of space technologies (students, members of the scientific teams). The last area of Commission's activity consisted in organizing workshops devoted to promotion of space technologies to the wide public. Main results of activity of Commission's members in past years can be summed up as follows:

The report on possibilities of utilization of Polish space orbital resources. The members of the Commission took active part during the preparation of the final report on possibilities of utilization of Polish resources on the geostationary orbit. The work was commissioned by the National Office of Regulation of Telecommunications and Post. In the report, the main information on the actual situation of the Polish orbital resources on the geostationary orbit were presented, along with the potential of using them in different areas of application. The document also stresses some issues connected with the perspectives of evolution of space technology and telecommunications in the world. The members of the Commission participated actively in the preparation of the final report, as well as the preparation of Annex 1 to this document, which presented the strategy of possible activities in the field of utilization of the space orbital resources to be followed in Poland under the accession to the European Union.

The concept of the design and development of the new mini-satellite. Under the auspices of the Commission, the research on concept, design and development of the mini-satellite was prepared. The research was the cooperative work of the Warsaw University of Technology, the University of Surrey, the Surrey Space Centre, and the Surrey Satellite Technology.

Patronage over the space technology scientific student teams. During the last few years, two student scientific teams started their active work in the field of space technologies under the auspices of the Commission. Both of these organizations exist at the faculties of the Warsaw University of Technology. A short description of the organization and activities of both teams is presented below:

Student Space Engineering Scientific Group

SSESG (Student Space Engineering Scientific Group) also known under its Polish abbreviation SKIK (Studenckie Koło Inżynierii Kosmicznej) is a student scientific group, which is formed by space technology enthusiasts at the Warsaw University of Technology, the Faculty of Electronics and Information Technology. For the last two years they have been doing their best to mark the Polish presence in the space technologies market and to increase the interests in this area among people in Poland. The current activities of SSESG are focused on building the core of an onboard data handling system for SSETI ESEO microsatellite. The group is also carrying out several other projects.

One of the first activities of SSESG was taking an active part in the concept and design of ESEO satellite (ESEO - European Student Earth Orbiter). The project is coordinated by SSETI (Space Engineering Technology Initiative). Currently, the group is working on the SSETI ESEO OBDH Core. OBDH (On-Board Data Handling System) Core for the ESEO microsatellite is being developed with the use of PC/104 industrial computer equipped with PowerPC processor. OBDH Core controls data flow on the board of the spacecraft as well as data flow between GS (Ground Station) and the spacecraft, using the radio connection provided by COMM (telecommand and telemetry packets are the means of communications). As a result, OBDH allows GS to monitor and control the operations of ESEO. However, OBDH Core is, to some degree, autonomous. In the case of absence of GS coverage, OBDH Core will execute the scheduled operations and monitor the key parameters. OBDH Core will reasonably minimize the consequences of detected errors. OBDH Core, together with the Attitute and Orbit Control System computer (delivered by students from Portugal) is closed within the aluminum housing. OBDH Core consists of four industrial PC/104 boards. The first one is a MIP405T computer with IBM PowerPC405GPr processor, tested and qualified by NASA, to be used in LEO (Low Earth Orbit). The second one is a so-called auxiliary board. Its main function is to communicate with the on-board devices using two CAN buses. The third board is a Power Supply module that converts voltage from external Electrical Power Subsystem to the level of 5 Volts for OBDH electronics. The last board is a Flash Board - a solid state drive of 32 MB. Its purpose is to accumulate a part of OBDH software, buffer pictures from a camera and other kinds of data, such as the status information, housekeeping data etc. Additionally, the Flash board is equipped with a microcontroller, which among other functions, is designed to measure the temperature of the critical OBDH components. All boards, except for the MIP405T computer, are custom-made boards, designed by SSESG students.

Another project of the SSESG group is the development of a new nanosatellite series O_3SAT and a picosatellite. To realize these goals, the group works in cooperation with the other scientific team from the Warsaw University of

Technology – the Student Scientific Group on Astronautics (see below). Thanks to this cooperation common works on the first picosatellite named PW-Sat have started-up. The main payload of this satellite is the balloon, designed to accelerate the de-orbitation process. PW-Sat will be inserted into the low altitude Earth's orbit and then slowly de-orbited with the use of the balloon. The mission goal is to test to way to effectively remove the space debris from LEO orbits.

PW-Sat: its mechanical structure (left) and the sketch of its balloon-assisted descending (right)



Student Scientific Group on Astronautics

Student Scientific Group on Astronautics was formed in 1996 at Warsaw University of Technology, at the Faculty of Power and Aeronautical Engineering. The members of the group are from different faculties and take part in different activities. One of them is a significant participation in the SSETI Express project organized by the European Space Agency. In the current project of SSETI ESEO (in cooperation with SSESG), the group is responsible for controlling and planning the space mission. They are also creating the configuration team, which is responsible for proper placement of the satellite components. The students associated in this group take active part in different projects organized by the European Space Agency as well as other bodies (picosatellite PW-SAT). They also participate in different scientific conferences: STEC (Space Tech Education Conference), the European Space Research and Technology Centre conferences, and the International Astronautics Congresses in different European countries.

Patronage over the Workshop on Space Technologies. The Workshop on Space Technologies STW'2006 was organized during the 2nd Microwave & Radar Week in Poland. It was organized by the Space Research Centre of the Polish Academy of Sciences (SRC PAS) and the Warsaw University of Technology under the auspices of the Polish Academy of Sciences – the Commission of Astronautics and Space Technologies of the Committee on Space Research. The Space Technology Workshop was devoted to the presentation of an ongoing space missions and their instrumentation as well as the future systems and spacecraft. The important element was the presentation of activities of Polish students. Nearly sixty of them have been taking part in the ESA Students Space Exploration and Technology Initiative

(SSETI) since 2001. The admission of Poland to the ESA PECS program will smooth the way for the young generation of specialists to start taking part in the European space activities. The areas covered by the workshop included: space instruments and subsystems, existing and future missions/satellites, and ground support equipment. A special emphasis was put on the remote sensing instruments and methods, in particular, on those operating in the microwave range. The workshop not only gave all participants the unique opportunity to exchange new ideas and scientific experience, but also opened a new series of conferences in Poland devoted to space technologies.

Regular Commission's meetings. During the last years the Commission of Astronautics and Space Technologies organized regular meetings, during which the current situation in the field of space technology was presented, and the most important issues connected with the subject matter were discussed. During the meetings, some presentations and papers were presented, all of them devoted to different areas of the contemporary modern space technologies and to its future prospects.

In the following years, the Commission of Astronautics and Space Technologies would like to continue its activities in the similar fields, as the increase of Polish scientists' potential in the field of space technologies can contribute to the rapid growth of these technologies in Poland and it hopefully allows us to think seriously about the first Polish commercial satellite in the nearest future.

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