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PAMELA experiment: Flight data receiving and quicklook

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Abstract: PAMELA is a satellite-borne experiment that measures charged particles cosmic-ray spectra across a wide energy range up to a few hundreds of GeV. The instrument was launched on the 15th of June 2006 onboard the Resurs DK1 satellite. PAMELA instrument consists of a time-of-flight system, a magnetic spectrometer, a silicon-tungsten calorimeter, a shower detector, a neutron detector and a set of scintillator anticoincidence detectors. Every day millions of events are detected and the information downlinked from the instrument to the ground station located in Moscow, Russia. The daily volume of data is around 14 GB. This paper describes the in-orbit conditions, the instrument control, the data receiving process as well as all on-ground operations of quicklook analysis, data preprocessing and archiving.

Introduction

The PAMELA (a Payload for Antimatter Matter Exploration and Light-nuclei Astrophysics) experiment is a satellite-borne apparatus designed to study charged particles in the cosmic radiation with a particular focus on antiparticles (antiprotons and positrons) [1]. PAMELA is installed inside a Pressurized Container (PC) attached to a Russian Resurs DK1 earth-observation satellite that was launched into space by a Soyuz-U rocket on June 15th 2006 from the Baikonur cosmodrome in Kazakhstan. The satellite orbit is elliptical and semi-polar, with an initial altitude varying between 350 km and 600 km, at an inclination of 70°. After short commission phase the continuous measurements began on July 11th 2006. The mission is foreseen to last for at least three years [2].
The PAMELA mission is devoted to the investigation of dark matter, the baryon asymmetry in the Universe, cosmic ray generation and propagation in our galaxy and the solar system, and studies of solar modulation and the interaction of cosmic rays with the earth's magnetosphere. The primary scientific goal is the study of the antimatter component of the cosmic radiation [3].

Satellite and condition on orbit

Resurs DK1 satellite is manufactured by the Russian space company TsSKB Progress to perform multispectral remote sensing of the earth's surface and acquire high-quality images in near real-time (see figure 1). The satellite has a mass of ~6.7 tonnes and a height of 7.4 m. The solar array span is ~14 m. The satellite is three-axis stabilized with an axis orientation accuracy of 0.2 arcmin and an angular velocity stabilization accuracy of 0.005 °/s. During launch and orbital manoeuvres, the PC is secured against the body of the satellite. During data-taking it is swung up to give PAMELA a clear view into space. The container is cylindrical in shape and has an inside diameter of about 105 cm, a semi-spherical bottom and a conical top. It is made of an aluminium alloy, with a thickness of 2 mm in the acceptance of PAMELA [1].
The instrument is pointing mainly to zenith during measurement. During imaging the satellite makes rotations on roll angle (see figure 1.) Maximum angle can reach 30 degree. Information about current inclination is transmitted to the PAMELA every 1.5 s providing accuracy of instrument pointing of about one degree.

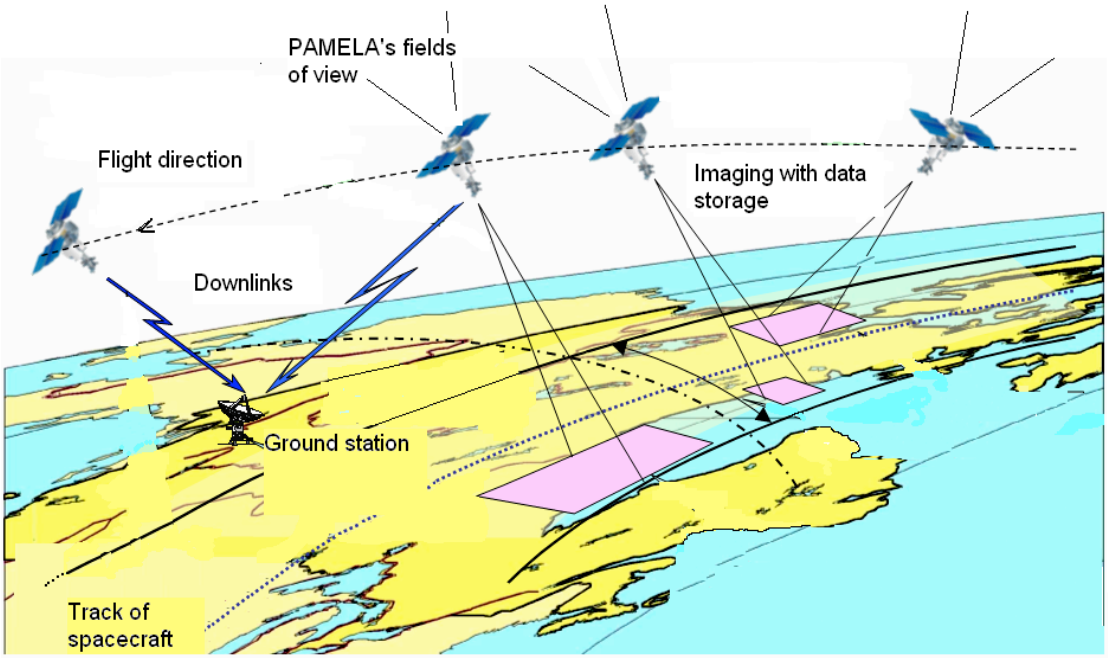

Figure 1: Data taking and downlinking during flight.

Routes from the image camera are stored in the satellite mass memory and then are downlinked to ground station. The same mechanism is used for PAMELA. PAMELA's "pseudo –route" lasts about 3 h when information is storing in instrument 2 GB memory. Then data are stored in satellite mass memory though special interface with speed 12 MBps. The average volume of stored data is currently of 14 GBytes/day. but in case of Solar Particle Event it can be more. Mass memory of satellite is about 768 Gbit and it is accessible for any on-board instrument
Every orbit on ascending node the instrument calibration takes place near the equatorial region. Data delivery to ground is realized via a high-speed radio link.

Ground data processing

Ground segment of Resurs DK1

The ground segment of the Resurs DK1 system is located at the Research Center for Earth Operative Monitoring (NTs OMZ) in Moscow, Russia. This forms part of the Russian Space Agency (Roskosmos) ground segment designed for acquiring, recording, processing and distributing data from remote sensing systems in space. The reception antenna at NTs OMZ is a parabolic reflector of 7 m diameter, equipped with an azimuth elevation rotation mechanism, and has two frequency multiplexed radio channels. The Resurs DK1 radio link towards NTs OMZ is active 4-6 times a day.

Ground segment of PAMELA

Dedicated control room was made in NTs OMZ for planning, receiving and quicklook of data from the PAMELA. Pamela data reception is performed at Digital Processing Data System (DPDS), which is component of Ground Station and has high speed disk recording and transmission system. The information from DPDS is sent to the ground segment of PAMELA where quicklook analysis takes place. There data are processed in short time to investigate status of the detectors and optimize the observation capabilities of the PAMELA. All computing operations are automatized to minimize the time delay between the data reception and the extraction of

monitoring information. Taking in to account result of the analysis as well telemetry information the daily schedule of measurement is preparing and send to fight Control Center.

Data processing

Data processing sheme is shown on figure 2. Data received from PAMELA are collected by a data-

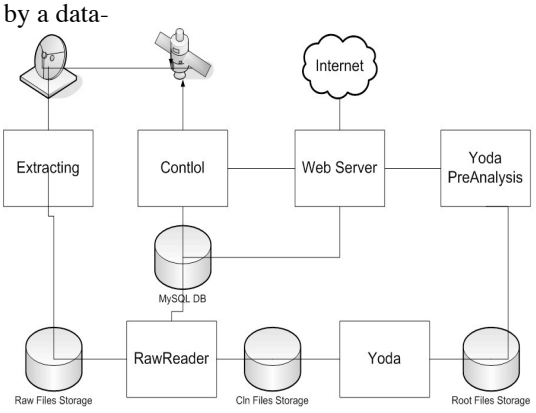

Figure 2: Data processing scheme at PAMELA Groung Segment in NTs OMZ.

set archive Server which provides security connection of Ground Station with PAMELA Ground Segment. Then the downlinked data are transmitted to a server dedicated to data processing for instrument monitoring and control, and is also written to magnetic tape for long-term storage. The RawReader program calculates the downlink session quality (the error probability per bit). Also RawReader program removes from files all transport headers and footers and prepares data for unpacking. At the same time information about received data files are stored in MySQL data base. The access to data base made through web interface gives possibilities to operators check up data and faulty downlink sessions can be assigned for retransmission up to several days after the initial downlink Data are then processed by the YODA Reader (YR) [4]. YR is ROOT based C++ program but many subdetectors analysis routines are made in FORTAN77. YODA unpack all different structures creating the various trees (event, calibration, housekeeping, orbital information, etc). A Quicklook task monitors the status of housekeeping and physics data in order to allow local and remote (web based) assessment of the status of the mission. Short term programming and telecomand / macrocommand issuing is based on the result of the quicklook. For instance in case of Solar Particle Event number of pseudorouts may be increased. After this first level of data analysis, both raw and preliminary processed data are moved through a normal internet line to the main storage centre in Eastern Europe, which is located at MEPHI (Moscow, Russia). From here, GRID infrastructure is used to move raw data to the main storage and analysis centre of the PAMELA Collaboration, located at CNAF (Bologna, Italy), a specialized computing centre of INFN. Here data are accessible to all various institutions within the PAMELA collaboration.

Conclusion

PAMELA mission started July 15, 2006. About 5 TByte data were collected and processed by quicklook system during first year of experiment.

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