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THE SMALL SATELLITE NINA-MITA TO STUDY GALACTIC AND SOLAR COSMIC RAYS IN LOW-ALTITUDE POLAR ORBIT

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ABSTRACT

The satellite MITA, carrying on board the scientific payload NINA-2, was launched on July the 15^{th}, 2000 from the cosmodrome of Plesetsk (Russia) with a Cosmos-3M rocket. The satellite and the payload are currently operating within nominal parameters. NINA-2 is the first scientific payload for the technological flight of the Italian small satellite MITA. The detector used in this mission is identical to the one already flying on the Russian satellite Resurs-O1 n.4 in a 840-km sun-synchronous orbit, but makes use of the extensive computer and telemetry capabilities of MITA bus to improve the active data acquisition time. NINA physics objectives are to study cosmic nuclei from hydrogen to iron in the energy range between 10 MeV/n and 1 GeV/n during the years 2000-2003, that is the solar maximum period. The device is capable of charge identification up to iron with isotope sensitivity up to oxigen. The 87.3 degrees, 460 km altitude polar orbit allows investigations of cosmic rays of solar and galactic origin, so to study long and short term solar transient phenomena, and the study of the trapped radiation at higher geomagnetic cutoff.

INTRODUCTION

The Italian satellite MITA (Minisatellite Italiano a Tecnologia Avanzata - *Italian Advanced Technology Minisatellite*) was launched with a Cosmos rocket from the cosmodrome of Plesetsk on July the 15^{th}, 2000. This launch, ♯401 for the Cosmos vector, carried also the German satellite CHAMP and the payload BIRD-RUBIN (Figure 1).

NINA-2 is the scientific payload of MITA and continues the observations begun with the first NINA telescope, launched in 1998 on board the Russian Resurs-O1 n.4 satellite. These detectors were realized and launched in space by the WiZard - RIM international collaboration, composed by INFN (Italian National Institute of Nuclear Physics), MEPHI (Moscow Engineering Physics Institute), and other universities and institutions (see also Sparvoli et al., 2000). In parallel to the NINA launches, two devices employing the same detector technology - RIM/SilEye experiments, Bidoli et al., 2000 - were placed on board the MIR Space Station to study radiation related effects in that environment.

The detector NINA-2 is identical to the NINA one but, making use of the extensive computer and telemetry capabilities of MITA, it will improve the active data acquisition time. NINA-2 will study charged cosmic ray

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Fig. 1. MITA satellite in downward position on the COSMOS rocket launch adapter 24 hours before the launch. Also the companion satellites CHAMP and BIRD-RUBIN are visible.

particles between 10 and 200 MeV/n (contained particles) and up to 1 GeV/n (outside containment) during the years 2000-2003, beginning from maximum solar activity. The main feature of the NINA instruments is their high segmentation which allows a very precise measurement of the Bragg curve of the incoming particle.

THE MITA BUS FOR SMALL SCIENTIFIC MISSIONS

The MITA satellite has been built under an ASI (Agenzia Spaziale Italiana - *Italian Space Agency*) contract by Carlo Gavazzi Space to implement a low cost platform for small Earth missions; its main characteristics are shown in Table 1. MITA represents a new generation of satellite architecture based on modular criteria that allow to build up a mission in short periods ($\sim$ 2 years), at low costs, taking advantage from the big flexibility for payloads and launchers. The satellite is placed in a circular polar orbit of 460 km height and 87.3 degrees of inclination. The mission lifetime has been foreseen to be 3 years, depending mainly on ballistic satellite life. The spacecraft geometry allows an easy placement as a secondary launcher payload thus greatly reducing launch costs.

In the first launch MITA hosted the NINA-2 detector (Figure 2), and the technological payload MTS-AOMS (MicroTech Sensor for **A**ttitude and **O**rbit **M**easurements **S**ystem). There are two main computer systems on board: the OBDH and the PL/C. The OBDH is linked to all spacecraft systems such as the telemetry frame formatter, the interface with the active control systems, the sensors and actuators, the engineering and scientific data readout. Data from the detector are read out from the Payload Computer which performs all tasks of data readout, reduction, second level triggering and active acquisition mode switching. This architecture allows good development flexibility and a relatively simple integration of the scientific payloads.

Works started in mid-1997; the integration phase included beam tests of the detector at the accelerator facilities of GANIL (France), GSI (Germany) and Uppsala (Sweden).

MITA is equipped with two 3-axis magnetometers. Magnetometer data are used for ACS (Attitude and Control System) and provide also data for in flight software and off-line analysis to correlate the particle fluxes with detailed measurements of the magnetic field.

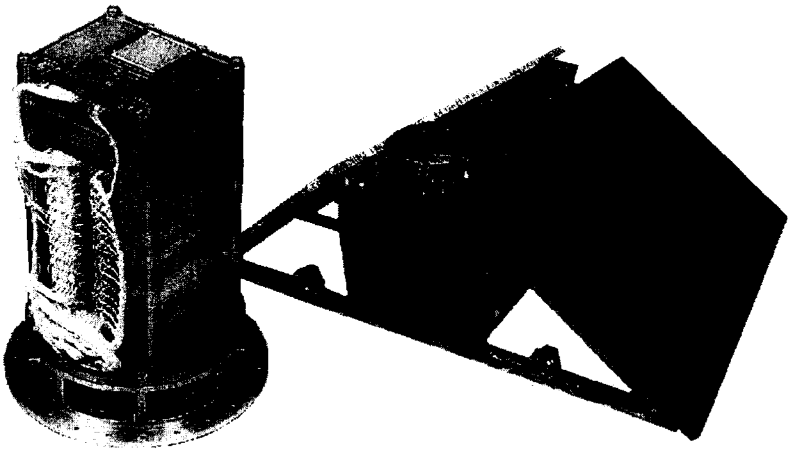

Fig. 2. The detector NINA-2 with the satellite MITA. The telescope, whose window is free from thermal covers, is placed in the rear side of the satellite with respect to the movement direction.

Mass	170 Kg
Dimensions	180 × 160 × 84 (cm)
Average (peak) power cons.	85 (120) W
Attitude Control System	3 axis stabilized, Earth point.
Attitude Accuracy	$\pm 1^{\circ}$ / axis
Communications	S-Band
Telemetry	512 Kbps - ESA Standard
Telecommand Uploads	4 Kbps
Mass Memory	64 MBytes
Payload Mass	30 Kg
Payload Power Budget	40 W

Table 1. MITA bus characteristics summary.

SCIENTIFIC OBJECTIVES

The scientific objective for NINA-2 mission is the study of cosmic ray nuclei from hydrogen to iron in the energy range between 10 MeV/n and 1 GeV/n, providing isotope information up to oxigen. The detector characteristics, the high inclination orbit of the hosting spacecraft (see Table 1) and the period of observation (beginning at solar maximum) allow to address several scientific items related to cosmic rays physics:

- **Galactic Cosmic Rays (GCR).** Data acquired at high geomagnetic latitudes represent a sample of the galactic cosmic ray component, which is modulated on the long term by the solar activity. Therefore, in addition to studies of the nuclear component of GCR, solar modulation phenomena will be considered. Detailed knowledge of the phenomena and processes behind the modulation and the interaction between the out-flowing solar material and the incoming galactic cosmic rays are still under study and await new data. This is necessary to improve understanding and modeling of these complex mechanisms; data will come not only from probes sent in different parts of the heliosphere, such as Ulysses, ACE and Voyager but also from 1 AU measurements, performed by SAMPEX and NINA-2.

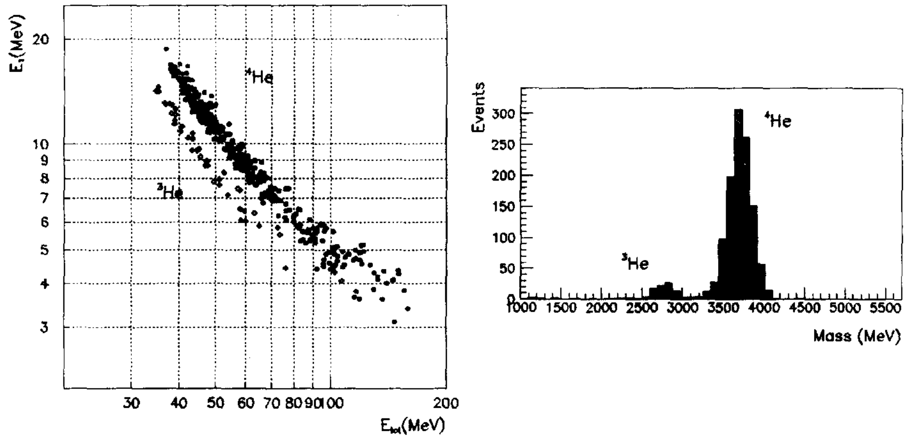

Fig. 3. NINA detector isotope identification capabilities. $^{3}He/^{4}He$ data refer to 6-8 November 1998 SEP event, detected by NINA on board the satellite Resurs.

- **Solar Energetic Particles (SEP).** In addition to long term modulation effects, the heliosphere is often perturbed by a number of transient phenomena due to the solar activity, such as solar flares and coronal mass ejections. Each solar event has its own characteristics which have been proved quite challenging for acceleration and propagation models. Multi-spacecraft studies with different instruments are again of critical importance toward a deeper understanding and classification of different solar events. In this case NINA-2 capability to perform isotope studies[1] with the same instrument should prove a precious asset (see Figure 3).

- **Particles Trapped in the Magnetosphere.** NINA-2 will monitor the position and Cosmic Ray composition of the South Atlantic Anomaly (SAA) for the duration of its mission. Although we expect low-Z particle flux toward the center of the Anomaly to be so high as to saturate the instrument, it will be possible to have an accurate monitor of the boundary of the Anomaly and perform measurements of high Z nuclei of the inner zone. Particle flux data will not only be correlated with the on board magnetometer data, but also with the very detailed magnetic measurements performed by CHAMP in the same orbit.

- **Anomalous Cosmic Rays (ACR).** The energy range of acceptance of NINA for the Anomalous component of cosmic rays is limited by the 300 μm aluminum window. Besides, the anomalous component is strongly dependent - due to its production and propagation mechanisms - on the solar activity, being greatly reduced at solar maximum. However, the possibility of performing some measurements of the trapped component of ACR is currently under study.

- **Cross-correlation with MIR data from SilEye-2 experiment.** The SilEye-2 experiment has been operating on board the space station MIR since 1997. It was designed with the two-fold objective of studying the Light Flash phenomenon and monitoring the radiation environment on board MIR. Due to the interposed material of the hull of the station and its equipment, the cosmic ray nuclear component has proven to be significantly different inside the MIR. A correlation between the data from NINA, NINA-2 and SilEye-2 would imply a more detailed understanding of the relation between the radiation inside the MIR and the incident cosmic ray flux. This will be of particular importance in the assessment of the radiation hazard in manned missions not only on MIR but also on the ISS (International Space Station) and for possible future missions to Mars.

[1]For instance, we mention the increase of $^{3}He/^{4}He$ ratio and the increased abundance of various elements in impulsive events.

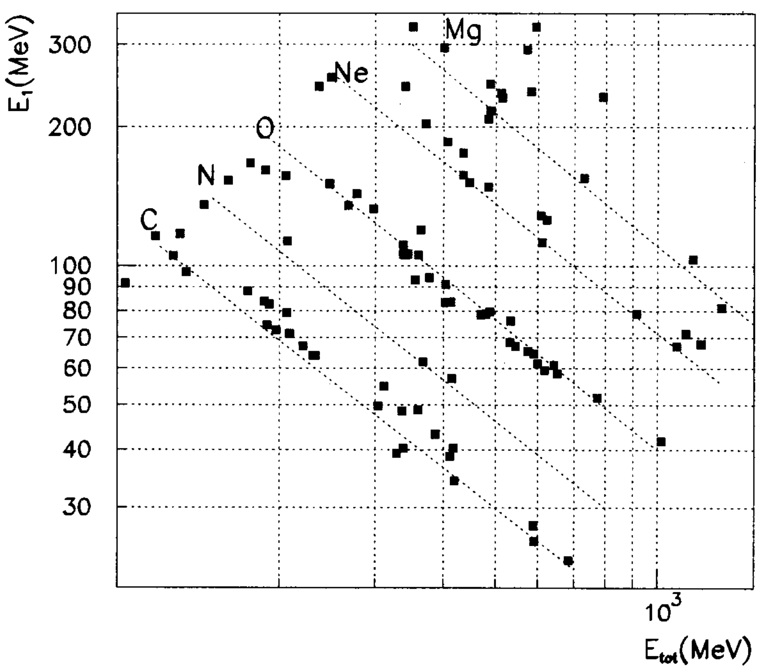

Fig. 4. Nuclear identification capabilities of the detectors NINA. Data refer to the 14 November 1998 SEP event, detected by NINA on board the satellite Resurs.

DETECTOR CHARACTERISTICS

The NINA-2 detector is composed of 16 X-Y planes, each one consisting of two n-type silicon detectors, 60 × 60 mm^2, divided in 16 strips and connected to a supporting ceramic frame under lateral strips (1 and 16). A photo of the whole device, without the Al vessel, is shown in Figure 2; for a detailed description see (Bakaldin et al., 1997, Bidoli et al., 1999). The geometric factor of the instrument ranges from 8.6 cm^{2}sr for low energy particles to 1 cm^{2}sr for particles crossing whole detector. The thickness of the detector is (2 × 150 ± 15) μm for the first plane, and (2 × 380 ± 15) μm for the remaining 15 planes. The active part of the detector is thus 11.7 mm, dead thickness amounts to 300 μm Al of the cover of the detector and 28.1 cm of N_2 at the launch pressure of 1.2 bar (pressure decreases because of vessel out-gassing to 0.8 bar in 3 years).

The segmented nature of the detector allows a very precise measurement of the Bragg curve of the incoming particle. In this way it is possible not only to perform particle and energy classification according to dE/dx methods for particles contained into the calorimeter (up to ~ 200 MeV/n) but also to identify particles not contained in the device (albeit with a reduced discrimination) thus extending the acceptance energy range to 1 GeV. An example of the nuclear identification capabilities of the device is shown in Figure 4.

The lateral strips are read by the same electronic channel to reserve channels for housekeeping values, since they are used as lateral anticoincidences (AC) for planes 2-16. Interplanar distance is 1.4 cm for planes 2-16 and 8.5 cm for plane 1-2 in order to improve determination of the particle incident angle. The bottom plane may be used as anticoincidence to exclude non contained particles. Preamplifiers are placed on the sides of the detector: the signal is then sent, via a multiplexer, to a 12 bit ADC and then to the satellite OBDH (On Board Data Handler - transputer CPU) via a FIFO (ADC and FIFO electronics board are placed under the 16 planes stack). ADC dynamic range corresponds to about 300 MeV of released energy;

the resolution is 73 KeV/ch. The whole structure is surrounded by a cylindrical aluminum vessel of 284 mm diameter and 480 mm height and 2 mm thick (aside from the aforementioned 300 μm thick window placed in front of the detector).

All satellite and detector systems have their cold redundant counterpart with the exception of the silicon detector which has a functional redundancy in the multiplicity of the strips and the different triggers which allow to cope with eventual malfunctions. Indeed, software second level triggers figures allow to discard broken strips or planes and substitute anticoincidence vetoes. The system performs automatic calibrations and checks of the dark current noise at intervals during acquisition; this allows to take into account eventual - but in so far not observed - shifts of the detector's pedestal or variations of the amplification chain gain. According to the trigger configuration, the detector can vary its observational characteristics in order to focus the acquisition of different particles and energy ranges. The PL/C (Payload Computer) can vary the trigger configuration as a result of telecommands sent from ground station or automatically adjust the trigger configuration to cope with increased particle flux.

ACKNOWLEDGMENTS

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