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ALTEA: Visual perception studies on astronauts on board the ISS

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Abstract. The ALTEA project is aimed at studying the possible functional damages to the Central Nervous System (CNS) due to particle radiation in space environment. The project is an international and multi-disciplinary collaboration. The basic instrumentation is composed by a series of active particle telescopes, one ElectroEncephaloGrapher (EEG) and a visual stimulator, arranged in a an helmet-shaped device. This instrumentation is able to measure concurrently the dynamics of the functional status of the visual system, the cortical electrophysiological activity, and the passage of each particle through the brain within a pre-determined energy window. The three basic instruments can be used separately or in any combination, permitting several different experiments. ALTEA is scheduled to fly in the International Space Station (ISS) in spring 2003. One part of the multi-sensor device - one of the advanced silicon telescopes and one EEG (project "ALTEINO") - will be launched in the Russian modulus of the ISS in early 2002 and serve as discriminating dosimeter for the particle fluences within the ISS, and as first monitoring device for the astronaut's electrophysiological activity.

1 Introduction

The assessment of the interaction of space environment with the functional status of the astronaut's CNS will raise to maximal importance during the long manned space flight in the ISS, and in preparation of the manned journey to Mars, outside the protection of the earth magnetic shield. Operations of increasing complexity and duration will in fact be requested to crew members and scientists in orbital flight: the effects on the Central Nervous System (CNS) should now be studied focusing both on transient and cumulative effects overlooked in the past missions in the absence of detectable long-term or irreversible symptoms. Previous studies have shown that large particle flux and microgravity can be among possible causes of modifications in the normal functioning of the astronauts' CNS, however both their transient and long term effects are not yet fully studied.

The visual system has been chosen to "probe" the CNS because it is particularly sensitive to space environment. This has been demonstrated since when, while awake in the darkness, astronauts on Apollo missions 11 through 17, Skylab 4 (Pinsky et al., 1974, 1975; Osborne et al., 1975), MIR Station (Bidoli et al., 2000) observed phosphenes that appeared as light flashes in the shape of thin or thick streaks, sharp lines, bars, single or multiple dots, clouds, etc.

In order to assess the LF phenomenon is mandatory the simultaneous determination of time, nature, energy and trajectory of the particle passing through the cosmonaut's eyes, as well as the cosmonaut's LF perception time. The observations mentioned above and several experiments performed in ground laboratories in the 70s (Bidoli et al., 2000; Charman et al., 1971; Charman & Rowlands, 1971; McAulay, 1971; McNulty, 1971; Tobias et al., 1971; Budinger et al., 1972; McNulty et al., 1972) link such phosphene perceptions phenomenon to the passage of high Z nuclei through the astronauts' head, possibly through their retina. The specific mechanism of the interaction, and its site, remain uncertain.

In addition to the parameters studied before, ALTEA will perform a complete electrophysiological assessment of the

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brain functionality concurrent with particle data acquisition. Furthermore the visual stimulator will permit to monitor the visual system status during the flight.

Sensory systems are just the most immediate targets of the ALTEA investigation. Higher cognitive function could also reveal anomalies due to particle radiation, for example in latency and discriminative power.

The ALTEA experiment has been funded by the Italian Space Agency (ASI) and by the National Institute for Nuclear Physics (INFN) and rated ”Highly recommended” by the European Space Agency (ESA). It will fly on the US modulus of the ISS in segment 8 (flight 12A1) in the spring 2003 where it will remain for three months. ALTEA will then be moved to the Russian modulus (agreement to be still finalized).

A precursor of ALTEA (”ALTEINO”) will be launched in the Russian modulus of the ISS in early 2002 and serve as discriminating dosimeter for the particle fluence within the ISS, and as first monitoring device for the astronaut's electrophysiological activity. ALTEINO consists of one single silicon telescope detector and one EEG.

2 Description of the system

The detector system consists of an helmet shaped mechanical structure holding 12 active silicon telescopes, assembled in 6 independent units, an ElectroEncephaloGrapher (EEG) and a Visual Stimulator (see Fig.1).

Each detector is made of three silicon strip sensors. The basic sensor is obtained assembling back to back two chips with ion implanted resistive strips, 2x(8x8) cm^2 of sensitive area, 380 m thick, strip pitch of 2.4 mm. To allow both x and y coordinate measurement the strips of the two detectors are perpendicular.

The distance between the sensors of each detector will be 37.5 mm. Detection threshold will be 0.21 MeV, saturation is at 1.6 GeV, maximum acquisition rate 5000 Hz. The worst case angular discrimination (single detector hit, normal incidence) is $\pm 1.8°$. A 27 bit time tag will allow for 37 hours experiment with a resolution of 1 ms.

The EEG system will measure the dynamics of the cortical bioelectrical activity. Electrodes are placed on an elastic cup in a pre-determined array. Studies about new materials for these electrodes are in progress. Polimeric conductive gels, soft enough to adapt on the head and hair of people without loosing the contact over time are being considered. The EEG system features 24 monopolar channels plus 4 dipolar channels. The acquisition frequency is set to 1 kHz, but can be chosen between 128 Hz and 16 kHz per channel changing the software.

The Visual Stimulator is an adapted virtual reality system, and will permit to perform suitable stimulation routines to determine the status of the visual system. This system has a 2 Mb video RAM and can show images at a maximum rate of approximately 30 Hz. Each frame can be shown with 256 colors, out of a 16 million colors palette. The field of view is 35° diagonal (21° x 28°). Spatial resolution is 1024 x 768 pixels, contrast 40:1, luminance 5-50 FL. The stimulation procedure is storaged in hardware and can be changed via simple software implementation. The whole system maximum storage is 8 Gb.

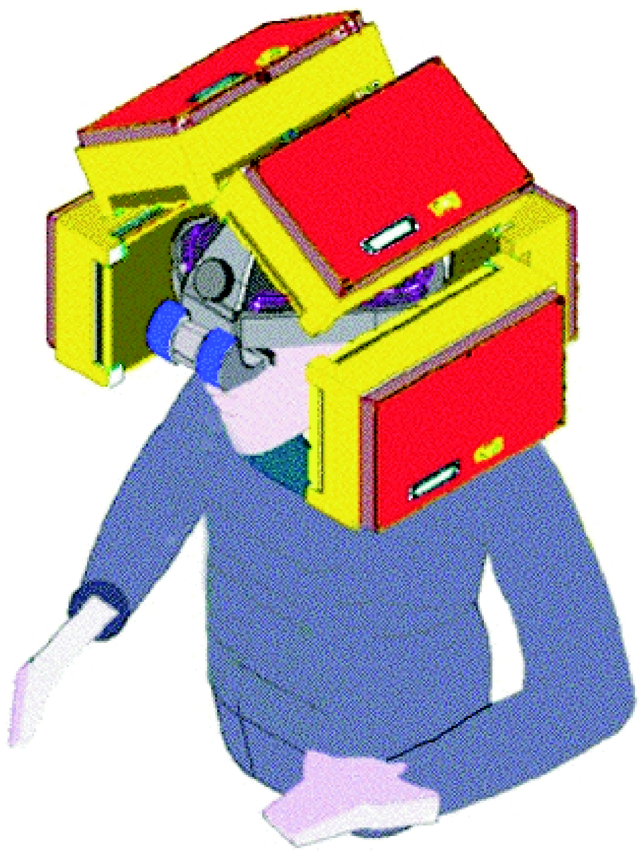

Fig. 1. A schematic view of the astronaut with the ALTEA system (frontal unit not shown).

A push-button will be used by the astronaut to mark the perception of a light flash. The three system plus push-button synchronizability will be within 1 ms. All information are stored together via an integrated data handling system that will also allow transmission of the data to ground.

The particle telescope of ALTEINO (see Fig.2) is equal to 1/2 of one of the box units, with a narrower inter-sensor distance (20 mm), 4 sensors and two scintillators to increase triggering capabilities (detection threshold : 0.042 MeV).

3 Procedures

A possible schedule of the ALTEA experiment is described in the following:

A) Astronauts Training.

B) Ground measurements (prior to launching):

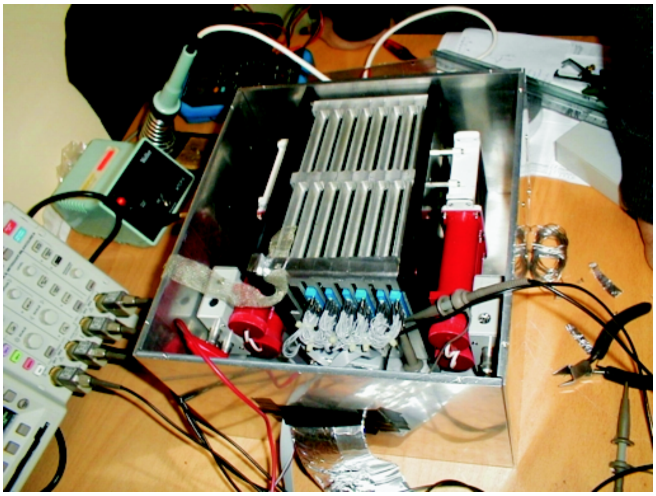

Fig. 2. Assembling phase of ALTEINO apparatus.

i) Set-up testing;
ii) Electrodes positioning (10 min);
iii) Stimulation paradigm with concurrent EEG acquisition (5 min).

C) Onboard measures:

i) Set-up testing;
ii) Electrodes positioning (10 min);
iii) Stimulation paradigm (5 min);
iv) Dark adaptation (15 min);
v) electrophysiological recording and particle assessment during a full orbit (90 min).

EEG will be acquired during (iii), (iv) and (v).

D) Ground measurements (after landing):

i) Set-up testing;
ii) Electrodes positioning (10 min);
iii) Stimulation paradigm with concurrent EEG acquisition (5 min).

Measures will be repeated on board in different moments of the orbital permanence of the astronaut to follow the dynamics of the CNS status.

4 Conclusion

The ALTEA experiment will permit to assess the risk on the Central Nervous System due to particle flux in microgravity conditions during long term space missions. It will provide information to define the causes of the anomalous phosphene perception of the astronauts. Furthermore the flexibility of the instrumentation of the ALTEA system will permit to set up experiments in electrophysiology, cognitive neurophysiology, particle flux measurements, psychophysics, dosimetry, etc, making ALTEA the first facility of this kind in space.

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