



Low Altitude Zone Ionizing Observatory (LAZIO)

A detailed study and understanding of the radiation environment in space and its effects on human physiology has a growing importance with current work on the International Space Station (ISS) and of a future mission to Mars.

Radiation in orbit comes from cosmic rays of different energies and origins. Cosmic rays come generally from within our galaxy (Galactic Cosmic Rays). In addition to the galactic component there are also solar energetic particles associated to phenomena such as Solar Flares or Coronal Mass Ejections. Inside Earth's magnetosphere there is also the significant contribution of trapped particles.

For Low Earth Orbits (LEO) – altitudes of 300-400 km – such as those of the International Space Station (ISS) or Space Shuttle, the effect of trapped radiation is mostly evident in the South Atlantic Anomaly (SAA). This is a region of enhanced radiation located between South America and Africa. In this region the higher energy particles normally at higher altitudes are “pulled down” closer to the Earth's surface, resulting in an increased radiation environment during the transition of LEO spacecraft.

Through studies of the composition and energy spectra of cosmic rays, we are able to learn about the origin and evolution of material in our galaxy and about fundamental physical processes that govern its dynamics. In addition to the interest related to fundamental physics, cosmic rays are the source of radiation absorbed by astronauts and therefore involve many health physics and medical issues.

Besides the effects due to radiation, there are also other processes that have to be studied in order to have a more complete knowledge of the human response to the space environment. One of these phenomena is the “Light Flash” (LF) effect, originally predicted in 1952 and reported for the first time in 1969 by the Apollo 11 mission to the Moon.

Subsequently, LFs were observed by astronauts in the Apollo, Skylab, Shuttle and Mir missions. LFs consist of unexpected visual phenomena caused by the interaction of cosmic rays with the eyes of the astronaut. They occur in space with frequency and type, which can vary considerably from subject to subject. In addition, geomagnetic

and spacecraft shielding play a role in this effect since they can alter the cosmic ray nuclear composition.

A detailed study of the frequency and type of Light Flash occurrence is of particular interest to understand the interaction between cosmic rays and astronauts' visual apparatus (eye or Central Nervous System) to reduce risk in manned missions.

In addition there is some evidence that Light Flash occurrence decreases with permanence of cosmonauts in space. Up to now no clear answer has been given to the presence and even less to the mechanisms involved in this phenomenon.

A further topic of research, and probably the most important one regarding this experiment, regards a phenomenon initially suggested by Russian scientists about two decades ago. This involves the interaction between geophysical phenomena and particle flux.

This hypothesis suggests that electromagnetic waves will be emitted from a location where an earthquake is about to occur. As these waves move towards the surface of the Earth the higher wave frequencies are attenuated, while the Ultra Low Frequency waves will continue to travel through the atmosphere, penetrating the lower part of the ionosphere. These waves generate disturbances in the lower part of the ionosphere (approximately 90 km altitude), which in turn interact with both the inner and outer Van Allen belts (bands of concentrated radiation around the Earth), thus perturbing their characteristics. By measuring rapid particle flux changes, and monitoring the stability of the Van Allen belts, it can be possible to establish the region where electromagnetic wave emission originated, thus possibly predicting the occurrence of an earthquake.

How is it done?

In this wide and interdisciplinary context, the LAZIO experiment aims:

- to detect and identify cosmic rays with high precision tracking capability employing novel technology based on fine pitch silicon microstrip detectors,



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- to determine the relation of cosmic rays to the Light Flash phenomenon. The astronaut will perform light flash observation sessions in the dark and describe the type of Light Flash and his impressions on a voice recorder. The time of arrival will be marked by pushing a joystick. The astronaut will be in a sleeping bag to avoid floating. He will wear a mask for dark isolation (which will make his eyes more sensitive to Light Flashes),



LAZIO-SIRAD Experiment hardware (Image: R Battiston)

- to study the effect of different shielding materials in reducing the radiation environment. This will be done by adding shielding tiles to the top and bottom of the cosmic ray detector ALTEINO, already on-board the ISS and used during a previous Soyuz mission in 2002.
- to measure the intensity and the variations of the magnetic field within the ISS, and to correlate this data with the measurements of the particle fluxes. This will be an important part of the experiment related to the high accuracy monitoring of the short time stability of the Van Allen belts, to study the possibility of precursor earthquake related phenomena.

Team Members:

R. Battiston ⁽¹⁾, P. Picozza ⁽²⁾, M. Casolino ⁽³⁾, V. Sgrigna ⁽⁴⁾

(1) INFN Sezione Perugia
Perugia, Italy
E-mail: r.battiston@tiscali.it

(2) Università di Roma Tor Vergata
Rome, Italy
E-mail: picozza@roma2.infn.it

(3) INFN Sezione Roma 2
Rome, Italy
E-mail: marco.casolino@roma2.infn.it

(4) Università degli Studi Roma 3
Rome, Italy
E-mail: sgrigna@fis.uniroma3.it



Technology Demonstrations

Analysis Experimentation Implementation Algorithms (ASIA)

The ASIA Flight experiment aims to verify the capability of a High Performance Computer Board, equipped with state-of-the-art Central Processing Units (CPUs), to sustain large doses of radiation when exposed to a space environment.

The study will evaluate the radiation sensitivity of the computer board after its exposure to the environment in the International Space Station (ISS), by analysing the effects caused by protons, heavy ions and cumulated dose.

The computer board will be un-powered during all mission phases. The evaluation of radiation effects will only be performed after the return to Earth of the board, by comparing its operability after exposure to space with that recorded before the launch.

The final objective of this study is to determine whether or not, depending on how the board is affected by radiation, these computer boards can be used in future generation satellites, providing enhanced performances.

How is it done?

The ASIA Flight is composed of an electronic board with commercial/avionic high-level components located inside a crate of aluminium alloy, which prevents all potential rupture of the board during the launch and return phases. No power generator is present on the ASIA payload; therefore the board will always be in the passive state. The equipment is delivered to orbit and will be stored in a NOMEX soft-bag with space-qualified foam.

The facility will be exposed to radiation inside the habitat module of the Russian segment of the ISS for a period of approximately 10 days. It will be uploaded using the Russian Progress 17P unmanned, re-supply module (launch 28 February 2005) and will be recovered upon re-entry with the manned Soyuz 9S capsule (landing 25-26 April 2005).

After the mission, the equipment will be retrieved and returned to the developer for the post-flight analysis. The facility will also be photographed in orbit with and without the transportation bag. The facility will be stored in a location near the LAZIO payload so that the data collected by the LAZIO

experiment can be used as a reference to evaluate the radiation dose received by the instrument.



ASIA Flight Experiment Hardware (Images: L. Paita)

Team Members:

A. Orlandi⁽¹⁾, L. Paita⁽²⁾, A. Murli⁽³⁾, B. Pelon⁽⁴⁾

(1) Information Technologies Services
Rome, Italy
E-mail: aorlandi@intese.com

(2) Alta SpA
Ospedaletto (PI), Italy
E-mail: info@alta-space.com

(3) Istituto di Calcolo e Reti ad Alte Prestazioni
Naples, Italy
E-mail: Almerico.murli@dma.unina.it

(4) CSPI - Corporate Headquarters
Massachusetts, USA
E-mail: info@cspi.com

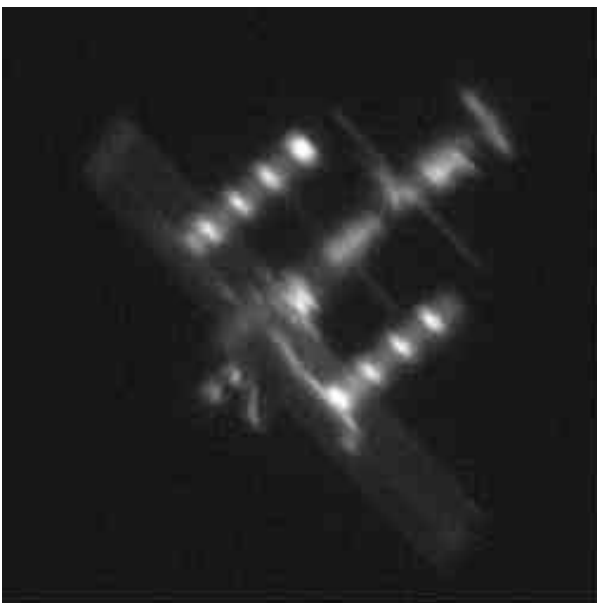


Specular Point-like Quick Reference (SPQR)

The Shuttle Columbia disaster has emphasized the importance of imaging in the detection of exterior damage of manned spacecraft in orbit. As in the case of Columbia, serious damage may not always be readily visible to astronauts from inside their vehicle. Various approaches to this problem are being investigated by NASA and other organizations. However, many of these methods require a number of months (or years) to implement the first set of tests.

This experiment proposes the test of a ground-based imaging system, using special optics and image processing, to determine the feasibility of developing an operational system. In principle, such a system would have a linear resolution on the International Space Station (ISS) of less than 20 cm. While a resolution of 1 cm or better would be ideal, this would be extremely expensive and require a long time to implement.

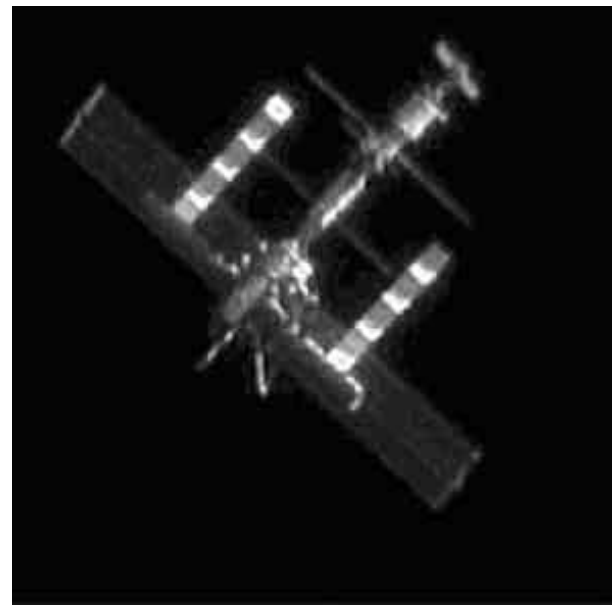
The 20 cm resolution would have probably been sufficient to detect the damage to the Columbia. Thus, since the evaluation of this approach would consist of a quick and inexpensive test, and the operational implementation of this system would also be relatively inexpensive and could be performed in a short time, a test would seem to be highly desirable.



Normal ISS image taken from Earth (Image: A. Paolozzi)

A small aperture telescope can, in principle, obtain a resolution of better than 20 cm on objects in low Earth orbit. Unfortunately, rapidly changing

distortions in the Earth's atmosphere blur the image, and nearly always prevent ground-based telescopes from reaching optimal theoretical performance. Capturing high frame rate, short duration telescopic images of manned platforms can be used to reduce such instantaneous atmospheric distortions.



Partially improved image of the ISS obtained using a bright feature as a point reference. (Image: A. Paolozzi)

How is it done?

The SPQR experiment will be based on a Cube Corner Reflector (CCR) that will be fixed close to an ISS window and will reflect the beam of a laser coming from a ground station.

The CCR must be fixed on a window (the CCR is provided inside a suitable mount) and left there for several days until the experiment is over or the window is needed for other tasks. This will limit the needed crew time to a total amount of just 0.5 hours. The selected window is oriented towards the Earth; in this way the CCR would be in visibility of the ground station (GS) when the ISS passed over it.

If the test is successful, in the future it will also be possible to use a small inexpensive spherical mirror to provide the point source of light. This will passively reflect the sun, and would provide a bright specular reflection of the sun without any need for power or control of the orientation. The ideal sphere would need to be about 30 cm in



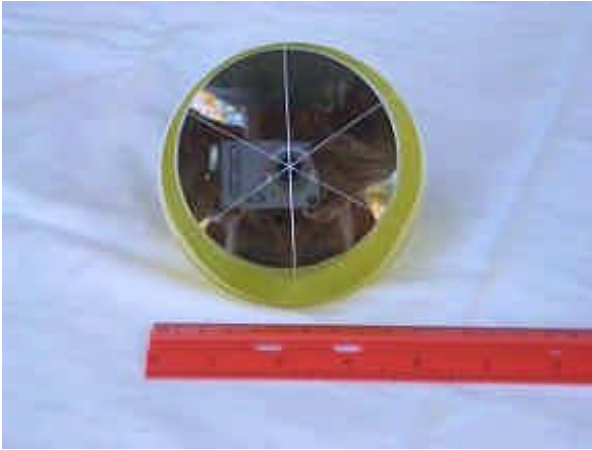
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diameter and would be similar in appearance to an oversized spherical “Christmas tree” ornament.



Cube Corner Reflector (CCR) - Diameter 102 mm

The specific choice of the material, size and weight would depend upon the details of the operational and safety considerations for the spaceflight. The spherical mirror would be supported in a small boom to remain available for a variety of observations.

Team Members:

F. Graziani ⁽¹⁾, A. Paolozzi ⁽¹⁾, D. Currie ⁽²⁾, M. Porfilio ⁽¹⁾

(1) University of Rome “La Sapienza”
Rome, Italy

E-mail: gauss@caspur.it
paolozzi@nero.ing.uniroma1.it

(2) University of Maryland
Maryland, USA

E-mail: currie@umd.edu



Technology Demonstrations

Electronics Space Test (EST)

Over the past few years there have been major technical improvements and reduction in size of electronic and microelectronic devices for space applications. But these devices can encounter problems, often with catastrophic consequences. These problems arise as a result of shocks and vibrations sustained during the launch phase, as well as the harsh environmental conditions of space, specifically thermal and radiation related aspects. Radiation resistant devices for space applications can cost up to 1000 times more than similar industrial components.

For these reasons, G & A Engineering has conducted an analysis and test campaign to demonstrate that industrial components that are adequately protected and used correctly, can be implemented in space. With this in mind, G & A has designed and developed a special radiation protective casing for low cost industrial components.

The Electronics Space Test (EST) is a technology demonstrator containing an electronic subsystem, which includes all the element parts of the industrial family chosen. The EST has passed all its ground tests and therefore a demonstration in space is now necessary. The demonstrator, which will fly to the ISS on the Italian Soyuz Mission, will validate an electronic high density power system, new generation batteries, advanced calculus devices for real-time computing, programmable and re-programmable devices for micro and pico satellite subsystems and different kinds of sensors typically found on-board spacecraft.



EST Equipment (Image: G. Pontetti)

A positive outcome to this demonstration will lead to the availability of future low cost "off-the-shelf" components for micro and pico satellites.

How is it done?

The EST operations on the experiment consist in the activation of the experiment by inserting a fresh battery and pushing the EST main switch button to ON before the launch phase; this button is located in a protected slot to avoid undesired de-activation; following this, the equipment is stored into the Soyuz in its transportation bag.

Once in orbit, the equipment in the transportation bag is removed from the storage area. The Battery is removed and disposed. The power supply cable and the bonding strap are attached to the EST equipment and to the ISS Power system so that the equipment is powered directly by the ISS.

The astronaut pushes the experiment pushbutton once a day, every day during the mission. The pushbutton activation will cause the electronic log of date and time, and the equipment reset in case of failures. The activation process also initiates the automatic execution of hardware and software tests to verify that the component is functioning correctly.

At the end of the mission the experiment is switched off. The data is automatically stored inside the electronic box that is returned to Earth by the Soyuz capsule.

Team Members:

G. Pontetti, R. Bellarosa

G & A Engineering S.r.l.
Oricola (AQ) and Rome, Italy

E-mail: giorgia@pontetti.com

Renato.bellarosa@gaengineering.com



Electric Nose Monitoring (ENM)

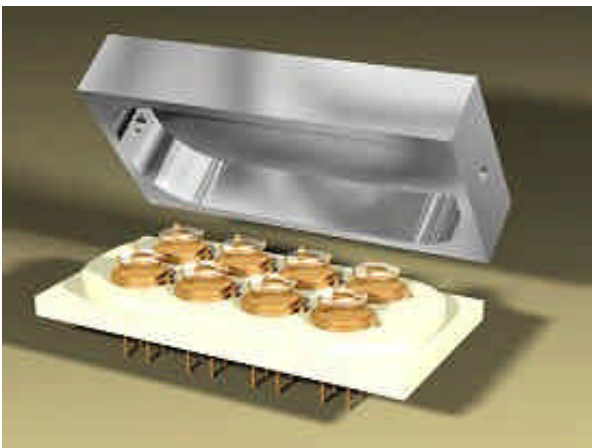
An artificial olfactory system (or simply put, an electronic nose) represents an interesting tool for various applications such as food quality control, identification of noxious gases and compounds in industrial sites and biomedicine. This type of system can also be useful as a diagnostic tool for space applications.

The device could also be used on board the ISS for the detection of stagnation states, where the air circulation is limited and where carbon dioxide or other gases can be present at high concentration or where mould could grow.

The ENM experiment is based on a very promising tool, which uses a new class of chemical sensors that are designed to provide the overall olfactory profiles of a large number of chemical compounds within a closed environment. The objective of this experiment is to test the technology of this system under microgravity conditions and to verify its applicability to space applications.

How is it done?

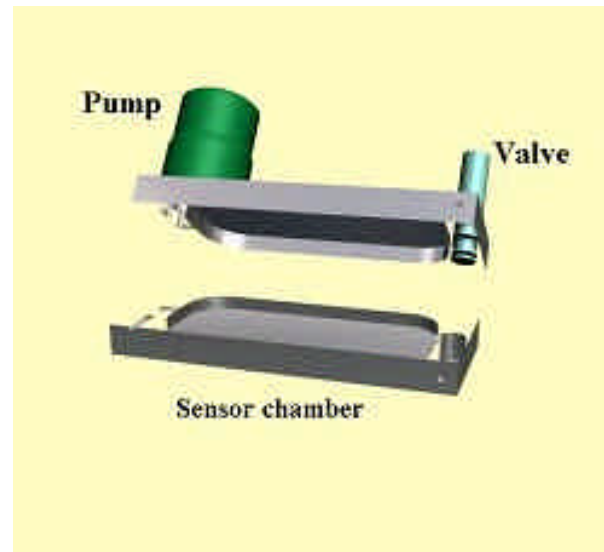
The ENM experiment is made up of an array of 8 thin disks of quartz, an electronic part related to the sensor interfaces and sensor signal processing and by a pneumatic part consisting in a valve, a pump and tubes. Each sensor can interact with different ranges of volatile organic compounds.



Quartz microbalance inside the sensor chamber

All the ENM equipment will be accommodated in a metallic container and located in the Soyuz capsule for launch in a passive configuration (i.e. power-off).

The experiment will require a set up phase followed by three runs carried out at different locations in order to test the functionality of the device under different conditions. The ENM works in such a way that requires a comparison of the sample under test with a reference sample, which in this case will be the ISS air outlet.



An open view of the integrated system composed by valve pump and sensor chamber

The experiment will consist of 3 runs, each lasting approximately 6 hours. The experiment is connected to a laptop, and data acquisition will be carried out in automatic mode. At the end of each session the ENM and the Laptop will be moved to a new location in the ISS to execute a new run.

Team Members:

A. D'Amico , E. Martinelli

Università di Roma Tor Vergata
Rome, Italy

E-mail: damico@ing.uniroma2.it
martinelli@ing.uniroma2.it



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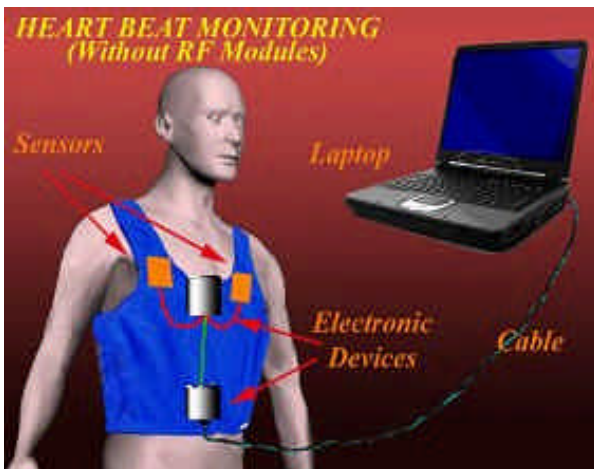
Heart Beat Monitoring (HBM)

The Heart Beat Monitoring (HBM) experiment aims at testing the development of 'intelligent' clothing for astronauts, capable of monitoring their vital functions using both wireless and non-wireless devices to allow free movement of astronauts in a closed orbiting environment.

The final objective of this study is developing hardware that allows for heart rate monitoring without having to use any items, which attach to the skin of subjects being tested (i.e. suction pads, sticking plaster, gel).

How is it done?

The HBM system is made up of a hardware and a software part. The sensors themselves, are embedded in a vest, which is worn by the astronauts. These sensors transfer information directly to a laptop computer using either a wireless or cable connection.



Layout of the HBM Hardware

Two different protocols will be executed by the astronaut.

The first protocol begins with the astronaut donning the vest and activating the system. In this first protocol, the astronaut must make sure that he has been at rest for a reasonable amount of time, and that no exercise has been performed prior to the experiment. It is important that the astronaut does not move during the data collection phase, so that a better signal can be achieved.

The second protocol involves the astronaut exercising with a chest expander prior to the start of the data collection. Again, it will be important for the astronaut to remain as still as possible.

The stored data is then returned to Earth with the Soyuz 9S capsule, where it will be analysed by the scientists.

Team Members:

A. D'Amico , E. Martinelli, F. Lo Castro

Università di Roma Tor Vergata
Rome, Italy

E-mail: damico@ing.uniroma2.it
martinelli@ing.uniroma2.it
lo.castro@ing.uniroma2.it



Technology Demonstrations

Food Tray in Space (FTS)

One of the major complaints by astronauts who spend long periods in space, is usually the lack of variety in the food that they eat during their stay in orbit.

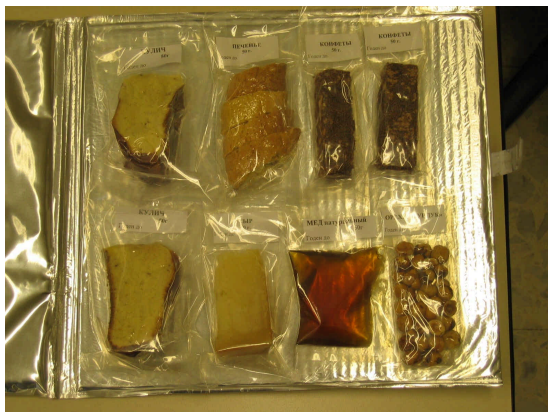
The objective of the FTS experiment is to increase the variety and quality of food available to crews in space, more specifically the International Space Station (ISS). This will be done by identifying new food items (typical, traditional food) from the Italian Lazio region, to be served in a tray-container as a meal on the ISS. FTS will be a demonstration that food items, produced from high quality products, are tasty and nutritious and they don't lose their quality in space flight conditions.

Providing more variety and top quality food can also have a positive impact on crew from a psychological point of view for the following reasons:

- It makes the stay onboard the ISS more pleasant;
- Traditional products can act as a reminder for the astronaut of the region or area he comes from;
- Traditional products may generate positive emotions and feelings relating to the personal life of the astronaut.

How is it done?

The FTS will consist of a tray-container (approximately 33 x 32 x 8 cm), containing 8 bags of food products from the region of Lazio in Italy, each individually vacuum-packed in certified plastic bags.



The 8 FTS food products (Image: ARSIAL)

The experiment will take place once, lasting about 30 minutes and will involve 2 astronauts. One astronaut will take the tray, open it, and take out one bag at a time. He will taste the food contained in each bag, and he will fill out a questionnaire, which contains a set of questions that the astronaut must answer after tasting each product. The second astronaut records the experiment via still photography.

The results of the test-card will then be analysed upon return to Earth of the tray-container, which will be stored in the returning Soyuz capsule.

Team Members:

O. Temperini, A. De Benedetto

ARSIAL
Rome, Italy
E-mail: ass@arsial.it



Technology Demonstrations

Garments for Orbital Activities in Weightlessness (GOAL)

This technology demonstration builds on the experience already gained during the Italian "Marco Polo" Soyuz mission in April 2002. The objective of that experiment was to evaluate a new integrated system of garments made of different types of materials intended for use in the space flight environment. The final purpose was to improve living and working conditions in space by designing innovative fabrics suitable for life inside the International Space Station (ISS) while keeping style a priority.

The aim of the GOAL experiment is to increase astronaut comfort and efficiency by improving the psychological and physiological well being by means of garment wearability, aesthetics, colours, thermal stability and bodily hygiene on board the ISS.

The project is based on the research of new structural materials suited to the peculiarities of the specific ISS environment with the aim of containing human skin inside clothes. Also, peculiar cuts, patterns and colours taking into account the 'neutral body posture' adopted by astronauts in weightlessness, will be studied.

The results of this test will help design future garments for longer and more complex missions with crews of different gender, race and size. Spin-offs of the experiment will extend the applications to different fields such as the medical environment.

How is it done?

The test item consists of a T-shirt made of fabric that increases thermal stability and bodily hygiene, and is cut to be comfortable in a microgravity environment.

Data will be collected and analysed by means of questionnaires and still images. Comfort and crew well being will be tested with a questionnaire based on the astronaut's opinions when wearing the garment during normal day-to-day activities on-board the ISS. The questions will cover parameters like body posture, movements, comfort and garment wearability in weightlessness.

An important session of questionnaires will involve colour perception in microgravity compared to the Earth. A second astronaut will document the test

sessions, when the garment is worn, by means of still photography.

The questionnaire will be answered by the astronaut post-flight, and will be a multiple-choice test. Several questions will act as a comparative analysis between the GOAL clothing item and the usual garments worn onboard the ISS.



GOAL T-Shirt (Image: A. Dominoni)

Team Members:

A. Dominoni

Spin Design, Politecnico di Milano
Milan, Italy

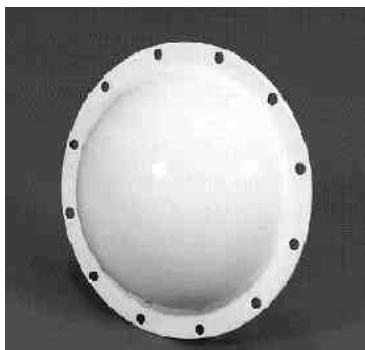
E-mail: annalisa.dominoni@polimi.it



Esperimento di Navigazione per Evento Italiano Dimostrativo di EGNOS (ENEIDE)

ENEIDE is an experiment, which will apply advanced navigation techniques based on the European Geostationary Navigation Overlay Service (EGNOS). EGNOS is Europe's first venture into satellite navigation and will augment the two military satellite navigation systems now operating, the US GPS and Russian GLONASS systems, making them suitable for safety critical applications such as flying aircraft or navigating ships through narrow channels.

The objective is to measure and verify in Low Earth Orbit, the GPS and EGNOS signals, which will be used in the combined GPS/EGNOS navigation system for spacecraft control and guidance. The experiment will exploit the EGNOS signals with the use of a spaceborne Global Navigation Satellite System receiver developed by Alenia Spazio in 1999. This will verify the performance of the GPS/EGNOS receiver on board the Soyuz spacecraft and compare results from the combined receiver during different phases of the mission with equivalent data received from the spacecraft and the ISS.



Antenna located outside the Soyuz capsule (Image: LABEN)

This experiment can be considered a precursor of a similar experiment that can be performed at a later stage to validate the use of the combined GPS/Galileo/EGNOS navigation system for spacecraft control and guidance. Galileo will become (around 2008) the European global satellite navigation system, which will consist of a network of 30 satellites, 24km above the earth with relevant control stations.

How is it done?

The experiment will be performed on board the Soyuz spacecraft by the Italian astronaut. It will be performed during the orbital phase and after the docking between Soyuz and ISS.

After launch, during the orbital phase of the Soyuz mission two time slots of at least 6 hours without spacecraft manoeuvres will be identified to perform the first stage of the experiment. In these periods the Italian astronaut will monitor the receiver activity every 60 minutes via a laptop.

After docking between the Soyuz and the ISS, at least three time slots of a minimum of 6 hours will be identified to perform this last phase of the ENEIDE experiment. The astronaut will monitor the receiver activities every 3 hours via a laptop.



ENEIDE receiver (Image: LABEN)

During the orbital phase, the Soyuz spaceship will receive the signals from the Inmarsat and/or Artemis satellites. These are in geostationary orbit about 36,000km above the Earth. These signals will be used to determine the position and velocity of spacecraft and to verify the correct reception of integrity message from EGNOS. The ENEIDE receiver will use these signals to determine the position and velocity of the spacecraft and to verify the correct reception of integrity messages from EGNOS.

Team Members:

G. Fuggetta ⁽¹⁾, S. Landenna ⁽¹⁾, M. S. Lavitola ⁽²⁾,
C. Aloisi ⁽¹⁾

(1) Alenia Spazio - Laben
Milan, Italy

E-mail: fuggetta.g@laben.it
landenna.s@laben.it, aloisi.c@laben.it

(2) Alenia Spazio
Turin, Italy

E-mail: msslavito@to.alespazio.it