HUMAN SPACEFLIGHT, MICROGRAVITY AND EXPLORATION

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COMPILED BY HME SCIENCE AND APPLICATIONS Division

THE RESEARCH AND OPERATIONS DEPARTMENT OF THE DIRECTORATE OF HUMAN SPACEFLIGHT, MICROGRAVITY AND EXPLORATION RELEASES A NEWSLETTER ON HIGHLIGHTS OF THE MONTH.

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FEATURES

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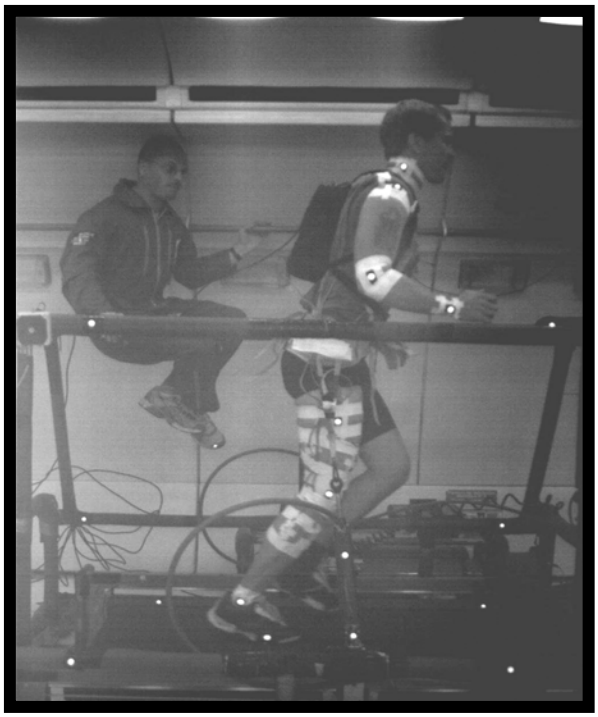
TWO YEARS' PARABOLIC FLIGHT EFFORTS MATERIALISE IN STEEPLY IMPROVED LOW GRAVITY TREADMILLS



A SYNERGISTIC EFFECT WITH A VERY POSITIVE OUTLOOK IS THE RESULT OF HARDWARE DEVELOPMENT BY ESA IN SUPPORT OF ONE OF THE EXPERIMENTS IN PARTICULAR ENGAGED IN RUNNING AS A COUNTERMEASURE TO DELTERIOUS EFFECTS OF LONG TERM SPACEFLIGHT ON BONE AND MUSCLE. THE SCIENTISTS BEHIND THE EXPERIMENTS ONBOARD ESA'S 46TH A300 PARABOLIC FLIGHT (PF) CAMPAIGN HAVE DEMONSTRATED THE IMPORTANCE OF THE FOOT IMPACT FORCE MEASUREMENTS UNDER A PROPER LOADING REGIME FOR FUTURE TREADMILL RUNNERS ONBOARD THE ISS. IN SUPPORT OF THIS LINE OF RESEARCH ESA DECIDED TO COOPERATE WITH NASA ON THE DEVELOPMENT OF THE SECOND GENERATION TREADMILL BY PROVIDING THE SUBJECT LOADING SYSTEM. THIS WAY THE COUNTERMEASURES GROUPS FROM ALL OF THE INTERNATIONAL PARTNERS MAY SOON RECEIVE REAL FLIGHT DATA FROM THE ISS IN SUPPORT OF CREW HEALTH.

Exercise onboard the ISS or any long-term human flight in space is mandatory. It occupies a significant number of crew hours, and crew health monitors (i.e. Medical Operations personnel) and research scientists have reached an agreement where under data is being shared, such that further research can be performed without extra time penalty.

The treadmill onboard the International Space Station that serves the health activities of the crew by offering to 'go for a run' as frequently as every day, if desired, is up for replacement in order to prepare for the phase where 6 crew – as opposed to the present 3 – will be onboard continuously. The activities onboard these PF campaigns serve as a good preparation and testing prior to engaging in construction of hardware that will be realized via contracts with relevant industrial partners.

BACK TO TOP...

An indispensable part of the treadmill exercise is the loading system that pulls the runner back down on the rolling band. If this system is not working properly, or if it is used at a lower force than required by the training protocol, the effects of this countermeasure are drastically reduced. Running on a treadmill without gravity is only possible with one or the other form for a harness and pull-down system, but at the same time it is evident that this hinders a part of the free movement that one normally enjoys during running. It has therefore been utmost important to investigate ways to minimise the hampering of the free running as much as possible. The influence of the loading characteristics is what has been tested scientifically by European researchers onboard a number of ESA's parabolic flight campaigns, the latest being the 46th PF campaign in November 2007. This scientist group has experimented with potential improvements to the loading system, compared to the old bungee system, in order to assess how useful treadmill running is for the main objective, namely maintenance of muscle and bone function and status. This is the main scientific focus of the Brussels group.

Earlier and ongoing research supported by ESA and partners via a number of ground based studies has been trying to find the 'code' for optimal maintenance of muscle and bone tissue. Impact and loading patterns seem crucial and it has therefore been attempted to reproduce the earth-bound movement and impact patterns as closely as possible in microgravity, more specifically by using ESA's parabolic flight campaigns.
Norman Heglund, Patrick Willems and Thierry Gosseye from Université Catholique de Louvain, specialists in biomechanical analyses of gait and running, have been testing these aspects in a state-of-the-art biomechanical setup, recording all essential parameters, on a treadmill with multiple load and movement sensors as well as a sophisticated harness controlled via vacuum or pneumatic pistons for servo-loop operation, needed to follow and restrain the running subject as smoothly as possible.

The latest set of data shows a remarkable resemblance with earth-bound running in these low gravity experiments, and the scientists involved actually see a systematic deviation from the perfect match of around 6%, which they think to know the reasons for. If this is so, it would mean that the match could come very close to perfect in the end.

So, does this then mean that subjects running in space have exactly the same feeling as running on Earth? Well, the subjective feeling is actually quite different even if the loading of muscles and bones seem almost as on Earth. One problem is that the loading is located to hips and shoulders, a restraint that you do not need on the ground. This will remain an issue, even though design of the harness should

BACK TO TOP...

compensate to a large extent for discomfort in this respect. Another aspect is that the balance organs in the inner ear still won't feel the direction of Earth-gravity, as there is no one (e.g. Earth gravity pull) to be sensed by persons onboard an orbiting space craft.

ESA considers this line of research important and supports that scientists influence the design of the routine countermeasures in the ISS. With this in mind, ESA is involving European Space industry for the development of flight hardware evolving from the findings of the University team.

NASA appreciates the initiative and has invited ESA to participate in the development of their second generation Treadmill for the ISS by providing the Subject Loading System. It is expected that this new system could be available onboard the ISS during 2010.

Video recordings of one test session onboard the 46th PF campaign can be accessed below:

http://eea.spaceflight.esa.int/attachments/parabolicflights/ID479ef93507720.mov

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BACK TO TOP...

SOUNDING ROCKET TEXUS 44 READY TO LAUNCH 263 KG OF SCIENCE PAYLOAD IN 3 SEPARATE EXPERIMENT MODULES FROM KIRUNA

MAXUS-7 lifting off from ESRANGE in Kiruna, 02 May 2006

A TYPICAL BUILD-UP OF THE TEXUS 44 ROCKET PAYLOAD E.G. ONE MODULE ON TOP OF THE OTHER IS AGAIN READY FOR LAUNCH (THE PLANNED LAUNCH 31 JANUARY WAS DELAYED DUE TO WEATHER CONDITIONS). FIVE EXPERIMENTS ARE PLACED IN THREE MODULES. THE CONSEQUTIVE DLR-LED MISSION, TEXUS 45 IS SCHEDULED TO LAUNCH A WEEK LATER, WITH ANOTHER THREE EXPERIMENTS, INCLUDING ONE FROM ESA. WEATHER CONDITIONS IN THE AREA HAVE FORCED SEVERAL LAUNCH POSTPONEMENTS. IN PRINCIPLE A LAUCH WINDOW IS AVAILABLE EACH DAY BETWEEN 09:00AM AND 12:00PM HOURS.

The experiments onboard TEXUS 44 are:
TEM-EML-2 module (178,7 kg) - MATERIAL SCIENCES - Two flown samples are shared between three experiments from the Microgravity Application Project (MAP) programme:

- High-precision thermo-physical property data of liquid metals for modelling of industrial solidification processes (THERMOLAB), by H. Fecht et al.
- Non-Equilibrium solidification, modelling for microstructure engineering of Industrial alloys (NEQUISOL), by M. Herlach et al., Bochum, Germany
- Undercooling and de-mixing of Cu-based alloys (COOLCOP), by I. Egry et al.,Cologne, Germany

TEM 06-30F module (66.7 kg) - CELL BIOLOGY
Responses on microgravity exposure of in-vitro cultures of epithelial follicular cell from thyroid, by S. Ambesi-Impiombato, Udine, Italy
(3 x16 samples as follows: zero-g, flight - one-g, flight control, and 1-g, ground control)

BACK TO TOP...

TEM 06-BIO module (17.6 kg) – CELL BIOLOGY – Funded by DLR

- Kinetics of gravity-sensitive membrane recycling under reduced gravitational conditions, by D. Volkmann, Bonn, Germany

EXPERIMENT BACKGROUND:

THERMOLAB:

The ThermoLab Project is concerned with the measurement of the thermo-physical properties of metallic alloys in the liquid phase to provide industry with data for the modelling of casting, solidification and process optimisation. The project is motivated by the inherent difficulty of thermo-physical property measurements on liquid metallic alloys because of their high chemical reactivity in the molten state. The further objective is to provide benchmark values of industrial alloys. One category of necessary experiments are being performed frequently onboard ESA's Parabolic Flight platform, but longer duration microgravity is needed for full experiments.
Till now eleven reports on specific industrial alloys have been written on the basis of the Parabolic Flight activities by this science team.
Present activities are in close collaboration with the EC FP6 IMPRESS project.

NEQUISOL: (I.E. 'NON-EQUILIBRIUM SOLIDIFICATION ..')

Deep undercooling of alloys below equilibrium liquidus temperature results in rapid solidification, yielding materials with improved mechanical, magnetic and electrical properties. Ni-based multicomponent superalloys are the starting material for the production of, for example, turbine blades; Al-based alloys are highly important for the aerospace and automotive industries.
More than 90% of all metallic materials are now produced from the liquid state. So far, efforts have been directed towards optimising the industrial production routes in the casting and foundry industry by computer-assisted modelling and simulation of solidification under different conditions. Techniques used range from electromagnetic levitation and melt flux processing, to short-duration experiments on Earth in drop-tubes and atomisation facilities. Influence of convection on droplet dispersion is being studied onboard ESA's Parabolic Flight platform. Reliable temperature profiles for heating and cooling cycles of separated and homogeneous samples have been obtained on the 46th Parabolic Flight, Nov 2007
As the Parabolic Flight microgravity periods are rather short, TEXUS 44 experiments are needed for the continuation of the experimental plan.

BACK TO TOP...

COOLCOP: (I.E. UNDERCOOLING …. OF COPPER-BASED ALLOYS)

Immiscible (e.g. 'can not mix') alloys have been investigated since the beginning of materials science research under microgravity conditions because of the attractive prospect of producing finely dispersed materials for various applications. Containerless processing offers new possibilities for investigating the properties of such systems. Of particular interest are the binary alloys Cu-Co and Cu-Fe, and the ternary system Cu-Fe-Co. All show a metastable miscibility gap in the undercooled melt.
Five parabolic flights have been flown. The microgravity time in PF is too short for full experiments, and Sounding Rockets therefore form the next logical step. Parabolic Flights have given preliminary data allowing next level of studies onboard TEXUS 44 using electromagnetic levitation. These are all forerunners for systematic studies in the Elctromagnetic Levitation Module in ESA's Material Science Lab (MSL) onboard the ISS.
Potential fields of application of this technology are: Catalyst , recycling, cutting tools, and sensor technology – exploiting the Giant Magneto-Resistance, for reading heads of hard-disks.

CELL BIOLOGY – S. AMBESI-IMPIOMBATO

Typically certain species gradually achieve preference by researchers (we have seen that the plant *Arabidopsis thaliana* plays such a role), often because they for one or several reasons become the organisms that get examined the most. This in turn creates a database which can be a useful reference basis when yet other experiments are planned on the same organism.
This is also the case with the cell line the FRTL-5 used here for investigation under microgravity, for its response to stimulus by a certain hormone for which this particular type of cells have a specific affinity. Even though this is one of many cell lines for such purposes, this one has been investigated in many contexts. The specific response to the stimulus will be investigated on DNA level and in terms of resulting protein formation, by use of modern chip technology.

GRAVISENSING OF PLANTS – D. VOLKMANN (DLR SCIENCE MODULE)

Yet another experiment using the grace of *Arabidopsis thaliana ,* in the form of seedlings (Wild Type and a gravitropic mutants) .
Detail gravity sensing mechanisms in plants are being examined in the form of two focal areas 1) the role of the structural proteins involved in giving stiffness and support to the cell, the cytoskeletion, and 2) the details of the theory under which

BACK TO TOP...

the communication of vesicles, so-called endosomes with the cell membrane should be involved in transmission and translation into chemical potentials of signals based on gravity induced mechanical stimuli.
Two chemical compounds are used to upset these mechanisms, namely brefeldin A, which affects the vesicle trafficking, and latrunculin B, which is supposed to influence the function of the cytoskeleton.
For fluorescence microscopy, samples will be chemically fixed during flight at 90 seconds intervals after launch. As reference molecules, RGII (cell wall pectin), PINs (putative IAA transporter) and plasma membrane ATPase, will be used, all of them being identified as molecules that are recycled within a few minutes. All data will be compared with controls from the ground experiments.

Onboard the following TEXUS 45 flight, ESA participates with an experiment which is a part of the MAP project 'Convective Boiling and Condensation' (CBC), with the title ''Two Phase Flow in Open Capillary Channels''. This is accommodated in a 66 kg heavy experiment module.

Learn about the Sounding Rocket Systems **here**

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BACK TO TOP...

BED REST STUDY: BED REST NO GOOD FOR BACK PAIN – CONTRARY TO TRADITIONAL THINKING

CONTRARY TO TRADITIONAL TREATMENT OF BACK PAIN THAT ADVISES THIS PATIENT GROUP TO STAY IN BED FOR EXTENDED PERIODS OF TIME, NEW PUBLICATIONS FROM THE BERLIN BED REST STUDY I (BBR-1, 2003-04) SHOW IN DETAIL WHAT HAPPENS TO THE LOWER BACK MUSCLES DURING EXTENDED BEDREST / UNLOADING. BUT EVEN BETTER, THE STIMULATION AND EXERCISE REGIME PERFORMED IN ANOTHER BBR-1 GROUP GIVE CLUES TO HOW THIS PROBLEM MAY BE REDUCED. ORIGINALLY AIMED AT HELPING ASTRONAUTS, THESE RESULTS ALREDY HAVE TERRESTRIAL CLINICAL APPLICATION

Reasons for development of low back pain (LBP) are many as are the theories for why this happens so often to so many people on Earth.
The ESA Low Back Pain Topical Team, composed of specialists with an expertise related to low back pain, from physiotherapists over medical doctors to biomechanical engineers, pooled their common knowledge to try to come closer to causal connection in the development of low back pain, also very frequently seen in astronauts in Space. As a follow-on of that activity the BBR-1 study was exploited for an investigation into these questions during extended stay in bed, although the study's main focus was on the effect of bed rest on bone and limb muscles of different stimulation regimes.

The multifidus muscle (Latin: split in many parts) connects the lower back segments of the spine with each other and the longer fibre parts with the pelvis, like the stays of ship connects to the deck. The difference however is that the mast of a ship is a rigid structure whilst the spine is composed of single vertebrae that have a certain, though limited movement freedom relative to each other. In order to ensure that these segments are always in the best position – in what is called the lumbar lordosis: the curvature of the lower part of the spine for which the multifidus muscle is so essential – the individual segments are under a constant, highly accurate

BACK TO TOP...

position and movement control via coordinated actions from muscles, size-wise in the range from a few to 10-20 centimetres' in length. This coordination happens in the form of muscle activation reflexes that ensure the optimal positioning of the vertebrae relative to each other in far the most cases, via appropriate tension and timing - all brought about via our reflex system.

Magnetic Resonance Imaging demonstrated quite clearly that the mutifidus muscle selectively loses its capacity, compared to other muscles in the region, measured as reduction in the cross sectional area[1], and thereby the lumbar curvature loses a part of it stabilising support. As LBP patients display specific atrophy in this muscle, it evidently can be assumed to play a key role. As additional features that resemble those seen in patients with chronic LBP are found in the bed rested persons in this study, the phenomenological links seems to be very strong.

These findings may turn out to be essential for different health stabilisation programmes for astronauts in space, as they may significantly help improving the way LBP is treated in the daily clinical setting.

Another submitted paper, accepted for publication, which will form the basis for a later article in this newsletter, addresses the effect on the status of the different muscles, of the countermeasures used in this study.

In the meantime continued research on LBP problems is continued onboard the International Space Station

Reference:
Hides et al.: Magnetic Resonance Imaging Assessment of Trunk Muscles During Prolonged Bed Rest, in SPINE Volume 32, Number 15, pp 1687-1692 ©2007. Contact: j.hides1@uq.edu.au

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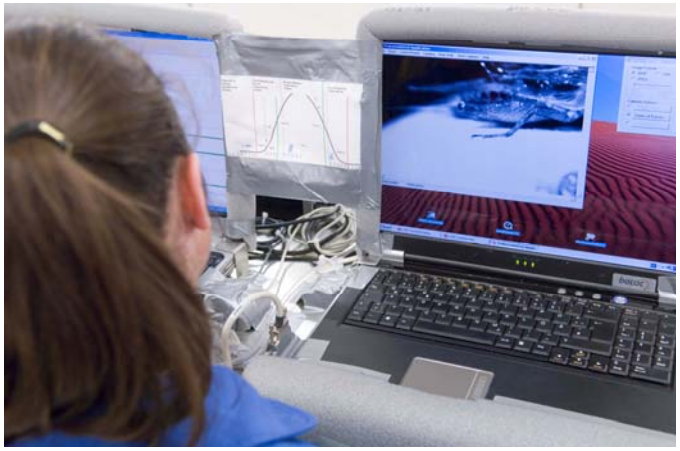
BACK TO TOP...

[1] The force of a specific muscle is proportional to its Cross Sectional Area (CSA)

CRICKETS GIVE IMPORTANT INFORMATION WHEN TAKEN FOR A MICROGRAVITY RIDE ON ESAs AIRBUS 300



Cricket on its walking wheel onboard the 47th parabolic flight campaign

CRICKETS HAVE BEEN STUDIED EXTENSIVELY BASED ON THEIR SPECIAL CHARACTERISTICS OF THEIR NERVOUS SYSTEM. THEY ARE KNOWN FOR HAVING INTERESTING COUPLINGS BETWEEN NEURONS THAT IN PRINCIPLE WOULD HAVE LITTLE TO DO WITH OTHER, E.G. THOSE RELATED TO WALKING AND THOSE RELATED TO HEARING. IN CERTAIN CASES AUDIBLE SIGNALS ENHANCE WALKING PATTERNS.

Whether such couplings exist between walking and sensing of gravity is one of the topics for this experiment.

The nervous system of the cricket *Acheta domesticus* has been used as a test-bed for neurological analyses and as a means to extrapolate what might happen to human homologues in particular during embryonic life.
Whether and to which extent gravity or lack of same influences the early embryonic development has been and still is a fairly unanswered question.

Now the same group who asked those questions on earlier space missions are changing focus to the effect of gravity on walking patterns of crickets. Do they alter that during periods with absence of gravity? And if they alter it, how are the characteristics of the changes?

In insects, gravity perception mainly depends on the perception of body displacements and, thus, on the stimulation of proprioceptors (i.e. movement and position sensors) located in the joints of the legs. There are only a few insect species such as crickets and cockroaches that have, in addition, specialized gravity sense organs located on the appendages of the abdomen. What is known to be the case is, that walking of the animal is required to obtain gravity related information, and

BACK TO TOP...

induce the gravity related behaviour such as the compensatory head movements.

Parabolic flights offer the chance to study the impact of different levels of gravity on the leg movement during loading and de-loading of the leg motor and sensory systems. A series of experiments with crickets as an experimental model was initiated by the team of Prof. Eberhard Horn from Ulm University, Ulm, Germany, to find out to which extent the body weight is taken into consideration in the control of leg movement besides the weight of the leg itself. One hypothesis is that the central patterns for hind leg movements are exclusively determined by genetic programs. The other hypothesis is that the control of leg movements needs gravity-dependent information. In this case, the activity of muscles and/or sense organs of the legs is related to the g-level, i.e., they change during the various g-periods of parabolas. It depends on the information processing within the underlying neuronal network whether both muscular and sensory activity are modified, or only one of them. Absence of g-effects on the trajectory of leg movements might be caused by a modification of muscular activity; vice versa, absence of g-effects on the muscular activity might cause a modification of the leg trajectory during movement.

The first parabolic flight experiment with the crickets was conducted during the 45th ESA Parabolic Flight campaign in 2006. The second experiment was recently performed during the 47th ESA Parabolic Flight campaign in December 2007.
the activity of hind leg muscles (electromyogram EMG) and simultaneous video-recordings of this hind leg to determine the trajectory of movements during individual steps have been performed.

An additional experiment during the 47th ESA PFC was dedicated to the analysis of the crickets' leg and body posture during absence of gravity, i.e., during free-floating. Elimination of any effect of body weight on the legs causes a basic, tension-free posture of the body and, in particular, of the legs. By this approach, the extent of proprioceptors on the leg and body posture can be estimated. For this experiment, the Cricket-Free-Float-Chamber (CFFC) was developed.

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BACK TO TOP...

ONBOARD ISS IN JANUARY 2008 – ESA SCIENCE PERFORMANCE

The STS-122 Atlantis crew with ESA astronauts Hans Schlegel and Leopold Eyharts.

THE PRESENT EXPEDITION 16 ISS CREW, COMMANDER PEGGY WHITSON, FLIGHT ENGINEER YURI MALENCHENKO AND FLIGHT ENGINEER DAN TANI ARE EXPECTING VISIT VERY SOON. THEY ARRIVED AT THE ISS ON 10 OCTOBRE 2007, AND THE FOLLOWING SPACE SHUTTLE ATLANTIS WAS SCHEDULED TO ARRIVE EARLY DECEMBER. THE LAUNCH IS NOW SCHEDULED TO TAKE PLACE THURSDAY 7 FEBRUARY, WITH TWO ESA ASTRONAUTS AS MEMBERS OF THE CREW, NAMELY LEOPOLD EYHARTS AND HANS SCHLEGEL . WITH THEM, IN THE CARGO BAY OF THE SHUTTLE THEY BRING ESA'S ISS MODULE **COLUMBUS.**

In the meantime the experimental programme is continued:

ESA Science Activities in January:

- **ALTCRISS** (using the Italian ALTEINO equipment), is now measuring radiation in the PIRS module and memory cards are exchanged roughly every three weeks. Further the equipment has been given a new attitude; it has been rotated to obtain radiation measurements from a different angle.

- **ETD or the Eye Tracking Device** had its last session on 12 December and 2 more sessions are planned for the Expedition 16 period. The ETD is used to analyse the responses of the so-called vestibular-ocular system under different circumstances. Eye movements are recorded on high-resolution video and head

BACK TO TOP...

movements registered via a set of accelerometers. This kind of measurements started as far back as onboard the Euromir missions in the mid 1990ies.

- **IMMUNO:** This experiment has been performed by a number of crewmembers over the last 8-9 months. Blood and urine samples are given for analysis of the status of the immune system under space conditions. Yuri Malenchenko has performed the latest session on 24-25 January.

- **MULTIGEN-1**, the experiment that was growing *Arabidopsis thaliana* plants during autumn, was terminated in December and the samples have been waiting since in frozen condition to be returned to the scientists for analysis. The sample material will be returned onboard Atlantis when it leaves the ISS again

A Russian cargo ship of the Progress type, the flight 28P has been launched Tuesday 5 February. It brings the usual cargo of fuel, water, oxygen, food items and equipment to the International Space Station. Thursday 7 February is the docking day after the roughly 50 hours the flight normally takes and the same day Atlantis is now scheduled to blast off from Kennedy Space Center in Florida with the Columbus module and the two ESA astronauts as a part of its 'cargo'. Atlantis in turn will also be underway for around two days before the shuttle will be docking with the ISS. Dan Tani is scheduled to return with Atlantis, once it undocks and return to Earth. Leopold Eyharts will remain onboard the ISS until his planned return with STS-123, that due to the significant launch delay of Atlantis with Columbus, is scheduled for launch not earlier that 11 March, according to the latest manifest.

WE WILL GIVE AN ACOUNT OF ESA'S EXPERIMENTAL PROGRAMME FOR THE INITIAL COLUMBUS PHASE IN THE FOLLOWING NEWSLETTER.

BACK TO TOP...