The CSA investigation **Space Health** utilizes the **Bio-Monitor** system for physiological monitoring before, during, and after a mission to the space station to assess the effect of space travel on heart health. NASA ID: jsc2022e062020.

Publication Highlights

Human Research

Space station research includes the study of risks to human health that are inherent in space exploration. Many research investigations address the mechanisms of these risks, such as the relationship to the microgravity and radiation environments as well as other aspects of living in space, including nutrition, sleep, and interpersonal relationships. Other investigations are designed to develop and test countermeasures to reduce these risks. Results from this body of research are critical to enabling missions to the lunar surface and future Mars exploration missions. From the beginning of station to date, more than 800 articles have been published in the area of Human Research.

The CSA investigation **Cardiac and Vessel Structure and Function with Long-Duration Space Flight and Recovery (Vascular Echo)** studies the effect of spaceflight on the stiffening of blood vessels, which can lead to elevated blood pressure and the progression of cardiovascular conditions.

In a brief communication published in *Aerospace Medicine and Human Performance*, researchers compared two different types of ultrasound technologies (traditional 2D and advanced 3D) to see if imaging quality differences would reveal the effectiveness of a countermeasure used to reduce cephalad (headward) fluid shifts in space (i.e., venoconstrictive thigh cuffs). Due to its manual operation, traditional 2D ultrasound has resulted in measurement errors that impact the reproducibility of the studies.

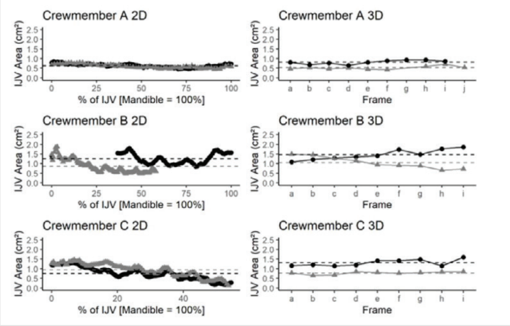


Figure 14. 2D and 3D imaging of the internal jugular vein in three crew members. 2D imaging was unreliable and it did not allow researchers to detect differences between baseline (black) and the effect of wearing thigh cuffs (gray). *Image adopted from Patterson, Aerospace Medicine and Human Performance.*

In the study, researchers revealed that motorized and semi-automated 3D ultrasound identified a 35 percent size reduction of the internal jugular vein after three crewmembers wore thigh cuffs for four hours during spaceflight (Figure 14). These changes were missed by the 2D option. The finding indicates that 3D ultrasound can more adequately measure cardiovascular anatomy than 2D ultrasound and demonstrates that venous congestion (i.e., pooled blood in lower extremities not flowing to the heart) is effectively diminished by thigh cuffs.

The large probe head, constant scan speed, and fixed contact with crucial body parts make the motorized 3D ultrasound superior to standard 2D technologies. This research demonstrates that 3D ultrasound allows non-expert sonographers to take precise measurements of challenging body parts to accurately assess vascular changes during spaceflight.

The ASI instrument **Light Ions Detector for ALTEA (LIDAL)**, installed in the Columbus module in January 2020, was designed to measure cosmic particles, light and heavy ions from phosphorous (P) to iron (Fe), in a wide range of energies. In a new study published in *Life Sciences in Space Research*, researchers report on the functionality of the instrument.

Patterson C, Greaves DK, Robertson AD, Hughson RL, Arbeille P. Motorized 3D ultrasound and jugular vein dimension measurement on the International Space Station. Aerospace Medicine and Human Performance. 2023 June 1; 94(6): 466-469. DOI: 10.3357/AMHP.6219.2023.

LIDAL takes into account the position of the detector inside station, which was moved along station's axes X, Y, and Z, the geomagnetic region (high/low latitude), and time-of-flight (ToF) of detected ions. The time-of-flight parameter adds information about the kinetic energy or velocity of the particles, enhancing the recognition of ions fundamental to understanding the effects of radiation on the human body.

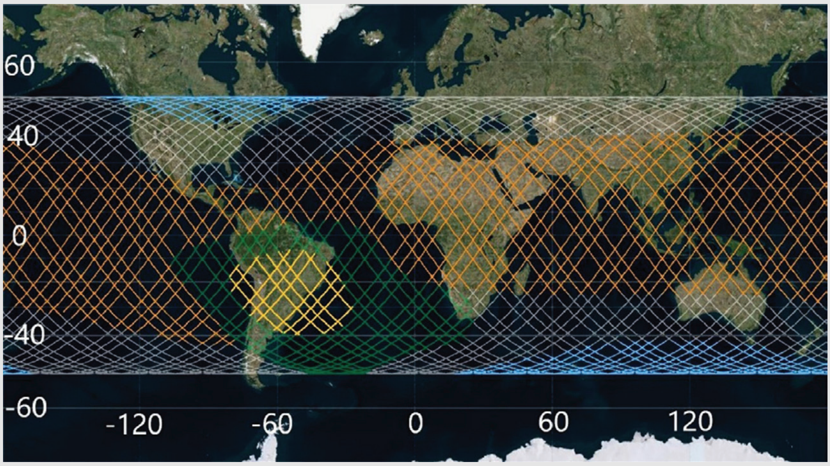
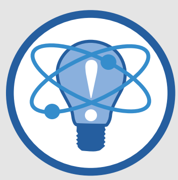


Figure 15. Regions of high latitude in blue, low latitude in orange and the excluded South Anomaly (SAA) region in yellow and green. *Image adopted from Di Fino, Life Sciences in Space Research.*

LIDAL upgrades the particle detection capabilities of a previous investigation, ALTEA, by using three Silicon Detector Units between two plastic scintillators for the fast timing of ToF measurement. These enhancements increase the sensitivity to cosmic ray ions for improved data acquisition.

Initial measurements of LIDAL with 17 months of data collection confirm the highly variable radiation field of station. Researchers found that the measurements of particles differ depending on the orientation of the detector due to the shielding arrangement of station. This study distinguished, for the first time, forward particles arriving to station from Earth and backward particles going to Earth from station. The radiation field peculiarities depended on whether particles were influenced by the Earth's shadow or passed through more mass inside the station as shown by LIDAL measurements. Additionally, flux and dose rate values are lowest at low latitudes and highest at high latitudes (Figure 15), but the total integrated dose is larger at low latitudes because the space station spends more time near the equator.

The LIDAL detector system allows the conversion of measurements from particle charge and velocity to radiation risk indices to enable researchers to determine the level of radiation exposure for crewmembers and devise countermeasures.



The ESA and Roscosmos investigation **Brain-DTI** measures structural and functional changes in the brain after spaceflight to search for clues of adaptation to microgravity, especially in areas of the brain involved in visual perception, balance, and orientation.

In a new study published in *Communications Biology*, researchers examined brain functional connectivity changes of cosmonauts (Figure 16) after spaceflight and eight months later to learn which changes remained and which changes reverted to baseline. Functional connectivity, estimated through resting-state functional MRI, refers to the coordinated function that exists between

Di Fino L, Romoli G, Amantini GS, Boretti V, Lunati L, et al. Radiation measurements in the International Space Station, Columbus module, in 2020-2022 with the LIDAL detector. Life Sciences in Space Research. 2023 May 6; epub: 30pp. DOI: 10.1016/j.lssr.2023.03.007.

different regions of the brain. For example, distinct areas of the brain work in concert to enable walking or reading.

Previous studies have revealed structural and functional changes after months in microgravity. Some of these findings are associated with microgravity-induced fluid shifts, such as larger ventricles, redistribution of cerebrospinal fluid, while other findings rather suggest possible neural adaptation, including gray and white matter increases in sensorimotor areas, and reduced activity of the vestibular system. In the current work, the researchers explored functional connectivity changes in a resting state that suggested adaptation in areas of vestibular and motor function as well as multisensory integration.

An assessment of brain activity while at rest in 15 cosmonauts revealed decreased functional connectivity after spaceflight in the left posterior cingulate cortex, an area involved in change detection, long-term memory, and divergent thinking. This decreased connectivity persisted at the 8-month follow-up. Additional decreases observed in the bilateral insula, which processes salient stimuli, returned to pre-flight levels after the mission. Increased connectivity was found in the right angular gyrus and was sustained during the follow-up period. This region is involved in verticality processing as well as detecting mismatches between actual and expected sensory outcomes. The sense of verticality has gained importance in view of the planned missions to the Moon and Mars during which crew landing capabilities must be optimal. A final analysis showed that the changes in functional connectivity were independent of structural changes in the brain during flight. Together, changes were mostly found in higher-order brain regions, suggesting adaptation at the level of multimodal integration.

Figure 16. ESA astronaut Thomas Pesquet on the space station, showing on the tablet his brain scanned pre-flight for the BRAIN-DTI project.

These results demonstrate the adaptability and plasticity of the brain under extreme conditions and provide new insight into the workings of the central nervous system. This newfound knowledge may contribute to the development of targeted countermeasures or ways of monitoring brain adaptations to promote healthy brain function and adaptation, as well as improved treatments for vestibular disorders.

Findings from various research studies tracking astronaut health in space are archived in the **International Space Station medical monitoring** investigation. This collection contains a wealth of knowledge regarding the effects of spaceflight on multiple body systems. A Roscosmos study classified as medical monitoring on station reported new findings about biomarkers of endothelial and immune function in the journal *npj Microgravity*.

The lining of blood vessels, known as the endothelium, plays an important role in blood circulation and vascular injury recovery. Endothelial cells serve metabolic and endocrine functions through the exchange of metabolites and hormones between

Jillings S, Pechenkova E, Tomilovskaya ES, Rukavishnikov IV, Jeurissen B, et al. Prolonged microgravity induces reversible and persistent changes on human cerebral connectivity. Communications Biology. 2023 January 13; 6(1): 46. DOI: 10.1038/s42003-022-04382-w.

the bloodstream and surrounding tissues. Despite its importance to human health, little is known about the impact of spaceflight on the endothelium.

In the study, researchers examined the function of the endothelium and its interaction with the immune system by collecting indicators of blood flow and immune health (i.e., anticoagulant receptors, various white blood cells, and cytokine secretions). Blood samples were obtained from 15 crew members before and after spaceflight.

Results showed increases and decreases in different blood-based indicators after spaceflight (Figure 17). Notably, these varying changes characterized the state of the immune system. That is, higher concentrations of biomarkers indicating endothelial dysfunction correlated with increased production of proteins that regulate immune responses. These results suggest a tendency toward increased blood clotting upon return to Earth. Changes to biomarkers involved in both endothelial function and inflammation may in turn affect the immune response.

Understanding the effect of spaceflight on blood vessel damage and blood flow enables researchers to develop countermeasures that prevent coagulation during long duration missions to the Moon or Mars.

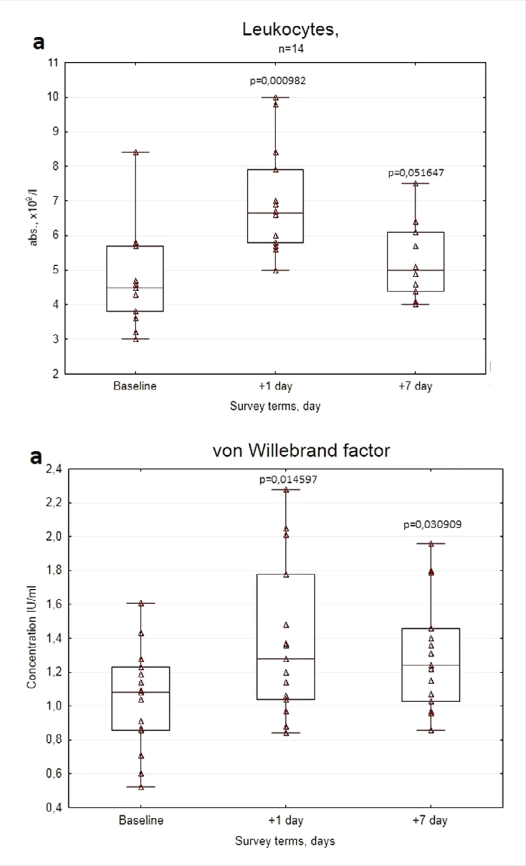


Figure 17. Data on von Willebrand factor, a protein involved in blood flow arrest, and leukocyte concentrations before spaceflight (baseline), one day and seven days after spaceflight. Increased endothelial dysfunction tends to occur in tandem with increased production of multiple white cell types one day after spacelfight. *Image adopted from Kuzichkin, npj Microgravity.*

Kuzichkin DS, Nichiporuk IA, Zhuravleva OA, Markin AA, Rykova MP, et al. Endothelial dysfunction markers and immune response indices in cosmonauts' blood after long-duration space flights. npj Microgravity. 2022 November 2; 8(1): 1-9. DOI: 10.1038/s41526-022-00237-0.