European vestibular experiments on the Spacelab-1 mission: 2. Experimental equipment and methods


Department of Physiology, University of Mainz, D–6500 Mainz, Federal Republic of Germany
Formerly Department of Neurology, University of Tübingen, D–7400 Tübingen, Federal Republic of Germany
Department of Experimental Biological Psychology, University of Düsseldorf, D–4000 Düsseldorf, Federal Republic of Germany
Landesnervenklinik Alzey, Department of Neurology, D–6508 Alzey, Federal Republic of Germany
CNRS Laboratoire de Physiologie Neurosensorielle, F–75006 Paris, France

Summary. A series of vestibular experiments were performed in conjunction with the first Spacelab mission, consisting of sets of pre-, in- and postflight tests. A multipurpose experimental apparatus used for the diverse flight and ground tests is presented. Additional apparatus together with the multi-purpose package were used in the baseline data collection facility at the landing site at NASA Dryden Flight Research Facility for the ground tests. The tests involved optokinetic, caloric and mechanical (whole-body or head-alone) stimulation. The latter included linear acceleration in the subject's x, y and z axes, static roll and yaw about an earth-vertical axis. Physiological parameters such as electro-oculogram (EOG), blood-volume-pulse (BVP), respiration, as well as the stimulus variables such as acceleration and caloric temperature were transmitted to the ground and recorded there. The flight and ground testing schedules are outlined. Problems arising from this complex venture are discussed, and some suggestions are made for future improvement.

Key words: Vestibular instrumentation – Methodology – Spacelab-1 mission – Hardware – Microgravity research

Introduction

The European Vestibular Experiments (ES 201) in the Spacelab SL-1 mission and the associated ground tests were performed primarily during a five month period in 1983 culminating in the space flight in November of that year. The preparation, design and construction of equipment, and the training, commenced some eight years earlier. The experiments performed and the scientific results obtained are described separately in this issue and in previous preliminary reports (von Baumgarten et al. 1984, Benson et al. 1984, Kass et al. 1984).

Apparatus

For these experiments separate apparatus were developed for 1) the flight tests and 2) the ground tests.

1. Equipment for flight experiments

A multi-purpose set of equipment was developed to satisfy the complementary and sometimes identical needs of the various flight experiments. The equipment basically consisted of the “Vestibular Helmet”, its electronic control unit, and the “Body Restraint System”.

The Vestibular Helmet consisted of a hollow aluminium frame, approximately 300 x 300 x 300 mm, enclosing the subject’s head and constructed such that the head could be fixed within it, as illustrated in Fig. 1. Fixation pads (two fronto-lateral, one fronto-medial, two parietal, one medial-parieto-occipital, and two occipital) kept the head fairly rigid. A visor, hinged from the main helmet frame, was arranged in front of the subject’s eyes; a light-tight goggle, which was moulded individually to each subject, fitted between the visor and the ocular region of the face. The visor carried a video-monitor facing the subject’s right eye and a CCD (charge-coupled device) camera facing the left eye. Stimuli presented on the monitor included 1) a latin target cross that subtended either 10x15 or 20x30 degrees of visual angle for calibration of eye movements, reference and control feedback, 2) optokinetic patterns as pre-recorded on a video tape player for stimulation, and 3) the image of the left eye as seen by the camera for adjustment purposes.

The camera basically consisted of an optical lens system and a 190 x 244 matrix CCD chip. This camera system, called EMIR (Eye Movement in Infra Red) operated with illumination from 20 An-Ga Infra-red light-emitting diodes (LED’s) at 960 nm wavelength. Because this wavelength is not in the visible spectrum, performed and the scientific results obtained are described separately in this issue and in previous preliminary reports (von Baumgarten et al. 1984, Benson et al. 1984, Kass et al. 1984).
the subject detected no visible light. The picture was digitized on board every 10 ms with a contrast of 16 levels per pixel. On the ground the corneal reflection of the LEDs and the black area of the pupil were digitized separately. The total transmission rate of the EMIR data to the ground was 13.3 Mbit/s.

Integrated within the main frame of the Helmet was the Caloric stimulator. Calorization of the ears was effected by insufflation of heated or cooled air at preselected different temperatures to each outer ear canal. The Caloric system consisted basically of two Peltier elements, a water loop, and an air loop. The water loop was closed and located within the hollow frame of the helmet, and had a heat exchanger that heated or cooled the air in the air loop. The latter, which was open, was connected directly to the ear pieces, at which point temperature was monitored, and through which the air was pumped.

Fixed to the frame of the Helmet were sockets for electrical connection with various sensors. These auxiliary devices, which could be plugged in as required, consisted of 1) a linear accelerometer that transduced linear acceleration in three orthogonal axes; 2) a single-axis angular accelerometer (only one of the two accelerometers could be attached at any one time); 3) a BVP transducer that fastened to the nose or earlobe, and measured heart rate and blood perfusion by transmission photometry; 4) a respiration belt consisting of two variable resistance transducers that responded to thoracic changes in circumference at levels of a) mamillae and b) lower thoracic aperture (epigastric angle); and 5) an EOG assembly made up of five Beckman mini-electrodes for recording horizontal and vertical eye movement. EOG DC amplifiers in the Helmet conditioned the signals, thus allowing measurement of eye position. A bitestick, individually fitted to the teeth of the upper jaw of each astronaut, was used as the fixation point for the accelerometer in use (so that the exact movement of the cranium could be measured). Part of the EMIR camera electronics and brightness- and contrast-control, was located in a “Seat Box” on the Spacelab floor. This Seat Box, so called because it was to be fixed to the seat of the Space Sled originally planned for, but not flown in this mission, was connected to the helmet by 2 m-long cables. It served as an interface between the Helmet and the rack-mounted control unit, located in one of the Spacelab racks, and performed some additional functions including signal amplification and digital picture processing.

Also attached to the Seat Box by a 2 m cable was a Target Setting Device. This consisted of a small box fitted with a Joy Stick that could move the target cross on the helmet video monitor (x-y translation). In like manner a potentiometer on the Target Setting Device could rotate the cross or control auto-rotation speed; the potentiometer could be set to control angular orientation or angular velocity. If illusory motion of the target cross was detected during the experiments, it could be “reset” by the subject and the direction and amplitude of the resetting signal was transmitted to the ground. Modes of operation were also available allowing the target cross to be fixed or removed from view in the helmet monitor while Joy Stick deflection still delivered signals to the ground. This configuration was used for indication of the detection of motion during linear acceleration in the Threshold experiment.

Accessories to the Target Setting Device, were a “remote” control unit for the potentiometer (connected by a 1.5 m cable), and an extension to the Joy Stick with a fixation element attached to the knee; bending of the subject’s ankle corresponded to movement of the Joy Stick and could thus be recorded. This apparatus was intended to measure “posture” during optokinetic stimulation. A battery powered metronome that emitted sound and/or light signals at a given adjustable frequency was also part of the instrumentation kit.

The rack mounted experiment control panel was the main unit for controlling, checking and calibrating the Helmet, and for running the experimental protocol. For checkout purposes a channel selector delivered signals from the various devices through an output that could be displayed on an oscilloscope (which was available in Spacelab). A mode selector could switch to different configurations preprogrammed to support the diverse experiments. The caloric temperatures for right and left ears could be available in Spacelab). A mode selector could switch to different configurations preprogrammed to support the diverse experiments. The caloric temperatures for right and left ears could be independently selected and the actual values measured by thermocouples at the inputs to the ears could be recorded. A calibration toggle switch produced a calibration cross on the monitor for reference recording of eye position signal. This was usually performed at the beginning and end of every functional objective. A balance toggle switch was also provided to reset EOG and BVP amplifiers if the signals drifted out of the working range.

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3 This air-caloric system was developed with consultive advice from U. Brandt and H. Scherer (Scherer et al. 1986)