The Space Congress® Proceedings

1993 (30th) Yesterday's Vision is Tomorrow's Reality

Apr 28th, 2:00 PM - 5:30 PM

Paper Session II-B - Evolution of Biomedical Payloads to Expand Human Presence in Space

Carolyn L. Huntoon
Space and Life Sciences Directorate, Lyndon B. Johnson Space Center, National Aeronautics and Space Administration

Howard J. Schneider
Space and Life Sciences Directorate, Lyndon B. Johnson Space Center, National Aeronautics and Space Administration

Gayle M. Karamanos
General Electric Government Services

Evolution of Biomedical Payloads to Expand Human Presence in Space

Carolyn L. Huntoon, Ph. D.
Space and Life Sciences Directorate
Lyndon B. Johnson Space Center
National Aeronautics and Space Administration
Houston, Texas

Howard J. Schneider, Ph. D.
Space and Life Sciences Directorate
Lyndon B. Johnson Space Center
National Aeronautics and Space Administration
Houston, Texas

Gayle M. Karamanos
General Electric Government Services
Houston, Texas

Abstract

Life sciences has always been an important part of the human space program. The effects of space flight on humans were monitored from the beginning and some research was conducted in the Gemini and Apollo programs. But it was only when a space station, Skylab, was available that we were able to perform in-depth medical experiments to examine the responses of humans to space flight. Since Skylab, flight research programs have been and still are progressing toward our goals of helping astronauts live in space for long periods of time and readapt to Earth's gravity as rapidly as possible, and studying the response of living systems to microgravity.

The Spacelab program provides the opportunity to conduct extensive research on short-term missions to lay the foundation for safe, productive, long duration missions on Space Station Freedom. Researchers around the world are involved in the investigations performed on Spacelab missions. To date, seven Spacelab missions involving life sciences investigations have been flown and five are currently in development. Four of these missions are dedicated to life sciences research. The first of the series, Spacelab Life Sciences 1 (SLS-1), was completed in June, 1991. The remaining missions, SLS-2, SLS-3, and SLS-4 are all currently in different stages of development. SLS-2 will continue the research conducted on SLS-1, SLS-3 will focus on musculoskeletal research, and SLS-4 will focus on neuroscience research.

During the series of Spacelab missions, sophisticated equipment for research and operational use in space has been developed which has allowed more extensive experiments to be conducted. Real-time data acquisition and communication with the crew also allow ground-based investigators to participate in the performance of their investigations, thereby providing enhanced scientific return.

The remaining Spacelab missions promise to build on the knowledge gained from previous missions to provide further understanding of physiologic changes occurring in and resulting from space flight. Investigation results and lessons learned from each of these missions will be used to influence future space shuttle missions and Space Station Freedom.

The National Aeronautics and Space Administration's (NASA's) life sciences goal is to ensure a safe and productive living and working environment for long duration manned stays in space. Prior to sending the first man into space, the effects of space flight on animals was investigated for several years. Since that time, extensive research, both ground-based and on-orbit, has been and will continue to be conducted to characterize and understand the human body's responses to a weightless environment.

The effects of space flight on humans were monitored during Project Mercury and limited life sciences research was conducted in the Gemini and Apollo programs. When the Skylab space station was available, in-depth, long-duration medical experiments were performed. These experiments led to the general conclusions that when astronauts return to Earth, they are said to be affected by "deconditioning" and must readapt. The physiologic changes that occur during space flight are generally associated with adaptation of the body to microgravity. The major responses are changes resulting from reduction of the hydrostatic gradient. This causes fluid to be redistributed toward the head resulting in a loss of body fluid and corresponding changes in the cardiovascular system. Another response, a loss of muscle and bone mass, is thought to be caused by the decrease in gravitational forces on the musculoskeletal system. In addition, reduced input to gravity-sensitive sensory receptors result in neurosensory changes. Questions still to be answered include: What are the mechanisms by which these changes occur? Do the changes intensify with time or cease after a certain period? What types of countermeasures would be most effective in reducing any consequences? Are there any long-term consequences due to these changes following return to 1 gravity?

Today, much of NASA's life sciences research is conducted through the Spacelab Program. The Spacelab research facility was built by the European Space Agency. The facility is located in the shuttle's cargo bay during Space Shuttle/Spacelab missions. It provides an shirt-sleeve atmosphere for the astronauts to perform experiments. Instruments and facilities flown inside the Spacelab are designed for use on more than one mission. Operationally, real-time data acquisition and communication with the crew is possible during flight, and early access to the crew and experiment samples is possible upon landing.

NASA's life sciences involvement in the Spacelab Program currently includes seven Spacelab missions that have flown and five that are scheduled for flight within this decade. The extent of participation has varied, from only a few investigations on a mission to a series of missions fully dedicated to life sciences research. Whatever the extent of participation, each mission builds on the next, in the areas of life sciences knowledge, technology, and operations.

The first series of Spacelab missions was Spacelab (SL) 1, 2, and 3. SL-1 was flown in November 1983. This was the first test of the facility and several disciplines were studied. Life sciences investigations included vestibular studies to provide information about the causes of space motion sickness and metabolic studies to analyze changes in red and white blood cell count. The SL-2 mission was flown in July 1985. Only limited life sciences research was conducted in flight. A vitamin D metabolite and bone demineralization study was conducted. Prior to SL-2, SL-3 flew in April 1985. On this mission, two life sciences hardware verification tests were performed. One test was for the Research Animal Holding Facility (RAHF). Two RAHFs were tested, one held two squirrel monkeys and the other held 24 rodents. Functional testing of the RAHFs was a necessary step in making it possible to perform in-flight experiments using animals, so that animal models for the effects of space flight on humans can be developed. The RAHFs maintain the animals in a laboratory-like environment. Although the animals on SL-3 were specific-pathogen-free, the RAHFs are designed to prevent cross contamination between astronauts and animals. Release of particulate matter from the RAHFs was detected during the SL-3 flight and a redesign of the facilities was required before they could be flown again. The other hardware verification test on SL-3 was for the Urine Monitoring System (UMS). This system, connected to the shuttle's Waste Collection System, can collect urine samples and measure urine volumes. Urine samples provide important information about changes in human body fluids during weightlessness. Air flow problems, discovered during testing of the UMS, were corrected prior to its use on future missions.

The next mission to fly was an international mission involving NASA and Germany's Space Agency, Deutsche Agentur für Raumfahrtangelegenheiten (DARA). Deutsche 1 (D-1) flew in 1985. Studies in the same areas of research as the SL series continued on this mission. Several vestibular, metabolic, and cardiovascular studies were performed, which included body impedance and venous pressure measurements, and cognitive behavior studies. A similar US/German Spacelab mission, D-2, is being planned with the DARA.

Another Spacelab series with life sciences investigations, the International Microgravity Laboratory (IML) series, is a joint effort between NASA and the European Space Agency. It consists of the IML-1 and IML-2 missions. IML-1 was launched in January

1992 with the life sciences focus on vestibular research. A special rotating chair was developed for the performance of a set of in depth vestibular investigations. IML-2 is scheduled for launch in June 1994 with an investigation studying the effects of Lower Body Negative Pressure as a countermeasure for cardiovascular deconditioning.

The last Spacelab mission flown involving life sciences was Spacelab Japan (SL-J), flown in September 1992. The Fluid Therapy System (FTS) being developed for Space Station Freedom was successfully tested on this mission. Intravenous solutions were made during flight and delivered by an intravenous pump to a mannequin arm. Part of this system, the intravenous pump, had been tested on the Spacelab Life Sciences 1 (SLS-1) mission. A problem with the pump that was encountered on SLS-1 was solved prior to the complete test of the system conducted on SL-J. Other investigations included a frog embryology study, a bone formation study using chicken embryos, and a passive radiation study.

The first dedicated life sciences Spacelab mission, SLS-1, was flown in June 1991. It was the first in the series of four Spacelab missions dedicated to life sciences research. Several space life sciences "firsts" were achieved on this mission. For the first time, a catheter used for measuring central venous pressure was worn by a crew member during launch and the first few hours of the mission. This permitted the first direct measurement of central venous pressure in space. Central venous pressure would be expected to show the effect of microgravity on the distribution of body fluids. Another first in cardiovascular research was measurement of the baroreflex, the sensor that monitors blood pressure in the neck and regulates it speeding or slowing the heart. The measurements confirmed the theory that the baroreflex is less efficient in space and on recovery than it normally is. A first for metabolic research includes the collection of blood samples within hours of entry into weightlessness. These measurements revealed that the body begins to adapt sooner than previously expected. SLS-1 was also the first time physiologic tracers were administered on-orbit.

Previously tested and modified hardware also flew on SLS-1. The UMS, which was tested on SL-3, was flown and used successfully on SLS-1. Urine samples were obtained and their volumes measured. The samples were stored in a freezer until their return for postflight analysis. One rodent RAHF, redesigned after SL-3, was flown on SLS-1. No problems with the facilities were noted this time. Rodent tissue samples were obtained before and after flight for studies of blood cell formation, muscle metabolism, bone metabolism, and gravity receptor structure.

A General Purpose Workstation (GPWS) flown on this mission was used in an experiment involving the development of jellyfish in microgravity, a neuroscience research investigation. The workstation provided a fume hood environment for use of chemicals needed for the experiment. A rodent was also transferred from the RAHF to the GPWS to observe the behavior of the animal and to test the capability of handling animals in the workstation.

Operations at landing, as well as in-flight capabilities, have advanced since the beginning of the Spacelab Program. A Crew Transport Vehicle (CTV) was used for the first time at the landing of SLS-1. This vehicle allows postflight data collection on returning crew to begin sooner than ever before. Returning astronauts enter the CTV directly from the orbiter and can begin postflight physicals and data collection while on the way to the postflight clinic.

The second life sciences dedicated Spacelab mission, SLS-2, is scheduled for launch this year. Research started on SLS-1 will continue on SLS-2. Most of the investigations from SLS-1 will be repeated on SLS-2 to increase the number of subjects in the human investigations. Rodents will also be flown on SLS-2, and for the first time tissue samples will be obtained from rodents during flight and returned to Earth for analysis.

The last two life sciences dedicated Spacelab missions, SLS-3 and SLS-4, are both currently in their development stages. SLS-3 will focus on musculoskeletal research and SLS-4 will focus on neuroscience research, two areas that are of major interest to NASA. Both missions will be flying the Rhesus Research Facility (RRF). The RRF is being built by the French Space Agency, Centre National d'Etudes Spatiales, and NASA. It will be capable of housing two adult rhesus monkeys. SLS-3 is scheduled for launch in January 1996 and SLS-4 is scheduled for launch in 1998.

Scientific knowledge gained from each mission is used to design new investigations. Data collected from the more recent missions is being analyzed. By the start of Space Station Freedom activities, answers to many of NASA's questions will have been found. Technological advances include all the equipment that has flown successfully, including the UMS and FTS, and facilities such as the RAHFs and the future RRF that is currently being designed. Operational advances have also been made. The capability to allow investigators to acquire data from their experiment real-time and communicate with the crew during the performance of the investigation is now available unlike the previous Skylab Program. Also, early access to experiment samples is possible upon landing.

Lastly, with the use of the CTV, access to the crew for postflight data collection is possible within an hour of landing.

Each of NASA's manned space flight programs has provided more insight into the physiologic changes associated with space flight, starting with the data gathered from medical monitoring during Project Mercury, and advancing to the sophisticated biomedical investigations currently conducted on Space Shuttle/Spacelab missions. Each new discovery continues to influence space shuttle missions, and will continue to influence Space Station Freedom and future space exploration.