# Zero Gravity Research Related to Human Body and Medicine

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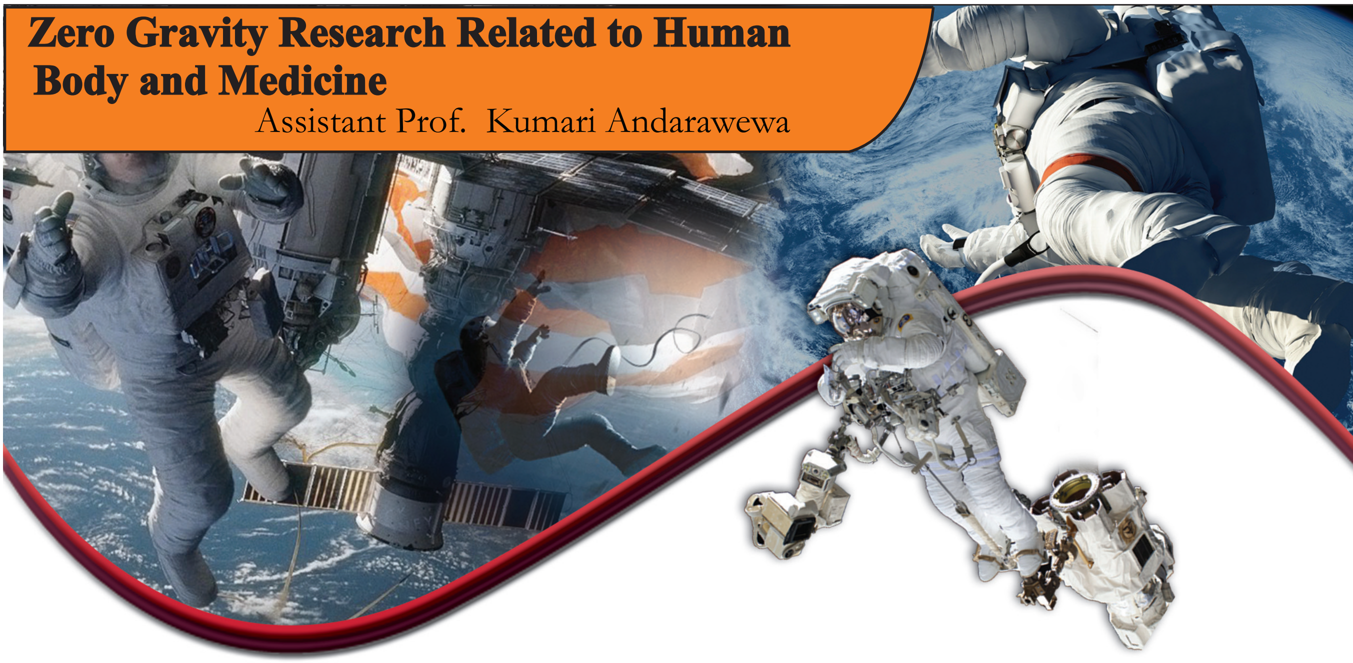
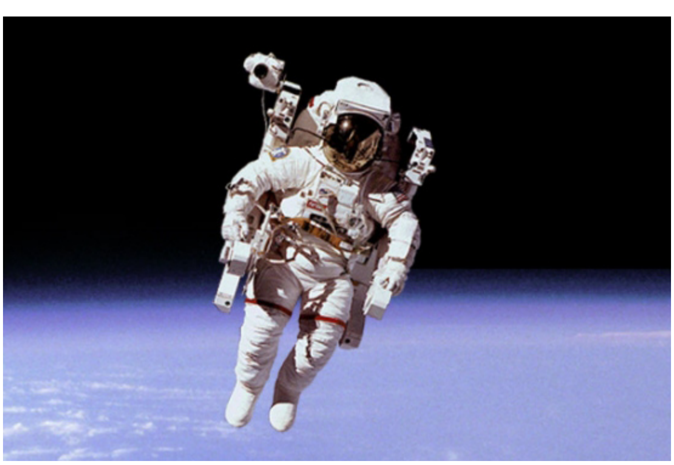


The human body has evolved by adapting to Earth's gravitational field, and the biological structure and mechanisms of the body have developed to suit normal Earth gravity. When the Earth is in orbit, the astronaut's body is still acted on by gravity, but much more weakly because of the distance. In addition, the speed acquired by the spacecraft to send the astronaut into space partially counteracts the gravitational force that continues to act on the spacecraft. This is the law of inertia. Thus ultimately gravity disappears, and the astronaut's body becomes weightless. An astronaut is in free fall when orbiting Earth. The reason why the astronaut floats inside the spacecraft is that he or she is falling at the same speed as it is. Naturally the astronaut does not fall to the Earth, despite being in free fall, because the speed imparted to the spacecraft keeps it in orbit. Both microgravity and floating have an impact on an astronaut's body in space. The effects of gravity on our bodies and the biological mechanisms involved in adapting to weightlessness are studied under real microgravity conditions. Research on astronauts has shown that body function is disturbed in microgravity. Space agencies are therefore continuing their research in the hope of eventually reducing or eliminating some of these undesirable physical effects that appear during a stay in space.



Protecting human beings against extreme environments requires an understanding of the underlying physiologic changes resulting from exposure, and the degree of medical risk associated with such exposure.

The problem that must be overcome for long duration space missions is the harmful effects of weightlessness. These effects include loss of bone density, muscle mass and red blood cells, fluid shifting from the lower to upper parts of the body, cardiovascular and sensory-motor deconditioning, and changes in the immune system. Such reactions by the body might be appropriate for zero-gravity flight, but are inappropriate when returning to the surface of our planet or another planet. Ensuring health, safety, and effective performance of astronauts are critical for human exploration of space. NASA Glenn Research Center's Human Research Program plays a vital role in providing solutions to critical problems that place human exploration missions and their crews at risk. These efforts are directed in support of the Johnson Space Center, which leads NASA's Human Research Program. Current focus is on three main projects: Exercise Countermeasures, Digital Astronaut, and Exploration Medical Capability.

## Exercise Physiology and Countermeasures Project

This project at NASA's Glenn Research Center supports the lead project office at NASA's Johnson Space Center in developing exercise countermeasure prescriptions and exercise devices for space exploration that are effective, optimized, and validated to meet medical, vehicle, and habitat requirements. A countermeasure can be defined as a therapy, procedure or device used to prevent or minimize adverse health effects that could result from spaceflight, (e.g. bone loss or weakened muscles). An exercise countermeasure prescription is a set of instructions for exercise that include the type of exercise device to be used as well as how long, how often and how strenuously it should be used. The prescription also measures the effectiveness of the exercise as a countermeasure.

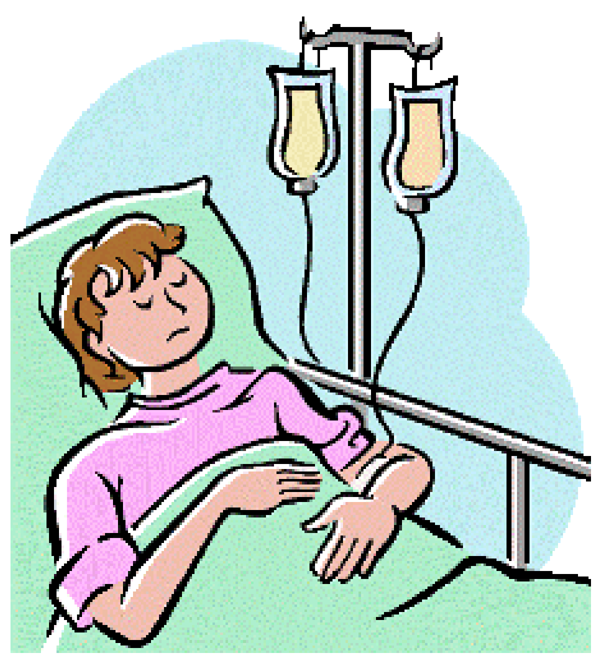
## Digital Astronaut

The NASA Human Research Program Human Health Countermeasures Element chartered this project. This project is an effort to utilize deterministic simulations of human physiological functions to answer targeted questions about changes associated with the microgravity environment. The project is currently focusing on several areas, one of which is quantifying the effects of exercise. In spite of attempts to use exercise to counteract losses in bone density and muscle tone during spaceflight, the problems continue, with longer flights generally correlating with greater loss. In an attempt to quantify the response to exercise, the project personnel created a model of the advanced resistive exercise device that astronauts currently use on the International Space Station (ISS). The team is currently integrating both models, with the goal of quantifying muscle force and joint torque produced by the exercise. Data produced by these simulations will allow exercise physiologists to design better exercise prescriptions for the astronauts.

In conjunction with the exercise models, project scientists are also developing computational simulations of bone remodeling and muscle function.

In the case of bone, no current analytic formulation is able to describe the effects of muscle stress, strain, and gravitational loading on bone remodeling. Bone tissue is actually in a perpetual state of flux, with old tissue constantly being destroyed and new tissue created. In healthy individuals living in earth's gravity field, these effects balance. In microgravity, however, tissue formation in weight bearing regions of the skeleton slows dramatically, leading to bone loss. These simulations should provide key insight into how the turnover process proceeds in microgravity, as well as providing recommendations for the daily amount of loading required to counteract the effect.

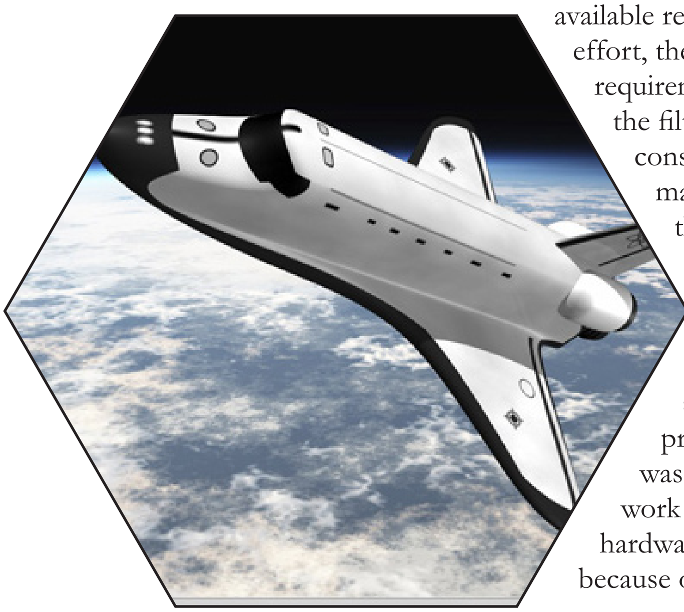
Finally, many astronauts return from space with vision changes, presumably caused by an increase in cerebral-spinal fluid pressure. This pressure change is likely to be the result of the well-known head ward fluid shift that occurs as soon as human beings enter microgravity. Scientists are currently conducting a survey to determine what



computational tools and data sets are available to simulate this problem. When that is complete, the team will use a combination of existing and custom tools to develop a simulation quantifying this effect.

## Exploration Medical Capability

When traveling in space, astronauts are exposed to many changes in their physical environment that can harm their health. For example, astronauts lose up to 2% of their bone mass in weight-bearing areas of the skeleton, and fluid shifts combined with lack of resistive motion can harm cardiovascular performance. Since future exploration missions will be much longer and more physically demanding than previous missions, NASA must expand its efforts to ensure the health and safety of the astronauts. NASA's Human Research Program consists of several projects to improve astronaut health during exploration missions, of which the Exploration Medical Capability Project is one. The componants of the project at the Glenn Research Center consists of several tasks, which include development of hardware to produce IV fluid from resources onboard space vehicles, the Integrated Medical Model (IMM) to quantify the risks associated with exploration missions, and the sensors to monitor astronaut health.



## Intravenous Fluids

In the event of a medical emergency, astronauts may require IV fluids to take drugs or rehydrate crewmembers that are unable to swallow. If it is to be used intravenously, water must be appropriately sterilized and mixed with the required drugs or electrolytes. The goal is to meet the requirement for IV fluid during exploration missions by constructing a filtration system that will generate fluid using available resources. In this effort, the fundamental requirement is that the filtration system consumes less mass and volume than would the equivalent amount of water that the filtration system is able to produce. Glenn was assigned the work to develop hardware such as this because of the center's expertise in microgravity fluid physics. Glenn has partnered with ZIN Technologies to identify water purification and mixing technologies that will function in microgravity environments and will be easy to operate in emergency situations.

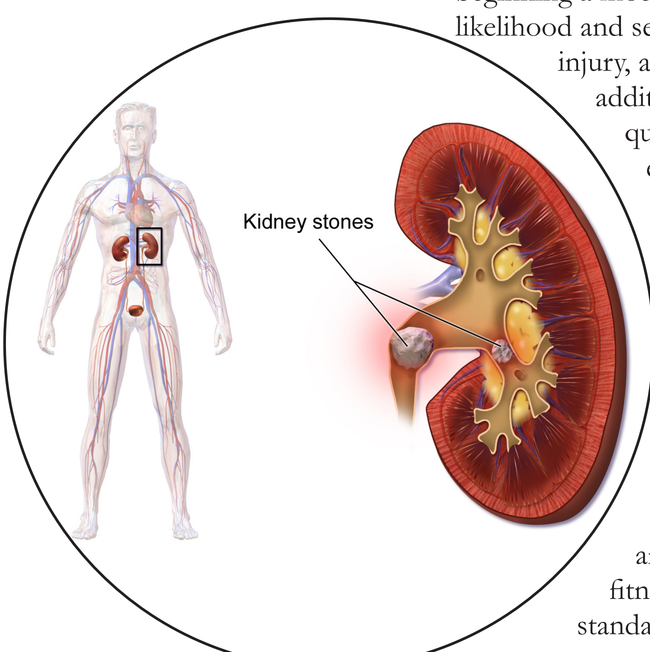
## Integrated Medical Model

What will happen if an astronaut falls during a spacewalk on the moon? Is a bone fracture likely to occur? Can this injury be treated effectively? What if the same event occurs on Mars? What will be the consequences? Treating medical conditions in microgravity can be very challenging. Microgravity can make stabilizing an injured body very difficult. The limited space within the spacecraft does not allow for excess equipment to be stored for possible medical treatment if the risk of injury is low. Decisions must be made quickly using the available resources to preserve an astronaut's life. Glenn is using clinical and biomechanical analyses of bone fractures that occur on Earth to develop a bone fracture risk module. Using this computer model, the data from the analyses on Earth will then be translated to conditions on the moon and Mars. A significant effect of microgravity is the reduction of an astronaut's bone mineral density and bone strength, which can make his/her bones more susceptible to fracture. Though gravity is reduced in space, an astronaut could still fall and injure him/her self during a space walk on the moon or Mars. As mentionaed earlier, Glenn is using clinical and biomechanical analyses of bone fractures that occur on Earth to develop a bone fracture risk module. Based on current flight experience and the best Earth-based clinical evidence, this model is designed to estimate the likelihood and health impact of fractures during exploration missions. Using this computer model, the data from the analyses on Earth will then be translated to conditions on the moon and Mars.

## Kidney Stones

As another part of the IMM, Glenn is also developing a model to assess the risk of kidney stone formation during long duration exploration missions as well as after an astronaut has returned to Earth. This condition can occur due to an increase of calcium in the blood, which is a result of bone loss during space flight. As an additional complication, astronauts become dehydrated in microgravity, which may also increase the risk for kidney stone formation. As part of the integrated model, the bone fracture risk and renal stone models will help NASA predict the likelihood of occurrence as well as the outcome of treatment. In the future, Glenn plans to create a simulation model to help predict behavioral health changes in astronauts during and after a mission. Once completed the integrated model will establish improved safety guidelines and fitness for duty standards for astronauts.

In addition to the above simulations, Glenn is also developing a module predicting the likelihood that an astronaut will need a sleep aid due to sleep schedule disruptions. Glenn is also beginning a model quantifying the likelihood and severity of a head injury, and will conduct additional analyses quantifying the expected incidence rate of glaucoma, stroke, and seizure. The IMM is an ongoing effort to quantify risks to astronauts, guide mission planners in improving safety, and helping improve fitness for duty standards.




**Kidney Stones**

As a spin-off from other research efforts, Glenn has developed sensors that are capable of taking metabolic measurements inside space suits. One example is the portable unit for metabolic analysis (PUMA). It measures the amount of oxygen an astronaut consumes and the amount of carbon dioxide produced. When combined with its heart rate measurement, PUMA software quantifies how hard the astronaut is working. This information helps the astronaut manage and conserve the limited supply of consumable resources available within the space suit. Additionally, the data are used to present the most accurate picture of the astronaut's fitness level and to prevent the astronaut from working past the point of exhaustion. In addition to the above research, there are a number of other projects conducted on microgravity. All these projects will help in understanding and predicting the effects of spaceflight on the human body. Such knowledge will allow us to establish meaningful mission requirements for health and safety. (Source: NASA news, features & press releases)

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