Human Spaceflight Laboratory









Moon • Mars • Beyond

UND Space Studies
University of North Dakota

The Human Spaceflight Laboratory in the Department of Space Studies

The University of North Dakota's Space Studies Department, in the John D. Odegard School of Aerospace Sciences, was the first program to offer a multi-disciplinary space education curriculum beginning in fall of 1987. Since 2004 dedicated students, faculty, and experts have contributed to incorporating a human spaceflight component into its program making UND one of the few universities in the world to offer human spaceflight-related courses.

The University of North Dakota, located in Grand Forks, North Dakota, is the first university with a NASA-funded laboratory dedicated to designing and constructing space-exploration and planetary surface exploration suits and habitat

Two crew members from the second Inflatable Lunar Martian Habitat Analog Mission planting the mission flag next to the Presurized Electric Rover.

prototypes. The Human Spaceflight Laboratory (HSL), under the leadership of Dr. Pablo de León, provides relevant, real-world experience to students from all over the world with hands-on involvement through graduate/ undergraduate research positions, NASA projects, and activities related to human spaceflight. Many theses and conference papers have been produced as a result of the work taking place at the Human Spaceflight Laboratory.

In 2009, UND became the first university to be awarded a grant from NASA to study advanced inflatable habitat architecture concepts that could be adapted for use on the surfaces of the Moon and Mars. The North Dakota Planetary Exploration Initiative also provided for the development of an attached electric rover. The Inflatable Lunar/Mars Analog Habitat (ILMAH) and the Pressurized Electric Rover (PER) were completed in 2012. In 2015 Dr. de León received a three-year NASA EPSCoR grant to add four more modules to the two original modules.

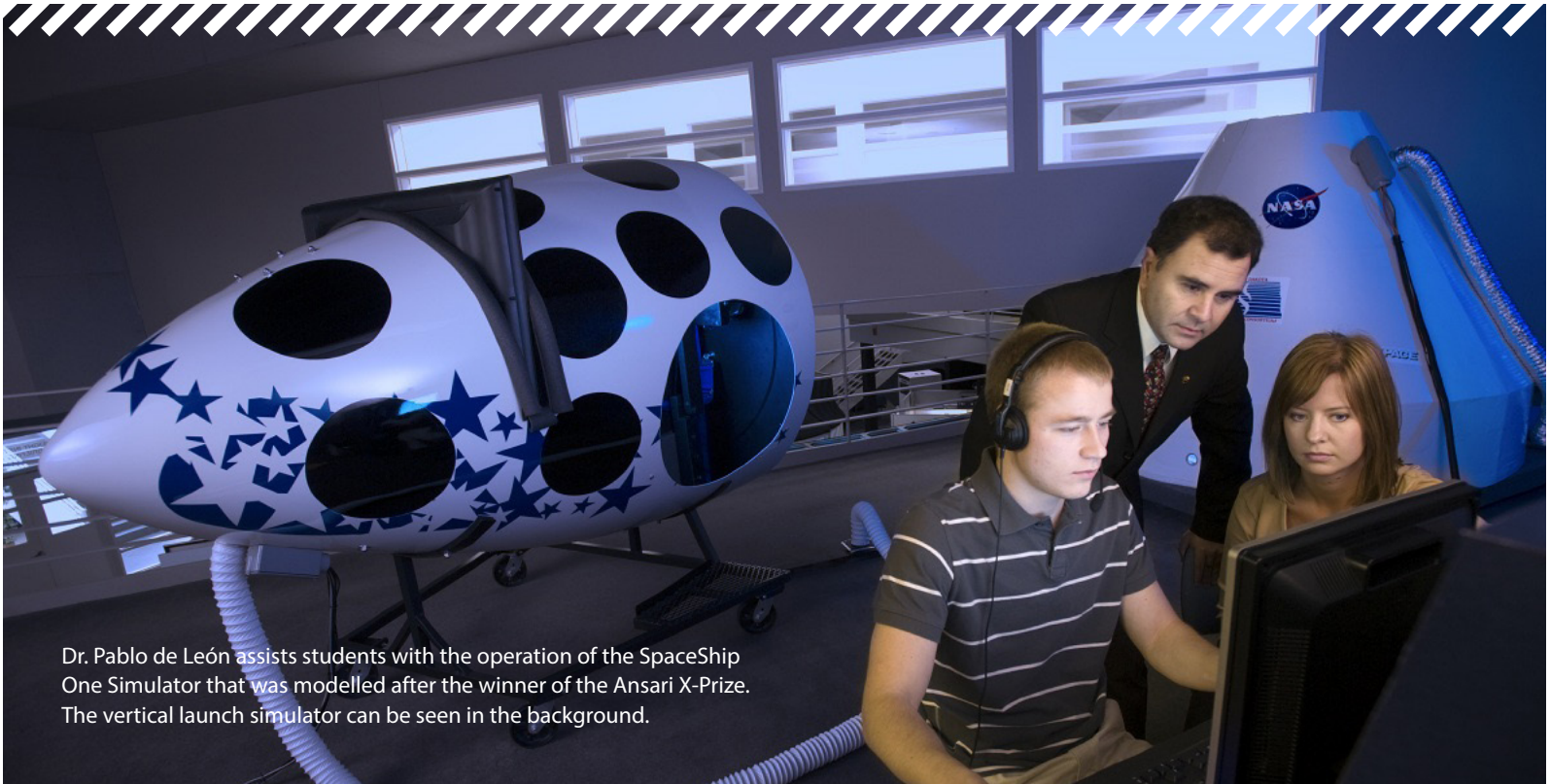
UND is also the first university with two fully-operational spaceflight simulators. These fixed spacecraft simulators, funded by the North Dakota Space Grant Consortium, are part of the Human Spaceflight Laboratory initiative. Located in the Spacecraft Simulator Facility, the Apollo Capsule vertical launch simulator and the SpaceShipOne horizontal launch simulator were designed and constructed by UND students from the Department of Space Studies, Mechanical Engineering and Electrical Engineering.

Mission

- **develop** state of-the-art spacesuit components and Extra-Vehicular Activity (EVA) technologies for the space explorers of the 21st Century and beyond
- **collaborate** with NASA on the development of spacesuits, their related systems, and to support the agency's space exploration objectives
- **cooperate** with the aerospace industry and assist in the development of new-generation spacesuits for private spaceflight
- **educate** the next generation of space engineers and space explorers in human spaceflight, human factors, and the design, construction, and operation of spacesuits

Education & Outreach

Each year, hundreds of visitors tour the facilities. Group and individual tours of HSL facilities are available to students of all ages, as well as aerospace industry personnel by appointment. Visitors are shown the HSL and Inflatable Lunar/Martian Habitat where they receive first-hand experience with the different elements of the Human Spaceflight Laboratory and learn about the rigors of conducting operations in space. Visitors are also shown the two simulators located in the Spacecraft Simulator Facility. When time allows, visitors may be invited to dock with the International Space Station (ISS) or fly a SpaceShip One mission.



Dr. Pablo de León assists students with the operation of the SpaceShip One Simulator that was modelled after the winner of the Ansari X-Prize. The vertical launch simulator can be seen in the background.

Graduate students troubleshooting with spacesuit air intake hoses in the Human Spaceflight Laboratory

Commercial Spacesuit Testing

The Human Spaceflight Laboratory (HSL) has been working actively in the development of full pressure systems for commercial spaceflight providers since the original ANSARI X Prize competition. Thanks to the facilities at the John D. Odegard School of Aerospace Sciences at UND, HSL has been able to test full pressure suits in near space conditions with the school's altitude chamber and perform mobility and dexterity tests at the Vertical Spacecraft Simulator.

Currently, HSL serve as consultant to some of the most successful commercial spaceflight providers. Strengthening these relationships and expanding consulting services to include more companies is a future goal of the HSL.

HSL believes relationships between universities and private companies are important and looks forward to contributing to the new era of private spaceflight to ensure it becomes reality.

North Dakota Experimental-1 (NDX-1) Mars Prototype Suit

The North Dakota Experimental-1 (NDX-1) Mars prototype suit, funded by the North Dakota Space Grant Consortium, was the first planetary spacesuit built at the university level. The project sought to combine educational instruction in spacesuit design and manufacturing, while simultaneously developing a usable test article. Over a one-year period, beginning in March 2005 and with a material's budget of approximately $25,000, the Human Spaceflight Laboratory developed a pressurized planetary spacesuit prototype in conjunction with five other institutions of higher education across the state.

This planetary suit concept prototype was designed by Dr. Pablo de León and mobility expert Gary L. Harris along with a team of graduate students. The process incorporated technical approaches appropriate to the project's schedule and budgetary constraints. The suit's design was influenced by its potential use in operations on the Martian surface.

The North Dakota Experimental-1 (NDX-1) suit serves as a test bed for new planetary suit materials and component assemblies. All suit assemblies are designed to be adjustable. All restraint layer joints and fabric assemblies are ruggedly constructed for long-duration test campaigns. The use of ball-bearing joints was precluded due to maintainability and servicing concerns.

The NDX-1 is a two-piece suit consisting of a torso and lower body "pants." It is donned by putting on the lower body portion, then slipping into the torso, with assistance, and locking the two pieces together. The NDX-1 is designed around a dual-plane enclosure ring built on a composite hard upper torso (HUT). The helmet can be easily removed.

The NDX-1 pressure bladder is a thermally-sealed, neoprene-coated garment made to the same dimensions as the restraint layer. The spacesuit is designed for an operating differential pressure of 26.2 kPa. The NDX-1 can be pressurized and operated on ambient air pumped through hoses, or it can operate autonomously on its Portable Life Support System (PLSS). The PLSS was designed specifically for the NDX-1 and functions by using two centrifugal pumps to push ambient air into the suit.

The NDX-1 features a backpack that conforms to the HUT and houses communications equipment. Wireless biomedical sensors mounted inside the suit and helmet monitor such parameters as heart rate, respiration rate, carbon dioxide concentration, oxygen concentration, body temperature, and relative humidity. This telemetry is sent to a base station for monitoring and recording.

Evaluation programs in both laboratory settings and at field sites are designed to test its performance and usability while ensuring safety. Ultimately, this project has provided a baseline set of knowledge for further planetary research and development within the state of North Dakota.

Testing

The suit has been used in extensive field tests in many novel environments, including:

- The Lunar Regolith Bin at **NASA Kennedy Space Center** in Merritt Island, FL
- Dust tunnel at the **NASA Ames Research Center**
- **The Badlands** of North Dakota
- **Mars Desert Research Station (MDRS)** near Hanksville, Utah
- **The Pilbara Region** in Northwestern Australia
- **Marambio Base** in Antarctica

The NDX-1 being tested at the Mars Desert Research Center in Utah. The suit is seen here with its protective outer layer that reduces the impact of dusty environments on the suit fabric.

North Dakota Experimental-2 (NDX-2) Advanced Lunar Suit

In September 2009 the Human Spaceflight Laboratory began the development of an advanced lunar EVA suit prototype, termed the NDX-2 (North Dakota Experimental-2), under the Integrated Strategies for the Human Exploration of the Moon and Mars NASA EPSCoR CAN 2009 grant project. Dr. Pablo de León served as the project manager and mobility expert Gary L. Harris (UND-HSL Consultant) along with a team of graduate students. The suit was assembled with a team of graduate student assistants directed by Dr. de León.

The NDX-2 incorporated the improvements and lessons learned from the earlier NDX-1 Mars spacesuit demonstrator program and new advanced systems that due to time and budgetary constraints could not be applied to the NDX-1.

After careful examination of the methods envisioned for lunar exploration, the conclusion was made that the new suit system would require a specific donning/doffing capability and method that was not contemplated for the NDX-1. Rear entry (for don/doff), as opposed to the Shallow Dual-Planar type entry used on the NDX-1, would have most likely been employed as part of the Constellation Extravehicular Activity (EVA) lunar missions, if that project had materialized.

The NDX-2 on its stand. Designed with reduced gravity in mind, this suit weights about 150 pounds and must be stored on a rigid metal structure.

The NDX-2's design incorporated the rear-entry into a one-piece suit comprised of a rigid torso structure with bladder material inside the arms and legs. Beyond the inclusion of a rear-entry closure, torso structure, shoulder, arm, hip, knee, and ankle joint designs were improved. The suit's design utilizes pulleys to assist in mobility while the suit is pressurized. The NDX-2 is donned and doffed by climbing into and out the suit through the opening in the back.

The North Dakota Experimental-2 (NDX-2) advanced lunar suit was completed in 2009 with its first pressurization tests conducted in 2010. The main purpose of the first test conducted in February 2010 was to pressurize the suit up to 2 psi and perform a donning (a procedure in which the subject puts on the spacesuit). The objectives of this test were to assess the grade of mobility of the material and the design suitability.

The NDX-2 was configured in such a manner that it could eventually be modified to interface with a suitport airlock allowing the rear-entry closure to dock directly to a habitat or vehicle and avoiding the intrusion of dust into the living spaces or cabin.

The NDX-2AT (North Dakota Experimental-2 Analog Testing) suit is based on the NDX-2 design and incorporates the suitport modification. The NDX-2AT connects to the Pressurized Electric Rover (PER) by means of the suitport assembly and is used in the Planetary Exploration Initiative tests for EVAs. The suitport concept is designed to function cooperatively together with the Portable Life Support System (PLSS) Assembly, and hatches for:

· relatively rapid coupling and uncoupling of the sealed suit and sealed vehicle,

· coupling and uncoupling of the PLSS assembly and the suit, and

· transferring the PLSS assembly and the wearer through the hatch at the appropriate phases of operation.

North Dakota Planetary Exploration Initiative

In early 2009, a team led by Dr. de León was awarded a three-year NASA grant to develop, design, construct, and test advanced inflatable habitat architecture concepts that could be adapted for use on the surfaces of the Moon and Mars.

The North Dakota Planetary Exploration Initiative consists of an Inflatable Lunar/Mars Analog Habitat (ILMAH), Pressurized Electric Rover (PER), and two spacesuits connected externally to the rover via suitports. All three main elements are connected allowing the inhabitants of the ILMAH to move into and out of the rover without having to venture "outside."

Completed in 2012, the ILMAH is a pressurized habitat that is approximately forty feet long, ten feet wide and eight feet high. It consists of a rigid frame covered by an inflatable bladder, much like the innermost layers on spacesuits, to protect the habitat from the surrounding atmosphere. The design allows both the tensile and compressive loads to be transferred from the soft fabric to the rigid frame, avoiding punctures or penetrations. The inflatable material is malleable and retains strength during folding. It is also lightweight and stows in a significantly smaller volume, which is an important feature for a future long-term space flight to Mars. This expandable soft goods structure offers a lower mass solution with increased volume versus using metal or rigid composite materials.

The Inflatable Lunar/Mars Analog Habitat can house a crew of four people for up to thirty days. There are four bedrooms, a galley, dining area, bathroom with shower and toilet, and a lab area for scientific work. The ILMAH is outfitted with extensive internal climate control designed to keep the crew in relative comfort.

The Pressurized Electric Rover is attached to the ILMAH via a docking tunnel allowing pressurized access to and from the rover. The PER is capable of traveling for several hours on a single charge of its batteries and has a top speed of 25 mph. The rover has been outfitted with special suspension and wheels to navigate rough terrain and slopes. It can accommodate two crewmembers who can use its cupola to locate an acceptable area in which to conduct an EVA. The PER is equipped with communications antennae, lights, and survival supplies in case the vehicle must stay in the field overnight. On the back of the rover are two NDX-2AT suits. These suits, based on the NDX-2's design, are connected to the PER via suitports that allow the crewmembers to climb into the suits and undock to conduct EVAs.

Analog Missions

Several analog missions have been conducted in the habitat. The initial analog mission was a 10-day mission with three crew members in 2013. Their mission was to testing the habitat's life support and other engineering systems. The crew also performed six EVAs to test the NDX-2 planetary exploration suits and the Pressurized Electric Rover (PER). This initial mission was the trial run for longer analog missions.

The second mission was a thirty-day planetary mission in 2015. Research projects conducted by the crew included microbial sampling in partnership with NASA's Jet Propulsion Laboratory, horticulture studies and waste production, geologic mapping of the surrounding area through both extra-vehicular activity and with the remotely operated MArs Compliment to Humanity rOver (MACHO), psychological studies, and physiological studies.

The third analog mission was a 10-day isolation mission designed to simulate the initial landing period on Mars. Four Space Studies graduate students made up the first all-woman crew and mission control. The mission ran in early 2016 with mission support crew member available 24/7 to assist them in missions and logistics. The crew conducted an experiment designed by a well-known space psychologist from a leading university, along with thesis projects relevant to their area of study.

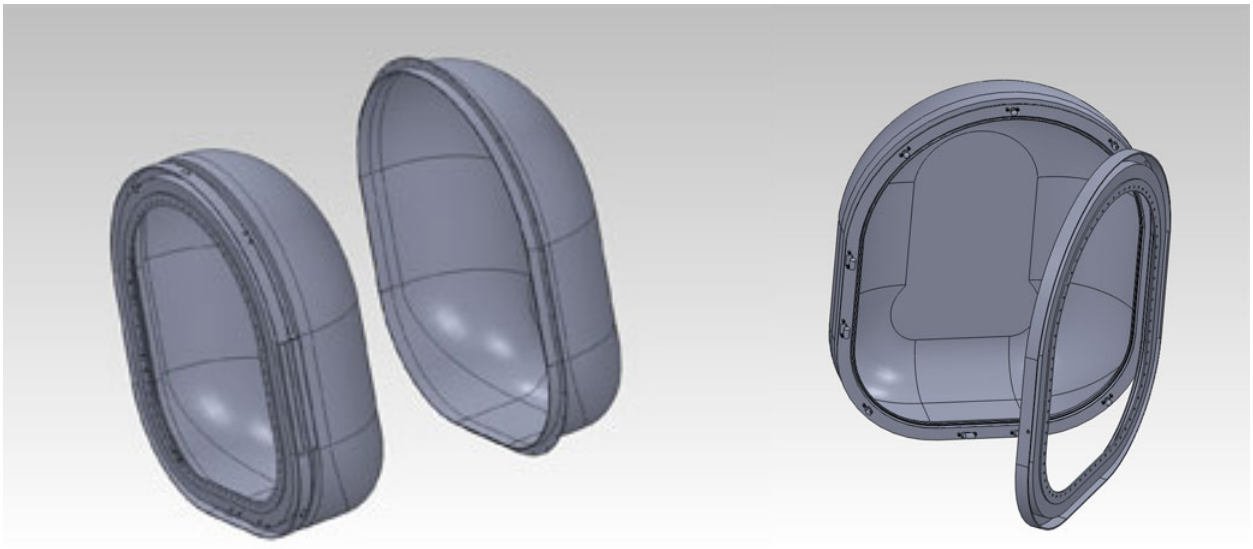
Suit Port Concept

The Human Spaceflight Laboratory designed and constructed a suitport system to address a number of issues. Current spacesuit designs require substantial time devoted to donning and doffing the multi-piece suit with assistance from other crewmembers plus the additional time and energy to evacuate the airlock before the astronauts can begin their Extravehicular Activity (EVA). For planetary surfaces, such as Mars, the airlock itself is a major source of contamination in the form of dust, which is abrasive compared to dust on Earth. The goal of the suitport system is to mitigate these issues and streamline EVAs.

The suitport is a two-part system with one half incorporated into the NDX-2AT, UND's rear entry spacesuit, and the other half attached to either the habitat or rover.

To enter the suit, the evaluator opens the hatch on the interior of the habitat or rover, then opens the hatch on the back of the spacesuit, and climbs into the spacesuit. The suitport connection hardware on the NDX-2AT encloses the spacesuit Portable Life Support System (PLSS). This allows a crewmember to don the spacesuit and conduct an EVA without assistance from other crewmembers. Once inside the suit, the evaluator operates few mechanisms to close and seal the suit, engages the PLSS, and uncouples the spacesuit from the rover or habitat to begin the EVA.

Thus, the suitport concept saves space inside the rover with the suits stored outside, reduces donning and doffing times, and eliminates the contamination of the rover's interior with the dust that collects on the suits during EVAs.



Left: Suitport assembly that connects to the NDX-2.
Right: Rover mount and Suitport dock.

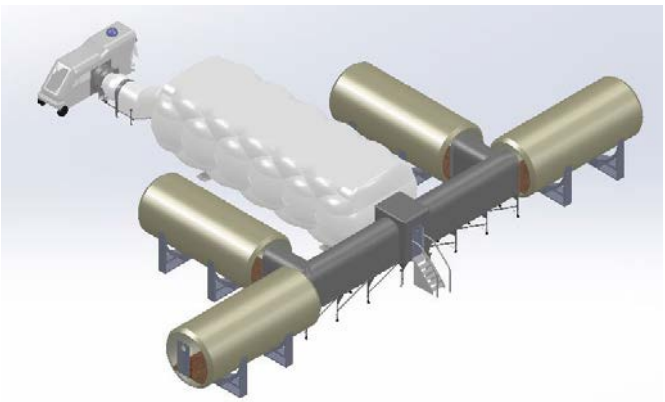
Space suit portion of Suitport in open configuration for donning/doffing

Multi-Purpose Research Station

Above: Dr. de León surveys the ILMAH with two of the four additional modules.

Below: A model of the completed ILMAH, including all four new modules and the Pressurized Electric Vehivcle.

In 2015 NASA awarded a $750,000 grant to the UND Space Studies department for the addition of four new modules to connect with the existing Inflatable Lunar/Mars Analog Habitat (ILMAH) core module. These modules include a Plant Production Module, EVA and Maintenance Module, Geology Research Module, and an Exercise and Human Performance Module. A dedicated team of NASA employees and UND graduate students under the direction of Dr. de León are involved in the design and construction of each module. These additions will greatly increase the space of the ILMAH and allow for scientific innovation and fidelity in the analog missions performed by the Human Spaceflight Laboratory.



Plant Production Module

Plant growth will be important for scientific exploration, closed ecological life support system operations and human health and wellbeing. The incorporation of a greenhouse-type module will allow for innovation related to all of these fields, where air and water recycled and purified by plants allow mission autonomy and interactions with plants and vegetarian dietary supplements support human mental and physical health. Future research and engineering breakthroughs will allow the Plant Production Module to provide enough growing space to support a crew of 4 throughout their analog missions.

EVA & Maintenance Module

One of the factors that makes the HSL ILMH a groundbreaking design is the fully incorporated Habitat-Rover-suit design which allows for minimal dust accumulation inside the habitat after EVAs. This new module will add to this functionality by facilitating rover-free EVA missions with the same contamination blocking suitport design, as well as create a space for the subjects to perform needed maintenance on the suits without bringing Lunar or Martian Regolith into the living compartments of the habitat.

Geology Research Module

A main scientific goal of NASA'a Martian exploration will be the analysis of geological samples. This module will support subjects' field science efforts, rover collection and scientific investigation of samples collected. Samples will be made available through a specially designed "glovebox" sample storage and transfer unit that will illuminate dust accumulation inside the ILMH.

Exercise & Human Performance Module

Human health is the most important factor when it comes to human space exploration missions, including both treatment and preventative measures and medicine. This module will allow for testing and health monitoring of subjects involved in analog missions by supplying medical monitoring and exercise equipment. The exercise equipment will mimic what is used by current NASA astronauts, including treadmills, weights, and hand grip strengthening devices, while the medical equipment will correspond with the monitoring equipment used at NASA facilities to ensure astronaut health before and after missions.

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