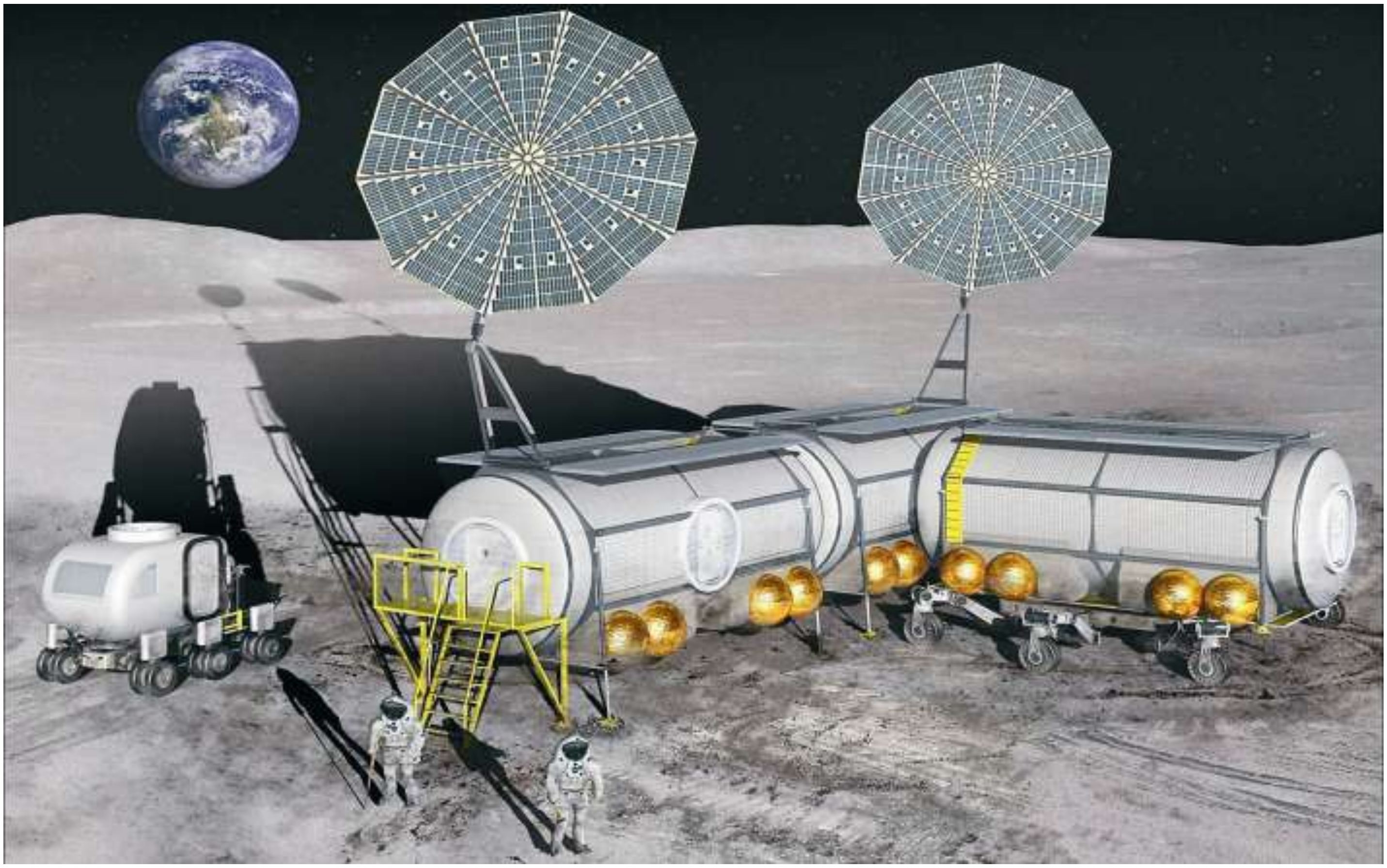

Figure 1. Artist's rendition of an outpost on the moon. ILC Dover is designing habitats for astronauts similar to the cylindrical structures pictured above.
(Image courtesy of NASA.)

Camping on the Moon—or even Mars

ILC Dover Uses Realistic Simulation to Design Habitats for Astronauts

ILC Dover, located at One Moonwalker Road, made spacesuits for NASA's Apollo astronauts in the 1960s and 70s and gear for the space shuttle crew that repaired the Hubble telescope earlier this year. Its latest out-of-this-world product is inflatable houses designed for future outposts on the moon—or even Mars.

A leader in the development of flexible material systems that withstand extreme environments, Delaware-based ILC designs both hardware and softgoods for the wide-ranging challenges of space exploration—from the high heat of re-entry, to the profound cold of a lunar night, to the airbags that cushioned the landings of the Mars Rovers. ILC makes a multitude of earthbound commercial products as well; from innovative containment systems for packaging powder pharmaceuticals to highly advanced protective military gear.

Still, it's the inflatable lunar habitat idea that grabs our imagination. From the first moon landing in 1969 to the last trip there three years later, no one ever spent more than three days on the surface, and they took the lunar module with them when they left. In the 21st century, NASA's proposed Constellation program—to return to the Moon, set up a permanent base, and from there send people to Mars—started taking shape. This program created a host of new challenges, including the most basic one: if you are living on the Moon for months on end, where is everyone going to sleep?

Launching a House into Space

ILC's engineers are working on the answers to that question. In partnership with several different branches of NASA, including Langley and the Johnson Space Center, the company has been developing ideas for different configurations of lightweight space habitat structures (Figure 1).

"When you are launching equipment into space on a rocket, everything needs to be as lightweight as possible, and packed densely," says Cliff Willey, ILC program manager of space inflatables. "Then you want to deploy something that expands on the surface of the moon without a lot of mechanisms. An inflatable, soft item does all that."

ILC recently completed the design work on a "mid-expandable" habitat with two hard endcaps and a deployable softgoods section in the center (Figure 2). The softgoods section packs into the endcaps and then unfolds and inflates via air pressure, more than doubling in length. A unique fabric lobe system allows for a structure that is much lighter in weight with a higher volume than a similar hard material configuration would be. The endcaps are where doors, airlocks, and other structures are mounted.

Harsh Lunar Environment

The Moon environment contains a host of external hazards to consider, including extreme temperature fluctuations—which softgoods withstand much better than metals—radiation, dust, and low gravity. The inflation pressure on the two innermost layers of the structure presented the biggest challenge to ILC's design engineers.

"You have to come up with a pretty clever design to handle the high loads inside a dwelling that is pressurized to a level in which astronauts can live," says Ric Timmers, ILC Senior Analysis Engineer. In the zero-atmosphere Moon environment, any significant fabric failure would result in a devastating outward explosion of the structure.

ILC's solution was to design interlocking webbing net over a gas-impervious, coated fabric. The fabric was deliberately oversized so that it would bulge out slightly between the webbing panels, transferring the pressure load to the webbing. This unique combination of fabric and webbing working together would allow the habitat to be inflated to nine psi (an acceptable pressure for humans living on the Moon), which meets NASA's safety standards for space construction.

Figure 2. ILC's "mid-expandable" habitat prototype is stored in two hard endcaps during rocket transport to the moon and then deployed on the lunar surface with air pressure, doubling in length.

"Earlier, we were contemplating building a test rig and physically measuring the pressure load on the fabric, the tension in the webbings, the pressure behind the windows —all simultaneously—but we were looking at well over a million dollars for a test like that," says Willey. "We couldn't rely on trial and error. We had to be able to build a reliable, finished product design the first time out."

Realistic Simulation Provides Down-to-Earth Answers

So the group turned to Abaqus finite element analysis (FEA) software to test virtual models of the fabric and webbing under varying load scenarios. "We relied heavily on Abaqus for this project," said Timmers. "It would have been pretty risky to do this without FEA—you had to sleep at night!"

ILC began its analysis of the fabric/webbing system by modeling a "unit cell" of fabric constrained by a square of the webbing net. The model was oversized slightly to simulate the bulge of fabric between webbings. The nominal pressure was applied to the model and Abaqus calculated the resulting stress (well within NASA's required safety factor of four) in the material (Figure 3).

"Using Abaqus FEA to identify the allowable limits of the fabric's performance was very useful because with this type of structure you have to be really sensitive to total mass," says Timmers. "When we found one material that worked, we could use Abaqus to virtually test another, lighter material to see how much we could save on total weight and still provide the right factor of safety."

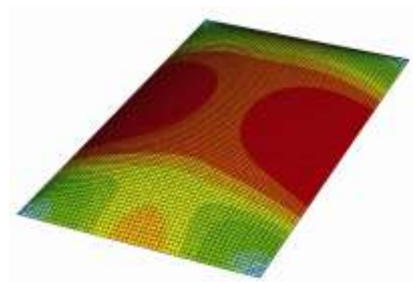

Figure 3. Abaqus FEA stress analysis of a "unit cell" of habitat fabric demonstrated that the maximum loads were well within NASA's required safety factor limits.

Keeping the Web of Safety Intact

In addition to low stress in the fabric restraint system, another important contributor to the stability of the habitat was evenly balanced loading of the ring of webbing itself. To test this part of the design, the ILC team used Abaqus to simulate the critical axial (end-to-end) length of the webbing.

"Our biggest concern this time was that any deviation in the length of one webbing could foreshorten the whole system, concentrating 100 percent of the load on a single section and leading to a cascade of breakage," says Timmers. When one webbing was shortened by just 0.125 percent, the analysis results showed that the load on it jumped to 4,815 pounds, versus 3,600 pounds on the rest of the webbings. But since the breaking strength of the webbing was 24,000 pounds, the safety factor was still met.

Camping on the Moon—or Even in the Antarctic

With their habitat design complete, ILC teamed with NASA to build a prototype for the "Camping on the Moon" exhibit, now on display at NASA Langley. Physical verification tests of a full prototype—including a deployment run-through, a high-pressure test, and tear-resistance evaluation—are pending further funding.

"We may very well run these tests ahead of time with Abaqus," says Timmers. "It's ideal to use a combination of modeling and testing back and forth, applying FEA to dial into just a few possible scenarios."

Whatever the timeline for deploying astronaut habitats beyond Earth, ILC's unique approach to such structures has applications closer to home as well: potentially as hyperbaric chambers for health clubs or hospitals or as dwellings for polar- or desert-based scientists. A similar habitat designed with Abaqus Unified FEA has been tested in the harsh environment of the Antarctic and will be going to the Arctic as well.

EDS Technologies in strategic partnership with Dassault Systemes plays a vital role in implementing Dassault Solutions, in India across various industry segments.

For More Information

www.ilcdover.com
www.simulia.com/cust_ref
www.edstechnologies.com