INFLATABLE MODULES FULL OF POTENTIAL

Beyond balloons

by Kendra Phipps

The next time you're packing a suitcase for a long trip, consider getting some help from an expert in inflatable space modules.

The beauty of these modules is their ability to be launched in a folded state and then expanded, or "inflated," in orbit. They can wind up three times larger than their original launch size.

"The shuttle has limited volume. The cargo bay is only so big," said Chris Johnson. "But we can fold this (inflatable module) up and get three times as much volume. We're maximizing launch capacity." Johnson, Crew Exploration Vehicle (CEV) Parachute Test Vehicle project lead, was a member of the Johnson Space Center team that designed, built and tested an inflatable module called TransHab in the late '90s.

Any vacationer would love to squeeze three times as many swimsuits or souvenirs into a suitcase, but in space, the benefits of this technology go far beyond convenience.

For long-duration missions to the moon or Mars, astronauts will need lots of room—not just for the additional supplies and equipment needed, but also for their psychological well-being.

"There are positive psychological aspects of a large structure," said Jasen Raboin, CEV Parachute Assembly System project manager and another member of the original TransHab team. "NASA will need something bigger than what we've done before."

Put simply, crew morale benefits from more interior space—whether in a transit vehicle or a surface habitation module. Using technology developed during TransHab, inflatables have potential as both.

While TransHab was originally designed as a transportation module, the team was asked to adjust it for use on the International Space Station. The team pulled together additional experts and came up with a module that Raboin says could have "almost doubled or tripled the stowage space of the station." Their ideas even passed the tough inspection of NASA long-timers such as Chris Kraft and Max Faget. But in 2000, the project fell victim to budget cuts.

"NASA had other bills to pay," said Raboin, "so we had to disband it and put the project and the technology on the shelf."

The good news was that inflatable module technology had proven its potential. The team had been able to build three full-scale units and put them through the wringer: The first two units were pressure tested in the Neutral Buoyancy Laboratory to verify restraint layer strength, and the third unit was tested in Building 32's vacuum chamber to verify folding and inflation techniques.

"We were showing that it was feasible, and the technology could be applied in the future," said Raboin.

"You mean a balloon?"

The word "inflatable" doesn't exactly conjure up images of cutting-edge spaceflight technology. Most people probably associate space exploration with cold, hard metal.

"That's the biggest mindset to overcome," said Johnson. "You say 'inflatable' and people think, 'You mean a balloon?'"

However, these modules are just as strong as traditional metal structures. Inflatable modules consist of layer after layer of protective materials such as high-tech synthetic fabrics and carbon-fiber composites. For instance, TransHab's inflatable shell contains nearly two dozen layers and is a foot thick.

"We provide as much micrometeoroid protection as any spacecraft NASA's ever flown," said TransHab team member and shuttle engineer Gary Spexarth. That protection comes from layers of ceramic fabric called Nextel alternated with thick layers of foam. This design would cause an incoming piece of debris to shatter upon impact, getting smaller and weaker with each layer. This protection, along with additional integrated layers, also keeps the extreme temperatures of space at bay.

The module's air is held in by bladders, the shape is held by super-strong webbing material and the inside "wall" is made of fireproof Nomex cloth and puncture-resistant Kevlar felt.

Another advantage of inflatable spaceflight technology is the vast array of possible configurations.

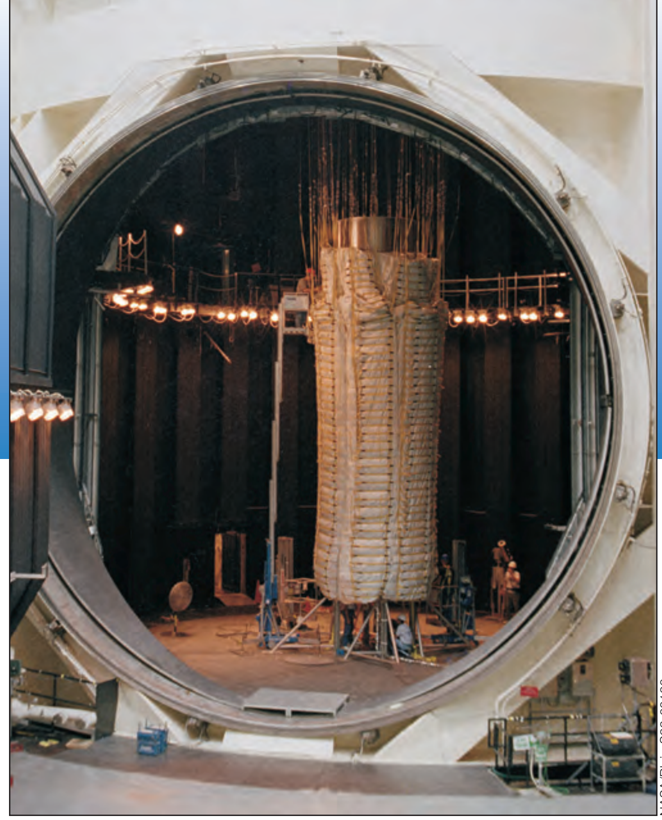
"Inflatables don't have to look like TransHab," said Spexarth. "They could be tunnels, airlocks, stowage modules or all kinds of shapes."

A match made in space

Although the TransHab design has not yet been used in space by NASA, inflatable structures and technologies have continued evolving through partnerships with the private sector.

In 1999, hotel entrepreneur Robert Bigelow read a magazine feature about TransHab and decided he wanted to build something similar, possibly leading to a hotel in space someday. He built a facility in Las Vegas and got started.

After a couple of years, Bigelow's interest in inflatable modules and NASA's lack of TransHab funding converged into a mutually beneficial arrangement called a Space Act Agreement. The TransHab team members had moved on to other projects at JSC, but under the new agreement, they were requested to visit the facility in Las Vegas a few times per year to offer advice to Bigelow Aerospace.



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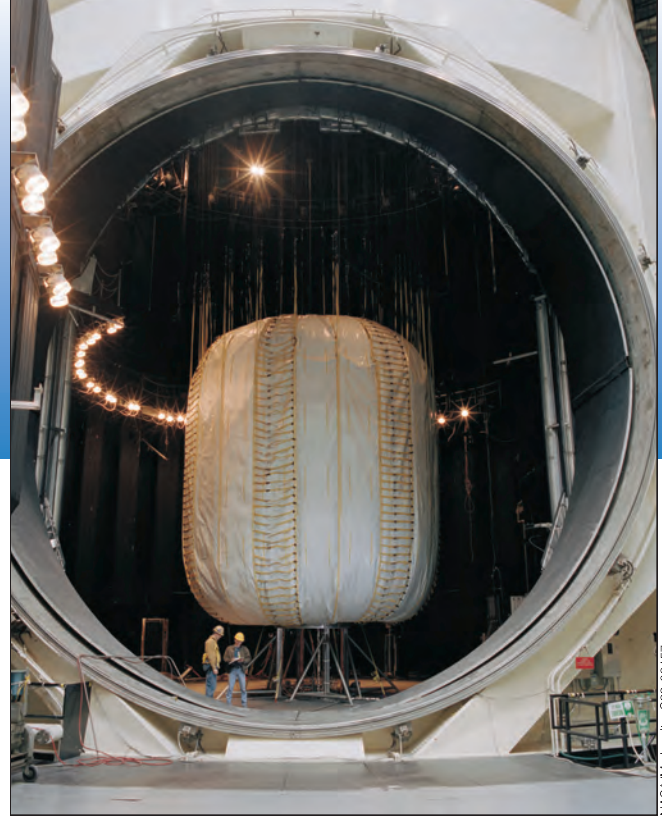

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In these 1998 images, a full-scale TransHab test unit is shown in Building 32's vacuum chamber—first in its compacted launch state, and then in its inflated operational state.

"He had some degree of success, but it wasn't going to get him to large-scale hotels in space," said Johnson. Seeking further support from JSC, Bigelow purchased a building near Ellington Field in late 2004. Johnson, Raboin, Spexarth and colleague Glenn Miller—now in JSC's Structural Engineering Division—helped transform the building into an inflatable module production facility.

The company had also licensed the rights to the patents for several TransHab technologies and materials. Interpersonal Act Agreements were arranged so that JSC's inflatable module experts could work side-by-side with Bigelow Aerospace full-time.

It became a truly symbiotic relationship: Bigelow's team gained invaluable expertise and experience from the JSC employees, while the team in turn had the chance to take the existing TransHab technology to the next level.

"We had the expertise and made it available to the commercial sector," said Raboin. "They're putting up the resources to help us further the technology."

For example, the partnership has allowed the JSC experts to develop micrometeoroid protection that is just as strong, but more cost-effective. Further advancements included a design for adding windows to the modules and an improved method of folding the structures for launch, both of which were successfully proven in recent tests.

In the year and a half that the two groups worked together full-time, three inflatable module test units were manufactured at the Clear Lake facility. Two were pressure tested in Las Vegas, and the other module test unit demonstrated shell folding and inflation at the Clear Lake facility.

Bigelow launched its first module, Genesis 1, on July 12 aboard a Russian rocket. Shortly after launch vehicle separation, it was expanded to full size and underwent a series of systems tests. The company plans to launch additional test modules and larger spacecraft in the future.

"Back to the front burner"

The launch of the Bigelow module is very much a success story for NASA as well as for the company. The collaboration between the two is an example of the kind of partnerships that the agency hopes to build on the path to the Vision for Space Exploration. It will take lots of innovation—from government and private enterprises alike—to get back to the moon and on to Mars.

"NASA can't do all of this alone," said Michele Brekke, director of JSC's Technology Transfer Office. "NASA wants to develop relationships with industry to enable and facilitate commercial involvement in space."

Spexarth says that NASA also benefits from the recent launch because of the increased awareness of, and renewed interest in, inflatable spaceflight modules.

"TransHab had been (in) the backs of people's minds for years," he said. "The fact that (Genesis is) up there orbiting, it kind of brings the technology back to the front burner again. It opens people's eyes that this is feasible."

The TransHab team members said they hope that the strength, size and adaptability of inflatable modules play an important role in upcoming Exploration missions.

"Absolutely!" said Raboin when asked if he thought the technology would be a part of the Vision. "I don't see how it can't be."

'We have a fire!'

When your job depends on...

crying wolf

by Catherine E. Borsché

We have a fire is not a statement anyone would relish hearing, especially if the person saying it were an astronaut in an International Space Station module while on orbit. Although the real-life scenario is nightmarish, it is the duty of the training teams in the Environmental Control and Life Support Systems (ECLSS) Group and the Station Training Lead (STL) Group to work with crews on potential, life-threatening emergency hazards. The goal of the training is to familiarize the crew with emergency scenarios by using a combination of classroom instruction and actual drills so, in the case of a catastrophe on orbit, handling it would be instinctual.

The training is basically broken down into two elements.

"The ECLSS Training Group provides what's called emergency introductory training, which (is) the basics of how to run the procedures, how to use the equipment, what you do in certain mockups—all the basic introductory how-to stuff," Clinton Balmain, station training lead for United Space Alliance, said. "Once they're done with that they hand the crew over to the STL Group, and we handle the emergency proficiency training. We take the skills they learned in the classes and reinforce and build on them. They get to actually use (those skills) out in the Building 9 station mockup."

Johnson Space Center is home to Building 9, a unique facility where life-sized mockups of station modules and the space shuttle serve as valuable practice arenas for astronauts before missions. In these mockups is where the real scenario training comes into play. The astronauts are not being taught anything new, but they are there to practice and put it all together with their fellow crewmates using real procedures and high-fidelity hardware to see how they really respond to emergency situations.

In the mockup, the teams rely on a variety of equipment to enhance the realism of their emergency training.

"We have a large pressure gauge we use for rapid depressurizations, so the crew can look at this gauge and tell, based on how fast the pressure is going down, how long they are able to stay onboard," Balmain said. "We do have a smoke machine. It's a standard disco, '70s fog machine, but we've got it set up and use it to dump smoke into the module to obscure the crew's vision."

The training in the smoke-filled module can be compared to the training conducted by the airline industry.

Cosmonaut Sergei K. Krikalev, Expedition 11 commander representing Russia's Federal Space Agency, participates in fire procedures training in the International Space Station mockup in the Space Vehicle Mockup and Training Facility at Johnson Space Center.

"It's a very similar setup to what the airlines use. In fact, one (airline) uses a similar machine to do flight attendant training. It enables them to practice what to do when you've got a plane full of people and there's smoke in the cabin," Josh Matthew, Expedition 14 ECLSS training lead for United Space Alliance, said.

The emergency scenarios training encompasses three types of emergencies: fire/smoke events, rapid depressurizations and toxic releases.

"Within those scenarios, we do different variations. We have the smoke versus the light haze, and you see immediately what it is and go handle it, all the way up to an open flame. We have rapid depressurization, where the crew has anywhere from six hours to 30 minutes until they need to leave (the module)," Balmain said. "And for toxic releases, anything from a leaky battery—something that you just kind of wipe up and throw in a trash bag—all the way up to ammonia in the atmosphere."

Rapid depressurization is usually caused by micrometeorites or other types of orbital debris that can penetrate the station.

"A half-inch hole gives the crew only a 30-minute to an hour-long reserve time, so it doesn't take a lot," Balmain said.

"Fortunately anything that big is being tracked," said Stacy Cusack, Expedition 15 ECLSS training lead for Barrios Technology. "It's the really, really tiny ones that are harder to track. Anything that could cause a big enough hole, they'll move out of the way for."

The training groups know that their mocked-up emergencies have a big impact in the overall confidence of the crews going into orbit.

"In the simulations, sometimes they have to power stuff down and bring down the entire mockup, so we will actually turn off the lights in the mockup. Now they're in smoke and it's dark, and we have masks that they put on to obscure their vision and their communication so that they learn what it's like to try to talk with this big rubber mask on," Balmain said.

"What I've always noticed is it's very interesting during cases that use (smoke) versus ones that don't," Matthew said. "In the cases that do use it, the crew moves much quicker. You can tell just by watching the crew that there is a different level of realism just in the way they respond. Even for a case where they don't necessarily have to go into the module that's full of smoke at the outset, when they see that visual indication is there, it helps to get them in the right frame of mind."

There are many training scenarios that make it obvious just how "real" it seems inside the mockup.

"We had a student very recently where we were doing a fairly drastic case with lots of smoke, and he was kind of on his own and the other two crew members were isolated…and I looked at him and his hands were shaking," Balmain said. "I had never seen that before in a student. But he was in the moment, and that adrenaline was going so much that he was physically responding to the environment around him."

Cusack also recalls a similar situation.

"We've seen some more things when we pretend one of the crew members is incapacitated. The emergency will call for one of them to be injured, and that is another way to definitely get different reactions. It certainly gets the heart rate up, and they start working really hard," Cusack said. "It changes everything."

The emergency scenarios training encompasses about 20 to 25 total hours for a particular crew, and the training takes place both at JSC and in Russia. Different instructors come to teach the crews depending on the type of emergency scenario being practiced. For instance, since fires are often electrical in nature, there is an electrical systems instructor on hand to oversee the drill. Toward the end of the training, mission operations personnel, such as a lead flight director, CAPCOM and others, come in to piece it all together.

Emergency scenarios training is a necessary element to safety in space exploration.

"Emergency training is in some ways a lot like drivers' education was. The classroom training we provide the crew is a lot like the classroom portion of drivers' ed.—you're learning the rules of the road, how to work the car, how to do certain things," Matthew said. "The scenarios training out in Building 9 (is) really the behind-the-wheel, on-the-road-type training, where you've got instructors with you and usually a car full of people. That's the correlation. We provide the rules up front, and then we do our best to go out and learn to drive."