5 AEROSPACE AMERICA MAY 2011

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Lows and highs for SBIRS

In search of cleaner skies

Strong UAS market attracts intense competition

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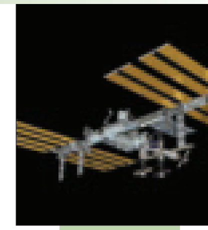


A green space station

Throughout the U.S. commercial and residential construction community, environmentally friendly 'green buildings' are all the rage. Inside the five-bedroom-equivalent public housing unit known as the international space station, NASA has staked its claim for green building leadership by devoting significant resources to an ambitious engineering project called ECLSS, the integrated regenerative environmental control and life support system.

ECLSS includes an oxygen generation system delivered in July 2006 by the space shuttle Discovery. Through a process called electrolysis, this system uses electricity from the ISS solar panels to generate breathable oxygen for crewmembers by breaking down water into hydrogen and oxygen. The ECLSS also uses a water recovery system (WRS) that recycles potable water, water for technical uses from humidity, used wash water, and crewmembers' sweat and urine. The WRS employs an extensive distillation and purification process to produce about six gallons every six hours. The system was delivered in November 2008 by the Endeavour shuttle.

Augmenting the ECLSS is Hamilton Sundstrand's Sabatier reactor system, delivered to the ISS in April 2010 by the shuttle Discovery. Sabatier takes carbon dioxide that is removed by the station's carbon dioxide removal assembly and combines it with hydrogen produced by the ECLSS water electrolysis systems. This combination produces both water, which is fed into the station's wastewater recycling system, and methane, which is vented into space. NASA has yet to figure out a way to use the waste methane, but notes that future experimentation on board the ISS may be useful in determining if the methane can be recovered for use as rocket fuel for deep space exploration.

ECLSS also features two devices for monitoring and ensuring atmosphere quality. One is the major constituent analyzer, a mass spectrometer that samples air quality. The other is a system of filters called a trace contaminant control subassembly, which removes over 200 atmospheric chemical compounds generated by equipment off-gassing and human functions. To monitor and ensure water purity, the WRS uses conductivity sensors and a device called the total organic carbon analyzer, which measures the amount of organic and inorganic carbon in station water samples, as well as their pH and conductivity.

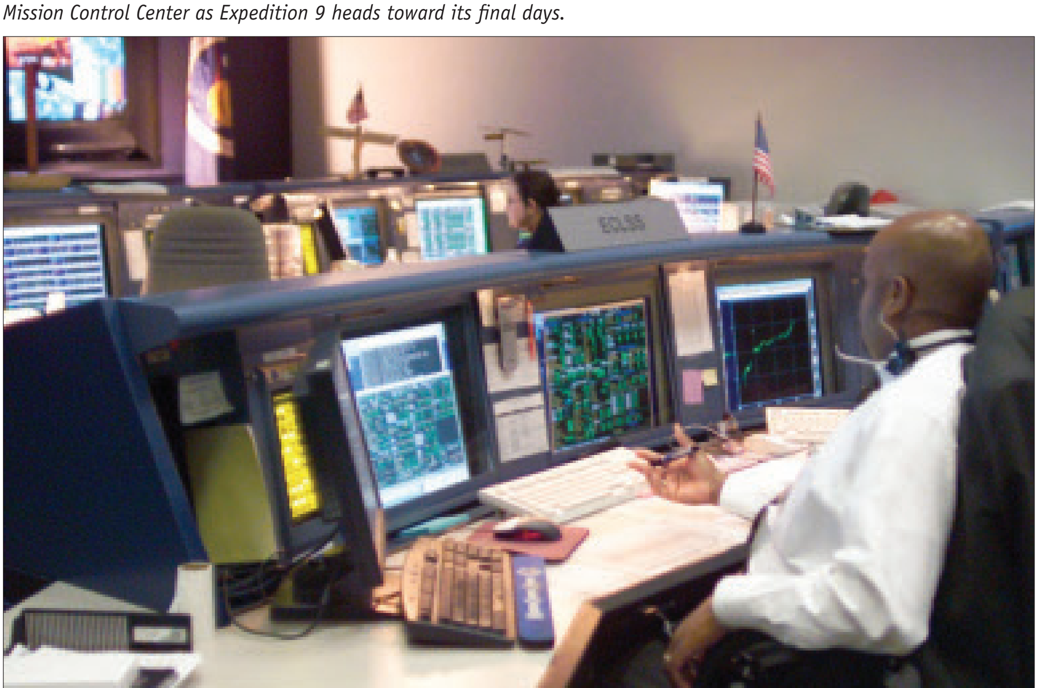
A philosophical shift

NASA's ECLSS venture is important for several reasons. First, from a practical standpoint, it relieves the ISS partners of requirements for costly water and consumables resupply missions, reducing annually the need for about 6.8 tons of upmass to the ISS. Second, it simply would not have been possible to double the station's crew size from three to six without the 2008 mission that delivered the WRS.

ECLSS also represents a major shift in design philosophy from open-loop life-support systems, favored in the first half-century of human spaceflight, toward a more functional closed-loop system.

With the older, open-loop systems, nearly all consumables were brought by spacecraft flown in Earth orbit or to the Moon. With the closed-loop approach, dependence on ground sys-

Kwatsi L. Alibaruho, ECLSS officer, monitors data at his console in the station flight control room in NASA Johnson's Mission Control Center as Expedition 9 heads toward its final days.



tems for consumables is increasingly limited, a vital criterion for future human missions to the Moon, near-Earth asteroids, or Mars.

Ron Ticker, manager for space station development at NASA Headquarters, refers to the ISS as a self-contained, life-sustaining ecosystem, or 'biodome.' By that he means that the station "is largely dependent on recycling. We do have resupply ships coming up there, but the more that we can do on board, [the more] it cuts our logistics requirements, and cuts our costs up there. So when I say it's a biodome, it is for the most part self-contained, or tries to be self-contained. That was the genesis, for example, of going to a more regenerative ECLSS to try to close those loops even more."

With ECLSS, "We're learning a lot about life support," says William Gerstenmaier, NASA's associate administrator for space operations. "We are close to an 85% level of regeneration with recycling urine into potable water, and we're learning a great deal about how to maintain systems in a microgravity environment."

"Sometimes the systems are tough to operate," adds Gerstenmaier. "With the oxygen generation system, for example, small particles clog up filters much more easily in microgravity. So we're learning to make the filter holes larger to avoid this problem."

Surprises in microgravity

NASA engineers responsible for the design and management of the ECLSS say that while it works well in space, the agency has had to deal with unexpected surprises simply because Earthbound tests of the refrigerator-sized oxygen and water regeneration equipment could not duplicate the station's microgravity environment.

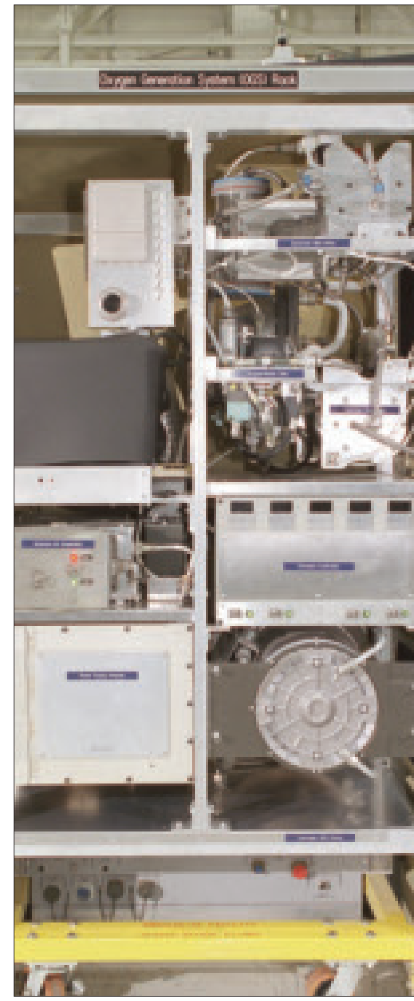
One example occurred in the recycling of urine into potable water, an effort never before attempted in space (since Mir, and on the ISS, the Russians have worked strictly on recycling humidity into drinkable water, though they have used recycled urine for regeneration of oxygen). The task is easier to accomplish on the ground than in microgravity conditions, explains Monsi Roman, project manager for life support and habitation systems at NASA. While it has been known for years that astronauts shed calcium in their urine, the mineral's high concentration added a layer of impurity to the recycling process, and it proved more difficult to filter out in space than in on-the-ground testing. "That's giving us a challenge we did not expect," Roman explains.

"With the rest of the process [for distilling humidity and waste water into drinkable water]," she adds, "you can recycle 100% of what you put in. But the urine you can't. That precipitant of water that you lose in the brine—contaminants from urine left over after water is boiled off in a large tank—is your net loss of how much you're actually recycling.

"Originally we thought we could recycle 93% of everything we put in [from the urine], but because of this high concentration of solids, we are not at this level….So it's a challenge, it's something that we needed to learn about on the space station. Distillation in itself is a very old technology. Making it work in microgravity is what makes it complicated. That's what the space station is there for—for us to check all these things we had never known in the past. If we had known them, of course we would have designed for them. If we go to Mars, we don't want to find out this information for the first time."

To improve the efficiency of the water recycling system, Roman says NASA advanced life support engineers are testing a number of concepts, including "concentrating all the water and distilling everything together, instead of distilling just the urine," which might make the recovery process "a little bit more effective."

Once the urine is fully distilled and processed, the potable water product is treated with iodine "to keep any residual microorganisms that might still be in your product water from regrowing and becoming a microbiological hazard," notes Robert Bagdigian, branch chief in NASA Marshall's Engineering Directorate. He says iodine is favored over chlorine as a disinfectant because "chorine is harder to handle, especially in a closed spacecraft environment." Because of medical concerns about the long-term effects of iodine on humans, Bagdigian adds that in a final filtration process the iodine is removed from the drinking water.



An oxygen generation system uses electricity from station solar panels to generate breathable oxygen through electrolysis.

Earthbound applications

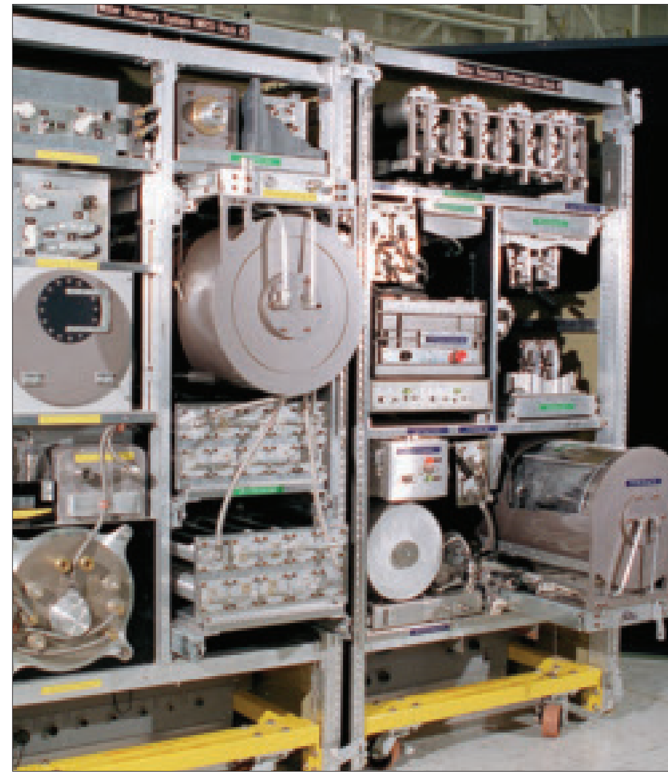
While recycling water in space has long-term human spaceflight implications, it also has immediate earthbound applications.

Ticker notes that Water Security, a private company, has used the technology NASA developed for this system to make "a product you can use in disaster recovery in the third-world areas where water purification is a big issue after earthquakes and other devastating events."

The system has been used to provide purified water for Kurdish villages in Northern Iraq and for earthquake relief in Pakistan. Adds Bagdigian, "We've gone out and talked to municipal water system operators, and businesses such as the pharmaceutical industry that want to learn how to produce high-purity water."

Operational lessons learned

A current challenge of operating ECLSS and other vital ISS systems is to make them more efficient. Regarding the filtration of dust, Roman notes, "The carbon dioxide removal system has issues with dust that we are trying to resolve by using a different kind of zeolites [molecular sieves] mix. Originally they put in a mesh that was too small. There was no flow of air. Now we have redesigned the mesh, so we should have a longer time in microgravity without the problem of dust clogging the air flow. As we learn to work the systems, they get more robust, and it takes less time for the crews to do repairs in flight."



The WRS provides clean water through the reclamation of waste waters.

NASA engineers are also seeking to make WRS equipment more efficient. "You would think we'd know how to make long-life pumps," says Bagdigian, "but in these applications, where we are trying to make these pumps as small as possible—relatively low-flow-rate pumps with high-pressure drop capabilities—you wind up having fairly unique pumps. So even with mundane things like pumps and valves, operating with this kind of complex waste water can be quite a challenge for us."

Regarding long-duration missions beyond LEO, NASA would also like to develop a way of efficiently laundering crew clothing in a closed-loop system. Bagdigian says this has not been an easy task: "Station crewmembers have taken some of their clothes, like socks and underwear, and on their own have been experimenting with putting them in bags and using a little water to push the clothes around. Operationally, we do not have the ability to do laundry. For exploration beyond space station, we are looking for technology to enable us to do it. We'd very much like to be able to reduce the amount of clothing we put on the vehicle." But for that to make sense, he says, they have to be sure any resulting weight savings "aren't more than offset by the weight that you'd add to the vehicle for all the equipment and supplies you'd need to do that laundering. There's a trade there."

Turning to the future of human spaceflight, Roman foresees regenerative life-support systems that are a hybrid of "basic chemical systems, and biological systems" such as "a greenhouse or system that will take the carbon dioxide out of the air using algae." She notes, though, that in-space greenhouses are not perfect solutions, because the carbon dioxide produced by humans will have to be scrubbed before it is absorbed by plants, and provisions must be made to provide the plants "with the right temperature and light. That's a lot of power that you need there, and a lot of area."

She adds that planners will need to figure out what to do with decomposed plant waste. "Greenhouses add a level of mass that you have to account for." Roman concludes, "I do not think NASA will send people to Mars completely dependent on one system or the other. I can tell you that regeneration is the right way to go. If you try to put together a trade study where you look at what it will take to keep a group of humans alive, it is still worth having a regenerative system in flight despite all the challenges."

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