

Solar Growth Chambers for NASA

Exploring agriculture for space colonies

Want to go live on the moon for a few months and still eat fresh vegetables? The idea of growing food in a space colony is not as far off as you might think. Engineers from The University of Arizona's Department of Agricultural and Biosystems Engineering are working on it right now, thanks to two grants from NASA. Growth chambers lit with both solar and artificial discharge lights are producing crops of fresh lettuce at the College of Agriculture's Environmental Research Laboratory (ERL).

"NASA has an Advanced Life Support program," says Joel Cuello, the UA biosystems engineer in charge of the solar chamber project. "Its main goal is to be able to provide the energy and materials astronauts will need to survive in enclosed space conditions. One way is through physical/chemical means, the other is through biological regenerative methods — using plants, for example, which can produce oxygen for breathing and also edible crops for food."

Cuello says the long-term goal is to set up a lunar or planetary space colony. "Because they've found ice on the moon, then water is present," Cuello says. "This points to the possibility of a colony on the moon." An extended stay in space means extensive food supplies must either be on board, re-supplied periodically from earth, or produced on-site. Bringing all of the food at once would require a fairly large space craft.

"And delivering from the earth to the moon — operating on a picnic or take-out principle — would be too expensive," Cuello adds. That leaves agriculture as the best possibility, but under more controlled conditions than we have on earth, where soil, light, water and air are more abundant. Funded by NASA through a university research grant and one of its Small Business Technology Transfer (STTR) grants, the latter in collaboration with a small company in northern California called Physical Science Incorporated, the UA project began in January of 1997 in an underground plant growth facility.

Cuello's research collaborators include fellow faculty members Kenneth Jordan and Dennis Larson; research specialist Philip Sadler; company scientist Takashi Nakamura, of Physical Sciences, Inc.; UA plant physiologist Patricia Rorabaugh; UA

environmental scientist Robert Frye, and graduate student Darren Jack.

"We used a combination of readily available solar collectors at the ERL, plus another developed by the company," Cuello says. He and his research team built the subterranean facility and lit one chamber with solar irradiance and the other with artificial light as a reference chamber. "We're testing lettuce in them, not because it's the ultimate crop that we want to grow but because it grows fast for experimental purposes," he explains.

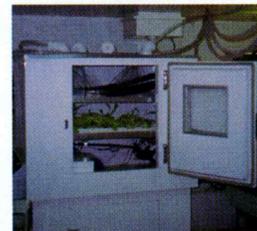
Current crops NASA is considering for advanced life support include wheat, tomatoes, potatoes, sweet potatoes, rice and others. The larger program, conducted at a variety of institutions, including NASA Kennedy and NASA Johnson Space Centers, also includes research in plant production; fish production; waste management and recycling; and food processing. The goal is to link all these units into a self-sustaining life support system, according to Cuello.

"The problem right now is the very high energy requirement needed for life support," he says. Generating enough artificial light for enclosed agriculture on the moon or Mars would be difficult. Cuello sees solar irradiance as an important supplement to artificial light for space plant production. But at the same time, solar irradiance can't completely replace artificial lighting, because there can be 14 earth days in a row without light on the moon, for instance.

The combination of solar and artificial light ensures a constant energy supply, and transmitting the light through fiberoptic cables into the growth chamber reduces the heat that would be generated inside. Removal of any heat would require additional and wasteful energy expenditure.

Each chamber measures three feet by two feet in area. Mirrors on top collect and concentrate the light, and focus it into fiberoptic cables that transport the light from the point of collection into the growth chamber. The cables extend through the ceiling into the top of the solar growth chamber, where their individual fibers fan out in a frame to distribute the light evenly to the plants. The plants are grown hydroponically, supplied with liquid nutrients.

A computerized system monitors the conditions inside the growth chambers, tracking air temperature, light



(Above) Underground plant growth facility with solar collectors on top, and (left) interior of growth chamber.

duration and intensity, and the pH of the nutrient solution. To keep light conditions as equal as possible, the researchers light up the solar chamber a day before the other one, measure how much light was used and then apply the same amount in the artificial light chamber.

Cuello says there has been an increase in yield in the solar chamber relative to the artificially lit chamber. "The only environmental difference between the two chambers is the quality of light," Cuello says, "one is natural light and the other is richer in the red spectrum." He notes that the project does not mimic weather conditions that might be encountered on the moon or on Mars. He says the weather might be more stable on the moon but dust could be a problem on Mars.

For this reason, Cuello would like to improve the design of the collectors. Right now he is using two different types. "The one provided by Physical Science, Inc. is more powerful, with larger mirrors and a larger collection area, but it has a primitive tracking system because that's what happens to be commercially available," Cuello admits. "The other one has a sophisticated tracking system but a smaller collection area."

He wants to develop a system with better mirrors and optical tracking systems. "NASA has just awarded us a new two-year grant to look into a system with a combination of natural and artificial lights, both delivered into a plant growth chamber through fiberoptic cables to provide stable lighting with minimized heat production," Cuello says. He and his team will be looking at different light sources, such as light-emitting diodes and xenon metal-halide lamps, to bring that salad on the moon or Mars closer to reality.

— Susan McGinley

J. Cuello