NASA growing food in space: An amazing technological feat

Steve Taranovich - October 28, 2017

When future astronaut crews begin living and working at more distant destinations in space, they will need to take a little of the Earth with them to help them breathe and allow them to eat their vegetables.

During my visit to NASA this August, I met Dr. Gioia Massa, a life science project scientist and deputy project scientist on NASA’s vegetable production system (VEGGIE) project for the International Space Station (ISS). The project was developed by Orbital Technologies Corp (ORBITEC) in Madison, Wisconsin, which is now Sierra Nevada Corp (SNC).

Figure 1 Dr. Massa (right) and I toured the “VEGGIE” program lab at NASA Kennedy Space Center (KSC). (Image courtesy of Loretta Taranovich)

The reason for growing food in space is not what you would first imagine. Astronauts will still
continue to eat NASA prepared foods on the ISS, similar to the freeze-dried ones most of us are familiar with, except they have greatly improved the quality. Growing food on the ISS has multiple benefits. When an astronaut can put a fresh piece of lettuce or another vegetable as a supplement into their prepared food, it is very positive psychologically to have something familiar from Earth. In the future, maybe oxygen can be generated via plants in such an enclosed environment, and this is also a tool for relaxation and recreation for the astronauts (see this interesting article on Science 2.0 by Robert Walker).

Dr. Massa commented that taste changes in space, sort of like having a cold, with the different pressure on the ISS. This is because fluids in the body get affected by the reduced gravity conditions (also called fluid shift). On Earth, gravity acts on the fluid in our bodies and pulls it into our legs. In space, this fluid is distributed equally in the body, so astronauts often add spices such as Sriracha or use Mizuna mustard to enhance the taste of their food.

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VEGGIE

This module in Figure 2 was sent up to the ISS soon after my visit. Dr. Massa runs ground control experiments there at NASA, monitoring temperature, relative humidity, and CO₂ concentrations.

Figure 2 Dr. Massa gave us a look into VEGGIE that would be sent to the ISS--you can see our reflections in the specially coated glass on the door that keeps ambient light out. (Image courtesy of Loretta Taranovich)

Plant pillows

Not for sleeping purposes, pillows with seeds in them are installed on a root mat, which is in turn installed into the VEGGIE bellows. Power is applied and water is added to the root mat to begin seed
germination. Water and growth height is maintained throughout the plant growth cycle until the vegetables are harvested and the growth cycle can be restarted.

![Figure 3 A plant pillow (Image courtesy of Loretta Taranovich)](image)

Inside these pillows is Arcillite, a solid growing substrate, used for growing plants in space in Veg-03.

**The advanced plant habitat**

The advanced plant habitat

Next, we met Brian G. Onante, NASA project manager for the Advanced Plant Habitat (APH).
The APH is the new plant system joining VEGGIE. This system provides a large enclosed environmentally-controlled chamber which is designed to support commercial and fundamental plant research or other bioscience research on the ISS; it is capable of at least one year of continuous operation without maintenance. The APH is configured as a quad-locker payload to be mounted in a standard EXpedite the PRocessing of Experiments to Space Station (EXPRESS) rack on the ISS.

The three main subsystems are water recovery and distribution subsystem, the environmental control subsystem, and the thermal control subsystem for the fluids division of the major system components; they work efficiently together and utilize the resources of the EXPRESS rack.

The astronauts will be able to monitor the experiment using an existing computer called Farmer or let NASA people on the ground run it. This plant habitat integrates previously proven microgravity plant growth technologies with newly developed fault tolerance and recovery technology to increase overall efficiency, reliability, and robustness. This system also provides single-level contained, embedded glove ports for the crew's use when sampling plant materials or conducting experiments. The basic design was based on an open architecture concept to allow critical subsystems to be removed and replaced onboard the ISS.

Typically, three crops are grown in this environment under 70W LEDs and fans to circulate the air. These crops have antioxidants that help protect astronauts against space radiation sources. These crops are: ‘Outragedous’ Red Romaine lettuce, Japanese Mizuna mustard, and Waldman’s Green lettuce.

The APH growing space will accommodate a shoot area of 1708 cm², a shoot height of 43 cm, a root area of 1853 cm², and a root height of 5 cm. This system has a method-active temperature control that uses thermoelectric coolers with a range of +18 to +30 °C and an accuracy of ±0.5 °C from the set point; temperature is uniform within ±1 °C in the plant canopy plane. Humidity is in the range of 50 to 90 percent relative humidity (RH) and is accurate within ±3 percent RH from the set point and...
uniform within ±5 percent RH in the plant canopy plane.

In the shoot zone, the APH provides sensor capability capable of measuring light levels in both the photosynthetically active and red/far red range as well as the ability to measure the surface temperature of a plant canopy or other sample surface. In the root zone, the standard plant habitat science platform provides a variety of sensing capabilities that include: root zone temperature, moisture levels, and oxygen content.

The system also uses high-intensity LED lighting composed of red (0-600 µmol m\(^{-2}\) s\(^{-1}\) at 630-660 nm ±10 nm), blue (0-400 µmol m\(^{-2}\) s\(^{-1}\) at 400-500 nm ±10 nm), green (0-100 µmol m\(^{-2}\) s\(^{-1}\) at 525 nm ±10 nm), broad spectrum white (0-600 µmol m\(^{-2}\) s\(^{-1}\) at 400-700 nm), and far-red (0-50 µmol m\(^{-2}\) s\(^{-1}\) at 730-750 nm ±10 nm) light.

Delivering water-nutrients is performed by active transfer through a rooting matrix via porous materials. The atmospheric composition of the plant habitat is 400 to 5,000 ppm ± 50 ppm of carbon dioxide. The system also includes an EXPRESS-rack-compatible data/photo interface and allows for real-time data telemetry, remote commanding, and photo downlink to the NASA Kennedy Space Center lab.

**Figure 5** A side view of the APH. (Image courtesy of NASA)
Careful monitoring of important parameters

The APH team runs tests here on Earth at NASA before sending the APH up to the ISS.

Figure 6 A front view of the APH (Image courtesy of NASA)

Figure 7 Close monitoring of all critical parameters is done via this system. (Image courtesy of Loretta Taranovich)
The APH is activated by astronauts aboard the ISS, but controlled by the team at Kennedy, minimizing the amount of crew time needed to grow the plants. NASA does not want astronauts to be farmers. The system has more than 180 sensors, relaying real-time information, including temperature, oxygen content, and moisture levels (in the air and soil, near the plant roots, and at the stem and leaf level), back to the team at Kennedy Space Center.

**LED lighting**

NASA tests have determined that LED lights are the optimum single source lights for plant growth on Earth as well as in space. Compare LED lighting vs. high-intensity discharge (HID) and other light sources lights [here](#).

LED lighting does not need a ballast like a fluorescent lamp, you can have monochromatic lighting or easily convert to a mix of lighting composed of different wavelengths with LEDs, and finally, LEDs produce little or no heat so they can be located much closer to the plants than other lighting, especially in small spaces.

Why the different colors? NASA research findings include the following:

- **Red Light** (630-660 nm) is essential for the growth of stems, as well as the expansion of leaves. This wavelength also regulates flowering, dormancy periods, and seed germination.
- **Blue Light** (400-520 nm) needs to be carefully mixed with light in other spectra since overexposure to light in this wavelength may stunt the growth of certain plant species. Light in the blue range also affects the chlorophyll content present in the plant as well as leaf thickness.
- **Green Light** (500-600 nm) was once thought not to be necessary for plants, but recent studies have discovered this wavelength penetrates through thick top canopies to support the leaves in the lower canopy.
- **Far Red Light** (720-740 nm) also passes through dense upper canopies to support the growth of leaves located lower on the plants. In addition, exposure to IR light reduces the time a plant needs to flower. Another benefit of far red light is that plants exposed to this wavelength tend to produce larger leaves than those not exposed to light in this spectrum.

Scientists have found that including white LED light mixes in arrays serve as a way to ensure plants cultivated indoors receive all the photosynthetically active radiation needed to optimize their health, growth, and yield.

**Power management**

There are four power systems for this system on the ISS; each at 1kW total that share the power sourcing of 1500W needed by APH.

**Interface**

Data telemetry is via a medium rate Ethernet system and a CAN bus.

[Read more: Biosphere 2 will improve Biosphere 1 and beyond](#)

**NASA innovative ideas for food in space**

NASA innovative ideas for food in space
Since NASA is working on a far smaller budget that its glory days of the '60s, technicians, engineers, and scientists have to think ‘outside the box’ for new cost-effective solutions. Here is one of them in the Food for Spaceflight effort for the Moon and Mars exploration teams at KSC as well as a possible future Deep Space Gateway between the Earth and the Moon.

This team, a combination of plant scientist/hardware people, researched advanced agricultural techniques like MIT's ‘Crops near urban areas' and Freight Farms that use shipping containers. It’s ideas like this that may lead to a Mars habitat in the 2030s when Orion will ferry astronauts to the Red Planet.

Assembling standard building blocks using creative industry electronic components, like custom Opto22 solid state relays (SSR), is a must for the future system architectures that will be needed in a habitat. We were told that systems engineering software such as National Instruments LabVIEW are good candidates to incorporate into some of these architectural space designs.

Designs being looked at are using custom, blue-enriched, white light at 300 u moles, which helps with human melatonin production. The human circadian system is sensitive to this light for night and day sleep and work patterns for astronauts.

As mentioned before, NASA does not want astronauts to be farmers, planting, caring, and watering crops, so automation is essential. In that vein, a NASA team went out and purchased a $3,500 automated electro-mechanical system and converted it to an agricultural farming system that could be controlled via smartphone, PC, etc (Figure 9).
Figure 9 NASA innovators spent only $3,500 on this system and is experimenting with it to plant seeds, water the plants, have automated fertilizing and include soil sensors in a feedback system that will optimize growth and care of vegetable growth in a space habitat. (Image courtesy of Loretta Taranovich)

Their system would be similar to Farmbot Genesis, but on a NASA budget.

Another area of this team’s research is how to deal with perchlorates and bacteria from Martian soil. Watch the following YouTube video from Space.com:
Figure 10 Standard modular components used in the electronics industry are fast becoming a way of life for development of systems to be used in space like the Deep Space Habitat. (Image courtesy of Loretta Taranovich)

Figure 11 Here I am with members of the team I met to discuss food in space. Larry Koss (left) is an engineering tech with ESC, Matt Romeyn (second from right) is a life sciences project scientist, and Ralph Fritsche (right) is a long duration food production manager. (Image courtesy of Loretta Taranovich)
For missions under five years, plans are to package food in bulk plus use other systems for fresh food to supplement that like the APH. There will be much more to come on these exciting technologies in my future visits to Mars (Just kidding, I mean NASA).

Steve Taranovich is a senior technical editor at EDN with 45 years of experience in the electronics industry.

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