NASAfacts

Veggie

NASA has led the charge in space exploration for more than six decades, and through the Artemis program, we will build on our work in low-Earth orbit. NASA's Artemis lunar exploration program includes sending a suite of new science instruments and technology demonstrations to study the Moon, landing the first woman and next man on the lunar surface by 2024, and establishing a sustained presence by 2028. The agency will leverage its Artemis experience and technologies to prepare for the next giant leap – sending astronauts to Mars.

As humans expand space exploration farther from Earth, the ability to grow a supplemental food crop is a solution to the challenge of long-duration missions into deep space. The packaged diet currently used by crews in low-Earth orbit works well and has supported an uninterrupted human presence in space since Nov. 2, 2000; however, it relies on frequent resupply missions. During a two- or three-year mission to Mars, the vitamins and quality of packaged food would degrade over time. Supplementation with fresh, edible crops will provide necessary nutrients while also enhancing dietary variety. Anecdotal evidence also supports the potential for psychological benefits for astronauts, rooted in the enjoyment of eating and caring for plants.

The System

- The Vegetable Production System (Veggie) is a plant growth unit on the International Space Station.

NASA astronaut Peggy Whitson is seen during harvesting and cleaning of VEG-03 in the space station's Node 2. VEG-03 used the Veggie plant growth facility to cultivate a type of cabbage to be harvested in orbit, with samples returned to Earth for testing.

- The Veggie concept is a simple, low-power system to grow fresh, nutritious food for our astronauts to supplement their diet and use as a tool to support relaxation and recreation.
- There are two Veggie units aboard the station, along with a more sophisticated growth chamber, the Advanced Plant Habitat.
- Veggie was built by ORBITEC in Madison, Wisconsin (Sierra Nevada Corporation acquired ORBITEC in 2014) under the NASA Small Business Innovation Research (SBIR) program.
- Earlier versions of the Veggie hardware were tested at NASA's Kennedy Space Center.
- The Veggie hardware and the VEG-01 experiment flew to the space station as commercial cargo, part of NASA's Commercial Resupply Services SpaceX CRS-3 mission that launched from Kennedy Space Center on April 18, 2014.
- Astronauts Rick Mastracchio and Steve Swanson installed Veggie in the Columbus Laboratory Module on May 7, 2014.
- Veggie runs on about 70 watts for the lights, fans and control electronics.

NASA astronaut Shane Kimbrough is photographed during VEG-03 harvest and stow of red romaine lettuce in the space station's Columbus Module.

- Veggie utilizes passive wicking to provide water to the plants as they grow.
- Currently, the seeds are glued into wicks, which are white flaps emerging from the top of a plant pillow.
- The glue actually is guar gum, a water-soluble natural polymer made from legumes called guar beans. This is what secures the seeds in place. Check your ice cream – you may find guar gum as a thickening agent.
- Plant pillows are Teflon-coated black Kevlar with a Nomex bottom, which contains the growth media (calcined clay – often used to condition baseball infields), controlled release fertilizer and water (injected through a quick-disconnect valve). Kevlar is a strong synthetic fiber and Nomex is a synthetic fiber that is flame- and heat-resistant.
- The water reservoir known as the root mat has a Nomex top, which wicks water from an interior water bag. The root mat Nomex, when in contact with the Nomex plant pillow bottom, allows water transfer to the pillows.
- Each plant pillow receives two or three seeds as a hedge against germination failure.
- Future plans are to have seeds embedded in a tape or film, which would allow seeds and pillows to fly independently. The space station could have a seed bank and a plant pillow bank, which would allow crews to decide what to grow.
- The plant experiment starts by placing the root mat on the Veggie baseplate, then the plant pillows are bungeed in place on top of the root mat. Water is injected into the plant pillow, then water is injected into the root mat. The wicks carry the water to the seeds, which are glued in, and the combination of water and light trigger germination. Seeds are oriented so that the plant grows up and the roots grow down into the plant pillow.
- As part of each plant experiment in Veggie, researchers at Kennedy grow crops on the ground in sync with the orbital experiments as a control group.
- Growing plants in microgravity is complicated by the fluid physics and lack of convective flow.

- Plants need oxygen and carbon dioxide, and the roots need water and oxygen at the same time. Too much water stresses plants like a flood, and too little is like a drought. The calcined clay media surface roughness, surface area and particle size traps air and absorbs water such that the root has both at the same time. Veggie has a fan system, which draws in cabin air for the growing plants to ensure they don't end up in a diffusion controlled bubble of humidity and oxygen.

- As a good practice and precaution, the Veggie team also developed a produce-sanitizing step for leafy greens utilizing food-safe, citric acid-based wipes that are used to sanitize the fresh produce and also clean the Veggie units.

- NASA is building up the ingredients for a pick-and-eat salad; or rather, a pick, sanitize and eat salad since there is no way to cook on the station yet.

- Astronauts have grown eight different types of leafy greens in Veggie for the astronauts to eat. Overall, 15 different types of plants have grown in space in Veggie. Researchers at Kennedy Space Center have tested more than 100 crops on the ground.

- Including experiments by teams of student citizen scientists working in partnership with the Veggie team via the Fairchild Tropical Botanic Garden's Growing Beyond Earth Project challenge, more than 200 crops have been tested for potential use in space.

- NASA is seeking further data on crop appeal and the benefit, if any, of having and caring for plants on crew morale.

VEG-01

Veggie's First Crop in Space

Astronaut Steve Swanson started the first crop of lettuce on May 8, 2014, and it grew for 33 days. VEG-01 A included one set of six plant pillows planted with red romaine lettuce seeds. The first crop of lettuce had one pillow with no germination and two plants that were lost due to water stress. Three healthy lettuce plants were harvested after 33 days, frozen, and returned to Kennedy for food safety analysis. Results were good with the plants being as clean, if not cleaner, than those purchased at grocery stores.

Veggie's Second Crop

Astronaut Scott Kelly initiated VEG-01 B, the second crop of lettuce, on July, 8, 2015, and both he and Astronaut Kjell Lindgren cared for the plants. The crop grew for 33 days. VEG-01 B included one set of six plant pillows planted with red romaine lettuce seeds. On Aug. 10, 2015, the crew enjoyed the fruits of their labor by harvesting half of the leaves from each plant for consumption. The rest of the plant tissue was harvested and frozen in the station's Minus Eighty-Degree Laboratory Freezer for ISS (MELFI) for return to Earth and further study (microbial analysis, antioxidant capacity, mineral analysis and anthocyanin concentration). This was the first crop grown and consumed in NASA hardware. The three U.S. Orbital Segment members enjoyed the leafy green with balsamic vinegar and extra virgin olive oil. They saved some of the lettuce for dinner with their Russian teammates. According to Kjell's Twitter account, he enjoyed the lettuce on a space cheeseburger!

Veggie's Third Crop

On Nov. 16, 2015, Astronaut Kjell Lindgren initiated VEG-01 C, with one set of six plant pillows planted with zinnia seeds. This was the last experiment for VEG-01. The zinnia has a longer growth period, different duration photoperiod and flowered as part of the experiment. They can be considered a precursor for a tomato and other plants that need to flower and fruit. Seeds were on-orbit for more than a year and a half and so germination data is of value for long-duration spaceflight campaigns. Long-duration growth will assist in determining viability of other long-duration crops in Veggie. Veggie did not encounter issues with pollen or flower production. Growing flowering plants and allowing them to flower verified this. Astronauts harvested plants and returned them, along with plant pillows, to Earth for microbial analysis and root structure visualization. It is of value to determine if microbial population changes by plant species. A NASA intern at Kennedy was able to germinate seeds from the zinnias returned from space, and researchers grew numerous daughter plants, indicating that pollination occurred in microgravity. When tomatoes are grown in space, crew members will need to pollinate the flowers to produce fruit.

All Veggie Crop Experiments for Human Consumption

- **VEG-01 B:** 'Outredgeous' red romaine lettuce – July 8, 2015 - Aug. 10, 2015.

- **VEG-03 A:** 'Outredgeous' red romaine lettuce using cut-and-come-again repetitive harvest technique – Oct. 25, 2016 – Dec. 28, 2016.

- **VEG-03 B:** 'Tokyo Bekana' Chinese cabbage – Jan. 20, 2017 - Feb. 17, 2017.

- **VEG-03 C:** 'Tokyo Bekana' Chinese cabbage using cut-and-come-again repetitive harvest technique – April 3, 2017 - May 31, 2017.

- **VEG-03 D:** Mizuna mustard, 'Outredgeous' red romaine lettuce and 'Waldmann's Green' lettuce using cut-and-come-again repetitive harvest technique – Sept. 26, 2017 - Nov. 23, 2017 (harvested and eaten on Thanksgiving).

- **VEG-03 E:** Mizuna mustard, 'Outredgeous' red romaine lettuce and 'Waldmann's Green' lettuce using cut-and-come-again repetitive harvest technique grown concurrent with Veg-03 F – Feb. 6, 2018 - April 6, 2018.
- **VEG-03 F:** Mizuna mustard, 'Outredgeous' red romaine lettuce and 'Waldmann's Green' lettuce using cut-and-come-again repetitive harvest technique grown concurrent with Veg-03 E – Feb. 9, 2018 - April 9, 2018.
- **VEG-03 G:** 'Red Russian' kale and 'Dragoon' lettuce – Oct. 25, 2018 - Nov. 28, 2018.
- **VEG-03 H:** 'Wasabi' mustard and 'Extra Dwarf' pak choi – March 9, 2019 - April 6, 2019.
- **VEG-04 A:** Mizuna mustard using Red-Rich and Blue-Rich light recipes – June 4, 2019 - July 9, 2019.
- **VEG-04 B:** Mizuna mustard grown using Red-Rich and Blue-Rich light recipes and cut-and-come-again repetitive harvest technique – Oct. 1, 2019 – Nov. 28, 2019.

Inside the Veggie flight laboratory in the Space Station Processing Facility at NASA's Kennedy Space Center in Florida, Matthew Romeyn harvests a portion of the 'Outredgeous' red romaine lettuce from the VEG-03 ground control unit.

All Veggie Crop Experiments Not for Human Consumption

Here is a list of space biology experiments that astronauts grew in Veggie but did not eat:

- **VEG-01 A:** 'Outredgeous' red romaine lettuce – May 8, 2014 - June 10, 2014 (proof-of-concept experiment).
- **APEX-03-1:** Arabidopsis – Jan. 15, 2015 - Jan. 26, 2015.
- **APEX-03-2:** Arabidopsis – Jan. 15, 2015 - Feb. 3, 2015.
- **VEG-01 C:** Zinnia – Nov. 16, 2016 - Feb. 14, 2016.
- **CERES:** Lentil, mustard and radish – Jan. 3, 2017 - Jan. 12, 2017 (European Space Agency's education program experiment that grew the same seeds as hundreds of school children on Earth).
- **APEX-04:** Arabidopsis – Feb. 25, 2017 - March 16, 2017.
- **APEX-05:** Arabidopsis – Dec. 20, 2017 - Jan. 9, 2018.
- **APEX-06:** Brachypodium – April 12, 2018 - April 20, 2018.
- **VEG-PONDS-01:** 'Outredgeous' red romaine lettuce – April 25, 2018 - May 14, 2018 (tech demo of a new type of container: the Passive Orbital Nutrient Delivery System).
- **Space Algae:** Algae.
- **Microalgae:** Algae.
- **VEG-PONDS-02:** 'Outredgeous' red romaine lettuce – April 25, 2019 - May 17, 2019 (second tech demo for PONDS).

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