

## Veggie Fact Sheet

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 explore space, we will want to bring plants for both aesthetic and practical reasons. We already know from our pioneering astronauts that fresh flowers and gardens on the International Space Station (ISS) create a beautiful atmosphere and let us take a little piece of Earth with us on our journeys. They're good for our psychological well-being on Earth and in space. They also will be critical for keeping astronauts healthy on long-duration missions in deep space.

### The System

- The Vegetable Production System ([Veggie](#)) is a plant growth unit on the [International Space Station](#).
- 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 ISS, along with a more sophisticated growth chamber, the [Advanced Plant Habitat](#), also on the space station.
- 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 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.
- 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 is actually 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 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 August 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 US 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 cheese burger](#)!

### *Veggie's Third Crop*

On November 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 of the plants.

## All Veggie Crop Experiments for Human Consumption

- **VEG-01 B:** 'Outredgeous' red romaine lettuce – July 8, 2015 - August 10, 2015.
- **VEG-03 A:** ['Outredgeous' red romaine lettuce](#) using [cut-and-come-again](#) repetitive harvest technique – [October 25](#), 2016 - December 28, 2016.
- **VEG-03 B:** ['Tokyo Bekana' Chinese cabbage](#) – January 20, 2017 - February 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 – September 26, 2017 - November 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 – February 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 – February 9, 2018 - April 9, 2018.
- **VEG-03 G:** 'Red Russian' kale and 'Dragoon' lettuce – October 25, 2018 - November 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 – experiment initiated on October 1st.

## 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 – January 15, 2015 - January 26, 2015.
- **APEX-03-2:** Arabidopsis – January 15, 2015 - February 3, 2015.
- **VEG-01 C:** Zinnia – November 16, 2016 - February 14, 2016.
- **CERES:** Lentil, Mustard, and Radish – January 3, 2017 - January 12, 2017 (European Space Agency's education program experiment that grew the same seeds as hundreds of school children on Earth)
- **APEX-04:** Arabidopsis – February 25, 2017 - March 16, 2017.
- **APEX-05:** Arabidopsis – December 20, 2017 - January 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 Deliver System).
- **Space Algae:** Algae.
- **Microalgae:** Algae.
- **VEG-PONDS-02:** 'Outredgeous' red romaine lettuce – April 25, 2019 - May 17, 2019 (second tech demo for PONDS).