

Internship proposal 2021 – Set up an open-source automated farming system

Nicolas Drougard, Thibault Gateau, Caroline Chanel

firstname.lastname@isae.fr

Department of Aerospace vehicles design and control (DCAS)



Key words: *Bioregenerative Life Support System, Precision Agriculture, Robotics, Web-app, Linux, Arduino, Raspberry, Computer network, NTP, Shell, HTML, SCSS, Javascript, TypeScript, Ruby.*

1 Introduction

When space missions include humans, it is necessary to set up a life support system (LSS). Future space missions (e.g. colonization of Mars) are expected to involve longer distances and durations. For such missions, resupply from Earth is too expensive (or even impossible for a one-way trip) both in terms of energy and time, and it therefore becomes necessary to design bioregenerative LSS [3].

This is why the implementation of such systems is of interest to ESA: *“For more than 30 years, the European Space Agency (i.e. ESA) is active in the field of regenerative life support system. MELISSA (Micro-Ecological Life Support System Alternative) is the European project of circular life support system. It was established to gain knowledge on regenerative system, aiming to the highest degree of autonomy and consequently to produce food, water and oxygen from mission wastes.”*¹.

Growing plants in space, in addition to providing fresh food for astronauts, makes it possible to mitigate *“stress effects from long-duration space travel”* [6]. This is also a subject of interest since research does not exclude that it is possible to grow plants on the Moon and Mars [11]. For the European Space Agency (ESA), *“cultivating plants for food was a significant step in the history of mankind. Growing plants for food in space and on other planets will be necessary for exploration of our Universe”*².

¹www.melissafoundation.org/

²https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/Research/Plants



Figure 1: First space-grown salad eaten by astronauts in 2015 on the ISS.

Space food has always been brought from earth³ but for more than twenty years some plant growth systems for space have been set up and tested in various conditions [13, 12, 2]⁴, for instance SVET (on Mir station, 1997) [5] and Lada (on the ISS, 2002) [1].

More recently, NASA set up the Vegetable Production System [7] (Veggie, 2014⁵) that produced the first space-grown salad eaten by the astronauts⁶ (see Figure 1). In 2017, it was supplemented by the Advanced Plant Habitat (APH), that *“is the largest growth chamber aboard the orbiting laboratory. Roughly the size of a mini-fridge, the habitat is designed to test which growth conditions plants prefer in space and provides specimens a larger root and shoot area.”*⁷.

The european project EDEN ISS [14]⁸ has also studied, until 2019, systems architecture for cultivating plants in closed-loop systems for applications on earth and in space. This project led for instance to greenhouse design concept for the Moon and Mars [4]. Within the framework of the MELiSSA project, prototypes have recently been developed (e.g. for cultivation of tuberous plants [10] in the ESA Project “Precursor of Food Production Unit”) and many research works have been carried out (e.g. on hydroponic systems [8] or potatoes in controlled environments [9]).

2 Automated farming systems

During most of the space missions, human time and attention are very precious. For instance, in the International Space Station (ISS), it is preferable not to assign additional tasks that are not related to ongoing experiments: *“At any given time on board the space station, a large array of different experiments are underway within a wide range of disciplines.”*⁹. Plant cultivation would be a long and repetitive daily task that would increase too much

³<https://airandspace.si.edu/exhibitions/apollo-to-the-moon/online/astronaut-life/food-in-space.cfm>

⁴see also www.astrobotany.com.

⁵<https://www.nasa.gov/content/growing-plants-in-space>

⁶https://www.nasa.gov/mission_pages/station/research/news/meals_ready_to_eat

⁷https://www.nasa.gov/mission_pages/station/research/Giving_Roots_and_Shoots_Their_Space_APH

⁸<https://eden-iss.net/>

⁹www.nasa.gov/mission_pages/station/research/experiments_category

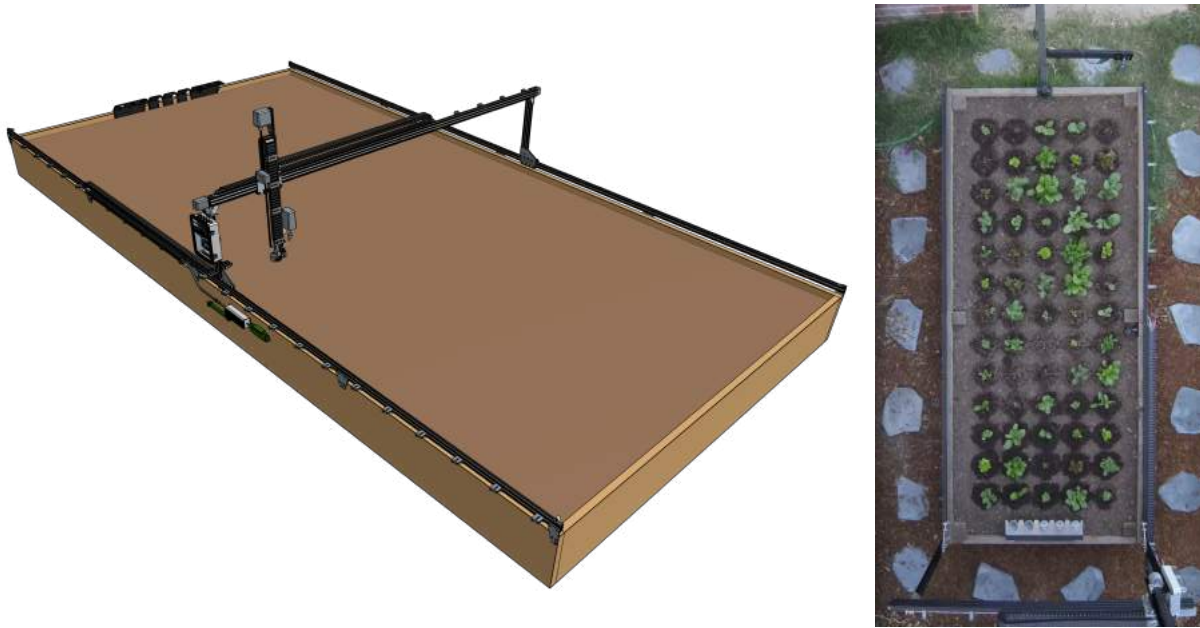


Figure 2: Farmbot Genesis XL robotic system.

the workload of the human team involved. It is therefore interesting to study systems for growing plants with automated monitoring and interventions.

In order to conduct further research on bioregenerative life support systems, the Department of Aerospace Vehicles Design and Control at ISAE-SUPAERO is now equipped with a Farmbot Genesis XL (<https://farm.bot/>, see Figure 2), an open source Cartesian coordinate robot farming machine. The research work that will be carried out with the help of this robot fits into the framework of the ALICE (AI for Life In spaCE) project. The goal of this project is to pave the way towards autonomous plant growing system capable of analyzing and reacting to the growing process in order to quickly obtain healthy plants while optimally use space and resources (nutrient, water, etc.).

The purpose of this internship is to assemble the Farmbot Genesis XL robot , control it, and set up the data collection. It will be carried out in the following stages:

- Carry out an inventory of the Farmbot's parts (see <https://genesis.farm.bot/v1.5/FarmBot-Genesis-V1.5>).
- Identify the location of the water and electricity supply, *i.e.* the final location of the farmbot.
- Considering the identified constraints, propose a way to make the web-app self-hosted (see <https://software.farm.bot/v12/FarmBot-Software>).
- List the lacking parts (planter bed, electric adapters, cables, garden hose, WiFi repeater, Raspberry Pi, etc.).
- Host the Farmbot web-app and create a local network to which the Farmbot and users can connect (see <https://developer.farm.bot/v12/Documentation>).
- Follow the necessary training to use the Fablab (InnovSpace) tools to assemble the Farmbot.

- Build and install the Farmbot in its assigned location.
- Propose and implement a data collection system.
- Propose and set up a system for deploying cultivation strategies.
- Formalize the cultivation problem and propose data-based strategy optimizations.

Good knowledge of computer development and familiarity with the following tools will be highly appreciated: Linux, Arduino, Raspberry, Computer network, NTP, Shell, HTML, SCSS, Javascript, TypeScript, Ruby.

References

- [1] Gail E Bingham, T Shane Topham, John M Mulholland, and Igor G Podolsky. Lada: The iss plant substrate microgravity testbed. Technical report, SAE Technical Paper, 2002.
- [2] Petronia Carillo, Biagio Morrone, Giovanna Marta Fusco, Stefania De Pascale, and Youssef Roupahel. Challenges for a sustainable food production system on board of the international space station: A technical review. *Agronomy*, 10(5):687, 2020.
- [3] Yuming Fu, Leyuan Li, Beizhen Xie, Chen Dong, Mingjuan Wang, Boyang Jia, Lingzhi Shao, Yingying Dong, Shengda Deng, Hui Liu, et al. How to establish a bioregenerative life support system for long-term crewed missions to the moon or mars. *Astrobiology*, 16(12):925–936, 2016.
- [4] Barbara Imhof, Molly Hogle, Waltraut Hoheneder, René Waclavicek, Bob Davenport, Daniel Schubert, Vincent Vrakking, Conrad Zeidler, Volker Maiwald, Paul Zabel, et al. Greenhouse design concepts for moon and mars. 2019.
- [5] Tania Ivanova, Svetlana Sapunova, Plamen Kostov, and Ivan Dandolov. First successful space seed-to-seed plant growth experiment in the svet-2 space greenhouse in 1997. *Space Research Institute, Bulgarian Academy of Sciences*. <http://www.space.bas.bg/astro/Aerosp16/tania1.pdf>, 2001.
- [6] Marios C Kyriacou, Stefania De Pascale, Angelos Kyratzis, and Youssef Roupahel. Microgreens as a component of space life support systems: A cornucopia of functional food. *Frontiers in plant science*, 8:1587, 2017.
- [7] Howard G Levine and Trent M Smith. Vegetable production system (veggie). 2016.
- [8] Mariantonella Palermo, Roberta Paradiso, Stefania De Pascale, and Vincenzo Fogliano. Hydroponic cultivation improves the nutritional quality of soybean and its products. *Journal of agricultural and food chemistry*, 60(1):250–255, 2012.
- [9] Roberta Paradiso, Carmen Arena, Youssef Roupahel, Luigi d’Aquino, Konstantinos Makris, Paola Vitaglione, and Stefania De Pascale. Growth, photosynthetic activity and tuber quality of two potato cultivars in controlled environment as affected by light source. *Plant Biosystems—An International Journal Dealing with all Aspects of Plant Biology*, 153(5):725–735, 2019.

- [10] Roberta Paradiso, Antonio Ceriello, Antonio Pannico, Salvatore Sorrentino, Mario Palladino, Maria Giordano, Raimondo Fortezza, and Stefania De Pascale. Design of a module for cultivation of tuberous plants in microgravity: The esa project “precursor of food production unit”(pfpu). *Frontiers in Plant Science*, 11:417, 2020.
- [11] GW Wieger Wamelink, Joep Y Frissel, Wilfred HJ Krijnen, M Rinie Verwoert, and Paul W Goedhart. Can plants grow on mars and the moon: a growth experiment on mars and moon soil simulants. *PLoS One*, 9(8):e103138, 2014.
- [12] Raymond M Wheeler. Agriculture for space: People and places paving the way. *Open agriculture*, 2(1):14–32, 2017.
- [13] Paul Zabel, Matthew Bamsey, Daniel Schubert, and Martin Tajmar. Review and analysis of over 40 years of space plant growth systems. *Life sciences in space research*, 10:1–16, 2016.
- [14] Paul Zabel, Matthew Bamsey, Conrad Zeidler, Vincent Vrakking, Bernd-Wolfgang Johannes, Petra Rettberg, Daniel Schubert, Oliver Romberg, Barbara Imhof, Robert Davenport, et al. Introducing eden iss-a european project on advancing plant cultivation technologies and operations. 45th International Conference on Environmental Systems, 2015.