

# Overview of experiment results from the first research campaign of the EDEN ISS greenhouse facility in Antarctica in 2018

Dr. Paul Zabel - German Aerospace Center (DLR)



EDEN ISS  
overview

Experiment  
Results  
2018

Outlook on  
future  
research

MELISSA Conference  
3-5 November, 2020

# Project overview

- Funded by the Horizon 2020 research framework of the European Commission
- Started in March 2015
- Project end in May 2019, but operation continues
- 14 partners from 8 countries

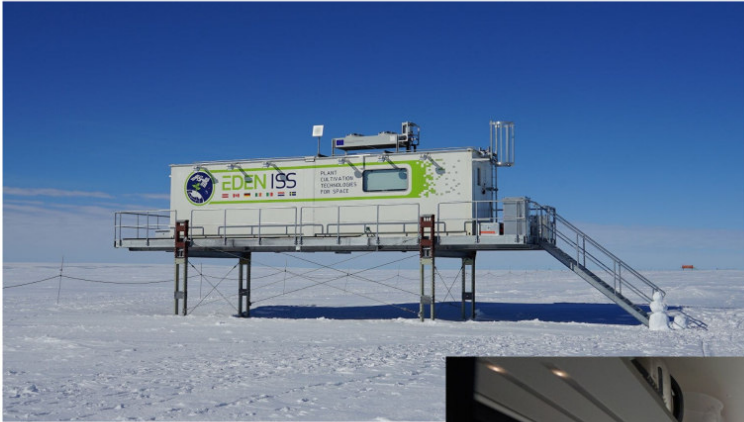


EDEN ISS facility and deployment team



EDEN ISS project team

# EDEN ISS Mobile Test Facility



MTF 400 meters away from Neumayer Station III



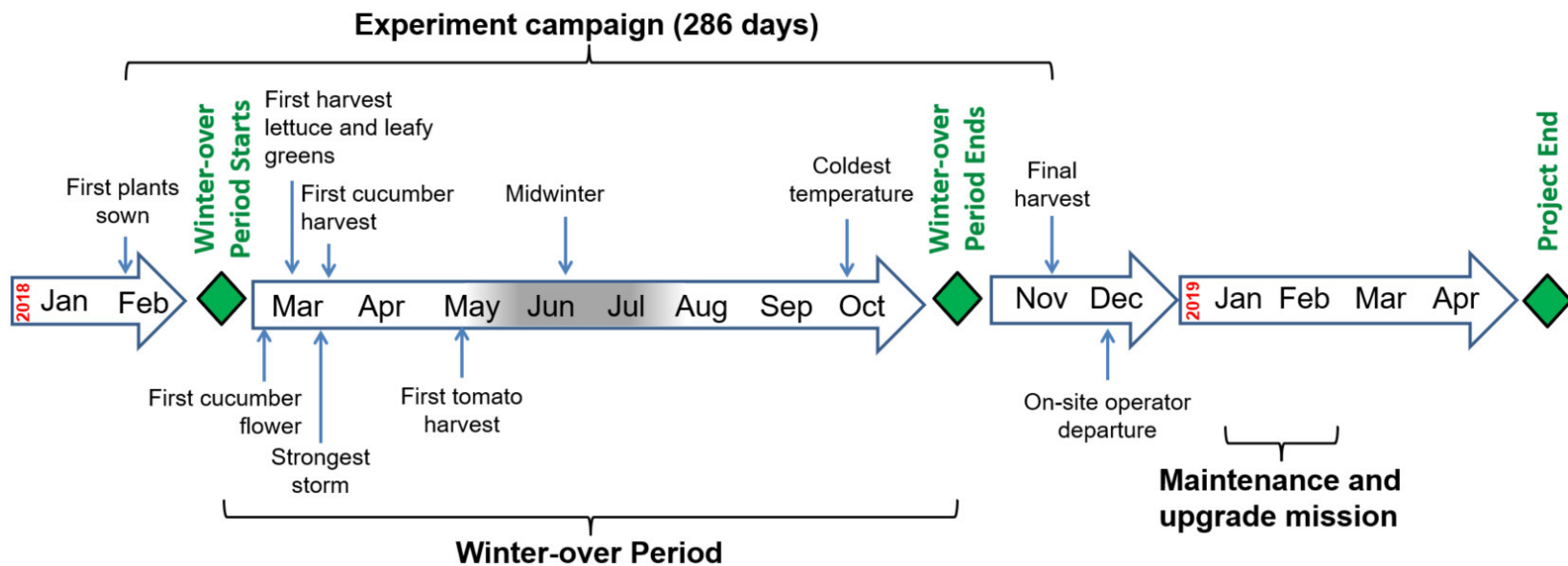
Inside of the Future Exploration Greenhouse



Inside of the Service Section



# Timeline of the 2018 season



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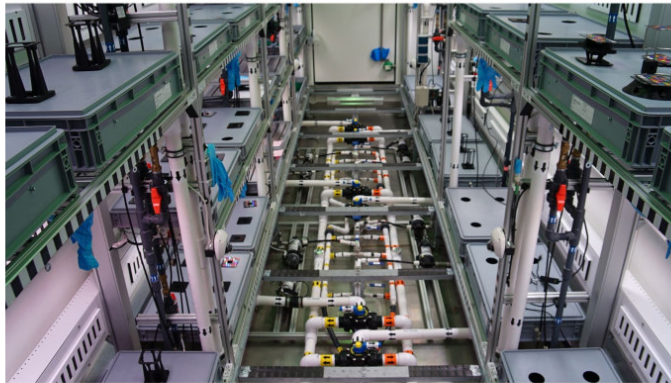
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# Multidisciplinary science program

- System performance
- Plant biology and horticulture
- Microbiology
- Food quality and safety
- Psychology and human factors
- Plant health monitoring



Basil



Piping of the nutrient delivery system

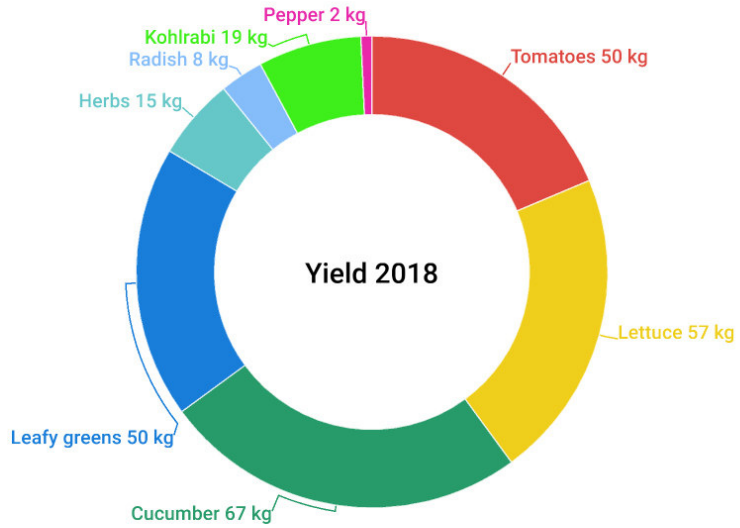


Dwarf tomato



# Food production

- In total 268 kg of food in 286 days on 12.5 m<sup>2</sup>.
- Almost 1 kg fresh food per day!
- Detailed production data for 18 crops available.

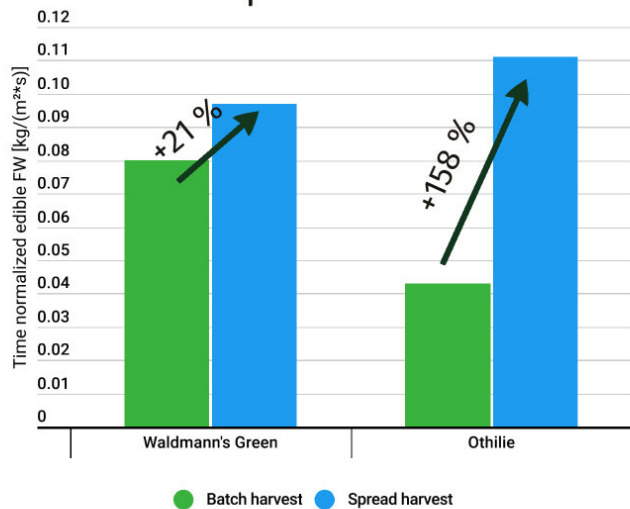


Top: First harvest 2018. Bottom: Paul Zabel with the first harvested lettuce.

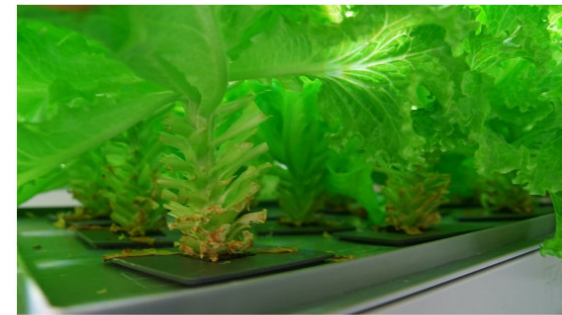
Zabel, P., et. al, 'Biomass Production of the EDEN ISS Space Greenhouse in Antarctica during the 2018 experiment phase', *Frontiers in Plant Science*, Vol. 11, p. 656, 2020. DOI: 10.3389/fpls.2020.00656.

# Harvesting strategies

- Comparing harvesting strategies. Batch = single harvest, spread = multiple harvests per cycle.
- Spread harvest is more productive than single harvest, but varieties respond differently.
- Even when factoring in additional crewtime and power demands, spread harvest is still 2-times as productive as batch harvest!



Waldmann's Green lettuce, spread harvested.



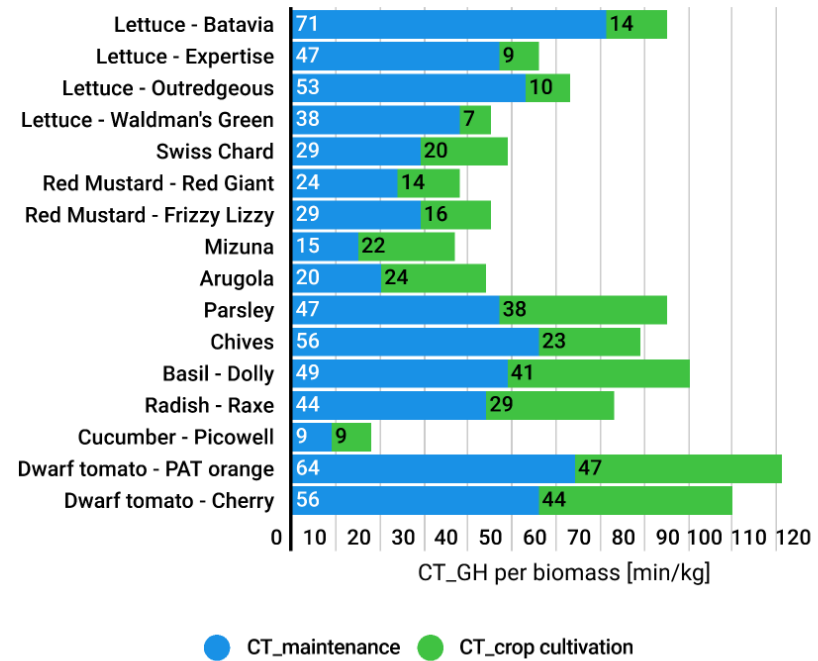
Othilie lettuce, spread harvested.

*Zabel, P., et. al, 'Implications of different plant cultivation techniques for food production in space based on experiments in EDEN ISS', International Conference on Environmental Systems, 2020.*



# Crewtime demand

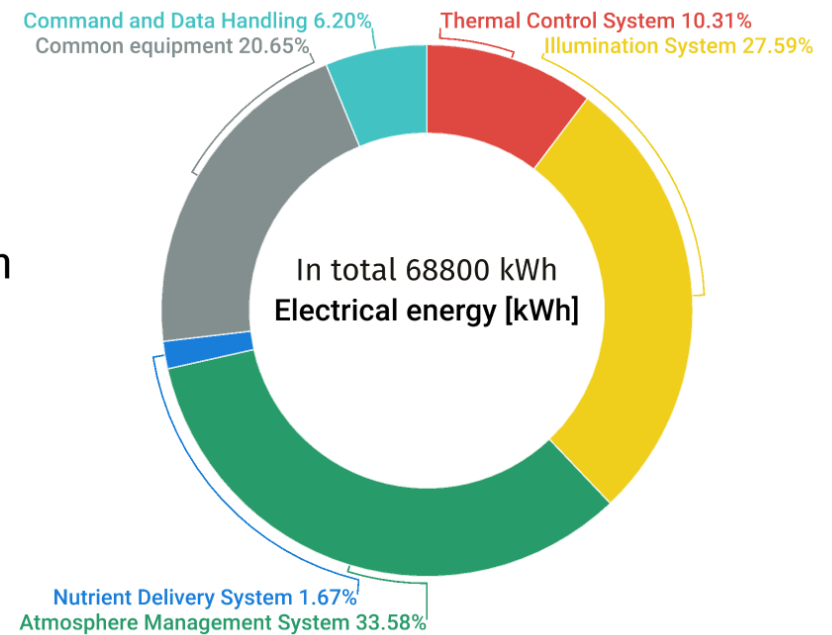
- Crewtime for system maintenance work (CT\_maintenance) and for crop cultivation tasks (CT\_crop cultivation) was tracked.
- Time was tracked per task and per crop.
- ~3-4 hours per day were required in total to operate the MTF, without accounting for science and repairs.



*Zabel, P., et. al, 'Crewtime in a Space Greenhouse based on the Operation of the EDEN ISS Greenhouse in Antarctica', 49th International Conference on Environmental Systems, 7-11 July 2019, Boston, Massachusetts, United States.*

# Power and energy demand

- In total ~68800 kWh electrical energy demand in 2018 season.
- ~ 20% is required for additional electrical heating required in Antarctica.
- Atmosphere conditioning and illumination have the largest energy demand.



*Publication of data in preparation.*

# Resources demand and waste production

- Water: ~3080 L water supplied to MTF of which 1300 L for washing and ~1780 for plant cultivation
- Liquid waste: ~1100 L depleted nutrient solution
- Solid waste: 8.9 kg paper/cardboard, 5.2 kg plastic
- Nutrients: ~17.75 kg of salts
- CO<sub>2</sub>: ~50 kg supplemented from high-pressure bottles



*Zeidler, C., et. al, 'Resource Consumption and Waste Production of the EDEN ISS Space Greenhouse Analogue during the 2018 Experiment Phase in Antarctica', International Conference on Environmental Systems, 2020.*



# Food Quality and Safety

## Food Quality:

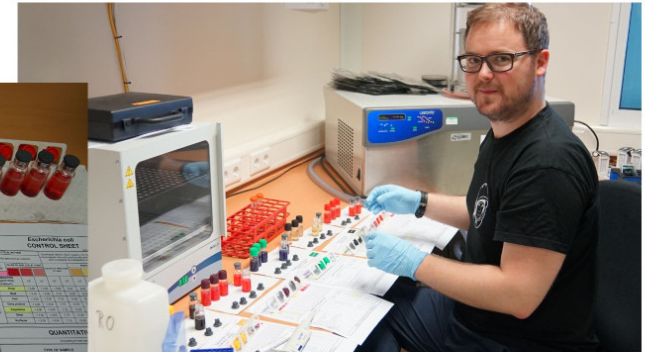
- On-site quality measurements: Nitrate content, sugar content, color, firmness, chlorophyll content
- More than 200 freeze dried samples for analysis in laboratories in Europe
- Food sensory panel, involving the station crew to rate taste of produce

## Food Safety:

- 30 frozen samples of plant material, taken under sterile conditions
- 'Lab in a vial' test kits for common microorganisms (e.g. Salmonella, E. Coli)
- Incubation of preconditioned petri dishes



'Lab in a vial' test kits



Paul Zabel doing FQS tests in Neumayer Station III

*Food Quality and Safety results not yet published.*

# Plant Health Monitoring

- Multi-wavelength imaging
- Monitoring with cameras, 1 image per camera per day
- Image evaluation algorithm to determine plant status



Images taken by the PHM cameras.



- Zeidler, C., et. al, 'The Plant Health Monitoring System of the EDEN ISS Space Greenhouse in Antarctica During the 2018 Experiment Phase', *Frontiers in Plant Science*, Vol. 10, p. 1457, 2019. DOI: 10.3389/fpls.2019.01457.
- Tucker, R., et. al, 'NDVI imaging within space exploration plant growth modules - A case study from EDEN ISS Antarctica'. *Life Sciences in Space Research*, 26, pp. 1-9, 2020. DOI: 10.1016/j.lssr.2020.03.006.

# Microbial environment of the greenhouse

- Monthly surface sampling in 15 different locations, monthly plant sampling of 10 different crops, monthly liquid sampling of nutrient solution and fresh water
  - Samples stored at -40 °C and shipped back to Europe
  - Analysis on quantity and types of microorganisms
- > Microbial load on plants >1000 times smaller compared to supermarket vegetables  
-> Microbial environment inside the greenhouse varies over time



Microbial sampling and frozen samples.



*Fahrion, J., et. al, 'Microbial Monitoring in the EDEN ISS greenhouse, a mobile test facility in Antarctica', Frontiers in Microbiology, Vol. 11, Article 525, 2020.*



# Psychological and Human Factors

- Questionnaire with respect to eating behavior and interest in greenhouse
- Current crew (with greenhouse) and former crews (without greenhouse)
- Guided group discussion with respect to human factors (e.g. accessibility, comfort)

## Questionnaire 2

### On interaction with the plants

(One possible answer. (\*)=comment possible, please write in capital letter)

**2.0 Do you have on the Neumayer Station plants** in the Greenhouse or in the Bottle Crops experiment?  
 Yes – please continue with question 2.1  
 No – please continue with question 2.8

**2.1 How often have you visited the greenhouse** (mark with cross) or by Bottle Crops Experiment (mark with circle)?  Never,  1 or 2 times,  <1 per month,  >1 per month,  Every week,  Almost every day  
How did you perceive that?  Positive  Neutral  Negative \* \_\_\_\_\_

**2.2 How did the location of the greenhouse** chamber impact Your experience with the plants?  
0 Not At All 1 A Little 2 Moderately 3 Quite a lot 4 extremely  
 Positive  Neutral  Negative \* \_\_\_\_\_

**2.3 Did you interact\* with the plants** on the Station? (\*=visiting, watching, growing, tending or/and processing them)  
from the Greenhouse?  Yes  No  
from the Bottle Crops experiment?  Yes  No  
Did you like/Would you like to interact\* with them?  
0 Not At All 1 A Little 2 Moderately 3 Quite a lot 4 Extremely

**2.4 How often did you eat** those plants or fruits?  
 Never (go to 2.5),  1 or 2 times,  <1 per month,  >1 per month,  Every week,  Almost every day  
Did you like to eat them?  
0 Not At All 1 A Little 2 Moderately 3 Quite a lot 4 extremely

Which kinds did you enjoy the most? (check a maximum of 3)

Tomatoes,  Strawberries,  Sweet peppers,  Cucumbers,  Radishes,  
 Lettuce/Rucola,  Herbs,  Other \_\_\_\_\_

Which aspect did you enjoy the most? (at least one answer)

Taste (e.g., acidity, sweetness)  Pungency (e.g., hot taste, bitterness)  
 Texture (e.g., crispness)  Appearance (e.g., fresh colors)

*Schlacht I.L., et. al, 'Impact of Plants in Isolation: The EDEN-ISS Human Factors Investigation in Antarctica'  
In: Stanton N. (eds) Advances in Human Factors of Transportation. AHFE 2019. Advances in Intelligent Systems and Computing, vol 964. Springer, Cham. [https://doi.org/10.1007/978-3-030-20503-4\\_71](https://doi.org/10.1007/978-3-030-20503-4_71)*

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# Outlook on 2021 season

- Corona pandemic makes Antarctic logistics even more complicated -> Season start is delayed
- Initial sowing of plants for winter season planned for 1st of March 2021
- Collaboration with NASA -> joint experiments
- Overwinterer: Jess Bunchek, Plant Scientist  
SURA/LASSO – Kennedy Space Center



Jess Bunchek

***The EDEN ISS facility is also available for new international collaborations.***

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