Proposed List of MELiSSA PhD Topics

Topic Title:
Study and characterization of plant canopy growth and plant canopy evapotranspiration through imaging techniques

Keywords: imagery system, crop species, MELiSSA loop

Abstract
MELiSSA stands for "Micro-Ecological Life Support System Alternative". MELiSSA is the European project for circular life support systems and is characterized by a biological and chemical/physical approach based on first principles modelling and implementation of a suitable deterministic engineering approach. Within the MELiSSA loop, the production of oxygen from carbon dioxide, the processing of water and the production of edible biomass is performed by the higher plant compartment, designed to accommodate various crop species (*Lactuca sativa, Solanum tuberosum, Triticum aestivum, Triticum durum, Glycine max, Oryza sativa, Solanum lycopersicum, Allium cepa, Spinacia oleracea*).

These crop species have been pre-selected for their capability to develop well in hydroponic systems and for their combined nutritional values that offer a high coverage of the human caloric intake requirements. Yet, the crew time constraints of any space mission demand a high level of automation and modularity while maintaining high constraints on energy, mass and volume budget of the higher plant chamber under the ALISSE criteria notion. Such constraint of automation calls for the implementation of non-destructive measurement capabilities that support the direct quantification of biomass growth and correlation with environmental parameters evolution. Previous studies have used visual images to follow the qualitative development of *Lactuca sativa* individual plants and have used thermal images to follow the qualitative state of health of the open canopy, or the evapotranspiration process at *Spinacia oleracea* leaf level. However, the quantification of canopy effective leaf area and the subsequent correlation with the closed canopy photosynthesis and evapotranspiration processes remain to be established.

The proposed PhD shall study the effective leaf area related to closed canopy photosynthesis and canopy evapotranspiration. Attention will be given to understanding the influence of the environmental parameters such as for instance air velocity fields within the canopy and at the surface of the canopy. Focus should be placed on the species *Lactuca sativa* and *Spinacia oleracea*, used in previous crop production trials and/or parabolic flights.

Impact on MELiSSA Project:
Improvements of canopy surface quantification and subsequent improvement of control laws applicable to automated crop production in space mission

Potential MELiSSA Partners:
CiRiS: Centre for Interdisciplinary Research in Space (NO), University Federico II of Naples (I), University Clermont-Auvergne (F)
Possible Wroclaw University of Science and Technology (P)

References:

Hezard P., Sasidharan L. S., Poughon L., Fontaine J.-P. and Dussap C.-G. 2012. Experimental setup, modeling design and preliminary results for higher plant growth control in

bioregenerative life support systems, *Proceedings 42nd International Conference on Environmental Systems*, ICES 2012 (San Diego, California, USA, July 15-19)

Hezard P., Sasidharan L. S., Creuly C., Dussap C.-G. 2010. Higher plant modelling for bioregenerative life support applications: general structure of modelling. *Proceedings of the 40th International Conference on Environmental Systems (ICES)*. Barcelone, Spain, 11-15 July.

Poulet L., 2018. Developing physical models to understand the growth of plants in reduced gravity environments for applications in life-support systems, https://theses.hal.science/tel-01983345

Poulet, L.; Poughon, L.; Dussap, C.-G. 2022. Importance of a modelling approach for bioregenerative life support systems. *Proceedings of the 73rd International Astronautical Congress, IAC 2022*. Paris, France, 18-22 September.

ALISSE criteria presentation. Version 1, issue 0, 18th November 2009.

ESA Technical Note 137.4 Appendix. Applicable document for using Oscar Methodology System Engineering applied to the MELiSSA data management system: requirements

Candidate's background requirements:
Candidates preferably possess a degree in chemical engineering, biotechnology or bioengineering. They must be familiar with imaging techniques, images analysis and processing. It would be an advantage, if the candidates also have some laboratory experience.