EnginSoft and the European Space Agency investigate hydroponic plant growth for future space missions

The ACSA Project

EnginSoft has been collaborating with the European Space Agency (ESA) for the past ten years, working actively in the MELiSSA program. At present, this project's main efforts concern the life support system sector and the idea of creating an artificially closed ecosystem that generates food and oxygen for space crews on long-term missions. The current MELiSSA Pilot Plant (MPP), built to monitor the progress towards the goal, is located at the Universitat Autònoma de Barcelona. A 5-meter plant growth chamber, able to cultivate 100 plants and investigate their growth process, has been installed

At the MPP, the Air and Canopy Subcompartment Analysis (ACSA) project was implemented to study the impact of airflow on hydroponically grown lettuce crops.

Objectives

The main objectives of this project were:

- To improve the conditions in the growth chamber by re-engineering the air management system;
- To investigate the impact of airflow on plant growth.

Computational Fluid Dynamics (CFD) Model of the system before the project

The 5-meter plant growth chamber was replicated using a CFD model of the complete system. This model provided deep insight into the air distribution and the local environmental conditions around the aerial part of the plants.

The model highlighted a strongly unbalanced air distribution: the airflow was mainly located in the central region of the chamber, reaching peak velocities of over 1 m/s around the crops. These velocities, if sustained for prolonged durations, place harmful mechanical stress on the crops. Indeed, tests performed on the lettuce before the ACSA project found uneven plant growth, with

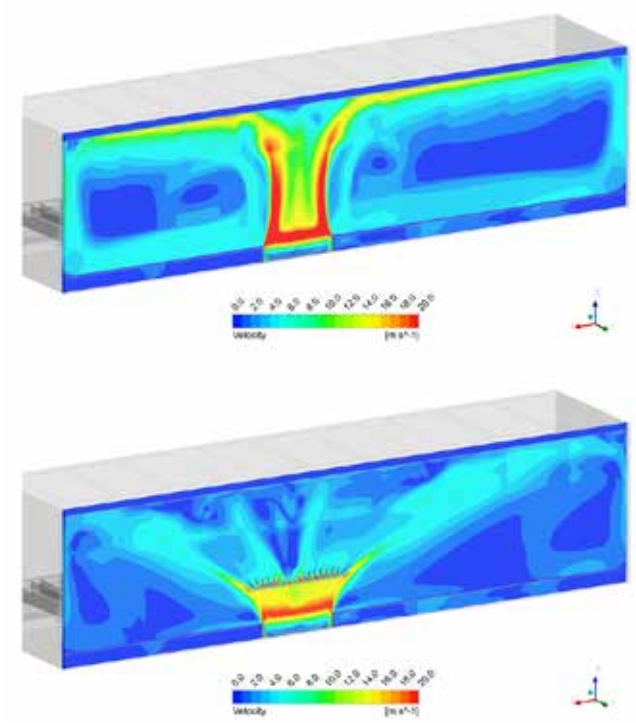

Fig. 1 – Air velocity contours before the project (top) and after the project (bottom).

a strongly reduced plant biomass in the crops cultivated in the central region of the chamber.

CFD Model of the system after the project

A detailed 3D CFD study supported the complete redesign of the air management in the chamber. Several components were added, and others were upgraded to create uniform air distribution around the growing plants. In particular, the CFD analyses enabled the design of a deflector which was assembled to impair the primary air flux by rearranging the perforated plates that are installed under the plant trays. In addition, some regulating components such as dampers were included to make the air distribution adjustable. These important modifications will enable the operators to perform new tests by changing the air velocity values to investigate their influence on various crops.

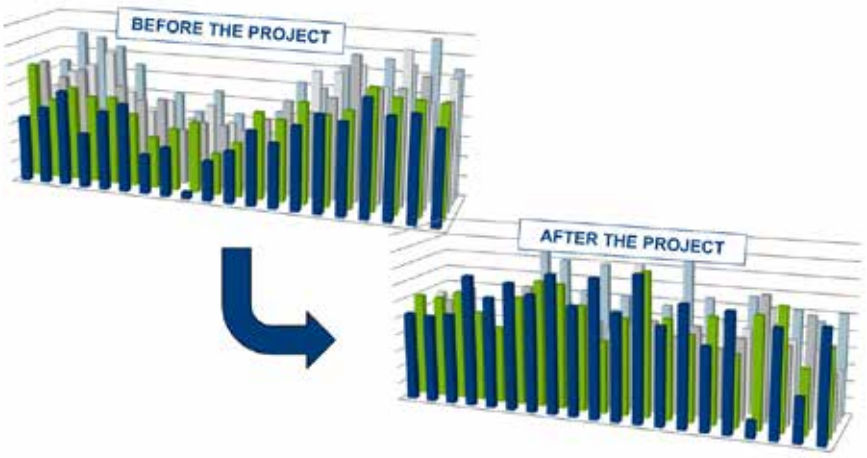

Fig. 2 – 3D histogram of the plant biomass of the 100 plants cultivated, before and after the project.

Figure 1 shows the air velocity field in the CFD models: the impact of the improvement -- making the airflow enter the chamber in a uniform manner -- is evident.

The modified air distribution means that the air velocity in the region of the growing plants can be maintained between 0.3 and 0.4 m/s. As a result, the crop tests measured an even growth among the lettuce plants.

At the end of the test, the operator weighed the dry biomass of each lettuce plant in order to compare them to past tests. The results are showed in Figure 2, which reports the histograms of the plant biomass before and after the ACSA project. The evenness of the harvested crops is demonstrated by the reduced standard deviation of the biomass test results.

Cameras were also installed in the chamber during the ACSA project to collect visual information on the plant growth at different stages in their development (Figure 3).

Conclusions

In summary, the CFD analyses performed during the project allowed the researchers to:

- Gain deeper knowledge about the conditions in which the plants are grown;
- Redesign the air management system in the growth chamber, to make the air distribution more uniform;
- Improve the resulting evenness of the harvest;
- Gain an insight into the plants' sensitivity to different airflow conditions.

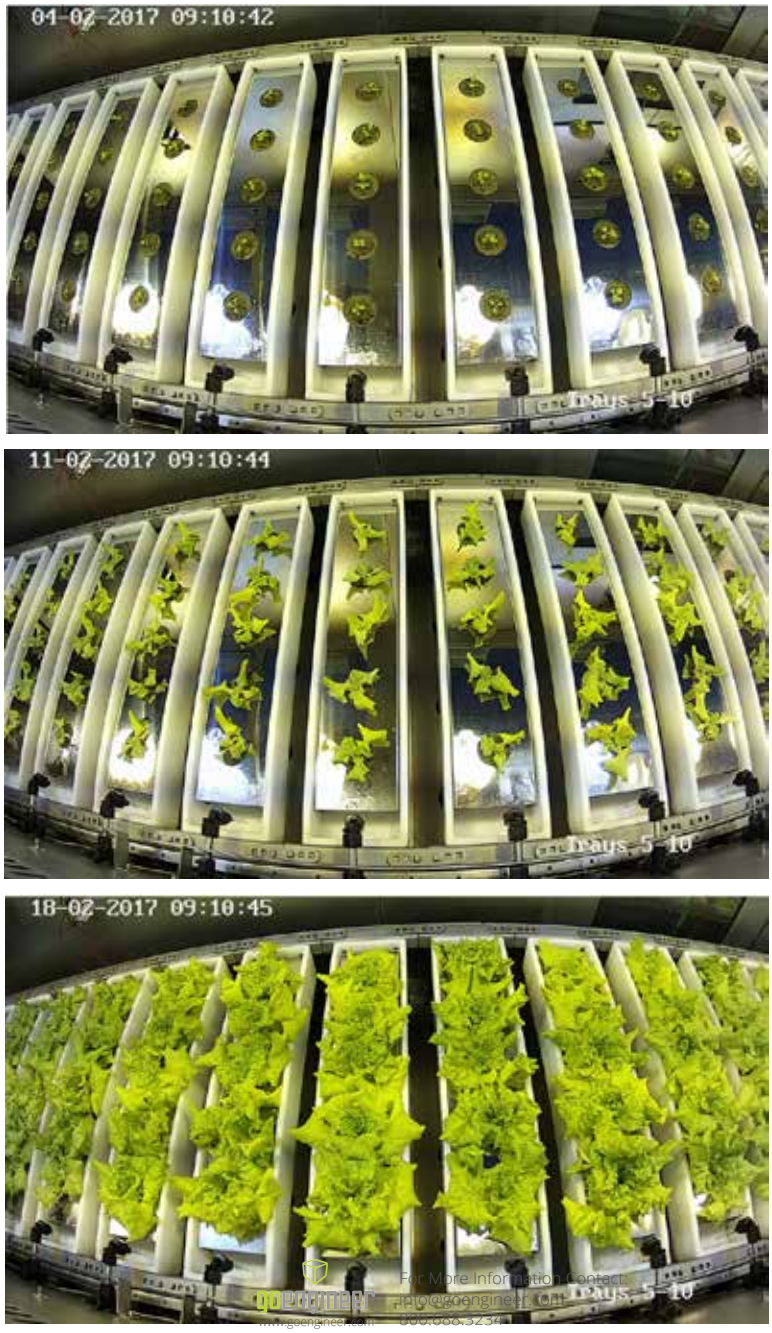

Fig. 3 – Evolution of plant growth process, as captured by one of the cameras installed.