Key partner in Design Process Innovation

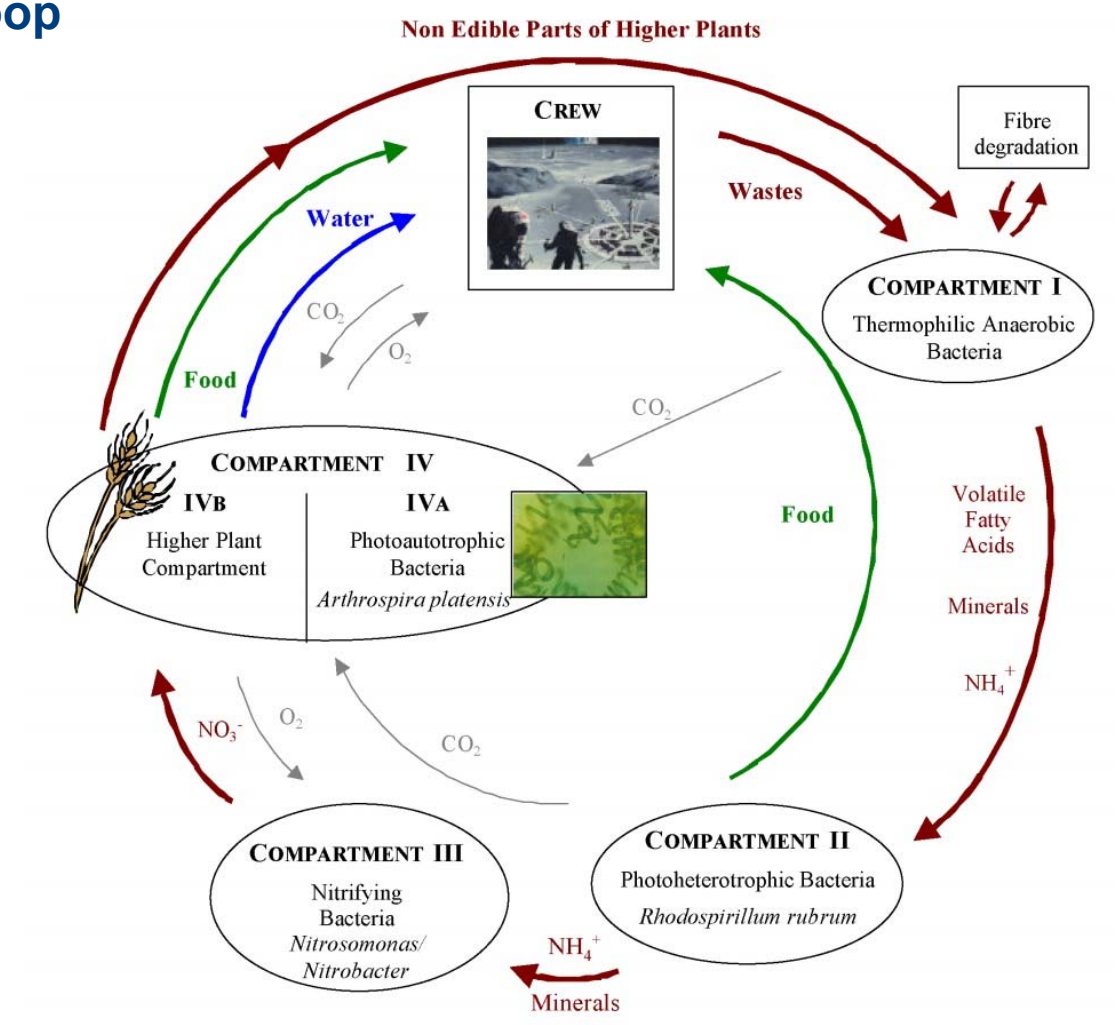
AtSSE
Atmospheric SubSystem Engineering

Agenda

- AtSSE Project - ATmospheric SubSystem Engineering
  - Background & Motivation
  - Modularity concept
  - Architecture Design
  - Developed system
- Future steps

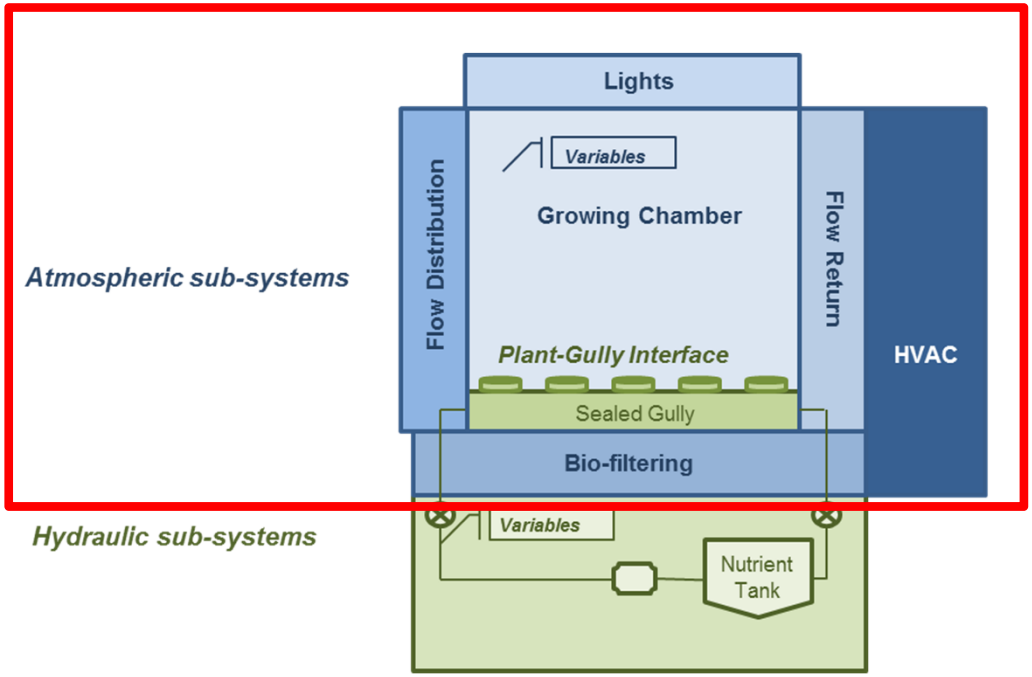
Motivation

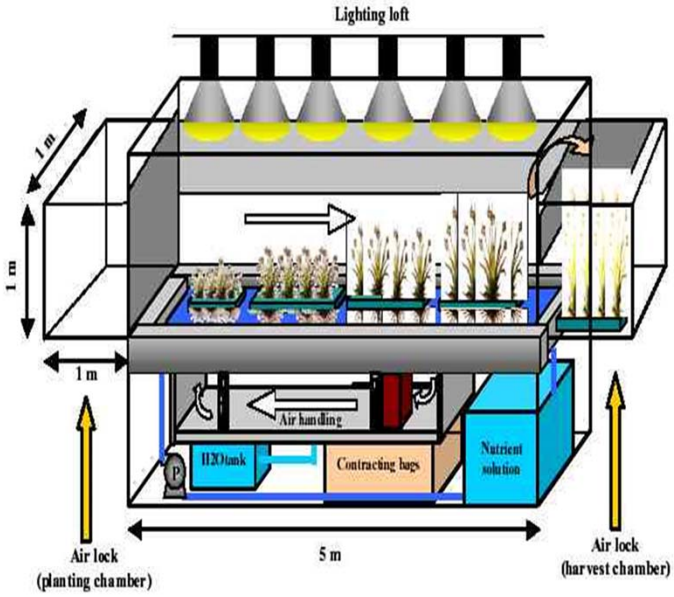
MELiSSA Loop



Motivation

HPC – Higher Plant Compartment IV b





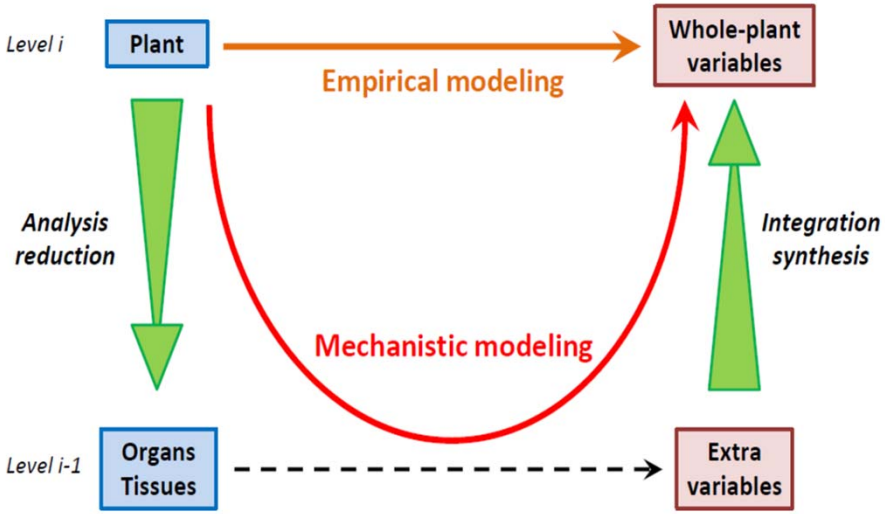
Motivation

Background

- **Need to characterize the plant mechanistic model**
- The Measurements have to be reliable, therefore we need
  - A controlled environment in terms of mass balance
  - With adequate sensor
  - With controlled conditions
- Their implementation in closed subsystems, would allow to:
  - *i. Have modular units to interface with other units: lighting, HVAC, bio-chem filtering;*
  - *ii. Allow upgrade and/or maintenance (i.e., new LED lights with assigned spectrum)*
  - *iii. Ease management of the subsystem such as control of mass and energy balances*

Characterization

What to Measure?



Parameter	Description
I	Intercepted light flux
I_0	Incident light flux
k	Light extinction coefficient
LAI	Leaf area index
U_{CO2}	CO_2 uptake rate
Dc	Diffusion coefficient
Ca	CO_2 concentration in the outside air
Ci	CO_2 concentration in the leaf
δ	Mass boundary layer thickness
LA	Leaf area
R_{H2O}	H_2O transpiration rate
G	Leaf conductance
T	Temperature for water vapour transfer
$P^0(T)$	Saturating vapour pressure at T
R	Gas constant
T	Temperature for water vapour transfer T
RH	Relative humidity
U_{H2O}	H_2O uptake rate
N_{vessel}	Sap vessel number
ρ	Water density
Ψ_s	Water potential gradient in the nutrient solution
Ψ_i	Water potential gradient in the roots
R_{vessel}	Radius of the sap vessel
M	Water molar mass
Mxxx	Mineral content (Zrinc, magnesium, iron, potassium, …)
L_{stem}	Stem length
μ	Xylem sap dynamic viscosity
Dens	Planting density
QY	Quantum yield
R_{CO2}	Respiration rate
Resp	Respiration/Photosynthesis ratio
Tr	Transpired/Absorbed water ratio
DM	Dry Matter content per water content in biomass
BC_{mol}	Biomass C-molar mass
$J_{Biomass}$	Biomass production rate
Biomass	Biomass accumulation

Background - HySSE

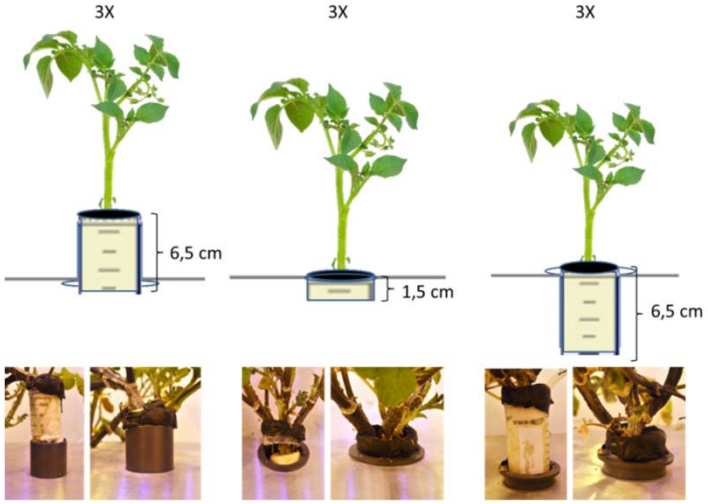
HySSE - HYdroponic SubSystem Engineering

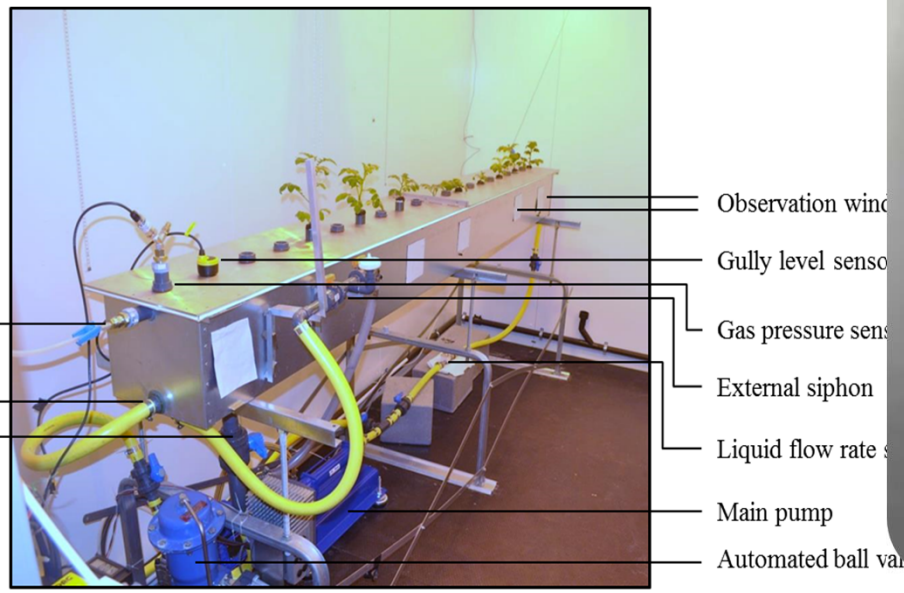
The objective of the project was to study and characterize the hydraulic system of the PCU and its processes related to crop growth

Goals:

- Nutrient solution supply strategy: Deep water culture (**DWC**) with a **variable nutrient solution level**
- Implementation of a sealed plant-gully interface, making the computation of mass balances feasible for the plant roots zone.
- Test some features of the hydroponic system and validate the design

Background - HySSE

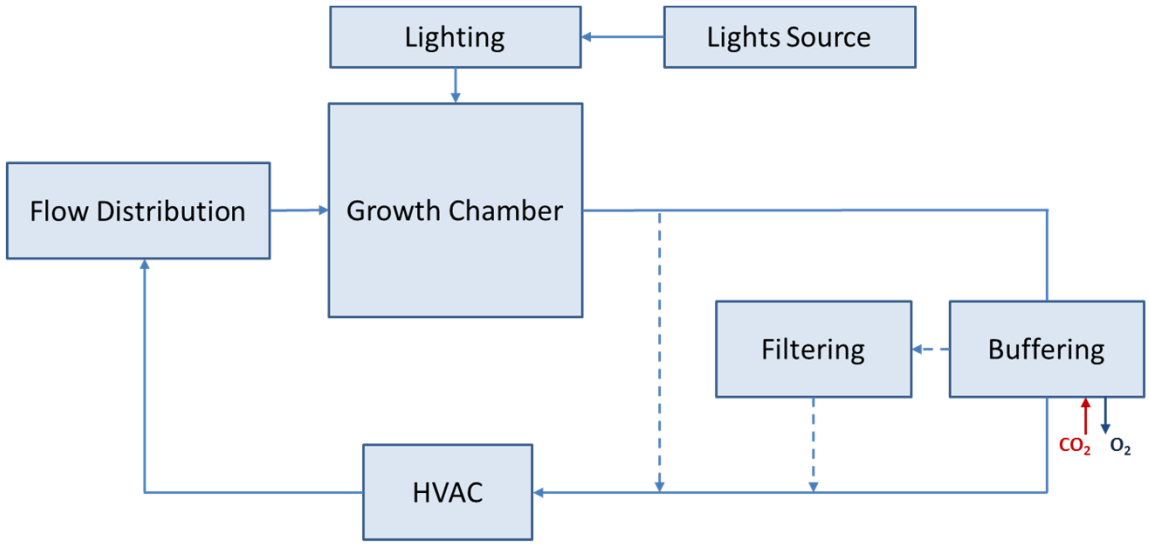




Atmospheric Sub-System

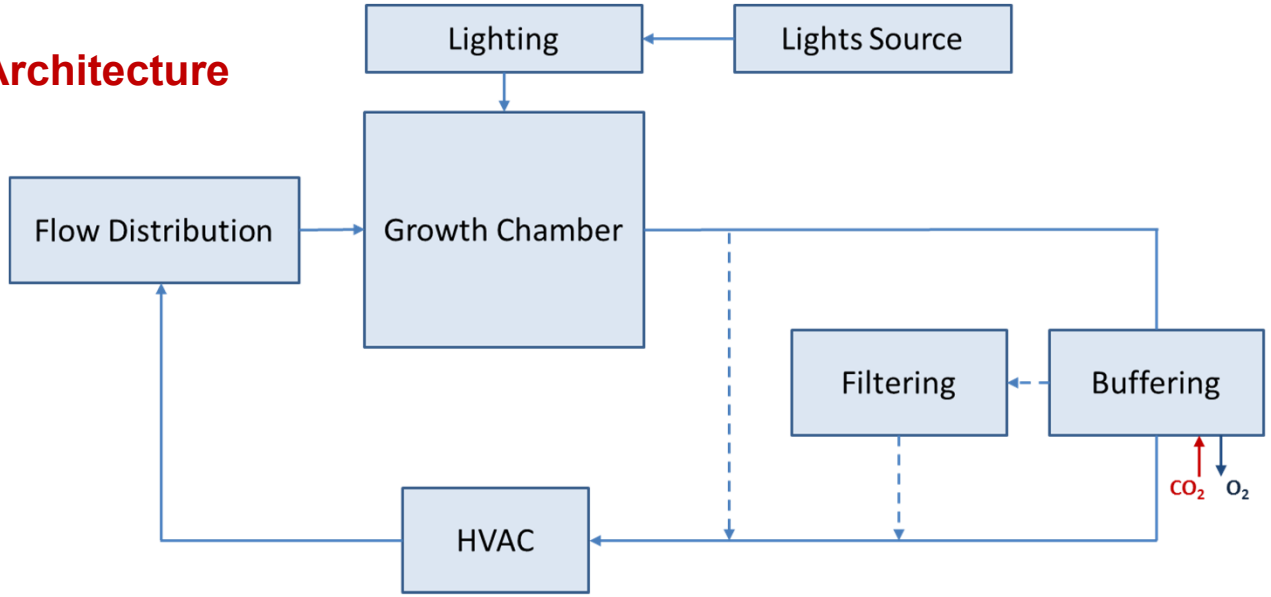
Concept

- The atmospheric system has the goal to accommodate the plant shoots during the culture till the harvesting, in a closed, controlled and automated environment
- The atmospheric system processes can be performed by means of seven units:
  - Plant growth unit
  - HVAC
  - Air distribution system
  - Lighting system
  - Filtering unit
  - Buffering unit
  - Monitor and control unit



AtSSE Concept - Modularity

Modular Architecture



1. **Module level:** the system is conceived as a module which can be potentially coupled with other identical modules
2. **Unit level:** the basic seven units are assembled with a rack-like approach, where each unit can be easily isolated or retrofitted for upgrades or, redesign
3. **Component level:** each component is easily reachable for maintenance or replacement

AtSSE Concept

Concept benefits

❖ Multiple system:

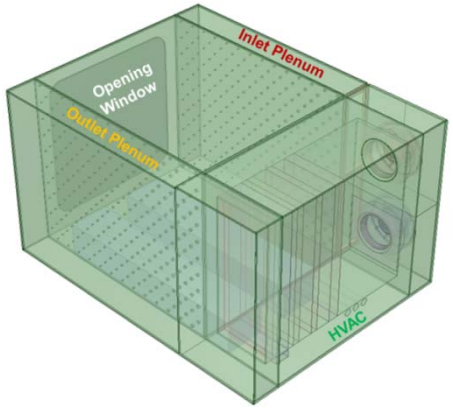
1. Multiple locations (geo-return constrain)
2. **Multi-crop culture** can be managed at the same time in different modules
3. Versatility for **research tests**
4. Tests **repeatability**

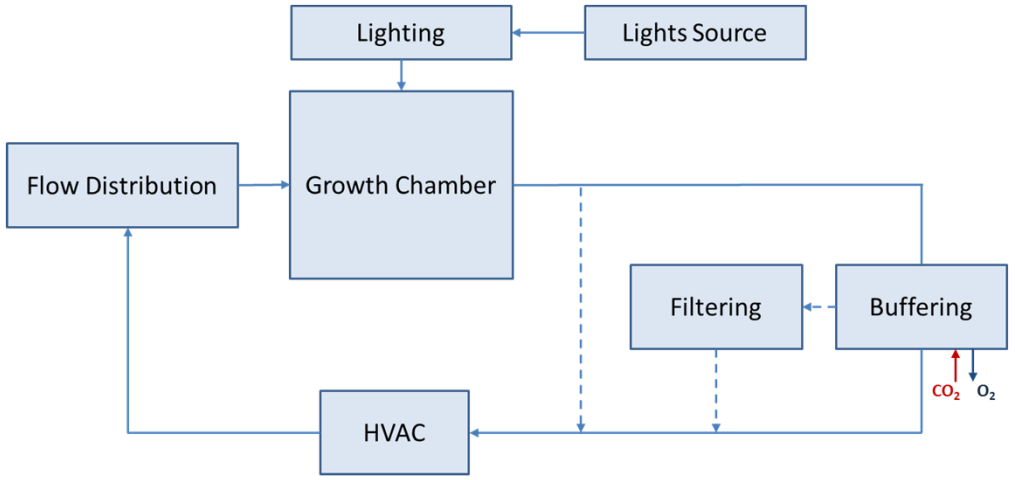
❖ Limited size of the system

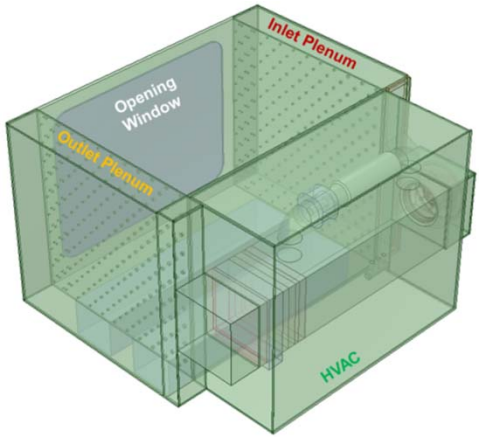
1. Reduced gradients in the chamber
2. Shorter dynamics in recovering after a perturbation and allow to obtain and to control **homogeneous conditions** easily.
3. Transportable/easy to be rebuilt
4. The basic units can be easily **retrofitted/upgraded**. Similarly, if plants contamination and/or disease occurs, the yield loss are limited to only one unit (0.5 m^2 of growth area).

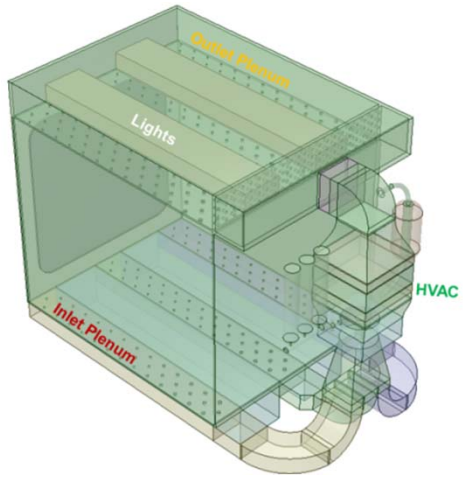
AtSSE - Architecture Design & Tradeoff

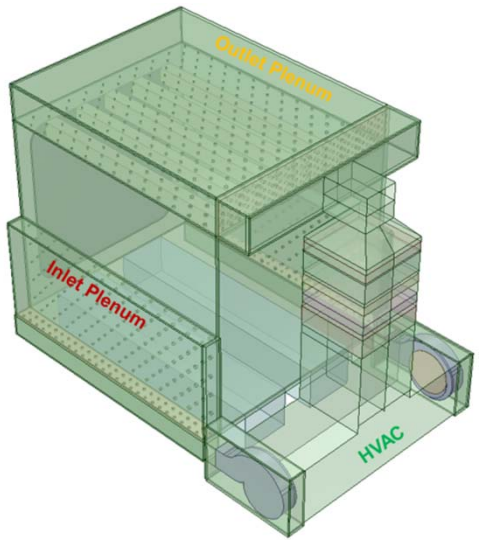
Modular Architecture





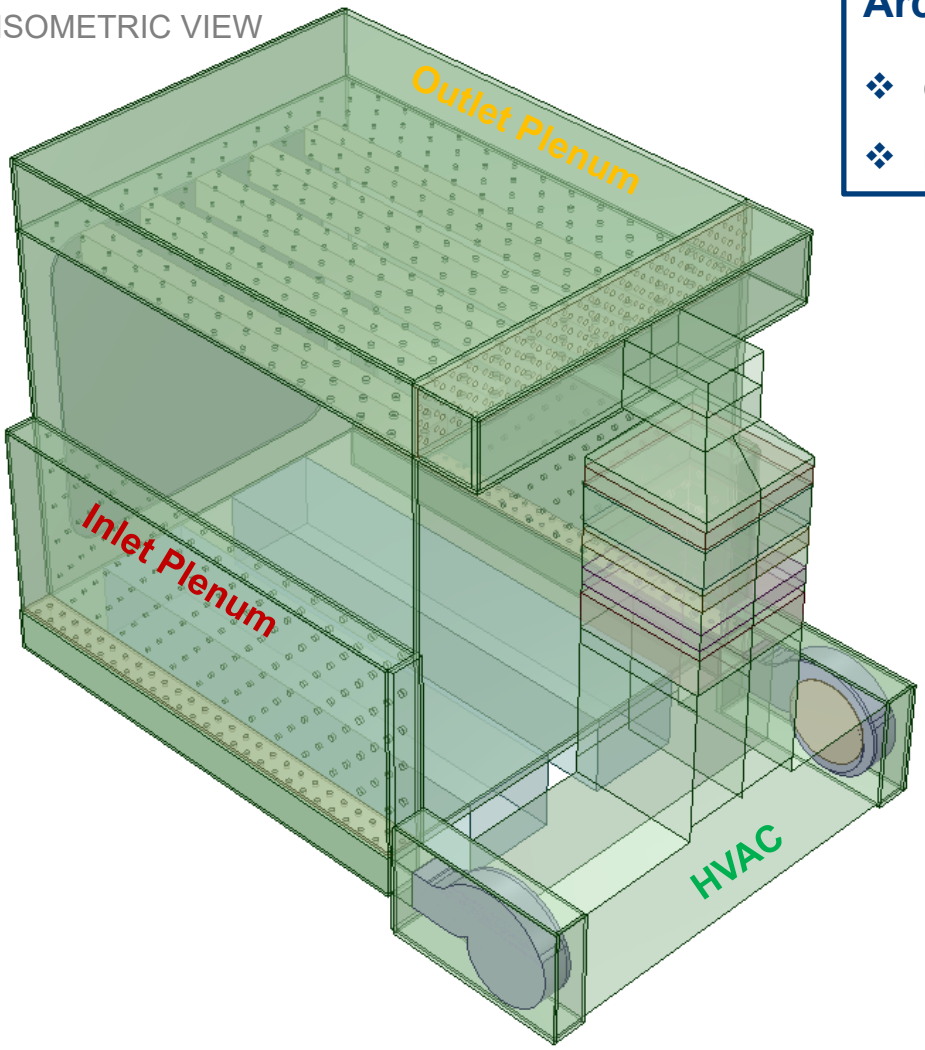






AtSSE - Architecture Design & Tradeoff

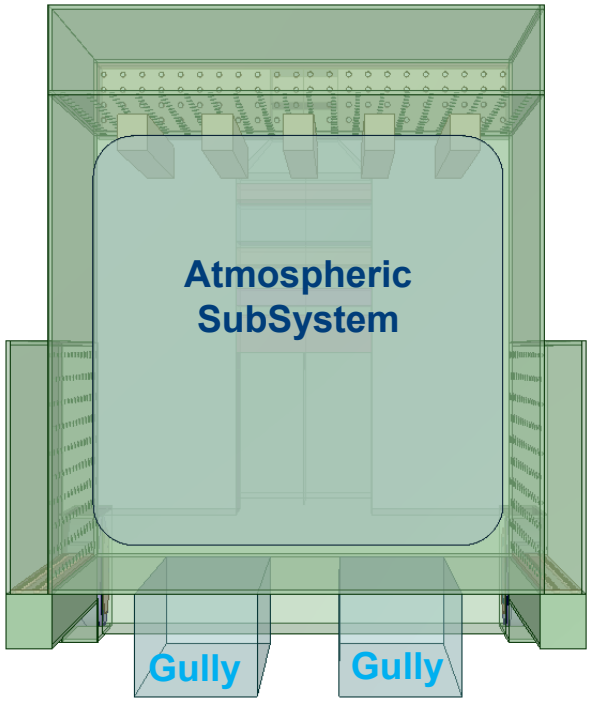
ISOMETRIC VIEW



Architecture 4:

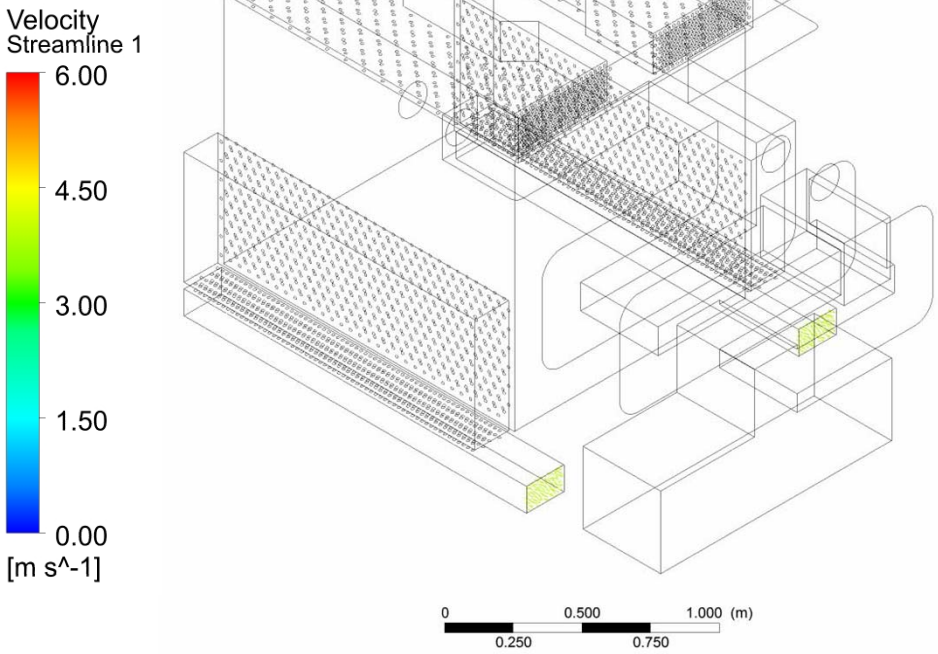
- ensure the same air flow conditions on each plant
- minimize thermal stratification

FRONT VIEW

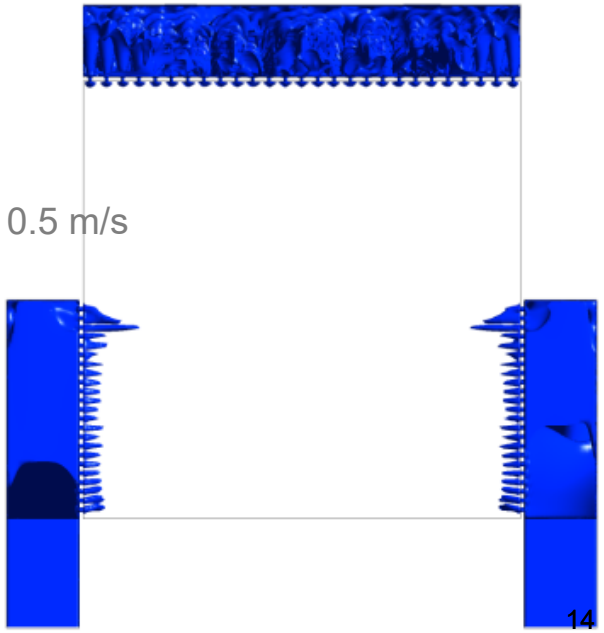


AtSSE - Modelling Motivations

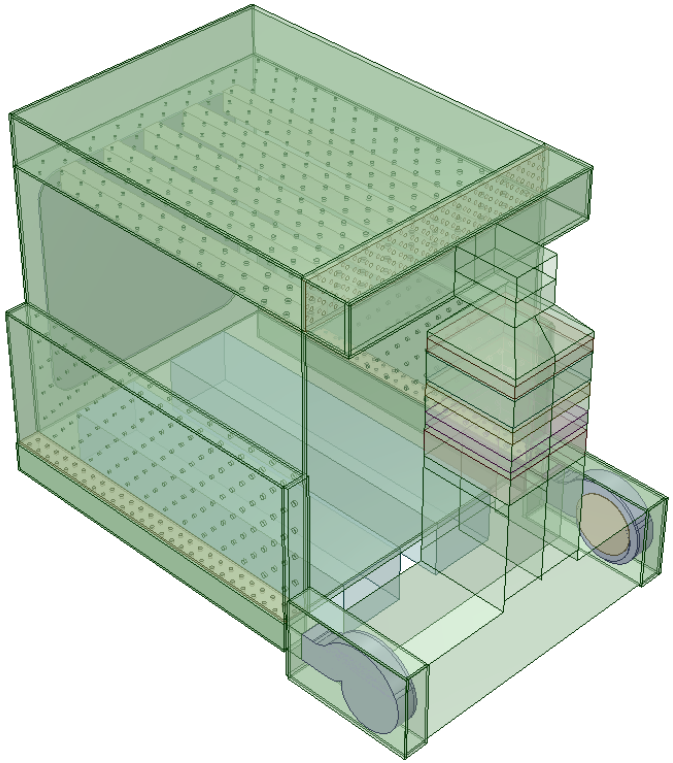
CFD

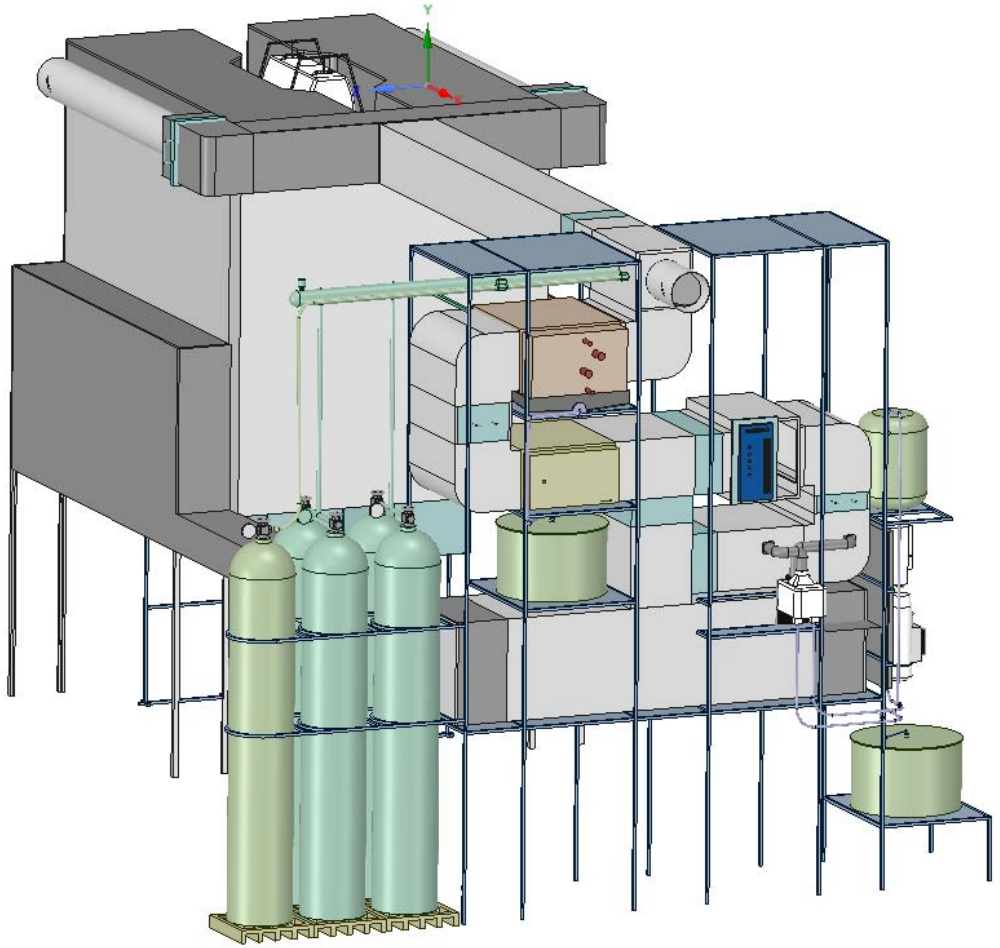


Isosurface:
Air velocity = 0.5 m/s

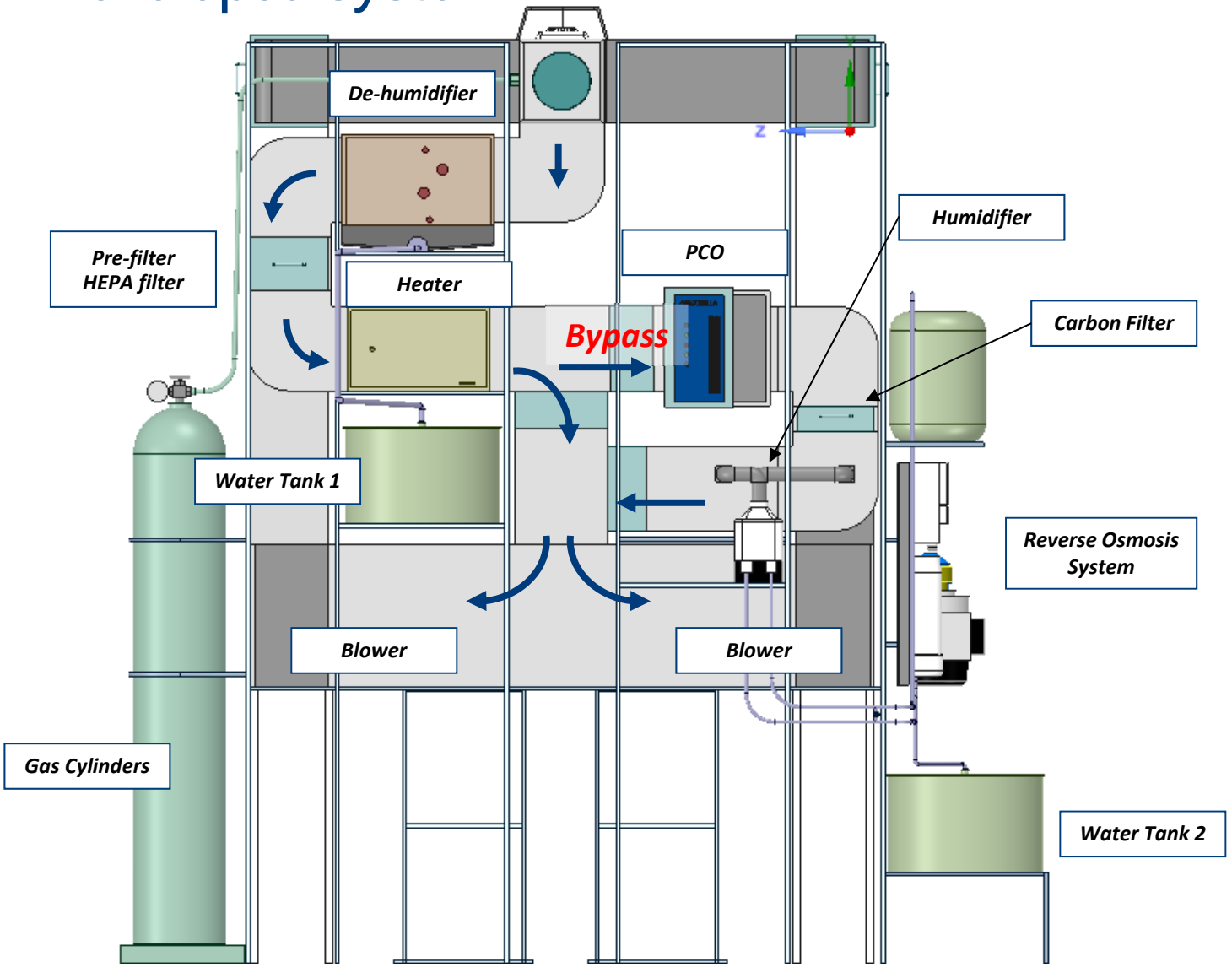


AtSSE – Detail Design





AtSSE – Developed system



AtSSE – P&ID

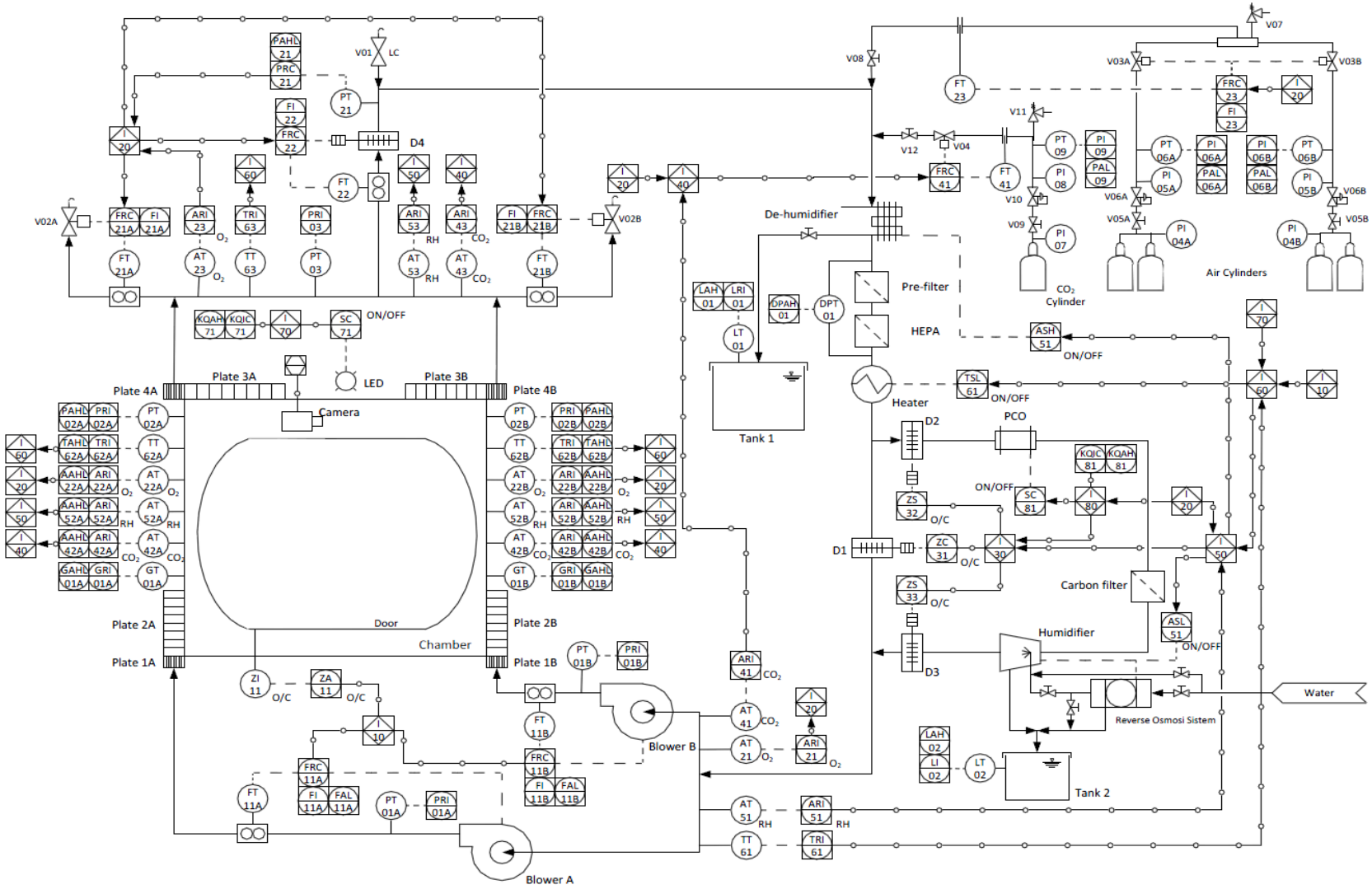


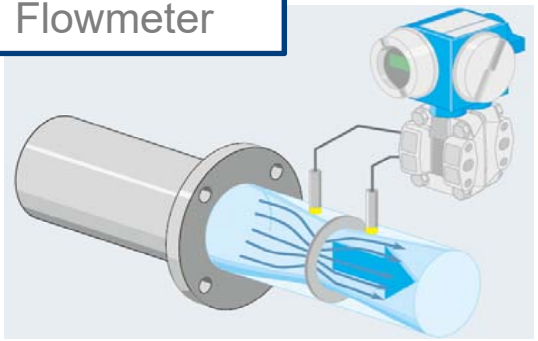
Plate 4A
Plate 3A
Plate 3B
Plate 4B
Plate 2A
Plate 2B
Plate 1A
Plate 1B
Camera
LED
ON/OFF
Door
Chamber
Blower A
Blower B
De-humidifier
Pre-filter
HEPA
Heater
Tank 1
Tank 2
PCO
Carbon filter
Humidifier
Reverse Osmosi Sistem
Water
Air Cylinders
CO2 Cylinder
D1
D2
D3
D4
O/C

AtSSE – Design - Sensors

Camera

Lux Meter

Flowmeter



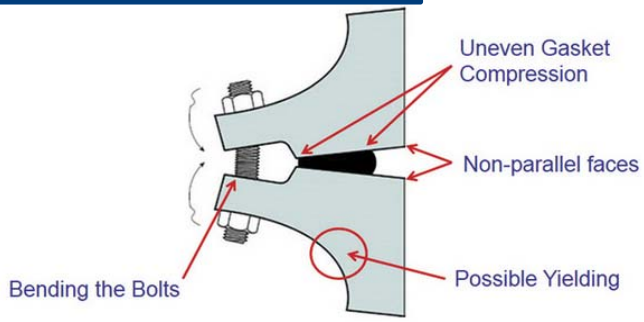
Pressure, Differential Pressure

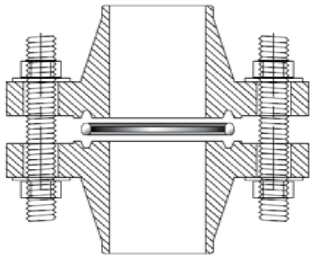
Thermo-hygrometer

Gas Analyzer CO_2 and O_2 concentration

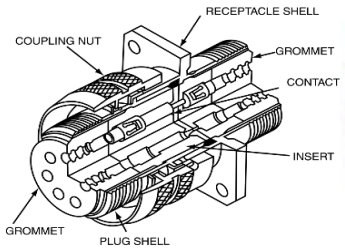
AtSSE – Design - Sealing

Sealing - Gaskets





O –Ring Joint



Bulkhead Connector

Manufacturing

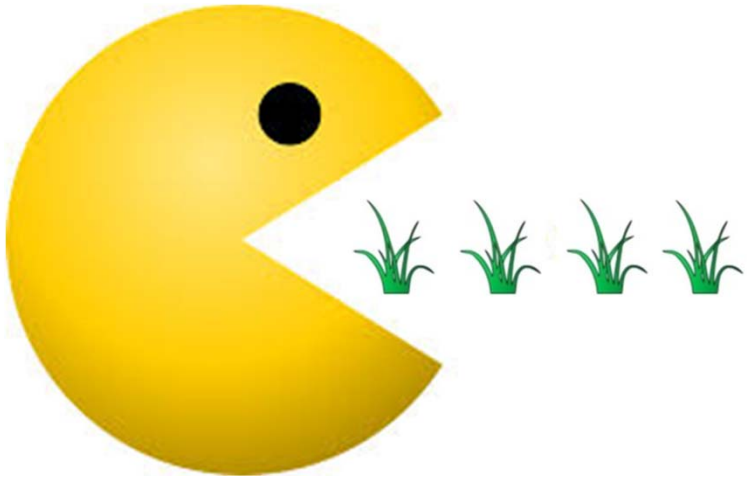
Gasketed joints

Inflatable seals

Future steps

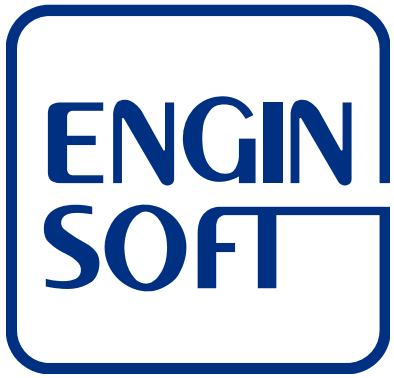
PaCMan Project

PIAnt Characterization unit for closed life support system engineering, MANufacturing & testing



Objective:

The objective of the project is to design, **build & assemble** and test a prototype of a PCU (**Plant Characterization Unit**) which is conceived as a generic crop research facility and will be used extensively for scientific experiments on crop growth tests.



Key partner in Design Process Innovation

Thank you

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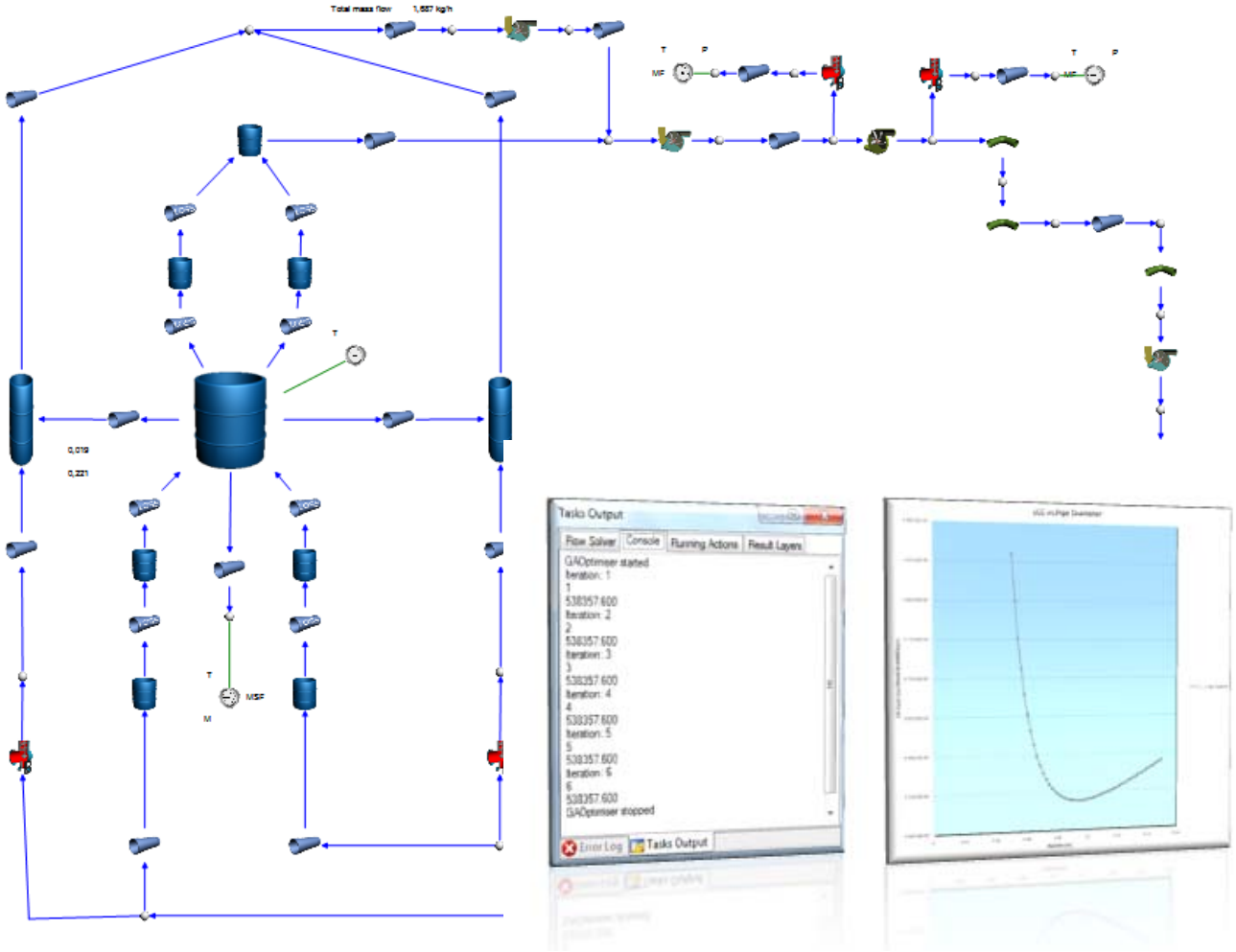
System Modeling

In order to study how systems where fluid is the driving factor will behave in the real world.

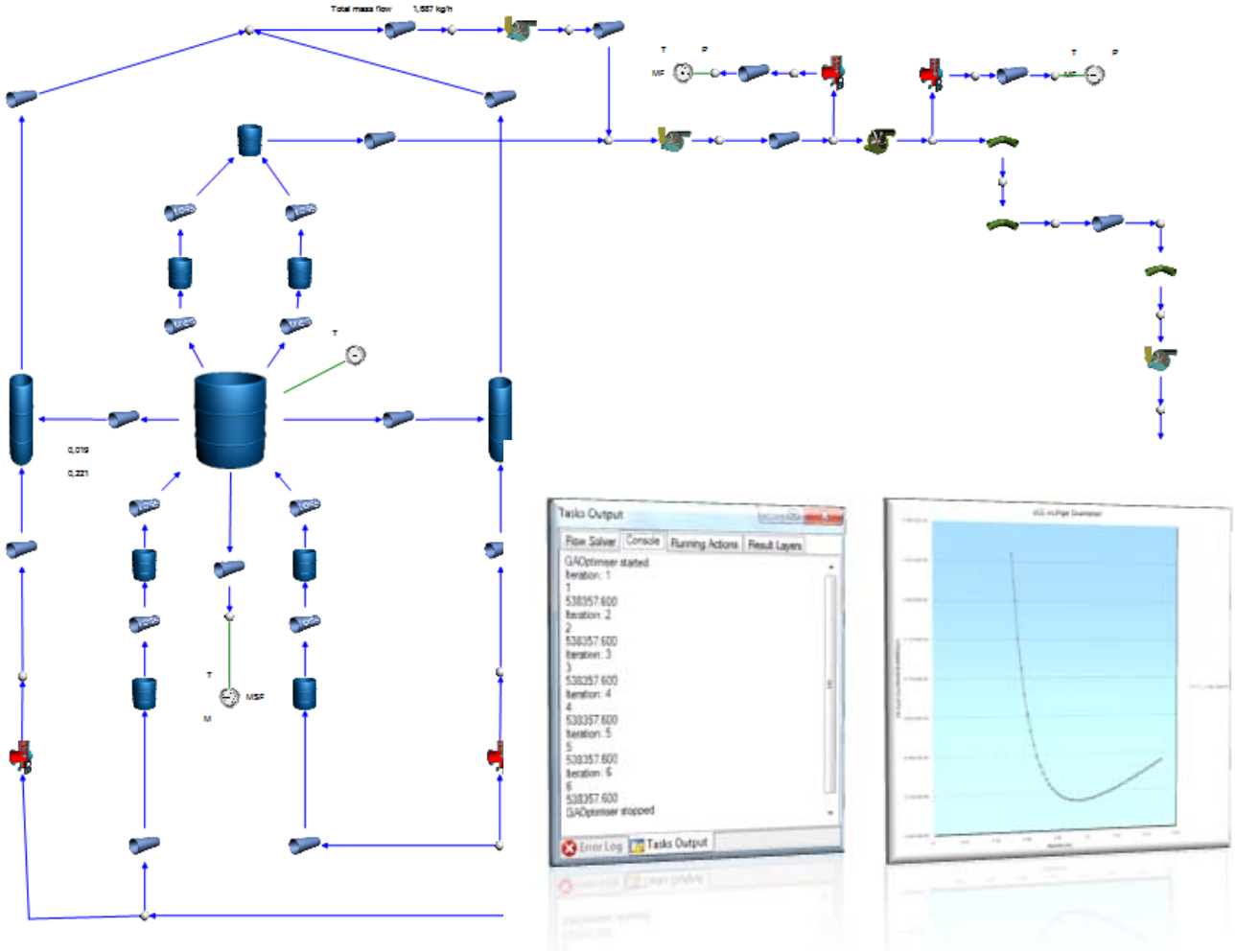


- Network of components characterized by real specific properties.
- Allow to accurately design, analyze or troubleshoot any flow system.

Atmospheric system

System Modeling

In order to study how systems where fluid is the driving factor will behave in the real world.



Objective:

- System validation;
- Evaluation of the leak rate impact;
- Simulation of the process control system logic.

Atmospheric system