TIME SCALE

The Horizon 2020 Programme

1st Joint AgroSpace-MELiSSA Workshop

System design and hardware development of the TIME SCALE Crop Cultivation System Breadboard

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University of Stuttgart Germany

NTNU Social Research

WAGENINGEN UNIVERSITY WAGENINGEN UR

UNIVERSITEIT GENT

CleanGrow

cmr Prototech

DTM TECHNOLOGIES

Interscience

Motivation (Space)

- Regenerative life support systems
  - Need for fundamental knowledge on plant physiology and biological processes under fractional gravity conditions
- Rotor-based plant cultivation facilities have for more than 10 years generated valuable life science results on ISS
  - European Modular Cultivation System (EMCS), installed 2006
  - Biolab, installed 2008
- Improvement potentials of current cultivation facilities

BACKGROUND and OVERVIEW

Concepts and design

Crop Cultivation System
- Plant Cultivation Chamber (PCC)
- Algae Cultivation Chamber (ACC)

Water and Nutrient Management (WNM) system

Plant Health Monitoring (PHM) system

Breadboard

Functionality testing

Life testing

Emphasis on PCC and WNM

Generic technology

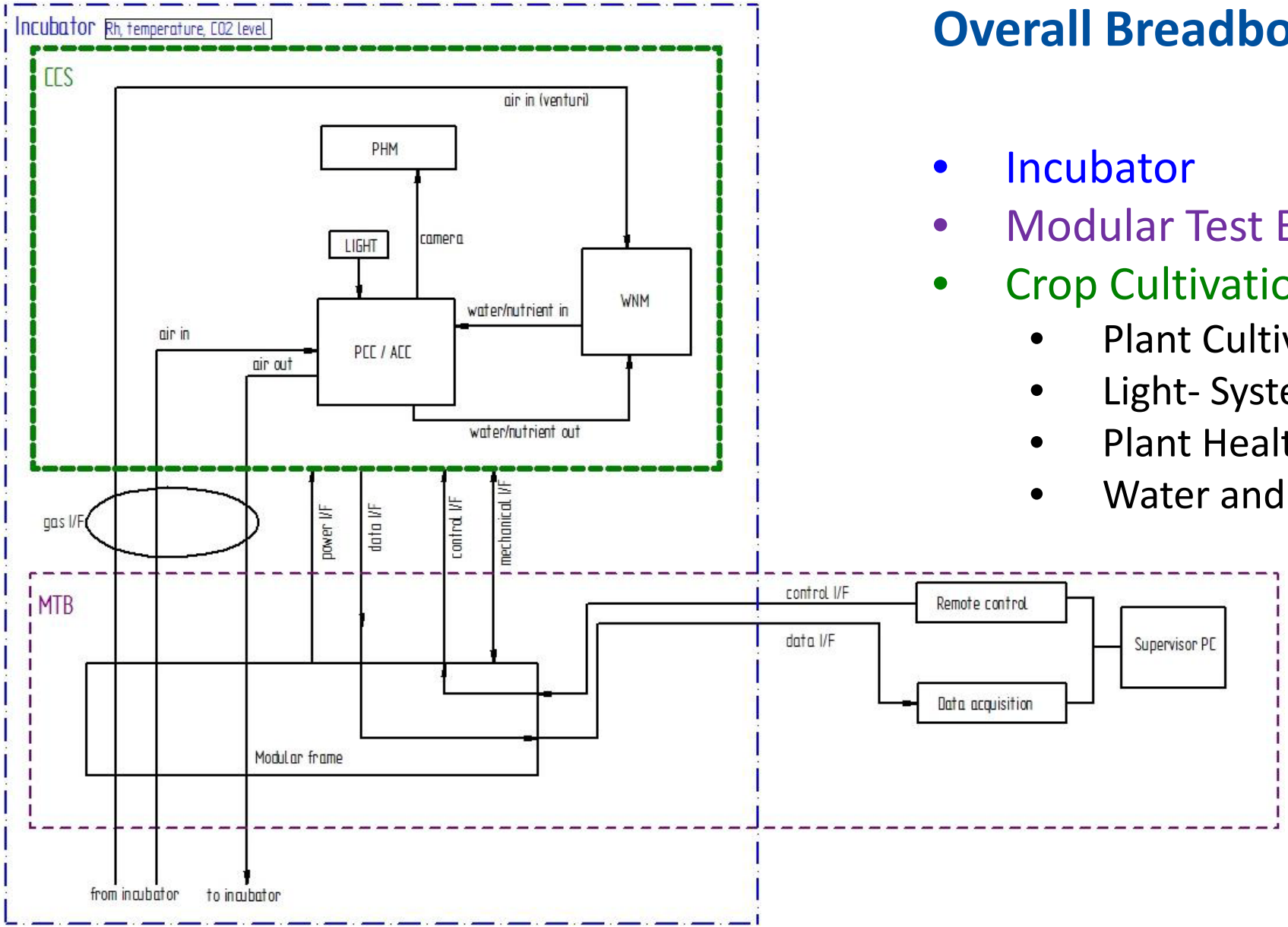
VOC analysis by SIFT-MS and CompactGC

Imaging techniques

Automated nutrient analyzer

Main Breadboard Objectives

- On-ground demonstration of a substrate-free recirculating hydroponic system to support plant cultivation experiments including.
  - Improved substrate-free Plant Cultivation Chamber
  - Closed Water and Nutrient Management System
  - Integrated specific Ion Sensing Unit
- Demonstration of operational capability onboard the ISS with focus on:
  - Plant Cultivation Chamber
  - Water and Nutrient Management



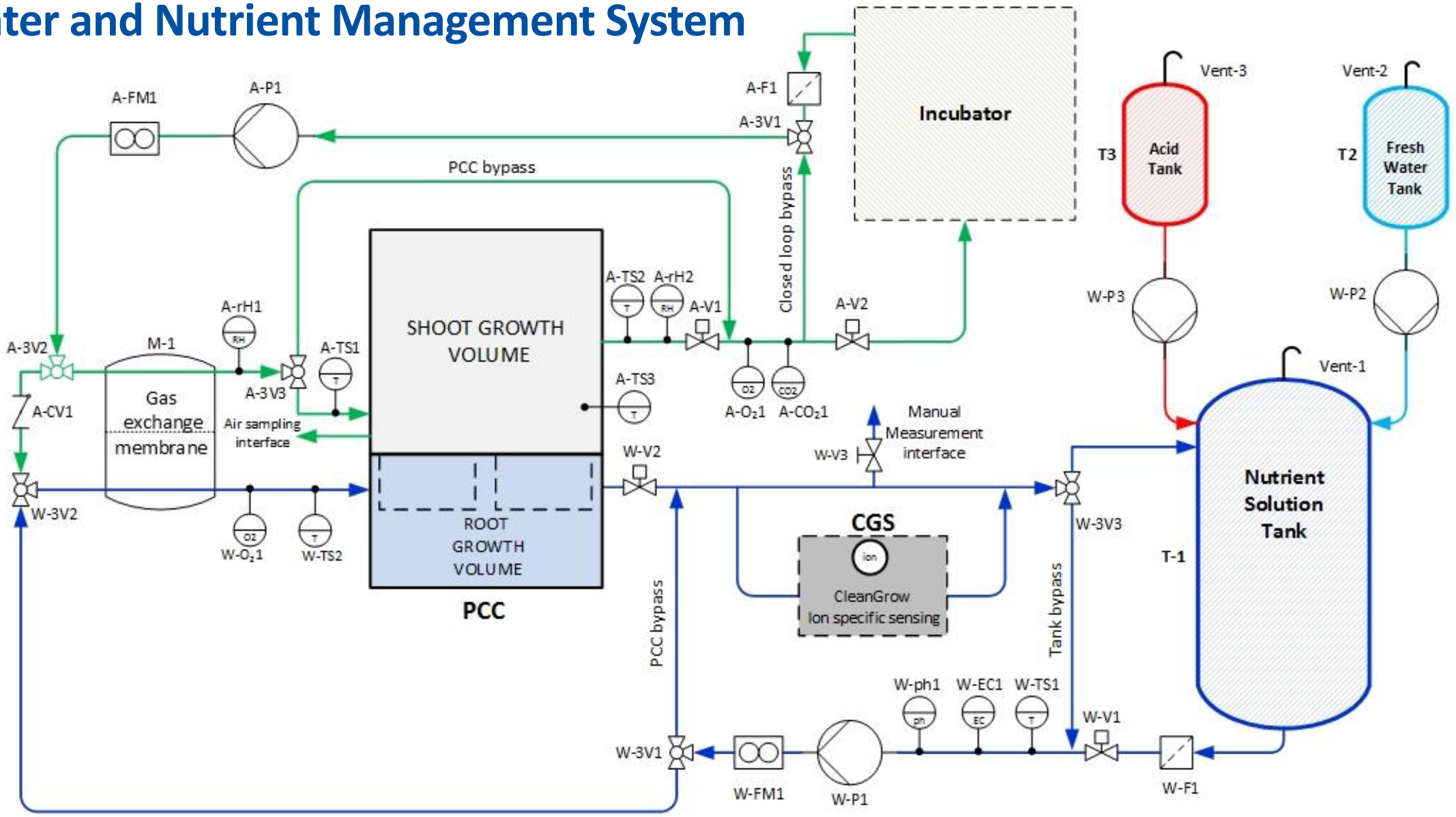
Overall Breadboard Structure

- Incubator
- Modular Test Bed (MTB)
- Crop Cultivation System (CCS)
  - Plant Cultivation Chamber (PCC)
  - Light- System (LS)
  - Plant Health Monitoring (PHM)
  - Water and Nutrient Management (WNM)

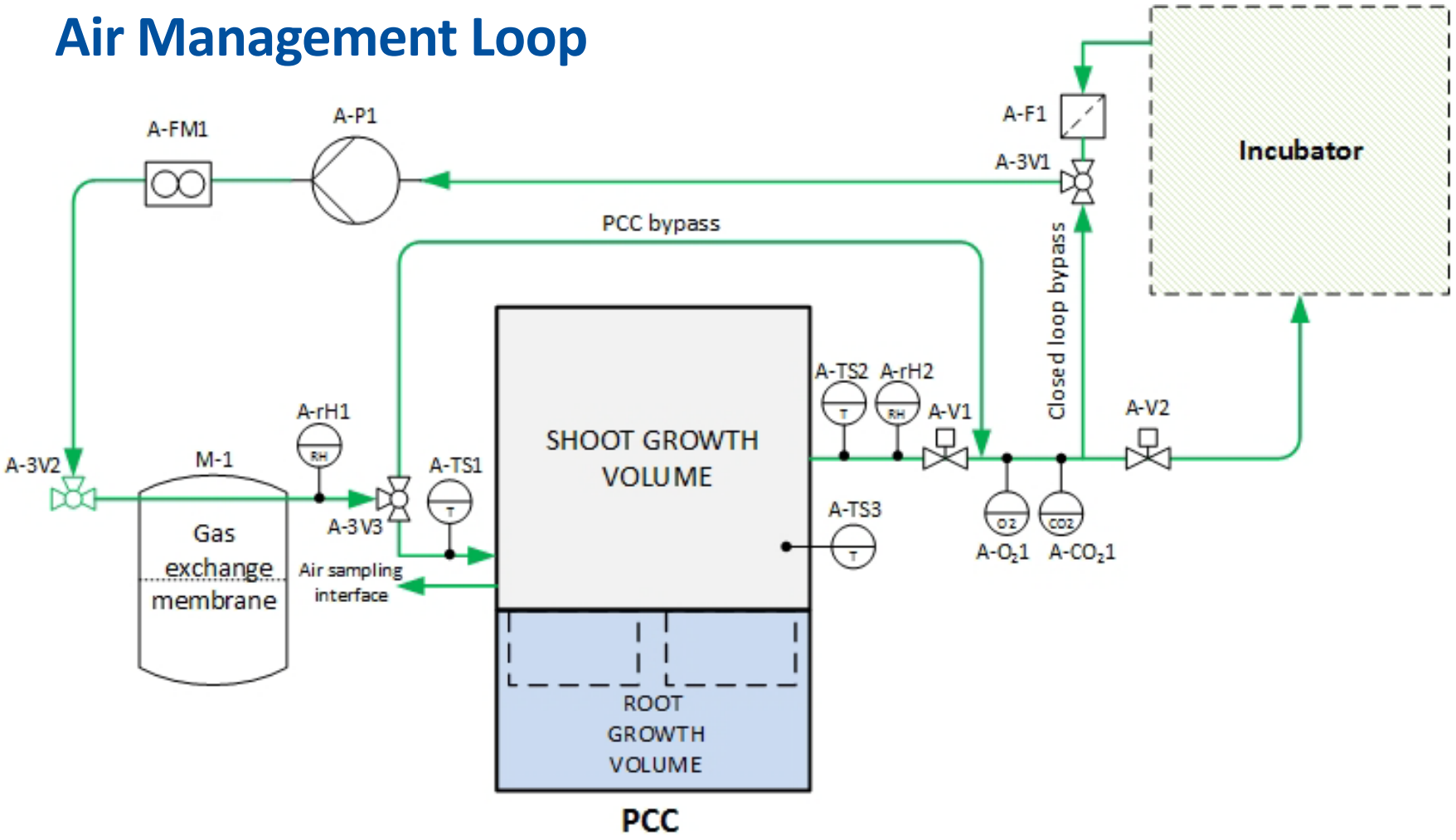
TIMESCALE

The Crop Cultivation System

Water and Nutrient Management System



Air Management Loop



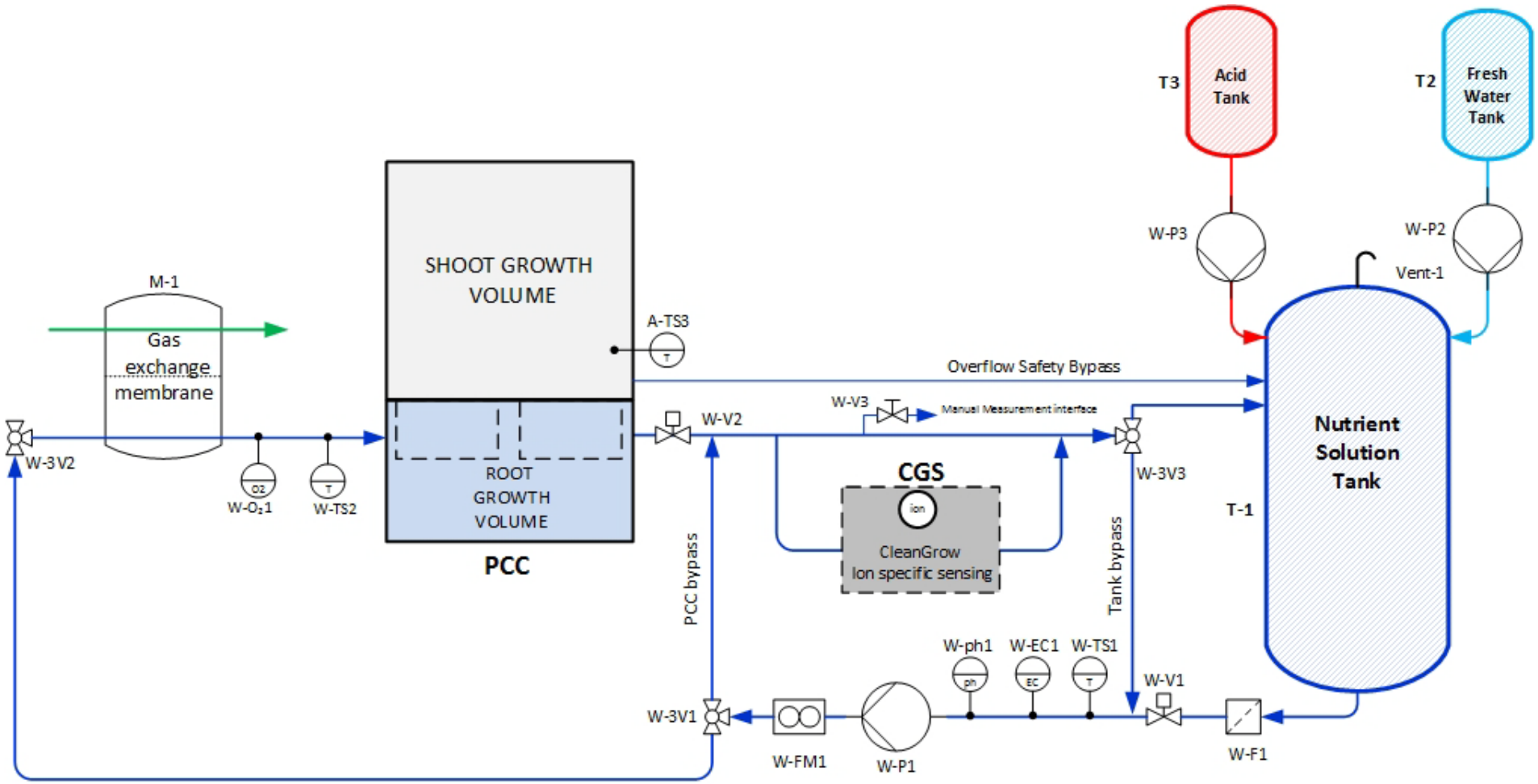
CONTROL

- Air flow (pump)
- rH (Incubator)
- CO_2 (Incubator)
- Modes (Valves)

MONITORING

- Air flow
- Temperatures
- O_2 concentration
- CO_2 concentration
- rH - value

Nutrient Management Loop



CONTROL

- Water flow (pump)
- pH (dosing pump)
- EC (dosing pump)
- Modes (Valves)

MONITORING

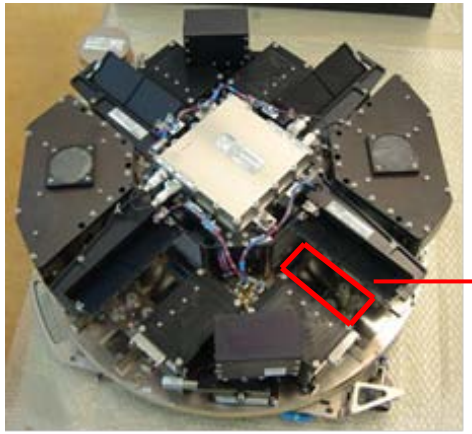
- Water flow rate
- Temperatures
- O_2 saturation
- pH - value
- EC - value
- Ion concentrations

The Specific Ion Sensing Unit

Features

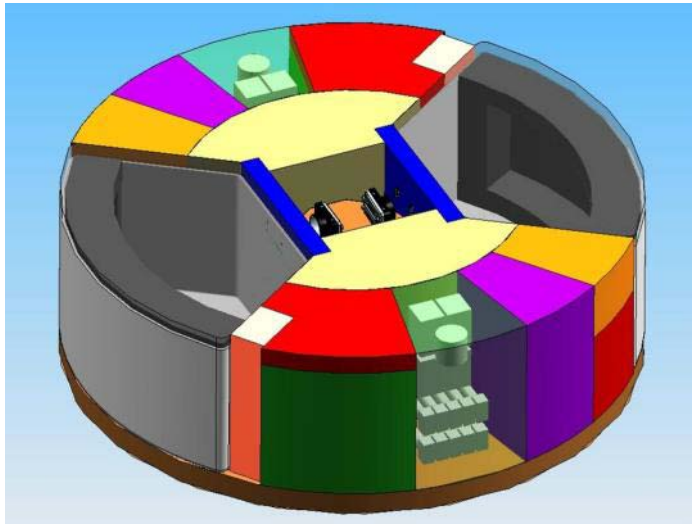
- EC measurement
- pH measurement
- Auto-Calibrating
- Ion-mesurements
  - Ca_2^+
  - Cl^-
  - K^+
  - Na^+
  - NH_4^+
  - NO_3^-
  - Mg^{2+}
  - $P[HP0_4^{2-}]$

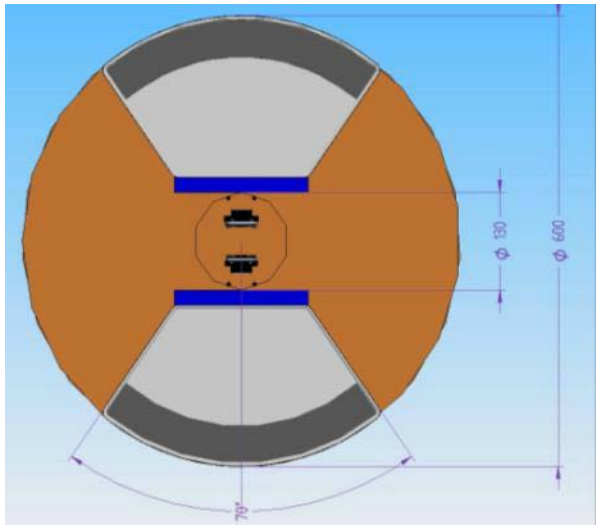
The Plant Cultivation Chamber

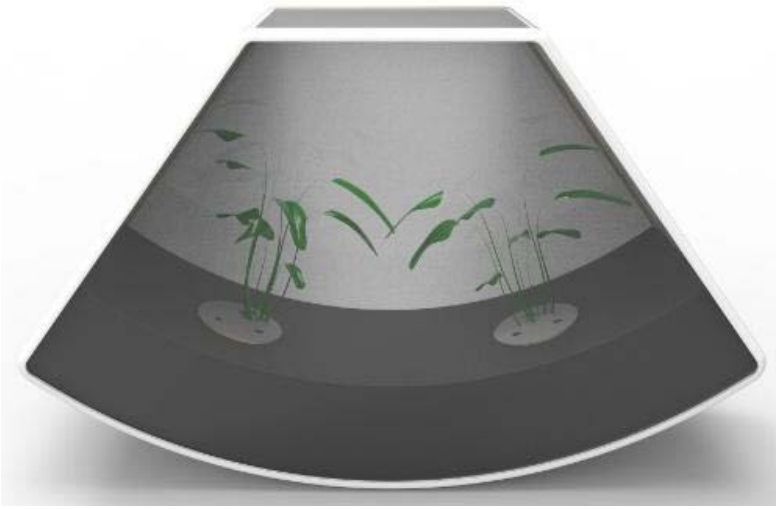


Design Drivers

- Geometrical rotor limitations
- Volume maximization
- Space for 2 lettuce plants (10 Arabidopsis plants)
- Capable of hydroponic substrate-free operation



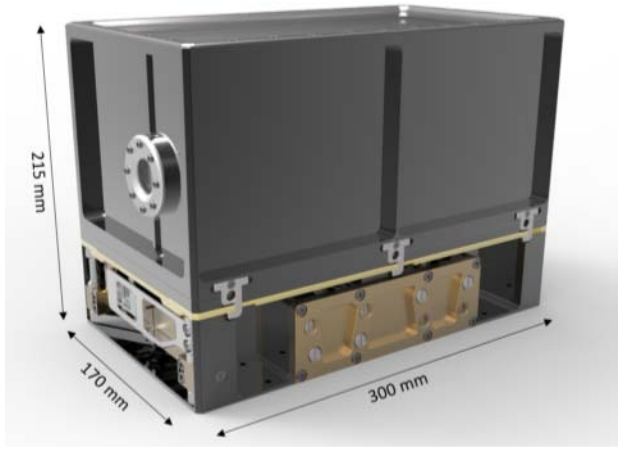


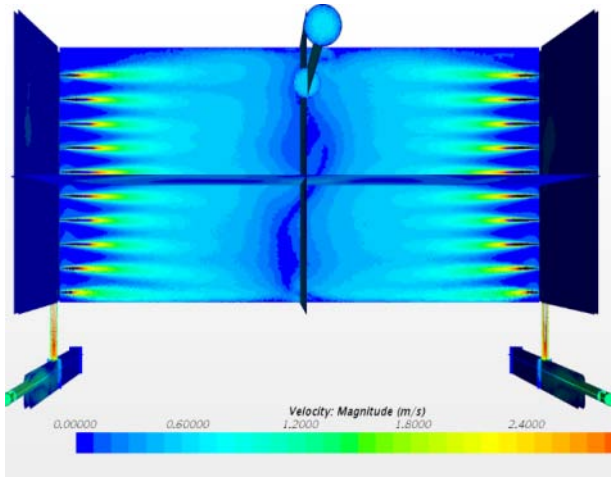


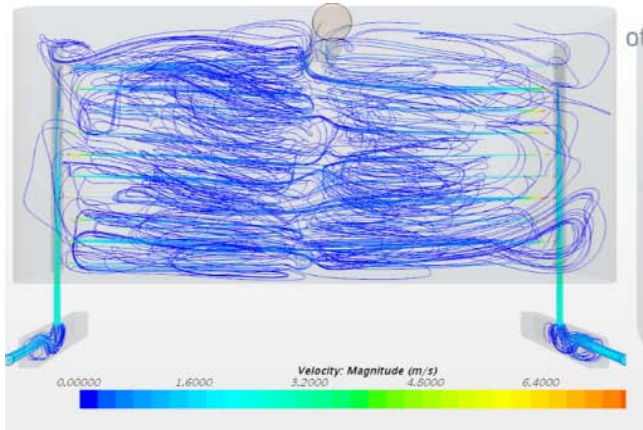
The Plant Cultivation Chamber

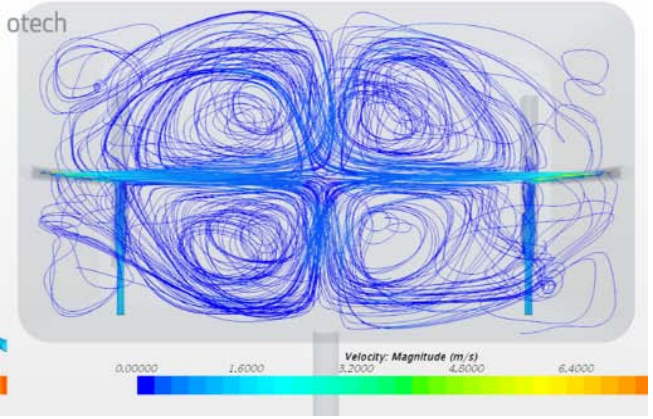
Design Requirements

- Maximize plant growth volume
- Minimize mass
- Observation and illumination interfaces
- Data monitoring/sensing interfaces
- Compatibility to Modular Test Bed
- Astronaut friendly operation
- Hydroponic substrate-free Nutrient supply
- Air-supply enabling minimum velocity



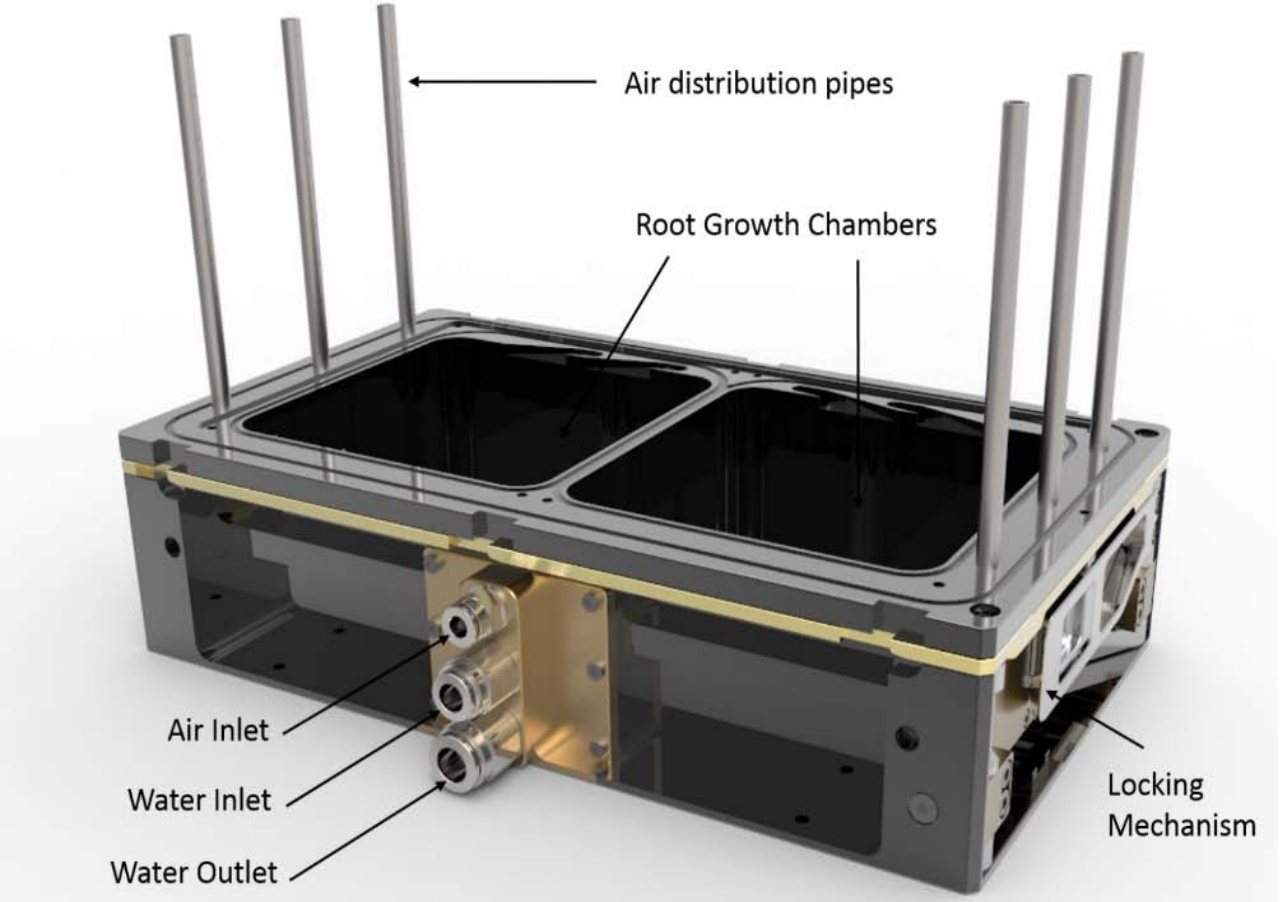


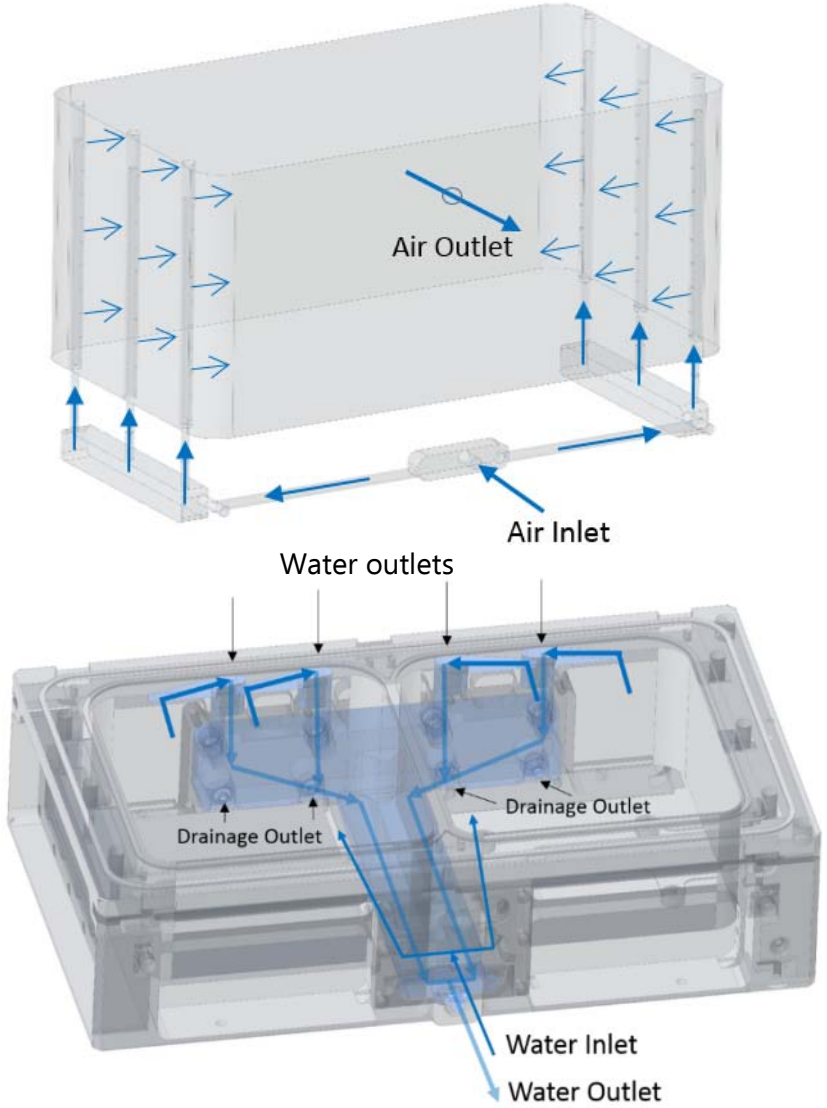




The Plant Cultivation Chamber

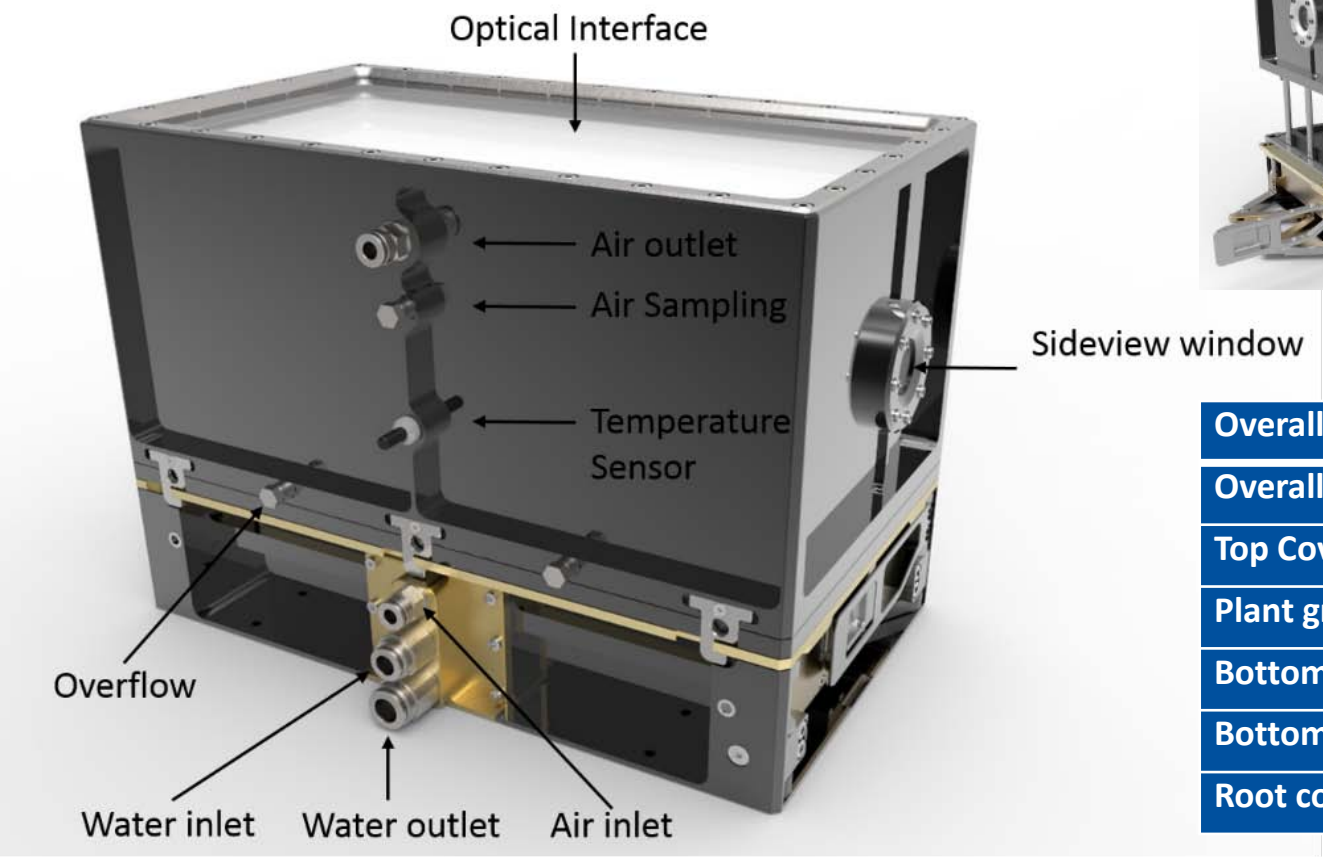
Air and Water Distribution

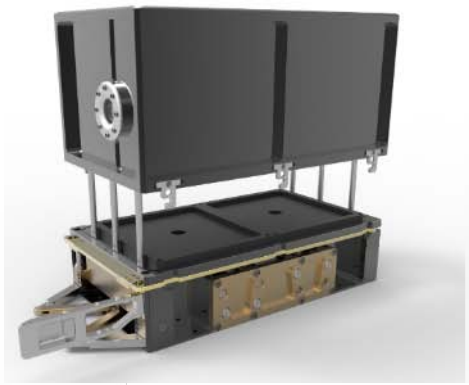


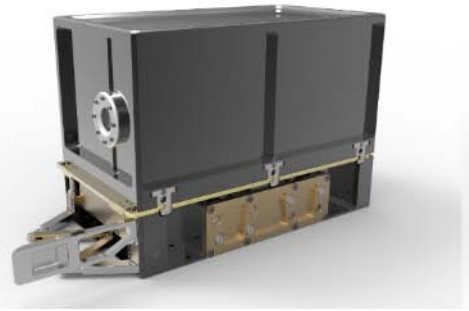


The Plant Cultivation Chamber

Interfaces and Assembly







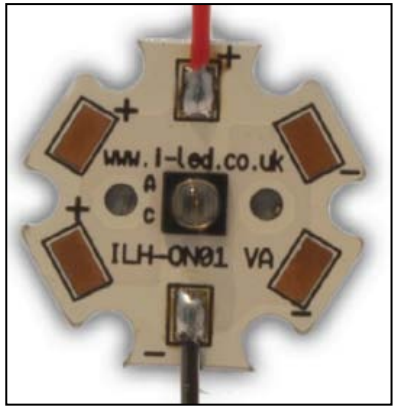
Overall PCC dimensions (mm)	**300 x 170 x 215**
Overall PCC Volume (l)	10,96
Top Cover dimensions (mm)	143 x 170 x 300
Plant growth (air) volume (l)	5,4
Bottom box dimensions (mm)	72 x 170 x 300
Bottom box volume (l)	3,6
Root compartment volumes(l)	2 x 0,8

The Plant Cultivation Chamber

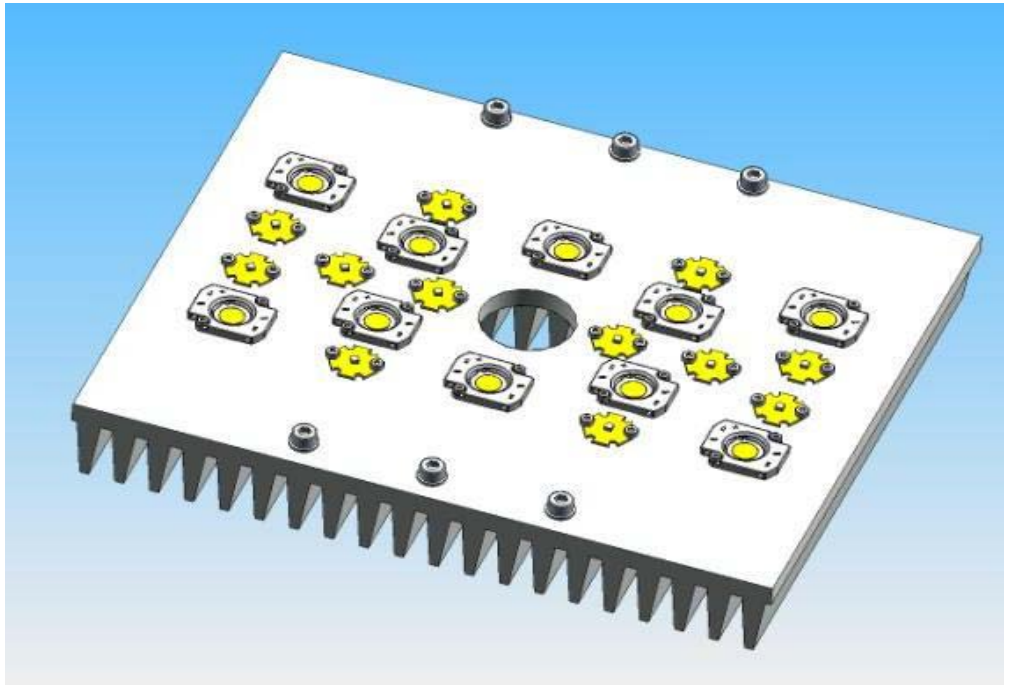
Pictures

The Light System

White LED
- 10 x
- 4000 K



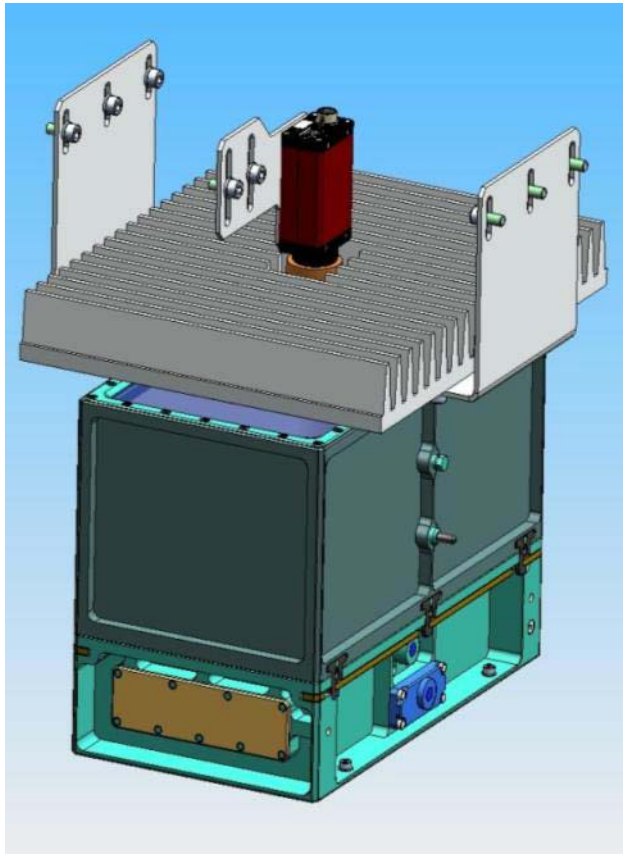
IR LED
- 12 x
- 940 nm

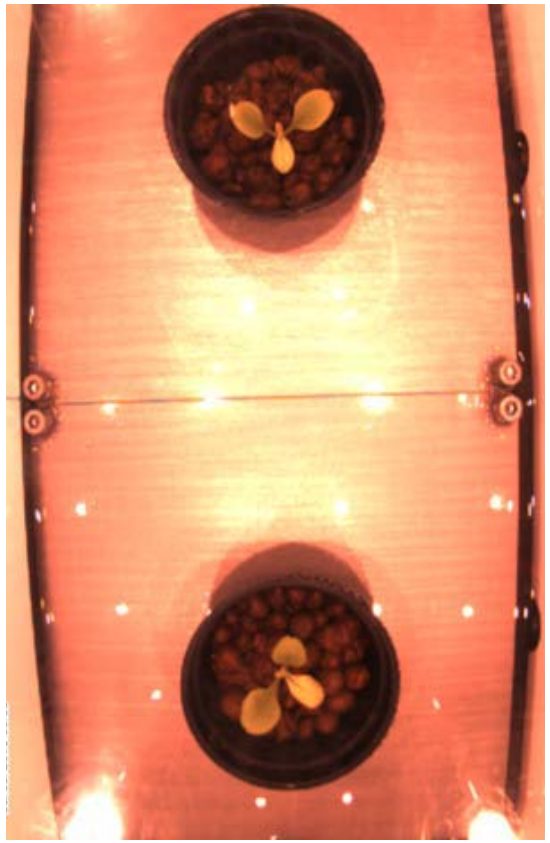


The Plant Health Monitoring System

Schneider Cinegon 1.8/4.8 lens
(with infrared correction)

Allied Vision Manta G-033C
(colour camera)





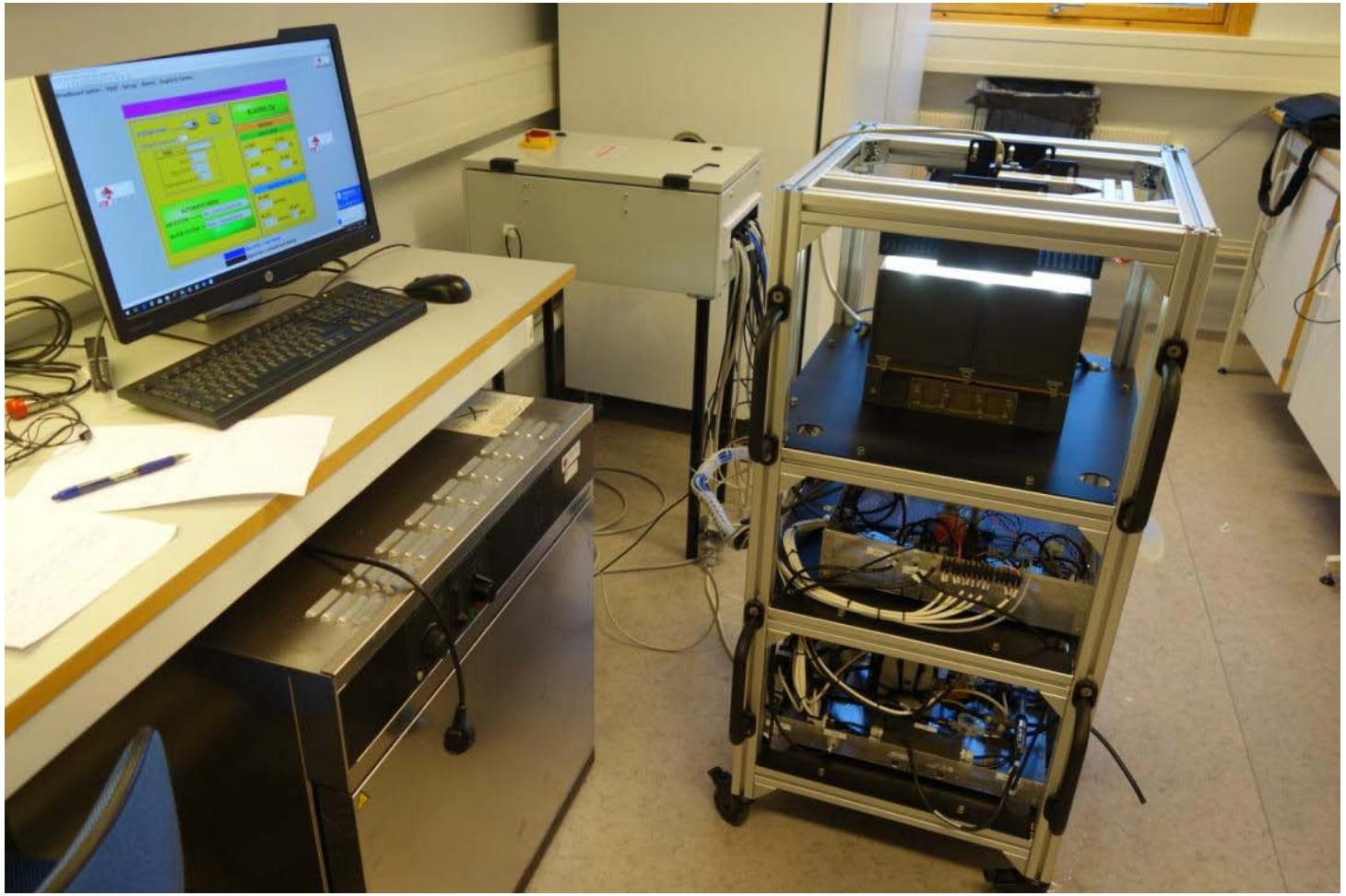
TIMESCALE

The Modular Test Bed

The Modular Test Bed

Main components:

- Incubator
- Modular frame
- Electronics box
- Workstation
- Software



The Modular Test Bed

Incubator

- SGC-120 by Weiss Technik
- Active control of T, rh, CO_2 level

The Modular Test Bed

Modular frame

- Providing structural support for the main ALSS breadboard components
- Allowing easy moving / transportation of the main ALSS breadboard components
- Providing all the required interfaces (mechanical, electrical, gas, data/signal, optical) to the CCS elements

The Modular Test Bed

Electronics box

- Accommodation of all electrical and electronic components in a single location outside plants environment
- Data acquisition of signals from CCS sensors
- Remote control of CCS actuators (valves, pumps, etc.)
- Providing adequate power supply to CCS components

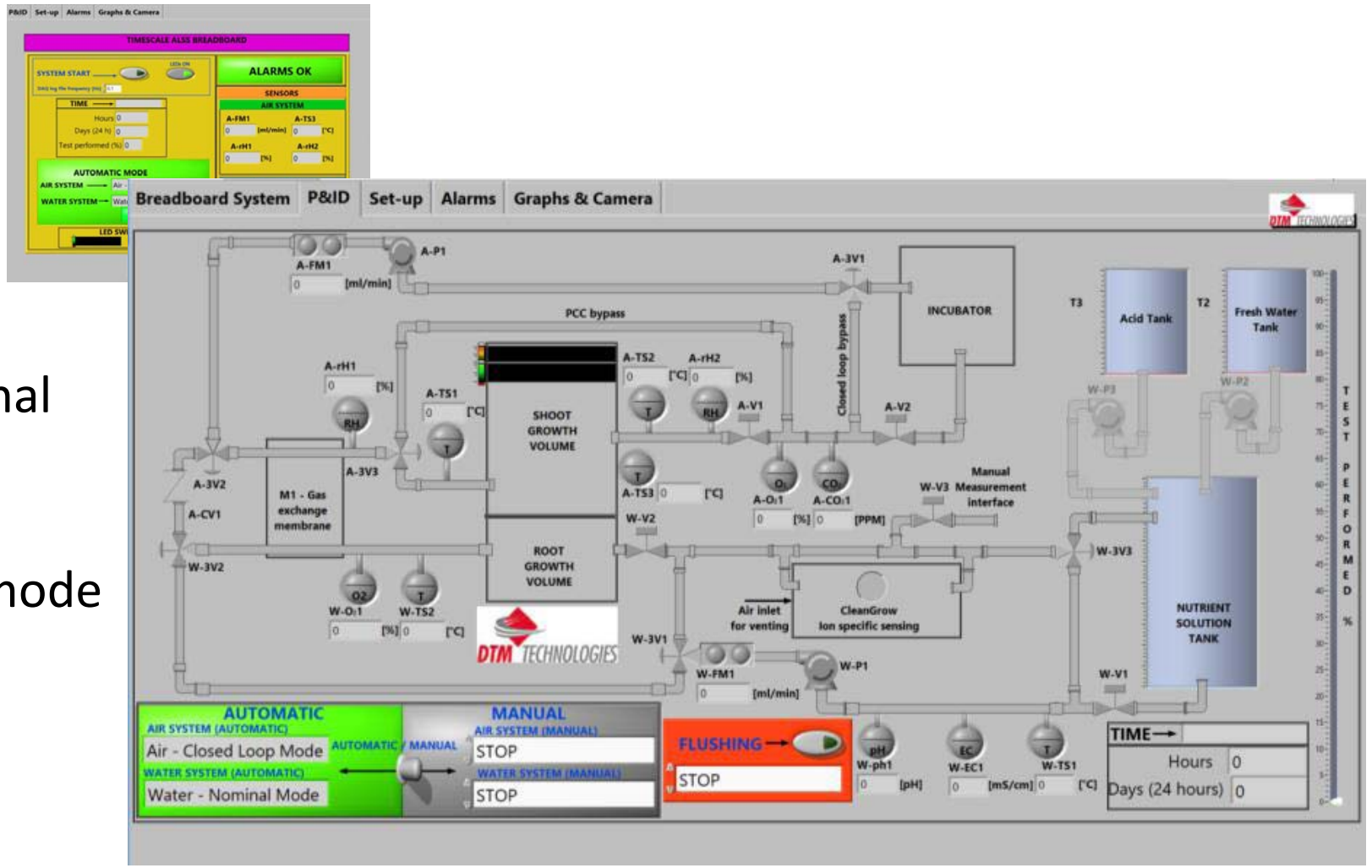
The Modular Test Bed

Workstation (operator interface)

- Data acquisition and remote control management via custom software (Labview environment)
- Data storage
- Providing interface to the breadboard operator

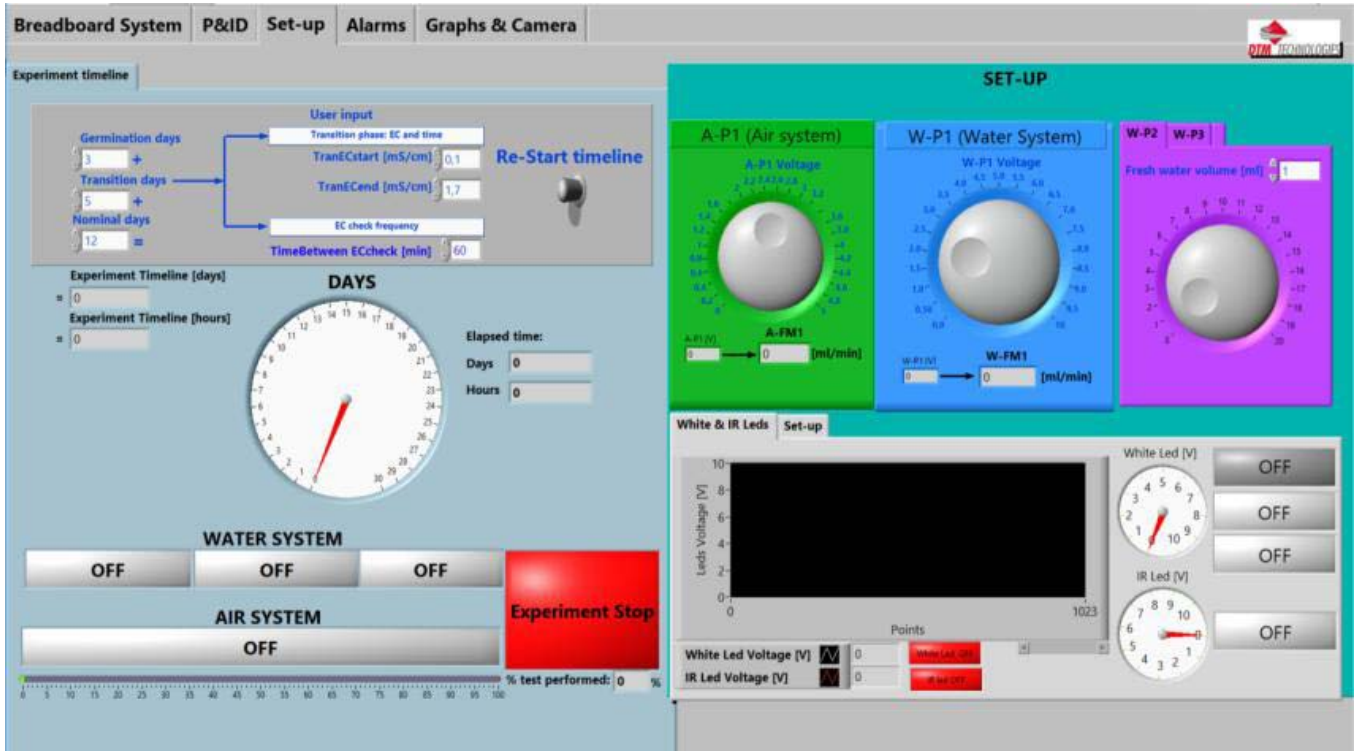
The Modular Test Bed Software (Labview)

- Custom software
- Implementation of operational modes for air and water
- Implementation of manual mode and automatic experiment execution
- Data logging



The Modular Test Bed Software (Labview)

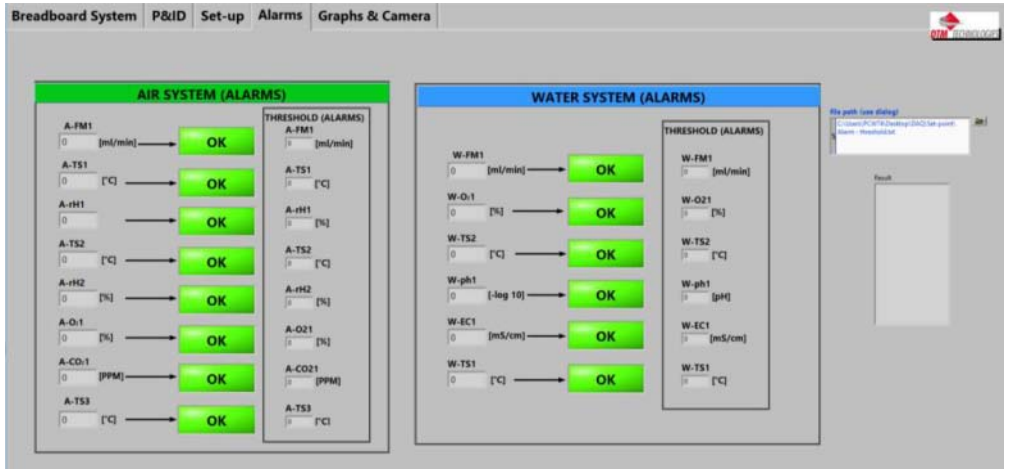
- Setting up of the main parameters

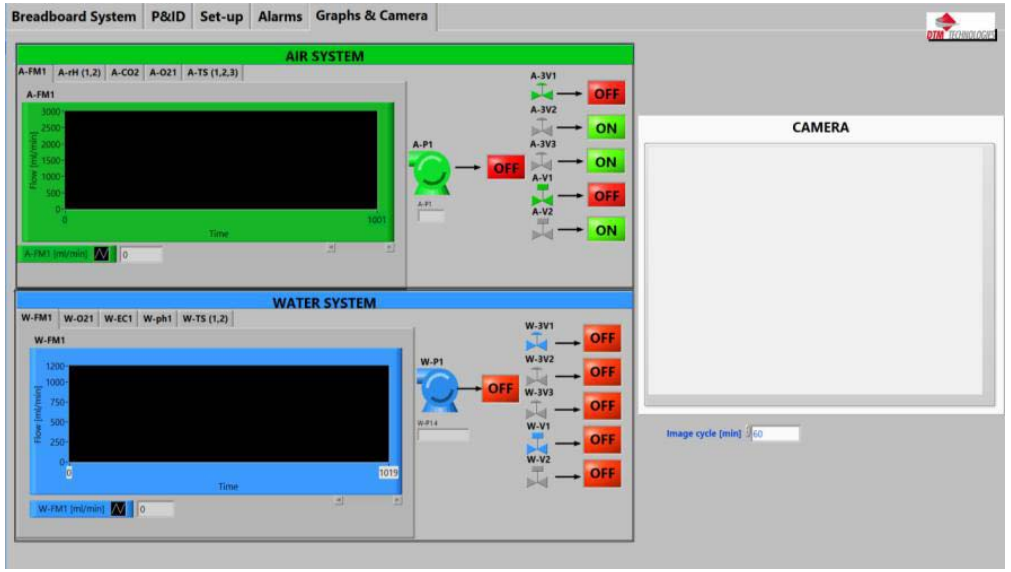


The Modular Test Bed Software (Labview)

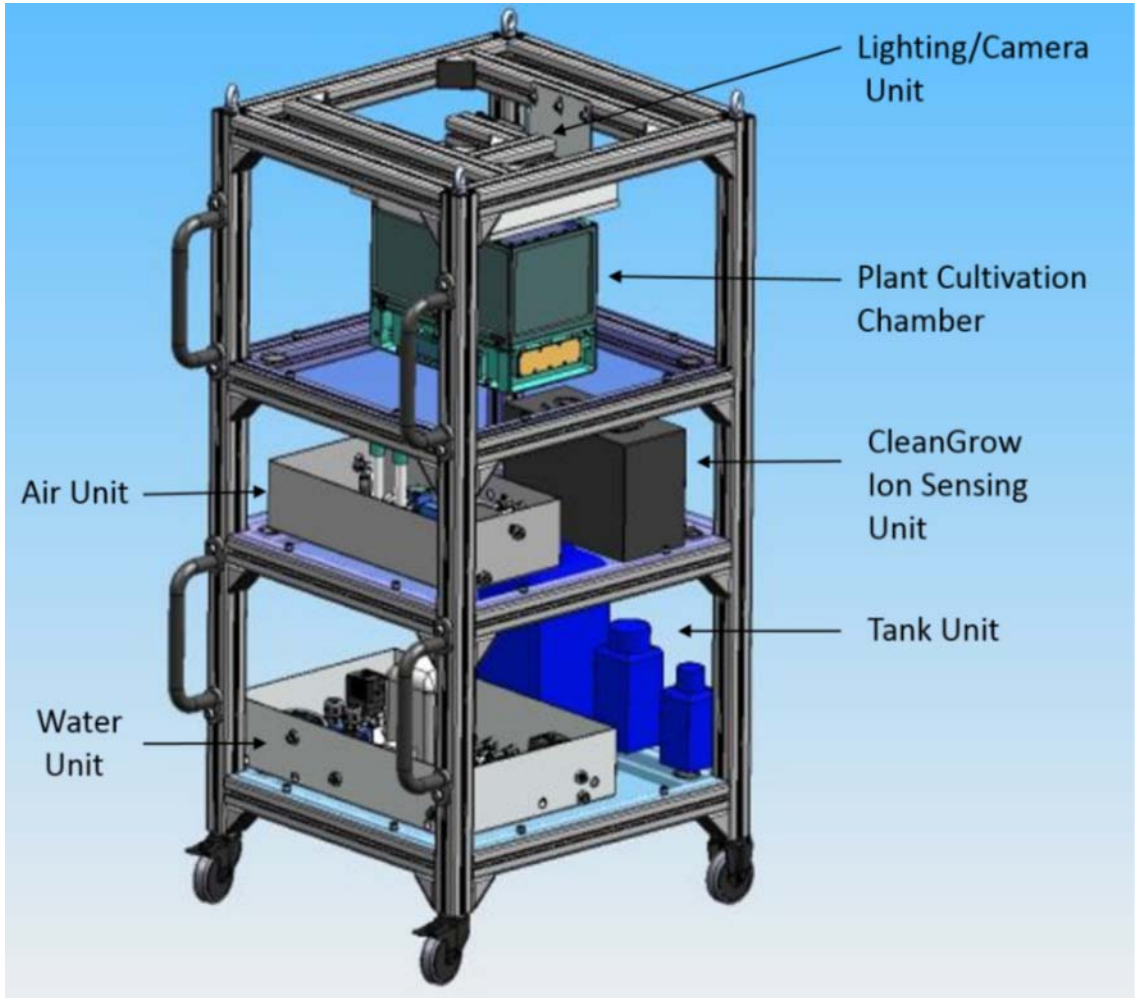
- Alarms features

- Measured parameters in graphical format





The final integrated Breadboard



BREADBOARD SUMMARY

Nutrient Solution

- Adjustable flow 0-40 l/h
- Adjustable EC
- Adjustable pH
- Monitoring of:
  - Temperature
  - EC
  - pH
  - O2-concentration
  - Ion-concentrations
  - flowrate
- Flexible use: Different modes for different growth stages or experiment objectives

Air Supply

- Adjustable flow 0-5 l/min
- Adjustable temperature
- Adjustable Humidity
- Monitoring of:
  - Temperature
  - Relative Humidity
  - O2-concentration
  - CO2-concentration
  - Flowrate
- Flexible use: Different modes for different growth stages or experiment objectives

Plant Monitoring

- Camera in visible and near IR range
- Possibility for volatile measurements in air

Lighting

- LEDs in visible range
- LEDs in near IR range
- Dimmable

Capacity

- Simultaneous growth of up to two lettuce plants
- Simultaneous growth of up to 10 Arabidopsis plants

Handling

- Modular setup
- Quick connectors and tool-less assembly for cleaning, maintenanence and storage

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Thank you for your attention

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