

PeaPod - Solution Overview

Outlining a Proposal to the PeaPod Requirements

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1 Introduction

1.1 Purpose

The purpose of this document is to outline the function and features of a design proposed to meet the PeaPod Requirements.

It accomplishes this by addressing the following prompts on a recursive tree basis:

1. **What** is the design's purpose and function?
2. **How** does it accomplish this? What is the method/process?
3. Justification on how the selected features meet the method better than alternatives.

2 Design

The purpose of the design is derived from the opportunity statement:

PeaPod is "an automated and isolated aeroponic crop growth system, able to generate any growth environment from a combination of independent environment parameters, with both environment and crop growth data collection for optimization".

The primary function of the overall design are derived from both the overall purpose as well as the system inputs and outputs as defined by the DSFC Applicant Guide [1].

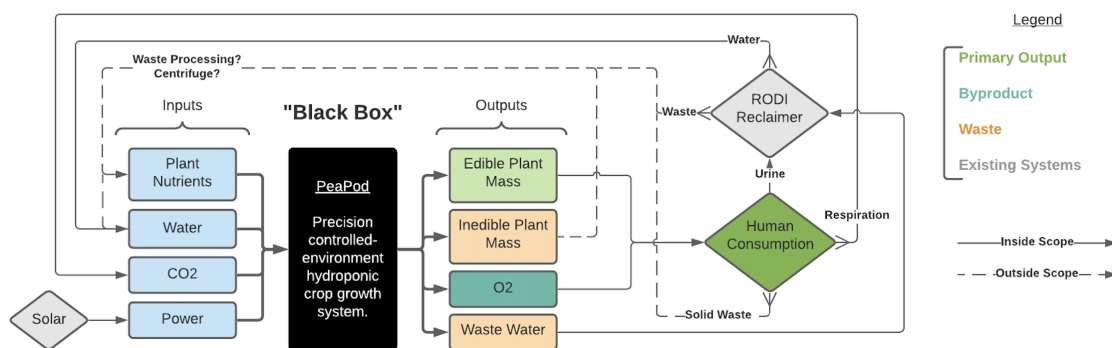


Figure 1: "Black box" function diagram of PeaPod.

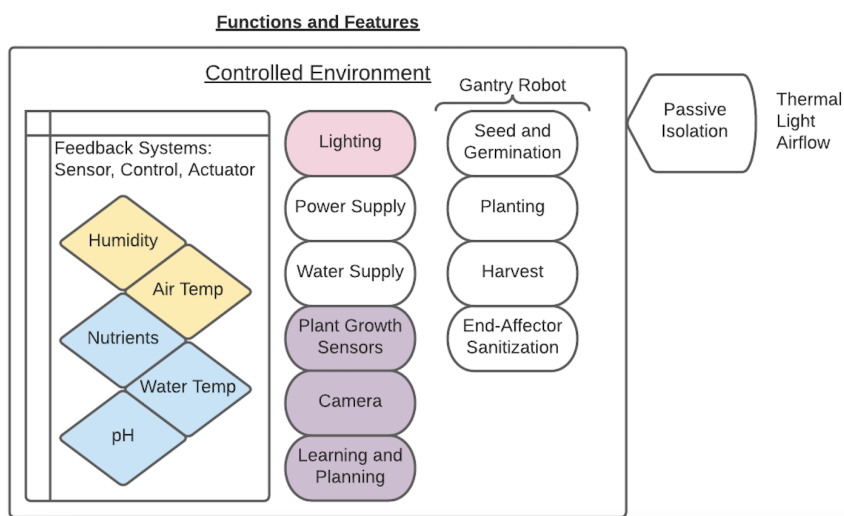


Figure 2: Features and feature types of PeaPod.

2.1 Automation

Function: Performing growth-, maintenance-, and data-related tasks autonomously on the basis of both schedule and necessity to reduce crew maintenance time. Maintains the homogeneity of the internal environment.

Process:

1. User inputs program:
 - Action-at-timestamp, e.g. lights on at 08:00;
 - Control target with start/end, e.g. hold air temperature at 22°C from 11:00 to 18:00;
2. Notification on maintenance requirement (i.e. non-automated input/output management);
3. "Sense, Plan, Act" robotics/control model:
 - (a) *Senses* current conditions;
 - (b) *Plans* a path to desired condition;
 - (c) *Acts* to change current condition to desired condition;

Features:

- Central computer system with internal clock and cloud connection;
- Environment sensors (*Sense*);
- "Program" of time-series and/or control target instructions (*Plan*);
- Actuators (*Act*);

Justification:

- **Purpose:** Increased accuracy/precision over human interference, minimize human hours spent. Enables control over all parameters simultaneously.
- **Process:** Data structure matches \vec{E} from the optimization routine (see Section 2.5). Control loop-style topology is common is well suited for controlled-environment agriculture.

- **Features:** Automation implies computers. Sensors and actuators directly parallel process components.

2.2 Isolation/Insulation and Housing

What: Isolates growth environment from exterior environment, provides structural integrity and mounting points.

How: Cube exoskeleton (aluminum extrusion) holds solid (acrylic/foam/corrugated board), internally-reflective (mylar) panels in place and aids in mounting plant growth platforms, lights, etc.

- Isolation:
 - Heat - Held in by mylar, blocked out by solid insulation via panels;
 - Light - Blocked out by panels, reflected in by mylar;
 - Moisture - Retained by caulking/other sealing around panels;
- Mounting:
 - Growth trays - Mounted to rails fastened to aluminum extrusion channels;
 - Lights - Many boards mounted to sheet fastened to aluminum extrusion channels;
 - Nozzles - Mounted to inside-bottom face of growth tray;
 - Sensors - Mounted to various points (per-sensor), often fastened to aluminum extrusion channels;

Why: Increases thermal and light efficiency. Isolation increases safety against cross-contamination, pathogens, harmful substances. Simple and strong construction with dedicated mounting channels.

2.3 Aeroponics

What: Medium-free growing method that uses nutrients dissolved within atomized water.

How: High-pressure nozzles deliver atomized nutrient solution to plant roots. Uses parallel distribution topology.

- Pump fills tank with water that has nutrients dissolved within;
- Tank uses an air bladder to hold water at desired PSI;
- Switch checks line pressure and activates/deactivates pump to maintain PSI;
- Solenoid ball valve feeds water to nozzle;
- Nozzle atomizes water to ≈ 50 micron droplets;
- T-quick connects with solenoid ball valves at every unit height feed individual trays;

Why: No water parameter feedback, 98% more water efficient, minimizes pathogens and waste water.

2.4 Environment Control

The environment control feature can be broken up into **control systems** (2.4.1-2.4.3; sometimes in two parts) and **set systems** (2.4.4-2.4.7).

2.4.1 Air Temperature

What: Maintaining desired air temperature within the enclosure.

How: Thermoelectric heating/cooling system (peltier tiles w/ polarity switch, 'dimming' current control, PID) on a heat sink w/ fan, feedback from distributed temp sensors.

Why: TECs have better space and energy efficiency, less complexity (no liquids, pressurized fluids, etc.), better control vs other methods. PID provides best control.

2.4.2 Air Humidification

What: Adding water vapour to air.

How: Ultrasonic nebulizer (piezo disc w/ custom driver circuit), RO water.

Why: Piezo for droplet size, commonly used; RO for purity of water vapour.

2.4.3 Air Dehumidification

What: Absorbs water vapour from the air.

How: Silica gel bead cartridges with fans/valves to control airflow across.

Why: Non-toxic, safe, cheap, effective. Color-changing indication at saturation, easily reset by baking and recapturing water.

2.4.4 Solution Temperature

What: Maintaining desired water temperature within the water store.

How: Same as 2.4.1; on a water block.

Why: Same as 2.4.1.

2.4.5 Solution Nutrients

What: Precisely dosing the correct amount of various nutrients (K^+ , NO_3^- , etc.) to the water system at setup/water addition.

How: Syringe-like dosage via servo motor to set ppm based on fill volume.

Why: Syringe dosage is precise, easy to refill.

2.4.6 Solution pH

What: Precisely adds pH up/down solutions to set the solution pH at setup/water addition.

How: Same as 2.4.5.

Why: Same as 2.4.5.

2.4.7 Lighting

What: Wide spectrum precision LED lighting targeting PAR.

How: N LED series/colors, N controlled-current PWM drivers, M LEDs per series = NxM LEDs.

Custom LED boards wired in series, one power board per tray, w/ diffusion.

Why: LED > every other type in every way, PWM easy protocol, CC because they're LEDs.

2.5 Optimization

References

- [1] “DSFC Applicant Guide,” Impact Canada, launched by NASA/CSA. [Online]. Available: <https://impact.canada.ca/en/challenges/deep-space-food-challenge/application-guide>