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 fuction 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 <u>purpose</u> and <u>function</u>?

2. **How** does it accomplish this? What is the <u>method/process</u>?

3. <u>Justification</u> 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 <u>automated</u> and <u>isolated</u> <u>aeroponic</u> crop growth system, able to generate any <u>growth environment</u> from a combination of independent <u>environment parameters</u>, with both environment and crop growth <u>data collection</u> for <u>optimization</u>".

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].
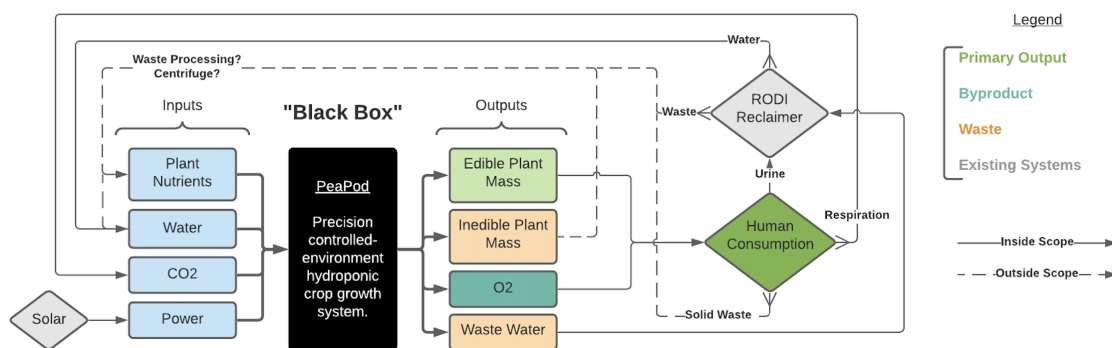

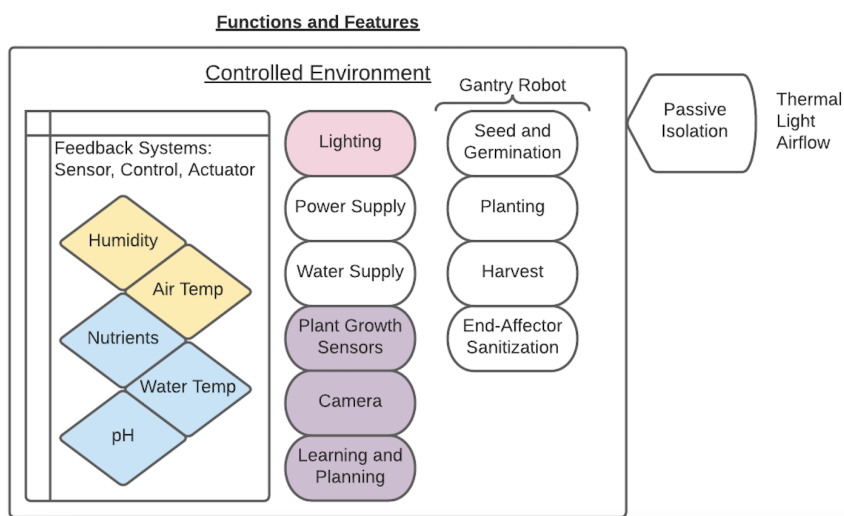Figure 1: "Black box" function diagram of PeaPod.

Figure 2: Features and feature types of PeaPod.

2.1 Automation

Purpose: Performing growth-, maintenance-, and data-related tasks autonomously on the basis of both schedule and necessity to reduce crew maintenance time.

Function: Accomplishes this via a central computer system with a set of connected sensors and actuators, an internal clock, and a "program" of time-series and/or control target instructions.

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℃ 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;

Justification:

- **Purpose**: Increased accuracy/precision over human interference, minimize human hours spent.

- **Function**: Automation implies computers. Sensor-actuator control loop-style topology is common is well suited for controlled-environment agriculture.

- **Process**: Data structure matches $\vec{E}$ from the optimization routine (see Section 2.5).

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