

PeaPod - Design Report

Primary Written Deliverable for the Deep Space Food Challenge Phase 1

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1 Design Abstract

Our solution is a modular aeroponic plant growth environment based upon controlled-environment agriculture principles. The ability to precisely control environmental parameters allows our system to grow any plant imaginable.

2 Design Report

2.1 Description

Part A

An automated and isolated aeroponic crop growth system, able to generate any environment from a combination of independent environment parameters, with both environment and crop growth data collection. The system takes the form of an enclosed cube, with most crew interaction limited to water and nutrient refill. Hardware components can be broken down into 4 primary categories: Feedback Systems, Resource Supply, Support Structures, and Electronic Control. Together, these 4 components create the "Black Box" seen in Figure ??.

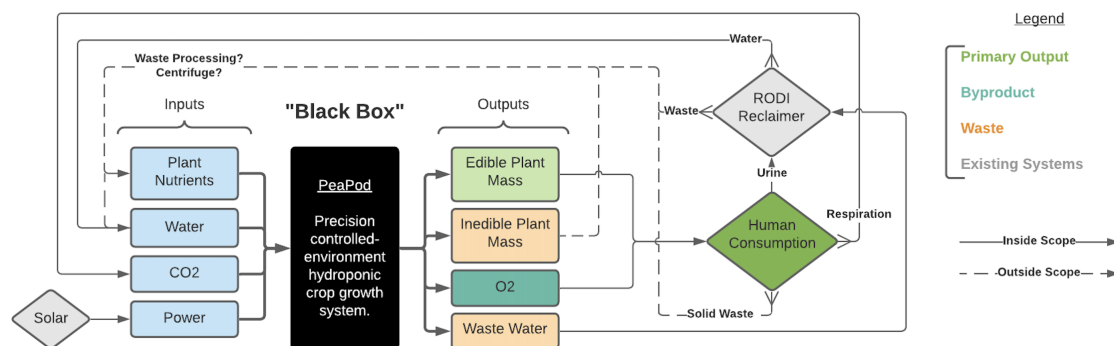


Figure 1: "Black box" function diagram for our solution.

Part B:

2.2 Innovation

2.3 Adherence to Constraints

2.3.1 Outer Dimensions, Volume

2.3.2 Power Consumption

2.3.3 Water Consumption

2.3.4 Mass

2.3.5 Data Connection

2.3.6 Crew Time Requirement - Setup & Maintenance

2.3.7 Palatability of Crop Output

Hydroponic crops have seen commercial success, suggesting that their output is of sufficient hedonic quality to be desired. Additionally, PeaPod is designed to optimize for edible plant mass, nutrient density, and other health indicators—pushing hedonic quality up over time.

2.3.8 Operational Constraints

2.4 Performance Criteria

2.4.1 Acceptability

Acceptability of Process

Acceptability of Food Products

2.4.2 Safety

Safety of Process

Being a sustainable isolated unit, PeaPod requires little cleaning. When it does need to be cleaned, PeaPod is easily disassembled due to its modularity. PeaPod uses safe materials in its chassis, insulation and circuitry. The main frame is constructed using aluminum. Although large quantities of aluminum in food are deemed dangerous, the small exposure of aluminum to the plants passes

well below the toxicity limit; as healthline says, when using aluminum cookware the, “amounts are very small and deemed safe by researchers” referring to the aluminum captured in the food (<https://www.healthline.com/nutrition/aluminum-foil-cooking>). The bracketing and mount of PeaPod is safe plastic by Acme Plastics (<https://www.acmeplastics.com/what-is-petg>). The insulation used in PeaPod is free soldering was used for all electronics. The dehumidification of PeaPod uses silica gel, which is commonly found in toxic gel packets (<https://www.millenniumwasteinc.com/news/article/silica-gel-repurposing-silica-gel-packets/>). All voltages of PeaPod are sub 48VDC, avoiding any high-voltage risks. The voltage risk is also mitigated by circuit/overcurrent protection. All pressures of the PeaPod experienced by its irrigation system stay below 100PSI, safe for solenoids (which primarily stay closed) and a pressure sensor shut off. Due to the aforementioned mitigation, gassing. The presence of microbes or other harmful pathogens are mitigated through the use of clean seeds, reverse osmosis water, and pathogenic compounds such as fungicides and algicides. To avoid cross-contamination, PeaPod provides plant

Safety of Food Products

2.4.3 Resource Inputs and Outputs

Resource Inputs

System Outputs

Optimization

Maximizing output is perhaps the greatest strength of PeaPod. Since it is fully automated, growth cycles have a high degree of certainty that let researchers hone in on the perfect conditions—and then repeat them ad infinitum. By collecting data in an isolated environment like this, optimization can be done on any number of parameters, including quantity of inputs. As trials are conducted and PeaPod gathers data, it measures the quantity of inputs taken and a plethora of plant data related to usable quantity, bringing PeaPod to the most efficient conditions over time. In addition, the array of sensors used to collect data double as input for PID control, letting PeaPod react to unpredictable events such as poor seed health and salvage otherwise poor outputs.

Food Output Quality

2.4.4 Reliability and/or Stability

Process Reliability

By nature of its design, PeaPod will last three years at near 100% functionality on minimal maintenance. This is achieved by self-monitoring component health, using servicable materials, and providing smart notifications to the user when maintenance is needed. For one, PeaPod is designed to be assembled by a single user with readily available tools. This means it can be disassembled, cleaned, and put back together by one person in a non-restrictive amount of time. For another, the sensors used to monitor plant health and growing conditions allow PeaPod to notify the user when a part needs to be fixed or replaced. For example, if humidity readings fall below historical levels for current water output, PeaPod will notify the user to replace the insulating material in the nozzle area. If light intensity begins to drop in a certain sector, PeaPod will tell the user to replace a certain bulb.

This said, every component in PeaPod has an expected lifespan over three years. From the LEDs (rated for 5 years) to the nozzle (only needs periodic cleaning) to the bonding agents (tested for materials used), replacement monitoring is only needed as a backup.

Scheduled maintenance breaks down to three primary tasks: refilling nutrients, cleaning spray nozzle, and harvesting/replacing plants. Since PeaPod mixes the nutrient solution automatically, the only required maintenance is replenishing stores of water and individual nutrients. By tracking consumption rates and using past trends, PeaPod can schedule the most efficient refill time in advance and notify the user. The spray nozzle, by way of its fine mesh, will build fine amounts of sediment over time. This can be easily cleaned by the user at either pre-determined times or, as mentioned above, when the unit detects an issue. Finally, plant harvesting is a quick task that simply constitutes opening the unit and removing the plant. Replacing it only requires the user to open the unit, place the seed in the grow cup, and digitally set the grow conditions for PeaPod to follow.

Input and Output Stability

PeaPod's input stability is maximized by a variety of design choices, the sum of which give them a shelf life above the three-year mark of a mission. Since the system doses nutrients automatically

and at a high-degree of precision, nutrient solution can be stored at a much greater density than would be possible with manual mixing. This minimizes degradation and loss of quality while reducing the space needed to store the solutions. Since the solutions can be stored in such a compact manner, it is feasible to store them in an insulated, opaque container that minimizes fluctuations in environment that could stimulate degradation. And, by utilizing the electrical infrastructure of PeaPod itself, it is trivial to maintain a set temperature within this container that further hampers deterioration.

Outputs will have a shelf life that is, in worst case, comparable to fresh produce grown outdoors. More realistically, crops are expected to last longer as a result of a lack of pests, disease, and optimization of characteristics for ambient conditions nearby. These are the result of PeaPod's isolated environment and data collection capabilities. For example, the same sensors used to optimize growth conditions can then be used to optimize traits for the given storage conditions, letting researchers select for crops and characteristics that will last the longest. Finally, PeaPod can let users grow crops on a rotation, providing a steady supply of fresh produce that will not need to be stored for particularly long periods of time, thus circumventing some of the restrictions posed by growing fresh crops.

2.5 Terrestrial Potential

Customer-facing Food Service

At present, a restaurant requires either a local supplier or a substantial amount of outdoor space (and labour) to serve fresh produce. Both of these are cost-prohibitive, and the latter is entirely impossible in many situations. Local suppliers' high costs are the result of a few things:

- Limited seasonal availability
- Frequent transport need
- High costs with little demand

PeaPod has the potential to reduce these barriers in a cyclic way. Partnerships between local suppliers and restaurants will provide these restaurants with space- and time-efficient PeaPod units with the purpose of generating both produce and data. The increase in produce will reduce

the frequency at which suppliers need to make deliveries, while the data produced will let suppliers maximize output. Over time, this can increase efficiency to the point where local suppliers can provide produce at a lower price.

Crowdsourced Research

Due to PeaPod's automated nature, off-site research is a feasible method of collecting data. As a result, universities and other institutions can save costs related to space and energy usage by subsidizing PeaPods to consumers, schools, or even restaurants. Users would receive sets of parameters within which to grow crops, and the data would be sent back to the institution. The user can use the produce, at the cost of space and energy, while the institution continues to provide parameters with which to grow. The end result is a massive set of data, conducted in identical conditions in different places, verified by comparison with the myriad devices conducting the same tests.

De-centralized Production

Many crops are only feasible in certain climates, making global transport a necessity to sell them worldwide. This reduces freshness, necessitates various preservatives, and increases carbon consumption. By upscaling PeaPod technology to a farm scale, it becomes possible to produce climate-bound crops in any location. This creates region-based farms that can produce a tremendous variety of crops, vastly reducing transport needs and making it easier to have a local food diet.