# Characterizing LEDs used in the Leafy Green Machine for Optimization of potential Extraterrestrial Farm

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*Biography*

Malena, Doug, and Amaninder are members of the Clemson Engineering Design Applications and Research (CEDAR) Group. The CEDAR Group at Clemson focuses on complex engineering problems, ranging from product design and optimization to research on engineering design theory and development of new design tools. Specifically, Malena, Doug, and Amaninder have experience ranging from leading corporate sponsored design projects, with partners such as BMW Manufacturing in Greer, SC; to applied engineering experience with companies such as Exotic Metals Forming Company in Kent, WA and Robert Bosch LLC in Charleston, SC.

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L-R: Doug, Amaninder, & Malena

## Overview:

Self-sustaining life support systems are critical in order for NASA to achieve its goal of deep space exploration. Freight Farms, Inc. produces a commercial hydroponic farm, the Leafy Green Machine (LGM). The LGM is capable of producing crops, such as lettuce, in harsh environments where food production is drastically limited. The scope of Clemson University's partnership with Freight Farms, Inc. is to improve some of the key systems of the current LGM, with Phase One focusing primarily on the performance of the main LED grow lights and HVAC unit's cooling ability. Results of initial testing performed on the main LED grow lights suggest that, the LED lights produce more heat than the current HVAC system is able to adequately remove from the LGM. The results from the initial LED testing will be used to render a computer generated thermodynamic model to simulate the inside the LGM. Phase Two of improving the LGM will shift towards making the LGM a closed loop system applicable for use in deep space exploration and unforgiving terrestrial environments.

## Motivation

The main motivation for this work is the need for a self-sustaining crop production unit that can supply the astronauts with a constant source of fresh food [1]. In order for the LGM to be used as a self-sustaining crop production unit for deep space exploration, it needs to be further developed into a self-sustaining crop production unit. In addition to space exploration, these LGMs can also find use in in environments with harsh climates, disaster relief, or dense urban sites. In order for these deep space and terrestrial functions to be fulfilled, the LGM must be improved upon so as to consume fewer resources. Specifically, the LGM's water and electricity consumption must be reduced from 10 gallons/day and 80 kW/hr respectively [2]. The crop production process used in the LGM must also be transformed into a closed thermodynamic system, where in no exchange in mass, and limited exchange in energy takes place between the LGM and its environment.

### State of the Art

A LGM hydroponic farm is housed inside a 40-foot-long refrigerated shipping container. Portions of the farm are dedicated for seed production and the remaining space is dedicated to food production. Other hydroponic farms are available on the market, however, lots are made for indoor use. The modularity of Freight Farms, Inc.'s Leafy Green Machine makes it a unique candidate for use in deep space exploration and terrestrial applications where a secure source of food production is needed.

### Intellectual Merit

Modification of the LGM requires specific design for deep space exploration. Meaning, the improvements made to the LGM must enclose the plant production system, thus optimizing the conservation of mass and energy. Design enhancements for the LGM can be replicated and applied to other terrestrial systems in order to create more efficient engineering systems, whether related to hydroponic farming or not.

### Broader Impact

Research on improving the LGM was initiated because of the need for a self-sustaining crop production unit for deep space exploration. However, through the development of a more efficient LGM, the applications of this self-sufficient hydroponic farm would not be limited to only use as a food source in deep space exploration. The enhanced LGM could be deployed to drought stricken parts of the world that require food production with minimal resource availability. The LGM machine can also be deployed to areas of the world where resources are scares and food production is limited due to the impact a natural disaster. Additionally, the LGM can be utilized in urban environments where space for farming is limited. The development of efficient, self-sustaining farming practices lays the ground work for future improvements in, not only hydroponic farming, but any engineering system pertaining to self-sufficient systems.

### Research Approach

Researching and modifying the LGM is occurring in two phases. The First Phase consists of empirically modeling the thermal/energy system of the current LGM design. The data collected from testing the main LED grow lights will be used to build a simulation model of the atmospheric conditions and heat transfer that occurs inside the LGM during steady state operation. Testing setup available in Figure 1. This simulation model will provide data that highlights areas of improvement for the LGM. The simulation data will be used to generate alternative system designs to improve efficiency by reducing energy consumption and improving the HVAC performance of the LGM.

a.

b.

**Figure 1 a. LED strip and T-Type thermocouple (circled) inside insulated cooler. b. Insulated cooler with LED lights under testing conditions.**

The Second Phase of this research will consist of transforming the LGM from a terrestrial hydroponic farm into a closed system, self-sufficient crop producing unit for deep space exploration.

## Findings to Date

Initial testing of the main grow lights has determined that the heat produced by the LED lights and equipment supplying the lights power is 7.67 kW during steady state operation inside the LGM. This data provides a heat source to model inside the computer generated thermodynamic model of the LGM. A scaled down thermodynamic model showing air flows inside a two-meter cube is available in Figure 2 below. The smaller model was used as a starting point for modeling the larger shipping container.

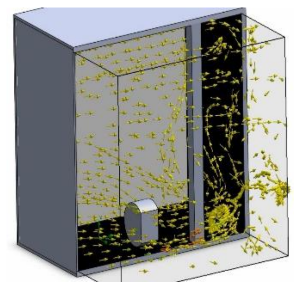

**Figure 2 Scaled two-meter cube used as a foundation for the thermodynamic model of the LGM**

## Conclusions

This project is still in the early phases, however, testing on the main LED grow lights indicate that the HVAC system in the LGM needs to be improved in order to sufficiently remove the heat produced by the LEDs. The empirical data gathered on the LED lights was check for validity by using the same method to test a 60W lightbulb. The data from the 60W lightbulb test correlates well to known efficiency values of 60W lightbulbs. This confirms that the heat produced by the LED lights is accurate and can be used to model the LED lights in the thermodynamic model.

The next phases of this project will involve producing alternative concepts for LED lighting, in order to reduce the heat generated, and proposing improvements to the HVAC system, Additionally, the design of a network of air velocity, humidity, and temperature sensors is underway. This sensor network will be placed inside a LGM to test the validity of the computer generated thermodynamic model created. The data produced by the sensor network and thermodynamic model will be used to identify additional opportunities for resource conservation. Thus keeping with the Phase One goal of reducing resource use, and the overall project goal of transforming the LGM into a self-sustaining crop production unit.

## References

[1] 2016, "NASA STTR 2016 Phase I Solicitation T6.04."

[2] Kelly J., and Summers J. D., 2016, "FREIGHT FARMS, Inc. Proposal # T6.04-9800 Self-Sustaining Crop Production Unit."