SpaceGAMBIT Project Registration Form

1. Project Title

BioMONSTAAAR
Magnificent OpeN Source True
Arduino Automated Algae Reactor

3. Project Summary

We are building an open source, automated photobioreactor (PBR) array with future applications for genetic engineering, bioremediation, and space research. The bioreactor will include integrated sensors for monitoring key aspects of the culture's health including pH, temperature, color, CO_2 gas, dissolved O_2, and oxygen reduction potential. We have also partnered with IO Rodeo to develop an automated hardware and software package based on their open source, manual, Arduino-based colorimeter to measure a variety of elemental characteristics of the culture including nitrate, phosphate, iron, potassium, calcium, and magnesium.

The electronic sensors will integrate with a Raspberry Pi - Arduino microcontroller system that will upload the sensor data into a community accessible Web application running on Google App Engine or similar cloud platform. A Graphical User Interface (GUI) will be developed to display the data in the form of user-friendly reports. We will develop a controller that allows the system to be remotely operated as needed. The project will be published online so other hackerspaces can replicate and build upon our efforts.

4. Relevance to SpaceGAMBIT Mission

Our project is relevant to SpaceGAMBIT's mission in the areas of habitats and human environments as well as maker education.

Controlled Ecological Life Support Systems (CELSS) are crucial for long term habitats and human environments in space. Spacefarers will require fresh food on extended missions away from our planet or when establishing colonies on distant worlds. They will also need systems to recycle waste water and provide fresh air.

During the Space Race that started in the mid 20th century, both the USSR and USA space agencies started developing CELSS that created the first gardens in space with algae and plants. These initial studies of algae cultivation in space showed that algae have the potential to be especially useful. Algae produce the highest amount of useable biomass per growing volume as a food source. Also algae are useful in remediation of waste water and are an efficient producer of oxygen. As the Space Race came to an end these projects were put on hold only to be recently resurrected when prolonged space missions again came within reach.

Recently we have also seen the rise of Maker culture, which is an extension of DIY culture focused on using technologies for invention and prototyping. A subset within this Maker culture is DIYbio. DIY biologists invent inexpensive versions of equipment found in professional and academic labs. Algae cultivation systems are popular among DIY biologists. Although various projects have emerged, they fail to progress beyond individuals or individual hackerspaces. These unique setups currently do not allow comparison of any data obtained by other DIY biologists. Most systems do not measure culture parameters or collect data, limiting their usefulness for conducting scientific experiments, optimizing algae growth, or better understanding closed algae cultivation methods.

BioMONSTAAAR aims to pave the way for DIY biologists around the world to be able to collaborate on building better photobioreactors (PBRs). We will develop an open source closed freshwater algae production system, which measures culture parameters and automates culture maintenance. Any group could build their own BioMONSTAAAR and experiment with it to collect and share data on optimal growth conditions for a wide array of freshwater algae species. This photobioreactor also offers an inexpensive way to test and measure growing conditions of genetically engineered strains and is a prototype for future space farmers.

BioMONSTAAAR's mission is to help educate DIY biologists to take part in the quest to survive and expand into space by creating better life support systems, supporting SpaceGAMBIT's mission.

5. Project Description

There are three parts to our project:

I. The Photobioreactor Array
II. The Photobioreactor Automation Hardware / Software
III. The Colorimeter

I. The Photobioreactor Array

We will build an array of three bubble column bioreactors that makes use of a reactor design already used in many hackerspaces, The AlgaeGeek Simple Photobioreactor Array V.2.

This design is modular, potentially stackable, inexpensive, and relatively easy to build. In the future we will investigate reactors that can more easily scale to a level suitable for harvesting, bio-remediation, and bio-fuel. This current design is intended for small-scale research into algae growth and the maintenance of cultures for genetic engineering.

We will grow three different algae:

1. **Spirulina (*Arthrospira platensis*)**
   A cyanobacterium that is used as an efficient protein source as well as a means of processing waste water and CO_2 during space exploration.
2. ***Chlamydomonas reinhardtii***

A model organism for genetic engineering.

3. ***Haematococcus pluvialis***

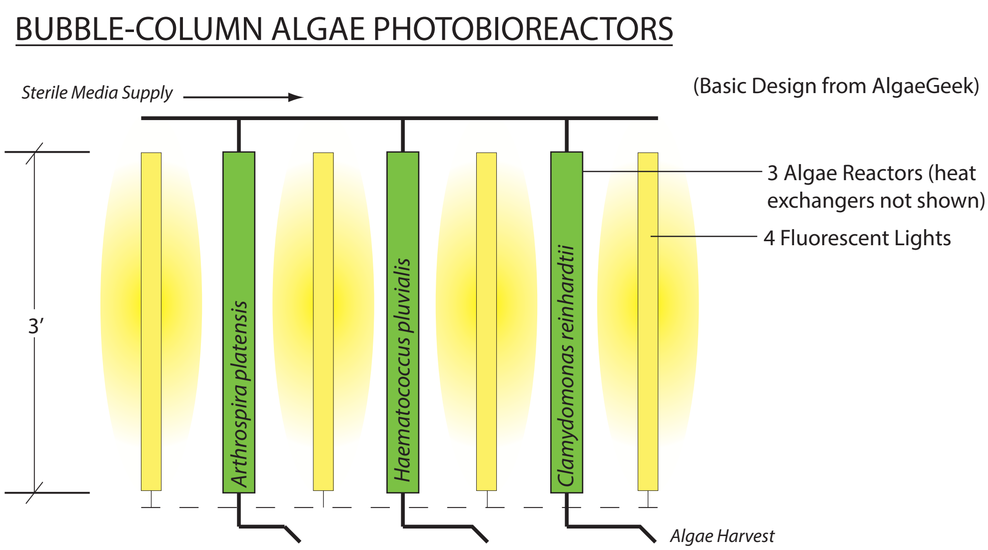
A notoriously difficult to grow species of Chlorophyta that will test the usefulness of our system. If the bioreactor can optimize the growth of *H. pluvialis*, we will know that our design can successfully cultivate fragile algae species--while also solving a common laboratory challenge.

The photobioreactor itself consists of:

The Column System
The Sparging System
The Water Filtration System
The Heating/Cooling System

The Column System

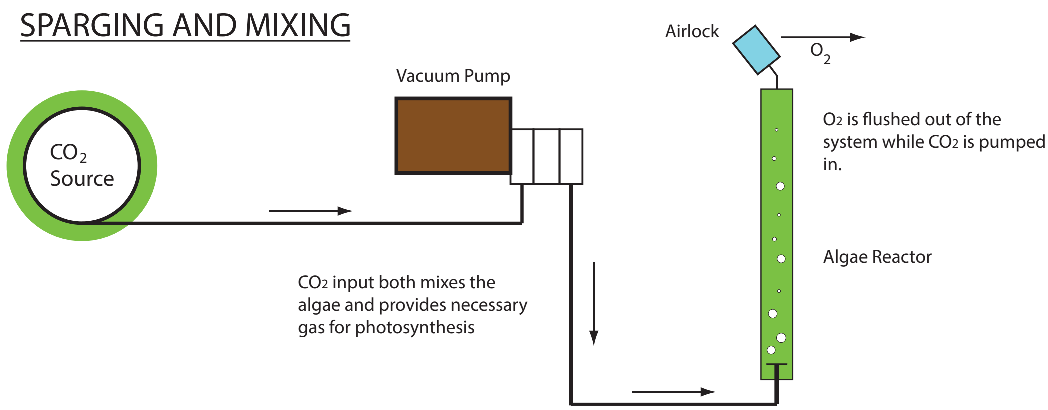
According to the AlgaeGeek design, the bubble columns are built with 3.75 inch (9.53×10^{-2}m) outer diameter cast acrylic tubing. The original AlgaeGeek design does not include a light source as it was built for the outdoors. We will control the lighting conditions by situating four fluorescent tubes between and around the columns in a linear array. The fluorescent tubes can be replaced with LED panels in future iterations of this project.



The Sparging System

Sparging is the process of bubbling a gas through a liquid. Although industrial fermenters use sophisticated systems for optimal gas exchange, our first reactor prototype will sparge using the sparging system included in the AlgaeGeek design.

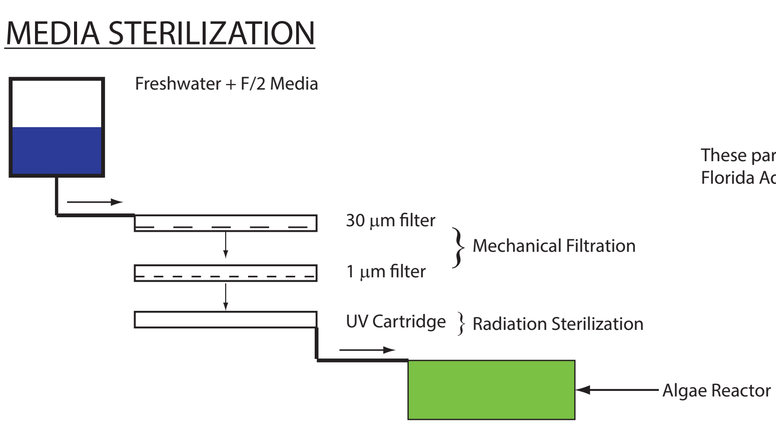
One large vacuum pump connected by a manifold to a carbon dioxide source (CO_2)will pump CO_2 into the reactors. As oxygen (O_2) is produced by the algae, it will be released from the system via a simple fermentation airlock.



The Water Filtration System

This system will consist of a set of mechanical filters followed by UV sterilizing. A small reservoir of water with added F/2 nutrient media will be sent through a 30 um filter, then a 1-5 um filter, then a UV cartridge, and only then allowed to enter the algal columns. This water reservoir will be small, so that all the media will be used up quickly--the nutrient mix is not stable for long.

It is also important for research that the algae stay consistently in the exponential log phase of growth, so we will regularly drain a portion of the algae and dilute the remaining culture with fresh media.



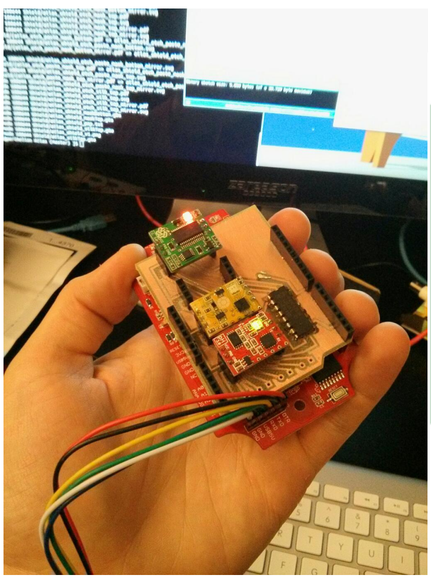
The Heating/Cooling System

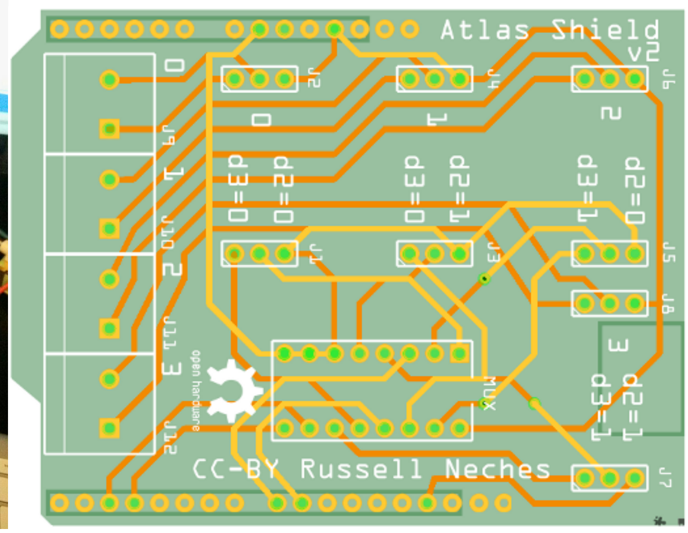
Heating and cooling will be controlled by copper tubing coil through which we will be able to run cool or heated water. The copper tubing will attach to clear vinyl tubing that can be hooked up to garden hose or a sink faucet.

II. The Photobioreactor Automation Hardware / Software

We will use the following seven sensors for each reactor: pH, dissolved O_2, conductivity, gaseous CO_2, temperature, water level, and ORP (oxygen reduction potential). Most of these sensors will be acquired through Atlas Scientific. The Atlas Scientific sensors provide data precision, but in the future we hope to find an alternative to the Atlas Scientific sensor. These sensors are rather expensive and proprietary. Our goal is to eventually make this project entirely open source.

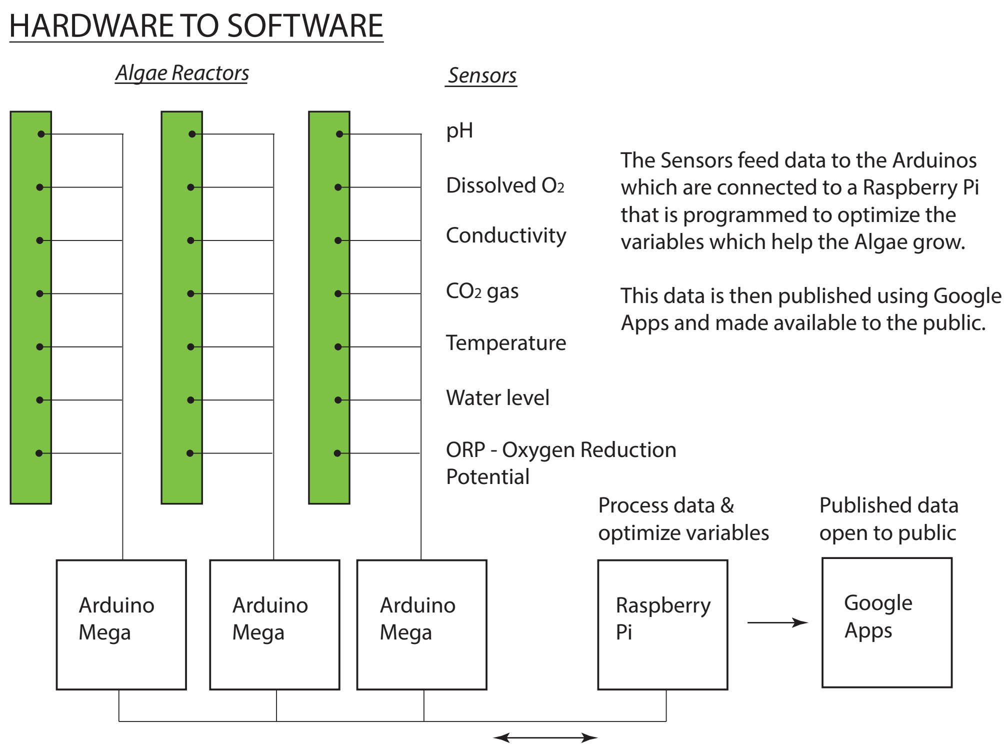
Sensor data from each bioreactor will be sent to an Arduino Mega board, one board per reactor. To interface the sensors with the Arduino, we will take advantage of an Atlas sensor shield currently being developed by Russell Neches at UC Davis. The shield design and the associated Arduino libraries are completely Open Source. Russell has ordered several batches of the PCB from different suppliers, and has offered to give us one of his boards for free.





The Arduinos for the three bioreactors will funnel their data to a Raspberry Pi, a small single board computer, which will then relay that data to the cloud via Google Apps.

The sensor data from the bioreactors will be available in real-time on our website. The data will be stored in a query-able database that relates our sensor data to metadata about each algal species (links to taxonomical databases, genome data, optimal growth conditions according to literature, etc.). Both graphs and statistics generated from the data will be updated in real-time to the website.

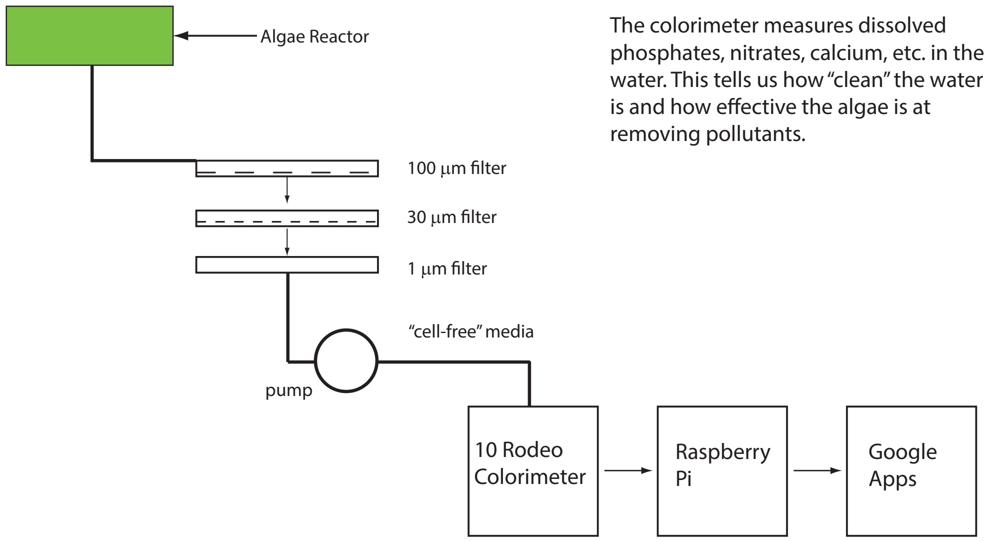


III. The Colorimeter

Hackerspace members have purchased several IO Rodeo Arduino colorimeters for use in various lab projects. This manually operated device provides users with a cost-effective solution to element quantification, including nitrates, phosphate, iron, magnesium, sulfates, potassium, calcium, and ammonia.

BioMONSTAAAR will subcontract with IO Rodeo to develop an enhanced open-source version of their colorimeter hardware which will automate the process of sampling directly from the algae bioreactor, adding appropriate reagents (we are targeting at least 5 assays), taking measurements and flushing the samples in preparation for the next test. The results of these scheduled samplings will post to our web-based data repository along with the other sensor data. We believe that this device will play a critical role in automating the system by measuring and optimizing the amount of nutrients and waste products in the bioreactor. Only the most expensive algae bioreactors on the market today are offering anything close to this kind of automated capability; and none post the data to the web where it can be easily manipulated and reviewed.

COLORIMETER



6. Methods and Implementation Plan

a. Objectives

The major objectives are as follows:

i. Build Photobioreactor Array
ii. Build Photobioreactor Automated Hardware and Software
iii. Build Colorimeter Apparatus
iv. Integrate All Design Features
v. Publish documentation

i. Build Photobioreactor Array

- Building photobioreactor array
- Build water filtration
- Build heating/cooling system
- Growing up algae stocks
- Instructable on photobioreactor

ii. Build Photobioreactor Automated Hardware and Software

- Coding/Preparing/Testing Sensors
- Integration of Sensors into Array
- Creation of Database
- Creation of Front-End Client
- Instructable on photobioreactor automation

iii. Build Colorimeter Apparatus

- Colorimeter development
- Colorimeter prototype
- Documentation for prototype
- Colorimeter final version
- Finalized documentation

iv. Integrate All Design Features

- Integration of Data, Database, Front-End into Array
- Integration of Colorimeter into Array

v. Publish documentation

- Blog Updates
- Instructables
- PDF Document

b. Tasks

The major tasks are as follows:

1. Building of photobioreactor array
2. Building water filtration system
3. Building heating/cooling coil
4. Growing up algae stocks
5. Coding/Preparing/Testing Sensors
6. Integration of Sensors into Array
7. Creation of Database
8. Creation of Front-End Client
9. Integration of Data, Database, Front-End into Array
10. Integration of Colorimeter into Array

c. Time allocation
d. Milestones and Deadlines

Time allocation, Milestones, and Deadlines are presented in this spreadsheet.

8. Budget

Here is a link to the live spreadsheet with a short description for each budget line.

9. Project Deliverables

Building of Photobioreactor Instructable,	June 8th, 2013
Photobioreactor Automation Instructable,	August 3rd, 2013

Final blog post summarizing the entire project	August 23rd, 2013
Final accounting report on all monies spent	August 30th, 2013
Final Instructable and PDF	August 30th, 2013