Team 7: Microalgae Photobioreactor

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Stephen Kassing

Presentation Outline

Why use microalgae as biofuel?
Background and motivation
Objectives for Fall 2013 semester
Algae growth process
Concentration and mass flow sensors design improvements
Mini-bioreactor test unit
Automatic Media Addition & Algae Extraction Units
Gantt Chart
Conclusion and Questions

Stephen Kassing

Why use Microalgae?

- Current resources are becoming unsustainable and have a negative effect on the environment.
- Microalgae has the highest energy per-acre output than other biofuels.
- Absorb carbon dioxide and release oxygen.
- Can be grown in many different environments as compared to other biofuels.

Stephen Kassing

Background and Motivation

- Current Operation
  - Photobioreactor is a batch operation
  - Requires lots of labor to maintain and change batches.
  - Every measurement and operation must be done manually.

- Desired Operation
  - Continuous Photobioreactor operation
  - Automated measurements

Stephen Kassing

Team 7 Objectives

- Change batch to continuous growth system.
- Compare growth of two different species of microalgae.
- Design and build mini-bioreactor test unit.
- Improve previously developed mass flow and concentration sensors.
- Design and develop automatic growth addition and extraction units.
- File invention disclosure and patent for select sensors.

Stephen Kassing

Microalgae

- In order to test our sensors algae must first be grown.
- Must find a source to cultivate the algae in during the algae’s early growth stages.
- A comparison test will be used on two different methods for algae cultivation using two different species of algae for each method (Chlorella and Scenedesmus).

First method, which is denoted as Batch #1, is grown using methods directly from the algae supplier, Carolina biological supply company (Carolina.com).

Batch #1

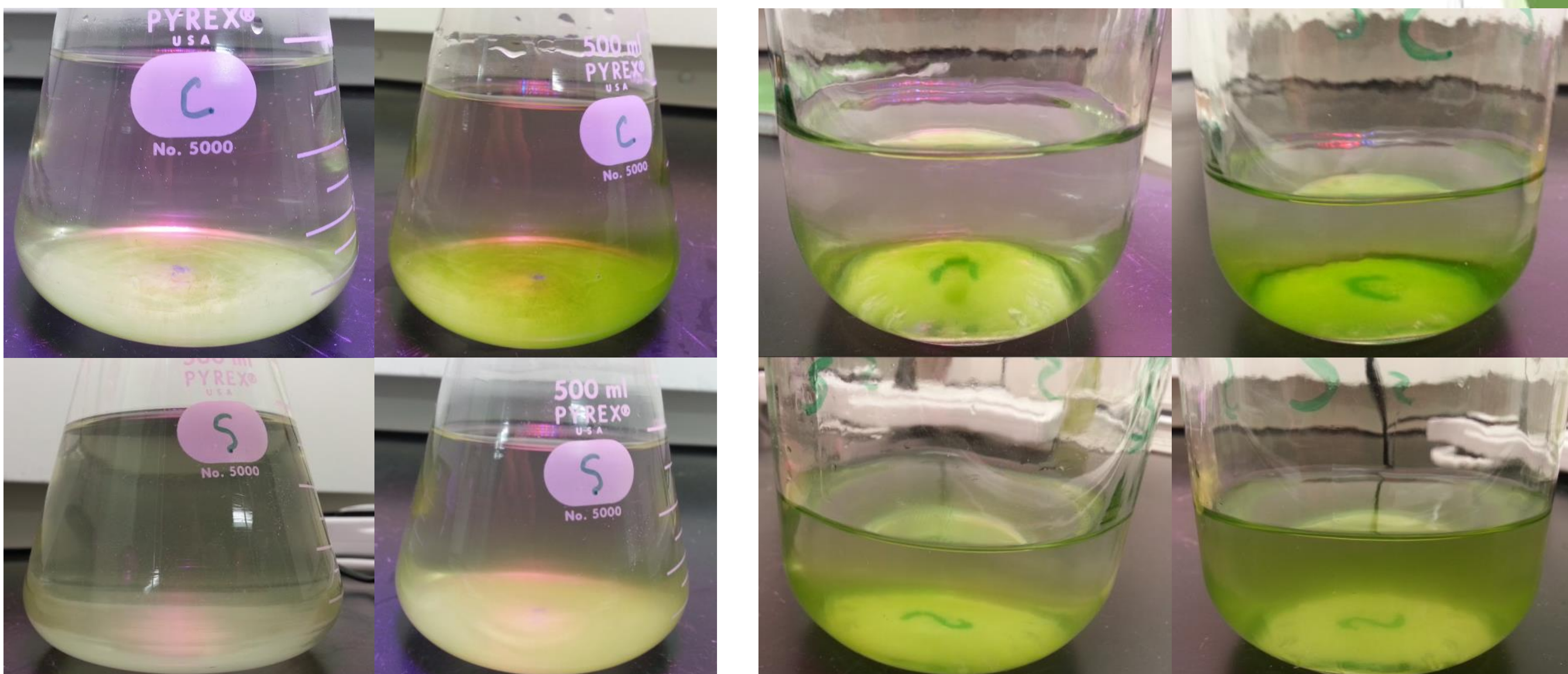
Second method, Batch #2, will be grown on a cycle very similar to the methods used in Brazil.

Batch #2

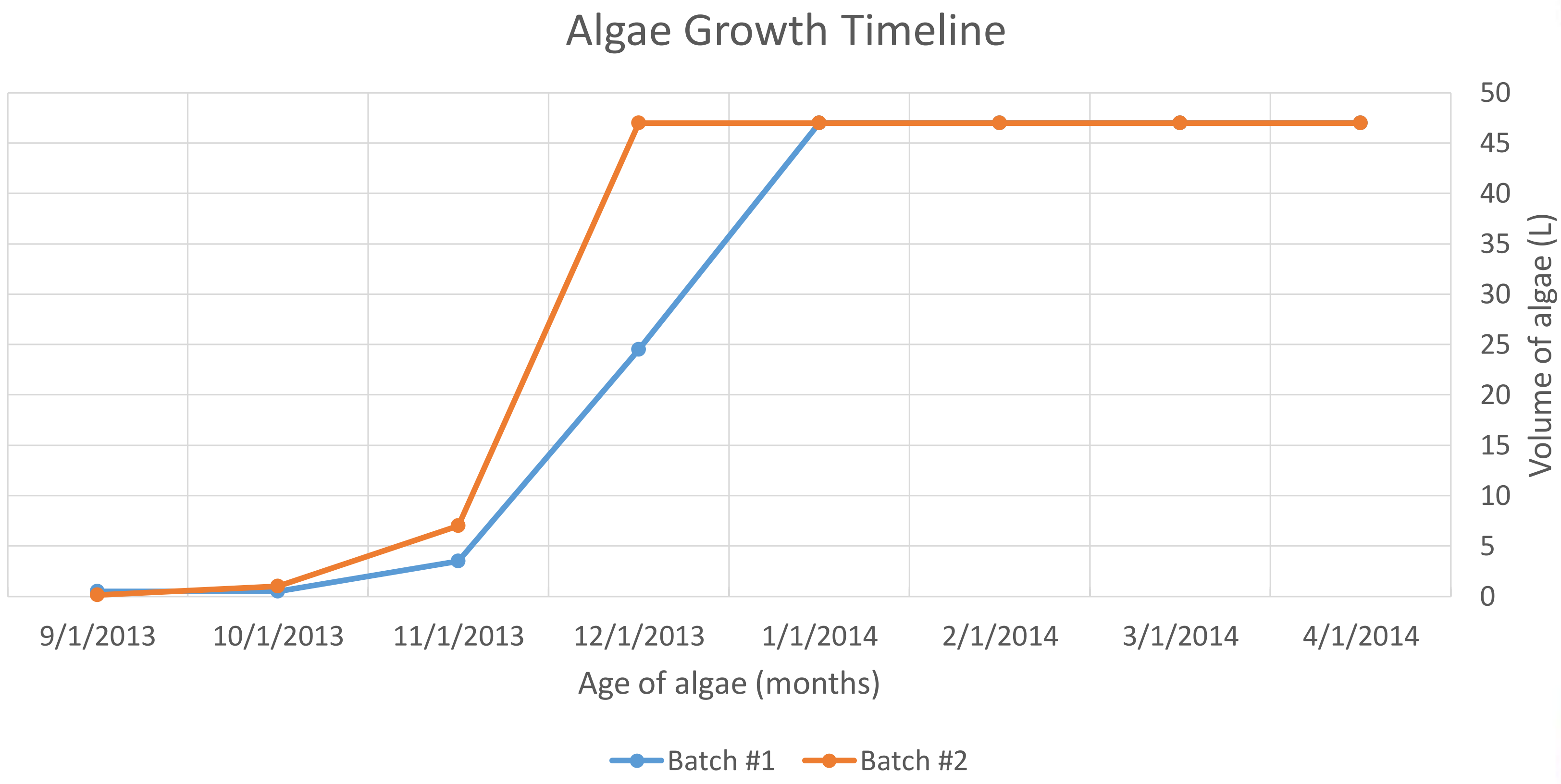
Markus Dillman

Microalgae Today

Batch #1 (10-16-13) Batch #1 (10-22-13) Batch #2 (10-16-13) Batch #2 (10-22-13)



Microalgae Timeline

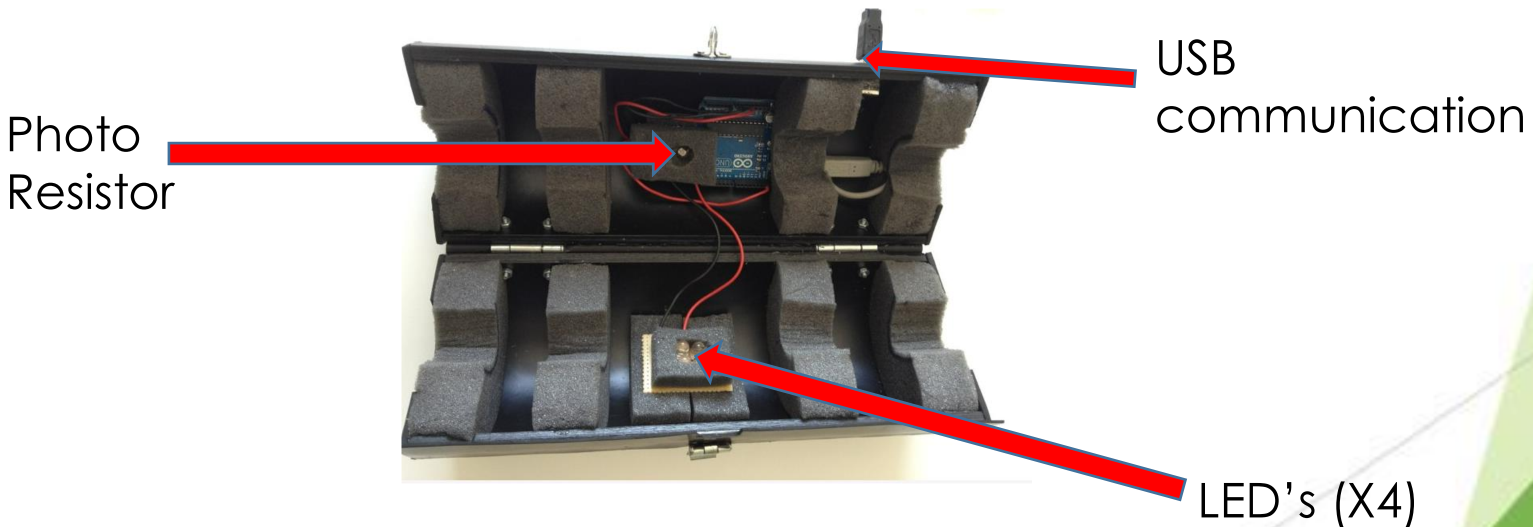


Concentration and Mass Flow Sensors Design Concepts and improvements

- Several design concepts have been made to improve the system and the next few slides will describe them and how they are an improvement from the original.

Current Concentration Sensor

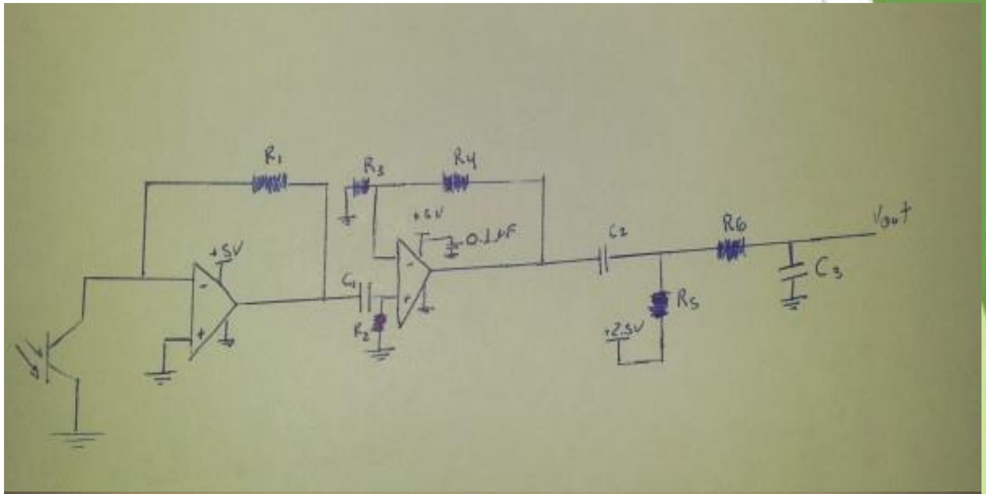
- 4 LED’s emit light through the PVC pipe to a sensor on the other side of the pipe. This sensor’s resistance varies with the amount of light and is converted to voltage.
- Calibration comes from doing comparison tests from counting the algae under a microscope and correlating it to the resistance recorded from light sensor.
- This is a manual operation and very time consuming.

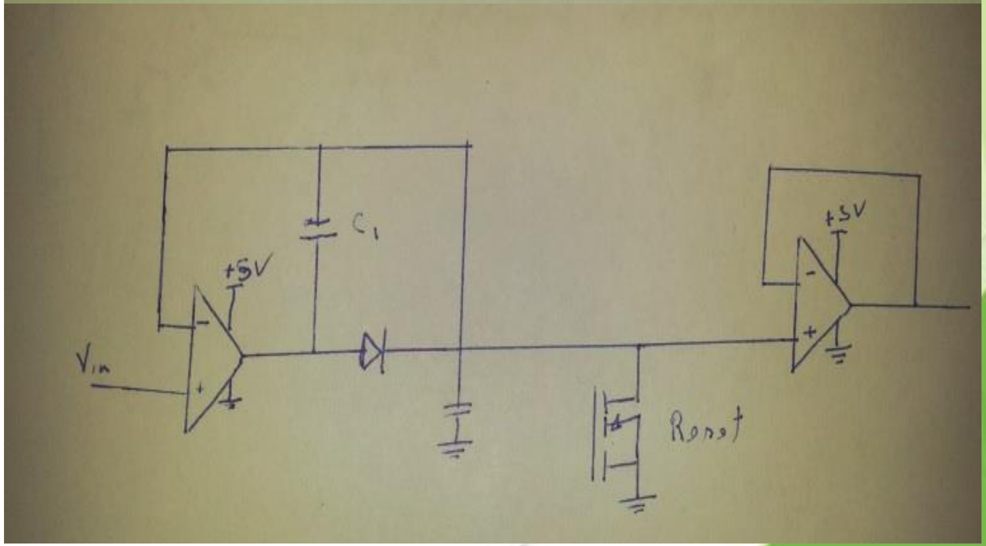


Concentration Sensor Improvements

- Another possibility
  - IR receiver emitter
    - An IR LED emit light through the pipe for the receiver which reads as voltage.
    - Shorter wavelength should result in less noise.

  - Add Peak detection, as the values shouldn't change during one measuring process.





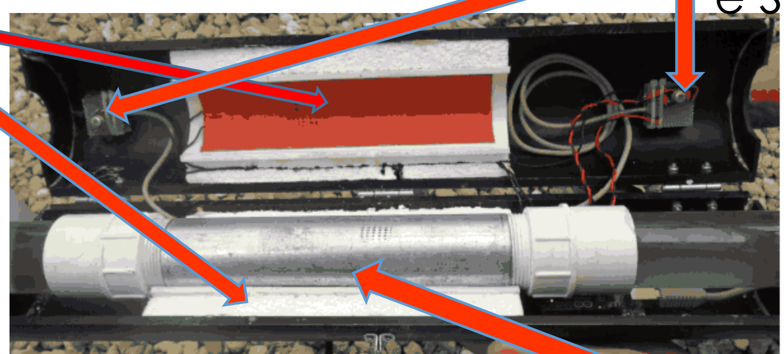
Diego Soler

Current Mass Flow Sensor

- Mass flow is measured using a basic thermodynamic property which correlates heat input to mass flow rate and the equation is below.
- $\dot{m} = \dot{Q}/(C_p * \Delta T)$
- Must be powered using standard wall outlet and must be connected to a computer to record data.

Temperatur
e Sensor

Heat
inpaut
pad (X2)

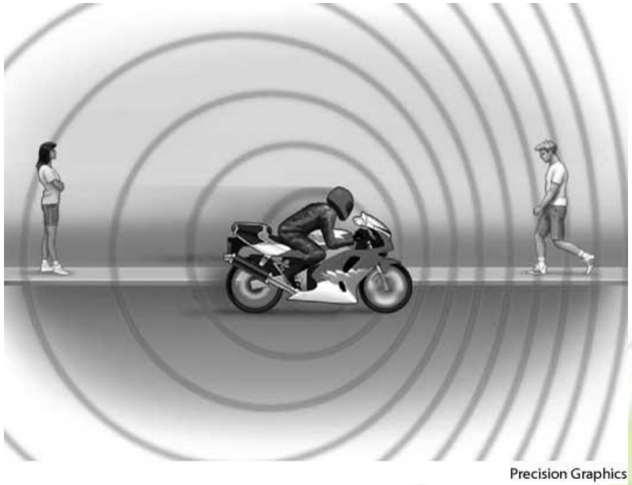


Steel pipe

Mass Flow Sensor Improvements

- Another possibility
  - Ultra sonic sensor
    - An sensor sends a ultrasonic wave that will be reflected by the algae's on the flow which will result in a shifted frequency, then the sensor receives it and convert this shift on velocity (Doppler Effect).
    - Has a patent involved, we cannot get an invention disclosure using this but can still use it to record data.

$4.91 at amazon.com

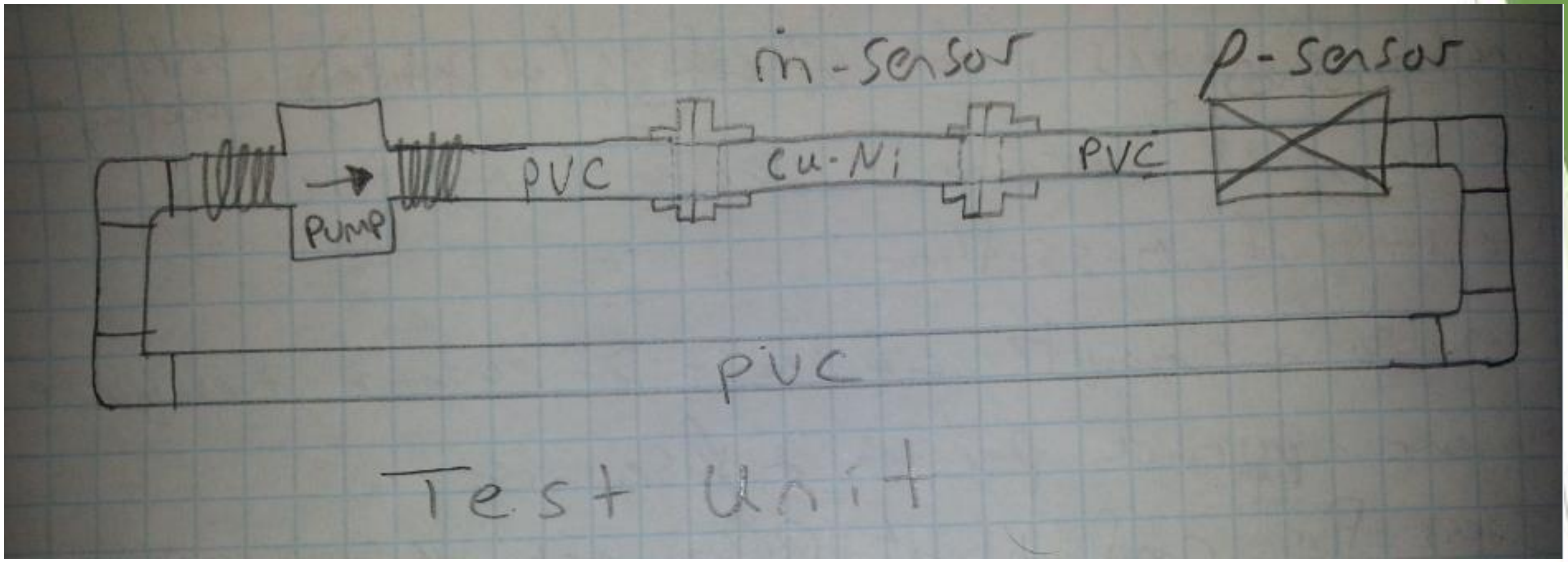


Mini-bioreactor Test Unit

- In order to optimize the existing system a test unit will be made to test the existing sensors and to also test the new sensor design concepts.

- Concepts and improvements are as follows:
  1. Material selection for metal pipe used in mass flow calculations.
  2. Connection interfaces and their fasteners.
  3. Orientation of degassing column, pump and clear piping network.

Mini-bioreactor Test Unit



- Simple set up and operation.
- Will need 12X less algae water mixture to operate (1 Gallon total).
- Cost will be dependent on the price of the 304 stainless steel for the flanges and for the new metal pipe, the PVC is already provided, estimated at 150$.
- Fasteners for the pump are under 5$ total.
- Elbows are under a dollar each.
- Total $159.50+tax.

Markus Dillman

Material Selection for Metal Pipe

- In order to minimize the exposure of high temperature to the algae a more efficient method of transferring the heat input to the algae is required.
- A material with a higher thermal conductivity is needed
- Algae starts to die around 30-31˚C minimizing the temperature difference that it can be exposed to.
- This will benefit the system by reducing the total time for the pipe to reach steady state operational temperature also reducing the cool down time to reach steady state ambient temperature.
- Overall reducing the high temperature exposure to the algae.
- The requirements are that the material be corrosion resistant, have a high thermal conductivity and to be rigid.
- Possible selections are aluminum 6061 or a copper-nickel (70/30%) alloy based on thermal conductivity charts.

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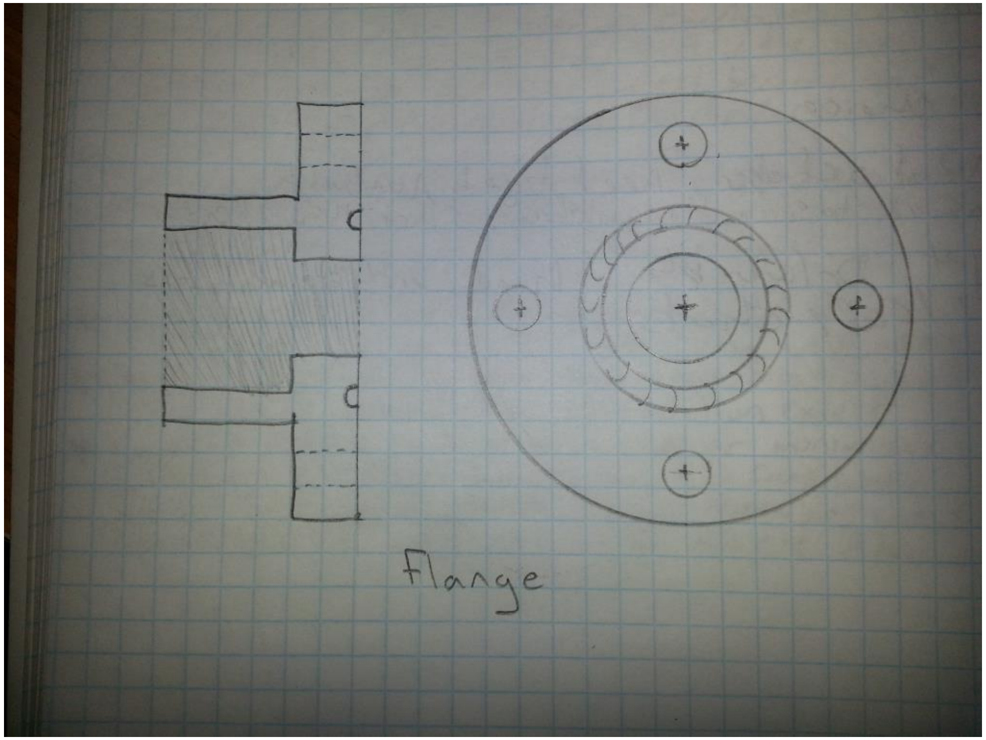
Easy Connect and Disconnect

- Using a flange an easy quick connect and disconnect will benefit the overall design.
- Cost is increased but overall maintenance of the bioreactor will decrease.
- O-ring insert to prevent leaks.



- To take apart a single section of the bioreactor from last year would require to cut and remove pipe and to re-glue new fittings and pipe sections that are lost from cutting.

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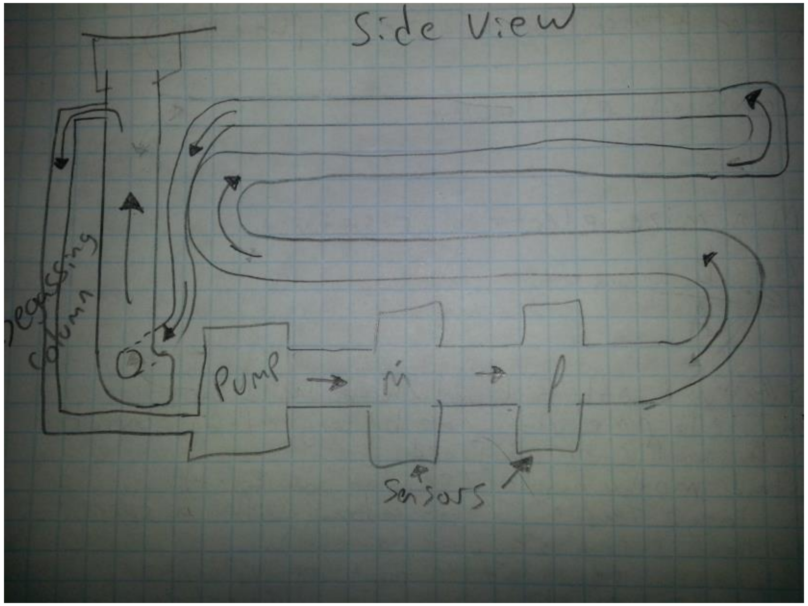
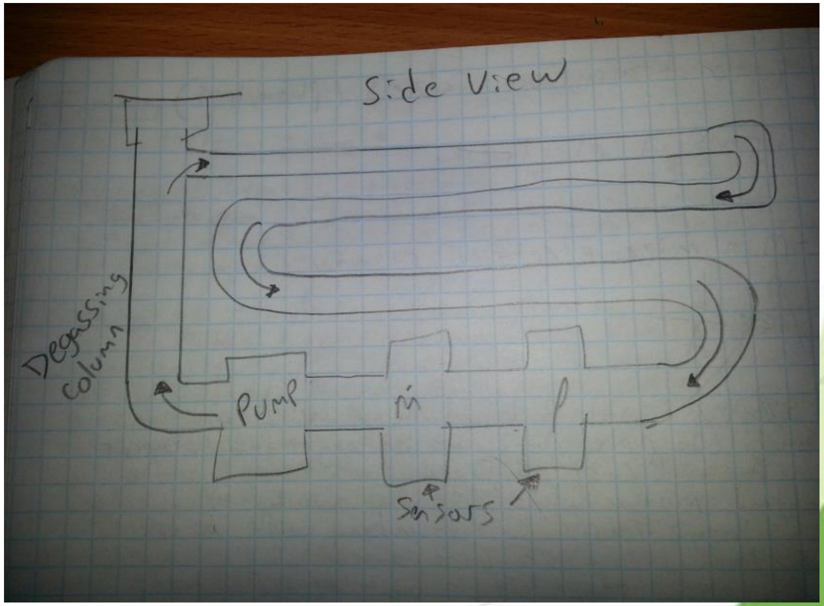
Pump and Piping Network

- As of right now the pump pumps the algae up the piping system and into the bottom of the degassing column.
- To decrease the pumping power required have the pump flow into the bottom of the degassing column and once the fluid reaches the top have it flow downhill through the rest of the piping network and back to the pump.
- Overall reducing the heat generation by the pump into the system.

Existing



Improved



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NEXT…

UFPR

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Automatic Media Addition & Algae Extraction Units

UFPR Team:
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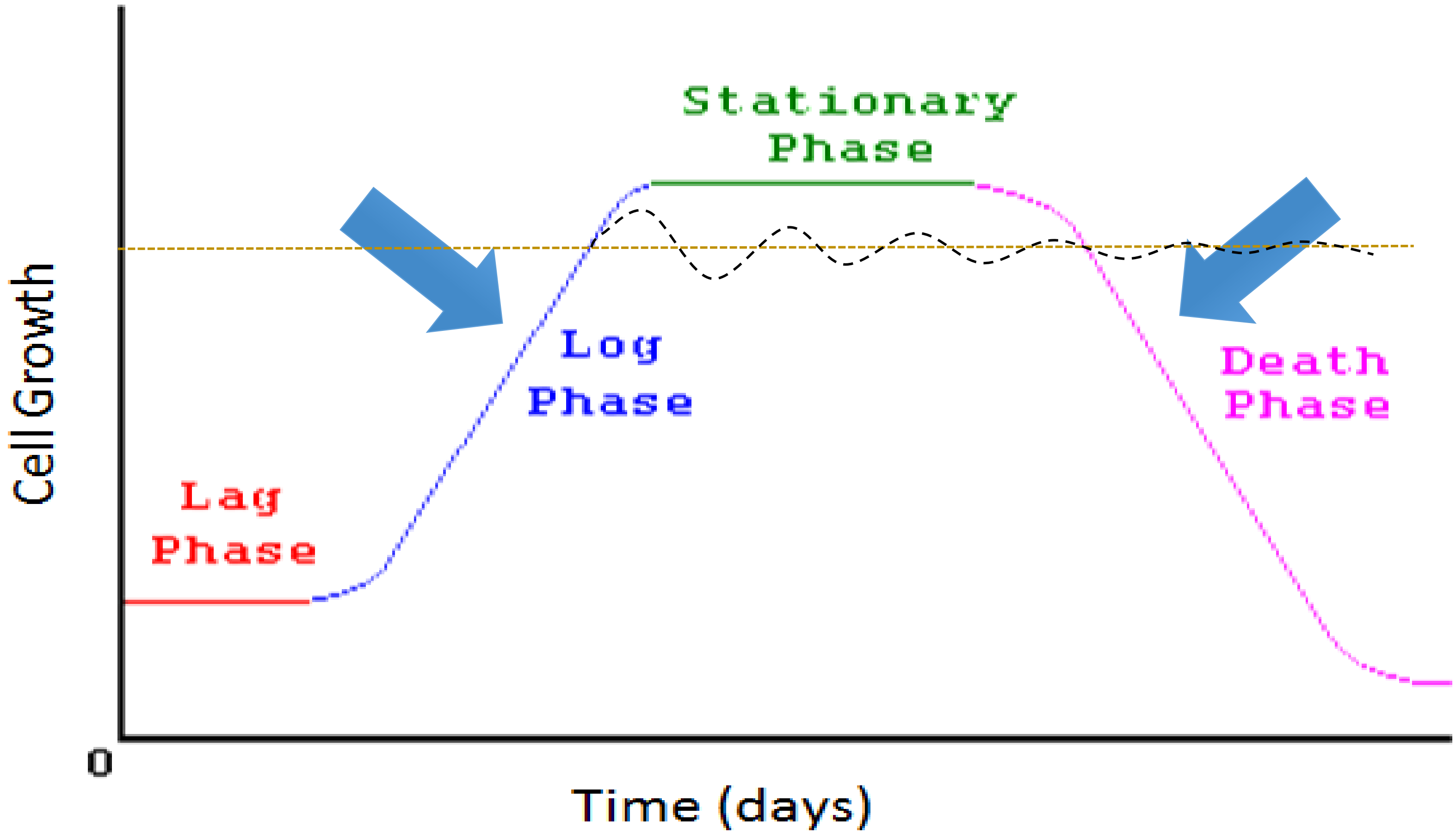
Dylan Oliani
Kassiana Ribeira
Matthew Vedrin

Matthew Vedrin

Background Review



http://www.peakprosperity.com/forum/population-growth-s-shaped-not-exponential/7250

Matthew Vedrin

Background Review

- Motivation:

http://ethicaalimenticia.blogspot.com.br/2013/05/eu-sou-marinheiro-popeye.html

http://disneywallpaper.org/wall-e-894772.html

automated continuous operation → increased production rate + reduction of manual labor

http://npdeas.blogspot.com.br/

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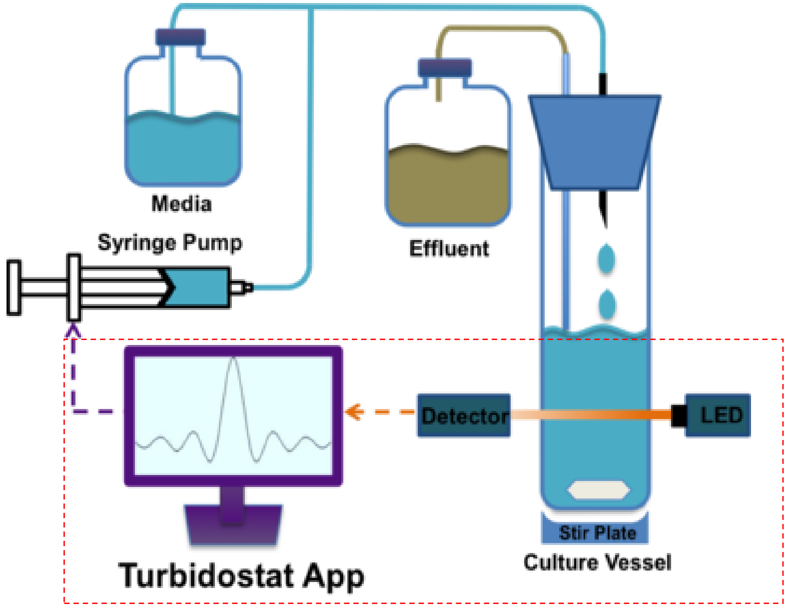
Background Review

- Known continuous operation device
  - Turbidostat
    - Control: Feedback
    - Measurement: Turbidity
    - Objective: Steady State (Active Control)



http://2012.igem.org/Team:Washington/Plastics

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Basic Mathematical Analysis

Basic Theory

$$D = Dilution\ Rate = \frac{Media\ flow\ rate}{Culture\ volume} = \frac{F}{V_{tot}}$$

$$\mu = specific\ growth\ rate = \frac{\ln\left(\frac{m_{t2}}{m_{t1}}\right)}{t_2 - t_1}$$

$$C = concentration = \frac{n_{cells}}{V} = \left[\frac{\#\ cells}{unit\ volume}\right]$$

$$m = \boxed{C \times m_{avg/cell} \times V_{tot}}$$

$$\mu = \frac{\ln\left(\frac{m_{t2}}{m_{t1}}\right)}{t_2 - t_1} = \frac{\ln\left(\boxed{\frac{C_{t2} \times m_{avg/cell} \times V_{tot}}{C_{t1} \times m_{avg/cell} \times V_{tot}}}\right)}{t_2 - t_1} = \frac{\ln\left(\frac{C_{t2}}{C_{t1}}\right)}{t_2 - t_1}$$

Determine Feed Rate

$$D = \mu = \frac{F}{V_{tot}} = \frac{\ln\left(C_{t2} / C_{t1}\right)}{t_2 - t_1}$$

$$\boxed{F = \frac{\ln\left(C_{t2} / C_{t1}\right)}{t_2 - t_1} \times V_{tot}}$$

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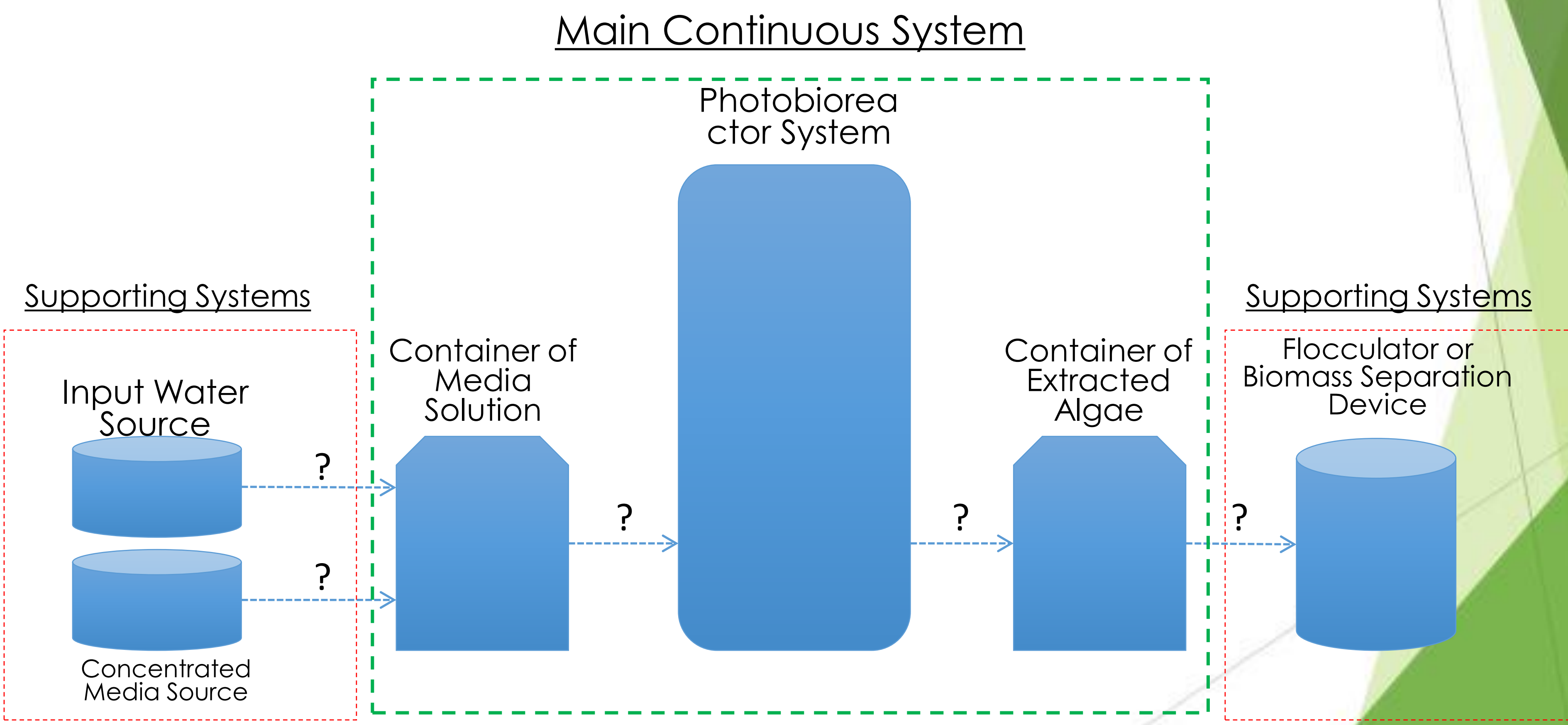
Design Options

- Basic Design Idea



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Design Options

Media Addition Unit			
Category	**Option 1**	**Option 2**	**Option 3**
Main Addition Equipment	Pump	Gravity Fed	
Supporting Addition Equipment	Automatic Check Valve	Solenoid Controlled Valve	Pneumatic Controlled Valve
Media Mixing Considerations	Pre-Diluted Media Solution	Controller Operated Mixing	
Operation	Continuous	Interval/Pulse	
Controller	Arduino Microcontroller		

Algae Extraction Unit			
Category	**Option 1**	**Option 2**	**Option 3**
Main Extraction Equipment	Overflow Fed	Gravity Fed	Pump
Supporting Extraction Equipment	Solenoid Valve	Pneumatic Valve	Check Valve
Algae Sedimentation Prevention	Mixing Arm	Sprinkler Flush System	Other Agitation
Operation	Continuous	Interval/Pulse	
Controller	Arduino Microcontroller		

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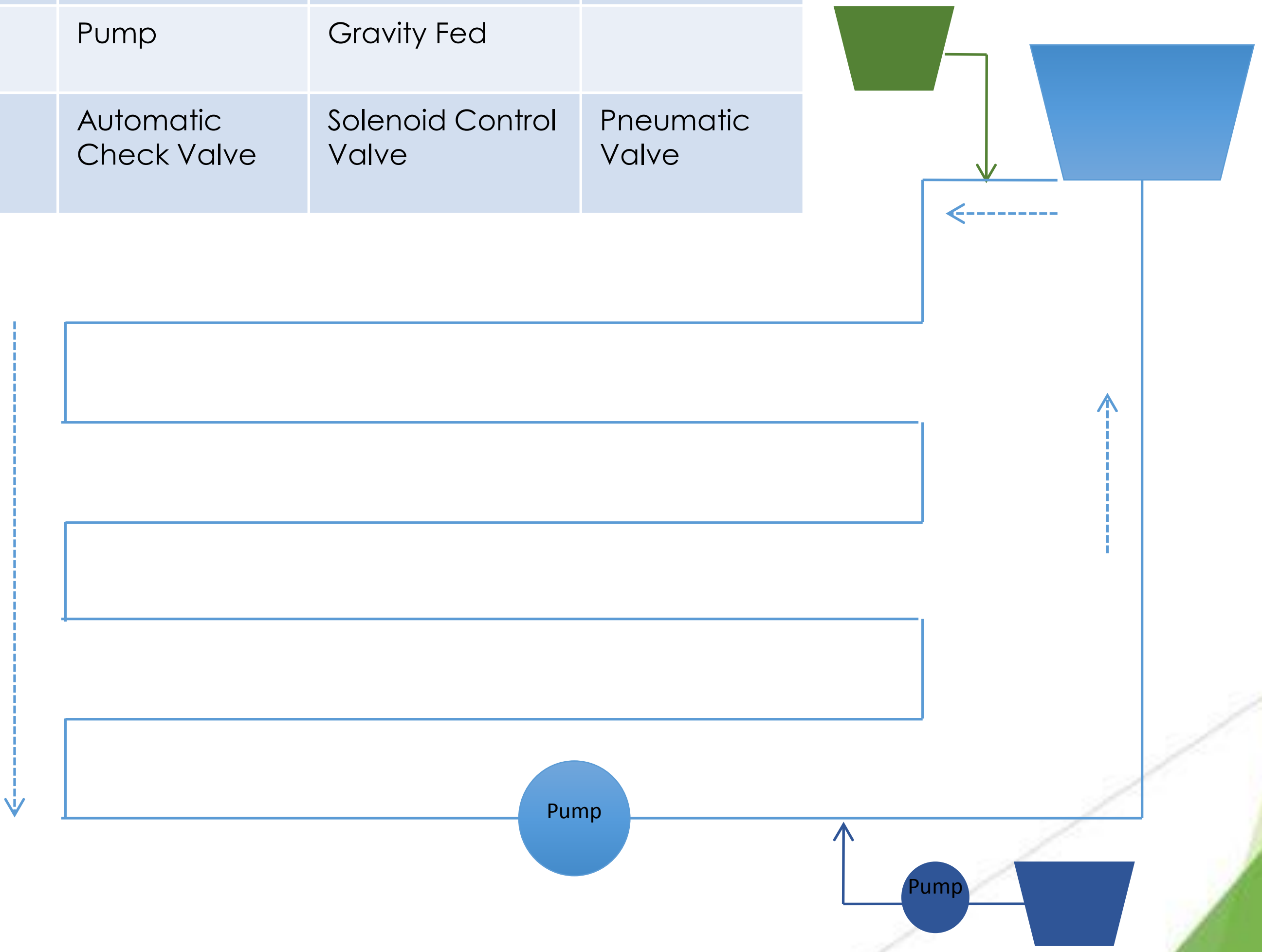
Design Options

Media Addition Unit			
Category	**Option 1**	**Option 2**	**Option 3**
Main Addition Equipment	Pump	Gravity Fed	
Supporting Addition Equipment	Automatic Check Valve	Solenoid Control Valve	Pneumatic Valve



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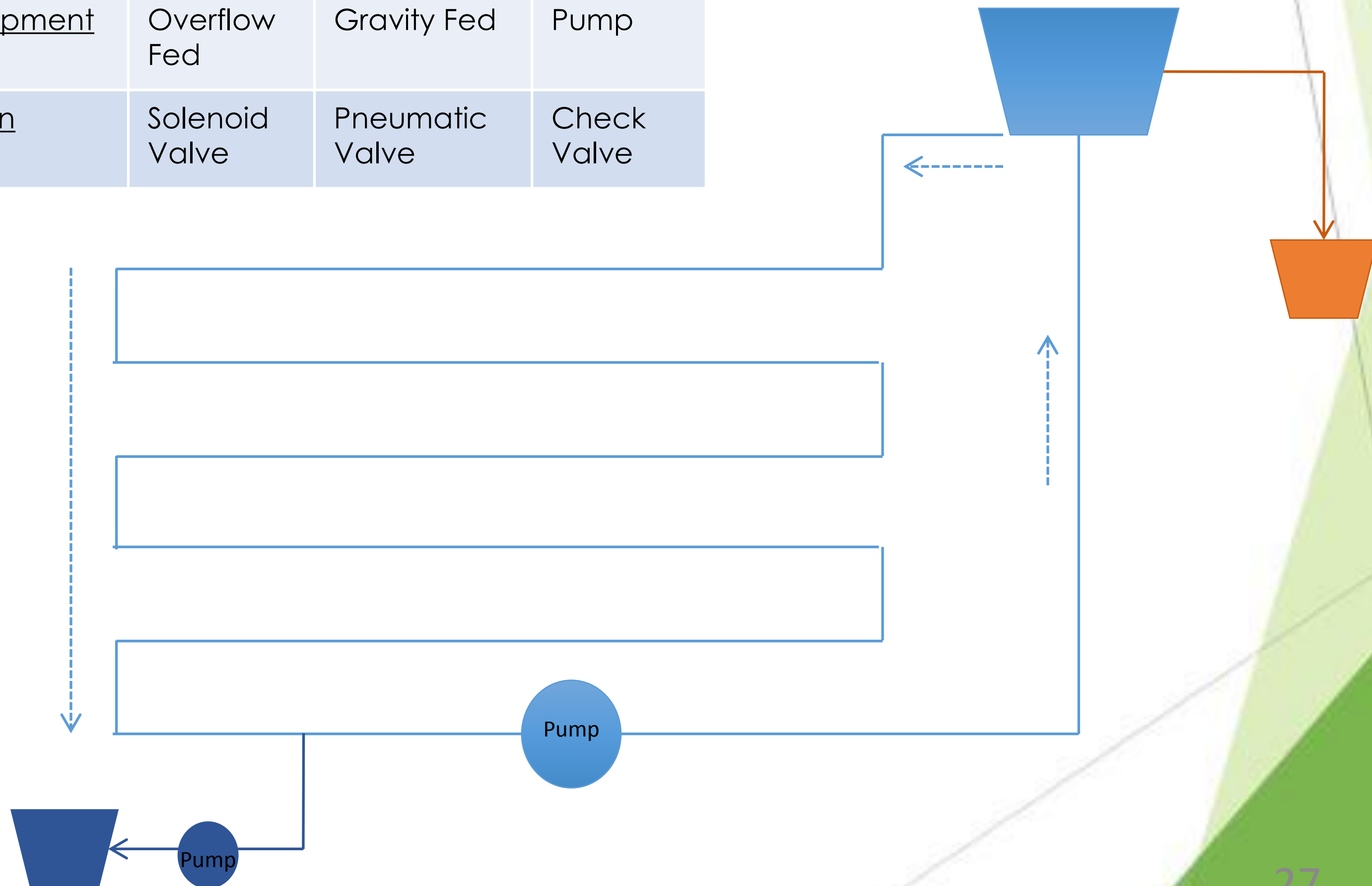
Design Options

Algae Extraction Unit			
Category	**Option 1**	**Option 2**	**Option 3**
Main Extraction Equipment	Overflow Fed	Gravity Fed	Pump
Supporting Extraction Equipment	Solenoid Valve	Pneumatic Valve	Check Valve



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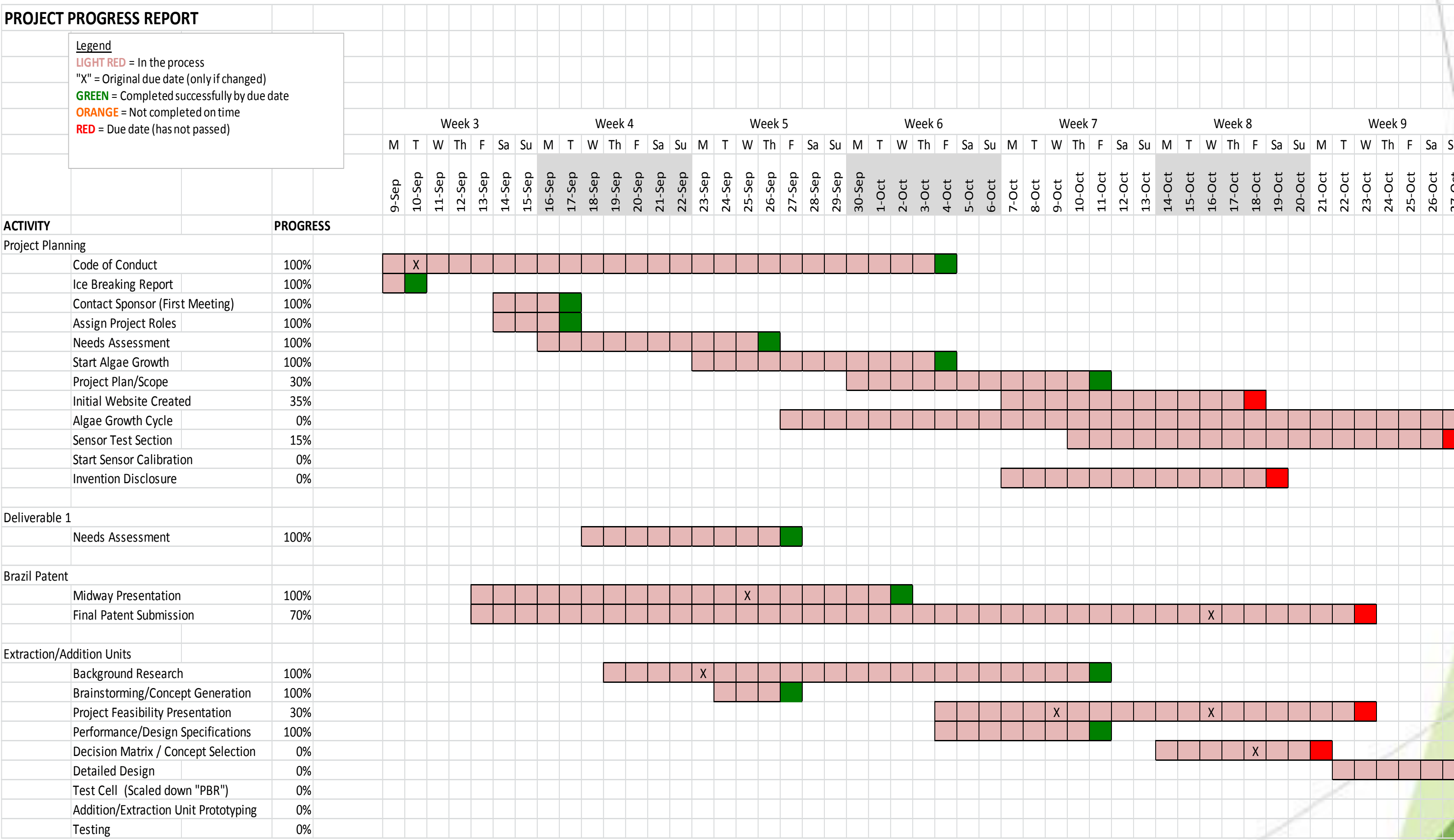
Gantt Chart



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Questions