Airlift Photobioreactor, Team 7
Final Presentation

April 17, 2014

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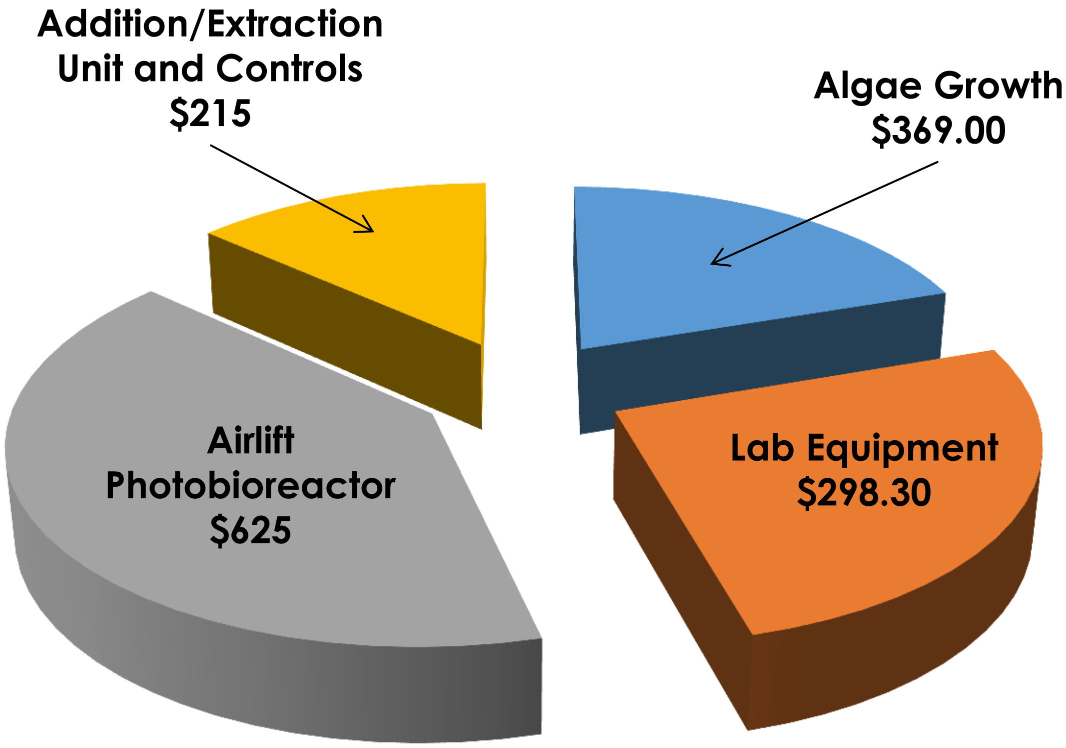
Presentation Outline

- Budget and Expenses
- Background and Objective
- Microalgae Growth
- Semi-Continuous Growth Curves
- Excising Photobioreactors
- What is an Airlift Photobioreactor?
- Our Photobioreactor Design
- Controls
- Addition and Extraction
- Future Improvements and Questions

Budget and Expenses



Background

Ultimate Goal = Biofuel

Microalgae ⟶ Biomass ⟶ Biofuel

Algae Growth

→

Biomass Extraction

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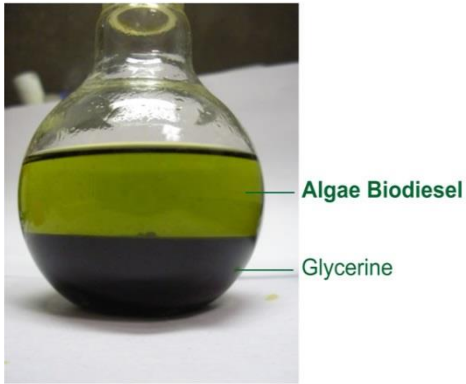


Oil is Refined using Glycerol

Objectives

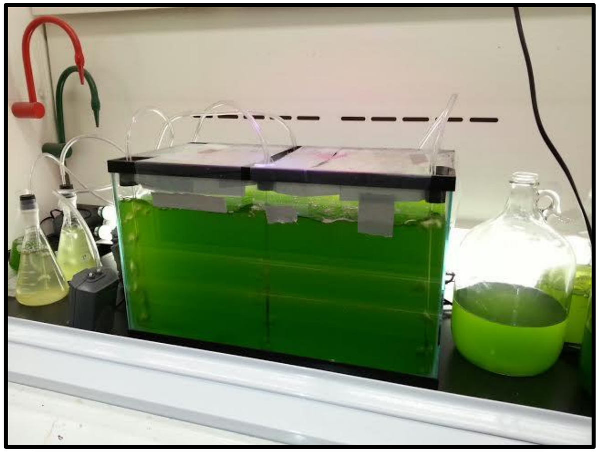
The customer needs a way to transform an airlift photobioreactor's current "batch" growth systems into a "semi-continuous growth system."

To accomplish this team 7 must:

- ✓ Grow and maintain a microalgae culture for design project experimentation
- ✓ Improve and modify last year's concentration sensor
- ✓ Design and build a prototype-scale airlift photobioreactor
- ✓ Design and develop fully automated addition/extraction units

Microalgae Growth

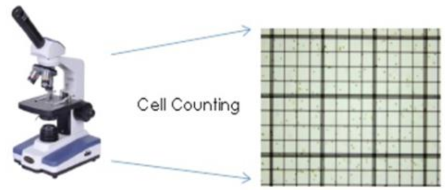
- Chlorella Vulgaris Microalgae
  - Resistant properties, optimal growth temperatures, low or high light growth levels
- Approximately 30L of Microalgae has been grown throughout the school year
  - Enough to fill the photobioreactor with some reserves leftover for further testing.
- Algae growth curves have been produced this semester to log the cell concentration and growth.

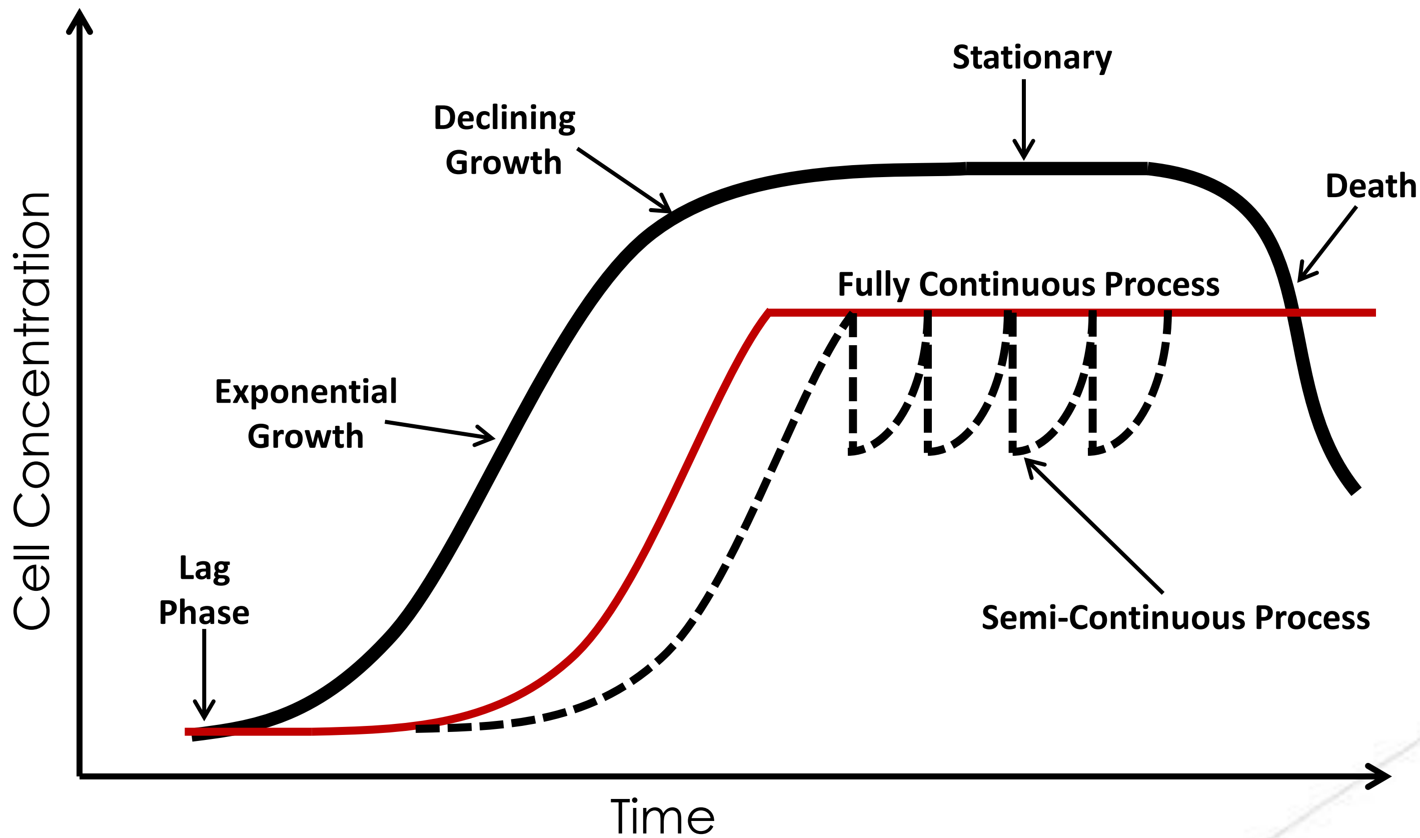


Erlenmeyer Flask Microalgae sub-cultured phase 1
Large Tank Microalgae sub-cultured phase 3
Gallon Jugs Microalgae sub-cultured phase 2

Microalgae Growth

How does the microalgae growth process work?





Microalgae Growth on a Small Scale

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Microalgae Growth on a Large Scale

Large-Scale Growth Photobioreactors

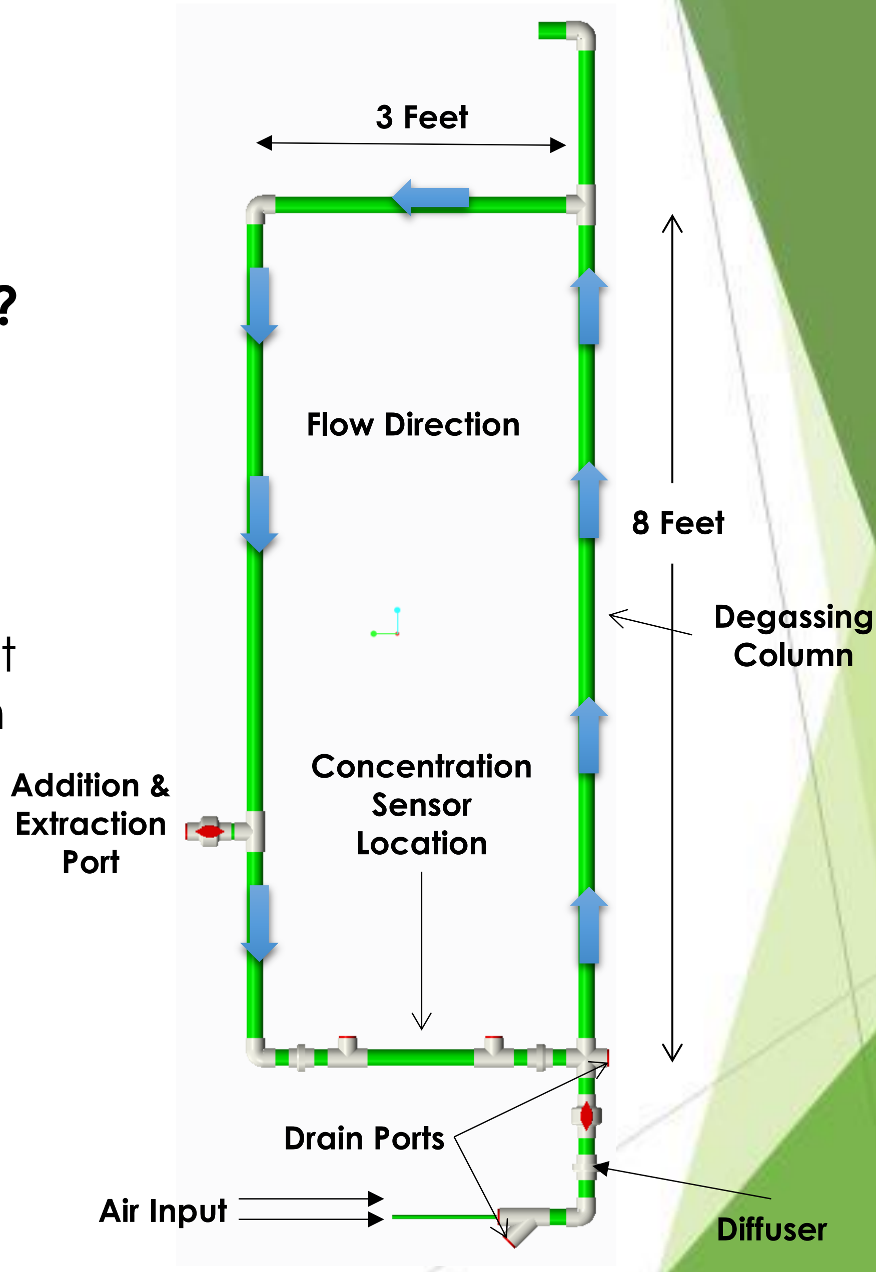
25L Airlift Photobioreactor used in Brazil

Main Commercial 10,000L Photobioreactor in Brazil

Airlift Photobioreactor

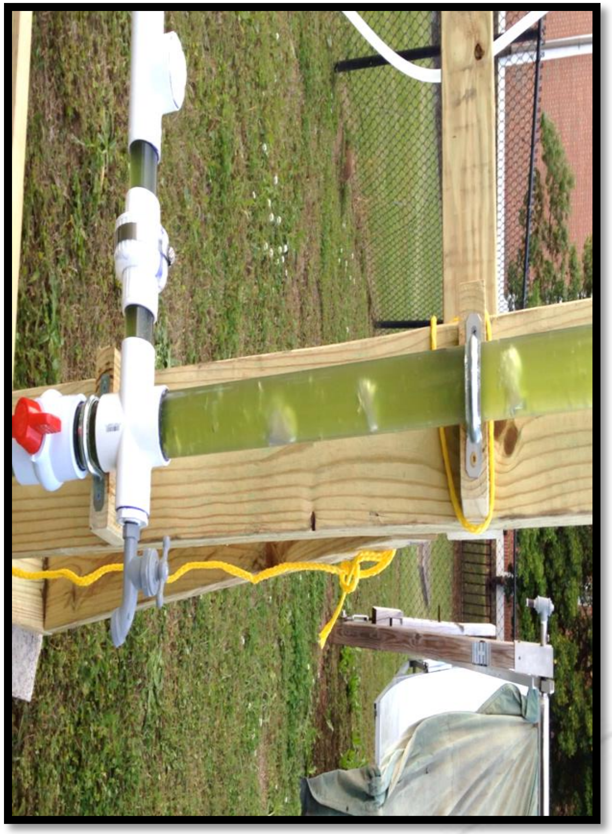
- **What is an airlift photobioreactor?**
  - A photobioreactor is container that grows living organisms using light
  - An airlift operated photobioreactor circulates the water using compressed air input and requires no pump operation

- **Benefits of Airlift ?**
  - Successful operation from Brazil.
  - Less water hammering
  - More energy efficient



Current Airlift Design

- What does our Photobioreactor look like today?
- Design maximizes area exposed to sunlight.
- Video time!

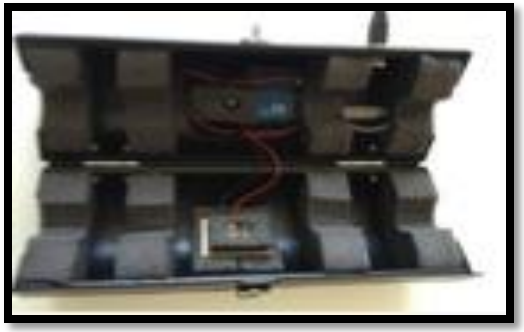


Controls – Overview

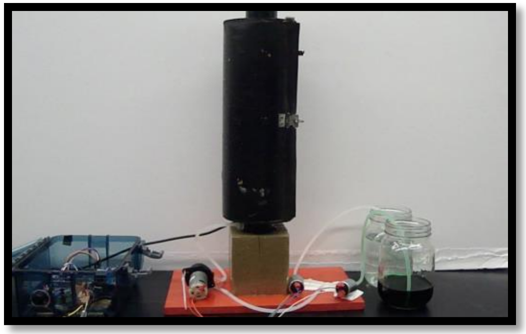
Batch operation: manual labor is reasonable

Semi-continuous operation: manual labor is not reasonable

<u>Conclusion</u>: Automated control systems needed

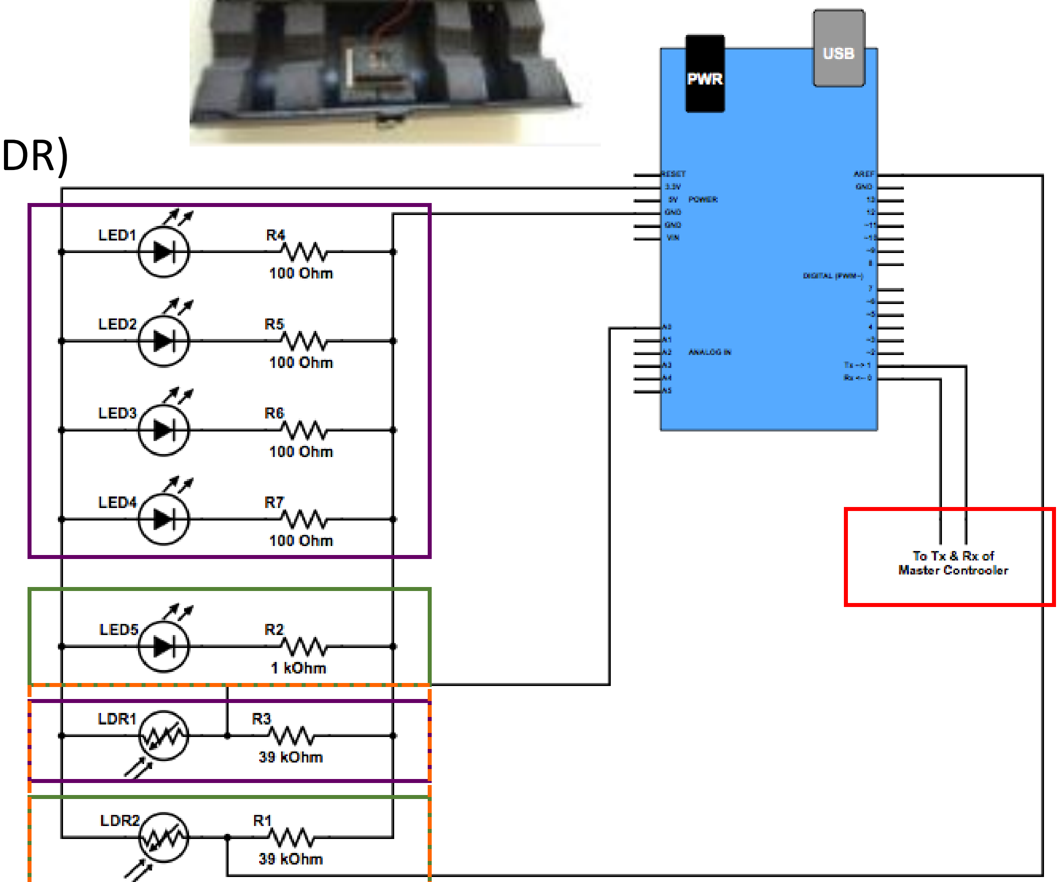


<u>Concentration</u>



<u>Addition/Extraction</u>

Controls – Concentration Sensor



Review

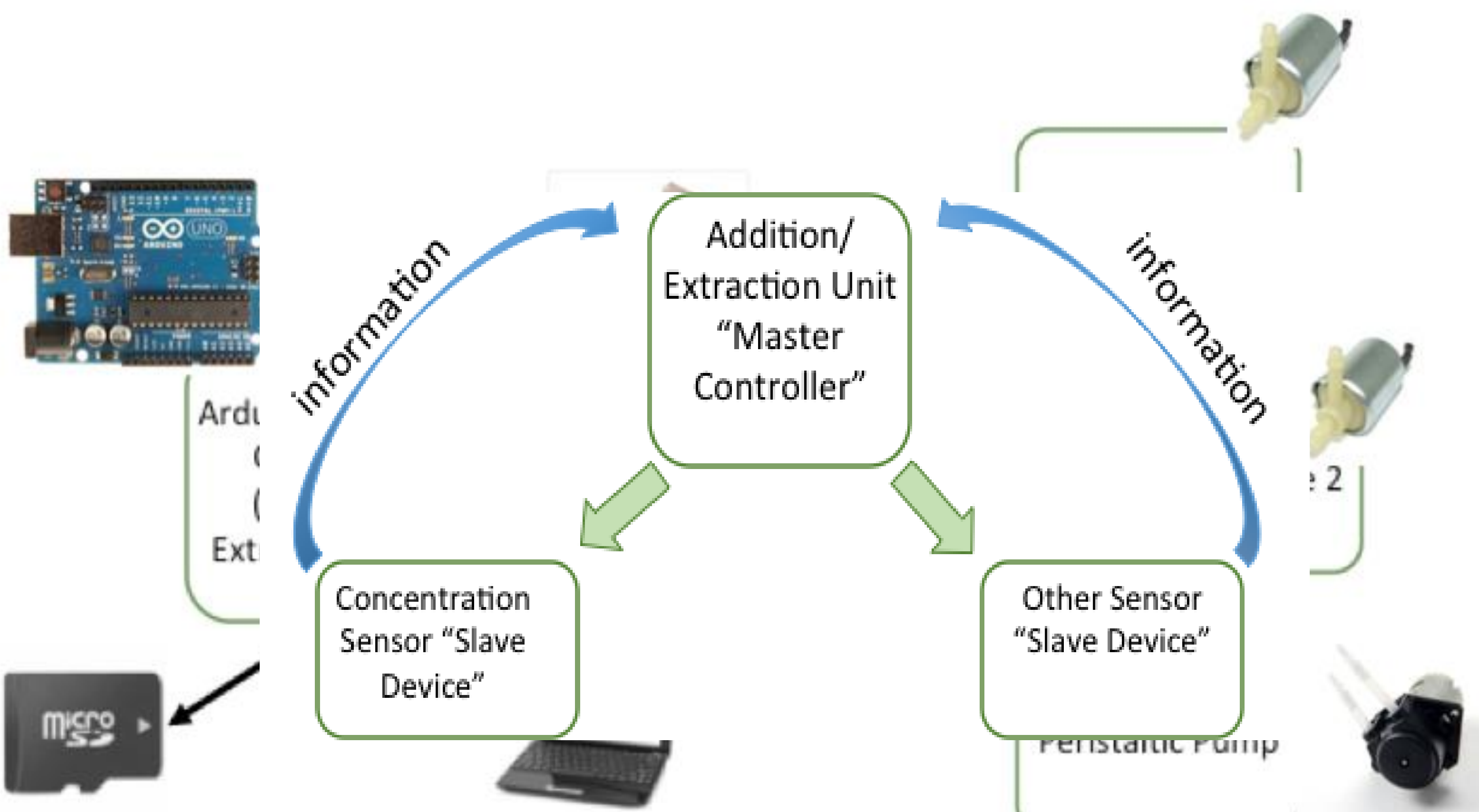
Electrical Components:

- Light Emitting Diode (LED)
- Light Dependent Resistor (LDR)
- Resistors

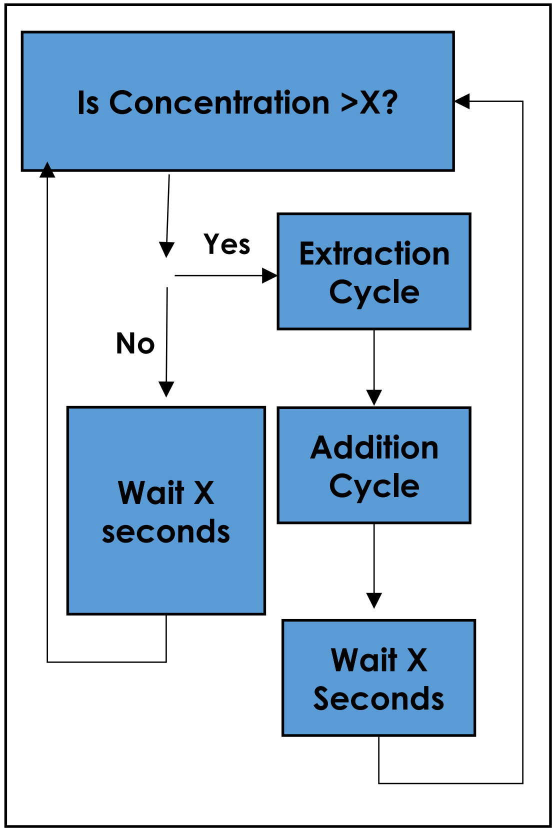
Main Sections:

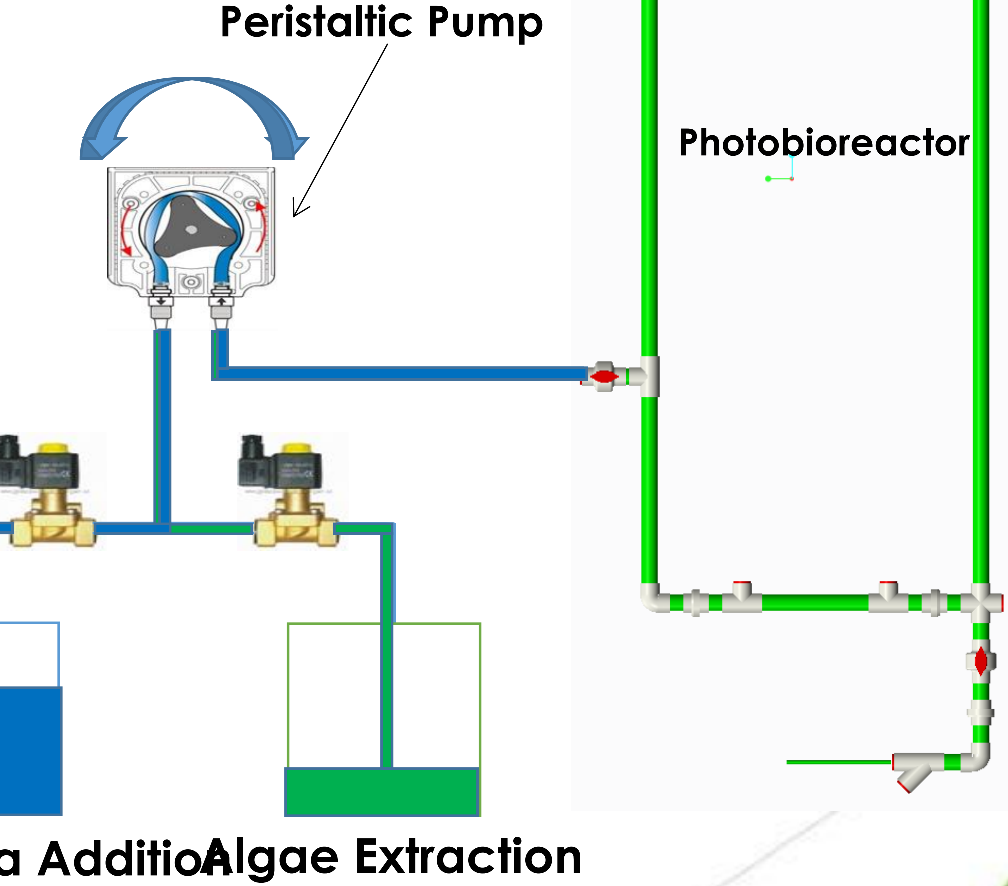
- Control
- Test
- Wheatstone Bridge
- Communication

Controls – Communication & Control Flow



Addition and Extraction Overview

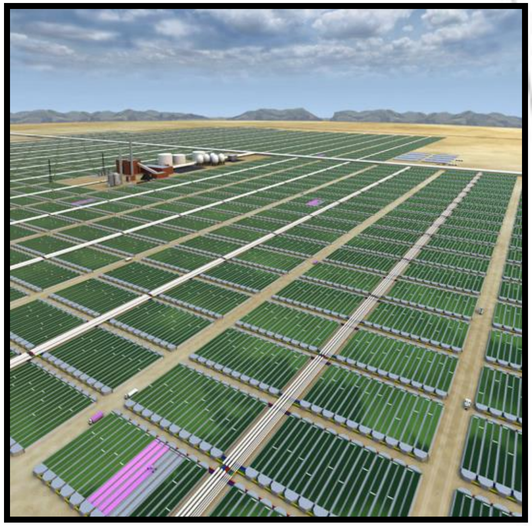




Addition and Extraction Demo

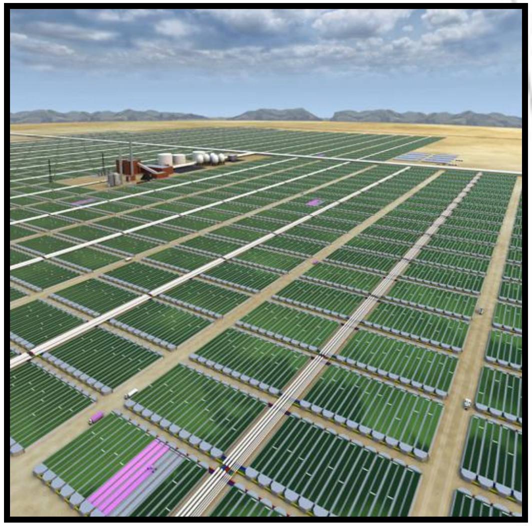
Project Results

- ✓ Successfully cultivated microalgae for project experiments using growth methods from Brazil.
- ✓ Designed and constructed automated addition/extraction unit controlled by an Arduino Uno microcontroller
- ✓ Improved concentration sensor's data-logging capabilities via serial communication with addition/extraction unit
- ✓ Designed and assembled working airlift photo-bioreactor based on previous designs at UFPR



Future Improvements

- ✓ Research alternative algae growth media
- ✓ Further develop non-invasive mass flow sensor
- ✓ Research and develop continuous addition/extraction system
- ✓ Create a large scale system capable of increasing the production of microalgae
- ✓ Optimization of algae growth using automated sensors and addition/extraction system



Project Learning

- ✓ Cross-disciplinary work (biology, mechatronics, mechanical systems, CAD design)
- ✓ International collaboration and communication
- ✓ Teamwork and group dynamics
- ✓ Advisor meetings
- ✓ "Hands on"
- ✓ Project management

Thank You

Any Questions?

Algae Growth Equations

- Batch System Analysis (Exponential Growth)
  - Idealized: No limiting factors (i.e. sufficient light, food, gas exchange, etc.)
  - Real: Clouds, rain, imperfect gas exchange

$$X = X_0 e^{kt} \dashrightarrow X_t = X_0 e^{mt} \dashrightarrow \boxed{m = \ln(X_t / X_0) / t}$$

$$\frac{\ln(X_t / X_0)}{t} = \frac{d}{dt}\ln(X) = \frac{d\ln(X)}{dX} \times \frac{dX}{dt} = \frac{dX / dt}{X} \dashrightarrow \boxed{m = \frac{dX / dt}{X}}$$

- Physical significance of specific growth rate: rate of change in concentration over concentration

X_0 ° *Initial concentration* $= [g / L]$ t ° *Time* $= [h]$ dX ° *Differential change of concentration* $= [g / L]$

X_t ° *Concentration at time,* $t = [g / L]$ m ° *Specific growth rate* $= [h^{-1}]$ dt ° *Differential change of time* $= [h]$

Algae Growth Equations

- Continuous System Analysis (Mass Balance)

$$\textit{Net increase in biomass} = \textit{Growth} - \textit{Biomass removal}$$

$$VdX = V\mu Xdt - FXdt \longrightarrow \frac{dX}{dt} = \mu X - \frac{F}{V}X = (\mu - D)X$$

<u>Steady State</u>

$$\frac{dX}{dt} = 0 \rightarrow \mu = D$$

<u>Transient State</u>

$$\frac{dX}{dt} = (\mu - D)X$$

$$\mu' = \frac{dX/dt}{X} = (\mu - D)$$

$dx \equiv$ *Differential change of concentration* $= [g/L]$

$dt \equiv$ *Differential change of time* $= [h]$

$V \equiv$ *Total volume* $= [L]$

$\mu \equiv$ *Specific growth rate* $= [h^{-1}]$

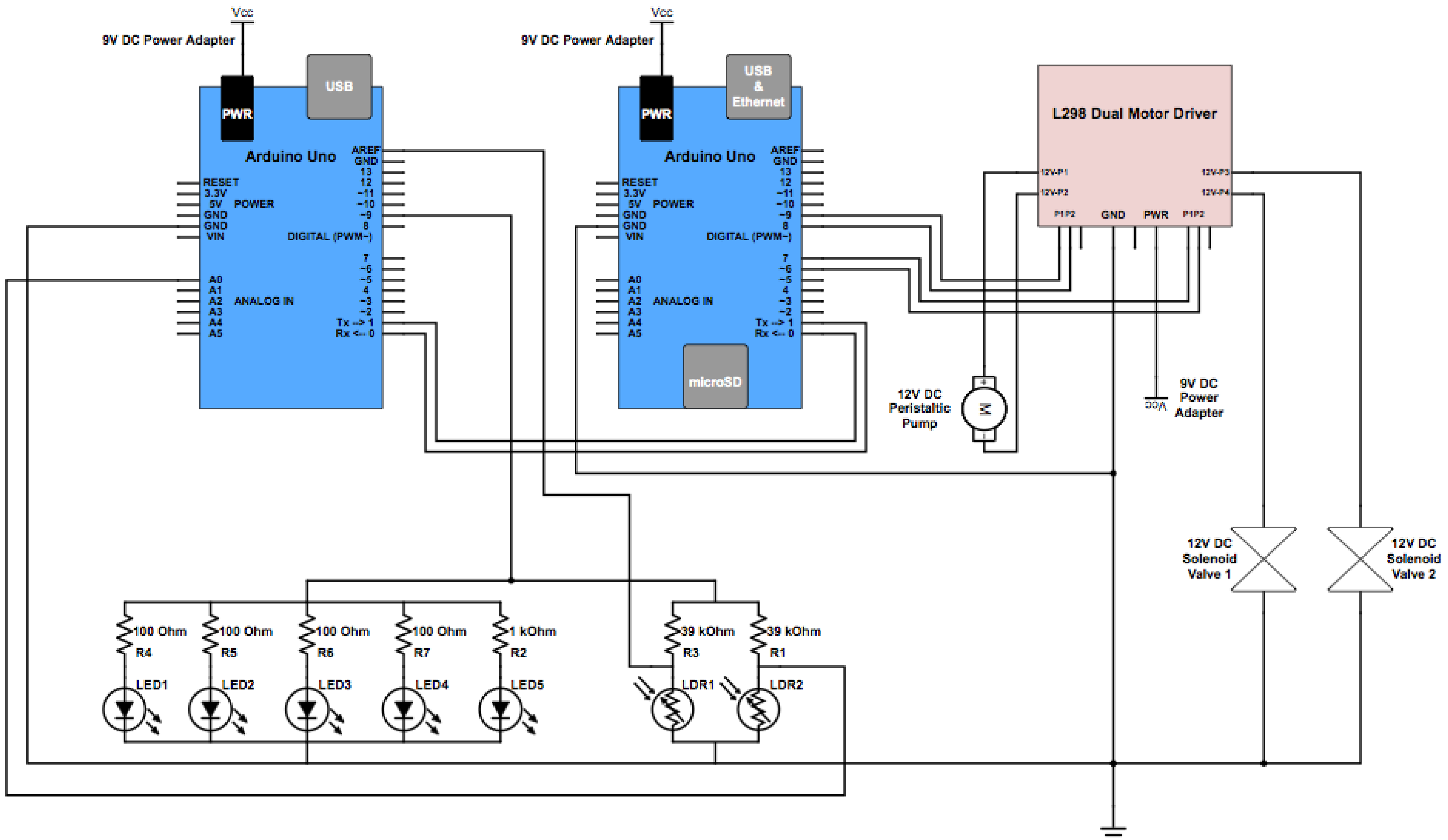
$X \equiv$ *Concentration* $= [g/L]$

$F \equiv$ *Addition rate* $= [L/h]$

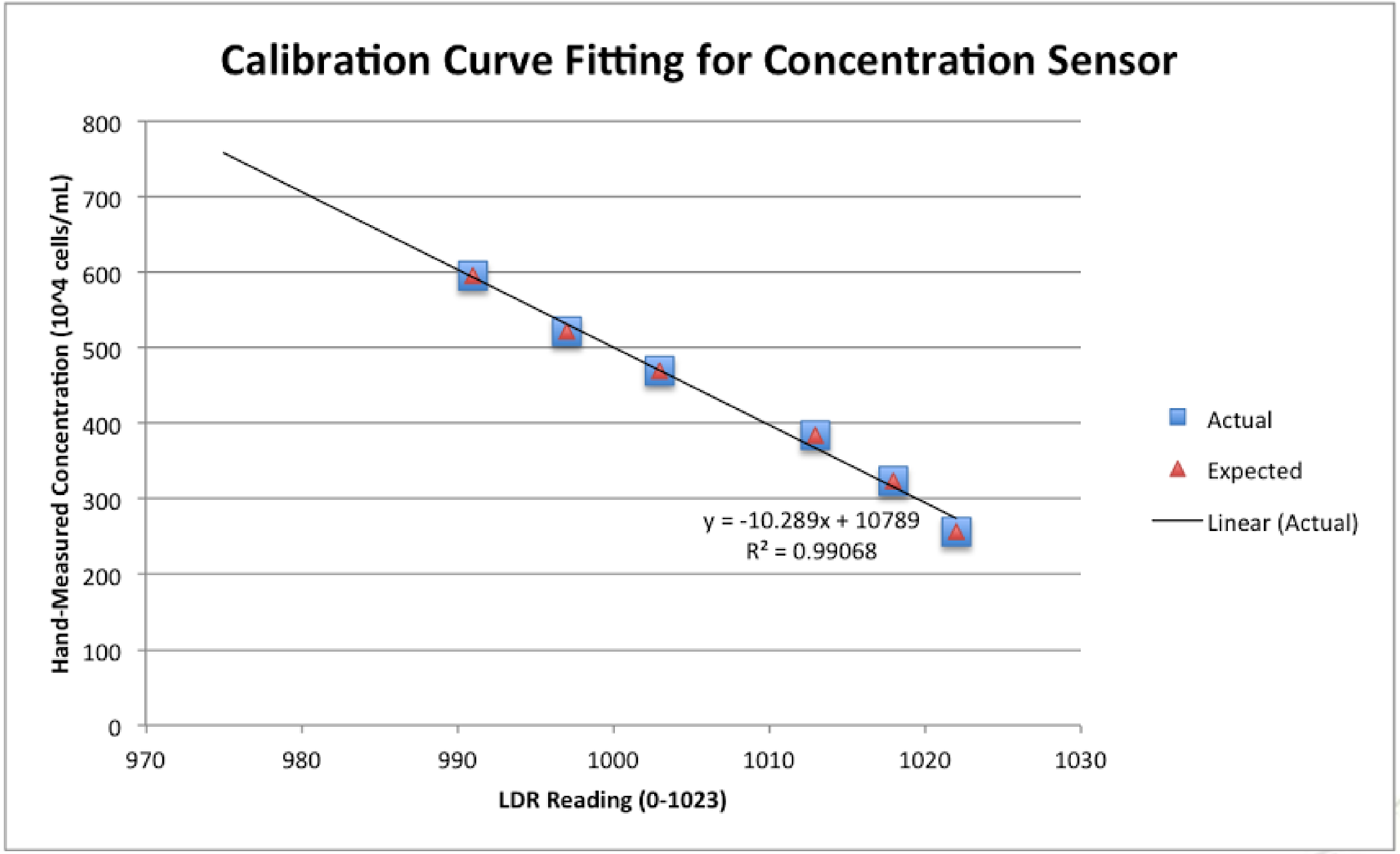
$D \equiv$ *Dilution rate* $= [h^{-1}]$

Matthew Vedrin

Control Diagram



Concentration Sensor Calibration



Biomass/Biodiesel Production

- PBR production capability (from Brazil): 1 – 8 g/L/day biomass
- Our unit (theoretical): 9 – 72 g/day biomass for 9L Airlift
- At 40% lipid content → 3.6 – 28.8 g/day oil
- Assume algae density ~920 g/L → 0.004 – 0.031 L/day

Program Process Flow

PROGRAM SECTION	MASTER CONTROLLER (ADDITION/EXTRACTION UNIT)	SLAVE CONTROLLER (CONCENTRATION SENSOR)
Setup (reset button or power-up)		
	Initialize variables and input/output pins	Initialize variables, input/output pins, and onboard hardware (microSD)
Data Acquisition Phase		
	Send command character, "b" for "begin", to the slave controller to request concentration data. After sending, enter while loop until serial reads the handshaking character. If no response within x seconds, send another character and wait again.	Enter while loop until serial reads buffer command character "b" from master.
		Once command is received, send handshaking character, "b" for "begin", back to master to indicate that it is ready to send data.
	Receive the handshaking character, "b", from the slave controller and enter while loop to continuously check serial buffer for concentration data. If waiting for more than x seconds, return to beginning of "*Data Acquisition Routine*"	Short delay
	Receive measurement and immediately save it into a data file on an onboard microSD card.	Enter data acquisition process: take concentration measurements. Send each measurement to master as it is taken.
	While in while loop waiting for data: if receive an "e" command from slave, leave the data acquisition while loop and calculate average of all measurements recently received.	When finished taking concentration measurements, send command character, "e" for "end", to master indicating data acquisition is finished.
	Input average value into concentration calibration equation. If average concentration is greater than or equal to target value, enter "Addition/Extraction Phase". If average concentration is less than target value, pause for a short duration and then return to the start of the "Data Acquisition Phase"	Return to while loop at beginning of "Data Acquisition Phase" to wait for next data request from master.
Addition/Extraction Phase		
	Sends a digital 5V signal to the motor driver, which holds open the extraction solenoid valve. Then pause for a short time to ensure the extraction valve opens before pump operation.	
	Send a second digital 5V signal to the motor driver, which corresponds to operating the peristaltic pump in the "extraction" direction of flow.	
	Return the digital signal that controls the pump back to 0V, pause for a short duration, then return the digital signal that controls the extraction solenoid valve to 0V to close the valve.	
	Wait for a short duration and then repeats steps above for the addition valve and "addition" direction of the pump.	
	Exit "Addition/Extraction Phase", pause for a short duration, then return to the beginning of "Data Acquisition Phase"	

Arduino Program Codes

- Text of Addition/Extraction Program
- Text of Concentration Program

Experimental Algae Growth Curve