Team 7: Microalgae Photobioreactor
Midterm 2 Presentation

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Stephen Kassing

Presentation Outline

Mini Airlift Photobioreactor Design
Algae Growth Equations
Why Semi-Continuous System?
Addition/Extraction Unit Design
Mechatronic Control Design
Question?

Current Photobioreactor at FSU

- **Current System**: Pump Operated Closed Batch Photobioreactor
- **Objective**: Make modifications to the previous system to make it semi-continuous or fully continuous
- **Plan**: Implement UFPR/FSU Semi-continuous design into the old system

Photobioreactor (Previous Year)

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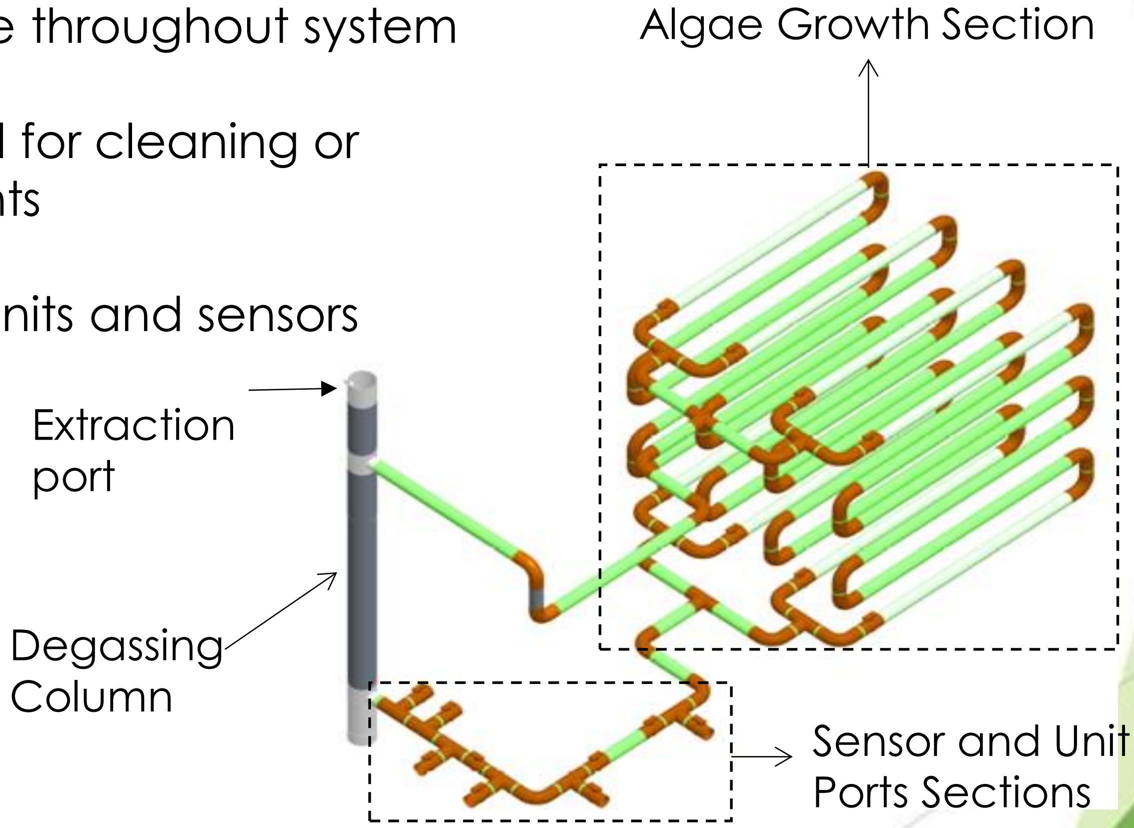
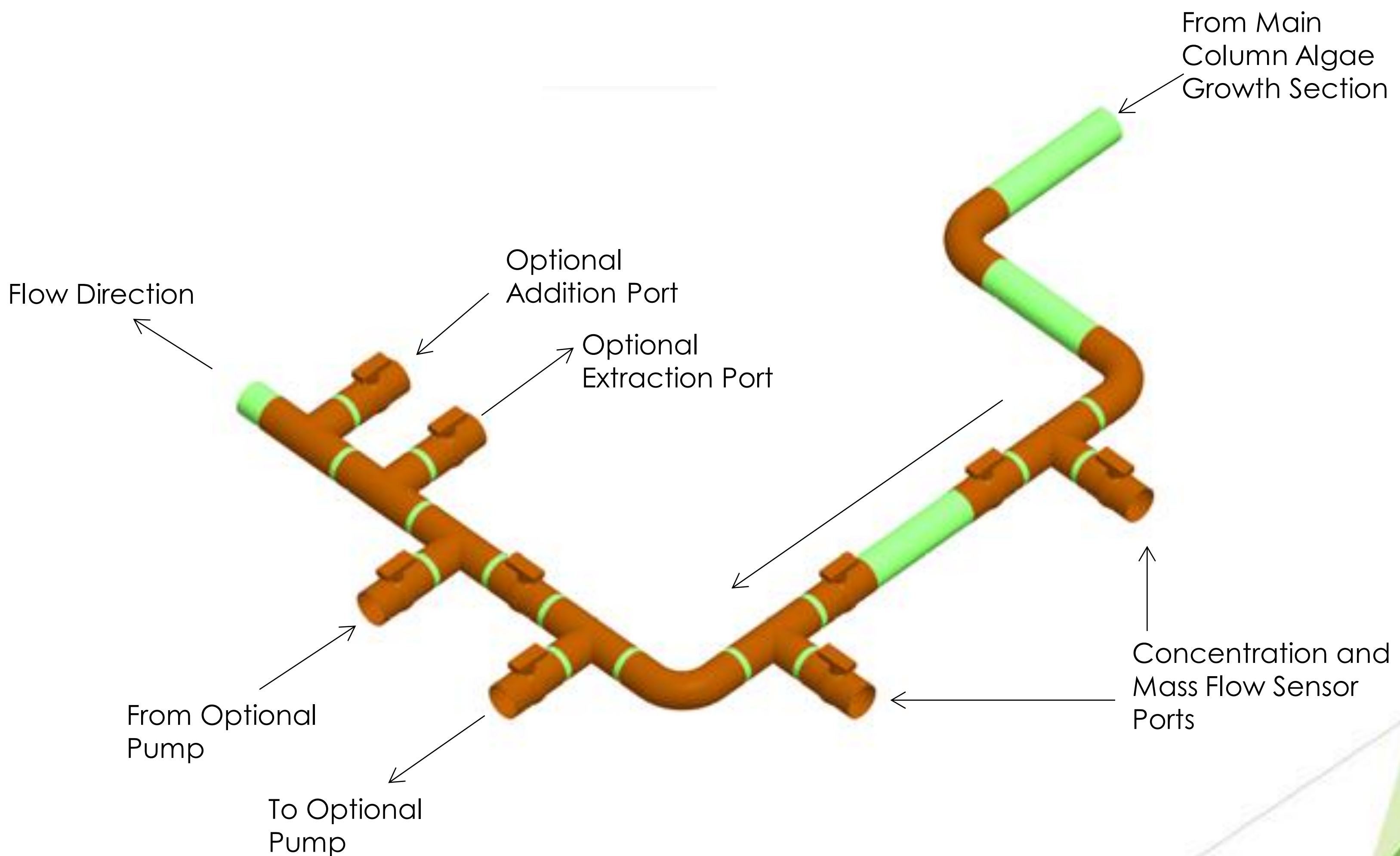
Semi-Continuous Airlift Photobioreactor

- Airlift Operating Photobioreactor
- Uniform flow rate throughout system
- Pump is optional for cleaning or other experiments
- Implements all units and sensors



Airlift Sensor and Unit Port Section



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Algae Growth Equations
(Matthew Vedrin)

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

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

Algae Growth Equations

- Continuous System Analysis (Mass Balance)

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

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

<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

Why Semi-Continuous System Over Continuous?

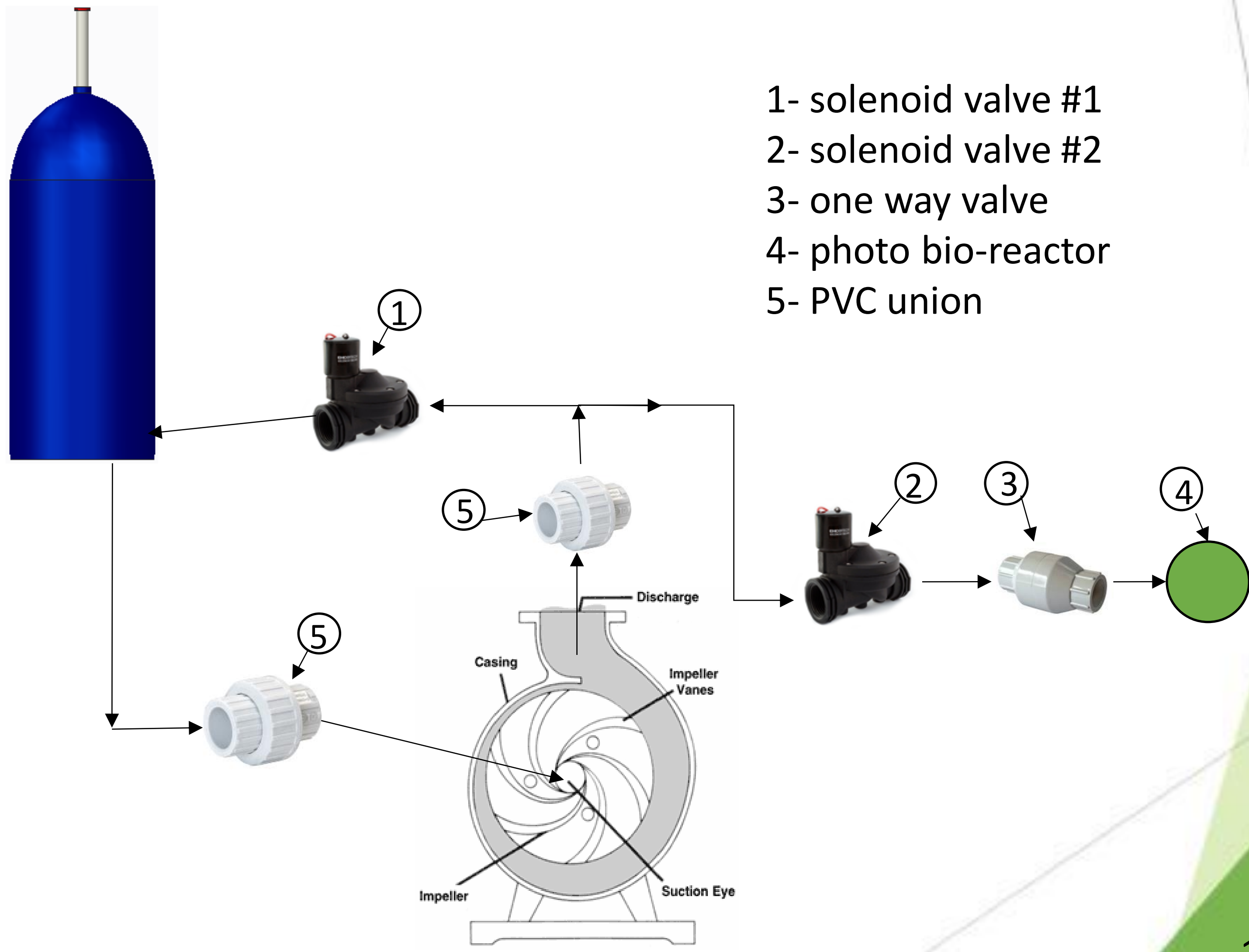
- **Original Concept**: Fully automated and continuous system to improve growth of algae
- **Semi-Continuous System:** Addition and extraction does not happen continuously but periodically
- **Cons of a Continuous System**
  - Very complex design and research needed
  - Variable speed pump and computer controlled valves are expensive and outside our budget
  - The optimal concentration for operation is still unknown

Addition Unit Design Concept

- Media storage container is located above pump to maintain minimum required pressure head to avoid cavitation
- Pipe network from pump to photobioreactor will contain valves with major and minor head loss which create pump resistance
- Pumping pressure must be higher in the pump than in the photobioreactor to obtain flow into the system
- These head losses can be plotted and match up with the pump curve to find the operating point for the addition unit
- The algae food storage tank will have buoy with distance sensor to determine how much volume has entered the photobioreactor
- Distance sensor will also tell us when we reach the minimum volume inside the unit or when the storage tank needs to be refilled

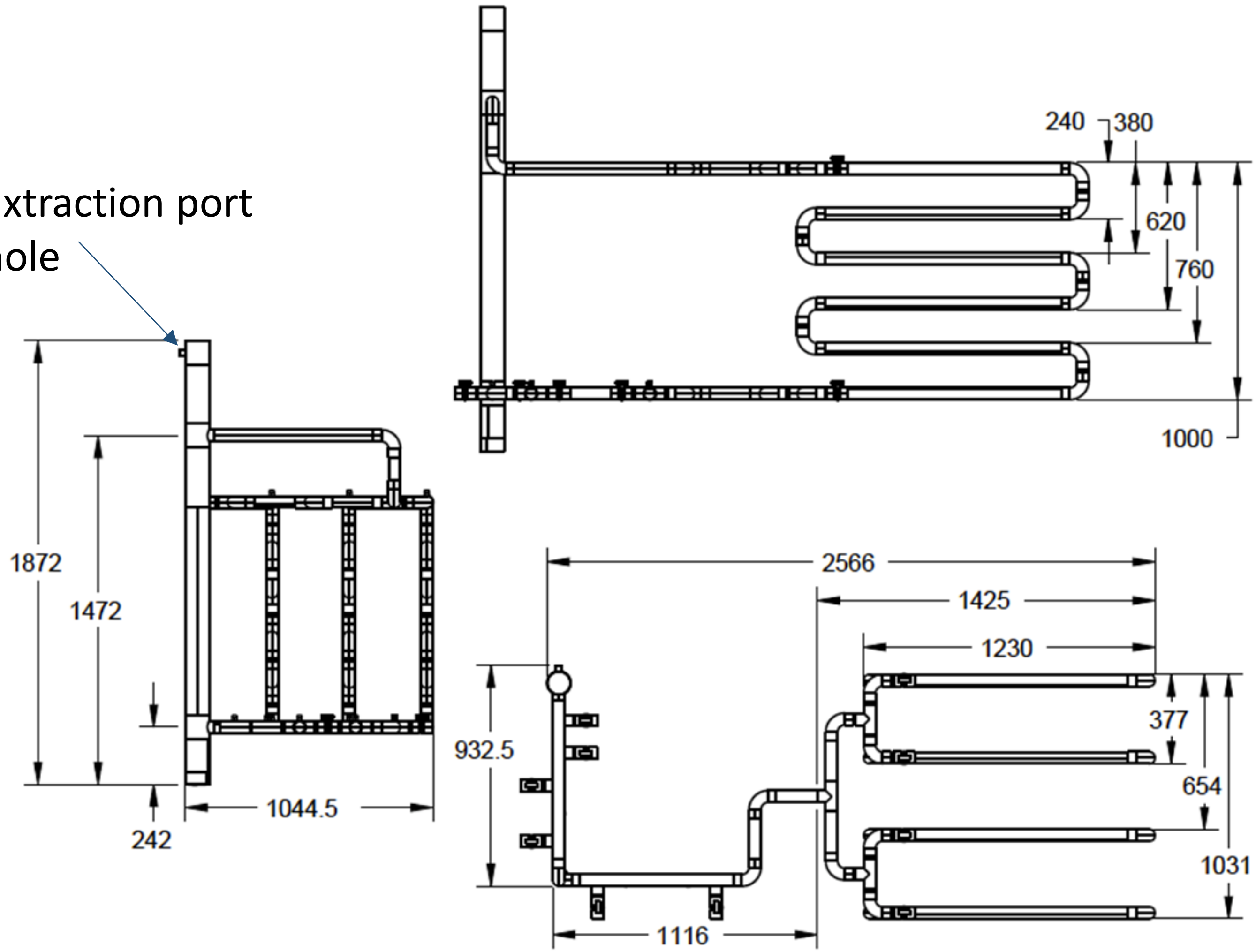
Markus Dillman

Addition Unit Operating Diagram



Airlift Photobioreactor

Extraction port hole



Airlift Photobioreactor Unit (all units in mm)

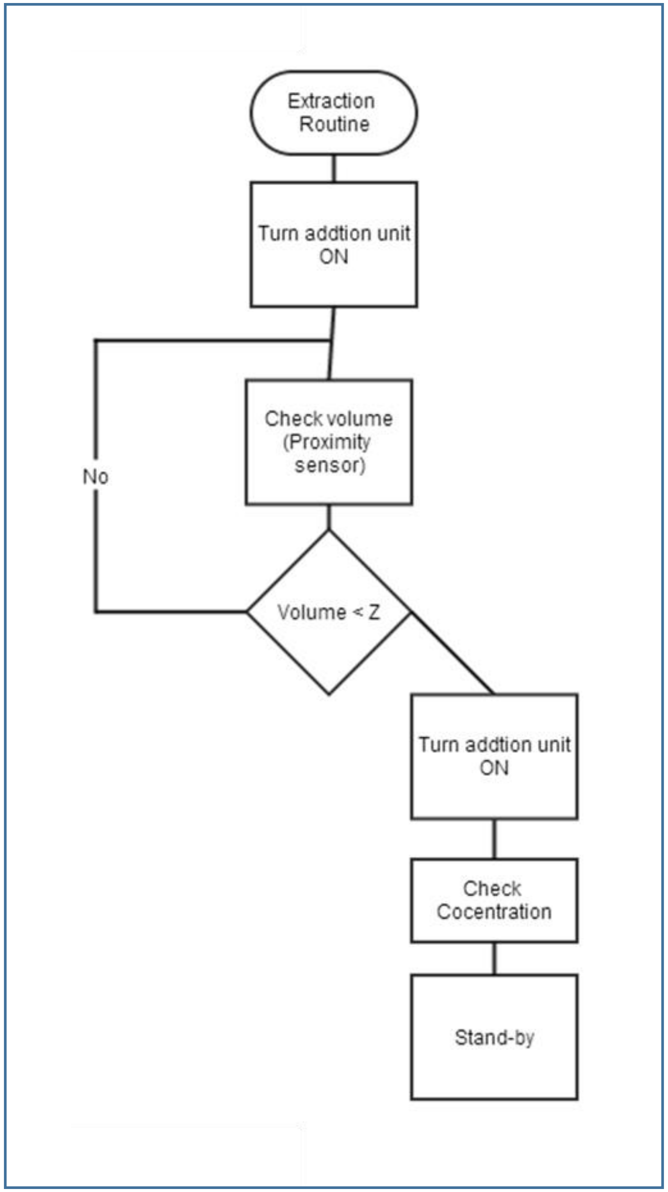
Materials For Addition/Extraction Unit

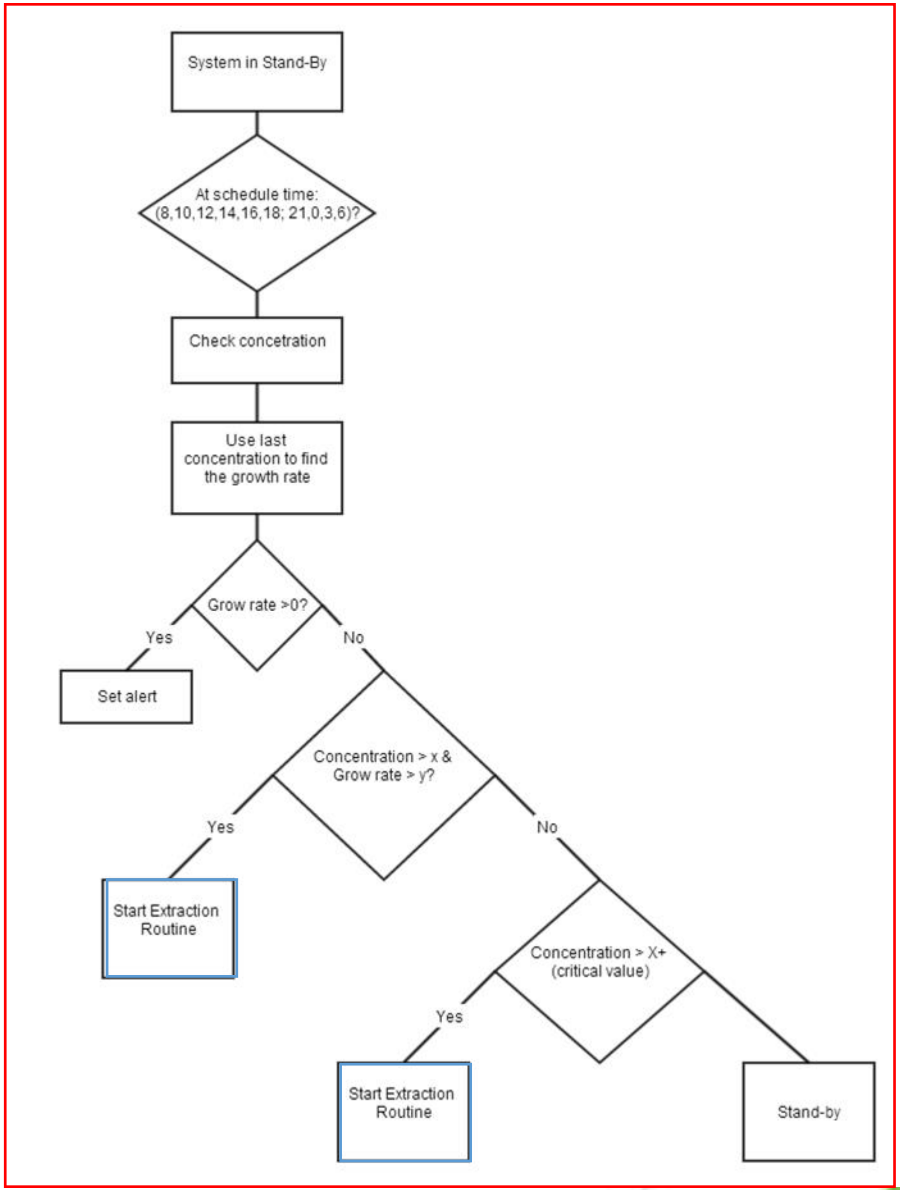
Calculations for Addition Unit Design			
		Qty	Cost
General Materials	PVC Cement Glue	1	$3.67
		subtotal	$3.67
Addition Unit	* Size 1 NPT		
Major Components			
Pipe network from pump to PBR	PVC Straight Pipe (10ft, 1 in D)	1	$3.49
	PVC union	1	$4.96
	90 deg connections (5pk)	1	$2.97
	solenoid valve (automatable)	2	$50.00
	check valve	1	$8.95
	end cap (5pk)	1	$2.53
		subtotal	$72.90
Pipe network from food storage to pump	1in adapter	2	$0.66
	PVC union	1	$4.86
	PVC Straight Pipe (10ft, 1 in D)	1	$3.49
	1/2 in adapter	1	$0.46
	distance sensor	1	$12.99
	1 1/2 pvc straight pipe (10ft)	1	$5.16
	5g Water Jug	1	$20.00
		subtotal	$47.62

Extraction Unit				
Overflow System	4x4x1 in T connection		1	$15.79
	PVC Straight Pipe (10ft, 1 in D)		1	$3.49
	5g Water Jug		1	$20.00
			subtotal	$39.28
			TOTAL	$163.47

Markus Dillman

Mechatronic Control





Diego Soler

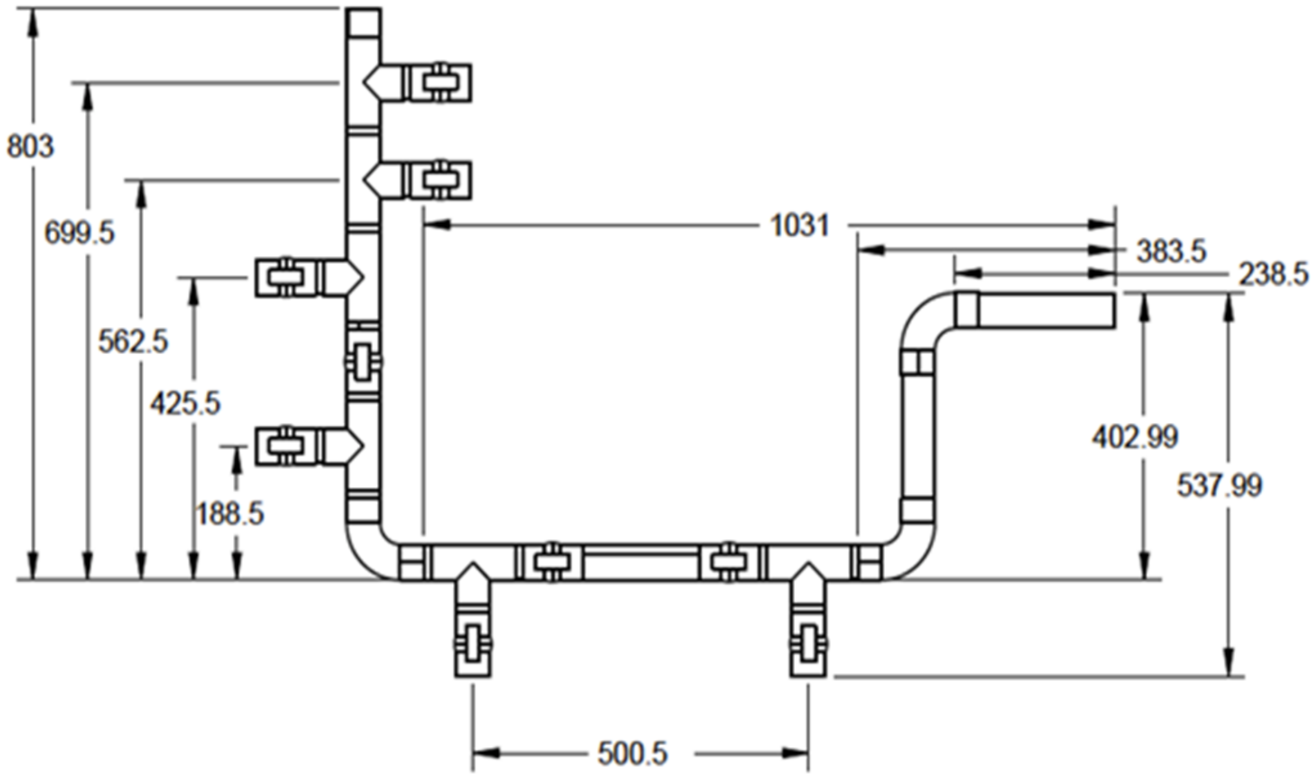
Addition/Extraction Unit Control

- Target addition/extraction concentration: N_h = 800
- Target post-dilution concentration: N_0 = 500

Example Dilution Process for 24 Hours					
Day	Time of Day	Measured Concentration 1 (N_t1)	Dilute?	Measured Concentration 2 (N_t2)	Notes
1	08:00 AM	500	NO	500	System Start
1	10:00 AM	650	NO	650	Low concentration
1	12:00 PM	850	YES	500	Target conc. & sufficient growth rate
1	02:00 PM	600	NO	550	Low concentration
1	04:00 PM	750	YES	500	Close to target conc. & high growth rate
1	06:00 PM	550	NO	550	Cloudy for past 2 hours
1	09:00 PM	615	NO	615	Light intensity is down
1	12:00 AM	675	NO	675	Night growth
1	3:00 AM	715	NO	715	Night growth
1	6:00 AM	765	NO	765	Close to target conc. but insufficient growth rate
2	08:00 AM	800	YES	500	Target conc. & sufficient growth rate

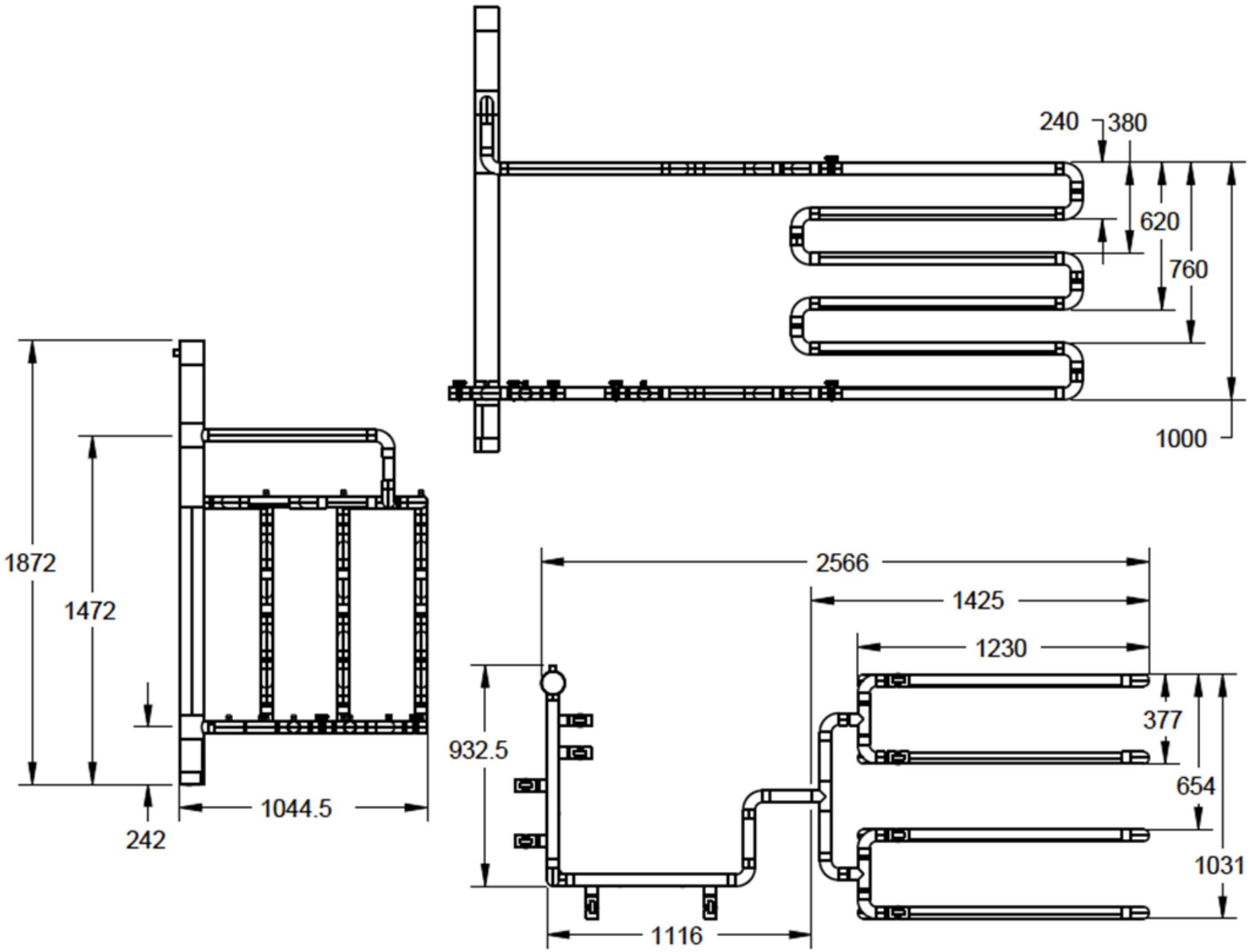
non-linear growth

Airlift CAD Drawings



Sensor and Units Port Section (all units in mm)

Airlift CAD Drawings



Airlift Photobioreactor Unit (all units in mm)

Stephen Kassing

Questions?

What is the current flow inside the PBR?							
			conditions				
Flow Rate	1	ft^3/min	average guess				
	0.00047194744 32	m^3/s					
Dynamic Visc	0.000798	N*s/m^2	30C			0.001787	0C
Kinem Visc	0.000000801	m^2/s	30C			0.000001787	0C
Density of H2O	995.7	kg/m^3	30C				
Diameter of Tube	0.0127	m					
Velocity	3.72560076705 867	m/s					
Re	59070.0745838 265	*Turbulent				26477.408920 8982	Still Turbulent
Entry Length (lam)	37.5094973607 298	m	Not applicable				
Entry Length (turb)	0.127	m					
e/D	0		pvc = smooth				
f	0.01995783633 3899		colebrook approx				