Semi-Autonomous Bioreactor (SABr)

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Abstract

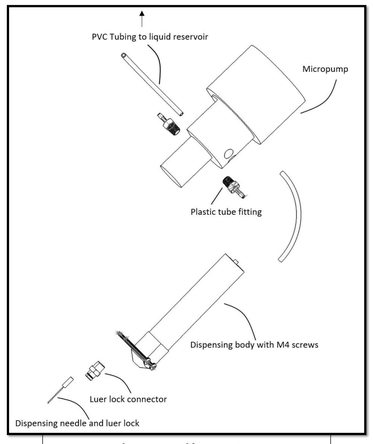
The Semi-Autonomous Bioreactor (SABr) improves upon products currently offered in the market, offering the most autonomous machine to optimize the user experience. SABr utilizes a custom culture plate to provide the user control over ambient temperature, gas levels, light intensity, and shake patterns of individual wells, as well as the capability to monitor optical density, fluorescence intensity, and other indicative bacterial properties. Any pre-existing well plate or conical tube formation can be loaded into SABr and cultured using conditions set by the user. To create a steady temperature for cell cultivation, SABr will take advantage of Peltier Modules and will be able to both heat and cool with minimal moving parts. With 3-axis motion and a reversible pump system, fluid can be added or removed from any well. The dispenser is cleaned with a 70% ethanol solution to prevent cross contamination, after waste products are safely stored away from the culture plate and cleaned by an ultraviolet light. The removable, fully sealed 8 inch diameter opening provides the user with a view of the processes happening inside SABr and the tabletop design makes SABr a highly user-friendly device.

Product Functionality

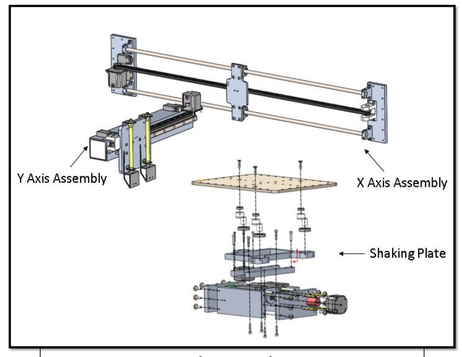
The SABr utilizes custom acrylic containers to culture bacteria. Attached to the 384 wells is a plastic tube for gas flow. The five gas containers are controlled through precision flow-adjustment valves, and a sandwich plate lid will be used to cover each container in order to keep gas and liquid in while also letting fluid in through the liquid handling system. The design will use Thermoelectric coolers to keep the environment at a constant temperature specified by the user through a Peltier effect. Two separate sensors are used to monitor OD and FI of individual wells. This system can detect any range of optical densities and 53 common fluorophores that might be detected by laboratory experiments. The dynamics and translation system provides three axes of motion for the fluid dispensing system and the sensing system, as well as two shaking plates which provide three programmable shaking patterns with a full range of speed and frequency control. A variety of laboratory equipment can be attached on the shaking surface. Gases and liquids are contained inside the welded structure. A hinged-flange access door is positioned at the top of the housing to facilitate installation and servicing of different components. The access door is sealed with a Viton O-ring to allow for full frontal access while ensuring a controlled environment.

Subsystems

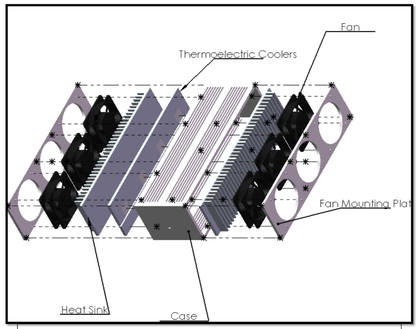
The SABr concept was divided into six main subsystems: Liquid handling, dynamics and translation, heating and cooling, sensing and imaging, microbiology, and overall structure.



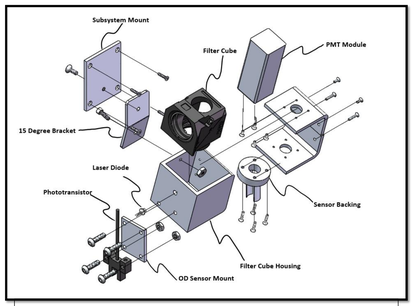
Liquid Handling System



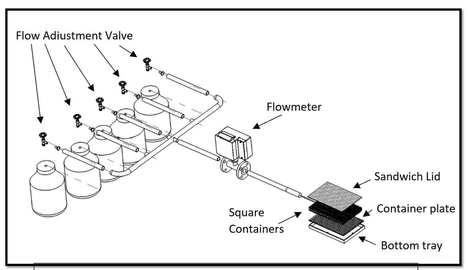
Dynamics and Translation System



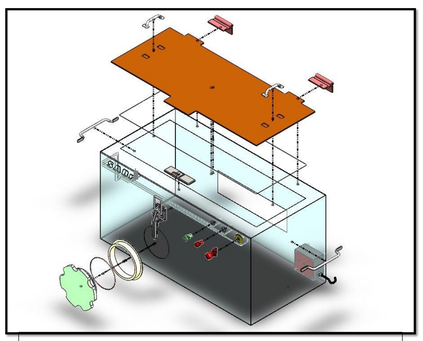
Heating and Cooling System



Sensing and Imaging System



Microbio System

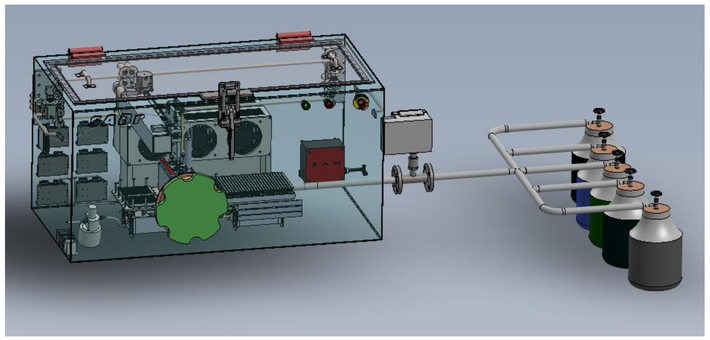


Structure System

Cost Breakdown

OTS Parts	$6,607.31
Raw Material	$2,620.37
Manufacturing	$1,991.59
Assembly	$318.03
Energy Consumption	$15.04
Total	$11,552.34

Concept Rendering



Acknowledgements

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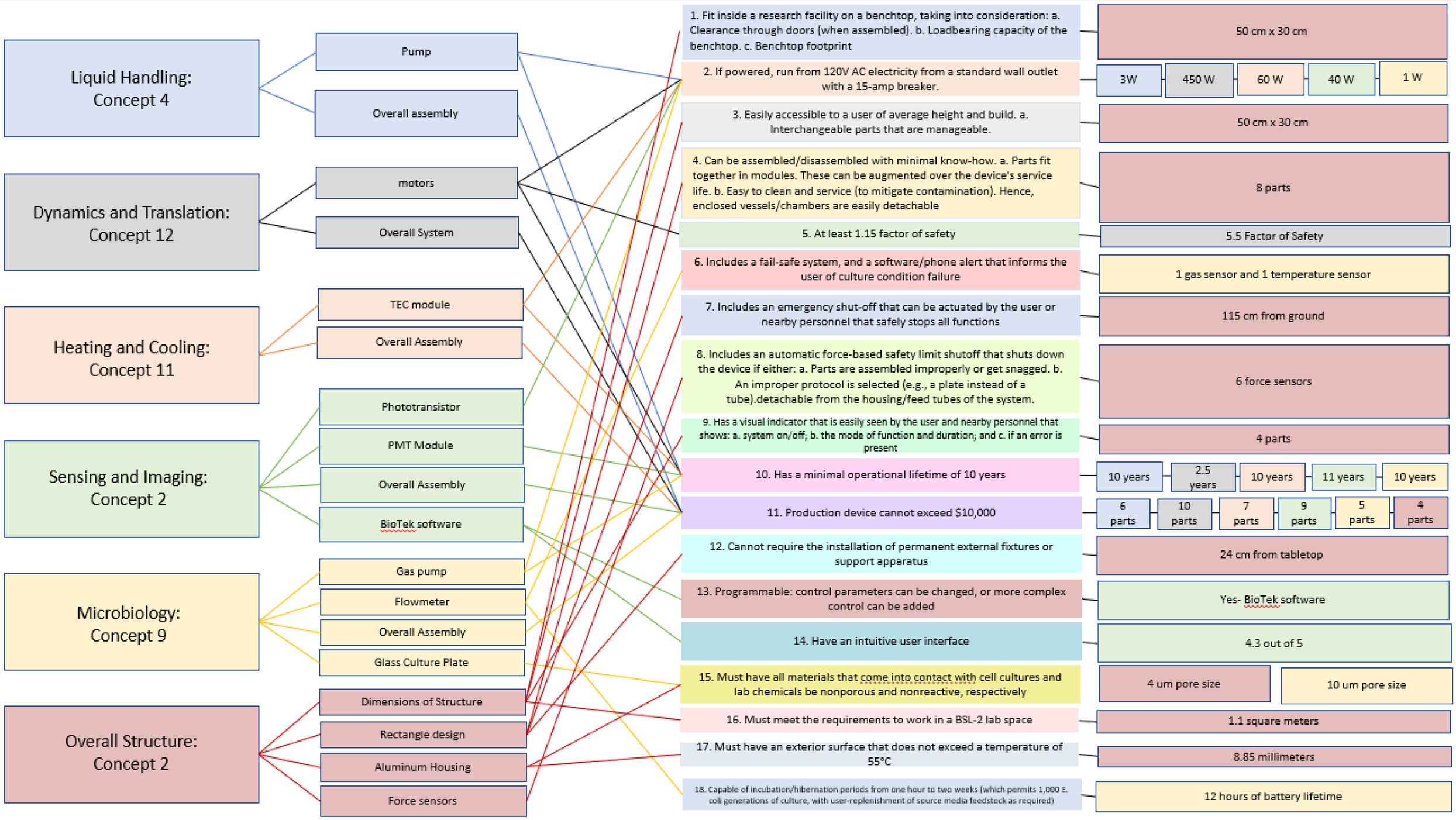
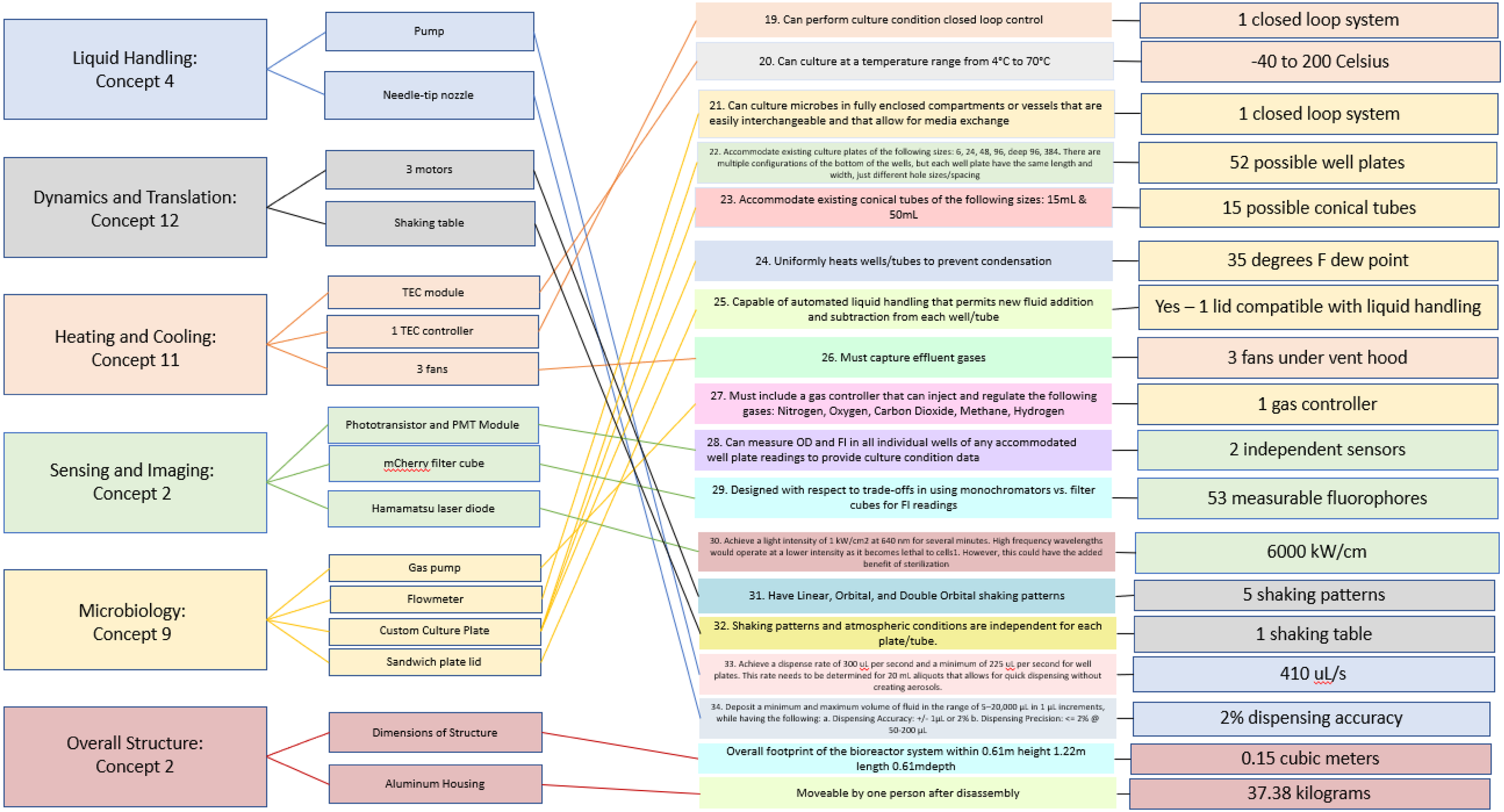
Customer Needs Mapping




Liquid Handling: Concept 4
Pump
Needle-tip nozzle
Dynamics and Translation: Concept 12
3 motors
Shaking table
Heating and Cooling: Concept 11
TEC module
1 TEC controller
3 fans
Sensing and Imaging: Concept 2
Phototransistor and PMT Module
mCherry filter cube
Hamamatsu laser diode
Microbiology: Concept 9
Gas pump
Flowmeter
Custom Culture Plate
Sandwich plate lid
Overall Structure: Concept 2
Dimensions of Structure
Aluminum Housing
19. Can perform culture condition closed loop control
1 closed loop system
20. Can culture at a temperature range from 4°C to 70°C
-40 to 200 Celsius
21. Can culture microbes in fully enclosed compartments or vessels that are easily interchangeable and that allow for media exchange
1 closed loop system
22. Accommodate existing culture plates of the following sizes: 6, 24, 48, 96, deep 96, 384. There are multiple configurations of the bottom of the wells, but each well plate have the same length and width, just different hole sizes/spacing
52 possible well plates
23. Accommodate existing conical tubes of the following sizes: 15mL & 50mL
15 possible conical tubes
24. Uniformly heats wells/tubes to prevent condensation
35 degrees F dew point
25. Capable of automated liquid handling that permits new fluid addition and subtraction from each well/tube
Yes – 1 lid compatible with liquid handling
26. Must capture effluent gases
3 fans under vent hood
27. Must include a gas controller that can inject and regulate the following gases: Nitrogen, Oxygen, Carbon Dioxide, Methane, Hydrogen
1 gas controller
28. Can measure OD and FI in all individual wells of any accommodated well plate readings to provide culture condition data
2 independent sensors
29. Designed with respect to trade-offs in using monochromators vs. filter cubes for FI readings
53 measurable fluorophores
30. Achieve a light intensity of 1 kW/cm2 at 640 nm for several minutes. High frequency wavelengths would operate at a lower intensity as it becomes lethal to cells1. However, this could have the added benefit of sterilization
6000 kW/cm
31. Have Linear, Orbital, and Double Orbital shaking patterns
5 shaking patterns
32. Shaking patterns and atmospheric conditions are independent for each plate/tube.
1 shaking table
33. Achieve a dispense rate of 300 uL per second and a minimum of 225 uL per second for well plates. This rate needs to be determined for 20 mL aliquots that allows for quick dispensing without creating aerosols.
410 uL/s
34. Deposit a minimum and maximum volume of fluid in the range of 5–20,000 µL in 1 µL increments, while having the following: a. Dispensing Accuracy: +/- 1µL or 2% b. Dispensing Precision: <= 2% @ 50-200 µL
2% dispensing accuracy
Overall footprint of the bioreactor system within 0.61m height 1.22m length 0.61mdepth
0.15 cubic meters
Moveable by one person after disassembly
37.38 kilograms