GM2 - Waterscope Team

Final Team Presentation

Overview

Project Aims - To test feasibility of sterilisation methods for WaterScope products, produce a working prototype, and ensure the findings can be used by Waterscope.

Team Members - After research stage, split into UV and Heat teams to work concurrently, then after mid-project split teams again with a greater focus on heat sterilization..

All team members were jointly & equally involved in decision making, analysis & team leadership.

Project Structure:

Research

Client interview

Team Split - UV/Heat Concept Testing

Whole Team - Interim Report & Analysis

Heat prototype development & modelling (Main focus)

UV prototype development (Side focus)

Bradley

Member of UV Team

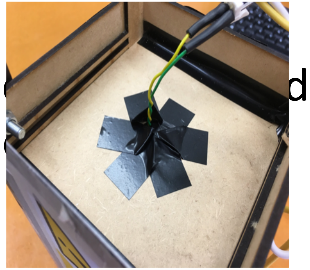
Main contributions:

- Plan client interview for specification definition
- UV Risk Assessment
- UV Enclosure co-design - meeting RA, electrical
- UV lab protocol specification
- Involved in design & manufacture of final prototypes.

UV - Health & Safety

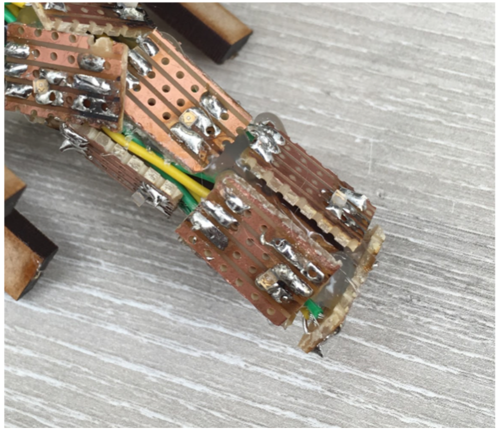
- Undefined wavelengths of UV - Skin and eye damage
- Full risk assessment required before use
    - ‘Black box’
    - Interlocks
    - Protect non-users - warning signs

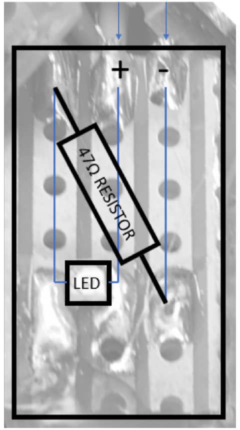
- Apply to LED testing, enclosure design & manufacture



UV Prototype

- UV Prototype
  - Focus on sample cup - simple geometry
  - Design to maximise intensity - multiple high power LED, 370nm
  - Manufacture of holder and circuit





Charlie

Member of UV Team

Main contributions:

- Research of UV as a sterilization method
- Feasibility calculations of UV (time to sterilise)
- Design and manufacture of test specimens
- Mechanical design and manufacture of UV test rig
- Wavelength testing of UV LEDs (with Calvin)
- Design of UV cup sterilizer prototype circuit
- Optimisation of cup sterilizer design
- Thermal studies on heat prototypes
- Estimate of cost to mass manufacture

Project Beginnings

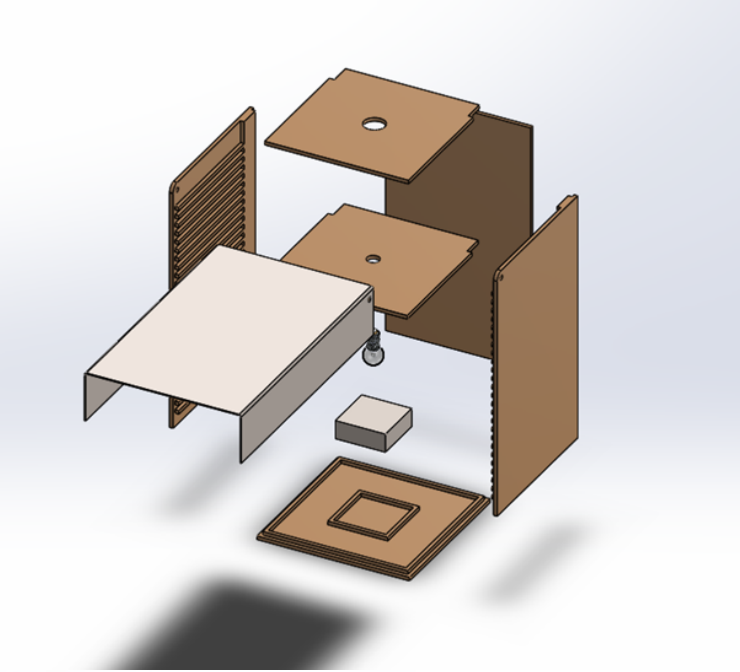
- Microorganisms require different doses
- 265nm most effective wavelength

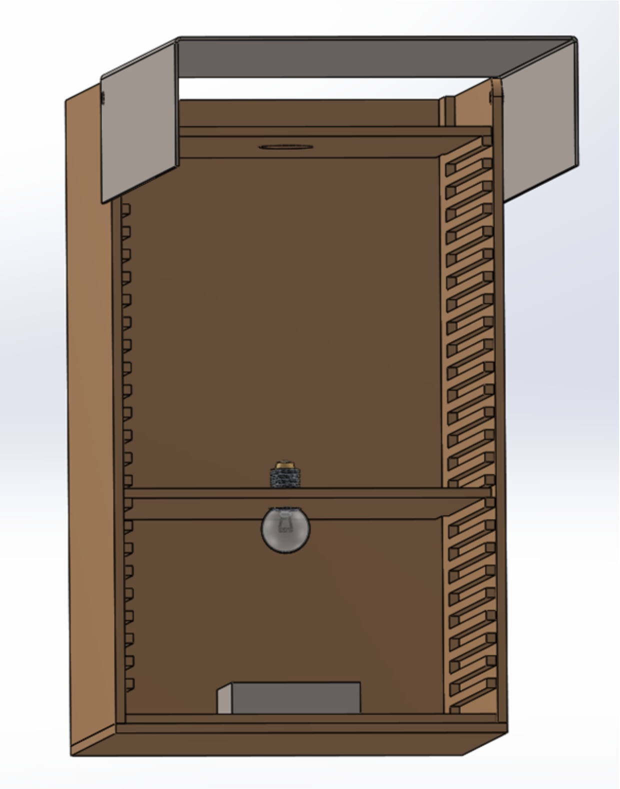
$$Dose\ (\mu J\,cm^{-2}) = \frac{UV\ Power\ (\mu W)\ \times\ Time\ (s)}{Area\ (cm^{2})}$$

Project Beginnings

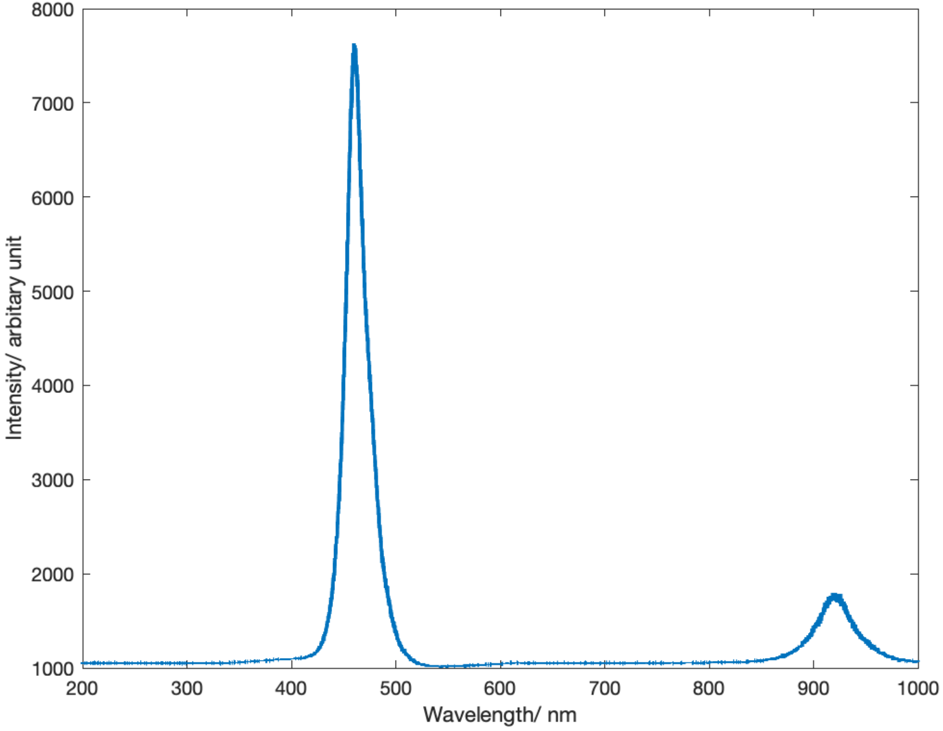
- Bulb sterilizers already exist
- LEDs more efficient and cheaper

Project Beginnings





Project Beginnings



Project Beginnings

- 365nm light is germicidal
- Decision to progress UV as a side project

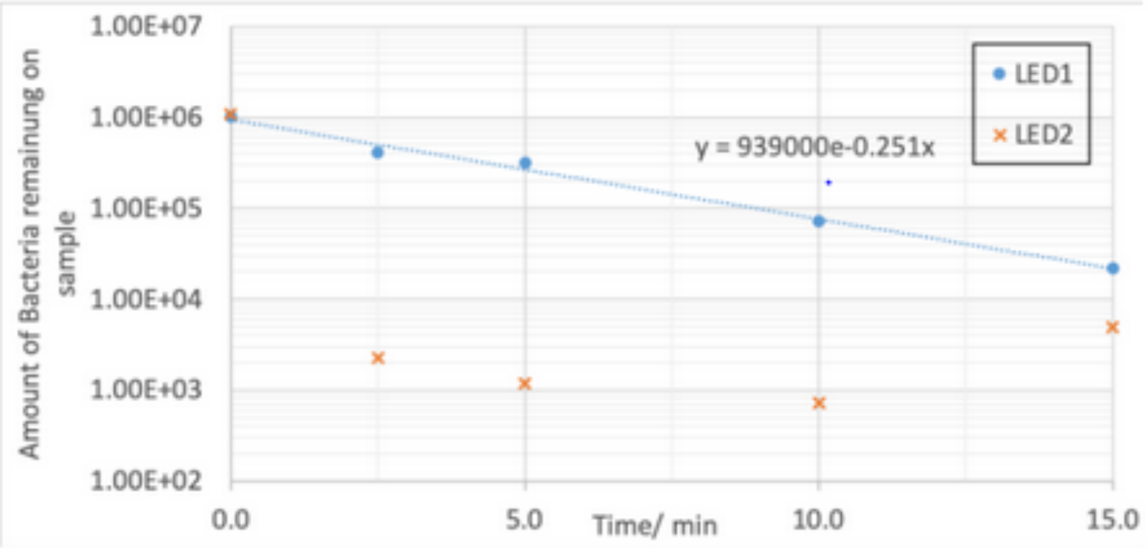
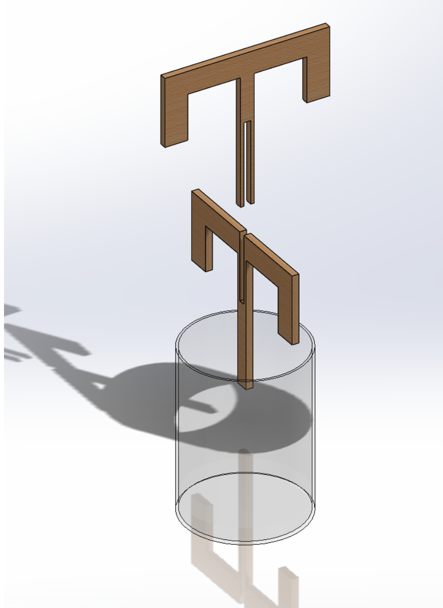


Fig. 5. Bacteria remaining vs time

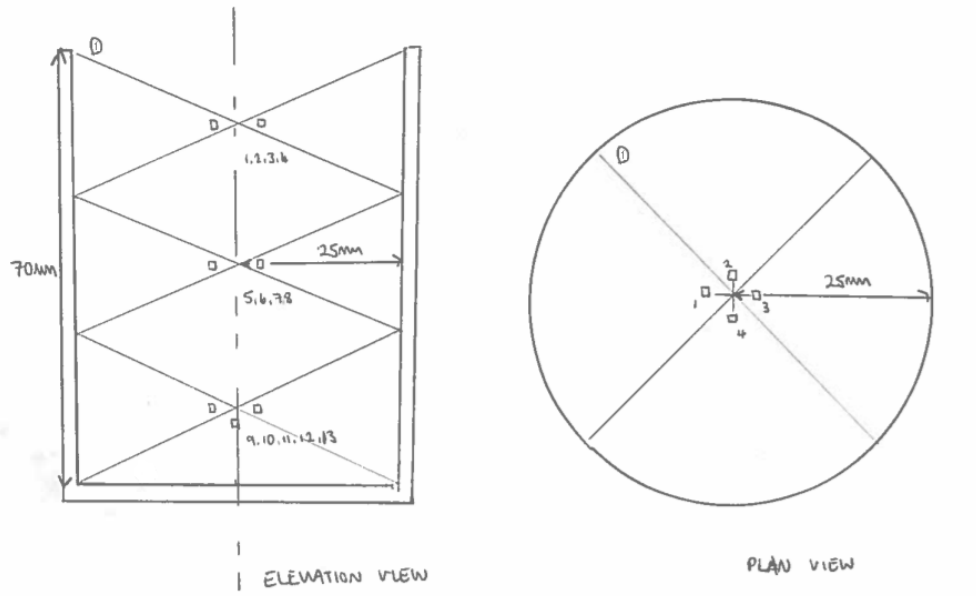
UV prototype

- Turn research into something useful
- Decision to sterilize cup not cartridge



UV prototype

- All areas must be covered
- Choice of high power cheap LED



UV prototype

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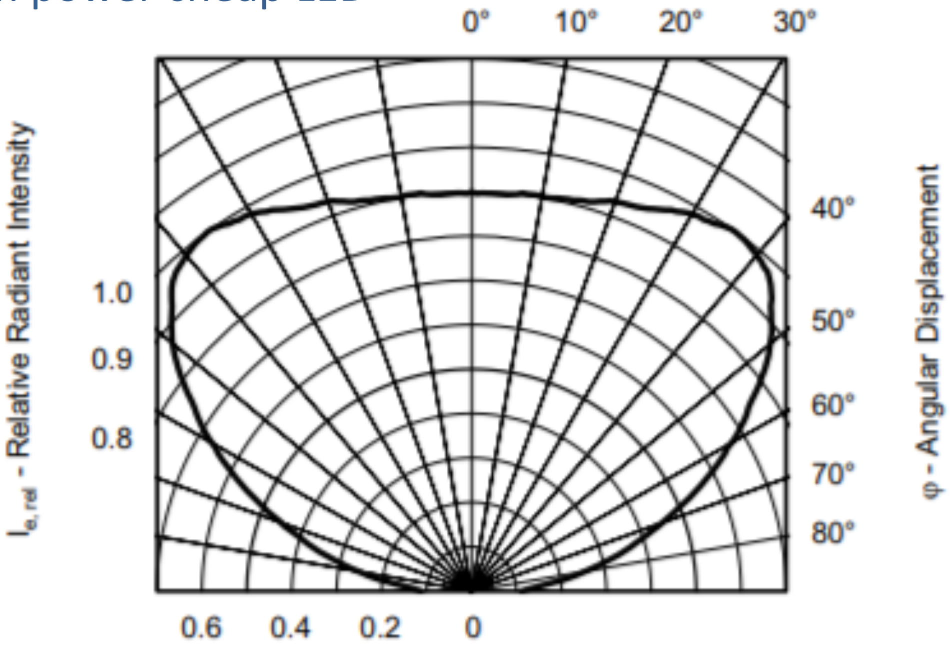
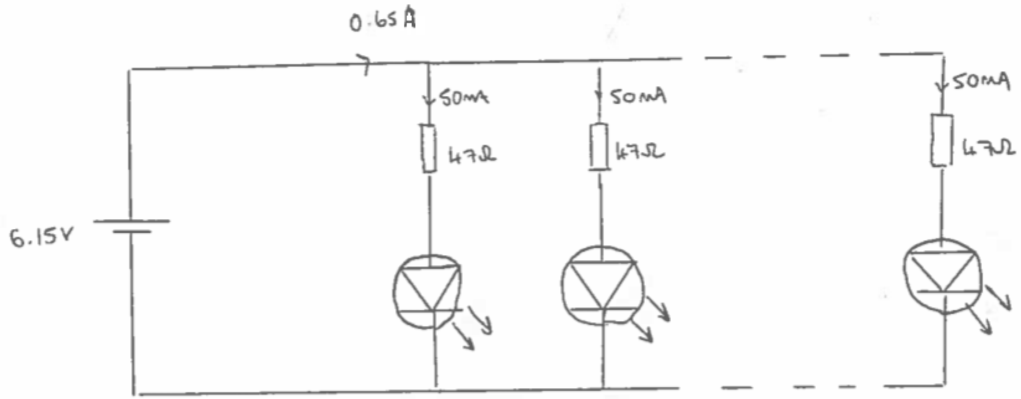


UV prototype

- Only draws 4W
- Choice of LED we think is most effective

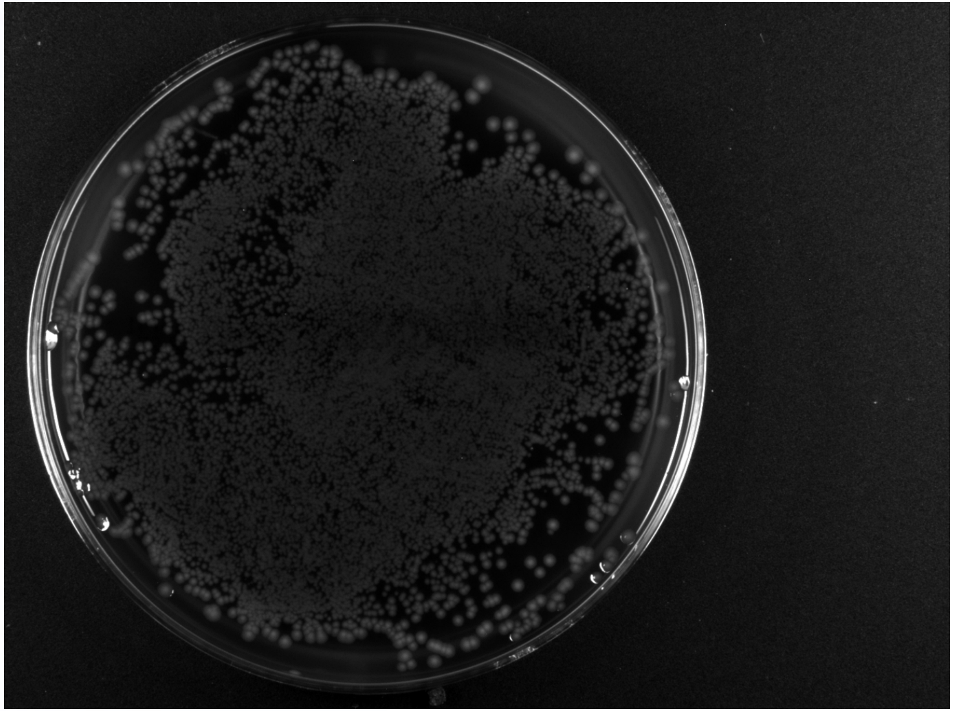


Total power required = IV

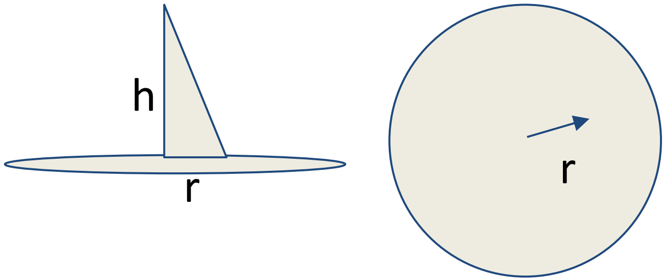
= 0.65 × 6.15

= 4W

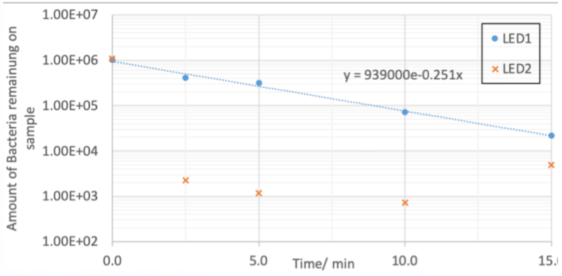
UV prototype



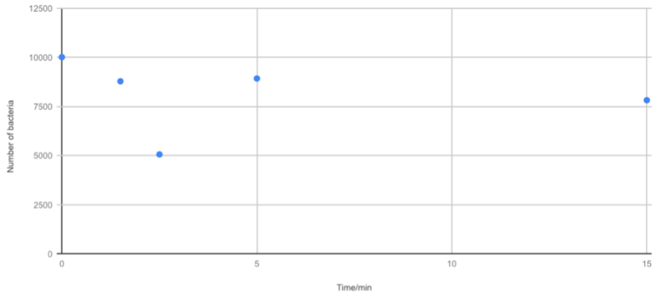
UV Results



- Expecting a linear relationship (log-log)
  - Intensity defined by inverse square law, sterilisation time inversely proportional to intensity - time-variant effective area
- Difficult to define empirical relationship from results
  - First trials anomalous, second trials contaminated, prototype trials inconclusive
- Prototype less effective than feasibility testing
  - Lower spectrum components?
  - Optical properties?



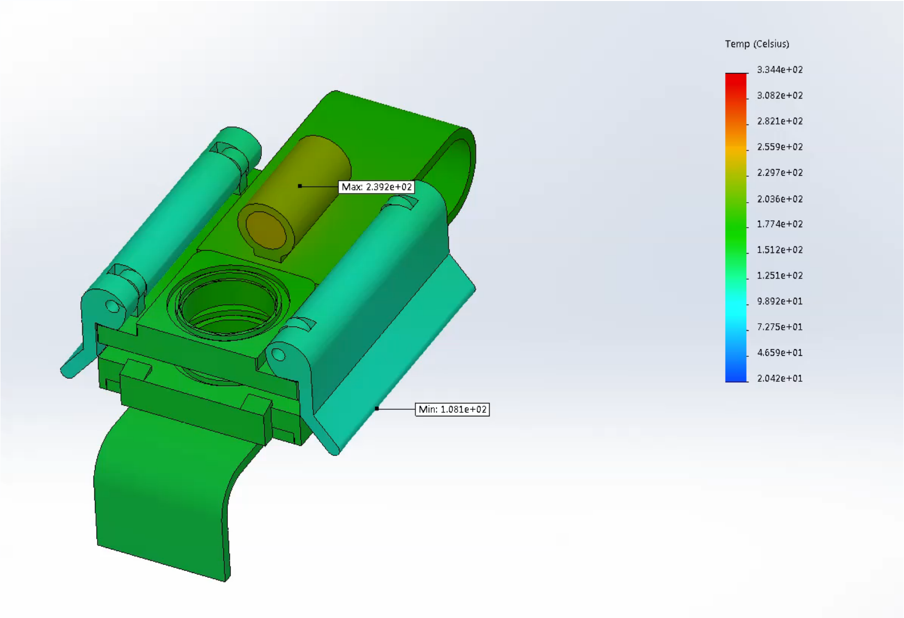
Initial Feasibility Testing



Prototype Testing

Thermal studies

- 24W power input into heating element
- Simulate conduction and convection

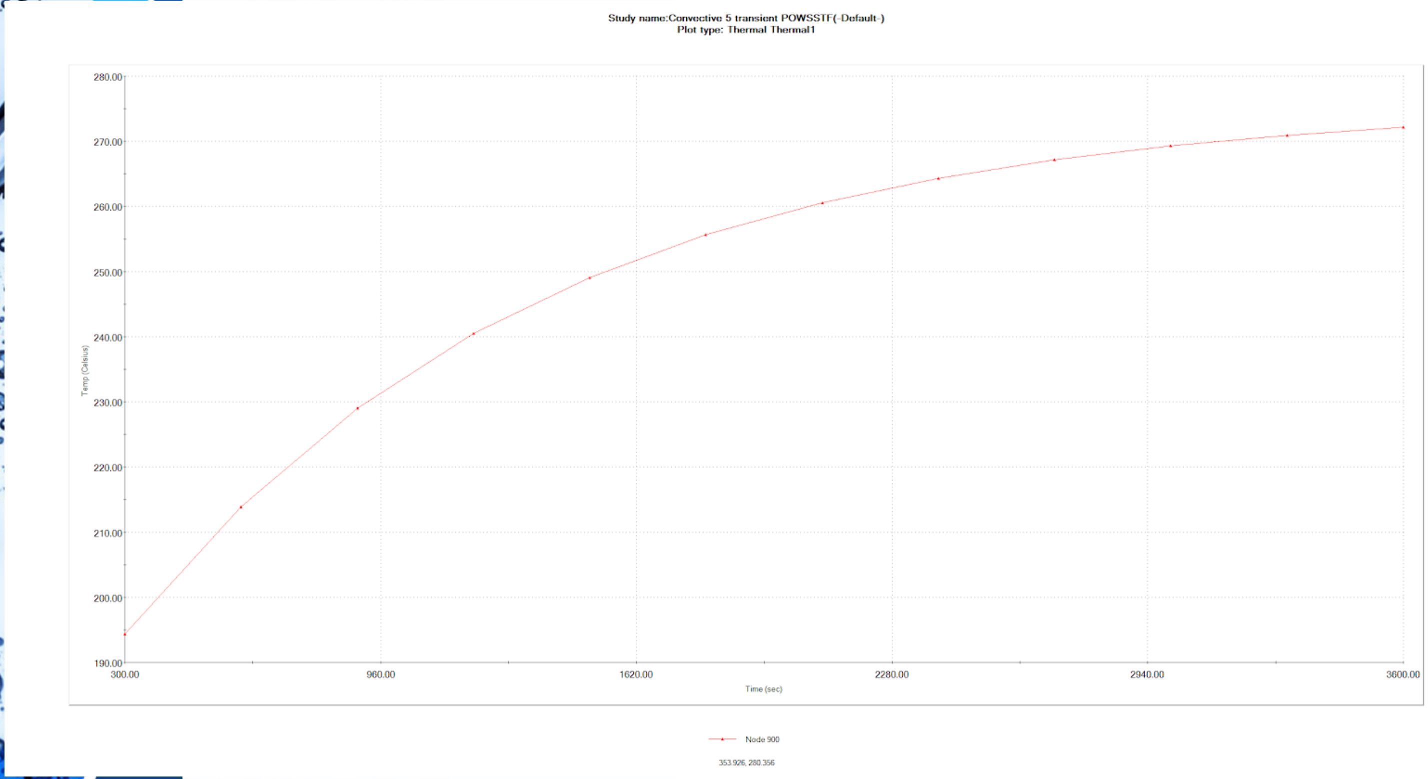


Thermal studies

- 3 tests per prototype
- Prototype 4 likely to be successful

Prototype	Temperature of the coldest part of cartridge (°C)					
	Perfectly insulated		Convection 5W/m²K		Convection 10W/m²K	
	10mins	20mins	10mins	20mins	10mins	20mins
1	70	139	60	106	53	84
2	187	433	128	221	93	132
3	188	454	134	238	100	145
4a	212	486	148	260	109	158
4	166	378	119	203	89	124

Thermal studies



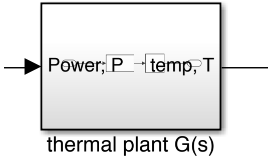
Calvin

Member of UV & Lab Team, Control

Main contributions:

- Developed the control system to control temperature
  - Designed the theoretical control system
  - Prototyped the majority of the system: thermocouple temperature sensor and code to interface with PC, op am circuit, pulse width modulation code
- Lab work:
  - Drafted experimental procedures templates
  - Developed the swab and rinse protocol
  - Performed lab work (in vet school with Becky) and performed calculations: tested the principles of heat and UV, the heat prototypes
  - Measured spectrum and power of UV LEDs (partly with Charlie)
- Developed the second heat prototype
- Investigated gas sterilization

Control system - plant

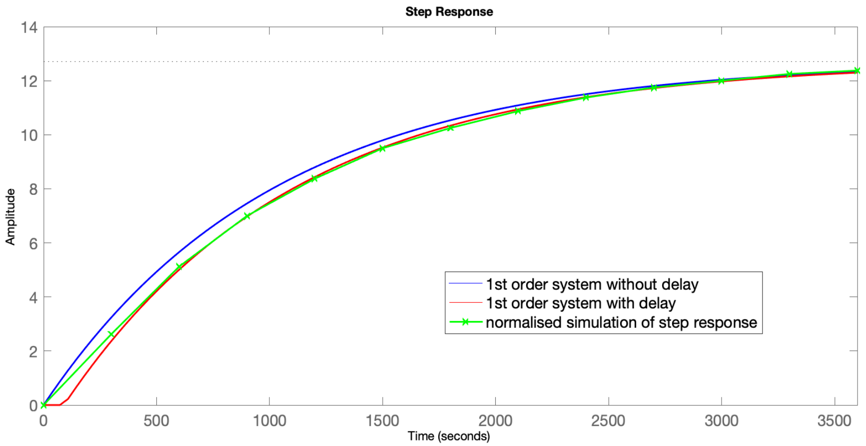


- At steady state (centre at 200°C), T = 173°C, P = 12W
- Obtain step response from simulation
- Fit first order plus deadtime model:

$$\alpha \dot{y}(t) + y(t) = K u(t - D)$$

$$\bar{y} = \frac{K e^{-Ds}}{1 + \alpha s} \bar{u}$$

$$K = 12.7, \quad \alpha = 1017, \quad D = 90$$



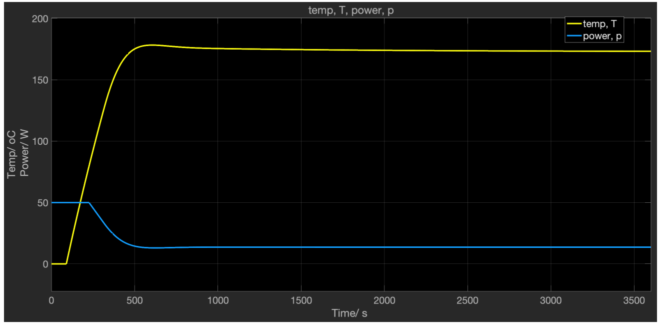
Control system - controller

- Controller transfer function:

$$K(s) = P + I\frac{1}{s}$$

$$P = 0.406, \quad I = 0.00036$$

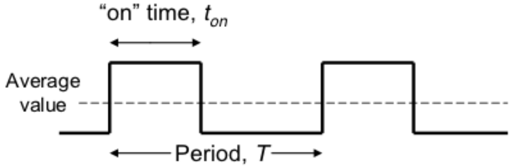
- Requirement: reach steady state as soon as possible with no overshoot (in order not to melt O rings)
- The parameters found give an almost critically damped response



Implementation of controller

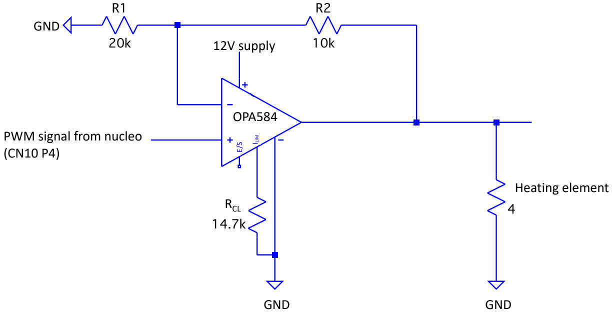
Made up of 5 steps:

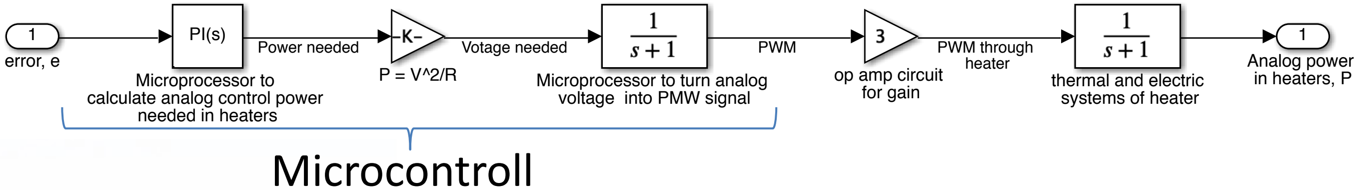
1. Controller calculates power needed, and
2. then convert this to voltage needed
3. This analog voltage cannot be output and thus use pulse width modulation (PWM)
4. PWM amplified by op amp circuit
5. Thus PWM appears across heater and the long time constants in electrical dynamics of the heater and thermal system low pass filters out the signal to give analog power



Duty cycle= t_{on}/T, T = 0.01s

Photo: https://os.mbed.com/media/uploads/phill/mbed_course_notes_-_pulse_width_modulation.pdf



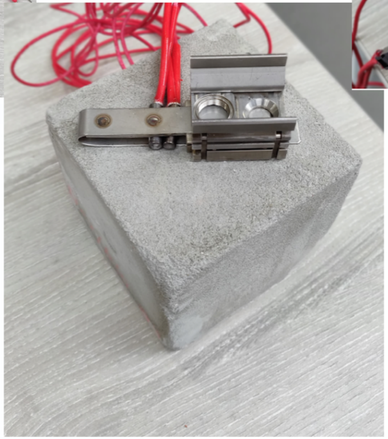


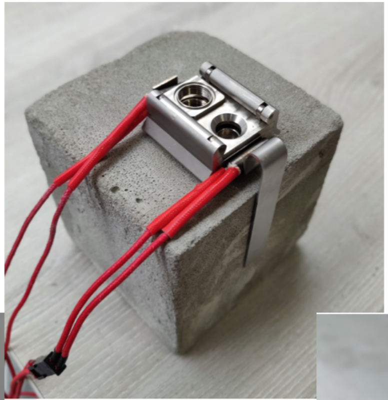
Will

Member of heat team

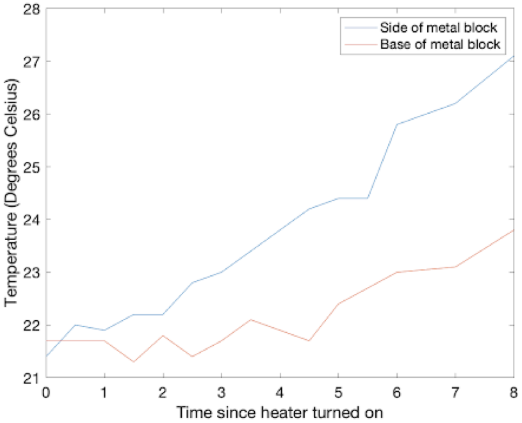
- Research of hydrophobic coating as a sterilisation method
- Heat risk assessment
- Development of heat prototypes
- Initial Testing of heat prototypes
- Analysing results of thermal simulation
- Analysing lab results for heat

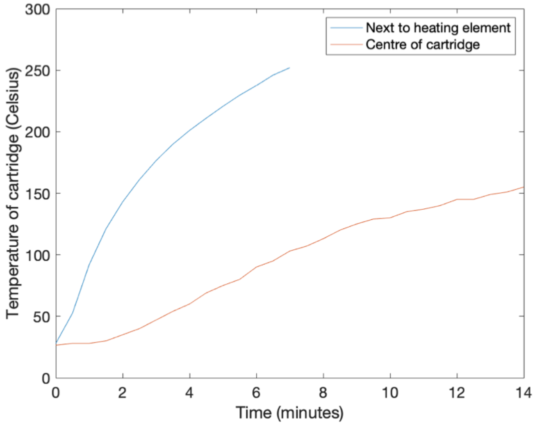
Heat Prototype Development





Heat Prototype Testing





Time/mins	Number (side)	Number (Cavity)
0	8120	9064
5	1	0
10	1	0
15	0	0

Renos Lyssiotis, Heat member

COMPOSING & COMPILING

- Draft of experimental procedure and lab protocol
- Report formatting and compiling

DESIGN

- Feasibility calculations for heat prototype
- Mechanical design of prototypes

RESEARCH

- Heat treatments and prototype materials
- Microprocessors & Temperature sensors

ANALYSIS

- Heating element characteristic behavior
- Analysis of heat petri dishes data (ImageJ)

MANUFACTURING

- Prototype manufacturing
- Temperature sensor

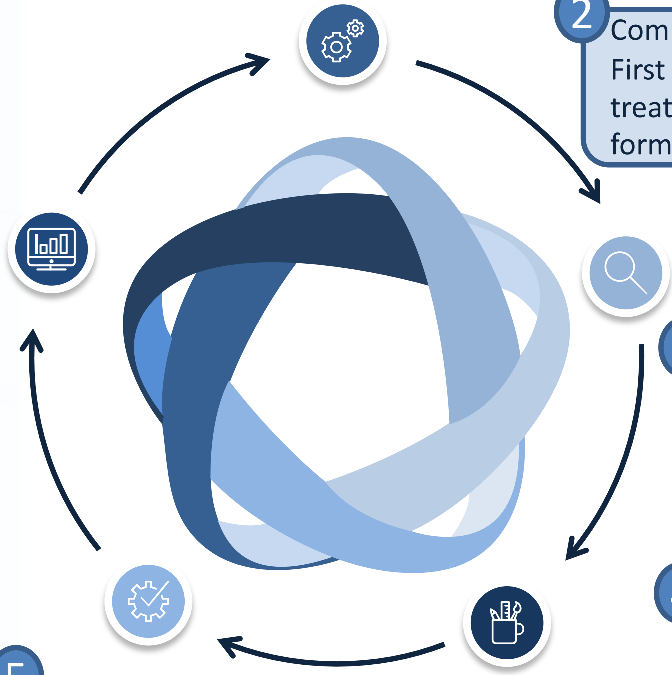
Research, Drafting, Design and Manufacturing

Week 1

1 Conducted research on various heat treatment methods.

Suggested **dry heat sterilisation** because of:

1) Sterilisation effectiveness
2) Time constraint
3) Complexity



2 Compiled specific sections of First Presentation (i.e. Heat treatment, Gantt chart) and formatted the final version

Week 2

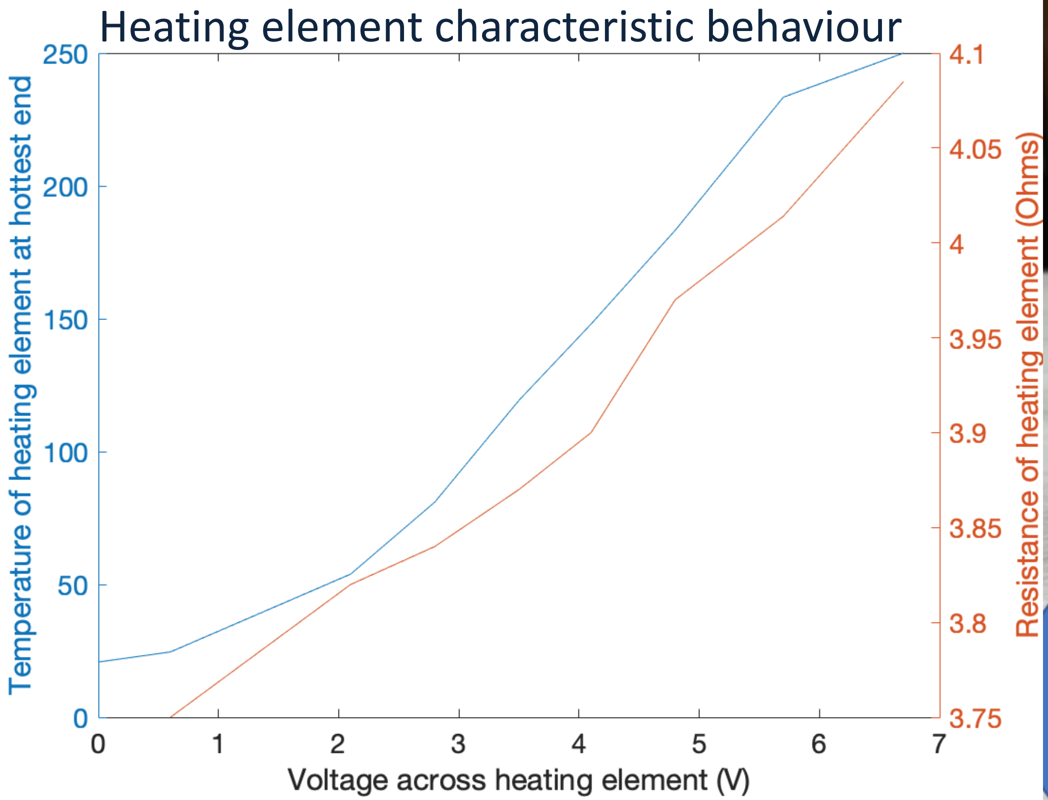
3 Drafted lab protocol and experimental procedure to be followed by lab team

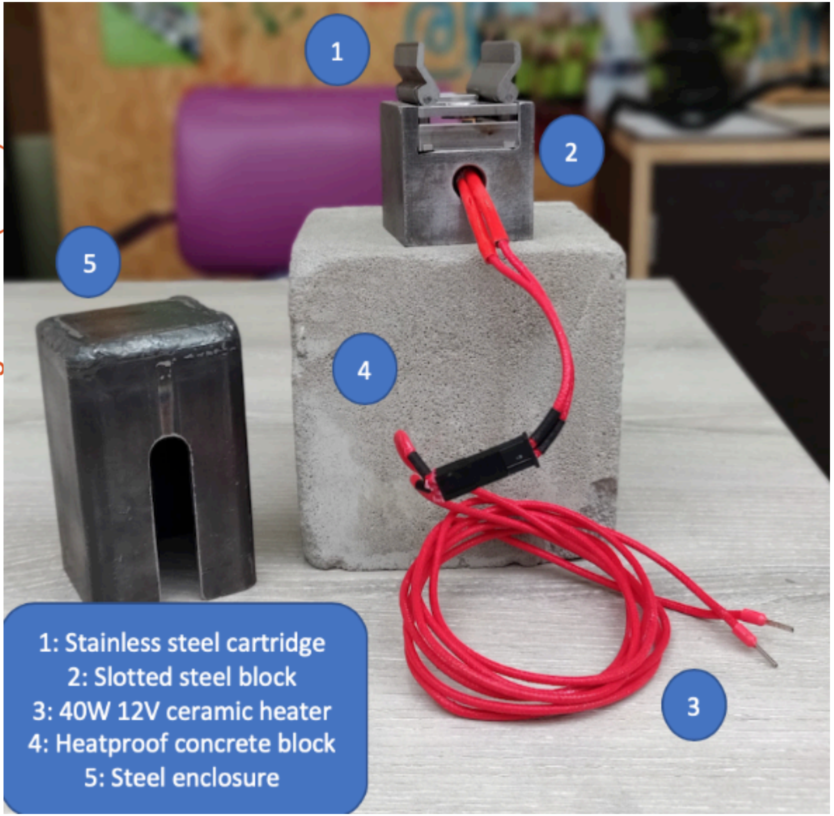
4 Investigated the heating element characteristics with sub-team colleague

5 Explored the feasibility of a prototype design with sub-team colleague but was then aborted

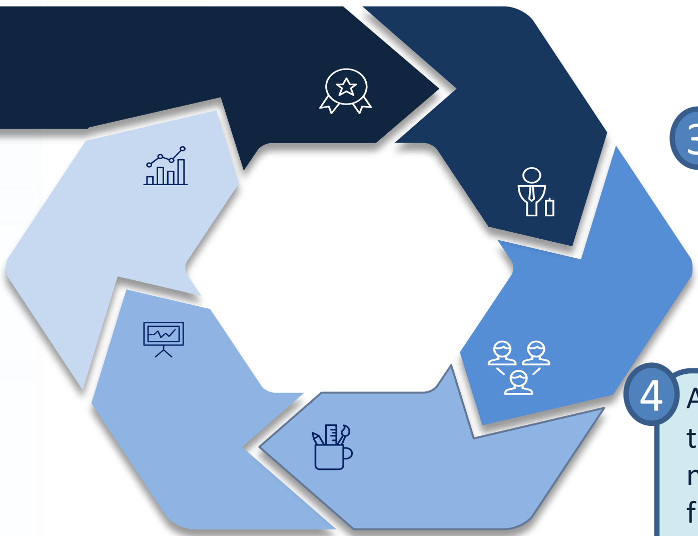
6 Performed feasibility calculations on heating time, researched on materials, designed and manufactured first prototype

Research, Drafting, Design and Manufacturing





Research, Drafting, Design and Manufacturing



Week 3

1 Drafted sub-sections on Dry heat sterilisation for Interim Report and formatted Report and Appendices

2 Designed and manufactured three heat prototypes (team work)

Tested their behaviour to heat from heating element/s

Week 4

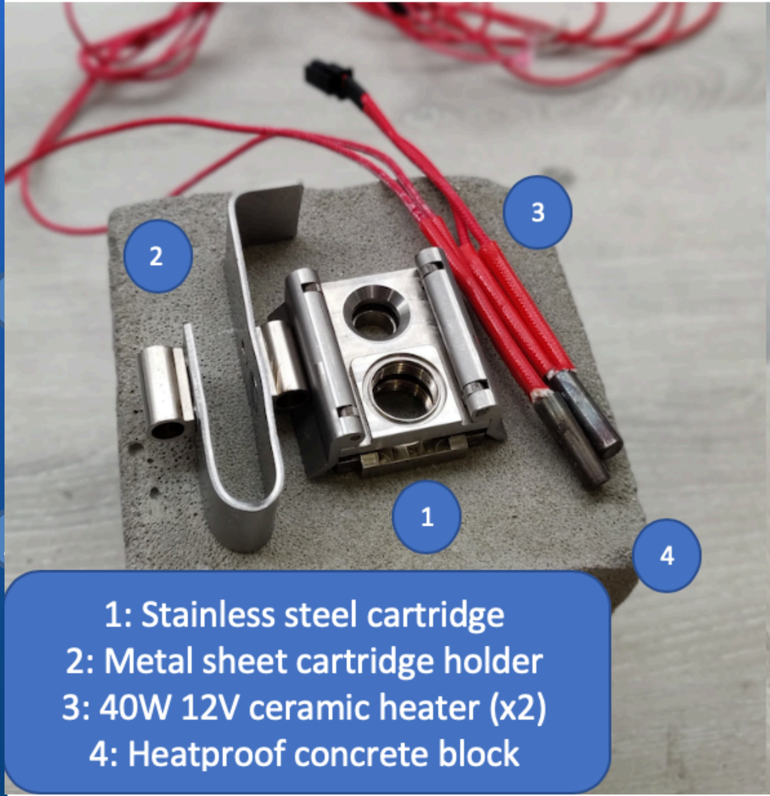
3 Researched about microprocessors, temperature sensors and practical control theory to assist Calvin

4 Analysed and determined the power (*W)* of the newly purchased UV LEDs from data generated by the lab sub-team

5 Drafted Dry heat sterilisation section of Final Report and formatting

6 Analysed heat lab results by counting bacteria on petri dishes using ImageJ software

Research, Drafting, Design and Manufacturing



Becky

Lab team and Heat Team

Main contributions:

- Investigating silver nanoparticles and chemical methods of sterilisation
- Developing lab microbiological protocol
- Performing microbiology experiments and image analysis
- Developing sheet metal heat prototypes (2 and 4)
- Insulation and fabrication of container for heat prototype
- Research into social impact
- Cost/Fabrication techniques for heat

Silver Nanoparticles	
Interact with the outer membrane of bacteria, causing degradation and eventually cell death	
No user input	Ion leaching => false negatives
Chemical Methods (Ethanol, Methanol, IPA)	
Methanol currently used by Del Agua in a special vacuum cup	
Ethanol/IPA - easy to use and procure	Disinfectant, not steriliser

Lab Protocol:

Consistency across methods

-Contamination with E.Coli

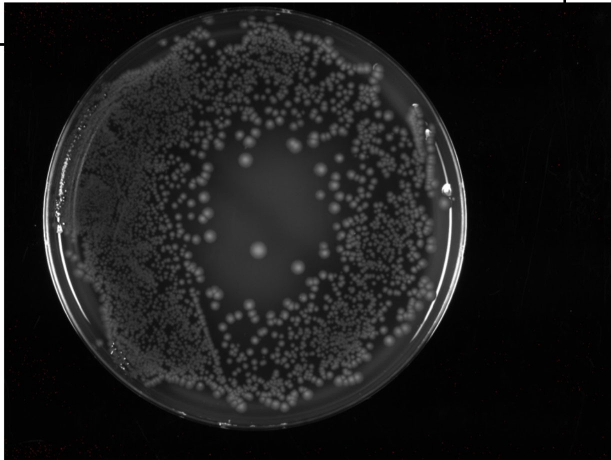
-Sterilisation

-Swab and Rinse

-Plate in Agar and Incubate

-Photograph with microscope

-Image processing by hand vs automated

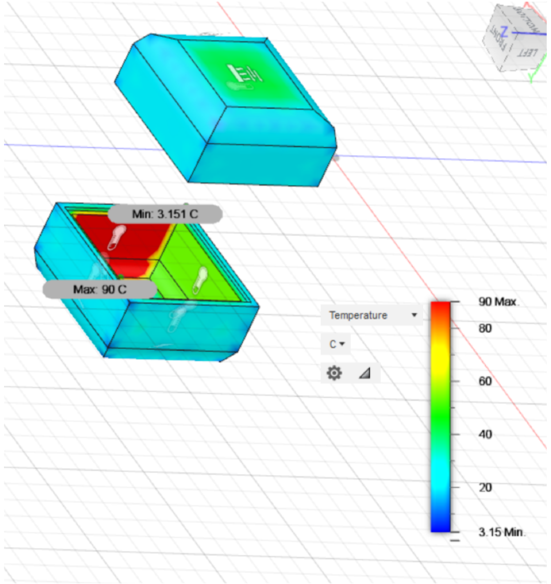


Container

Formlabs heat proof resin

Ultimaker PLA

Silicone made in mould (3D print mould)



Insulation

Polyester

Silicone

Thin ceramic layer

<u>Social Aspects:</u>

Usability, Power, Safety

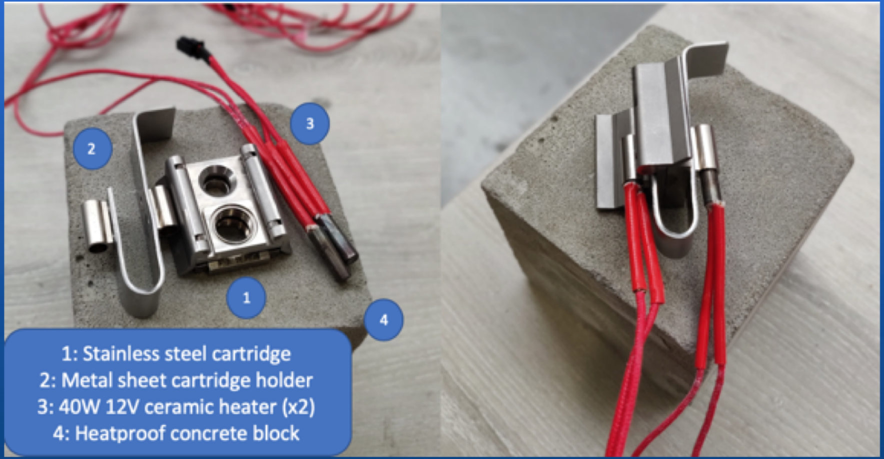
Potential other uses:

- Water Treatment
-Rural

Healthcare Facilities

- Equipment sterilisation in

Summary



Final heat prototype

Final UV prototype