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Calibration of a Modular Dish Design using Lunar Flux Mapping

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Clean Energy Research Group (CERG)

Overview

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Introduction

- Increasing demand for off-grid power generation in rural Africa.
- Settlements and farmsteads experience inflated rates for electricity or are not reached all-together.
- An experimental study on the efficiency of a small-scale solar thermal Rankine cycle using direct steam generation.

Problem

- Focus has shifted towards large scale CSP, supplying directly to the grid.

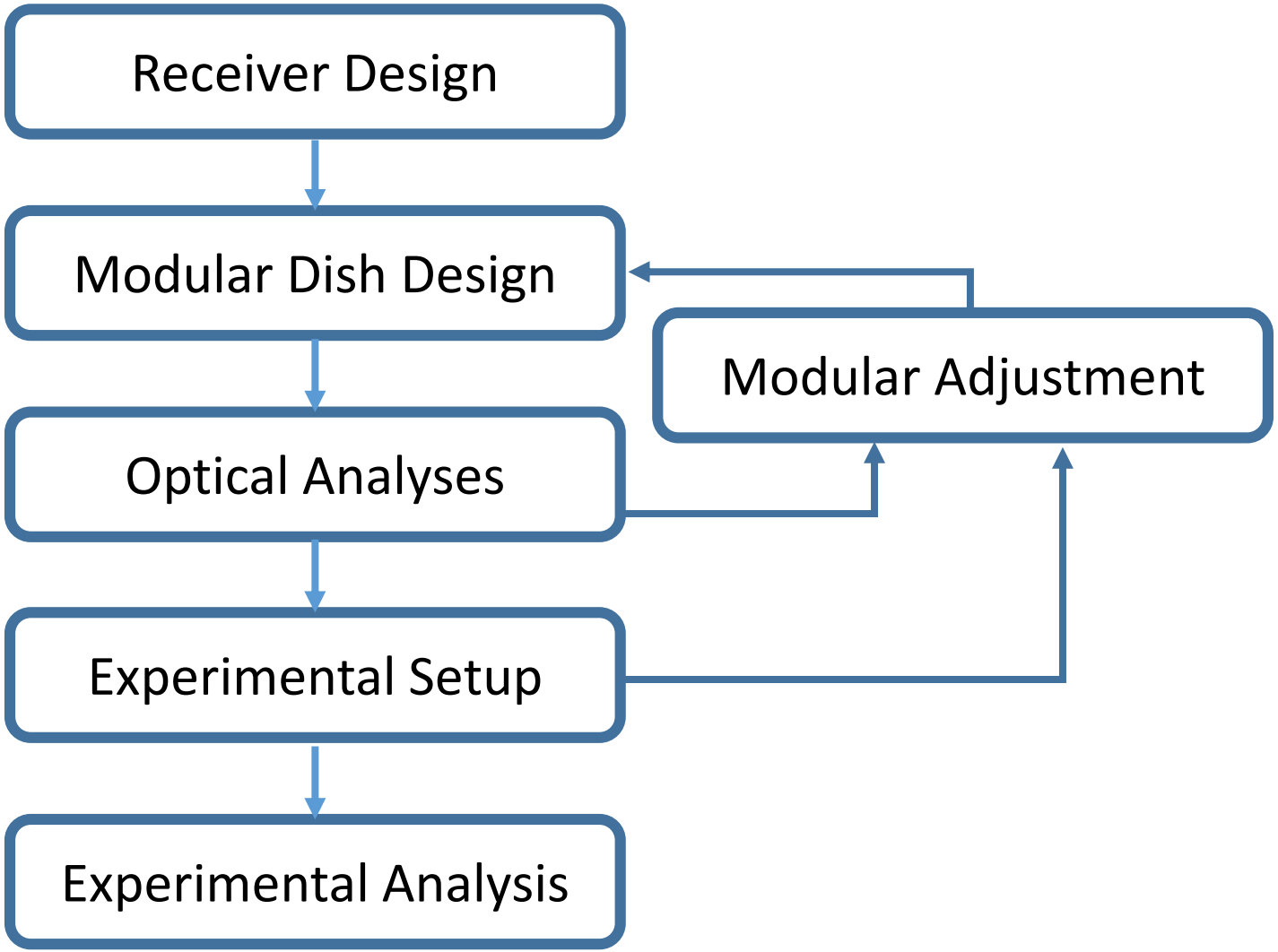
- Relevant research is outdated or does not take into account the conditions within sub-Saharan Africa.

Research Objectives

Determine the potential for direct steam generation solar thermal Rankine cycles, at distributed scale, to assist in meeting the needs of powering rural settlements.

- Develop a solar concentrator that can be locally manufactured out of affordable materials.
- Analyse the efficiency of a simple cavity receiver design in a Rankine cycle power generation process.

Research Methodology



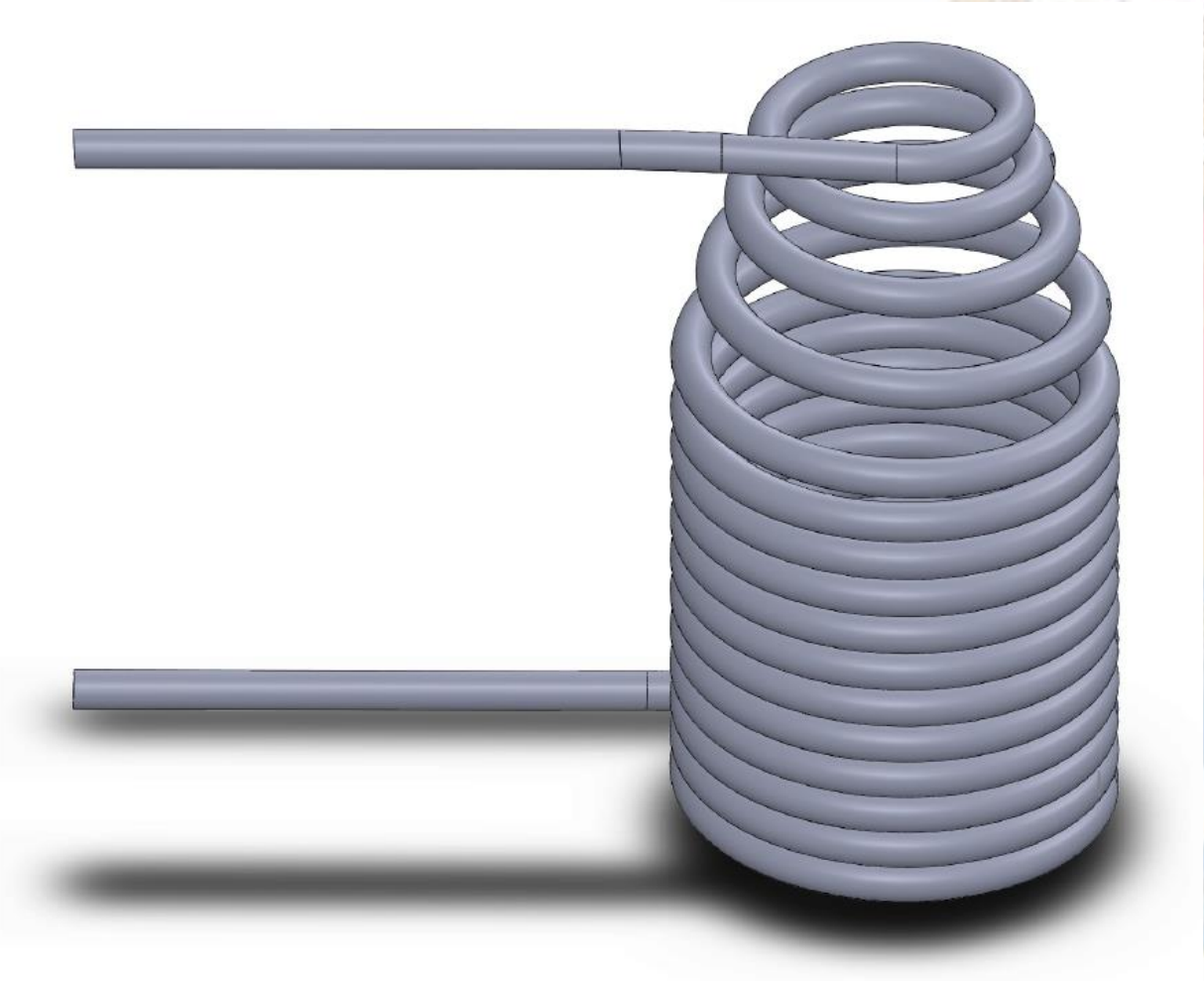
Current Progress – Receiver Design

- Receiver cavity designed through basic analytical methods.

- The experimental model differed largely from the analytical design.
  - Materials were sourced locally, within a budget at the time.
  - The receiver was manufactured by students.

- This lends itself towards manufacturing simplicity in industry.

Current Progress – Receiver Design



Current Progress – Modular Dish Design

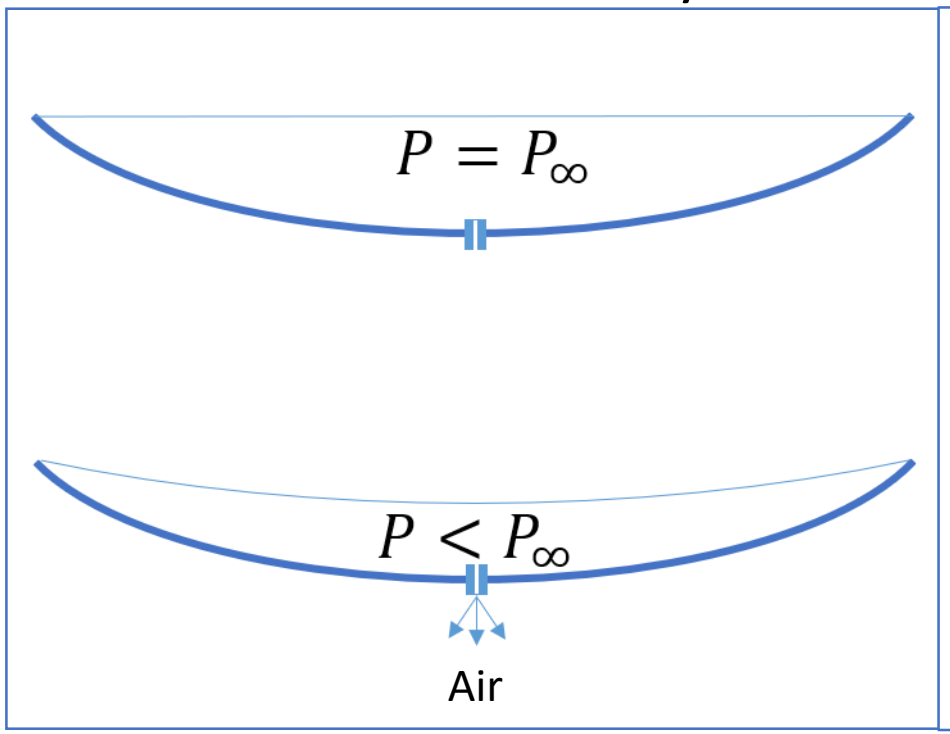
In collaboration with Casey Roosendaal (BEng Honours Mechanical)

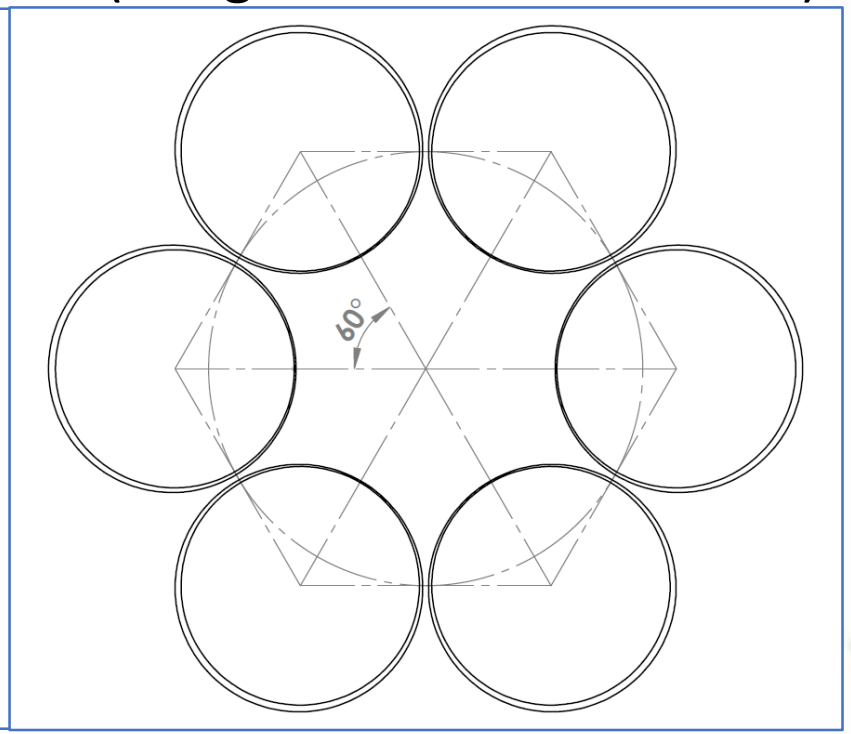
- Materials for parabolic dish reflectors are not manufactured locally and are required to be imported.

- Parabolic dish reflectors are limited by the fixed geometry.

Current Progress – Modular Dish Design

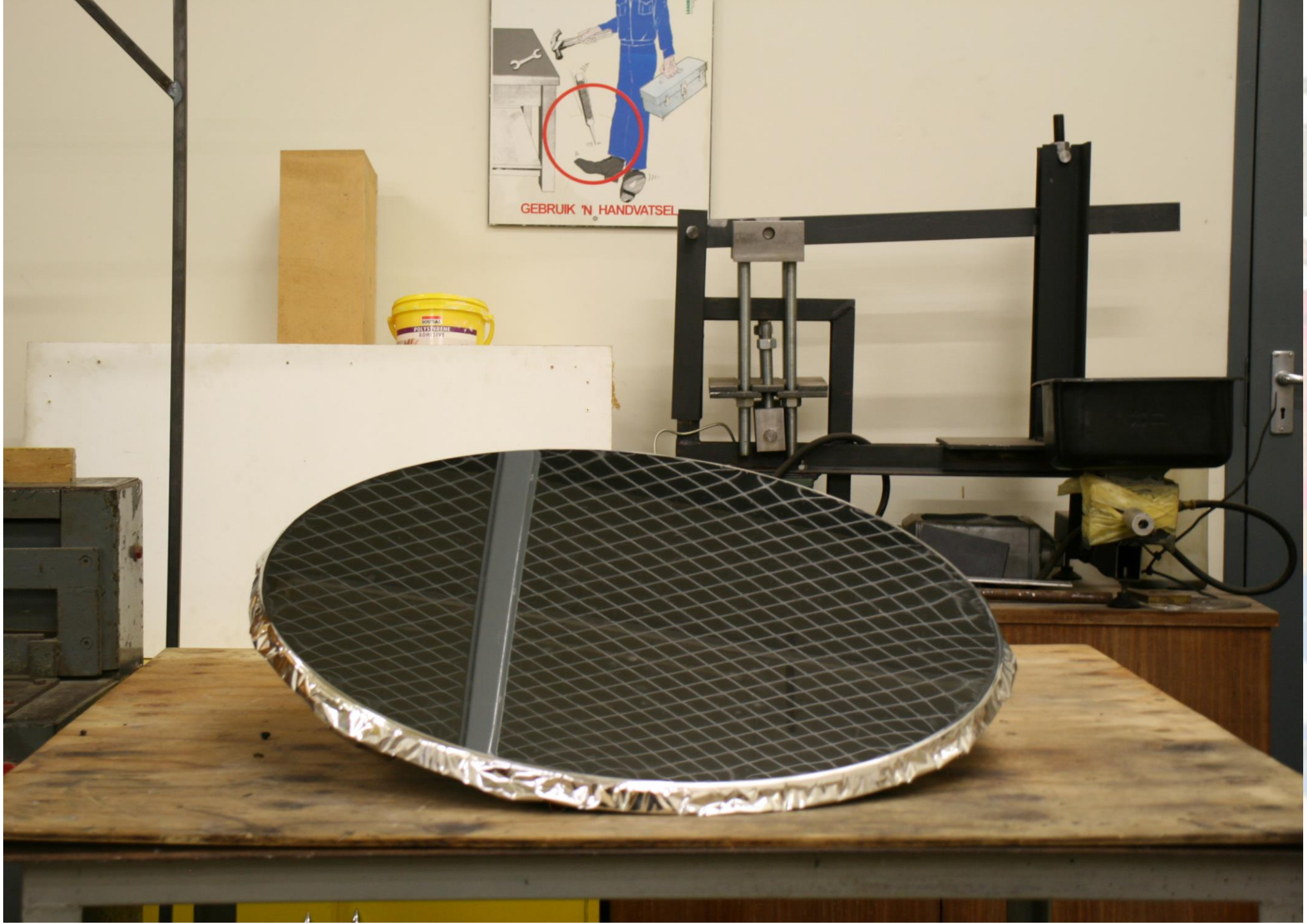
In collaboration with Casey Roosendaal (BEng Mechanical Honours)





Current Progress – Modular Dish Design

- The new design offers an affordable solution that can be locally manufactured.
- The dish reflector consists of multiple smaller dishes that were described in the previous design.
- The dish reflector is considered to be modular since it allows for the parameterisation of the reflector's effective diameter and effective rim angle.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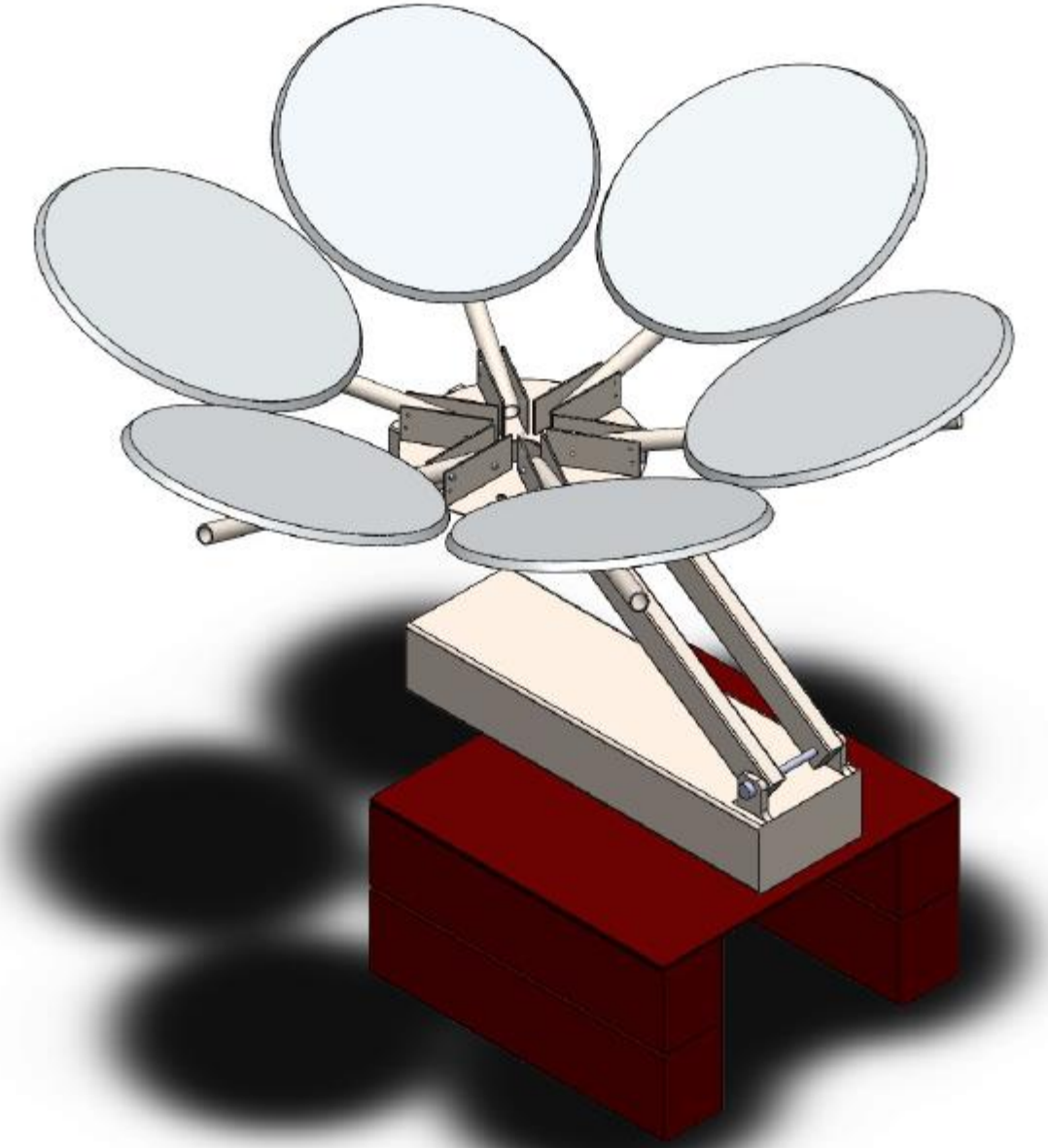


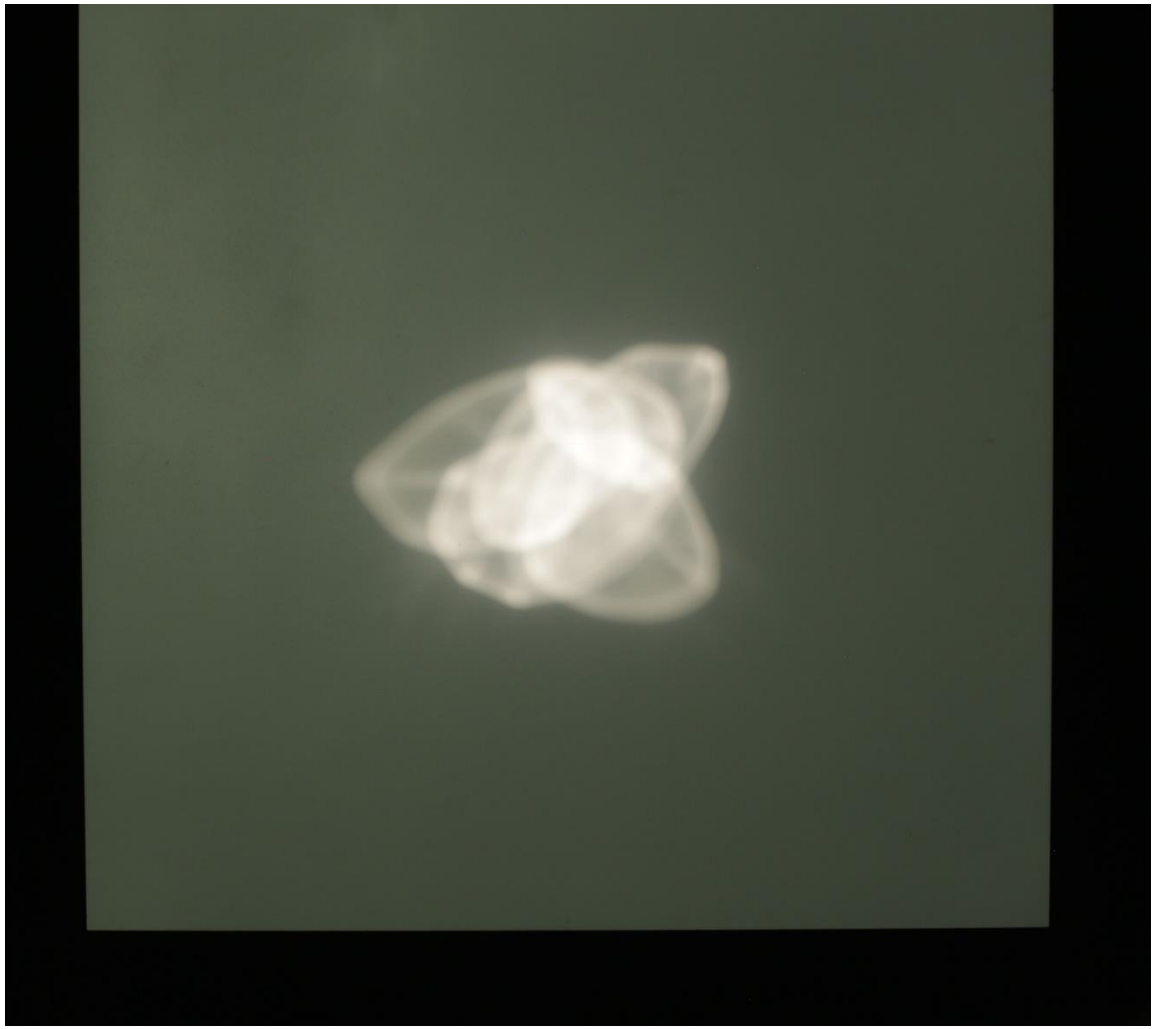
Current Progress – Modular Dish Calibration

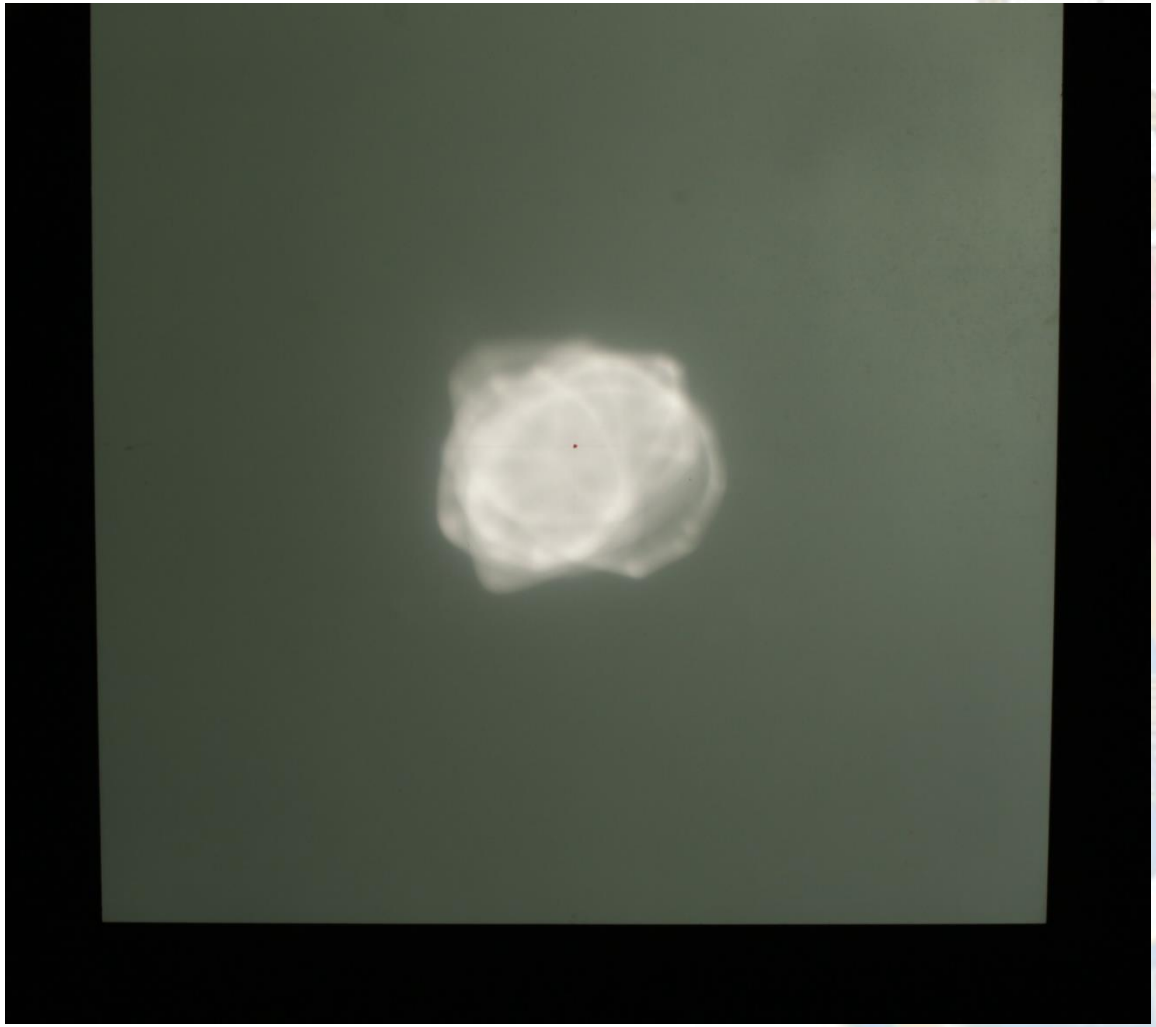
- The dish is made to face the moon and an image is reflected onto a near Lambertian target surface.

- The image reflected onto the target surface is used to orientate the dish for an optimum interception factor.
  - Full moon is only necessary if intending to use the calibration results in an optical analysis.

  - The light reflected onto the earth from the moon has a similar angular width to that of the sun.

  - No, cooling is required for the target surface.





Current Progress – Modular Dish Calibration

- An effective dish diameter and rim angle is obtained after calibration.
- The dish setup is intended to hold its shape over night for testing the next day.

Current Progress – Preliminary Optical Analysis

- In collaboration with Casey Roosendaal.
- Interception factor can be calculated from lunar mapping results (For full moon condition).
- Python's PIL module – "Python Imaging Library" for image processing.
- Pixel intensity (I_{xy}), is a scaler value describing/relating to the intensity of light.

$$I_{xy} = \frac{R_{xy} + G_{xy} + B_{xy}}{3}$$

Current Progress – Preliminary Optical Analysis

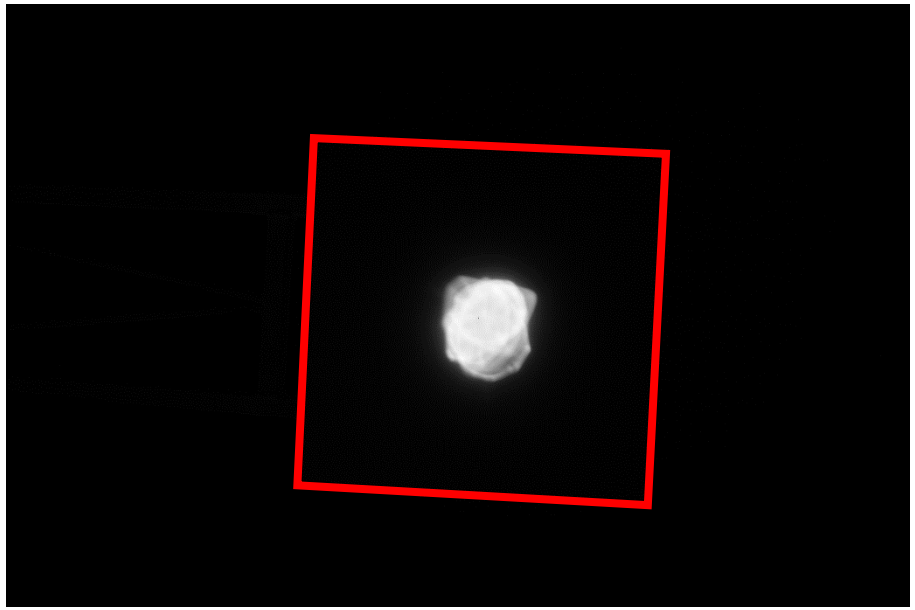
- Pixel saturation condition:

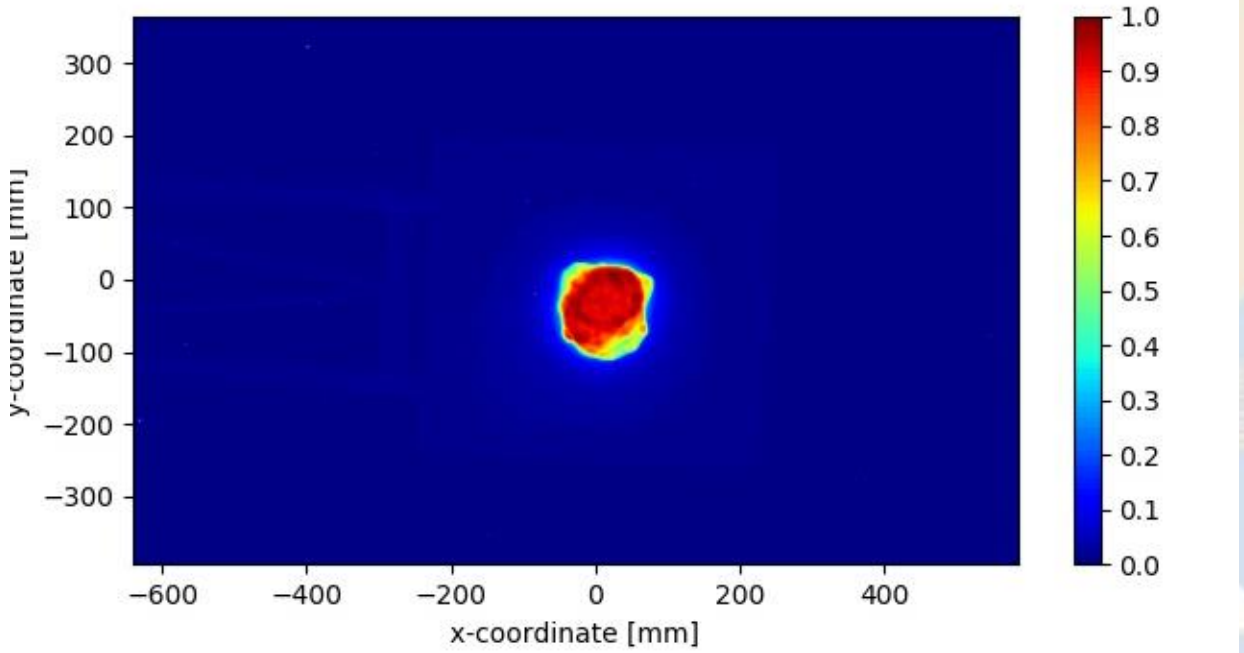
$$I_{xy} > 255$$

- Calibration and analysis conducted using a CANON EOS 400D

Camera Settings	Values
ISO Setting	100
F number	4.5
Shutter Speed	2’’

Current Progress – Preliminary Optical Analysis





Research to Follow

- Challenges:
  - Mylar sheet reflectivity
  - Light pollution

- Complete optical analysis – Interception factor, SolTrace etc.

- Analysis of the solar receiver for realistic day light conditions.

- Second Law analysis of receiver to determine collector's power potential.

Conclusion

- The research progress made up to current date has been presented.

- A calibration of the modular dish design was conducted.
  - The smaller dishes were positioned to form a modular dish with an effective dish diameter of 1600mm and an effective rim angle of 45°.

  - Assistance is needed to determine the reflectivity of the mylar sheet.

Thank You
&
Questions?