# Thermal Analysis and Experimental Design of the Super-Sharp Unfolding Telescope

Super-Sharp Space Systems
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## Introduction

Super-Sharp Space Systems specialises in making unfolding infrared telescopes for high-resolution thermal imaging of the Earth. To provide such high quality images, telescope mirrors must be positioned precisely and be able to withstand thermal cycling and extreme temperatures in space. Therefore, a detailed thermal analysis of the mirrors' displacements at extreme temperatures was required.

## Analysis

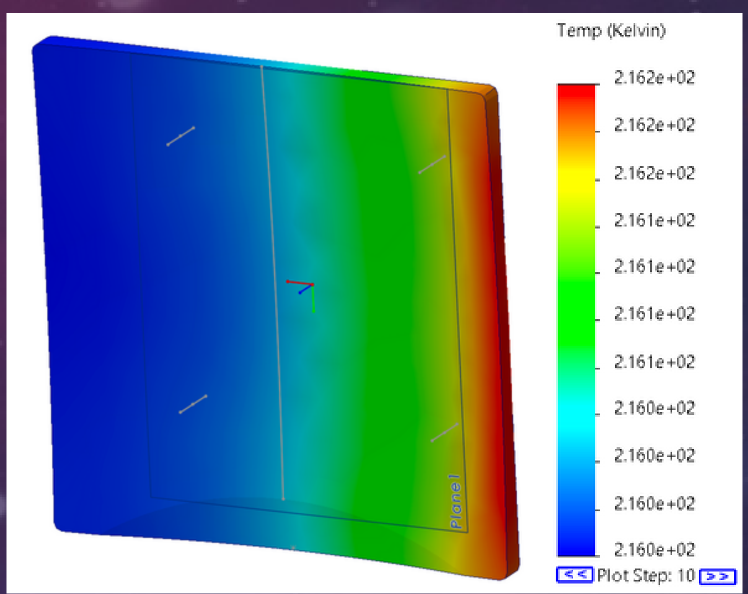



Figure 1. Thermal analysis of the aluminium mirror

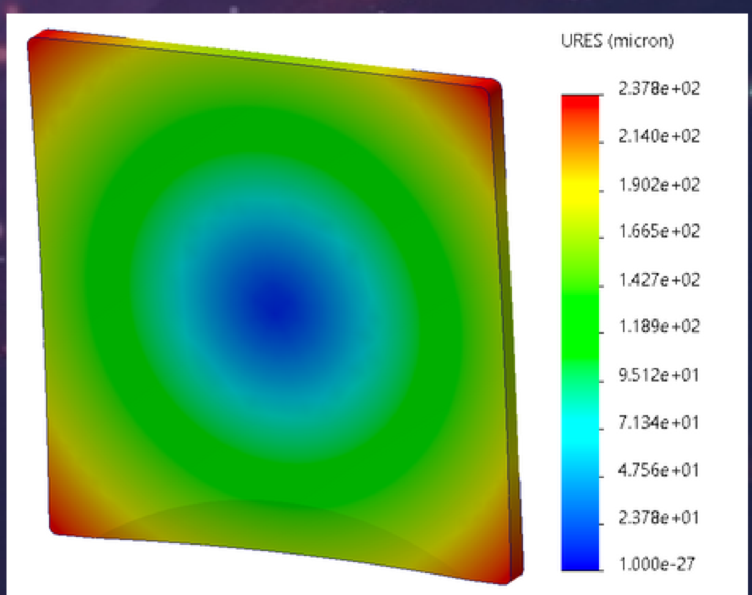



Figure 2. Static analysis of the aluminium mirror

SolidWorks Simulations package was used to perform the analysis, taking into account the solar flux, Albedo effect, planetary radiation and radiative cooling of the mirror. Figures 1 and 2 show that an aluminium mirror is expected to reach thermal equilibrium at 216K, and the maximum resultant displacement of 237.8 microns at the corners.

Given the required precision of alignment, these displacements are rather big, so different materials such as macor and zerodur were researched as well. These gave better results, with zerodur reaching a maximum displacement of 1.6 microns at its thermal equilibrium.

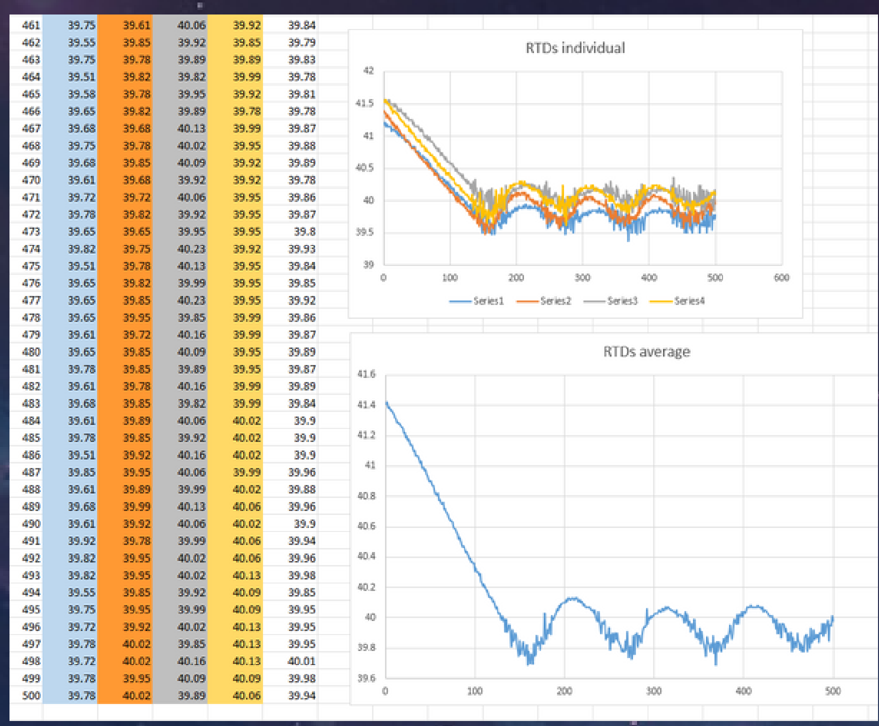
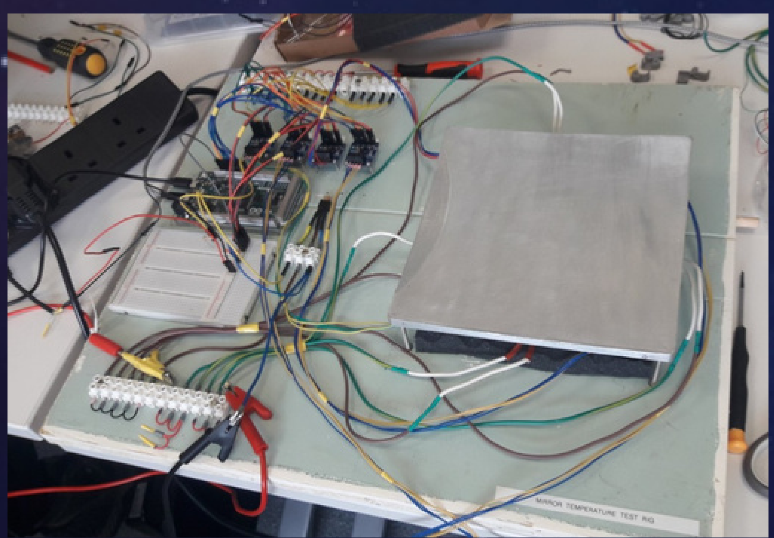


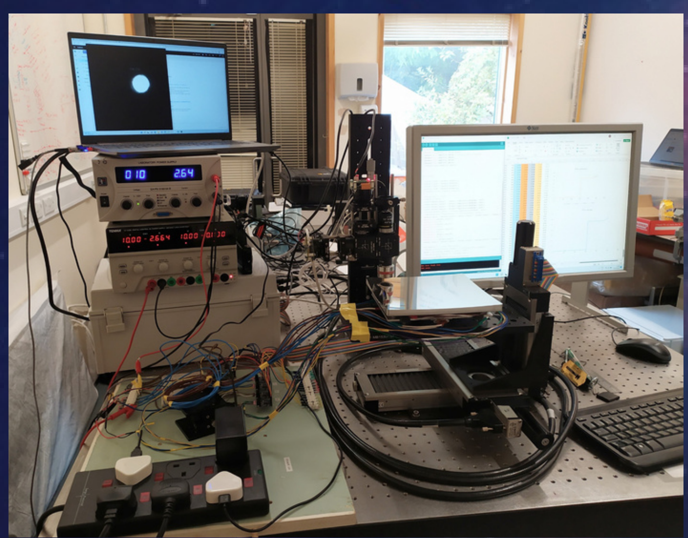

Figure 3. Variation of temperature with time of a mirror heated to 40°C

Profilometer data was gathered for testing a new hypothesis: if the heated mirror is just a uniformly scaled version of the original, the issue of distorted images due to big displacements in aluminium could be solved by simply moving the mirror and adjusting the focal point.

## Testing

A thermal test rig encompassing resistive heaters, RTDs, Arduino circuitry and a MOSFET was developed to enable physical testing of the mirrors at different temperatures.





The mirror was placed under a profilometer which mapped its surface into a set of 3D points. A PID control loop was coded in Arduino IDE to maintain a constant temperature, and the Data Streamer feature in Microsoft Excel allowed for the temperatures to be monitored in real time (Figure 3).

## Results

Displacements obtained from both the SolidWorks analyses and the profilometer were run through a Python script and compared to a best fit curve governed by the equation of the mirror surface. Differences between the two, called "residuals", are shown on Figure 4 for SolidWorks and Figure 5 for the profilometer. Slightly greater profilometer residuals are suspected to be due to the intrinsic mirror distortions caused by the manufacturing process.

If we ignore the measurement noise, these residuals are within a workable range. The fact that they are so similar for different temperatures implies that thermal effects are not what contributes to displacements the most and that the manufacturing-imposed displacements are of much bigger significance. This is left as future work to be investigated, but alternative materials are already being taken into consideration as well.

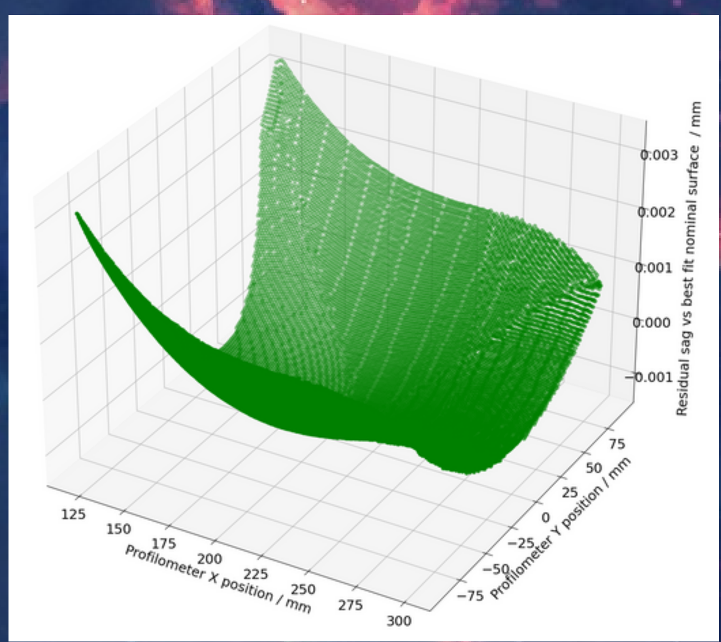



Figure 4. SolidWorks data best-fit residuals at 60°C

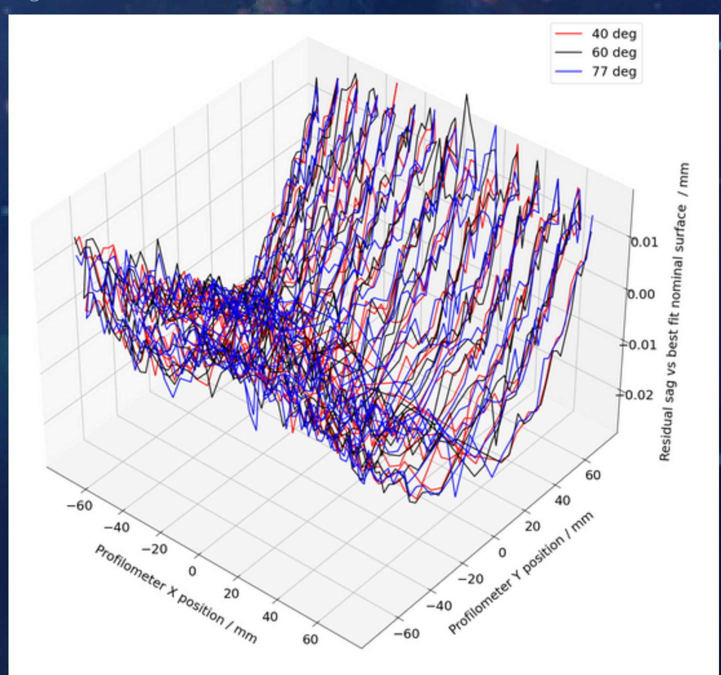



Figure 5. Profilometer data best-fit residuals at 40, 60 and 77°C

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