CUI Basic

Thermal Analysis of the Nancy Grace Roman Space Telescope

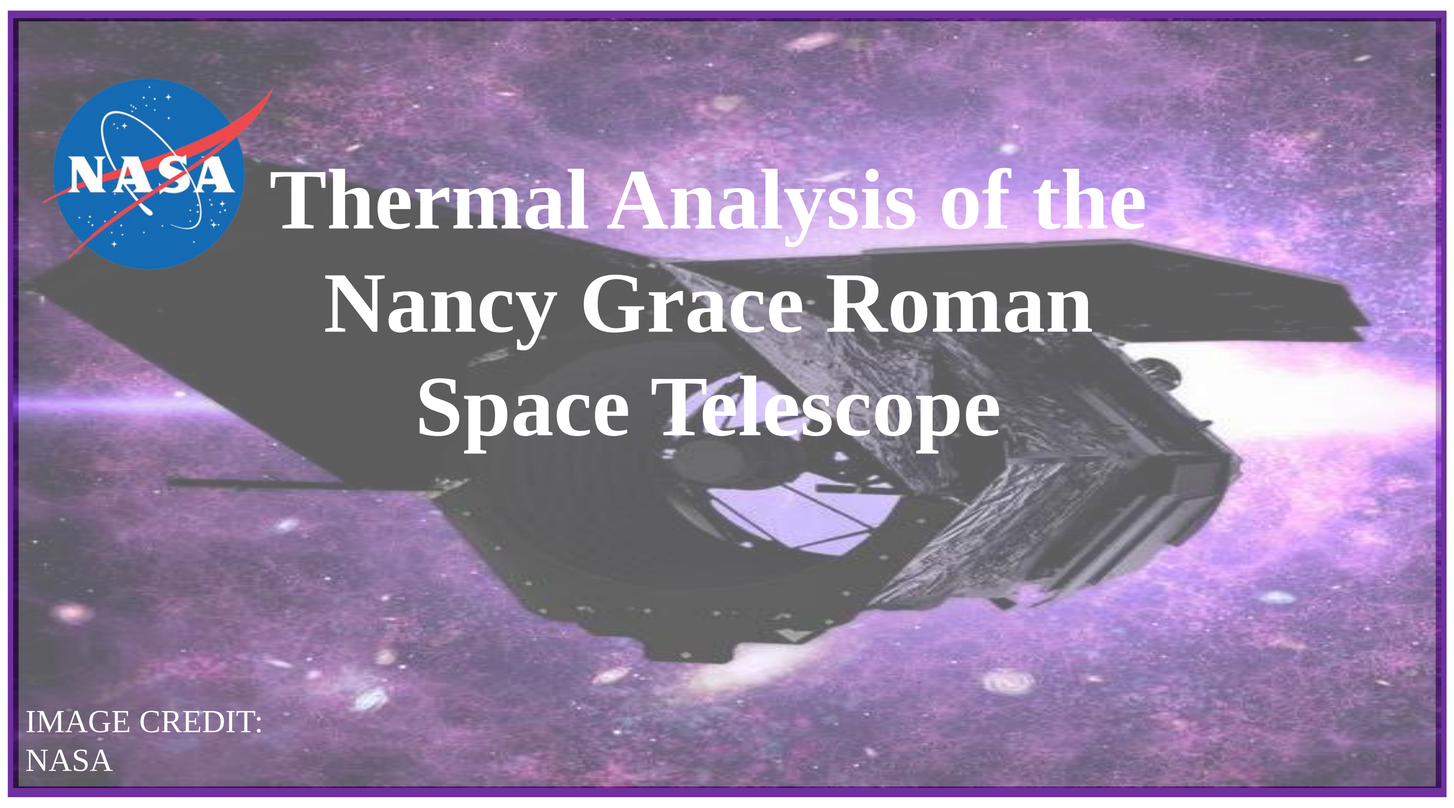

IMAGE CREDIT: NASA

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Introduction

The Nancy Grace Roman Space Telescope (RST) is a NASA observatory that will be going to Lagrange Point 2, where it will provide us with a panoramic view of the universe and help us dive into the history of dark matter in space.

Fig. 1: Roman Space Telescope High Gain Antenna System
Image Credit: NASA

My internship primarily revolved around RST's High Gain Antenna System (HGAS), which is the communication subsystem that accommodates uplink and downlink data for commands and housekeeping telemetry and data for science (Figure 1). This dish, which is about six feet in diameter, can move in multiple directions using gimbals. This dynamic motion allows the antenna to point at Earth in every configuration in which the telescope may be while in orbit.

Thermal Vacuum Chamber Testing

All components of spacecraft must go through testing in a thermal vacuum chamber to simulate the space environment in which the space vehicle will be experiencing, including extreme hot and cold temperatures. In order to simulate RST's complete assembly during testing, NASA's engineers have designed the Spacecraft Integrated Payload Assembly (SCIPA) Pathfinder Model (Figure 2). This includes all of the Ground Station Equipment (GSE) for RST.

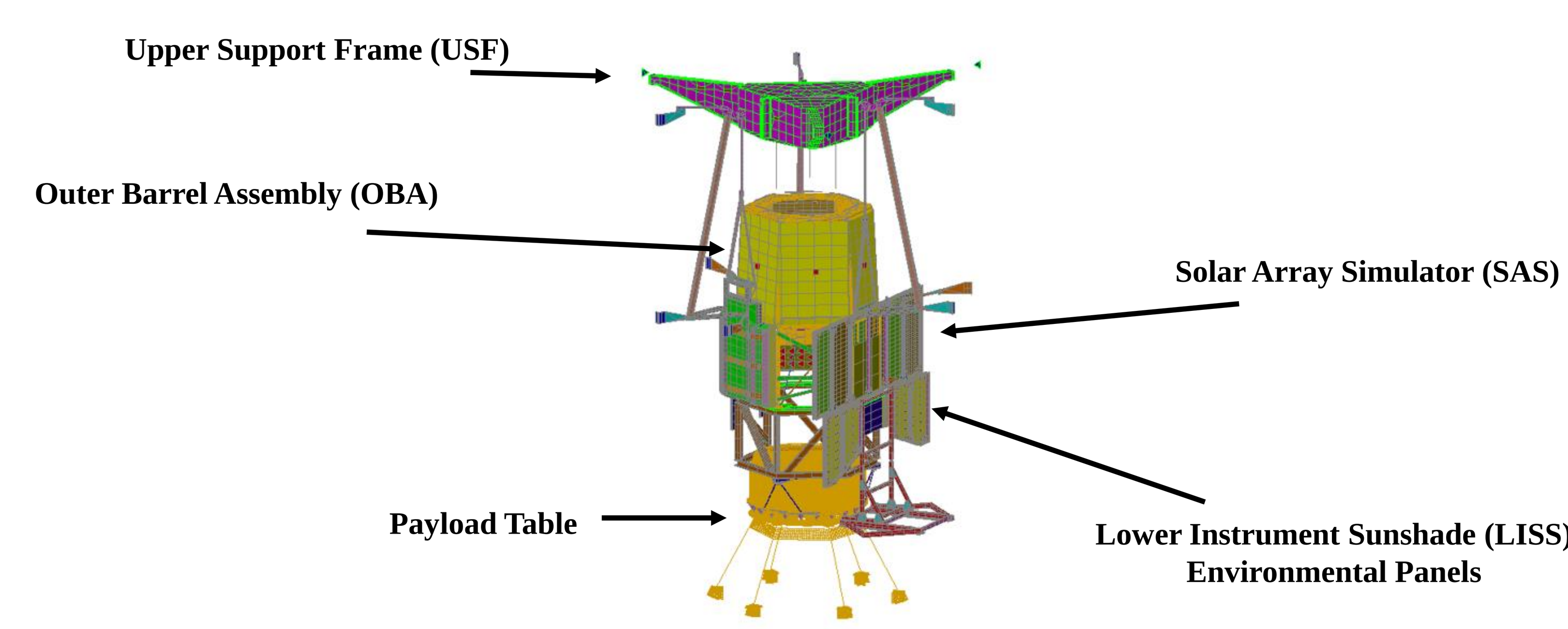

Fig. 2: RST SCIPA Pathfinder Model
Credit: Thermal Model of SCIPA Pathfinder by NASA

HGAS

Antenna Pointing

If the antenna is oriented in a position in which its gimbals are too exposed to the sun, the gimbals are at risk of overheating. This would risk HGAS's mobility relative to RST, causing issues with communication. To investigate the positions of RST in orbit in which the gimbals may be exposed to the sun, I experimented with all possible roll, pitch, and yaw configurations using the thermal model (Figure 3).

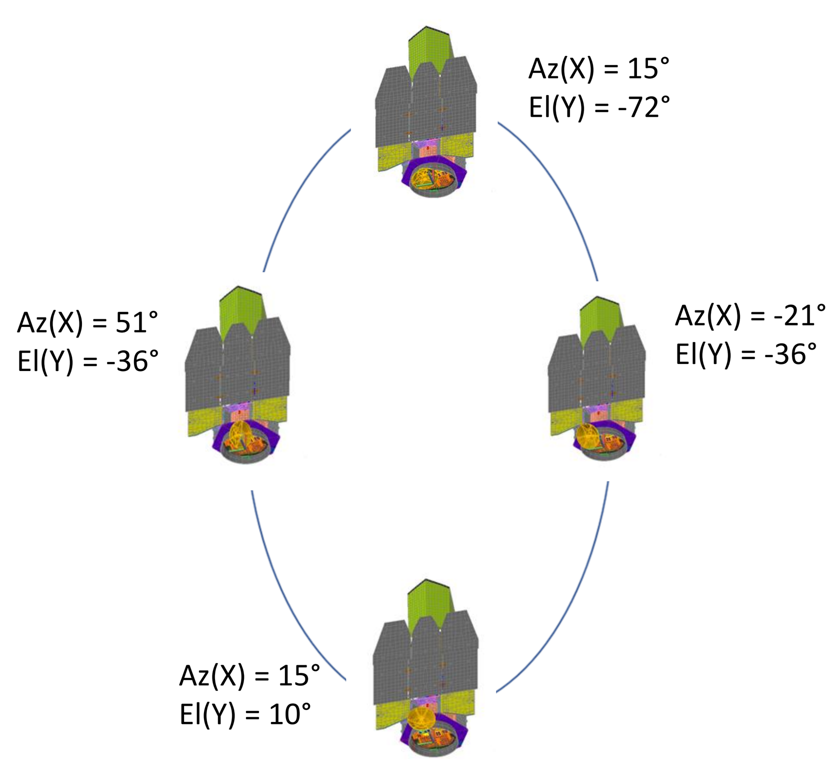

Fig. 3: HGAS Configurations at RST position X-15, Y36 (view from the sun)
Credit: Thermal Model of RST by NASA

Thermal Testing

HGAS was tested in GSFC's Space Environment Simulator (SES) in May of 2024. From the test data, I analyzed the temperatures that each of the components exhibited while in the SES and compiled them into profiles (Figure 4).

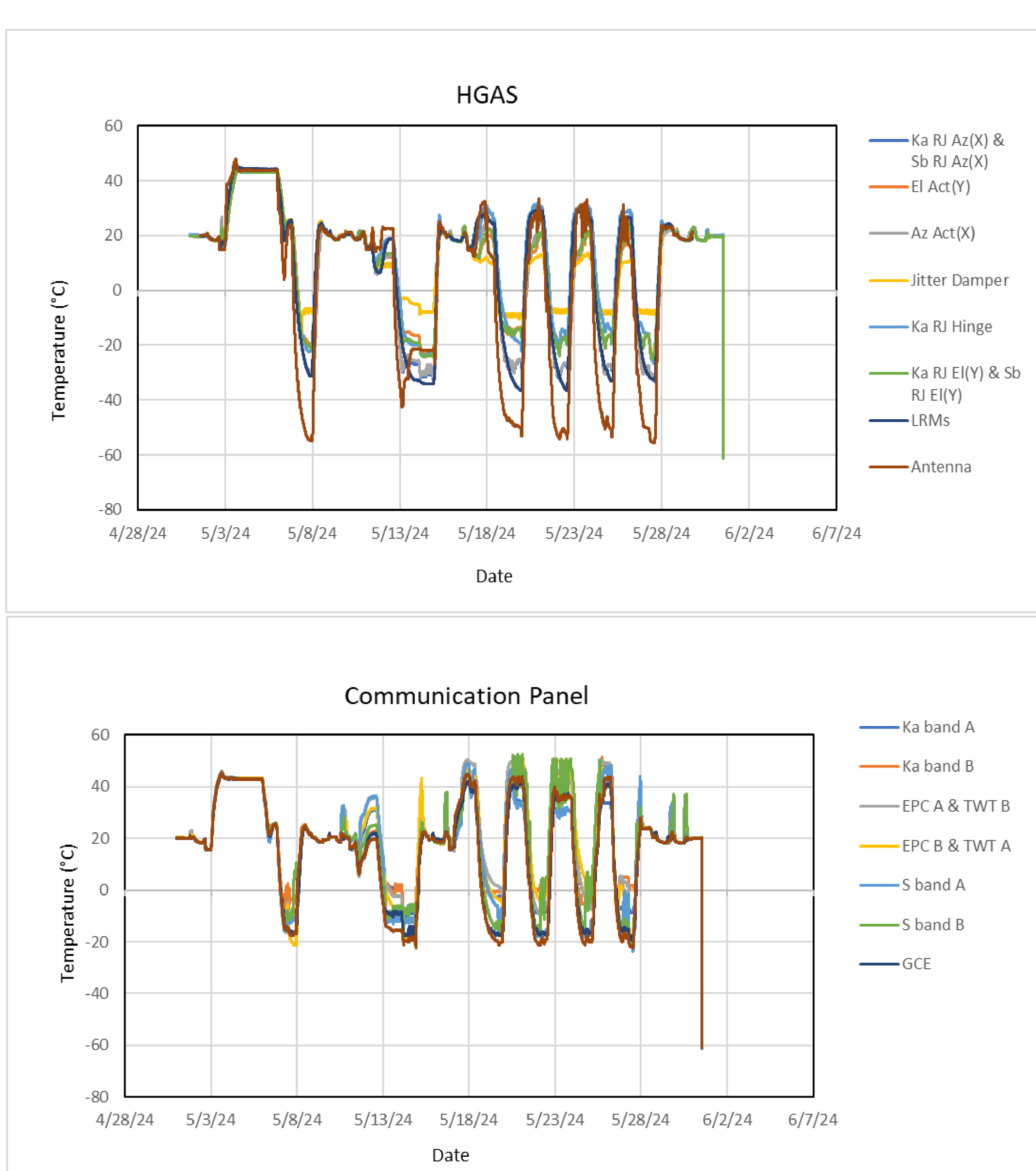

Fig. 4: Achieved Temperature Profiles from HGAS Testing

Conclusion

My results from the experimentation with the Thermal Desktop model of RST will assign the new bounding cases for antenna pointing in thermal trading.

The achieved temperature profiles from the HGAS test will be compared with the predicted temperature profiles in the original test plan. These profiles, along with data regarding heater power during testing, will be included in a report for the verification of HGAS.

SCIPA Pathfinder

Regarding the Pathfinder model, my task was to perform a trade study on the effective emissivity (ϵ^*) of the multilayer insulation (MLI) that is used to insulate the telescope. I completed three separate runs of the Pathfinder model in Thermal Desktop, each time varying the MLI ϵ^* value (Figure 5).

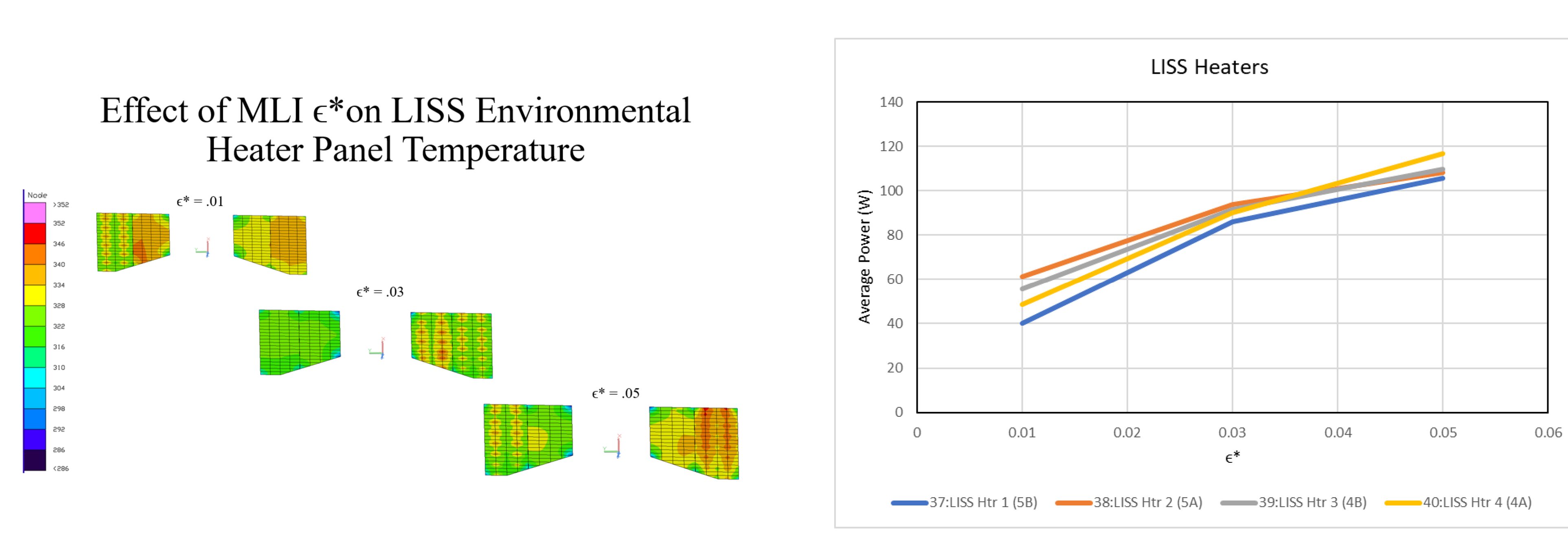

Fig. 5: Effect of MLI ϵ^* on LISS Temperature & Heater Power

Conclusion

This trade study will help to validate the heater performance within Pathfinder. Generally, it can be concluded that the MLI ϵ^* value is directly proportional to the heater power of each component of Pathfinder. This is driven by the fact that a higher MLI ϵ^* provides less insulation to the GSE, which results in its heaters performing at higher powers to protect it from cold temperatures.

Tools Used:
AutoCAD/Thermal Desktop
Microsoft Office
RST Spacecraft Thermal Model
SCIPA Pathfinder Thermal Model