Optimization of Instrumentation and Testing Strategies for Thermal Design in Space Vehicles: A Case Study of UPMSat 3.

Master Thesis
MSc in Space Systems

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Chapter 1

Introduction

In the context of thermal testing, the effectiveness of sensor placement plays an important role in ensuring, not only the accuracy and reliability of test results but also the significance of them. That is why this project establishes a new methodology to optimize sensor placement for thermal testing and /or control. The motivation to improve thermal testing is highlighted by the substantial costs —both in terms of finances and time— associated with thermal testing procedures, which makes even more necessary to get useful results.

Traditional approaches to sensor positioning often fall short in defining thermal experiments due to the complexity of representing the physical proccesses and properties in a thermal mathematical model. That is why an important part of the developed method revolves around parameter selection and model reduction. This might seem obvious at first sight, but complex thermal mathematical models can have up to thousends of parameters and surpass the million of nodes, so the job of selecting adequatelly the parameters that represents the physics of the problem for every charge case must not be underestimated.

In order to validate the method, it has been used in 3 thermal models:

- A 4 nodes model, which is a simple model where that allows to test the method in a controlled environment.
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- The UPMSat-3, a real satellite that is currently being developed by the Universidad Politécnica de Madrid. This model is used to test the method in a real scenario.

1.1 Spacecraft Thermal Control

The thermal design of a spacecraft is primarily influenced by the conditions it encounters during its mission in space. From a thermal perspective, the space environment is characterized by a vacuum, Solar radiation (both direct and reflected by nearby planets, known as albedo), and the infrared emission of celestial bodies.

The main driver of a spacecraft thermal design is the in-flight environment where it needs to operate. From a thermal point of view, the space environment is characterized by the vacuum, the incoming Solar radiation, both direct and reflected by a nearby planet (albedo), and the infrared emission of the planet.Because a spacecraft operates in a vacuum, the only possible thermal interaction between the spacecraft and its environment its through radiation. On an Earth orbit, solar irradiance is the main heat load, with a mean value of 1366 W/m2 and a seasonal variation of ±1.7% due to the eccentricity of the orbit of the Earth around the Sun. The solar irradiance value scales with the square of the distance to the Sun, and its spectrum can be modeled, from a thermal point of view, as a black body at some 5762 K, where 99 % of the spectral emissive power of the Sun lies in the range 0.15 to 10 µm wavelength.

1.1.1 Thermal mathematical modelling

1.1.2 Analaysis cases

1.1.3 Reduced thermal mathematical models

Chapter 2

Mathematical formulation

2.1 Problem definition

2.2 Error definition

2.3 Model requirements

2.4 Data acquisition

2.5 Observability

2.6 Parameters and nodes reduction

In order to choose the most adequate parameters to determine the reduced model, the matrix of influence $\mathbf{I_X}$ is defined below:

$$\mathbf{I_X} = \begin{bmatrix} \frac{\partial T_1}{\partial X_1}\delta X_1 & \frac{\partial T_1}{\partial X_2}\delta X_2 & \dots & \frac{\partial T_1}{\partial X_{N_P}}\delta X_{N_P} \\ \dots & \dots & & \dots \\ \frac{\partial T_{N_N}}{\partial X_1}\delta X_1 & \frac{\partial T_{N_N}}{\partial X_2}\delta X_2 & \dots & \frac{\partial T_{N_N}}{\partial X_{N_P}}\delta X_{N_P} \end{bmatrix} = \mathbf{M}\delta\boldsymbol{X} \tag{2.1}$$

where $\mathbf{M}$ is the jacobian or sensibility matrix and $\delta\boldsymbol{X}$ is a vector containing the allowable variation of each parameter within the design. In the influence matrix $\mathbf{I_X}$ each column represents the temperature variation of the nodes that would be generated by a deviation on the parameter δX_i. Therefore, the elements of this matrix have dimensions of temperature, showing the effect of every parameter in the model, which would not be possible using the jacobian matrix directly

2.7 Sensor positioning

Chapter 3

Application to a 4 nodes models

Chapter 4

Application to the UPMSat-3

4.1 Context

4.2 Thermal mathematical model

4.3 Model reduction

4.3.1 Parameter identification

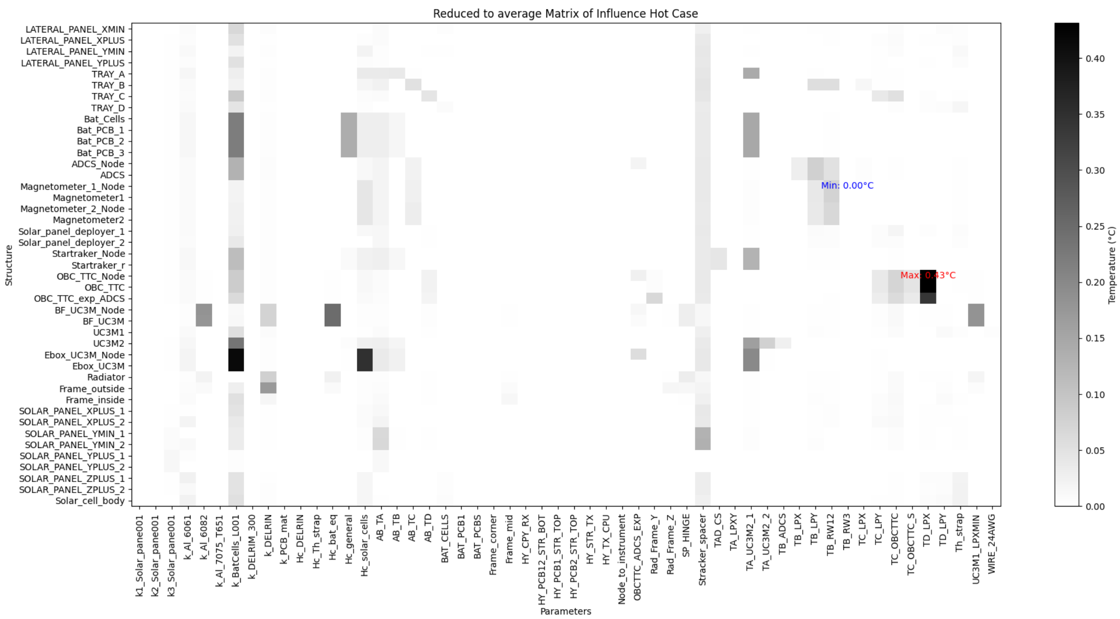

Figure 4.1: NO SIRVE, ES V0.

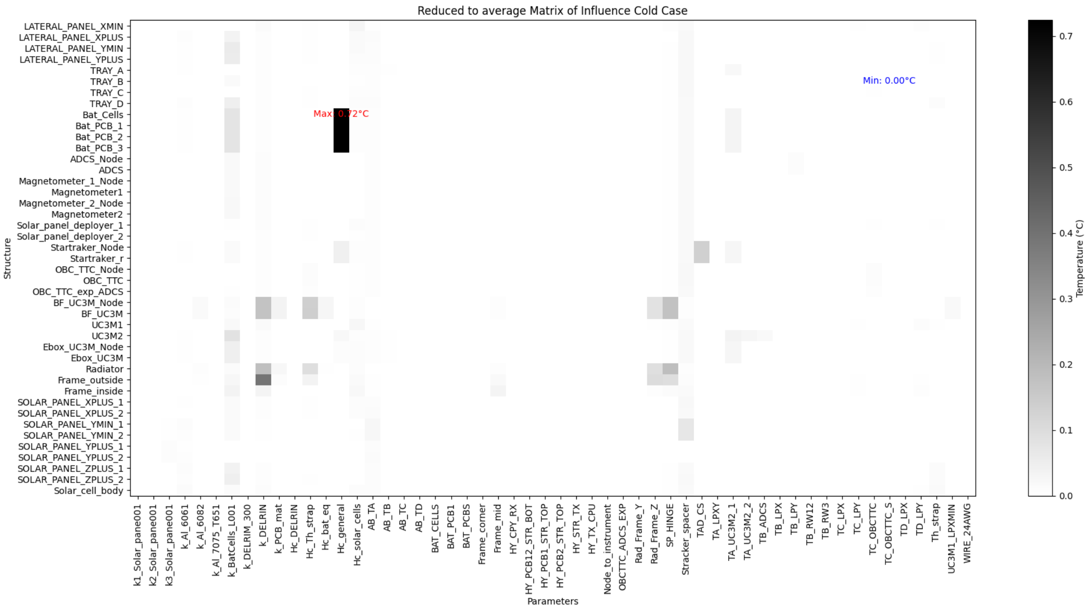

Figure 4.2: NO SIRVE, ES V0

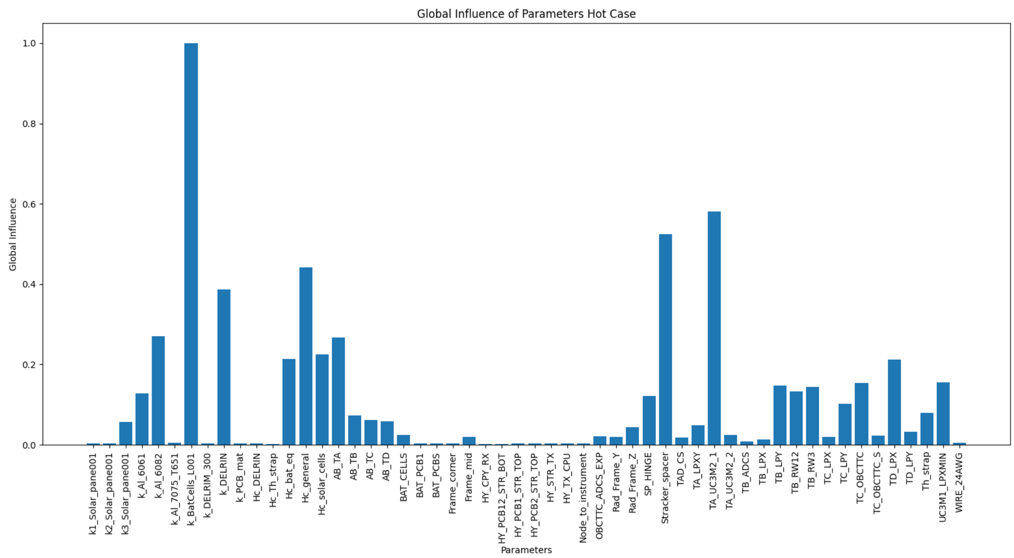

Figure 4.3: NO SIRVE, ES V0

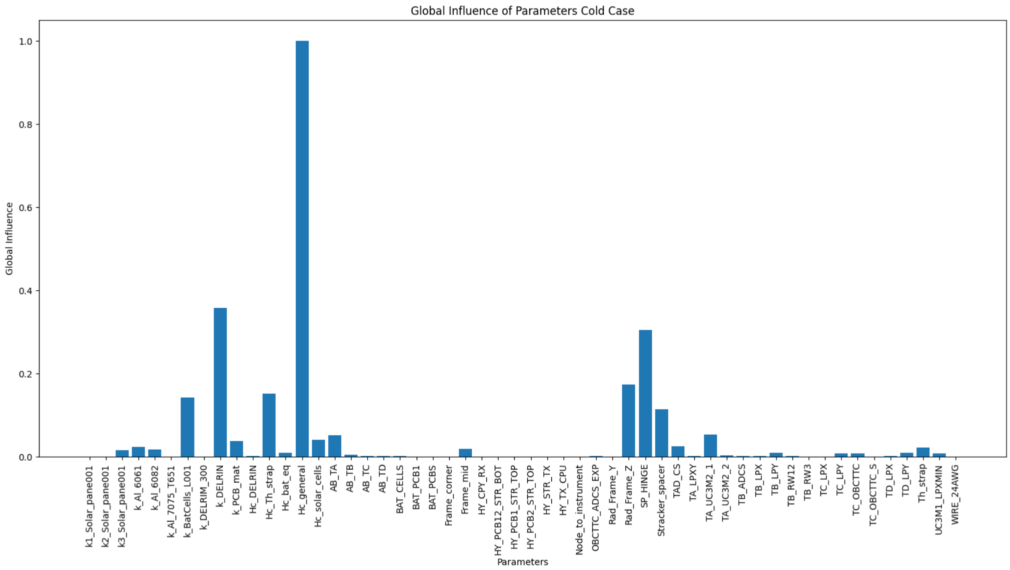

Figure 4.4: NO SIRVE, ES V0

4.3.2 Nodal reduction

4.3.3 Results

Appendices

Anexo A

Título del anexo

Aquí puedes meter la información que no sea imprescindible en el cuerpo del trabajo pero si que interese que esté en el documento.