Thermal Analysis of the Mechanical Structure of the Solar Telescope GREGOR

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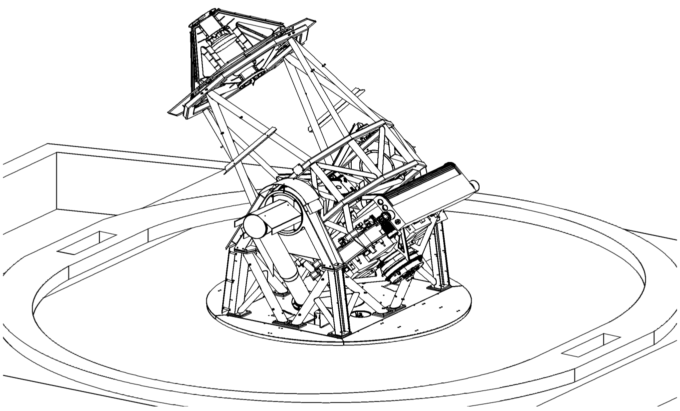
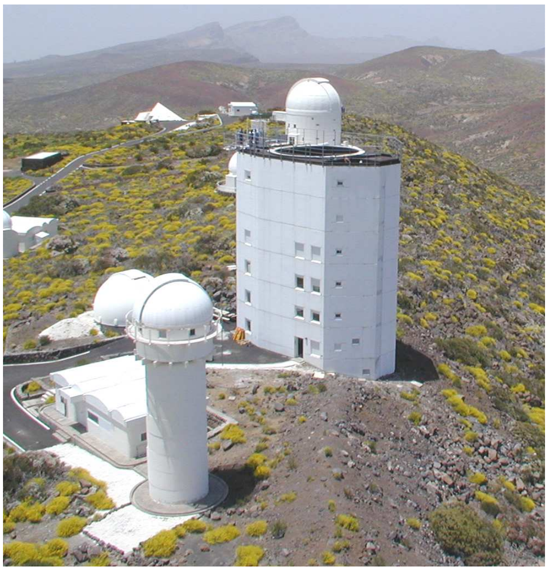
Contents

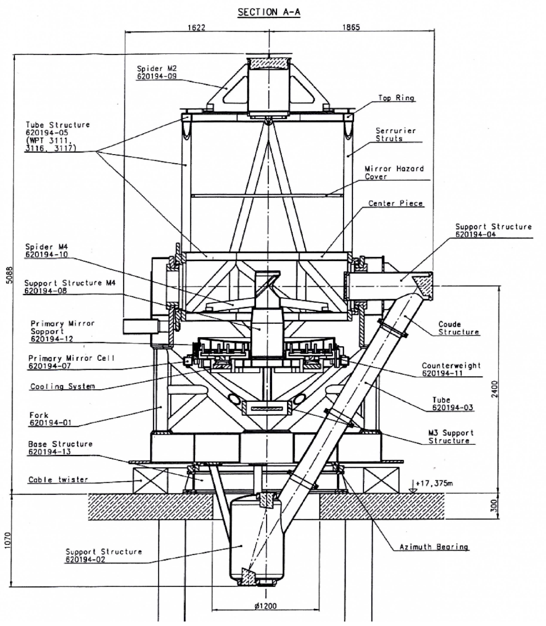
- Introduction
- Thermal Requirements
- Passive Thermal Design of the Telescope Structure
  - Structural Parts – Sun-Shields
  - Surface Material
- Thermal Analysis
  - Numerical Simulations
- Conclusion and Outlook



Motivation



Telescope building



Telescope structure

Thermal Requirements

- The telescope structure and the main mirrors are expected to be heated up by a solar radiation of 750 through 1100 W/m² depending on the time of day.
- The mechanical structure must maintain a minimal temperature deviation in order not to introduce thermal inhomogeneity of ambient air (“internal seeing”).
- The telescope structure shall therefore maintain a temperature deviation to the ambient air within -0.5K through +0.2K by passive means.
- Use of reflecting sun-shields which are thermally isolated from the remaining structure to improve the thermal behaviour of the main structure.

- The main mirror requires an active thermal control to maintain its surface temperature within given limits from the temperature of the ambient air.
- Temperature difference ΔT of less than 2K from ambient temperature with an accuracy of $\pm$ 0.1K across the mirror surface.

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Thermal Design Features

- Sun-shields at all surfaces directly exposed to the sunlight.
- Largely open steel truss structure allowing the wind to go through and to cause air turbulences and thus contributing to the avoidance of internal seeing.
- Surface coatings:
  - TiO_2 paint on sun-shields; high emissivity in the infrared domain
  - Metallic foil on Serruier struts
  - Paint with low infrared emissivity on remaining structure
- The Cesic main mirror is actively cooled by a nozzle system of six integrated cooling segments. Each nozzle cools one triangular cell of the primary mirror rear side by conditioned air.

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Thermal Analysis

- The analysis was performed with the finite element program ANSYS using a detailed finite element model of the telescope and of the environment.
- Due to the fact that the used program can not consider the wavelength dependence of the emissivities the analysis was only performed in the infrared domain.
- The finite element model contains all structural parts and optical elements which are necessary for a realistic thermal analysis of the whole structure.
- The absorbed heat flux of the sun-shields was applied as thermal load with 15 percent of the relevant sun radiation
- The analysis considers the heat conduction in the telescope structure, the convection between the telescope structure and the ambient air, the radiation heat transfer between the telescope structure and the environment (earth and cold sky) and between the telescope's structural parts as well.

Materials

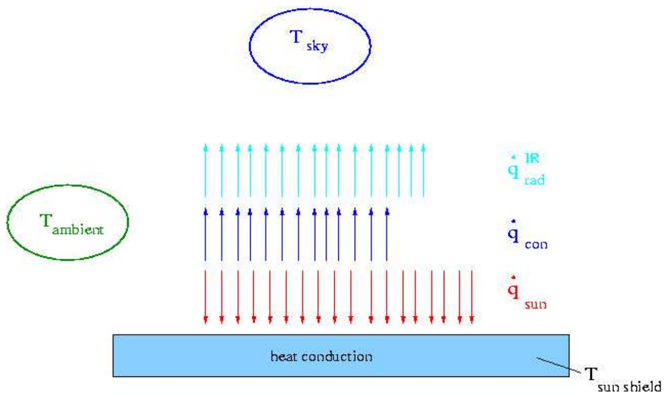
- Telescope structure is made of steel: standard material parameters
- Aluminium sun-shields: standard material parameters
- Emissivity coefficient:

Emissivity	Paint Steel Structure	Titan dioxide Sun-Shields	Reflecting Foil Serrurier Struts
ε_{IR}	0, 25	0,91	0,1

Boundary Conditions

- Sky temperature: 220K
- Earth temperature and ambient temperature: 288K
- Heat flux: elevation 90° ~ 165 W/m²; elevation 45° ~ 112 W/m²
- Wind velocity: 4 m/s => heat coefficient α= 20W/m²K :

Scheme of the heat fluxes



$$\dot{q}^{IR}_{rad} = \varepsilon_{IR} \cdot \sigma (T^4 - T^4_{sky}) \,, \qquad (1)$$

$$\dot{q}_{con} = \alpha \cdot (T - T_{amb}) \,, \qquad (2)$$

$$\dot{q}_{sun} = \varepsilon_{VL} \cdot S_r \,, \qquad (3)$$

whereas ε_{IR} is the emissivity of the sun-shields, σ is the Stefan-Boltzmann constant, α is the heat transfer coefficient, S_r is the reduced solar constant and ε_{VL} is the emissivity in the visible domain.

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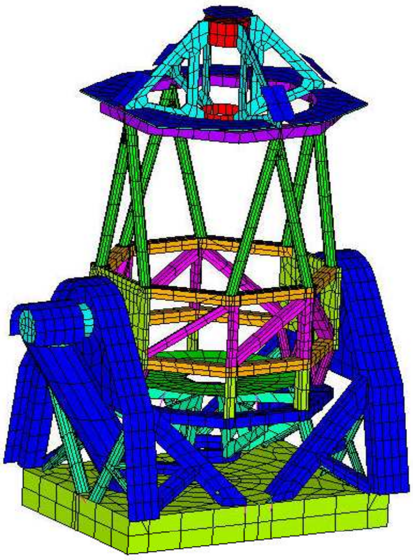
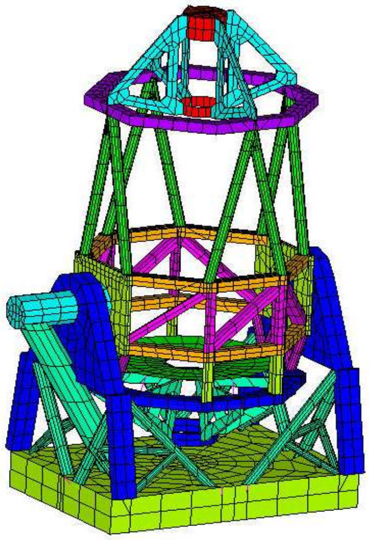
Thermal FE model



90° elevation; plus sun shields



90° elevation; plus sun shields

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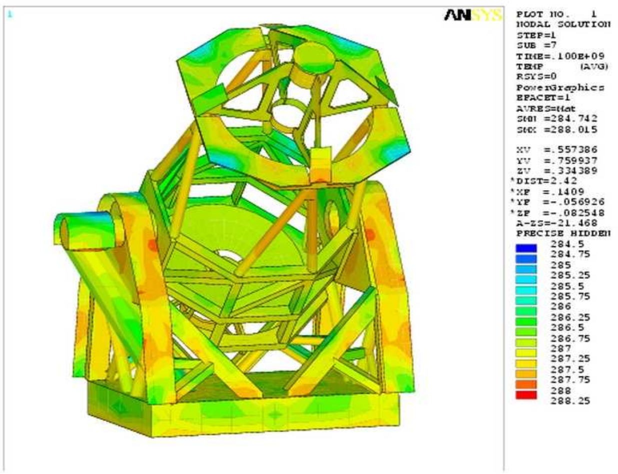
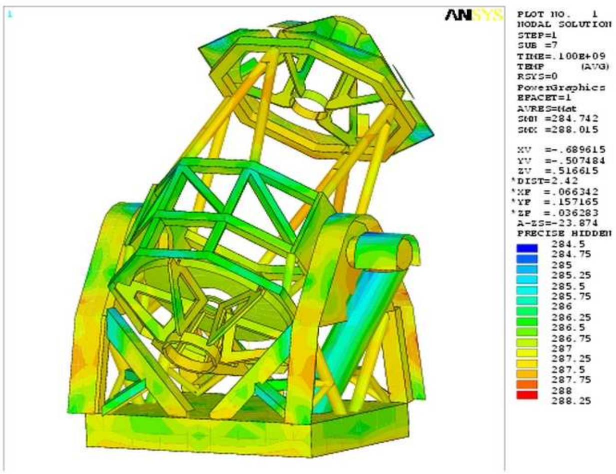
Temperature distribution for 45° elevation





Temperature of the main telescope structure is within the requirements

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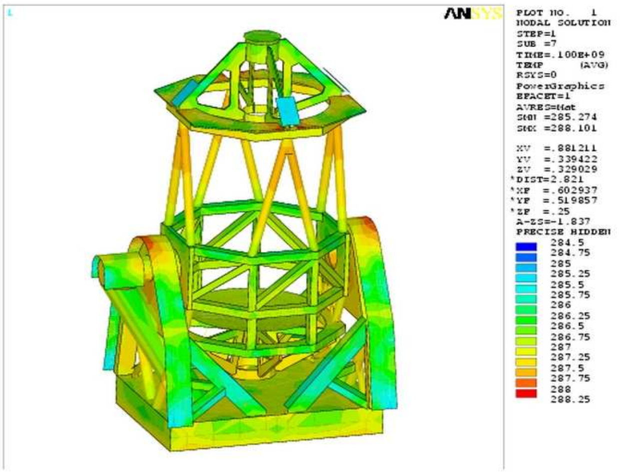
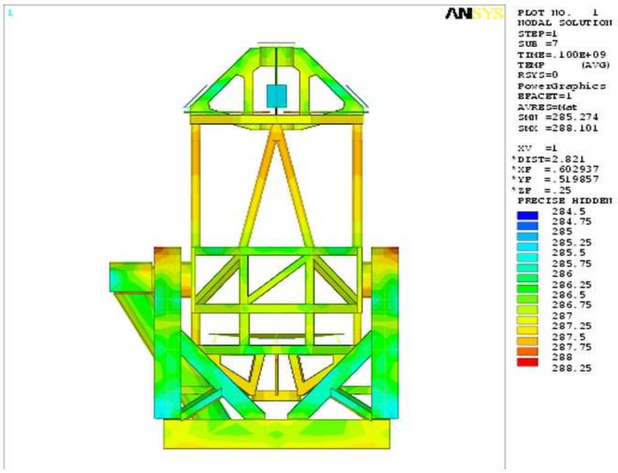
Temperature distribution for 90° elevation





Temperature of the main telescope structure is within the requirements

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Conclusion and Outlook

- The temperature of all structural parts is within a range of approximately 284.7 and 288.1K. The highest calculated structural temperature is 0.1K above the ambient temperature of 288K and thus fully within the requirement of +0.2K.
- The lowest temperatures can be found on the sun-shields.
- The top ring and the Serrurier struts which are in the critical path of the light are due the selected surface coatings also within the required temperature range of not more than 0.5K below the ambient temperature.
- The small temperature gradient across the struts has a negligible influence on the pointing of the telescope.

- First light at the beginning of 2005.
- Temperature measurements to verify the numerical results.