A Simple Thermal Analysis of the Quad Controls System and Comparison to LASTI Test Results

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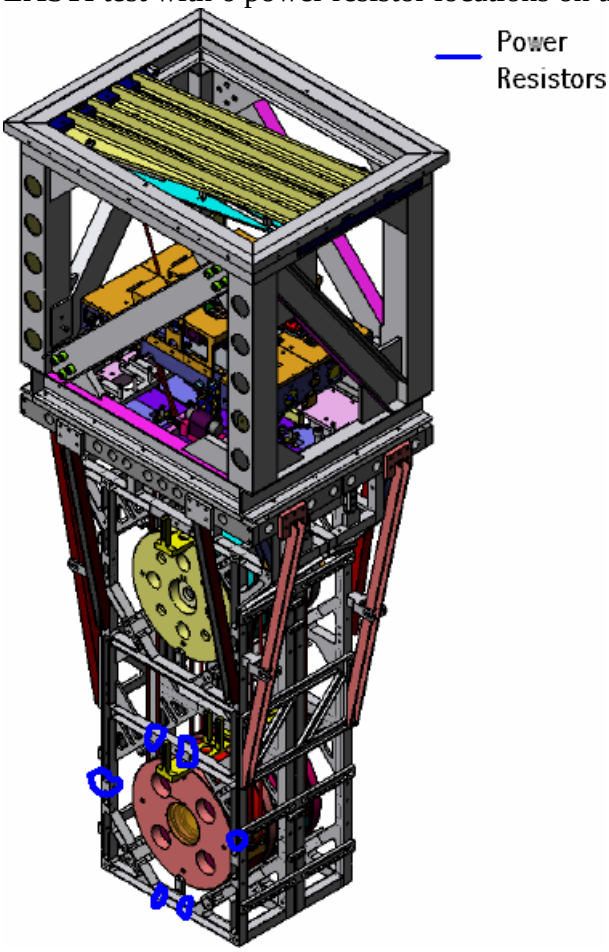
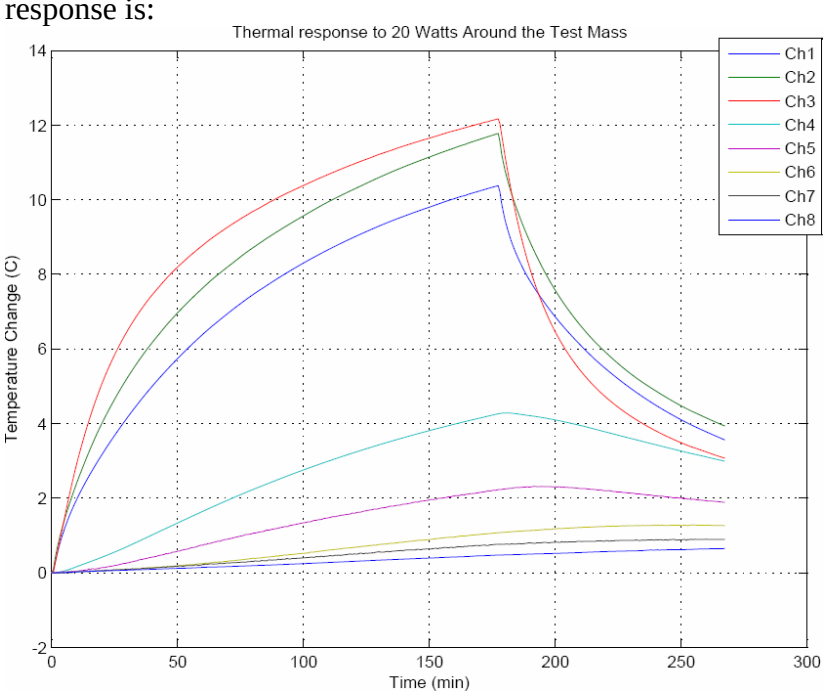
A preliminary thermal analysis of the quadruple pendulum suspension (T060115-01) indicates about 5 C temperature rise per W of heat input in the steady-state condition. In a recent test at LASTI 20 W of heat were input at around the test mass region with a resulting temperature increase of only 12 C and a projection of ~15 C at the steady-state condition (assuming no longer time constants exist in the system). So it would appear (as noted by Justin Greenhalgh, 16-Oct-2006 email) that there is a > 5 times difference between these results. The purpose of this memo is to convey the results of another simple thermal analysis which is in somewhat better agreement with the LASTI test result.

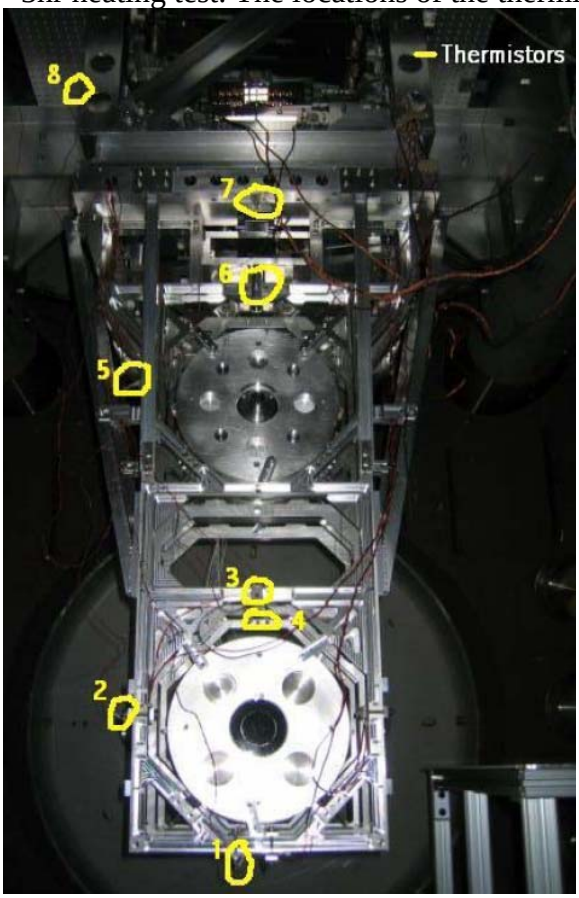
LASTI test with 6 power resistor locations on the quad controls prototype:



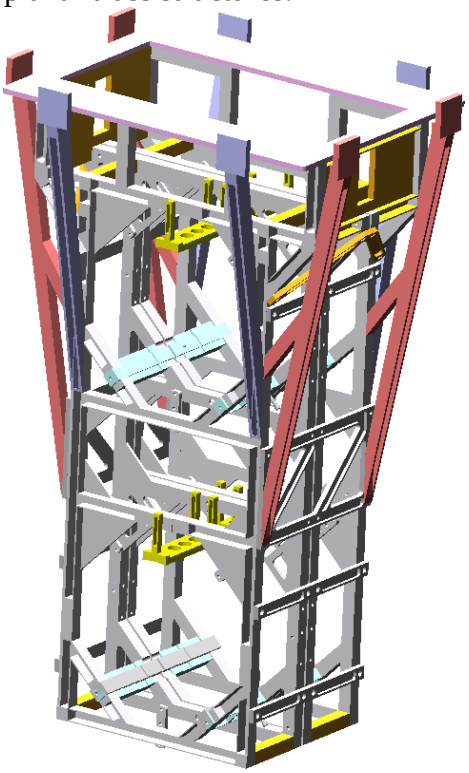
With 20W of total power dissipation equally split in these 6 resistors, the temperature response is:



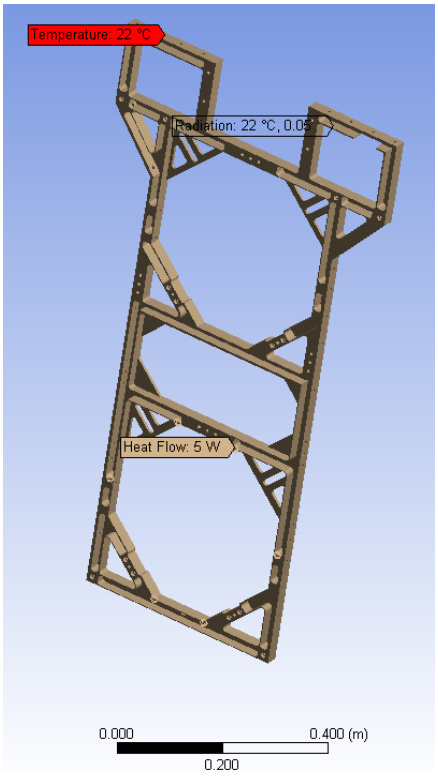
Note that multiple time scales likely apply and a steady-state was not achieved in this ~3hr heating test. The locations of the thermistors are shown here:



Due to the considerable thermal mass of the seismic isolation table, and to some extent the upper structure of the quad, one can approximate the interface of the lower structure and the upper structure as a constant temperature boundary condition in the early time history of the response to a ring heater in the vicinity of the test mass. The lower structure basically consists of 4 vertical aluminum plates which are machined into monolithic, planar truss structures.

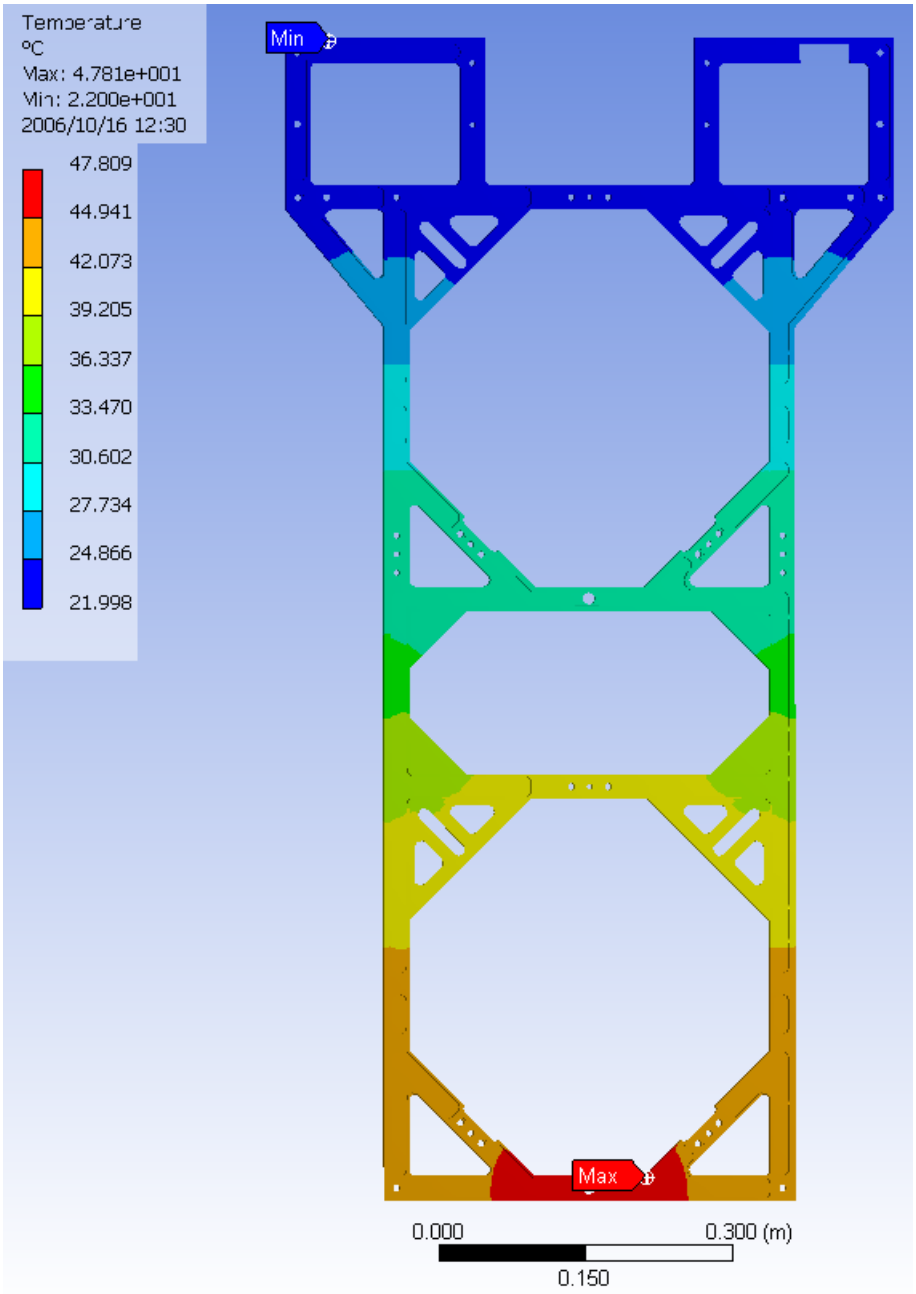


The details of the planar truss is simplified and then meshed for thermal analysis with Ansys:

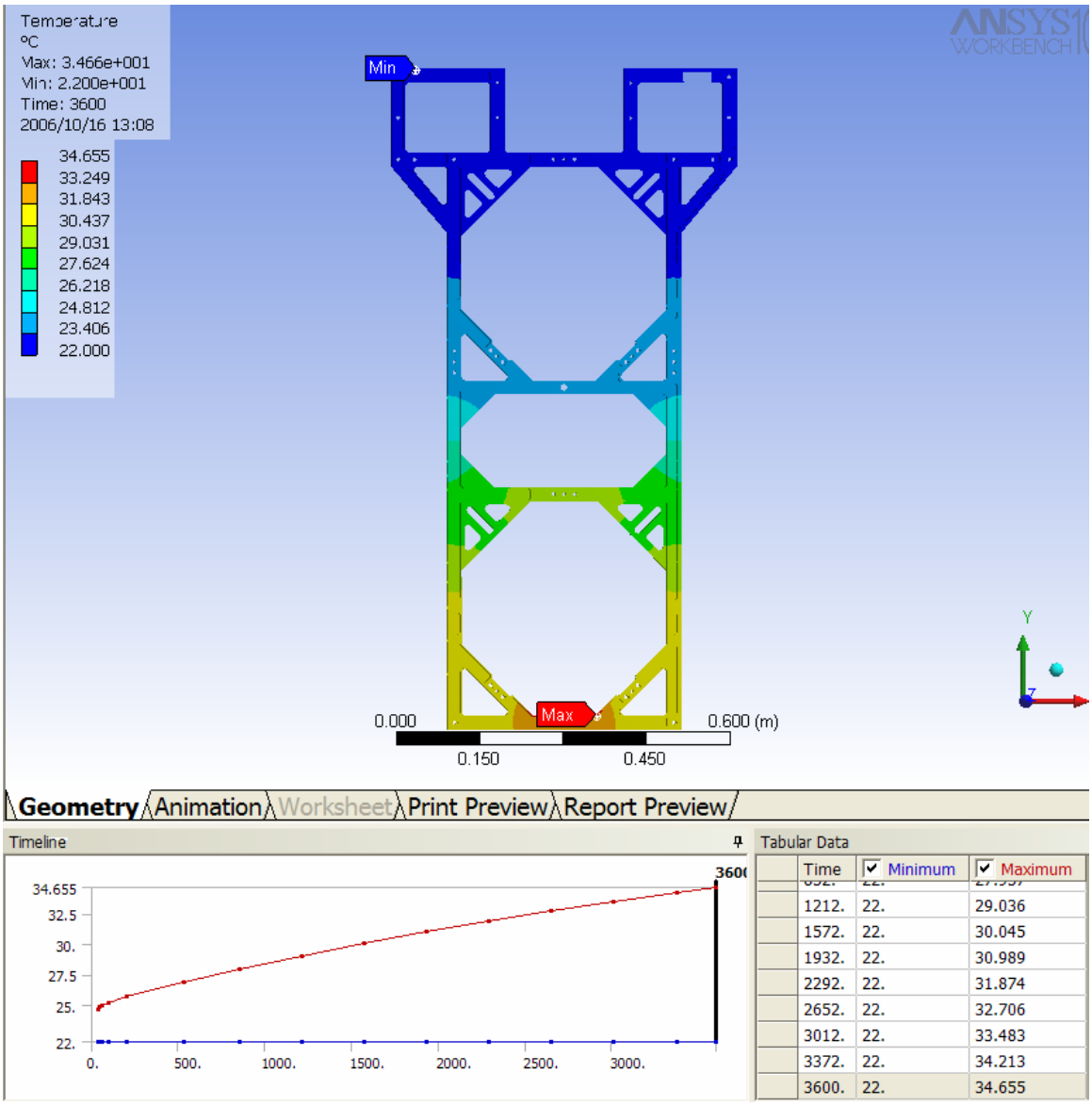


The surface total hemispherical emissivity of the aluminum structure is assumed to be 0.05, which is appropriate for 6061 Al alloy polished and degreased1. If the aluminum is 120 size, grit blasted then the emissivity is 0.40. However, this treatment may not be compatible with ultra-high vacuum (UHV) practice. It may be possible to increase the surface emissivity for temperature control in a UHV compatible manner, but this was not assumed in the analysis.

The steady-state thermal analysis for this (essentially two-dimensional system) indicates a maximum temperature increase of ~26C for 20 W of dissipation (assuming all 4 planar trusses have the same temperature field, i.e. 5 W dissipated and conducted/radiated from each).



Transient analysis shows ~10C rise at the lower thermistors after 1 hr (3600 sec), as compared to ~8.5 C from experimental results.



Single frame has 5.14 kg
Surface area = 0.81 m^2
Note that the surface includes all surfaces of the machined plate even though the view factor for some of these surfaces to the ambient temperature walls of the chamber may be considerably less than unity.

We need a much longer duration LASTI thermal test to determine the true steady –state temperature and the time constant associated with the large thermal mass and weak radiation dissipation of the seismic isolation system (which to remind people is currently a simple rigid structure in LASTI and so analsyis should be used to extrapolate to the final AdL SEI design).