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The SERMS laboratory: a research and test facility for space payloads and instrumentation

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ABSTRACT

The SERMS laboratory (Study of Radiation Effects on Materials for Space Applications) is a joint laboratory of the Perugia University and the Italian National Institute of Nuclear Physics (INFN) . It is located in Terni, as part of a network of research laboratories and test facilities at the Engineering Faculty of the University premises in Terni. Constituted in 1995, the SERMS laboratory has provided support to major scientific projects in the field of astrophysics and astroparticle physics, as the GLAST, LAZIO-SIRAD and AMS Projects. Since 2004, an university spin-off - the SERMS s.r.l. - contributes to the SERMS development and extends the field of its activities to industrial projects. In this paper, an overview of the SERMS laboratory with a brief description of all the equipment and some examples of thermal analysis, design and thermo-vacuum tests done in the laboratory will be presented.

INTRODUCTION

Space instrumentation is operated in hard environmental conditions, being subject to severe mechanical and thermal stresses along its life. Nevertheless, it is required to function with a very high level of reliability to minimize, when possible, any intervention after launch. Key points to reach full reliability are:

- A careful design: detailed thermal and mechanical stress analyses of the instrument and its subsystems are performed to the fulfillment of all the relevant specification requirements through the specified mission phase
- An extensive campaign of qualification tests verifying the system functionality in the expected environmental conditions. Correlation among measured thermal/mechanical behavior of the items under test with the model predictions constitute a valuable validation of the adopted design
- redundancy for the most critical parts (electronics, control systems).

Main objective of SERMS laboratory is to cover a wide spread of activities ranging from theoretical studies (performed by FEM technique) and CAD simulation qualifying materials and electronic instrumentation which have to be exposed to vacuum, mechanical stresses, radiation and extreme temperatures. SERMS is a good example of a laboratory where design and theoretical analysis of structures can be validated with experimental measurements and qualification tests. Experience in this field has been accumulated in the last ten years with a constant support to scientific payloads in space as GLAST, LAZIO-SIRAD and in particular with AMS-02, an astro-particle physics experiment which is designed to operate for a minimum of three years on the International Space Station (ISS). In the following sections, after a general overview of the SERMS facility, we will present some examples of our thermal department activities:

- design and thermal analysis for a prototype of an electronic crate of the AMS-02 experiment, including experimental measurements on the prototype structure and their correlation with the thermal model
- Thermal tests in vacuum of the electronic crates of the AMS-02 experiment
- Evaluation of the Thermal conductivity of materials.

SERMS OVERVIEW

The SERMS laboratory plan and layout is shown in Figures 1 and 2. In an area of about 500 square meter there are a vibration laboratory, a clean room that houses a thermo-vacuum chamber and a thermal lab. Two cranes, a 12.5 tons crane and smaller ones, allows to move cumbersome and heavy objects.

Figure 1 – SERMS laboratory layout.

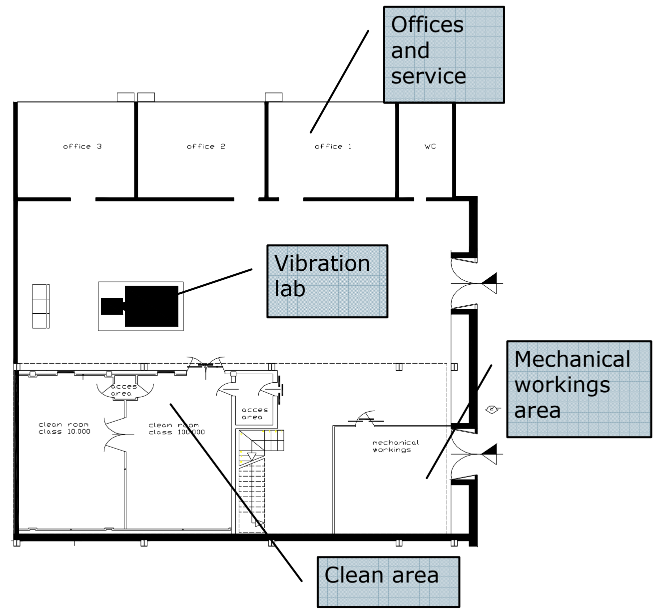

Figure 2 – Map of SERMS inner area.

In Figure 3 a typical qualification sequence that can be entirely processed at SERMS is presented.

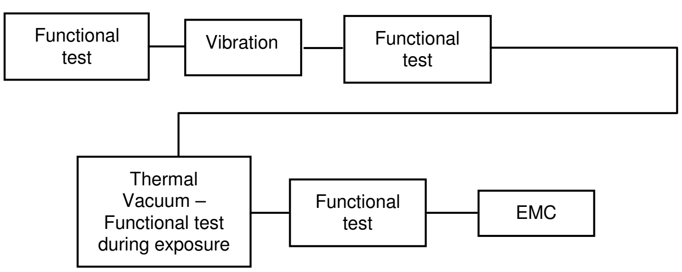

Figure 3 - Flow of qualification testing for components. A component is qualified by a series of functional tests and exposure to environmental conditions.

DYNAMICAL TEST AND ANALYSIS

A component must withstand vibration caused when launch vehicle acoustics and engine rumble couple to it through its structural mount. Components experience shocks from explosive release devices such as aerodynamic fairing separation or spacecraft separation bolts. In SERMS laboratory it is possible to perform dynamic and numerical analysis by FEM technique and CAD simulation. This allows solving for the resonances of the mechanical structure, predicting the conditions under which the material can be damaged and optimizing the design of the mechanical and electronics structural supports under mechanical stresses. The dynamic and vibration tests can be conducted using an electro dynamical shaker with a frequency working range between 5 Hz and 3000 Hz and a maximum force of 80 KN (see Figure 4).

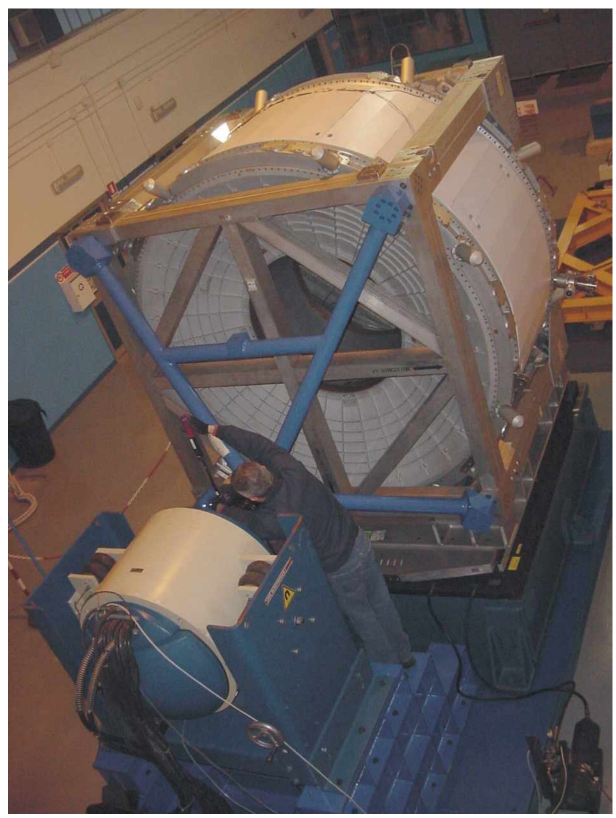

Figure 4 - Electro dynamical shaker.

THERMAL TESTS AND ANALYSIS

Regarding thermal test, testing levels derive from analysis results conducted at extreme conditions and the following predictions of the maximum and minimum flight temperatures. The purpose of all these tests is to demonstrate that the items comply with the specifications and perform satisfactorily in the intended environments with sufficient margins. So, each test environment should be based on actual flight data, often scaled for differences in parameters, or if more reliable, by analytical prediction or a combination of analysis and flight data. A margin can include an increase in level or range, an increase in duration or cycles of exposure, as well as any other appropriate increase in severity. Humidity and thermal qualification tests in climatic rooms, are performed to verify the behavior of the electronic components and mechanical supports under thermal and humidity changes. At the same time it is possible to analyze the effect of thermal stress on mechanical structures and electronics instrumentations at ambient pressure. The tests can be conducted using two climatic chambers, having a temperature range between -70℃ and +180℃. The possibility to conduct test using climatic chamber allow us to check and improve in real time the thermal model of the mechanical structure.

Figure 5 – Thermo-vacuum chamber.

THERMO-VACUUM TESTS

To test a component under thermo-vacuum, the Device Under Test (DUT) shall be installed inside a vacuum chamber whose temperature can be controlled both in cooling and heating. To perform thermo-vacuum test, a space simulator is available at SERMS (see Figure 5). The space simulator consists in a thermo-vacuum cylindrical chamber, 2100 mm length and 2100 mm inner diameter, located in a clean room (class M6.5). It has been installed in January 2006. Since then, it has been extensively used for the test of instruments and subsystems, for a total of approximately 3100 hrs. It is suitable for small size satellites and instruments that have to be qualified in absence of atmosphere ($P < 10^{-5}$ mbar). A vacuum level of 10^{-3} mbar is attained by means of a mechanical pump, while a cryogenic pump allows to reach a pressure of 10^{-7} mbar with an empty chamber conditions. Temperature is controlled in the temperature range -70℃, +125℃ and monitored within the chamber volume with 7 thermal sensors. Up to 64 temperature sensors and up to 128 strain gages can be used to continuously record temperature and mechanical stresses on the devices under test. Using conductive coupling and/or radiative coupling, it is possible to cycle the item under test within its specified temperature range. The temperature extremes equal or slightly exceed the expected temperatures at which the item will be exposed during its operating life.

THERMAL QUALIFICATION OF A SPACE COMPONENT

The qualification campaign of a space component can be divided into few steps. The first step consists in the development of requirements and constraints. The second step is to determine and define the space environment (in terms of temperatures, heat transfer ways, worst hot and cold case, etc) that will characterize inputs throughout the entire life of the component. Then an important role in the process of qualification is the thermal analysis; lumped parameter methods and/or FEM (Finite Element Methods) analysis techniques should be used to predict the temperature distribution of the design under the extreme boundary conditions. Once an acceptable thermal model has been reached, the next activities are the test predictions to correlate thermal verification tests with the test results. If this correlation is acceptable, the thermal model is used to perform flight predictions. If, however, the correlation shows problems, the thermal analysis has to be carefully checked to see if the thermal model requires some modifications or update.

THERMAL ANALYSIS

Thermal analyses are carried out to:

1. verify the item thermal design, showing the fulfillment of all the relevant specification. This includes the prediction of temperatures, heat fluxes, as well as the prediction of the thermal control system (heaters, valves) performance
2. predict the item temperature, heat fluxes during the thermal testing (TB, TV) as well as the performance of the thermal control system
3. predict the item flight temperature distribution and its thermal control system performance (after the correlation between analyses and test results has been performed)
4. provide input to TV-test procedures and TV-test performance.

VERIFICATION

After the thermal analysis has been done, the next important step is the verification. Verification shall demonstrate that the thermal design of an item conforms to specified performance requirements. Testing is the preferred method for verification of the performance requirements. Verification by test shall be the demonstration of conformance to specified requirements through exposing the item to test conditions as close as possible to the expected real conditions by performing thermal vacuum or climatic tests. Generally for testing, two limits are frequently defined: operational limits that the component must remain within while operating and survival limits that the component must remain within at all times, even when not powered. Table 1 gives typical component temperature ranges for the AMS-02 detector most of them tested in our facility.

Component	Typical Temperature Range	
	Operational	Survival
Electronic crates	-20°C to +50°C	-45°C to +85°C
AMS-02 subdetector	-20°C to +40°C	-30°C to +50°C
Star Tracker	-35°C to +60°C	-45°C to +85°C

Table 1- Examples of Typical Thermal Requirements for some of the AMS-02 detectors. Note that the temperature extremes on the outer portions of spacecraft can vary between ± 200 °C.

Thermo-vacuum test

The last test, usually done at the end of a qualification campaign, is the thermo-vacuum test. The purpose of the thermal vacuum test is to demonstrate the ability of the equipment to perform in a thermal vacuum environment that simulates the worst conditions in-orbit, including an adequate margin. The equipment is installed in a vacuum chamber, in a thermally controlled environment. Inside a thermo-vacuum chamber its is possible to define two different zones:

- The internal walls of the chamber (usually called shroud) coated with a black paint to reproduce the black body optical properties; through the shroud the test item could be radiative coupled to the chamber
- Plates made usually of aluminum alloy (called cold plates) used to conductive coupled the test item to the chamber.

Depending on the test item and its final destination (i.e. equipment mounted inside or outside the spacecraft), the fixing type and mounting is chosen. If the equipment exchanges heat essentially by conduction, it can be bolted on the cold plates using some kind of interface (usually an aluminum plate 10mm thick). While if the equipment under test exchange heat essentially by radiation, it should be suspended inside the test chamber, in a manner that a minimal conductive path shall exist between the equipment under test and the attaching system (using a thermal insulator like Teflon). During the test, the shroud and cold plate temperatures are controlled to give the qualification temperature level on the equipment itself. To drive the chamber temperature a Temperature Reference Point (TRP) is defined. There are several boundary conditions that have to be considered in order to determine the correct position of the test item inside the chamber:

- Thermal interface (radiative or conductive)
- Attaching system definition; it depends on the final position of the equipment under test and so on the way the heat will be transferred
- Temperature control points that will control the temperature of the chamber during test
- Temperature reference points on the test item that will drive the temperature of the chamber assuring that the temperature requirements will be satisfied
- Positioning of temperature sensors to monitor the test item
- Use of thermal blankets (such as MLI-Multi layer insulation), painting or heaters as it will be used in the final flight configuration.

The temperature sensors used at SERMS are PT100 (Platinum resistance thermometer). PT100 are temperature sensors that exploit the predictable change in electrical resistance of Platinum with changing temperature. PT100 sensors have a nominal resistance of 100 ohms at 0 °C. The sensitivity of a standard 100 ohm sensor is a nominal 0.385 ohm/°C. Figure 6 shows the dimensions of the sensors used. They have ceramic bodies and are fixed on the object using a space qualified kapton tape. The kapton tape is generally used in testing electronic equipment due to its good properties and overall performance such as adhesion, low level of outgassing and electrical insulation properties. Finally the thermal profile is defined in terms of number of cycles, functional test and pressure level requirements (see Figure 7).

Figure 6 - PT100 temperature sensor used to monitor and control the temperature of the equipment under test.

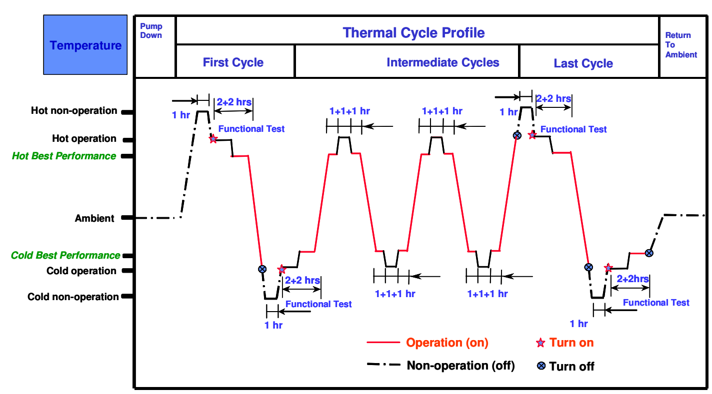

Figure 7 – Typical temperature profile for a Thermo-vacuum test on electronic equipment.

CORRELATION BETWEEN THERMAL MODEL AND TEST RESULTS

In this section an example of the correlation between a thermal model, done using FEM techniques (ANSYS), and test results is presented. To perform the test, the space simulator has been used. The test item is a prototype of an electronic box for AMS-02 experiment, whose dimensions are 184x302x210 mm, with a wall thickness of 2mm (see Figure 8).

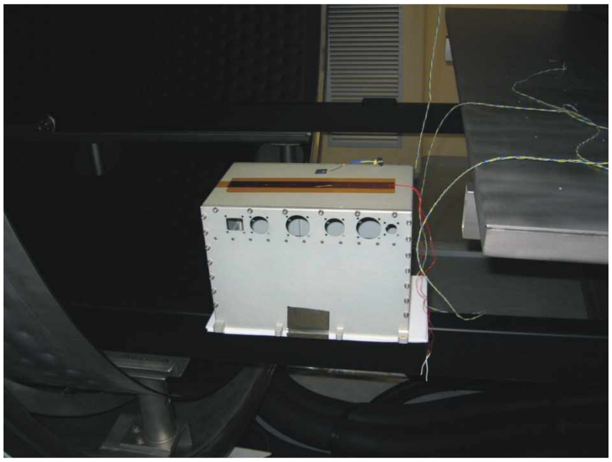

Figure 8 – Photo layout of the test item. Both the lateral holes and he Teflon layers used to fix the object are clearly visible.

The two lateral walls are built with some holes, which are simplified in the modeling used for the simulation. The box is built up by Anticorodal Aluminum 6061 T6. To perform the test the box has been placed on a Teflon layer 5 mm thick. The optical and thermal properties of the materials are summarized in Table 2.

Material	Emissivity	Thermal conductivity [W/mK]	Density [Kg/m^2]	Specific Heat Capacity [J/Kg K]
Anticorodal Al 6061-T6	0.84	167	2710	896
Teflon	0.38	0.001	2160	1400

Table 2 – Thermal and thermo-optical parameter for the material used in the test.

THERMO-VACUUM TEST DESCRIPTION

The thermal environment to which the object will be exposed, is represented by the reference temperature of the shroud and cold plates that has been set to -50°C (see Figure 9). The object exchanges heat with the surrounding environment only through radiation. The Teflon layer helps to avoid any kind of conductive heat exchange. A constant heat input has been applied to the test item using a 16 W heater (see Figure 10). To monitor the temperature of the test item, three temperature sensors have been used: sensor n° 8 has been placed near the heater, while sensors n° 9 and 10 have been placed on the lateral walls of the box (see Figure 11 and 12 for details).

Figure 9 – The shroud and cold plates of the space simulator.

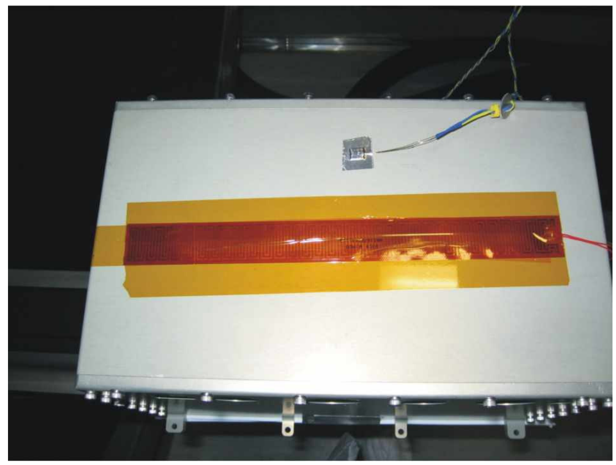

Figure 10 – 16 W heater dissipater applied to the test item using a Kapton heater.

Figure 11 – Sensor layout. In the figure it is possible to see sensor n°8 placed near the heater and sensor n° 10 placed on a lateral wall.

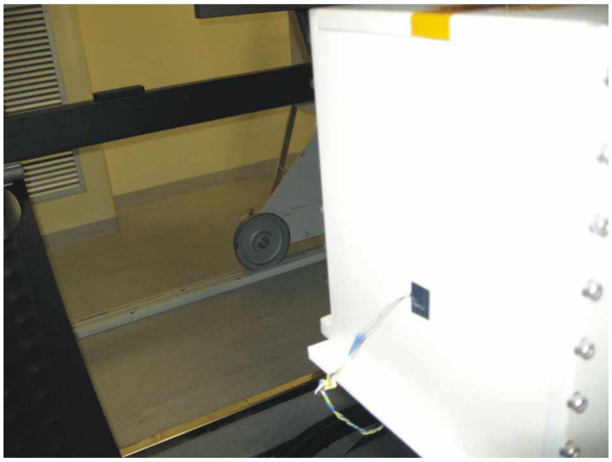

Figure 12 – Sensor n°9 located on the shorter lateral wall.

Figure 13 – The test item placement inside the Thermo-vacuum chamber.

THERMAL MODELING

Using the ANSYS software, a geometrical model similar to the object under test has been created. To obtain a final mesh for the model as simple as possible (to have realistic and reliable results), instead of the holes on the lateral wall of the test item just one big hole has been modeled (see Figure 14). A perfect thermal contact has been assumed between the box and the Teflon layer (while in the real test the object has been simply rested on the Teflon layer). A thermal flux of 1088 W/m^2 has been applied (see Figure 14); it corresponds to the power dissipated by the heater. Then in the model a *space node* has been defined to simulate the radiative heat exchange. The temperature of the space node has been set to the same temperature of the shroud and cold plates (T= -50°C).

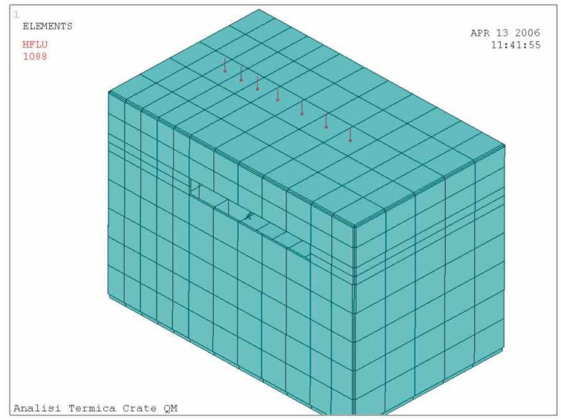

Figure 14 – Geometry and mesh of the test item in the finite element model. The heat flux applied on the upper surface of the box can be seen.

The element used for the mesh of the object was SHELL57 with two different emissivity values: one for the Anticorodal Aluminum 6061 T6 and one for the Teflon. To compare the test results with the simulation, the steady state case has been solved. In Table 3 the temperature value of the nodes near the location of the temperature sensors are reported.

		TEMPERATURE [°C]
Node 131	**Sensor 8**	-33.63
Node 228	**Sensor 9**	-39.40
Node 391	**Sensor 10**	-39.49

Table 3 – Temperature values of the nodes near the temperature sensor locations.

Figures 15, 16 and 17 shows the global temperature profile.

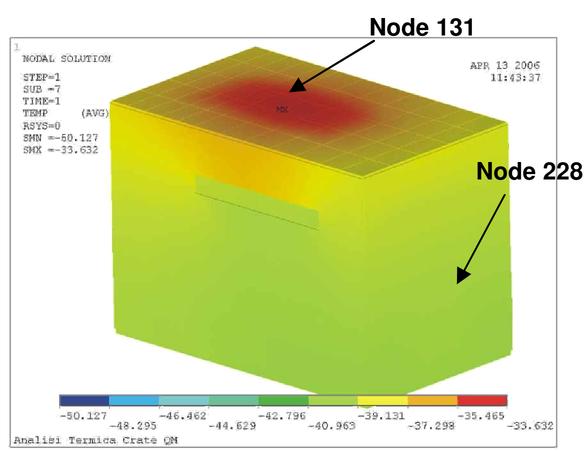

Figure 15 – Temperature values of the nodes 131 and 228 in the steady state case.

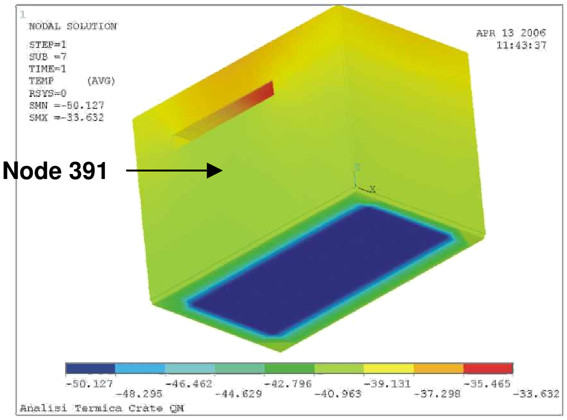

Figure 16 - Temperature value of the node 391 in the steady state case.

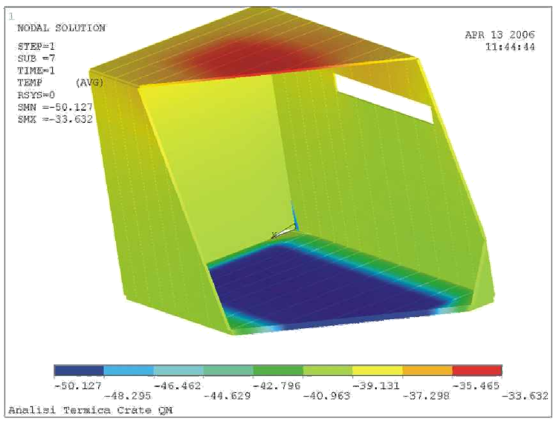

Figure 17 – Cross section of the object with the corresponding temperature for the steady state case.

CORRELATION BETWEEN TEST RESULTS AND SIMULATIONS

In Figure 18 the temperature profile obtained from the thermo-vacuum test is shown. The test lasted for two days. In Figure 19 the part of the graph useful for the correlation is reported. During the test, the temperature of the sensors needed 300 minutes (about 18000 seconds) to reach the steady state conditions. These experimental values have been compared with the results obtained from the transient analysis done with ANSYS. The graph of the temperature values for the three nodes that correspond to the temperature sensors locations are shown in Figure 20, 21 and 22. Also in the simulation the temperature values needed about 300 minutes to reach the steady state conditions.

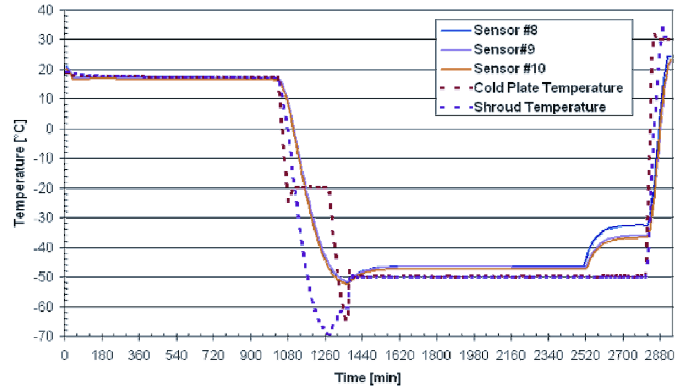

Figure 18 – Temperature profile for the temperature sensors placed on the test item during the thermo-vacuum test.

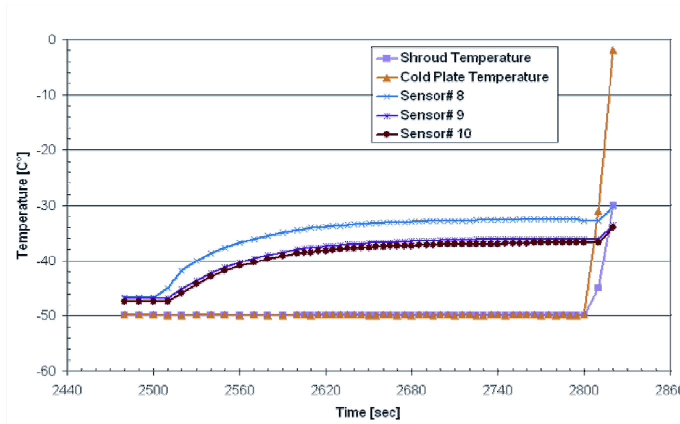

Figure 19 – Time interval needed to reach the steady state condition during the test.

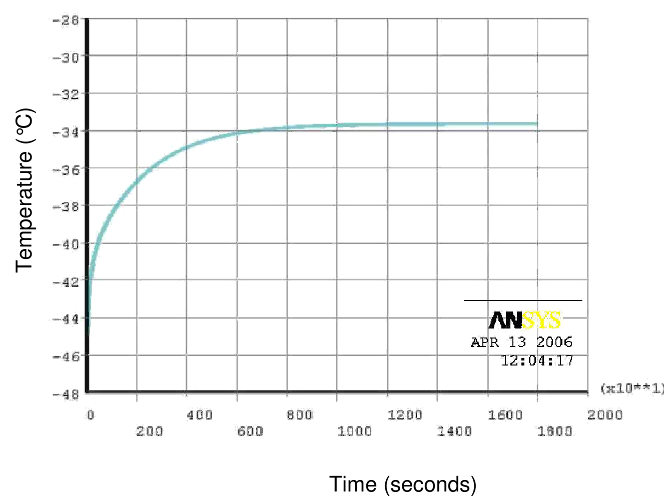

Figure 20 – Temperature profile during the transient phase obtained form simulation for the sensor n°8.

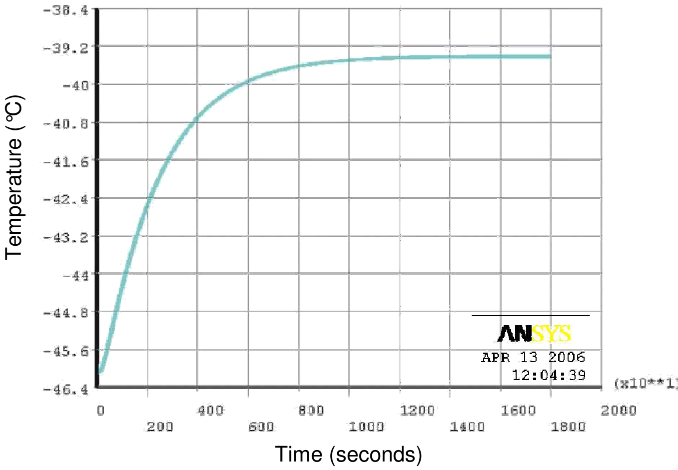

Figure 21 - Temperature profile during the transient phase obtained form simulation for the sensor n°9.

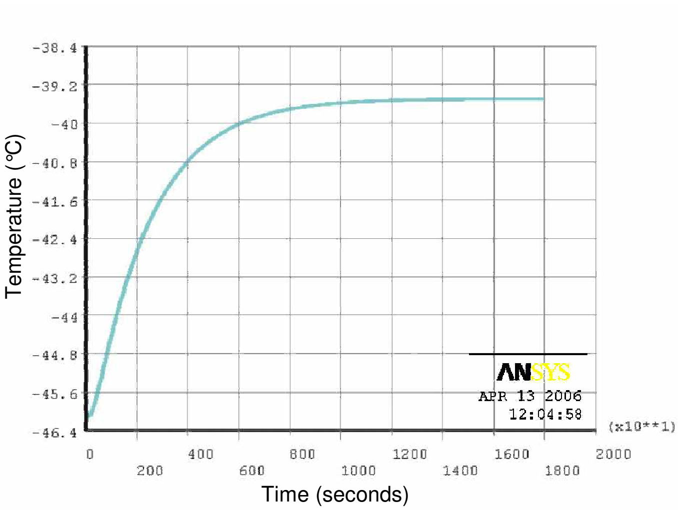

Figure 22 - Temperature profile during the transient phase obtained form simulation for the sensor n°10.

A comparison between the test results and the data obtained from the simulation are reported in Table 4.The temperature differences between the experimental results and the simulations are minimal. This confirms the accuracy of the thermal model. The slight differences can be attributed to the hypothesis done to model the geometry of the test item and to simulate the thermal contact between the box and the layer of Teflon.

	TEST TEMPERATURE [°C]	THERMAL MODEL TEMPERATURE [°C]	Delta T [°C]
Sensor 8	-32.8	-33.6	0.8
Sensor 9	-36.1	-39.4	3.3
Sensor 10	-36.8	-39.5	2.7

Table 4 – Comparison between the test results and the thermal model data. The values refer to the steady state conditions.

THERMO VACUUM TEST ON AMS-02 ELECTRONIC CRATES

The Alpha Magnetic Spectrometer (AMS-02) experiment is conceived to accurately measure the cosmic radiation on board the International Space Station (ISS) for at least three years. The AMS detector is a unique apparatus, using custom built HW and electronics. Extensive testing has been required on all AMS subsystems and electronics in order to space qualify the HW and meet the NASA safety requirements for Shuttle and ISS payloads. Due to the qualification campaign, three different module productions were realized, each corresponds to a defined step in the design process: the engineering module (EM) used to perform functional qualification, the qualification module (QM) used to conduct qualification test and the flight module (FM) that shall be subjected to complete acceptance testing. At SERMS more than 15 thermal, vibration and thermo-vacuum tests have been performed in 2006 both on AMS electronics (QM version) and sub-detectors. In this section we present the typical thermo vacuum test on electronic crates of the AMS-02 instrument. This test represents a long term test simulating the conditions on the ISS. Several temperature cycles will be set. Temperature range for electronic crates amounts from -45 °C to +85 °C. The maximum allowed operational temperature for electronics range from -25 °C to +55 °C. Power is switched on and off at minimum and maximum operational temperature. Functional tests have been done both on first and last cycles, and on intermediate cycles. Figure 7 shows the thermal profile used to test the electronic crates in thermo-vacuum chamber while Table 5 reports the temperature hot and cold values for non operating and operating phases.

	HOT	COLD
Non-operating phase	85°C	-45°C
Operating phase	55°C	-25°C

Table 5 - Hot and cold temperature values for non operating and operating phases in the AMS electronic crates test.

TEST SET UP

All the crates tested at SERMS are QM (qualification module) versions. They will be mounted on the AMS-02 radiator (see Figure 23 and 24). So regarding thermal interface, there should be only conduction and minimal radiative exchange of heat. This was realized putting the crate on the cold plate of the thermo-vacuum chamber (see Figure 25). A thermal interface made of an aluminum plate was been used. To encourage the thermal conduction between the crate and cold plate, some layers of a conductive composite material (Cho-term) have been placed at the interfaces crate/Al plate and Al plate/cold plate (see Figure 26). To minimize radiative heat exchange, all the crates have been covered with a thermal blanket called MLI (Multi Layer Insulation). On crates two TRPs (Temperature

Reference Points) have been mounted (for redundancy) near their mounting feet. The temperature profile of these points should reproduce the profile shown in Figure 7. In addition other temperature sensors were mounted in order to monitor the temperature of the devices during the test.

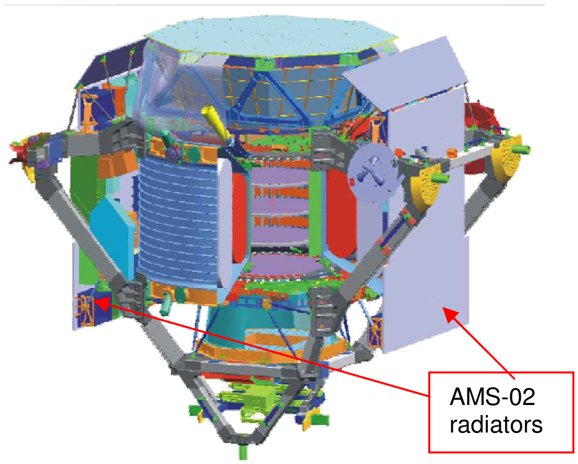

Figure 23 – AMS-02 global model. The two main radiator are visible. Most of the electronic crates are fixed on the radiator panels.

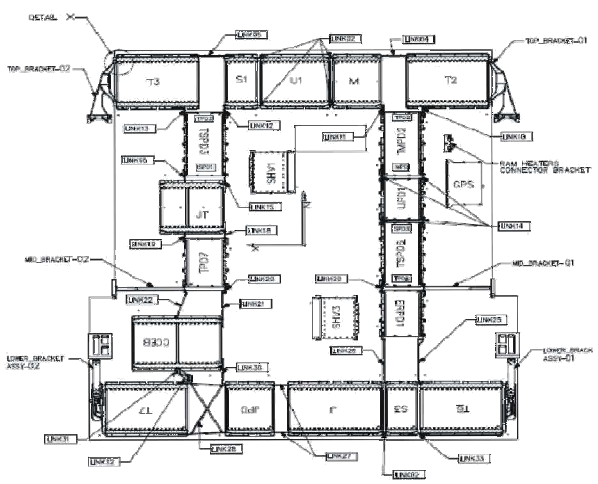

Figure 24 –Location of the electronic crates on one of the two main radiator of AMS-02.

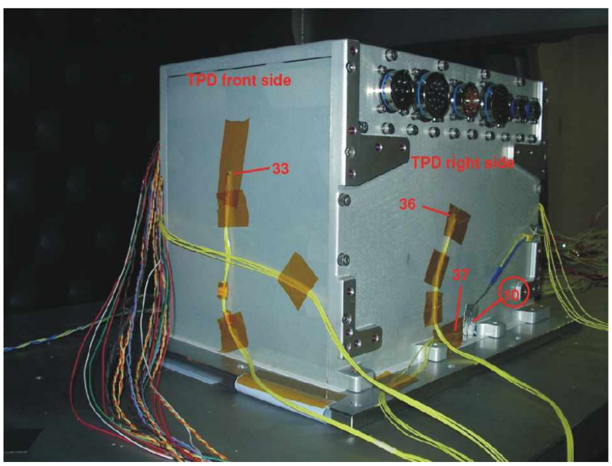

Figure 25 - Crate fixed to the chamber cold plate.

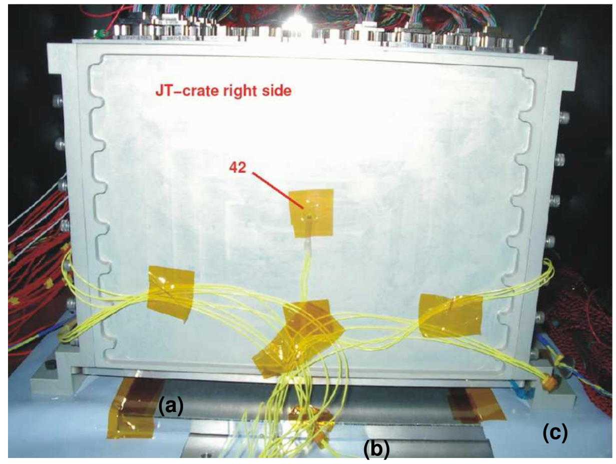

Figure 26 - Particular of fixation of crate on cold plate. (a) Aluminum interface plate; (b) Chamber cold plate; (c) Cho-term.

TEST RESULTS

During the test all the temperature sensors have been acquired every 60 seconds using a National Instrument acquisition system. In this section the test results for some of the AMS-02 electronic crates (ERPD, UPD and U-crates) have been reported. In Figure 27 the crates positioning inside the Thermo-vacuum chamber is shown.

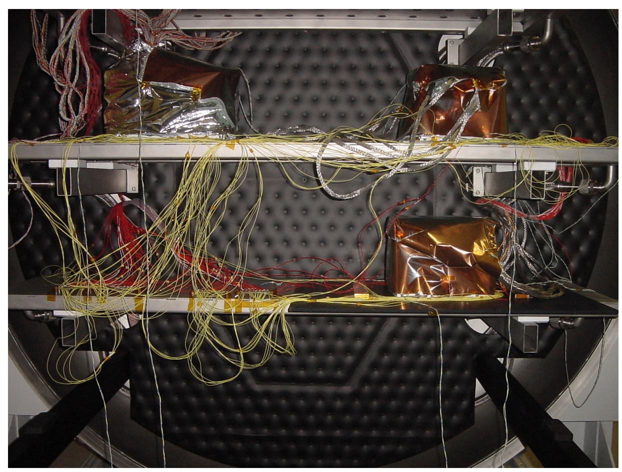

Figure 27 – ERPD, UPD and U-crate inside the Thermo-vacuum chamber before test starts.

In Figure 28 and 29 the pressure profile and the temperature profile of TRPs are shown. No failure of the systems under test has been observed. The pressure profile follows the temperature variations very well. However analyzing the profile (Figure 28) it is clearly visible the large variation in pressure that cannot only be caused by the temperature increase. This pressure change is ascribed to the outgassing of contaminants inside the crates. This has required, in all the other test, a careful inspection and cleaning of the test items in order to achieve the pressure level required by the procedure ($P<10^{-5}$ mbar before starting the temperature cycles). Comparing Figure 28 and 30 the importance of an accurate cleaning of the test under test is perceptible: due to the absence (or low level) of contaminants the

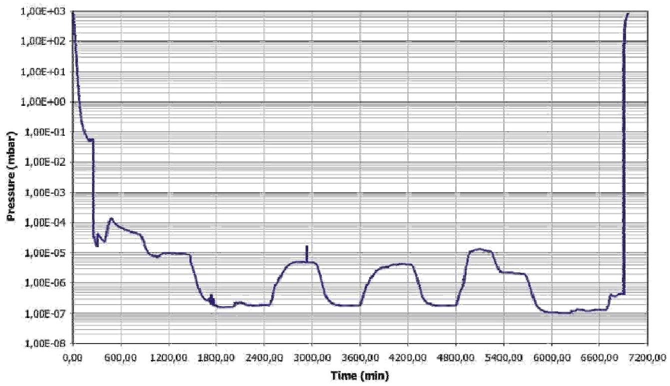

Figure 28 – Pressure profile without careful cleaning and outgassing.

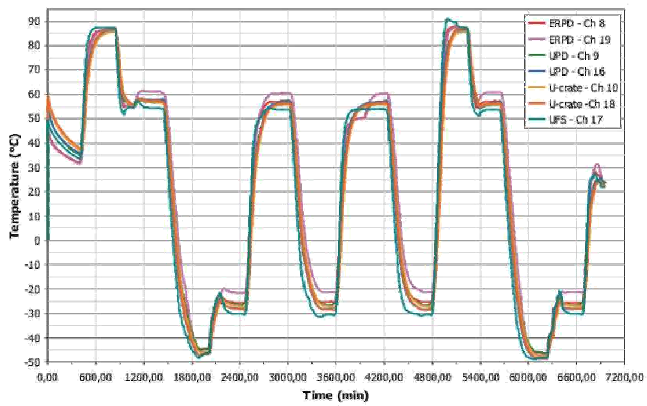

Figure 29 – Temperature profile.

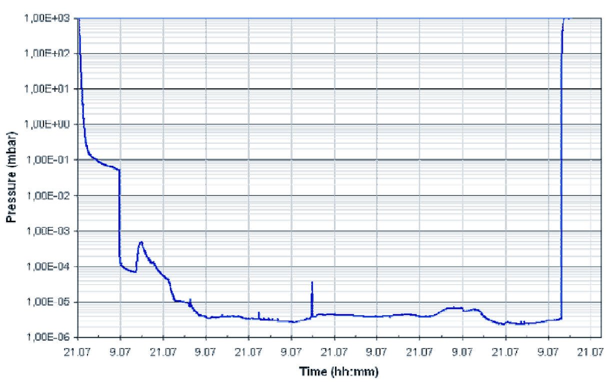

Figure 30 – Pressure profile (after careful cleaning and outgassing) for E-crate thermo-vacuum test.

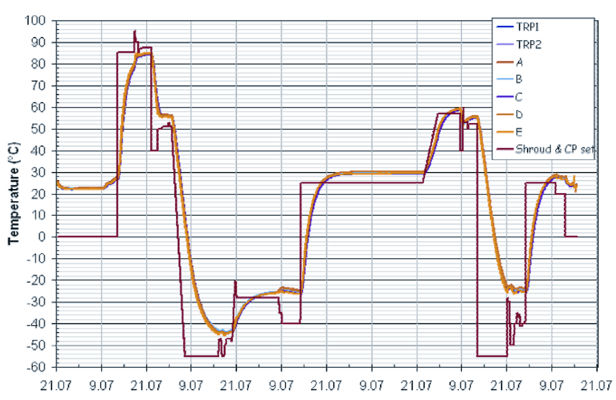

Figure 31 – Temperature profile for E-crate thermo vacuum test.

pressure remains below 10-5 mbar during the whole test. Figure 30 shows the pressure profile for the E-crate thermo vacuum test done at SERMS in June 2006. The temperature profile followed has been the same. In this case only two cycles instead of four have been done (see Figure 31). The spike in pressure is due to a wrong acquisition of the pressure sensor.

THERMAL CONDUCTIVITY

One of the SERMS capabilities is the measurement of thermal conductivity of materials. In particular some polymeric fiber reinforced composite and metal specimens have been successful tested with innovative methods. **ASTM E1225 – 99** standard gives the method for the measurement of thermal conductivity of solids by means of the guarded comparative longitudinal heat flow technique. This standard is taken as reference for the general architecture of our test setup, but methods for insulation and heat flow measurement have been deeply modified. The main purpose of this test is to transmit all the heat produced by an electrical heater through the specimen by conduction and to dissipate it by a heat sink (see Figure 32).

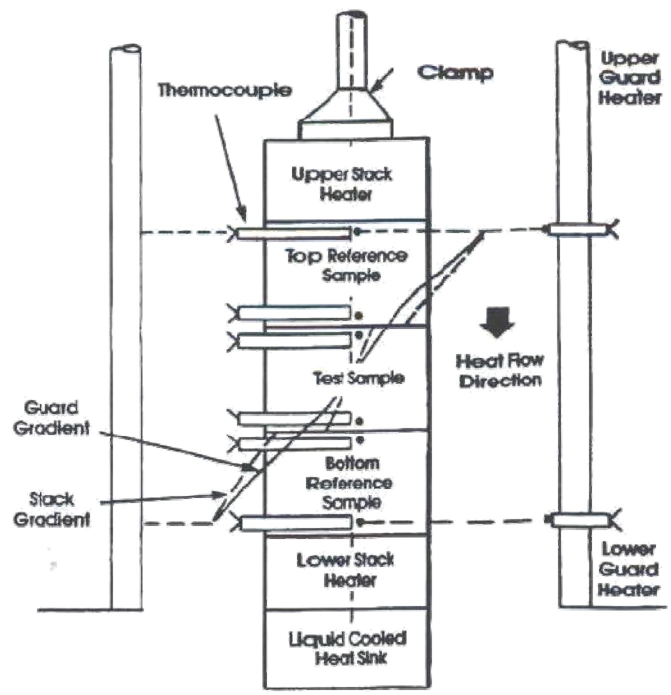

Figure 32 - : Schematic of typical test stack and guard system suggested by ASTM 1225 – 99.

The thermal conductivity coefficient is calculated by the measurement of the temperature difference between fixed points on the specimen and on reference samples. To minimize radiative and convective heat losses, the ASTM standard suggests the use of a longitudinal guard having approximately the same temperature gradient of the specimen. Instead of this method, vacuum conditions have been used (approximately 1x10^{-3} mbar) to avoid convective heat losses while a MLI screen has been placed around the specimen in order to minimize radiative heat losses. Moreover ASTM standard suggests inserting the test specimen under thermal load between two similar specimens of a material with known thermal properties. The measure of the thermal drop inside these specimens gives the heat flow value. This method is affected by some uncertainties, i.e. the perturbation of the thermal flow lines into the test specimen, due to the high temperature drop into reference specimens. Captec thermal fluxmeters have been used to measure thermal flux; they are characterized by a little temperature drop and small perturbation of thermal flux, due to their thickness (0.4 mm) and small thermal resistance (0.00015 ℃/W/m^2) These high accuracy sensors are designed to measure the thermal flow through their surface, providing a voltage signal that is proportional to the heat flow with a coefficient independent from the temperature. Two thermal fluxmeters have been used: one to measure the heat flowing from the heater to the top of the specimen, the other to measure the thermal flow dissipated through the heat sink. The setup consisted basically of a vacuum chamber that acted like a heat sink, due to the fact that it has been placed into a climatic chamber capable to reach temperature between -70℃ and 180℃ (see Figure 33). Inside the vacuum chamber a fixture (capable to test specimen of different dimensions with calibrated contact pressure between elements, **Errore. L'origine riferimento non è stata trovata.**), a heater (controlled with a digital thermostat), two Captec thermal fluxmeters and some temperature sensors (Pt100 thermistors, fixed on the specimen with accurately measured distance) have been placed. Thermal conductive grease has been used between specimen and fixture pieces in order to reduce thermal resistance.

Figure 33 - Vacuum chamber placed into the climatic chamber.

All the data have been acquired by SCXI National Instruments Data Acquisition system. The measure has been done setting a certain temperature of the heater and a proper temperature for the climatic chamber. After some hours of stabilization, when equilibrium conditions have been reached (the gradient and thermal flux on the specimen constant) the thermal conductivity value at medium specimen temperature has been calculated. When fiber reinforced composite specimens have been tested, the thermal conductivity has been measured along three directions: planar-x (parallel to the fiber),

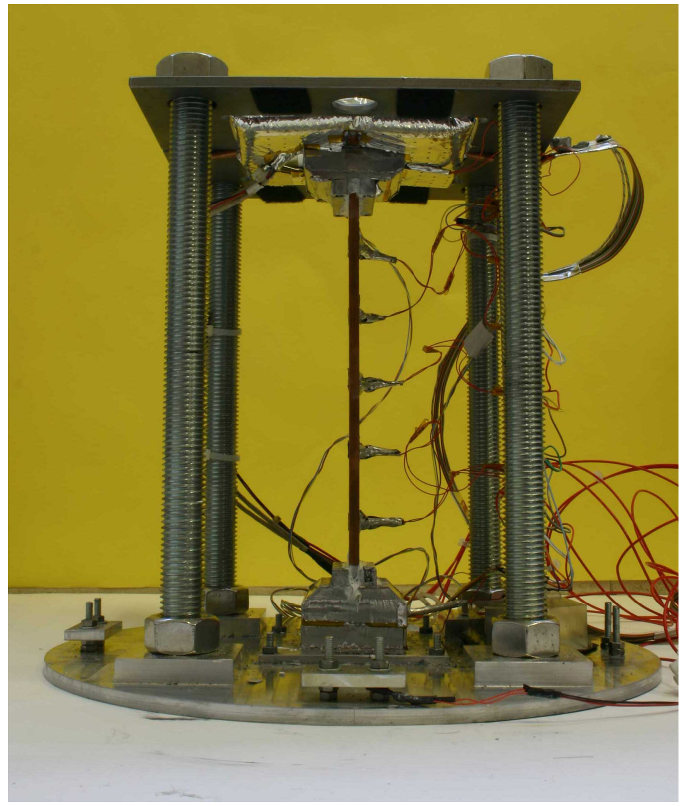

Figure 34 - Test stack, with control of contact pressure between elements

planar-y (perpendicular to the fiber) and thickness-z (across the thickness of the specimen). For fiber composite specimens, y and z thermal conductivities have usually the same values, because these directions are both perpendicular to the fiber. Small differences can be observed in z direction: in this direction thermal conductivity takes into account the thermal resistance between the different layers of composite materials. However this is negligible when proper processing techniques (like vacuum bag molding) are used to obtain the specimens. It is possible to use this setup also for thermal conductivity measurement across the thickness with specimens of different shape: 200 x 20 x 4 mm (200 mm along fiber direction, 4 mm of thickness) for x-thermal conductivity and 50 x 50 x 9.6 mm (9.6 mm of thickness) for z-thermal conductivity. The specimen and test setup fixtures design has been performed by 2D finite elements thermal analysis (see Figure 35: x-dir simulation; see Figure 38: z-dir simulation), considering the section of the setup and taking into account radiative and convective effects. The analysis have been performed in order to have a flat profile of temperature into the specimen section (see Figure 37) and uniform heat flux direction and magnitude into the thermal fluxmeter and into the specimen (see Figure 36). Many fixture profiles and materials have been evaluated; In **Errore. L'origine riferimento non è stata trovata.**4 the fixture chosen for x direction is shown. A different fixture has been designed to measure z-direction thermal conductivity.

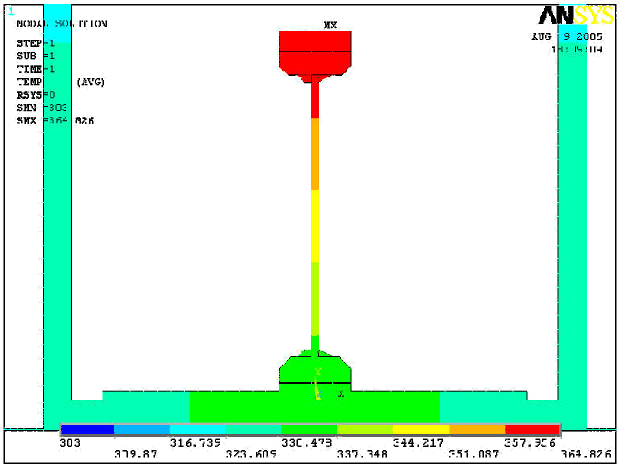

Figure 35 - 2D finite element thermal analysis: x-dir simulation.

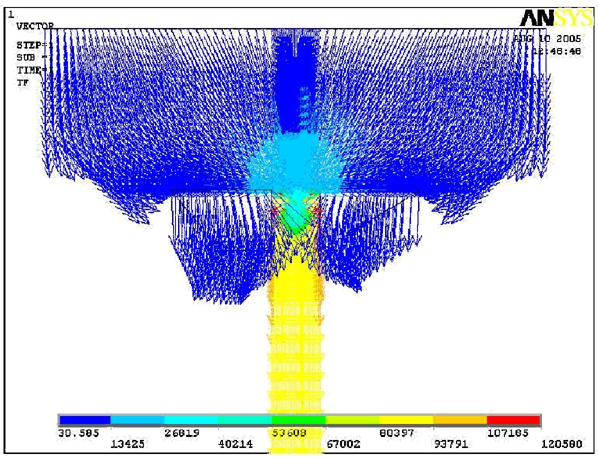

Figure 36 - Thermal flux vectors.

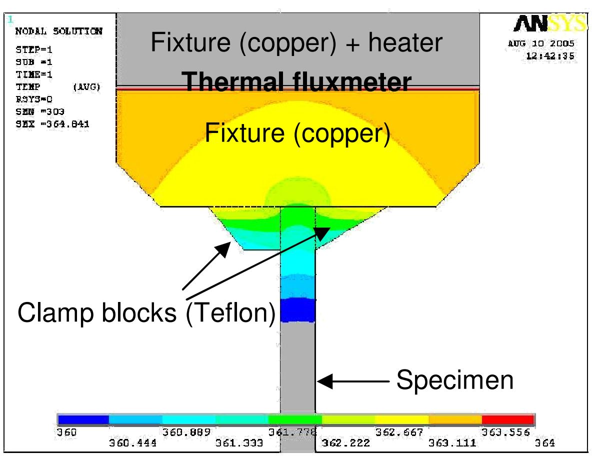

Figure 37 – Temperature Profile.

CONCLUSION

SERMS laboratory offer technologies and test tools to fully design and qualify payload and instrumentation for space application. SERMS is a good example of a laboratory where design and theoretical analysis of structures can be validated with experimental measurements and qualification tests. SERMS laboratory houses a vibration laboratory, a clean room, a thermo-vacuum chamber and a thermal lab. These technologies can be successfully applied also in

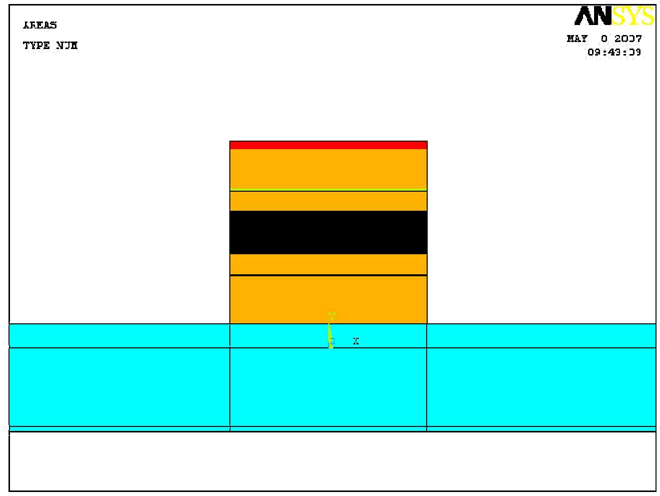

Figure 38 - z-dir simulation.

qualification and certification of materials as in civil and research engineering. In this paper three examples of SERMS thermal department activities have been presented: a thermal analysis and correlation with test results for an electronic crate prototype, some of the thermo-vacuum tests successfully done on AMS-02 electronics and a research activity for the evaluation of the thermal conductivity of a composite material. Since the space simulator has been installed at SERMS, several tests have been done. Most of them deal with the qualification of some AMS-02 detectors such as L-TOF (Lower Time of Flight), ECAL (Electromagnetic CALorimeter) and Star Tracker. [9] [10] All these tests have been performed in close collaboration with some of the most important international space agency (ASI, ESA, NASA, NSPO).

ACKNOWLEDGMENTS

During these last years the SERMS laboratory started and grew an important collaboration with Carlo Gavazzi Space. Most of the thermal model and simulation for the equipment tested in the laboratory have been done by CGS people. This collaboration allows both SERMS and CGS people to improve their knowledge on thermo-vacuum tests. In particular we would like to thank Marco Molina. We are also very grateful to our support CARIT.

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DEFINITIONS, ACRONYMS, ABBREVIATIONS

AMS-02: Alpha Magnetic Spectrometer

CAD: Computer Aided Design

Correlation: correspondence between analytical predictions and test results

FEM: Finite Element Method

ISS: International Space Station

MLI: Multi Layer Insulation

P: Pressure value

PT100: platinum resistance thermometers; temperature sensors that exploit the predictable change in electrical resistance of Platinum with changing temperature

Qualification Test: verification process that demonstrates that hardware functions within performance specification under simulated conditions more severe than those expected during the mission

QM: Qualification Model

TB: Thermal Balance Test; test conducted to verify the adequacy of the thermal model and the adequacy of the thermal design

Thermal node: representation of a specific volume of an item with a representative temperature, representative material properties used in a mathematical lumped parameter approach

TRP: Temperature Reference Point physical point located on a unit and unequivocally defined; the TRP provides a simplified representation of the unit thermal status.

TV: Thermo-Vacuum Test; test conducted to demonstrate the capability of the test item to operate satisfactorily or to survive without degradation in vacuum at predefined hot and cold temperatures