

# PRELIMINARY DESIGN: A THERMALLY INSULATED CASING FOR THE MICROMAPS INSTRUMENT

Graduate Student Researcher: Charles E. Walston II  
Virginia Tech, Blacksburg, VA

Primary Faculty Advisor: Dr. William H. Mason  
Virginia Tech, Blacksburg, VA

**The MicroMAPS instrument is currently housed on the Proteus research aircraft and measures the amount of carbon monoxide in the atmosphere. One of the bigger problems with the instrument is its sensitivity to changes in temperature. The goal of this research is to determine if it is possible to house the instrument in a thermally insulated pod that could be attached to the external hardpoints of various aircraft. This would result in an increase in the amount of data that can be collected, less time needed for data reduction, and less dependence on the availability of a single aircraft. Simulations were run using the thermal software package within ANSYS for two different configurations. The initial results indicate that the desired amount of thermal regulation is possible, but further study is recommended.**

## **Background**

Typical design of electrical components for engineering applications require that a significant amount of consideration go towards overheating, since the size of these components continue to get smaller and smaller with increases in technology. There has been a lot of research done to cool such systems, but one of the problems with NASA's MicroMAPS instrument is its inability to retain heat.

The MicroMAPS instrument is one of the few instruments used by NASA to measure and track carbon monoxide distributions in the lower atmosphere. It is currently being used on Scaled Composite's Proteus aircraft where it has flown on numerous missions. Before each flight, the instrument must be calibrated at sea-level conditions and kept at a relatively constant temperature from that point on to make accurate readings. But with temperatures typically ranging from 23°C at sea-level to -47°C at 40,000 feet this task is quite difficult. This research looks into designing a pod that is capable of containing the little heat the instrument does produce while pumping additional heat into the system

to counteract the large rates of cooling at altitude. The pod is initially being designed to be attached to the external hardpoints of the Altair (General Atomics' High Altitude Research Aircraft) because of its long range performance capabilities and NASA's current access to it. Being able to provide this regulated environment for the MicroMAPS instrument would increase the amount of data that could be collected during each flight, decrease the amount of time needed for data reduction, and decrease the program's dependence on the availability of a single aircraft.

## **Design**

### **Structure**

A basic shape for an external store called the "Standard Streamline Form"<sup>1</sup> was selected for the pod casing as it provided an easily modifiable profile in case changes needed to be made due to space requirements. As recommended in the Altair manual<sup>2</sup>, a nominal pod 5 feet long with a 20 inch max diameter was modeled. The components on the interior of the pod would be accessible with the removal of the nose section which is designed to be inserted and locked into the midsection.

The interior of the pod consists of a base plate fixed in the middle to provide attachment points for all the necessary MicroMAPS components, which consist of the PC-104 stack and power supply. Since the interior of the pod is tightly packed, this plate is designed to slide in and out for easy access.

A number of materials were considered for the internal and external structure of the pod, including aluminum, carbon-fiber composites, and titanium. Carbon-fiber composites and titanium have exceptional thermal properties making them ideal for this project, but because of their disproportionately high cost, a typical aluminum alloy was chosen for the structure of the pod.

### Insulating Materials

To aid in keeping the MicroMAPS instrument at a constant temperature, an insulating material is needed as the outer shell, whether made of a metal or a composite, is going to readily transfer heat to the atmosphere. There are a number of insulating materials available but those most prevalently used in the aerospace industry include Teflon sheets and Multi-Layer Insulation (MLI) blankets. MLI blankets consist of various layers of extremely thin but highly reflective materials such as Mylar and Kapton<sup>3</sup>. They are popular in thermal control for satellites because of their nearly impervious nature to radiant energy. Unfortunately MLI blankets work best in the near vacuum environment found in space and are not very good insulators against conduction and convection heat transfer. Teflon, on the other hand, is a great insulator against conduction and convection. The material is typically used in the insulation of electrical wiring since it is easily machined into various extrusions and is also a good electrical insulator. Here Teflon's thermal properties and machinability are ideal for this project.

### Initial Designs

The first design, shown in Figure 1, consists of a pod with  $\frac{1}{4}$  inch layer of Teflon lining the interior except for two small cutouts to connect the base plate to the outer shell and another for the viewing window.

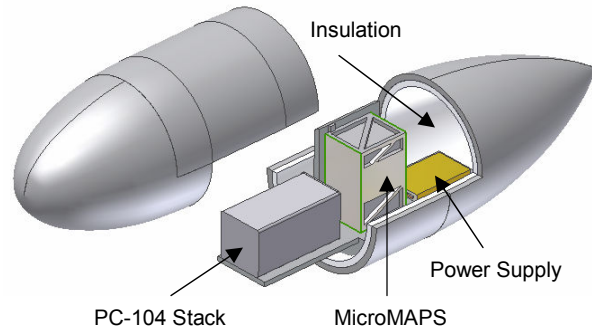


Figure 1: 1<sup>st</sup> Pod Configuration

The drawbacks with this configuration are the large amount of Teflon that is required and the difficulties that could be encountered securing it to the outer shell.

The second design, seen in Figure 2, aims to reduce the amount of Teflon needed by creating a second, smaller encasing just around the MicroMAPS instrument itself.

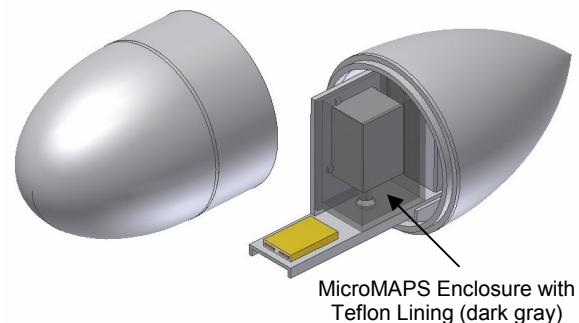


Figure 2: 2<sup>nd</sup> Pod Configuration

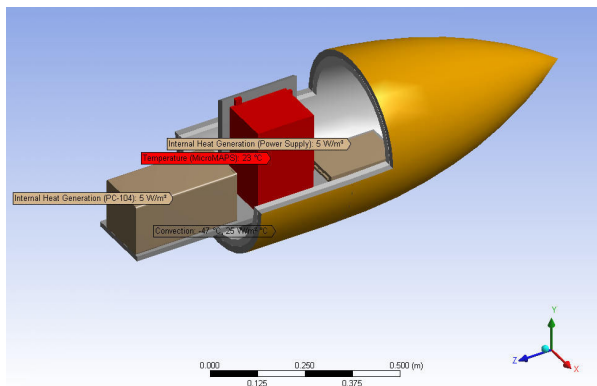
Here only the interior of the MicroMAPS enclosure is lined in  $\frac{1}{4}$  inch of Teflon. This significantly reduces that amount of insulation needed and should decrease that amount of heat that needs to be added to the system since the amount of air that needs to be regulated is much smaller. The drawbacks with this

design include a much tighter fit around the MicroMAPS instrument, that could pose accessibility problems and the other components are now exposed to the  $-47^{\circ}\text{C}$  environment at altitude.

### **Thermal Analysis**

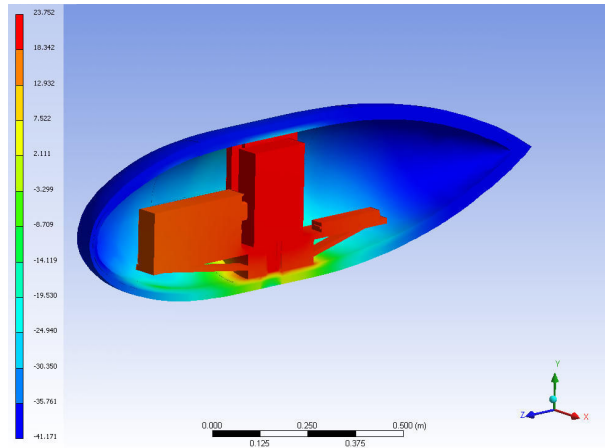
All simulations for this study were run using the thermal software package included in ANSYS: Workbench 10. An initial calibration of the software was performed with experimental data that was obtained from the engineers at NASA Langley currently working on the project. The data included temperature histories from various points within MicroMAPS's current enclosure on the Proteus. This provided a means for selecting the necessary boundary conditions and an actual atmospheric temperature profile that could be expected during ascent.

The first set of tests run on the pod designs were steady-state analyses with the MicroMAPS instrument being held at a constant  $23^{\circ}\text{C}$ . This was done to determine the amount of heat that needed to be added to the system to keep the instrument at a sea-level temperature and to determine which design, if either, did a better job at minimizing the amount of heat transfer to the atmosphere. The figure below shows the boundary conditions that were applied.

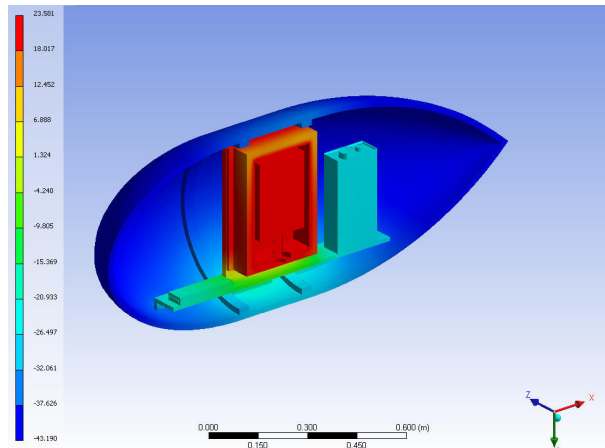


**Figure 3: Representative boundary conditions that were applied to each pod design.**

A convection current at a temperature of  $-47^{\circ}\text{C}$  was applied to outer shell of the pod with a film coefficient of  $25 \text{ W/m}^2$ , while the power supply and PC-104 stack were set both to produce  $5 \text{ W/m}^2$ . The result of these analyses is seen in Figures 4 and 5 below.



**Figure 4: Steady-State Temperature Distribution for the 1<sup>st</sup> Pod Configuration**



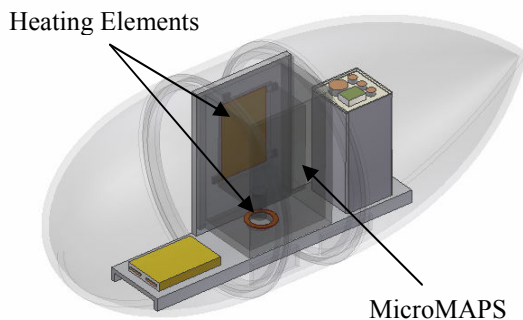
**Figure 5: Steady-State Temperature Distribution for the 2<sup>nd</sup> Pod Configuration**

These results depict the temperature distribution that would occur if the MicroMAPS instrument itself could be held at sea-level conditions. Along with these temperature distributions ANSYS can be configured to output the amount of heat that would have to be produced around the instrument to make this possible. For the first pod design a heat transfer rate between 700 and 715 watts was obtained while the second pod design required 540 to 550 watts. As

expected, the second pod design required less energy over time because of the smaller volume of air that needed to be regulated. The second pod design also provides a medium to directly heat the air immediately around the instrument, so for these reasons the second design with the separate enclosure around the MicroMAPS instrument is used for future analyses.

The amount of heat that needs to be transferred to the system for this design is still quite large considering the options for delivering the heat and the amount of space available. A small thin-film heating element is the most desired heater to accomplish this because it can be cut and sized such that it can be applied to the inside of the smaller MicroMAPS enclosure. This would concentrate all the heat produced to the air around the instrument. Only a few actual heaters could be located that had a high enough watt density to produce the required heat.

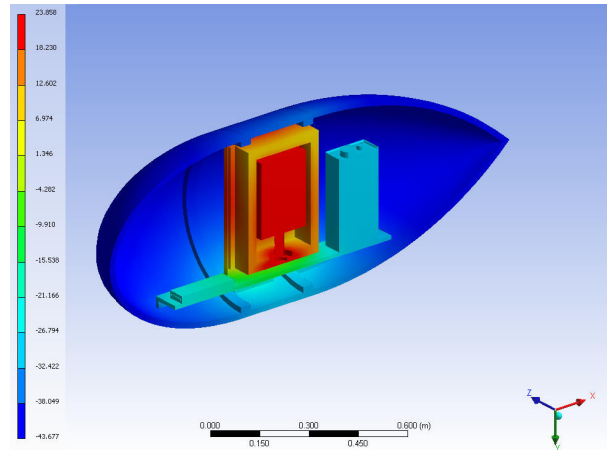
Models of the heaters were created and attached to the inner base plate and casing as shown in Figure 6. The second circular heater is added around the viewing window to create convection currents that would allow the air within the casing to be circulated without the use of a fan.



**Figure 6: Heater Locations within the Pod**

The same boundary conditions were applied to this new model as the previous test, except this time the constant temperature condition

set for the MicroMAPS instrument was removed and replaced by a combined internal heat generation condition for the heaters, equal to that previously calculated from ANSYS. The result of this analysis is seen in Figure 7.



**Figure 7: Temperature distribution throughout the pod with the heating elements.**

This analysis show that the heating elements are capable of keeping the MicroMAPS instrument at a temperature between 20°C and 15°C when at max altitude without actually being in direct contact with the instrument.

### Conclusions

The results from this study initially indicate that designing an insulated pod capable of keeping the MicroMAPS instrument at a relatively constant, sea-level temperature is indeed possible. But one of the major concerns that arose when looking at the data more closely was whether or not ANSYS was treating the space in between the various components as a fluid (air) or as a solid with conductive properties similar to air. The expected convection currents would lead to a greater amount of heating in the upper portions of the pod and internal casing instead of the seemingly symmetric heating around the elements. This is not expected to cause a large difference in the overall goal of keeping the MicroMAPS instrument at a relatively constant temperature, but it would redistribute the temperature profile a considerable amount.

Another point of concern comes from the circular heater placed just above the viewing window. Depending on the properties of the material used, the large temperature gradients across the viewing window's surface could lead to cracking, which would end all useful data collection.

### **Acknowledgements**

A large amount of work on this project was done by a group of senior aerospace engineering students at Virginia Tech. They did everything from researching aerodynamic shapes for the pod to performing the thermal analyses in ANSYS. This research was funded through a number of grants from the Virginia Space Grant Consortium and was made possible through our contact at NASA Langley, Dr. Vicki Connors and John Companion at VSGC.

### **References**

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