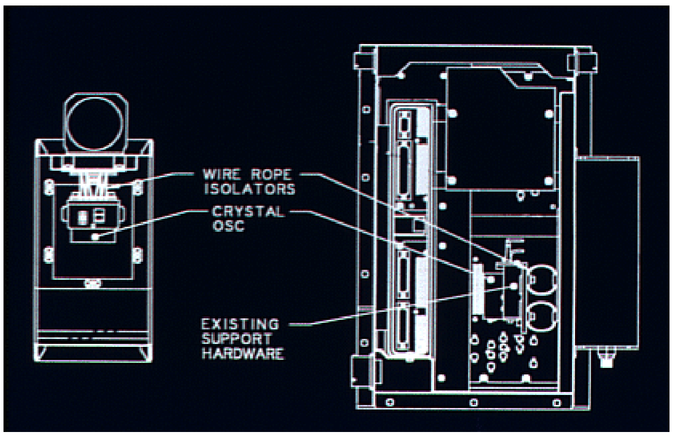
Cooling Analysis Eliminates Fan, Reducing Weight by 60% and Power Draw by 75%

By Thomas Nickell, Principal Mechanical Engineer
Lockheed Martin WS (Wideband Systems), Salt Lake City, Utah



The oscillator assembly. Diagram on left side of picture shows the top section of the oscillator. Diagram on right side of picture shows the right section of the oscillator.

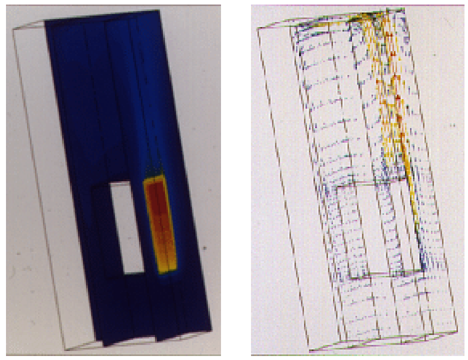
The weight of an electronic assembly was reduced 60% and its power draw was decreased 75% by using computational fluid dynamics (CFD) to optimize radiative and natural convective cooling. The particular component was an oscillator in an aircraft electronics assembly. Being an airborne application, weight and power consumption were of vital importance. Using CFD, it was possible to show the power level for which a cooling fan in the preliminary design would not be required to meet system thermal requirements. As a result, the power draw and weight associated with the fan were eliminated, significantly improving the overall performance of the assembly.

The main electrical component in the assembly is an oscillator. The oscillator is a box mounted inside a case. The oscillator is about 2 inches by 2 inches by 3-1/2 inches (See Figure 1). The heat generated in the oscillator is dissipated on one vertical face of the oscillator. Vents in the outer case were not allowable for design reasons. The most critical specification from a thermal standpoint is that the vertical baseplate where the heat is dissipated remains at no higher than 85^{o}C in order to meet reliability and performance requirements for the electronics.

In the past, Lockheed Martin WS engineers would have correlated the geometry with approximate likenesses from literature and used the resulting closed-form equations to predict dissipation. For this problem, however, the fit between the literature and actual geometry was not close enough to make accurate predictions. As a result, a conservative preliminary design included a fan to ensure proper cooling. The fan would have added about 1.5 pounds to the 1 pound oscillator and would have consumed about 25 watts compared to just 2-8 watts for the component itself.

Given these severe weight and power penalties, Lockheed Martin WS engineers decided to use computational fluid dynamics (CFD) to model the assembly and evaluate alternative design configurations. The key advantage of CFD is that it can model the exact geometry of the component and thus produce far more accurate estimates of component temperatures. Another advantage is that once an initial model is produced, modifications can be made to investigate what-if scenarios in a relatively short period of time. This makes it possible in most cases to optimize cooling efficiency.

With these benefits of CFD established, Lockheed Martin TCS engineers performed a comprehensive trade study to evaluate different CFD codes. FLUENT CFD software from Fluent Inc., Lebanon, New Hampshire was selected primarily because it provides modeling tools needed for analyzing their thermal management issues.
These modeling tools include radiative and natural convective cooling and a porous media model that was not offered by any of the other packages that were investigated. In addition, the popularity of this software package makes it an industry standard. Finally, the price of the software was quite reasonable, especially when one considers the expert technical support that is provided with a software license.



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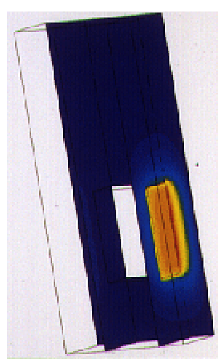
Heat is generated in the oscillator and dissipated by conduction through the mounting plate. The mounting plate in turn rejects heat to the surrounding air by natural convection and to the enclosure walls by radiation. The approach taken was to model the air inside the case around the oscillator. A plane of symmetry was used to reduce the size of the problem. A heat flux boundary condition was applied at one wall of the oscillator to simulate the oscillator heat load.One wall on the outer case that the baseplate faced was held at a constant 60^{o}C because it was exposed to the outside ambient environment. The otherwalls were treated as adiabatic (i.e., insulated).



An oscillator was later chosen for electrical performance reasons that had a much higher power dissipation, making necessary the use of a fan.

The overall goal of the project was to maintain the baseplate at a temperature below 85^{o}C (358K). As long as the temperature of the baseplate stays below this level, the temperatures of the electronic components within remain at an acceptable level. When the model was completed, the analysis was first run with natural convection only. The temperature was too high, but our thermal engineers realized that radiation would be a significant factor in heat rejection from the baseplate. When the effects of radiation were added to the model, the baseplate temperature was predicted to be 85^{o}C (358K) (See Figures 2 and 3). With the combined effects of natural convection and radiation being sufficient to meet the thermal requirements, active cooling with a fan would not be required.

The elimination of the fan provided the customer with a significant performance improvement - less power draw and lower weight. Because of the tight time schedule on this project, the engineers decided to go with the preliminary design minus the fan. If time had been available, they could have optimized the geometry and achieved an even lower baseplate temperature or further reductions in weight or volume. Note: Later, an oscillator was chosen for electrical performance reasons that had a much higher power dissipation (see Figure 4), forcing them to use a fan. Later, electrical engineers selected yet another oscillator. CFD gave us the ability to know at what power level a fan was required. It generally enables thermal design refinement.

An important step in the design study was to validate the accuracy of FLUENT for this problem. To do this, a simplified geometry was chosen so that results from the CFD simulation could be compared to a simplified analysis using correlations from literature. The simplified analysis matched the CFD simulations quite well and gave us the confidence to proceed with the design.

This type of performance gain is typical when Lockheed Martin WS uses CFD for thermal management studies. We now use CFD to analyze components whose geometries are too complex to handle through correlations in the literature. In critical design studies, prototypes are used to validate the CFD analyses. However, Loral engineers have enough confidence in FLUENT that in some cases it is possible to move directly from the design study into production.