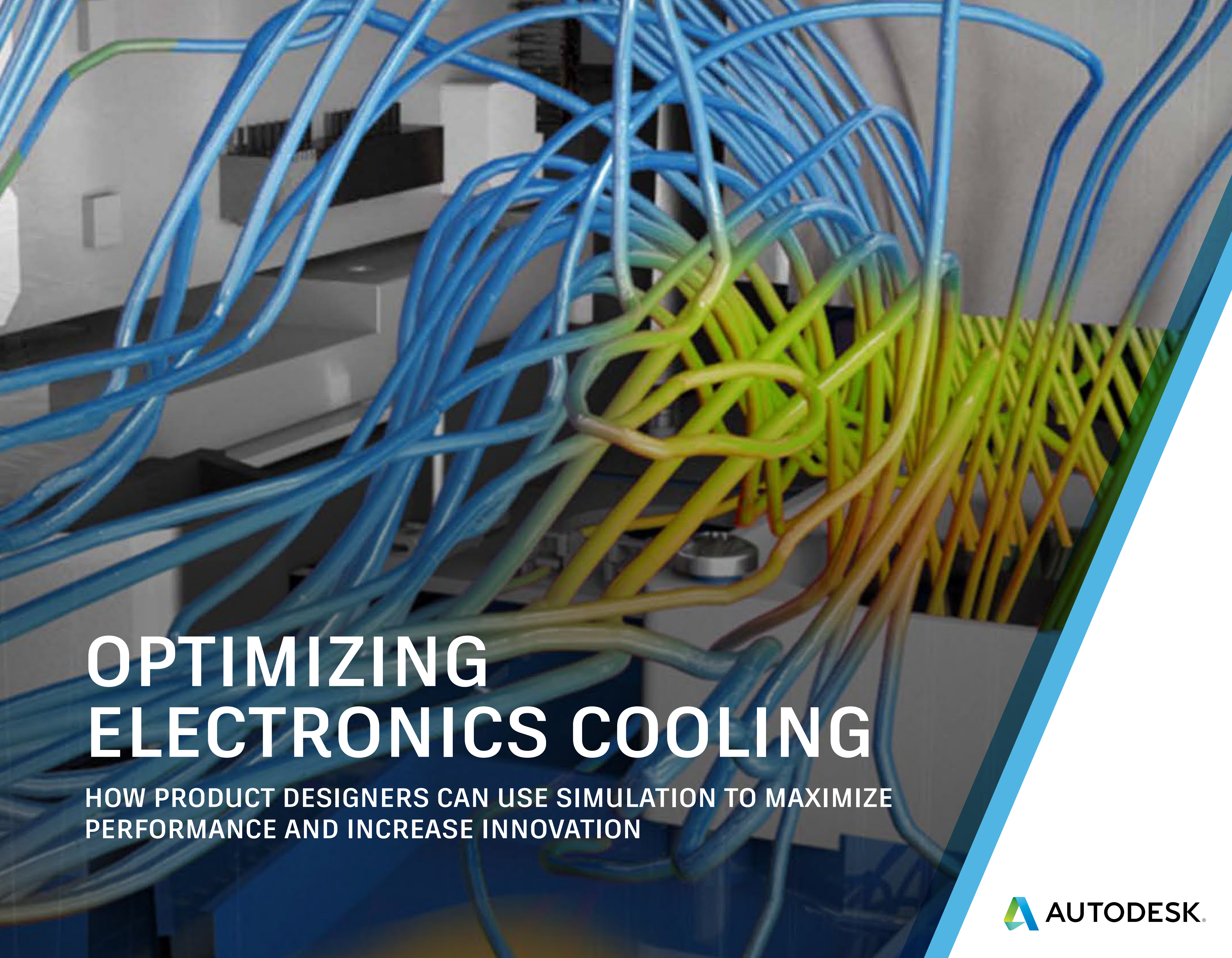

OPTIMIZING ELECTRONICS COOLING

HOW PRODUCT DESIGNERS CAN USE SIMULATION TO MAXIMIZE PERFORMANCE AND INCREASE INNOVATION

AUTODESK

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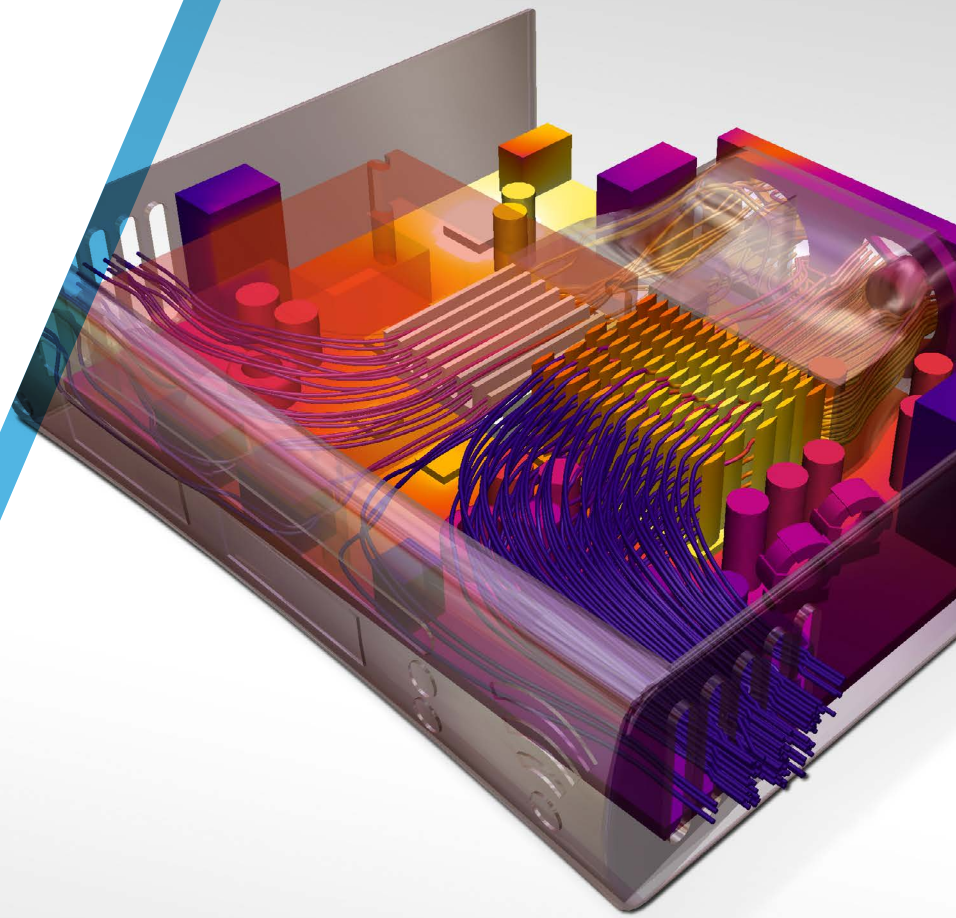


INTRODUCTION

In this ebook, we will explore why cooling is such an important issue in electronics design, how the CFD process works, and look at five challenges that CFD is well-suited to solve.

INTRODUCTION
Visualizing the invisible

Designers of electronics prefer to identify potential issues early in development, before they manifest in finished goods that fail to meet customer expectations. Typically, the way to predict product performance is physical prototyping and testing. This expensive process isn't perfect, however, which means you can invest a great deal of time and resources and still generate a design that falls short.

One of the biggest reasons why is heat. Heat transfer and airflow inside electronic product enclosures are essentially invisible (see Fig. 1). They are hard to understand and even more difficult to test in a prototype.

Simulation makes these invisible phenomena visible. Specifically, computational fluid dynamics (CFD) gives designers the power to visualize airflow throughout the product to understand if parts are at risk of overheating. With a simple thermal analysis, you can see how heat radiates through the enclosure and predict whether components will fail. What's more, you can simulate a variety of solutions from fans to heat sinks to rearrangement of PCBs and find the most appropriate one more efficiently. As a result, you end up with a stronger, more reliable design and a complete understanding of why your new design is better.

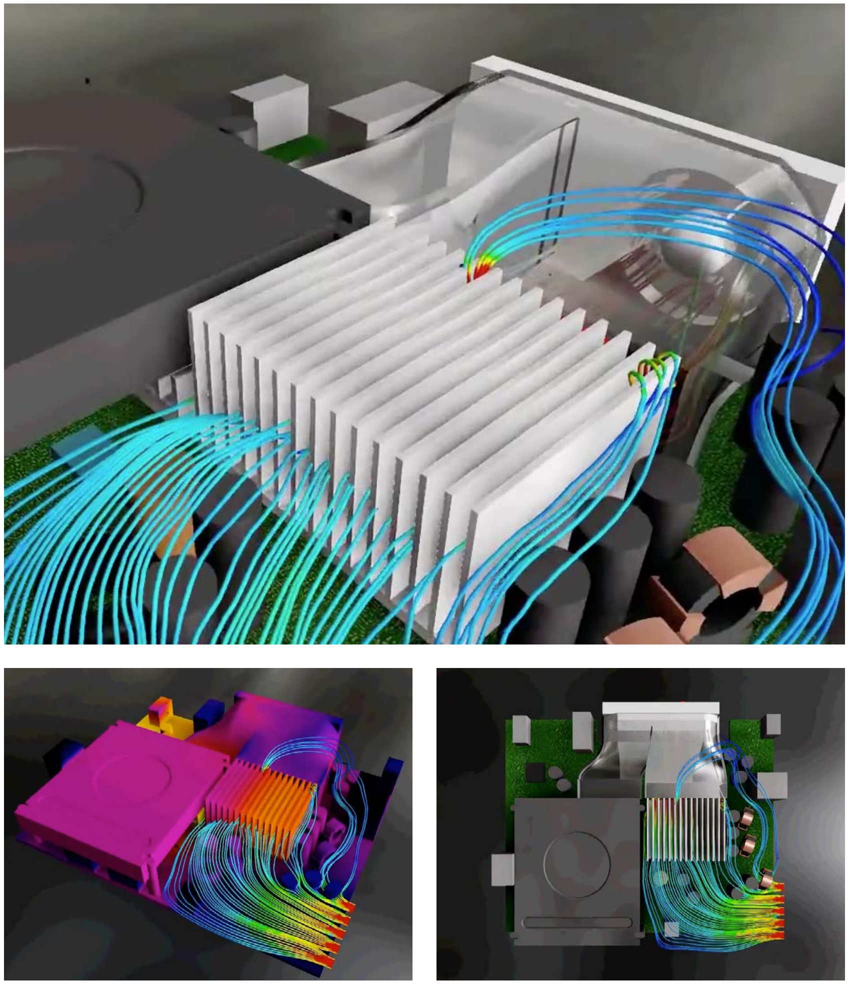


FIG. 1

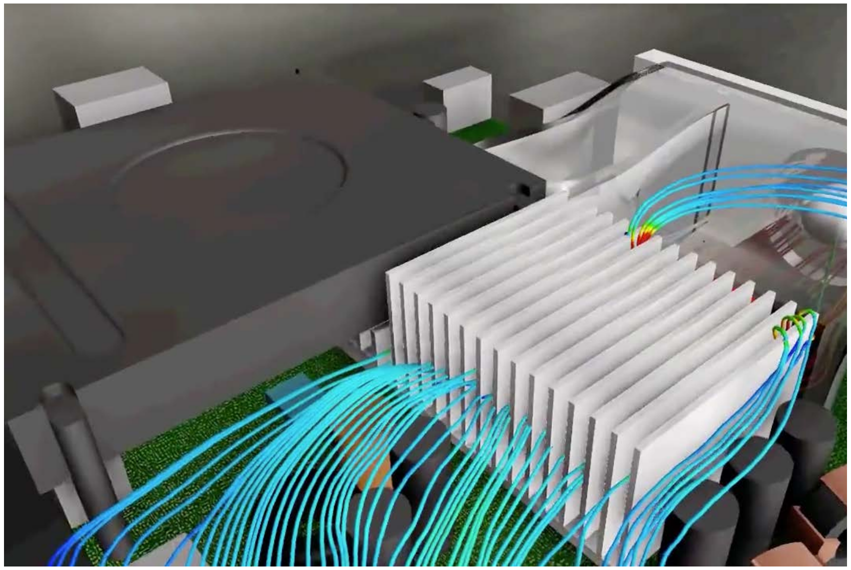
CFD simulation helps product designers visualize the complex flow of air and heat within electronic components.

WHY COOLING IS CRITICAL

Heat management is one of the most challenging problems to solve in the design process for electronics.

Why cooling is critical

Understanding electronics cooling more precisely is important for a variety of reasons. In general, consumers have higher expectations for quality. They want the same or better reliability at a lower price. Proliferation of LED lighting leads to more localized hot spots. Products are only getting smaller, especially consumer electronics. (When is the last time you were asked to make the enclosure bigger?) While smaller products decrease production costs, they complicate cooling. “Smart” products pose similar challenges, creating the need to integrate electronics in thermostats, refrigerators, and other products that haven’t had them previously.



WHY COOLING IS CRITICAL

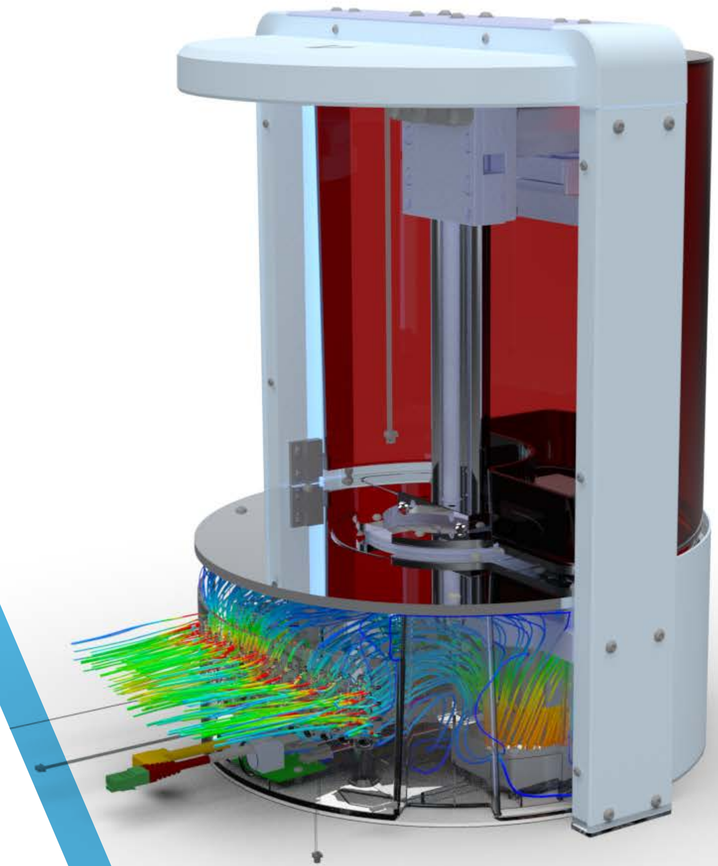
Considerations for optimal cooling

Optimal cooling can be complicated by a number of design factors as well, each of which can affect the others. The first (and most obvious) is determining the reasonable operating temperature for the product to run safely and efficiently.

Size is the next most important consideration. Failing to account for the effects of heat on a smaller design can cause warpage and failure, primarily due to reduced airflow. Noise can be a big factor as well. Larger inlets and outlets allow more sound to escape from the part, and bigger fans produce more noise.

The operating environment comes into play as well. Military products, for example, must withstand extreme outdoor conditions. Consumer products may operate well during normal conditions, but not if they are left in the sun.

Cost can be the most difficult problem to solve of all. Many solutions for keeping temperature under control may drive up costs and erode margins.

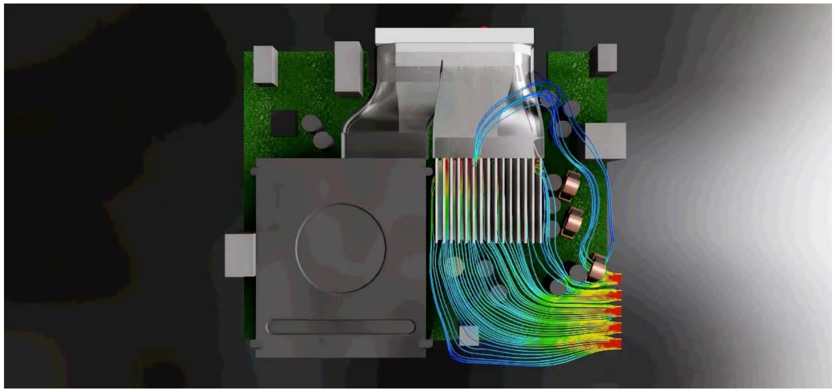


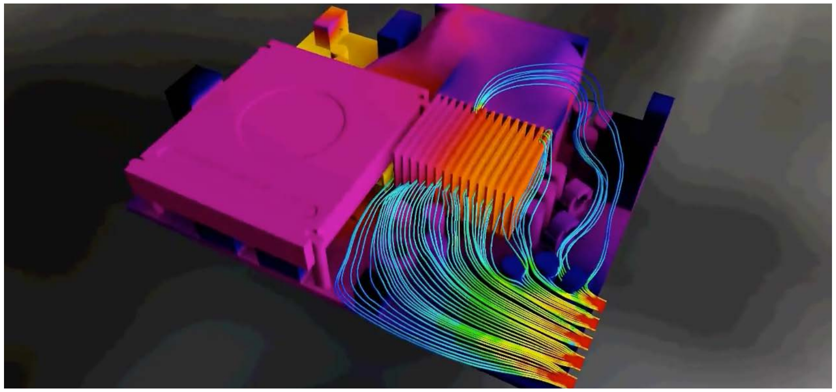
WHY COOLING IS CRITICAL

The challenges of heat management

Managing all of these factors is important because suboptimal cooling creates its own cascade of interrelated challenges. Adding or upsizing fans, for example, not only adds cost but also requires additional parts to design. High-end materials and more advanced components, such as liquid-cooled heat sinks, do not require additional space but can be extremely expensive.

Failure to manage these factors sooner, rather than later, can have potentially devastating effects on the product and even your company. Microsoft famously failed to discover a design flaw in its Xbox gaming system that caused the unit to overheat and lock up. Referred to as "the red ring of death," the flaw caused Microsoft to spend more than a billion dollars on extended warranties. Needless to say, the average company can't sustain a billion-dollar loss. Predicting and resolving these potential heat-related failures in advance of launch is vital.

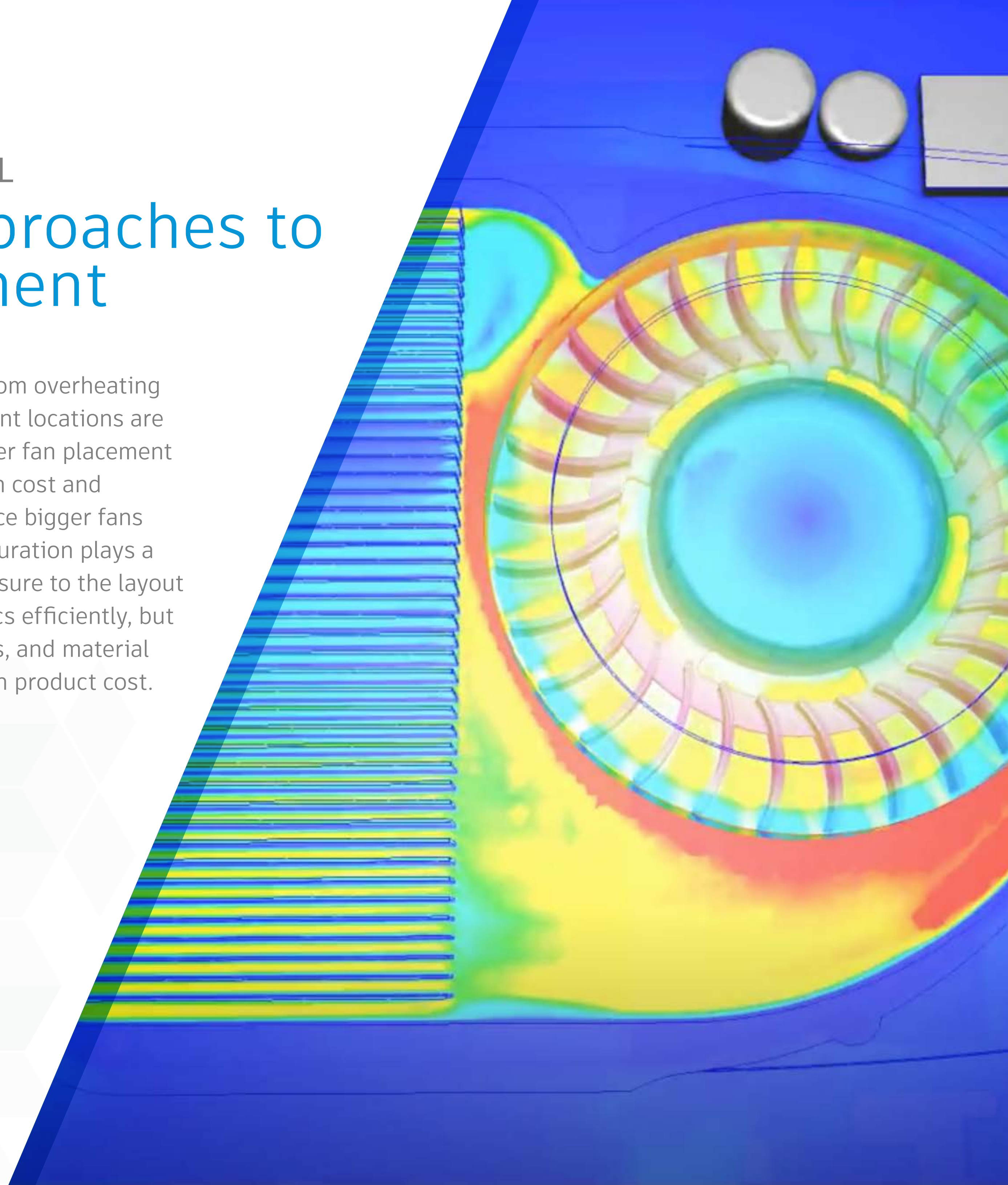




WHY COOLING IS CRITICAL

Traditional approaches to heat management

The solutions for preventing products from overheating are well known. Designers can ensure vent locations are situated to allow sufficient airflow. Proper fan placement and sizing improves circulation, although cost and aesthetics complicate the instinct to place bigger fans near hotter locations. Component configuration plays a role as well, from placement in the enclosure to the layout of PCB boards. Heat sinks cool electronics efficiently, but there are a wide range of types and sizes, and material choices can greatly affect their impact on product cost.



THE POWER OF SIMULATION

CFD simulation can provide valuable insights that help solve cooling issues earlier in the development process.

THE POWER OF SIMULATION

Why use simulation

The bigger challenge is making these changes earlier in the product development lifecycle, rather than later. Changes made earlier in the process have a greater effect on functionality and cost less to implement. Changes made later in the process—as the product approaches testing, manufacturing, and launch—have less impact on functionality and yet are more expensive to make. This, in essence, is the business case for simulation.

Simulation gives product designers the tools to analyze and detect potential overheating issues during the concept phase. It reduces the number of prototypes and allows organizations to design products faster and more cost-effectively. On average, companies with low-complexity products saved 33 days and $19,000 while developers of high-complexity products saved more than 250 days and $3 million.

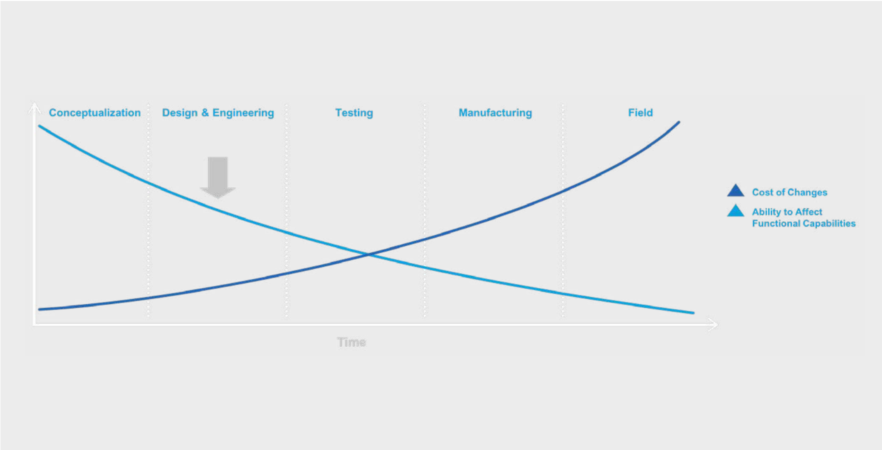


FIG. 2

Solving heat management issues earlier in the development cycle is more effective and less expensive.

THE POWER OF SIMULATION

The basics of CFD simulation

Computational fluid dynamics uses data analysis to solve problems that involve fluid flows, including the flow of air and heat transfer, as well as the interaction of heat and air with surrounding materials. CFD software is often thought of as a virtual wind-tunnel, flow bench, and thermal test rig all in one (see Fig. 3).

Simulation in general and CFD in particular have become more popular because these CAD-centric tools allow designers to test products digitally, in a variety of virtual environments, using the actual 3D CAD models of the product. These simulations provide data that would be difficult or even impossible to obtain through physical testing alone.

But simulation is more than using a computer as a virtual test bench or wind tunnel. Simulation can provide extremely valuable insight into the performance of a design; helping to identify potential failures and address them at the earliest opportunity. Simulation also opens the door to innovation because it enables designers to try more design solutions and assess their impact more rapidly than with physical prototyping. Accelerating this process makes it easier for designers to try a wider variety of approaches to heat management issues, find the optimal solution faster, and improve speed to market.

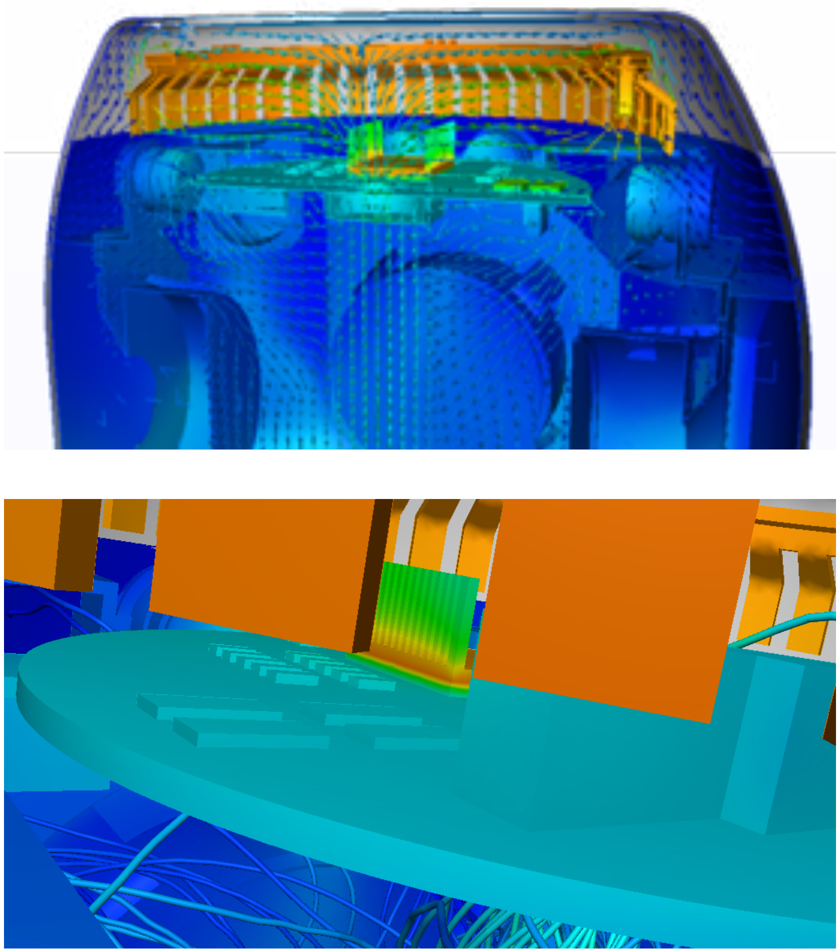


FIG. 3

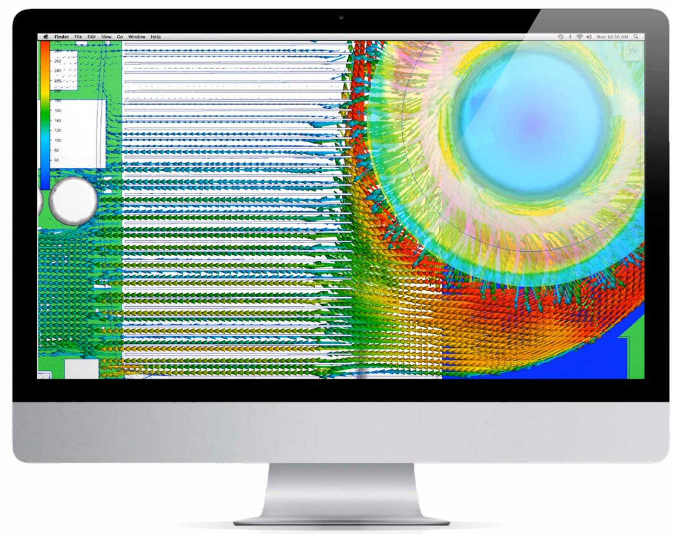
CFD simulation uses data analysis to help product designers understand the complexities of heat management and PCB placement.

THE POWER OF SIMULATION

The basics of CFD simulation

The issues that CFD simulation can solve more effectively than prototyping will be familiar to designers of electronics products. Often, it is not possible to predict how air will flow between parts, or it is not possible to measure the temperature in confined spaces. CFD allows you to visualize the flow of heat in these locations with contour mapping and flow lines.

CFD simulation typically allows you to define not only the size of the fans but also dictate the RPMs, so you can determine if you are over or under-cooling the part in question, and if the current setup can be improved. It also makes it simple to change the size and geometry of the enclosure and analyze the performance of each one. In the same way, you can change the board design to quickly determine how the components should be arranged to optimize heat management. Making these evaluations with prototyping would take significantly longer.



SOLVING FIVE COMMON CHALLENGES

Here are five ways CFD simulation can help product designers overcome familiar design challenges related to heat management.

SOLVING FIVE COMMON CHALLENGES

1. Reduce product size

CFD simulation helps product designers create smaller enclosures that contain the same electronics. Running a coupled fluid thermal analysis ensures that the design is set up in a way that allows the air to cool the parts generating the most heat—especially when the components are in a smaller space.

The 3D printer (see Fig. 4) is a perfect example. The original design was too large and operated at high temperatures which compromised print quality. With the help of CFD simulation, designers reduced the size by two-thirds and brought down internal temperatures to an acceptable level.

As any design gets smaller, it relies less on natural convection and more on conduction. With the ability to understand conduction paths and material conductivity during concepting, thermal designers can complete this work up front, passing the information to the electrical designer who can then arrange components efficiently based on this work.

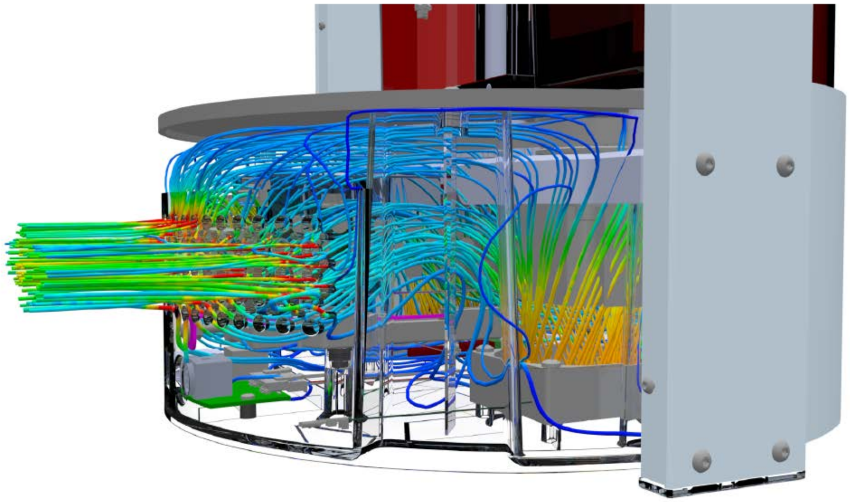


FIG. 4

CFD simulation can help optimize the size of the enclosure in addition to its internal operating temperatures, as with this 3D printer.

2. Improve performance

The ability to change the loads and boundary conditions of a design with a few clicks makes it very easy to determine if the existing enclosure can support more powerful electronics. Autodesk CFD, for example, allows you to quickly change the CAD design to more accurately represent components or change their configuration within Autodesk Fusion 360, then bring the changes back into Autodesk CFD to analyze the new layout.

Another way to increase component performance is by increasing the down force for better contact between components. This change, however, could lead to higher thermal loads while the increased compressive force could lead to part failure or thermal fatigue failure over time. These situations can be avoided with the interoperability of Autodesk CFD and Autodesk® Nastran® In-CAD software, which provides finite element analysis.

The graphics card (see Fig. 5) went through a number of design cycles to optimize the heat sink used to increase performance. Everything from its size, material, and placement were taken into account and compared in the design study environment where the changes that produced the best results were selected for the optimal setup.

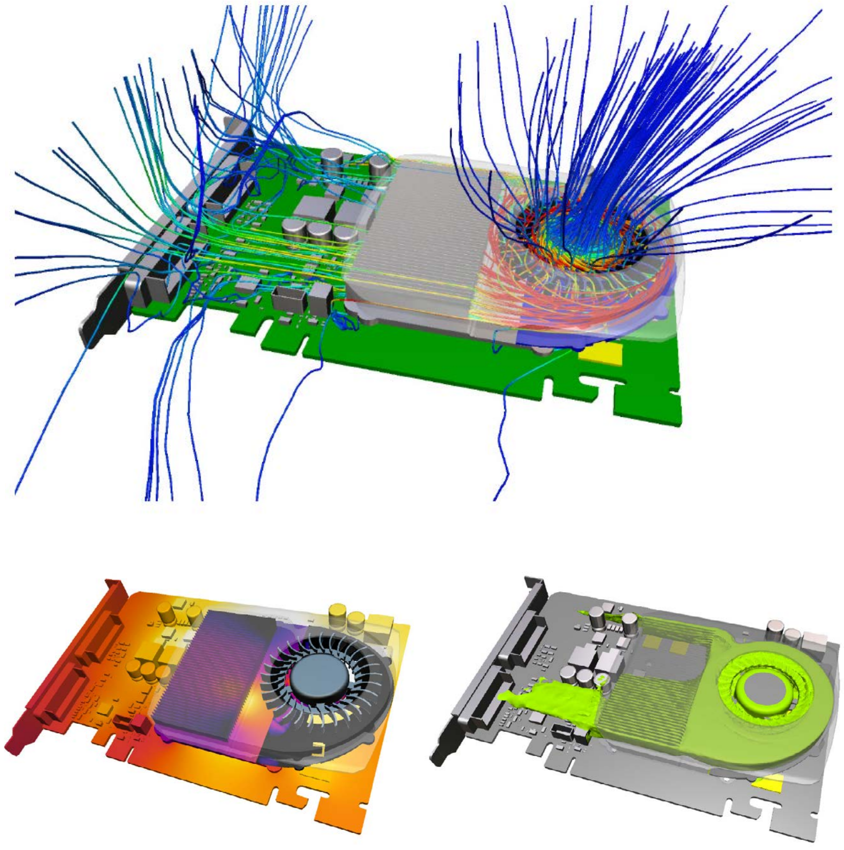


FIG. 5

Graphics cards are notoriously fickle and must be carefully designed to avoid temperatures that could compromise performance.

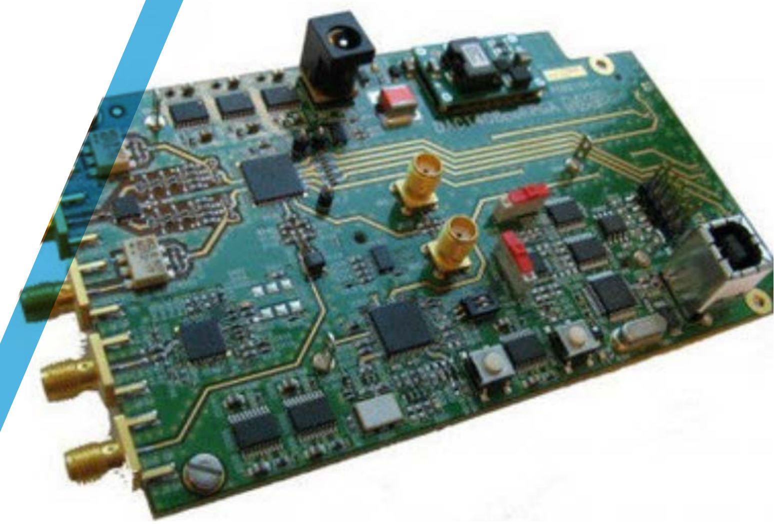
SOLVING FIVE COMMON CHALLENGES

3. Minimize cost

CAD-driven CFD simulation allows product designers to run multiple design iterations and compare results side-by-side. Whether the change in question is higher fan speed, varying the power of different components, or eliminating parts from the design altogether, this design study environment makes it clear which changes will help you reach your goals.

If cost reduction is the priority, it can be achieved many ways. The most obvious one is part reduction; a product with fewer fans costs less to manufacture. The same is true of less expensive materials that still provide sufficient cooling. Minimizing assembly time with fewer overall components is another way to reduce cost through higher output efficiency.

In some cases, the best design is one that allows for the enclosure itself to serve as a heat sink. Making the right choice in this instance involves more than selecting the right parts. Material choice is also important. High percentage fiber-filled materials, for example, dissipate heat extremely effectively, reducing the need for metal heat sinks. CFD simulation allows you to quickly test various materials to determine which one is best—without over-designing.



SOLVING FIVE COMMON CHALLENGES

4. Extend lifespan

CFD simulation makes it easy to analyze designs under any number of conditions to account for potential forms of failure. Within Autodesk CFD, for example, product designers can make sure components operate correctly while exposed to large solar loads, subzero temperatures, or dusty and dirty environments. In addition, thermal results can be transferred to Autodesk Nastran In-CAD for thermal stress analysis. This helps ensure that operating temperatures stay within the desired range and do not deflect enough heat to damage other components.

The enclosure (see Fig. 6) is a great example of how this works. In its first design iteration, the enclosure’s components were failing due to excessive temperature loads. After redesigning the layout, the lifespan of the product increased to the point that failure occurred elsewhere in the system before the electronics even started to show signs of wear.

FIG. 6

Running multiple simultaneous CFD simulations in the cloud can drive design efficiency while freeing up local computing resources.

SOLVING FIVE COMMON CHALLENGES

4. Extend lifespan

Any product that is part of a larger system or mounted on a rack with other products needs to perform at the correct temperature, not radiate so much heat that the surrounding parts are affected, and continue to operate indefinitely while other products increase the ambient temperature. Understanding these setups, as well as the abnormal environmental conditions the product may experience, can result in a huge number of scenarios to analyze.

Setting up multiple simulation studies with different materials and design iterations, however, places a heavy demand on local computer resources. During most simulation studies, your computer may be rendered unavailable for other activities. The problem becomes exponentially larger as the number of materials and design iterations increases.

This is where cloud-based solving can provide a huge benefit. It allows product designers to use local computing resources to iterate and optimize the setup for analysis. Then, when the time comes to run a more computationally intensive simulation, the cloud runs multiple scenarios simultaneously (instead of in series) while the local computer remains free for other work. In addition, Autodesk CFD gives designers the ability to do this with only a single license.

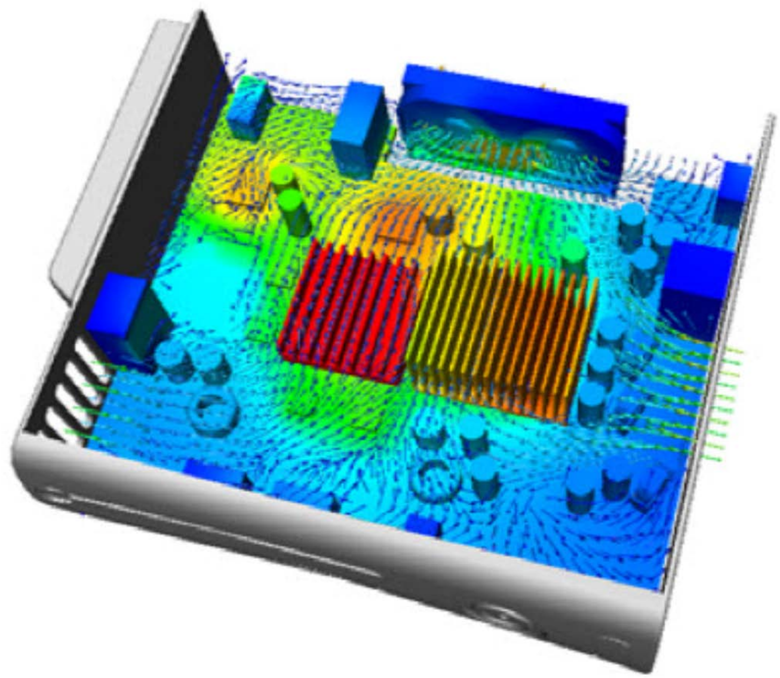
SOLVING FIVE COMMON CHALLENGES

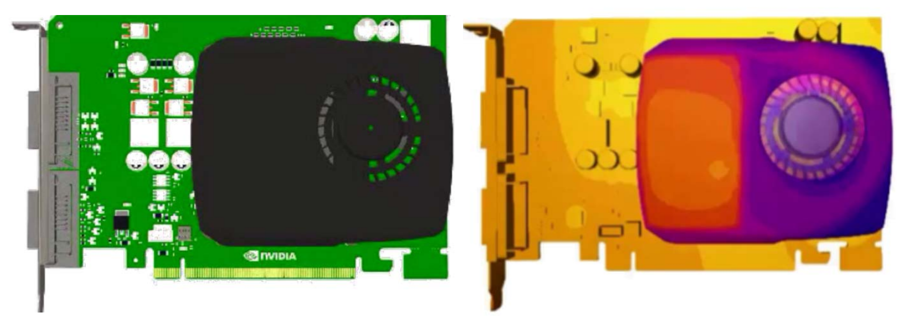
5. Optimize circuit boards

As electronics continue to get smaller and more powerful, product designs must utilize smaller PCBs with more components that generate more heat. To accommodate these increasingly complex designs, you need the ability to analyze how hot various components will get depending on their placement within the enclosure.

CFD simulation gives you the ability to do this very efficiently. Autodesk CFD, for example, has tools specifically geared toward PCB design and evaluation. It helps optimize everything from the layers of the board, to thickness, to component placement—all of which can be thoroughly investigated before you make a single prototype.

It also allows various stakeholders in the process to collaborate more easily. For example, a thermal designer can place key components to deliver superior cooling efficiency. With this knowledge, the electronics designer can account for these localized hot spots while minimizing trace routing. This upfront simulation can save weeks of rework later in the process.





CASE STUDY: HEAT MANAGEMENT IN A MODEM

How a modem manufacturer used CFD analysis to stop a critical part from overheating.

CASE STUDY

Heat management in a modem

Here is a real-world example of how CFD simulation can help with the optimization of air flow and heat management (see Fig. 7). The original design of this modem unit featured a small housing and large heat sink, but a critical component was overheating at 62.8°C.

The new design used a larger housing and an offset fan to divert more air flow over the critical component. This approach reduced the junction temperature to 51.2°C, but this was still too high for reliable operation.

Through CFD simulation, it became clear that the optimal mode of heat removal was conduction. The optimized design removed the heat sink to save cost and weight and increased the copper content on the board. Removing the heat sink provided less flow resistance, which enabled the fan to operate at a higher point on the fan curve (0.6 cfm vs. 0.44 cfm). These simulated changes reduced the junction temperature to 44°C—a 30% reduction from the original design—and delivered a lighter, more cost-effective solution.

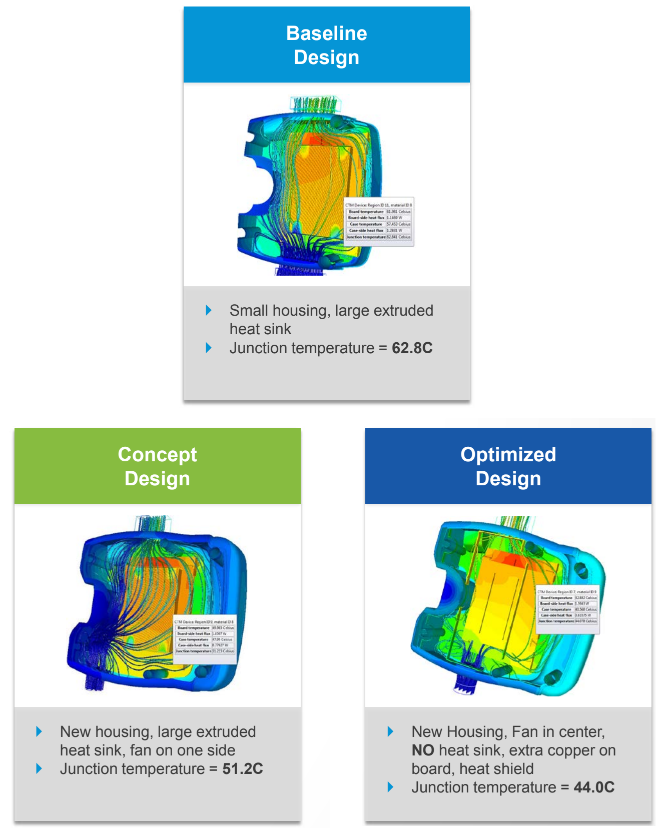


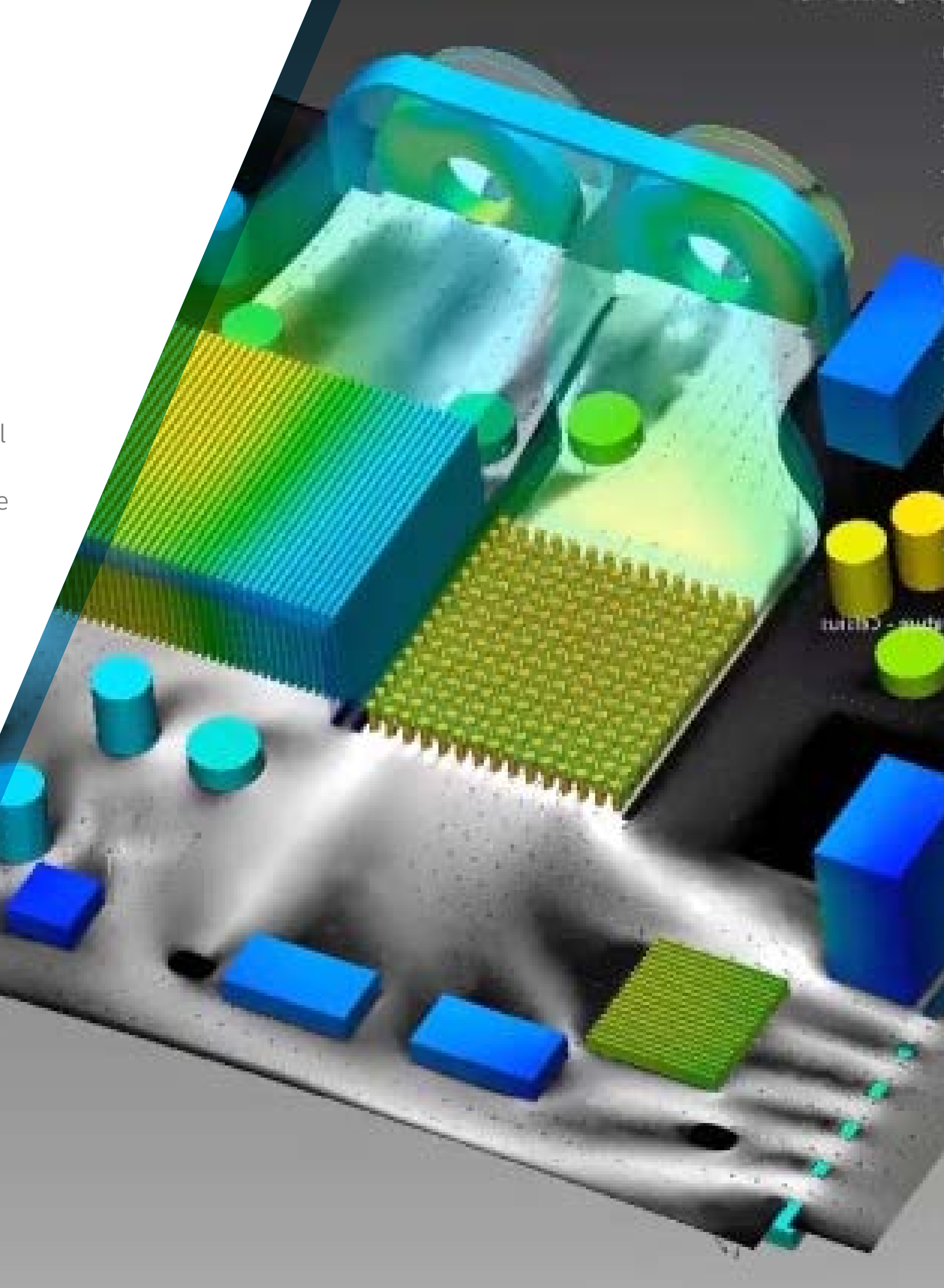
FIG. 7

CFD simulation helped optimize the design of this modem to reduce the internal temperature as well as reduce weight and manufacturing costs.

CONCLUSION

Conclusion

CFD simulation gives product designers powerful tools for optimizing heat management and air flow in electronics much earlier in the development lifecycle. By radically reducing the need for physical prototyping and testing, simulation enables designers to identify potential issues while they are relatively easier to solve. When directly integrated with CAD, it allows designers to create multiple variations and compare them side by side. This not only creates new opportunities for innovation, but ensures that designers find the best possible balance between heat management, product performance, product lifespan, and total cost.



GET STARTED

To learn how Autodesk software can help you capitalize on all the opportunities of CFD simulation, **contact us** today or visit our **Electronics Cooling Solution Center.**

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