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ENGINEERING EDGE

Accelerate Innovation with CFD & Thermal Characterization

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Mentor Graphics
Mechanical Analysis

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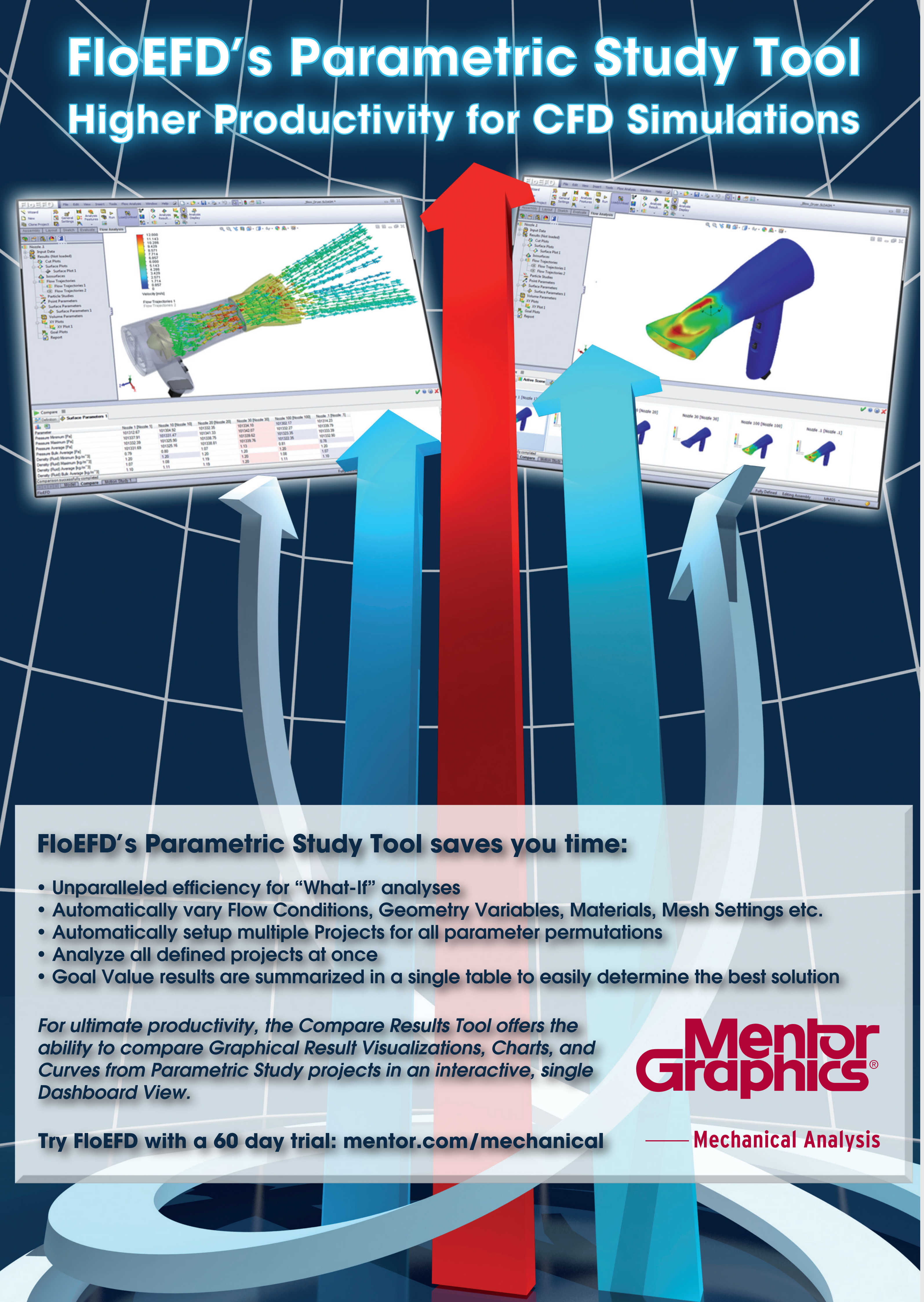

Mentor Graphics
Mechanical Analysis

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Perspective

Vol. 03, Issue. 01

Greetings readers! It is my pleasure to offer you this edition of Engineering Edge as the new General Manager of the Mechanical Analysis Division. Many of you will know me from my previous role as Product Line Director for our FloEFD®, FloTHERM® and FloVENT® products. As I take over from Erich Buergel, who was promoted to Vice President of sales in Mentor Graphics in September, I feel both humble and excited. Humble, because Erich leaves big shoes behind him having grown the Division substantially during his tenure, and excited because being a product man I believe we have an exciting technology roadmap to execute on to increase our innovation.

I am also very excited because we have two very weighty products that were released to the market recently: FloTHERM V10.0 and the brand new MicReD Power Tester 1500A. We devote several pages of this newsletter to explaining the changes and unique capabilities of these two world class products so I commend them to you. After our 25th Anniversary for FloTHERM last year, V10.0 unveiled some exciting product interface changes implemented by Product Management that have been well received by you, the users. The Power Tester 1500A is also a significant evolution of our MicReD product line where we have produced an 'Industrial' solution rather than a laboratory-level product. The 1500A has all the accuracy and reliability of the standalone T3Ster® but in a very robust power cycling and testing station that can be used by operators in a manufacturing environment. We have put a lot of effort into user experience for the software that goes with the Test Station 1500A, and its touch-pad screen is both intuitive and easy to navigate. We genuinely think it will be a game changer in power electronics cycling and testing, especially for IGBTs. If you get the chance, check out the video of the Power Tester 1500A on our website; it gives a good feel for what it can do.

Finally, Engineering Edge wouldn't be Engineering Edge without a slew of customer stories. The cover story from Facebook shows how they use FloTHERM to design custom rack systems for their datacenters. In addition, ADA designed combat aircraft fuel systems, Black & Decker's Power Drill electronics cooling, Seiko's big time savings with FloEFD for projector design, Flanders Drive automotive electric powertrain cooling, Cofely's revamping of a biomass furnace, and Mercury Systems' military avionics thermal design, are all noteworthy in their own right. Do read John Murray's interesting survey of Engineering Apps, plus an interview with long-time veteran of the electronics cooling industry, Bill Maltz from ECS. He has some great insights showing his company is still working at the cutting edge, his colleague Guy Wagner's story on how they tear down and analyze several tablet computers is well worth reading.

I commend Engineering Edge to you and I trust we will continue to work with you to produce industrial solutions that meet your current and emerging needs.

Roland Feldhinkel, General Manager
Mechanical Analysis Division, Mentor Graphics

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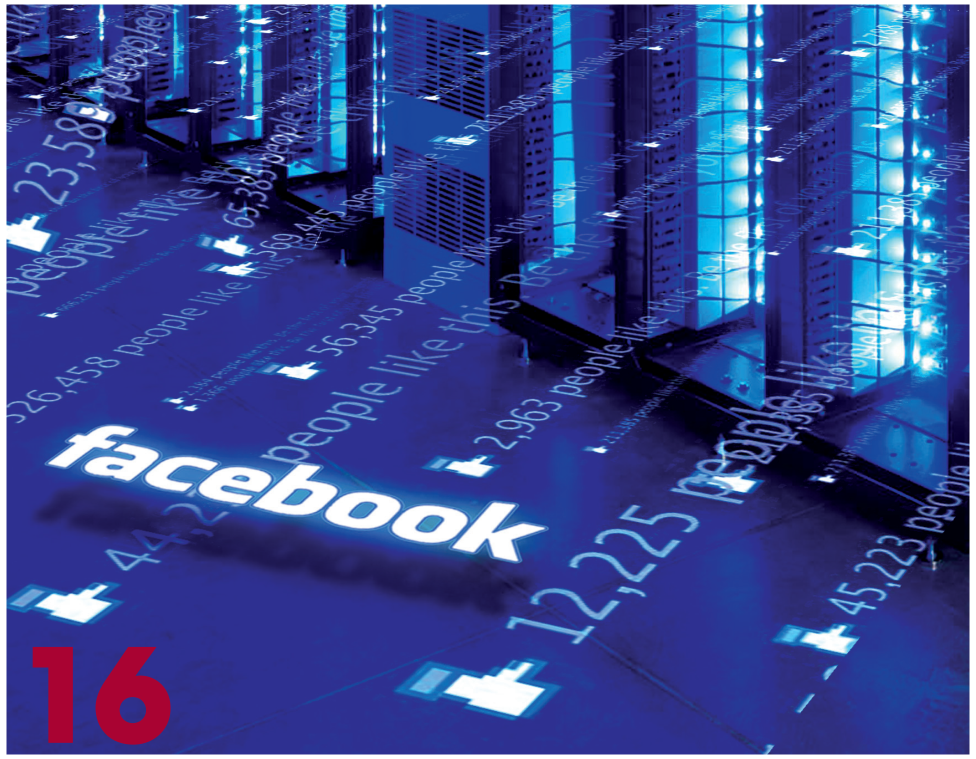

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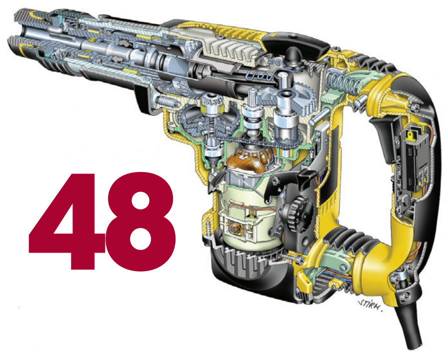

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Engineering Edge

Technology & Knowledge Bank

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PROFILE: Roland Feldhinkel

Age: 53
HQ: Forstadt near Frankfurt
Apple or Android: Windows
Hobbies: Classical Music, Jazz, Literature, playing piano
First Car: VW Golf GTI

Introducing the new General Manager of the Mentor Graphics' Mechanical Analysis Division.

The recent promotion of Roland Feldhinkel from Product Line Director to General Manager of the Mechanical Analysis Division is a milestone in the history of the Division. Roland brings a diverse and eclectic résumé to the role, he started out as a pilot of military helicopters and a Captain in the German army, (where he obtained a Master's degree in Aerospace Engineering from the German Military Academy) and ended his time in the German army as an instructor for new recruits.

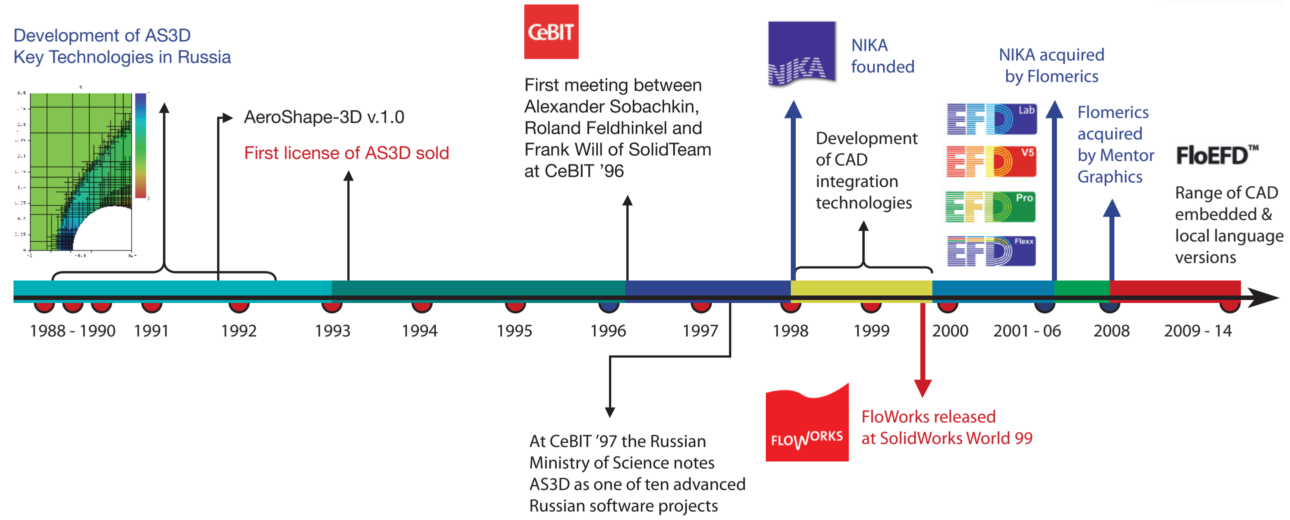
When he left the army, Roland set up an engineering consulting company, SolidTeam, in northern Germany with a university colleague, offering structural analysis (FEM) services for aerospace companies, using an early version of Cosmos (now part of the SolidWorks suite of products). The duo quickly realized that becoming resellers of the Cosmos product line in Germany would be beneficial as a result of the wave of FEM analysis happening in the early to mid 1990s. In 1996 Roland met Alexander Sobachkin from Moscow at the spring CeBIT Computer Expo Fair in Germany. Alexander had a radical CFD code that needed commercializing. In the same year, SolidTeam became resellers of the fledgling 3D CAD product, "SolidWorks" and were one of the first distributors in Germany for the product that subsequently took the CAD market by storm.

SolidTeam generated enough revenue from reselling SolidWorks to fund a business partnership with Alexander's team in Moscow to allow for the development of a new type of finite volume, immersed boundary, cartesian mesh CFD software that had originated in the Russian aerospace sector in the late 1980s (see Figure 1). Roland and Alexander identified the opportunity to embed the CFD technology inside the SolidWorks MCAD product to offer both high productivity as well as upfront design benefits to both designers and engineers who had never used CFD before. In 1998 they took an extraordinary risk to "go it alone" and founded Nika GmbH, targeting the CFD market with a new type of CFD they called "Engineering Fluid Dynamics". The product morphed into several CAD variants over the next five to six years, including what became the foundational technology for SolidWorks Flow Simulation and all the variants of FloEFD that Mentor Graphics sells today. It is also the enabling technology for FloTHERM XT.

Roland's experience includes all the unpredictability of establishing and running a start-up business: managing start-up venture capitalists; living hand-to-mouth during cash flow difficulties; controlling exceptional high growth scenarios (Nika GmbH grew 200% between 2004 and 2006); creating and developing a reseller and direct sales channel network; and then overseeing the acquisition process with potential purchasers. Nika GmbH was acquired by Flomerics Ltd in 2006 and then in 2008 Mentor Graphics acquired Flomerics. Through both dislocations Roland led the transfer of both FloEFD and FloTHERM/FloVENT technologies into one product strategy and roadmap. Since 2008, ever closer EDA integrations with his product line inside Mentor Graphics, ultimately culminated in the release of FloTHERM XT last year.

Throughout Roland's 25 year CFD/CAE career he has maintained a strong vision for design-focused engineering products closely coupled with CAD. Having lived and worked in the UK, US and Germany, he built a strong family culture at Nika that still exists today.

Time with his two sons, a love of classical music and literature fills his spare time. With Roland we will have continuity of our roadmap, a strong passion for technology innovation and an acceleration of innovation inside the Mechanical Analysis Division.



Events Update
Global U2Us a Success

The Mentor Graphics Mechanical team enjoyed a busy end to 2013 with a whirlwind trip of U2Us across three continents.

Product Managers Robin Bornoff, Ian Clark, Andras Vass-Varnai, and Mike Croegaert toured North America, Japan, Germany, France, India, China, Taiwan, South Korea, and Singapore in November and December meeting Customers and showcasing new development in the Mechanical products.

"There is nothing that compares to discussing real-life challenges with our Customers. At every U2U we see a new application for our products and meet users who are pushing the boundaries of engineering simulation. This is all feedback we can use as we continue to improve products", said Mike Croegaert, who sees tremendous value in these events for both Mechanical Analysis and its Customers.

Ivo Weinhold, our User Experience Manager also conducted face-to-face user experience testing at many of the events. He questioned over 50 users across several locations to gain access to information that will help to improve the interface and user experience of upcoming releases of FloTHERM®, FloEFD™ and Flowmaster®.

Customers attending these meetings extended to some 1,600 attendees and covered a diverse range of industries including Lighting, Power Generation, Automotive, Marine, Consumer Electronics and even Meteorology. We will be showcasing some of these interesting projects in upcoming copies of Engineering Edge.

Each event featured a product update session followed by User stories from both end-users and distributors of Mechanical products. In 2014 there will be U2U events in North America, China, India, Germany, Taiwan, Japan and Korea. These again promise a full agenda of technology and user application stories. Dates and venues will be announced on our website and via our e-News bulletins.

New Flowmaster - Link for THESEUS-FE® Coupler

Mentor and P+Z Engineering have a long history of co-operation, with 2013 marking an important milestone in our relationship when P+Z became an OpenDoor development partner.

The need for a formal relationship was driven by P+Z's desire to create a new capability for its THESEUS-FE Thermal Simulation software product, specifically allowing users to co-simulate with Flowmaster. The new Flowmaster–Link is an important element of the new THESEUS-FE Coupler module of Version 4.4, as it provides users with an easy to manage solution for co-simulation between geometrically complex 3D Finite Element (FE) and CFD models, and 1D thermo-fluid system networks. The THESEUS-FE Coupler can control data communication and synchronization between two or more solvers, and it currently supports Flowmaster, OpenFOAM and another 3D CFD tool as exchange partners.

A typical automotive application for the THESEUS-FE Coupler is where vehicle cabin inlet conditions (i.e. air temperature and mass flowrate) are supplied by a Flowmaster HVAC network to a 3D CFD cabin model. Heat transfer and humidity for the solid elements within the cabin model (i.e. manikin physiology and cabin structure) are modeled by THESEUS-FE, and the resulting change in the 3D cabin CFD model is then fed back as the re-circulated air boundary conditions to the Flowmaster 1D model.

A1 Racing
Journey to a Championship

In 2009, eight teenage students from schools in Victoria, Australia, began an exciting journey that would lead them to meet F1™ boss, Bernie Ecclestone as his VIP guests at the American F1 Grand Prix as winners of the prestigious Formula 1 in Schools Program.

Figure 1. A1 Racing Team (from left to right): Dyaln Sexton, Ben Marshall, Beau Gieskiens, Luke Merideth, Sam Young, Jacqui Cunningham.

The program offers a way to learn for Science, Technology, Engineering, and Mathematics (STEM) subjects in a way that is exciting, to encourage more students into engineering careers. It requires a team of students to design, develop, manufacture, market, manage, and race a miniature Formula 1 car. The teams are judged on all these areas but most importantly, and accounting for a third of the overall score, they must race a model car that they have created down a 20 meter track at over 80K/h to a race time of just over a second.

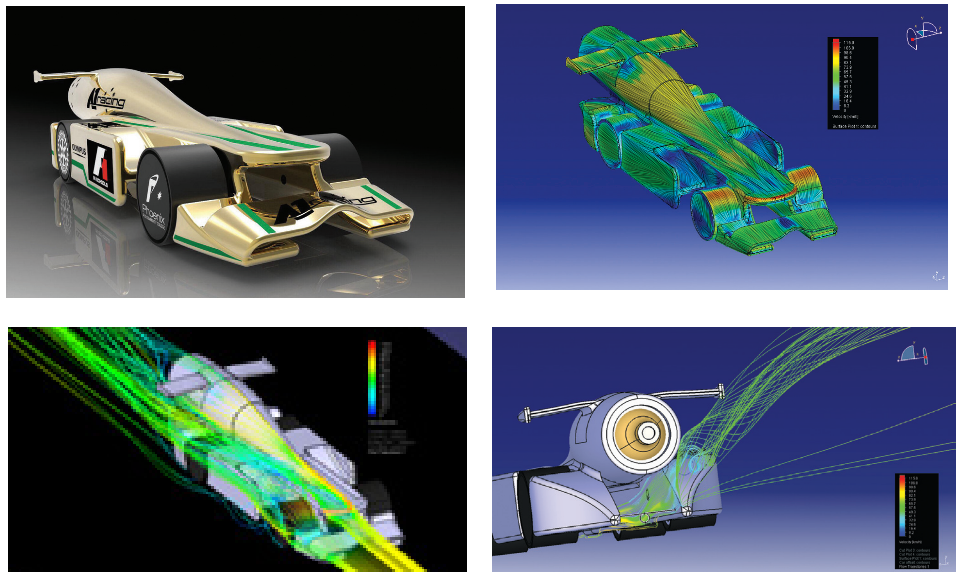


Figure 2. A rendered illustration and simulation results of the final race car design.

A1 Racing was formed from an amalgamation of two rival national runner-up teams. As high school students they had little experience in areas regarding advanced mathematics and aerodynamics and so sought professional help by contacting Mentor Graphics. Boris Marovic, Automotive Industry Manager, offered guidance and support to A1 Racing by offering tuition in Computational Fluid Dynamics (CFD) as well as running numerous diagnostics and simulations of their model in Mentor Graphics' FloEFD CFD software. Their weekly sessions ran through until the week of the World Finals, held in Texas last year and were vital to the success of the team. "These simulations were imperative to the success of our car, and the overall success of the team. Through over 500 CFD images we were able to analyze all 23 design stages of the car, ensuring each detail was optimized to peak performance on the track." said Ben Marshall, 15, A1 Racing Development Engineer.

The collaboration was an important means of giving the young students an insight into the industry, offering them valuable experience of working with engineering experts. It also taught them valuable life skills such as presentation and public speaking, which gave them a massive advantage over other students going into university and into employment. "In Texas, we were pitted against 300 students in 38 teams, from 22 countries around the world. With the CFD knowledge and help, our car was able to achieve the fastest time at the World Championship, an amazing 1.043 seconds." continued Ben Marshall.

The anxious team waited nervously during the awards ceremony at the World Finals. It was worth the wait, as they were presented not only with the award for the Fastest Car, but also with the 2013 World Championship.

The World Championship award is supported by F1 Management and the City University of London. A1 Racing was invited to the USA Grand Prix at the Circuit of the Americas, and as the World Champions were given VIP access to the Formula 1 paddock and pits where they were presented with a trophy by Bernie Eccelstone. "It was the best feeling to know that after so many years of hard work, we had achieved our dreams. What we had worked for every day and night, we had achieved. At times things were stressful, but it was all worth it. We had a trip of a lifetime. None of it would have been possible without the mentoring and support given to us by people throughout the world. We cannot thank you enough for being involved and helping a group of kids reach their dreams", Ben Marshall.

Figure 3. A1 Racing team with Bernie Eccelstone at the USA Grand Prix in Texas

New Release: FloTHERM® V10.0

The latest release of FloTHERM V10.0, announced in November 2013, is a significant user experience enhancement for longterm FloTHERM users, with several functionality and usability enhancements that continues the product line's 25 year history of technical product innovation. FloTHERM V10.0 incorporated over 40 ideas collected from Mentor Graphics' IDEAS website, where we solicit requests on software enhancements and features that Mentor customers recommended and voted on as the most popular.

This next-generation FloTHERM® product features a new native Windows graphical user interface (GUI) to handle pre-processing and large models with ease, targeting today's most advanced electronic designs. As well as the new Windows-compliant GUI, FloTHERM also features a parallel CFD solver and efficient handling of massive models for pre-processing, solving and post-processing.

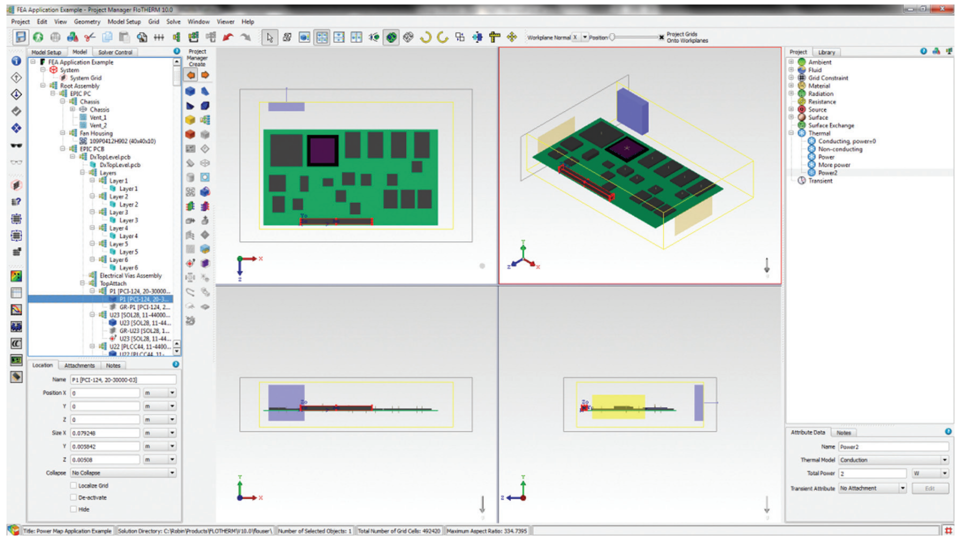


Figure 1. New FloTHERM GUI

Details of FloTHERM V10.0 product enhancements:

- The new Windows-compliant user interface can handle models with thousands of objects. A query-based search function, together with data columns integrated with the model node tree, provides critical model checking capabilities to define data, identify errors and to further enhance the FloTHERM user experience.

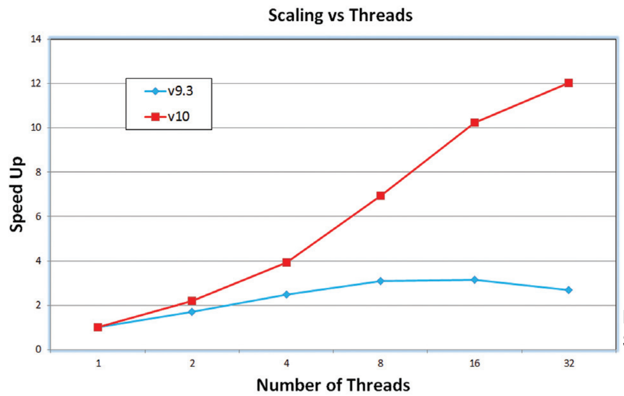


Figure 2. Typical Parallel Solver Speed-up

- A new parallel solver provides scalability and fast performance for multi-processors. This capability was the No. 1 requested functionality from the Mentor customer-feedback portal, and makes this FloTHERM release on average two to three times, and up to 14 times, faster than previous versions.

- The addition of new modeling objects to represent racks of equipment and datacenter cooling devices enables users to simulate and optimize everything from a chip to an entire room.

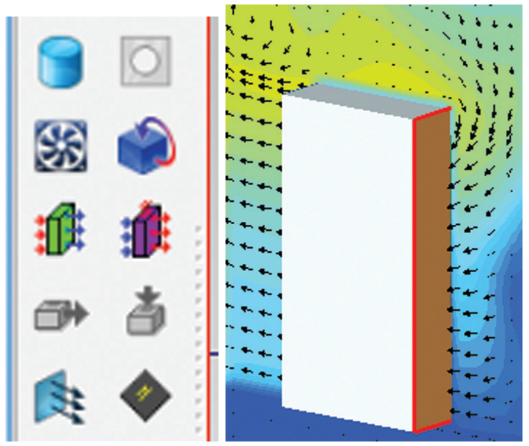
- The transient thermostatic control modeling functionality allows model inputs to be varied in time and as a function of the temperature during a transient simulation. A key benefit from this feature is the ability to reduce component power dissipation, either the component's own temperature, or those from external stimuli. Customers involved with thermostatic control systems, such as consumer electronics, computing and hand-held telephony and tablets find this new functionality helpful.

- The FloTHERM product now also supports FEA interfacing through a mesh-based parallel code coupling interface (MpCCI) bridge developed at the Fraunhofer Institute SCAI. Now engineers can export CFD analysis data for finite element analysis (FEA) with a wide range of popular structural simulation programs thereby enabling users to conduct multi-disciplinary analyses.

- The extended FloEDA Bridge offers the ability to measure x and y distances between object edges, corners, or centers. There is also the capability to move or deactivate components. Deactivated components will be retained but ignored from any subsequent solutions.

- FloTHERM V10 FloSCRIPT functionality provides an action log file recording all commands issued in Project Manager or Drawing Board. Files are saved in XML format, human readable, and are amenable to file editing and file authoring tools.
  FloSCRIPT files are easily recorded, and XML based and can be played back. Ideal for consideration for automated work flows.

"As one of the first FloTHERM users, I've always been happy with the speed of FloTHERM's solver, especially when handling large models. Nevertheless, improvements are always welcome when we talk hours of CPU time and hence, I was pleasantly surprised when I tested this new version of FloTHERM. The scale-up that has been achieved was at least a factor of four on my computer with a dual processor, reducing the solution time from six hours to one-and-a-half for a specific project requiring two million cells."
Clemens Lasance, Philips Research Emeritus



"Our market-leading FloTHERM technology was established 25 years ago and clearly demonstrates our ongoing commitment to customers by continuing to innovate and provide solutions that they need and want. By providing an intuitive Windows-based GUI and advanced features, we are delivering a dynamic solution that will increase user productivity and enable the development of innovative products. This is truly the next generation of the world's most popular electronics cooling solution."
Roland Feldhinkel, General Manager, Mentor Graphics Mechanical Analysis Division

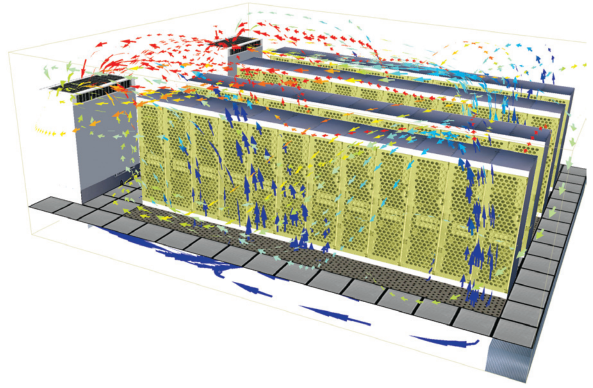


Figure 3. Extended Datacenter Applications in FloTHERM V10.0

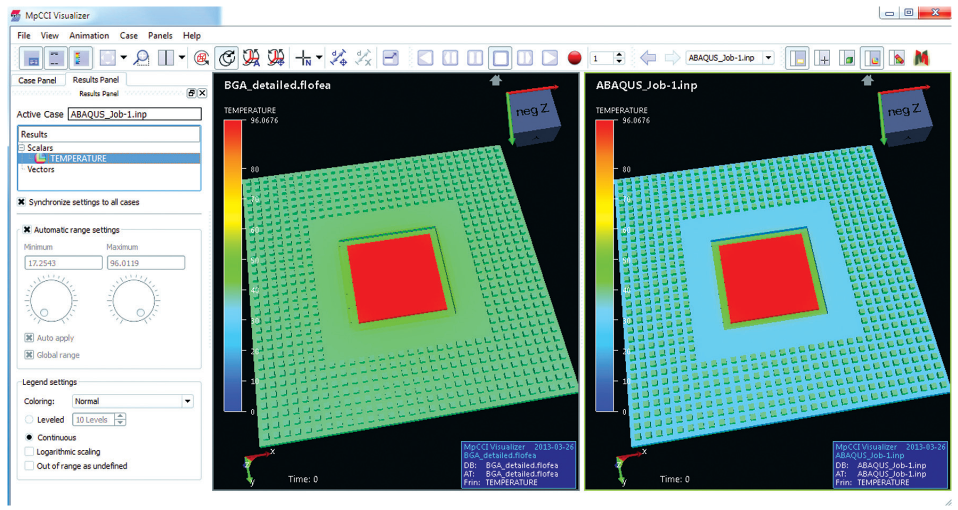


Figure 4. Typical CFD-FEA Analysis inside MpCCI

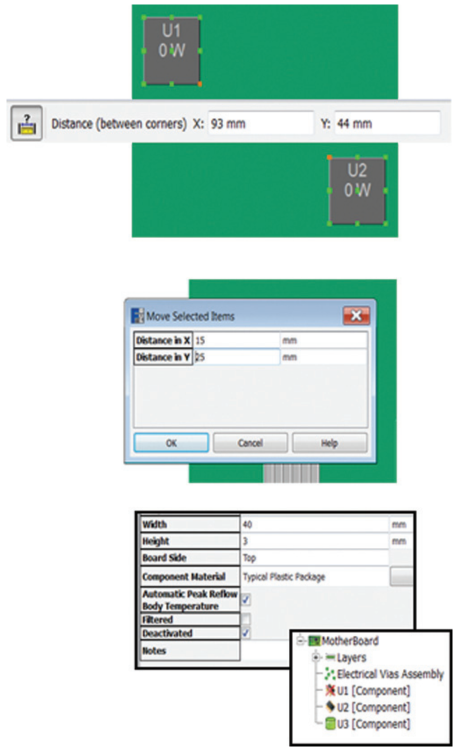


Figure 5. Extended FloEDA Bridge in FloTHERM V10.0

For more information, contact your Mentor Graphics sales associate or visit the company website at: mentor.com/products/mechanical/products/flotherm

New Release: MicReD® Industrial Power Tester 1500A

Figure 1. Mentor Graphics Launches MicReD Industrial Power Tester 1500A for Power Cycle Testing of Electronic Components

Introducing the new MicReD® Industrial Power Tester 1500A for power cycling and thermal testing of electronics components to simulate and measure lifetime performance. The MicReD Industrial Power Tester 1500A tests the reliability of power electronic components that are increasingly used in industries such as automotive and transportation including hybrid and electrical vehicles and trains, power generation and converters, and renewable energy applications such as wind turbines.

It is the only commercially available thermal testing product that combines both power cycling and thermal transient measurements with structure function analysis while providing data for real-time failure-cause diagnostics.

Power electronics components are used for applications in which electrical energy is generated, converted, or controlled and where very high reliability is required during many years of constant operation. This new product is built for industrial electronic manufacturers to test reliability by examining the thermally induced degradations within the module stack-up. Both power cycling and thermal transient measurements are conducted on the MicReD Power Tester 1500A, without needing to remove the components from the test environment. A technician or engineer is able to see the failure as it progresses and determine the exact time/cycle and cause.

Reliability is a prime concern in many industries that use high-power electronics, so accelerated testing of these modules through a lifetime of cycles is a must for the component supplier, the system supplier, and the OEM. The MicReD Power Tester 1500A can power modules through tens of thousands—potentially millions—of cycles while providing real-time failure-in-progress data for diagnostics. This significantly reduces test and lab diagnosis time and eliminates the need for post-mortem or destructive failure analysis. Common thermally-induced mechanical failures that the Power Tester 1500A analyzes in real-time include die-attach wire bond separations, die and package stack-up delamination and cracks, and solder fatigue.

"The ability to pinpoint and quantify degradation in the thermal stack for all semiconductor devices during development will greatly assist in the development of cost-optimized packaging solutions currently hampered by package-reliability concerns," said Mark Johnson, Professor of Advanced Power Conversion, Faculty of Engineering, University of Nottingham. "Mentor's Power Tester 1500A should be an invaluable tool for investigating thermal path degradation in all types of power modules."

The MicReD Power Tester 1500A is based on the Mentor Graphics® T3Ster® advanced thermal tester used in industries worldwide for accurate thermal characterization of semiconductor device packages and LEDs. The Power Tester 1500A is the first product in the MicReD Industrial line and it provides fully automated power cycling and testing (both thermal and electrical measurement) of power modules to provide comprehensive data for failure cause assessment. This enables organizations to make product improvements for reliability and extended performance. MicReD Industrial products incorporate the laboratory-level accuracy

"Mentor's Power Tester 1500A should be an invaluable tool for investigating thermal path degradation in all types of power module."

Mark Johnson, Professor of Advanced Power Conversion, Faculty of Engineering, University of Nottingham

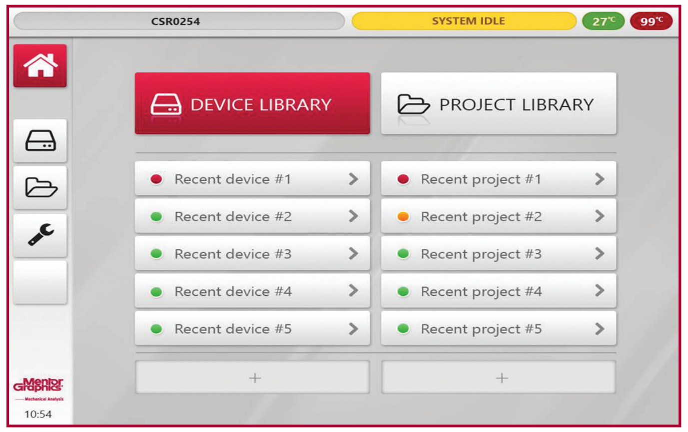


Figure 2. User-friendly touch-screen interface

Figure 3. Device creation in interface

of the T3Ster product in robust machines for operators to use inside manufacturing facilities.

"Our MicReD Power Tester 1500A serves the growing demand for power electronics components that need to perform under extreme conditions with high reliability," stated Roland Feldhinkel, General Manager of Mentor Graphics Mechanical Analysis Division. "We're leveraging our expertise in thermal characterization and testing to deliver a product for industrial applications, where we see great potential – from electric vehicles and railway systems to renewable energy products."

The MicReD Industrial Power Tester 1500A can perform power cycling tests of metal-oxide semiconductor field-effect transistors (MOSFETs), insulated-gate bipolar transistors (IGBTs) and power diodes. The MicReD Power Tester 1500A provides a user-friendly touch-screen interface and can record a broad range of information during test, such as current, voltage and die temperature sensing, and detailed structure function analysis to record changes in the package's thermal structure. This makes it an ideal platform for package development and quality checking of incoming parts before production.

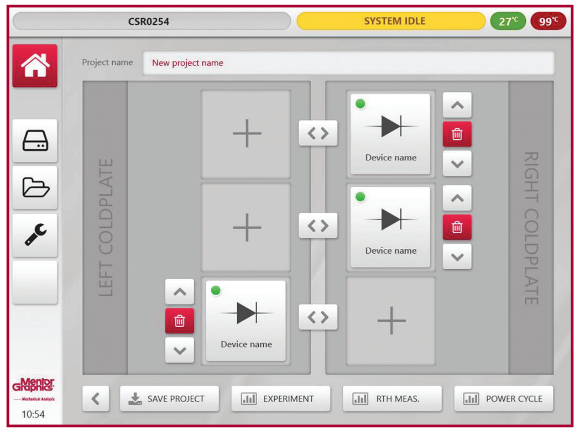


Figure 4. Placing devices on cold plate in interface

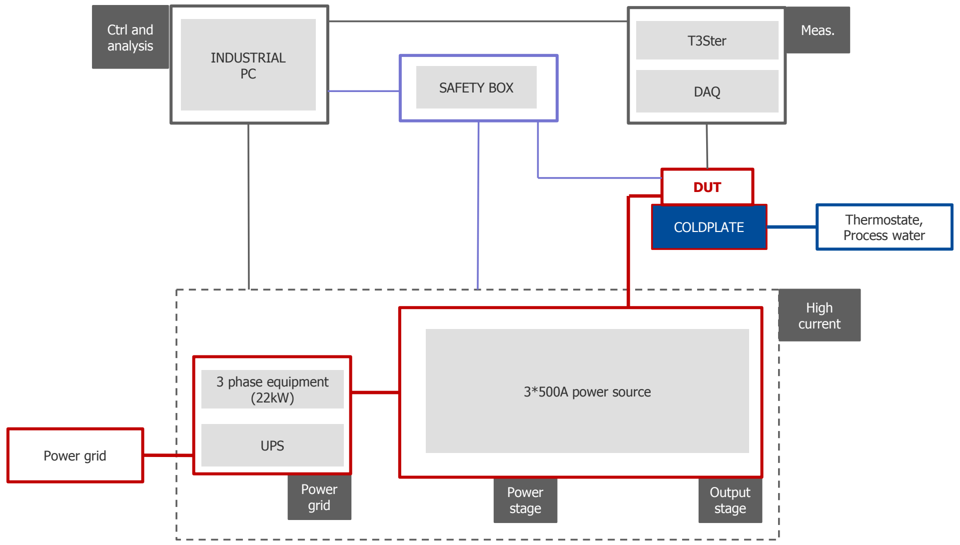


Figure 5. Power Tester Configuration

The MicReD Industrial Power Tester 1500A provides several key benefits:

- Continuous power cycling until failure, which saves time because the component doesn't need to be removed, taken for lab testing then back to tester for more cycles.
- Shortens total testing time by up to 10 times.
- Leverages MicReD's industry-proven T3Ster technology with laboratory-precision accuracy.
- Enables multiple samples to be tested concurrently.
- Different powering strategies (constant power on/off time, constant case temperature swing, and constant junction temperature rise) can be applied during operation.
- Provides "real-time" structure function diagnostics to show failure in progress, number of cycles, and failure cause.
- Eliminates the need for lab post-mortem (x-ray, ultrasonic, visual) or destructive failure analysis.
- Features touch-screen setup and controls enabling use by both specialists and production personnel.

For more information visit: mentor.com/powertester-1500a

Influence of Power Cycling Strategy on IGBT Lifetime - A Case Study

By John Parry, Industry Manager, Mentor Graphics

Vendors are working hard to increase the maximum power level and current load capability of IGBT and other power devices, while still maintaining high quality and reliability. Innovation has brought new technologies such as ceramic substrates with improved thermal conductivity, ribbon bonding to replace thick bond wires, and solderless die-attach technologies to enhance the cycling capability of the modules.

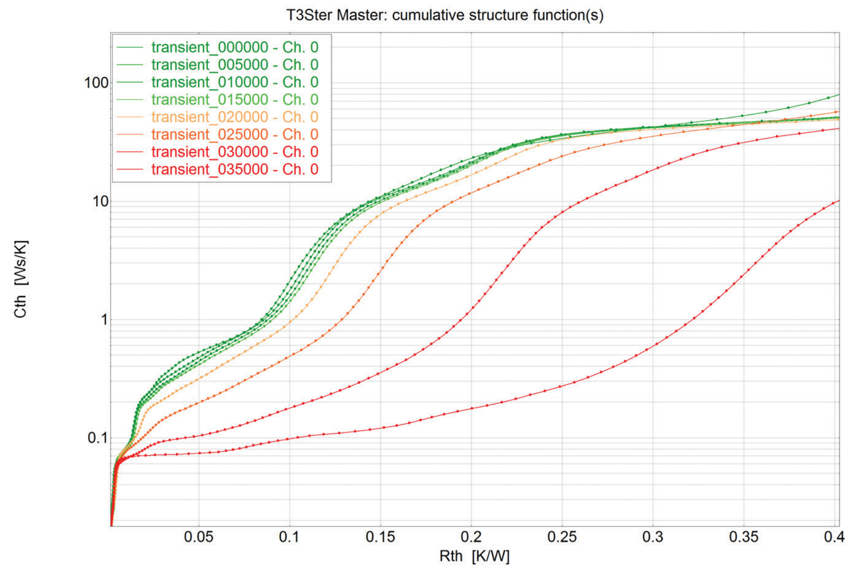


Figure 1. Structure functions of Sample 0 corresponding to control measurements at various time points

Power modules are also being designed and manufactured by end-users because the chips, the required direct bond copper (DBC) substrate, and a variety of different die-attach materials are all available on the open market. This offers increased flexibility in terms of mechanical design, however it raises severe thermal and reliability challenges as their end use is typically where high reliability is critical such as hybrid and electric vehicles. High junction temperatures and high temperature gradients during operation induce mechanical stress especially at contacting surfaces between materials with different coefficient of thermal expansion, which may lead to the degradation or the complete failure of these components. To avoid premature failures, proper thermal design and material selection is necessary.

Mentor's Power Tester 1500A is designed to automate the process of qualifying the reliability of parts to make a good estimate for the power module's lifetime during service, and to identify weaknesses that can be removed during development thereby increasing reliability and lifetime. This case study details the application of the Power Tester with four medium power IGBT modules containing two half bridges, demonstrating the rich data obtained from automated power cycling of the components. This article is abstracted from the two technical papers given in the references. [1,2]

The modules were fixed to the liquid cooled cold plate integrated into the Power Tester with a high-conductivity thermal pad to minimize the interfacial thermal resistance. The coldplate temperature was maintained at 25°C throughout the whole experiment using a refrigerated circulator controlled by the Power Tester. The gates of the devices were connected to their drains (the so-called magnified diode setup) with each half bridge powered using a separate driver circuit. Two current sources were connected to each half bridge. A high-current source that can be switched on and off very fast was used to apply stepwise power changes to the devices. A low current source provided continuous biasing of the IGBT allowing the device temperature to be measured when heating, connecting it to a separate measurement channel of the Power Tester.

An initial set of tests on four samples was conducted using constant heating and cooling times. Heating and cooling times were selected to give an initial temperature swing of 100°C, for a power of ~200W with 3s heating and 10s cooling. This most closely mimics the application environment, where degradation of the thermal structure results in a higher junction temperature leading to accelerated aging. Of the four devices, Sample 3 failed shortly after 10,000 cycles, significantly earlier than the others. Samples 0, 1 and 2 lasted longer, failing after 40,660, 41,476 and 43,489 power cycles respectively. Figure 1 illustrates the structure functions generated from the thermal transients measured on Sample 0 after every 5,000 cycles. The flat region at 0.08 Ws/K corresponds to the die-attach. It can be seen that the structure is stable until 15,000 cycles, but after that point

"Across all semiconductor devices the ability to pinpoint and quantify degradation in the thermal stack during development will greatly assist the development of cost-optimized packaging solutions that are currently hampered by package reliability concerns."

Mark Johnson, Professor of Advanced Power Conversion, Faculty of Engineering, University of Nottingham

the degradation of the die-attach can be clearly noticed as its resistance increases continuously until the device fails. Again, the immediate cause of the device failure is unknown, but we found that a short circuit is formed between the gate and the emitter and burnt spots could be seen on the chip surface.

A second set of tests were performed on an identical set of samples using the different powering strategies supported by the Power Tester. In this case we kept the current constant for IGBT1, the heating power constant for IGBT2, and the junction temperature change constant for IGBT3. To ensure a fair comparison, the settings were chosen to give the same initial junction temperature rise for all components, with 3s heating and 17s cooling, and ~240W initial heating per device chosen for the test. The whole heating and cooling transient is measured for each device in all cycles, with the following electrical and thermal parameters monitored continuously by the Power Tester:

- Device voltage with heating current turned on, V_{on}
- Heating current applied in the last cycle, I_{Cycle}
- Power step, P
- Device voltage after heating current turned off, V_{hot}
- Device voltage before heating current turned on, V_{cold}
- Highest junction temperature during the last power cycle, T_{hot}
- Lowest junction temperature during the last power cycle, T_{cold}
- Temperature swing in the last cycle, ΔT
- Temperature change normalized by the heating power, ΔT/P

Additionally, the full length thermal transient from powered on steady state to powered off steady state was measured after 250 cycles using a 10A heating current, to create structure functions to investigate any degradation in the thermal stack. Again, the experiment was continued until the failure of all IGBTs.

As expected, IGBT1 failed first, as there is no regulation of the supplied power as the part degrades. Interestingly, it showed

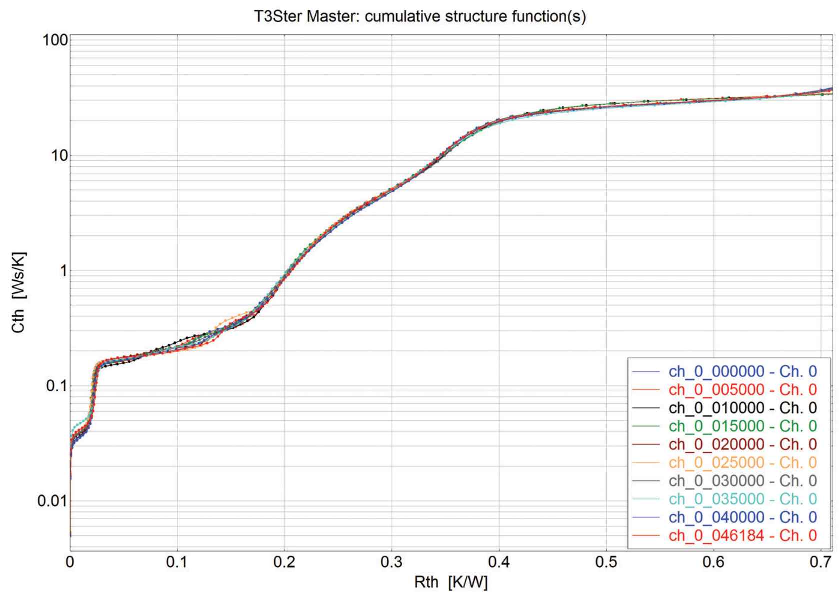


Figure 2. Change of the structure function of IGBT1 during the power cycling

no degradation in the thermal structure as shown in Figure 2.

In order to find the cause of the device failure we have to examine evolution of device voltage during the experiment. In Figure 3 the forward voltage of IGBT1 at heating current level can be seen as function of elapsed power cycles. In the first three thousand cycles a decreasing tendency can be seen.

This initial change caused by the slow change of the average device temperature that decreased by almost 5°C. Despite the negative temperature dependence of the device voltage at low currents, at high current levels the temperature dependence of the forward voltage become positive. After about 35,000 cycles this tendency changed and the voltage started to increase slowly. This was followed by stepwise changes in the device voltage while the increasing tendency continuously accelerated until the failure of the device. As the structure did not change the increasing

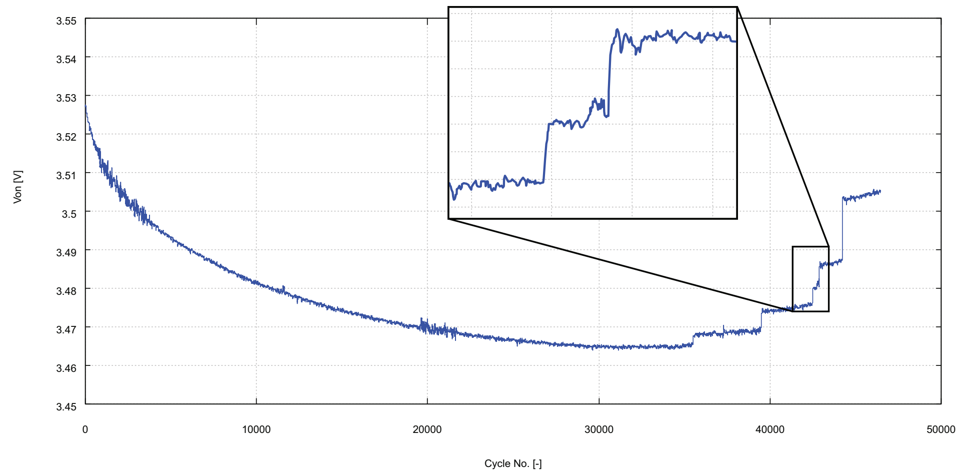


Figure 3. Forward voltage of IGBT1 at heating current level as function of applied power cycles

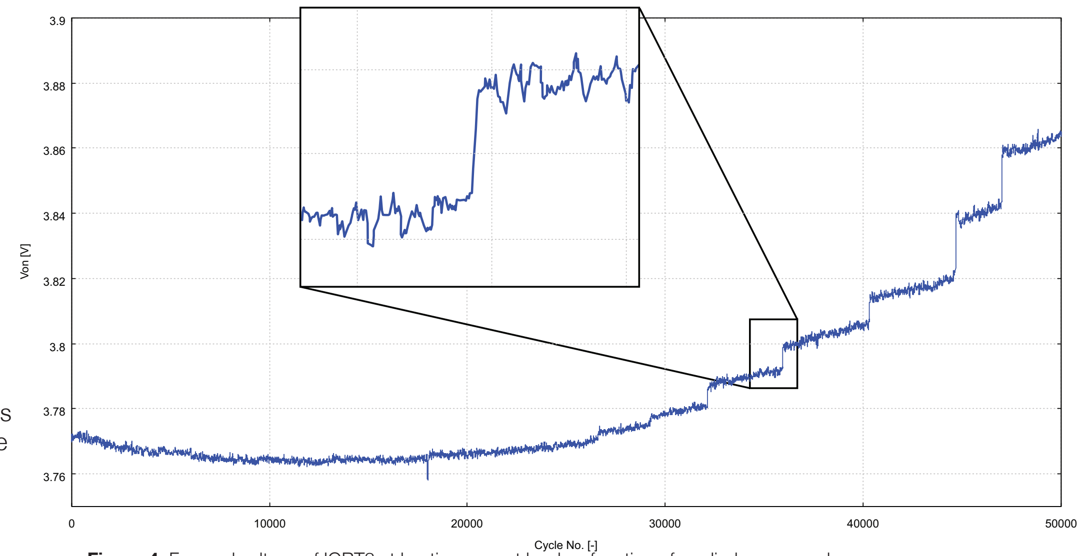


Figure 4. Forward voltage of IGBT3 at heating current level as function of applied power cycles

voltage can be attributed to the degradation of the bond wires. This also gives an interpretation to the stepwise changes of the voltage when a bond wire finally detaches.

The increasing heights of these steps are caused by the increasing change in the parallel resistance sum of the bond wire thermal resistance as the number of bond wires decreases. If we use constant current strategy, the crack of a bond wire increases the current density in the remaining bonds and accelerates aging.

Figure 4 shows the same type of curve corresponding to IGBT3. Here the increasing tendency of the device voltage starts even earlier but due to the regulation to keep the junction temperature constant, the heating current was proportionally decreased. The decrease in current reduced the load on the bonds and increased the measured lifetime.

To conclude, the two sets of experiments were conducted which showed different failure modes, illustrating how different powering strategies, and possibly electrical setup, can influence failure mode. The first set of measurements at a constant cycle time, that most closely reflects operational use, verified that the Power Tester is able to detect immediately the appearance of degradation within the device's structure, including the die-attach and other compromised layers.

The second experiment clearly identified degradation of the bond wires as the forward voltage of the device was observed to increase stepwise. While with these powering options, (current constant, constant heating power, and constant temperature rise), the thermal structure did not change for any of the samples tested. Due to the low number of samples we have to be conservative in formulating conclusions. However the results warns us that the measurement results can differ depending on the cycling strategy, and lifetime predictions based on certain strategies can overestimate the real lifetime of power devices.

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[2]. Zoltan Sarkany, Andras Vass-Varnai, Sandor Laky, Marta Rencz (2014) Thermal Transient Analysis of Semiconductor Device Degradation in Power Cycling Reliability Tests with Variable Control Strategies, Proceedings of SEMI-THERM 30, pp. 236-241, San Jose CA.

Thermal Efficiency: Facebook's Datacenter Server Design

By John Parry, Industry Manager, Mentor Graphics

Large-scale datacenters consume megawatts in power and cost hundreds of millions of dollars to equip. Reducing the energy and cost footprint of servers can therefore have substantial impact.

Web, Grid, and Cloud Servers in particular can be hard to optimize, since they are expected to operate under a wide range of workloads. For its first datacenter in Prineville, Oregon, Facebook set out to significantly improve its power efficiency, cost, reliability, serviceability, and environmental footprint. To this end, many dimensions of the datacenter and servers were redesigned, using a holistic approach. This article is abstracted from the Facebook paper "High-efficiency Server Design," which was presented at the 2011 ACM Conference on Supercomputing, and focuses on this server design, combining aspects of power, motherboard, thermal, and mechanical design. In this article we have looked at the thermal aspects in isolation. In the full paper, Facebook calculated and confirmed experimentally that its custom-designed servers can reduce power consumption across the entire load spectrum while at the same time lower acquisition and maintenance costs. The design does not reduce the servers' performance or portability, which would otherwise limit its applicability. Importantly, the server design has been made available to the open source community via the Open Compute Project, a rapidly growing community of engineers around the world whose mission is to design and enable the delivery of the most efficient server, storage and datacenter hardware designs for scalable computing.In the past decade, we have witnessed a fundamental change in personal computing. Many of the modern computer uses such as networking and communicating; searching; creating and consuming media; shopping; and gaming—increasingly rely on remote servers for their execution.

The computation and storage burdens of these applications has largely shifted from personal computers to the datacenters of service providers such as Amazon, Facebook, Google, and Microsoft. These providers can thus offer higher-quality and larger-scale services, such as the ability to search virtually the entire internet in a fraction of a second. It also lets providers benefit from the economies of scale and increase the efficiency of their services.

As one of these service providers, Facebook leased datacenters and filled them with commodity servers. This choice made sense at small to medium scale, while the relative energy cost is still small and the relative cost of customization outweighs the potential benefits. As the Facebook site grew to become one of the world's largest, with a corresponding growth in computational requirements, they started exploring alternative, more efficient designs for both servers and datacenters.

Thermal Design

The goal of server thermal design is to cool down the hot components to their operating temperatures with a minimal expenditure of energy and component cost. The typical mechanism used to cool servers at the datacenter level is to cool air at large scale and push it through the servers using their internal fans. The cool air picks up heat from the server components, exits from the server outlet, and is then pushed back to the atmosphere or chilled and recirculated.

More efficient cooling is achieved with air containment in aisles, with the front (or inlet), side of the server facing the "cold aisle" and the back facing the "hot aisle." Yet another technique to improve cooling efficiency is to create an air-pressure differential between the aisles using large datacenter fans. In this case the specific design goal was to be able to cool the upcoming datacenter without chilling the outside air almost year round by allowing effective server cooling even with relatively high inlet air temperature and humidity. To achieve this goal, a more effective design was needed for heat transfer than currently used in the commodity servers.

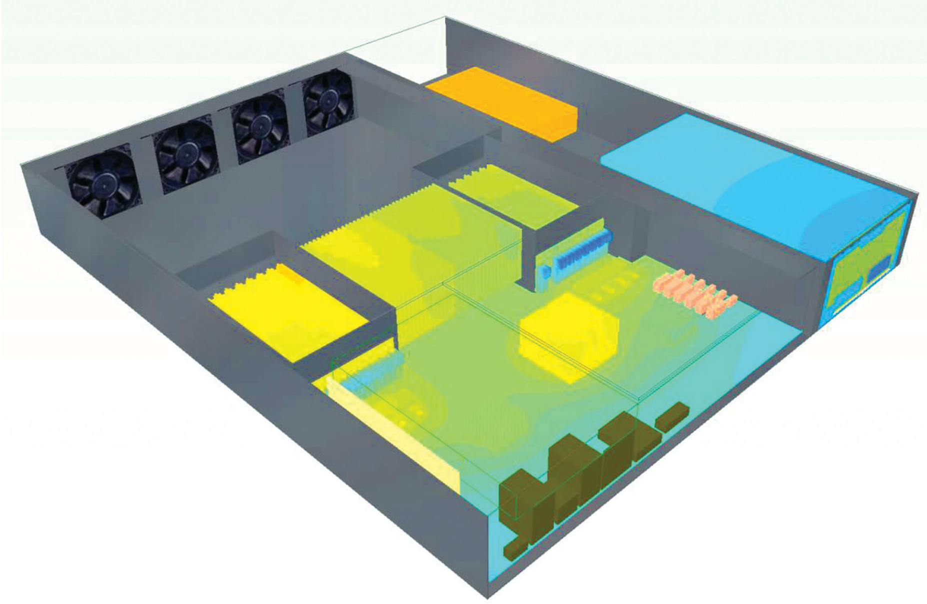


Figure 1. FloTHERM isometric view of thermal design shows chassis, motherboard (with dual processors and memory slots side-by-side), fans, and the hard-disk drive (HDD) behind the PSU. The temperature range here assumes an inlet temperature of 27°C. The air duct on top is elided for visualization purposes.

Improving airflow through the server is a key element here: when internal server components impede airflow, more cooling energy is expended (for example, by faster fans, cooler inlet air, or higher air pressure). One technique by which improved airflow is achieved in the chassis is to widen the motherboard and spread the hot components side by side, not behind each other. The hottest components—processors and memory—were moved to receive the coldest air first, by locating them closer to the air inlet than in the typical back-mounted motherboard.

Another modified dimension was the server height: given a relatively constant rack height (for servicing purposes), a taller server reduces cooling energy but also the rack's computational density. Calculations found that the optimal server height to maximize the compute-capacity per cooling-energy ratio to be the uncommon 1.5U height with large-surface-area heat sinks. This height also allows for an air duct that sits on top of the motherboard and "surgically" directs airflow to the thermal components in parallel heat tracks, reducing leaks and air recirculation inside the chassis. Obstructions to airflow are kept to a minimum, decreasing the number of fans required to push the air out (Figure 1).

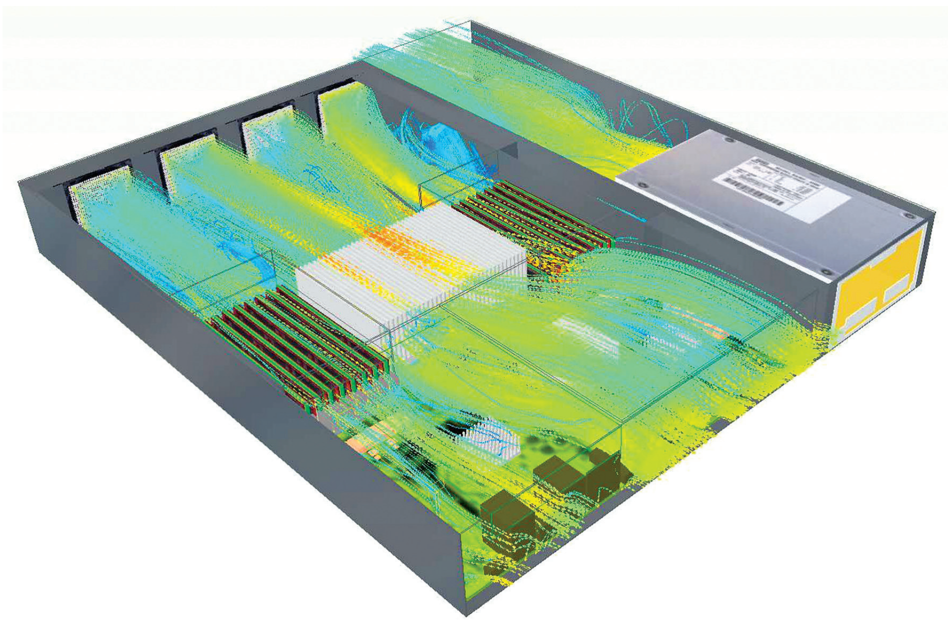


Figure 2. FloTHERM CFD simulation of airflow speed at minimum continuous fan speed

And since the high-efficiency PSU generates less than 20W of waste heat under load, the HDD remains well within specified temperature operating range even behind the PSU. Contrast this with typical server designs that locate the HDD in the front of the chassis to meet its cooling requirements. Also reduced is the amount of airflow required through the system to keep it cool—up to half the volume flowrate compared to standard 1U servers, for the same inlet to-outlet temperature difference (Figure 2).

This low requirement, combined with smart fan-speed controllers, results in fans that spin at their minimum continuous speed nearly year-round, depending on ambient temperature and workload.

An additional advantage of this low speed, continuous operation is a longer expected fan lifetime compared to the typical fan's start-stop cycles, leading to overall improved server reliability. It also naturally translates to lower power and operating costs for server cooling—approximately 1% of the total server power—compared to the more typical 10% in commodity servers. Somewhat surprisingly, even the CAPEX of the server's cooling components alone is about 40~60% lower than a typical server, depending on OEM component pricing. The two main reasons for this improvement are the use of thinner fans (owing to the reduced airflow) and simpler heatsinks without a heat pipe (owing to the larger surface area). Closing the cycle, these efficiency gains carry forward to the datacenter level as well. The server is capable of working reliably at air inlet temperatures of 35°C and a relative humidity of 90%, exceeding the most liberal ASHRAE recommendations for datacenter equipment. In practice, this allows Facebook's datacenter to be cooled almost exclusively on free (outside) air, relying on infrequent evaporative cooling instead of chillers only on particularly hot days.

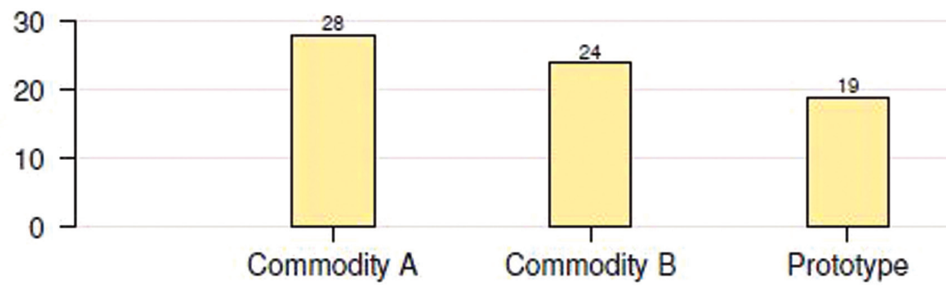


Figure 3. Airflow comparison (in CFM) at 200W

Methodology

Facebook have evaluated the power, thermal and performance properties of a prototype of the new design against two commodity servers. Both commodity servers are a common off-the-shelf product from two major OEMs, with dual Xeon X5650 processors, 12GB DDR3 ECC memory, on-board Gigabit Ethernet, and a single 250G SATA HDD in a 1U standard configuration. The first server, "Commodity A," is widely deployed in the leased datacenters for Facebook's main Web application. The second server, "Commodity B," is a three-year-old model that was updated to accept the latest generation processors. To ensure a fair comparison, the exact same CPUs, DIMMs, and HDD unit are used in turn, moving them from server to server. The only differing components between the three servers were therefore the chassis, motherboard, fans, power supply, and power source (208V ac/277V ac).

Thermal Efficiency

Thermal efficiency is another important element of the total cost of ownership (TCO), both in terms of cooling energy in the server (fan energy) and in the datacenter. The thermal design is based on a spread and unpopulated board placed in a 1.5U pitch open chassis, and employs four high-efficiency custom 60 × 25mm axial fans. In contrast, the commodity servers use a thermally shadowed, densely populated 1U chassis with six off-the-shelf 40×25mm fans. To evaluate the thermal efficiency, each server was placed in a specially-built airflow chamber that can isolate and measure the airflow through the server, expressed in cubic-feet per-minute (CFM). The measured CFM value was also confirmed analytically by measuring the server's AC power and air temperature difference between inlet and outlet. The servers are loaded with an artificial load resembling Facebook's production power load (around 200W, with leakage power at less than 10W), while maintaining the constraint that all components remain within their operating thermal specifications. The results for the prototype (Figure 3) show a significant improvement. For a typical 7.5MW datacenter, this reduced airflow translates to a reduction of approximately 8~12% of the cooling OPEX. More importantly, it enables free air cooling to be used for the datacenter.

Conclusions

This new server design measurably reduces TCO without reducing performance. The customized server design can:

1. Reduce operating and cooling power (e.g. efficient power conversions, higher-quality power characteristics, fewer components, thinner and slower fans, improved airflow).
2. Lower the acquisition cost and server weight (e.g. fewer and simpler components, lower density, fewer expansion options).
3. Cut costs on supporting infrastructure (e.g. no centralized UPS, no PDUs, no chillers).
4. Increase overall reliability (e.g. fewer and simpler components, distributed and redundant batteries, smooth normal / backup transitions, staggered HDD startup, slower fans).
5. Improve serviceability (e.g. all-front service access, simple cable management, no extraneous plastics or covers).

At large scale, this design translates to substantial savings. Facebook calculate that over a three year period, these servers alone will deliver at least 19% more throughput, cost approximately 10% less, and use several tons less raw materials to build than a comparable datacenter of the same power budget, populated with commodity servers. When matched with a corresponding datacenter design (including all aspects of cooling, power distribution, backup power, and rack design), the power savings grow to 38% and the cost savings to 24%, with a corresponding power usage effectiveness (PUE) of ≈ 1.07.

Reference:

[1]. Eitan Frachtenberg, Ali Heydari, Harry Li, Amir Michael, Jacob Na, Avery Nisbet, Pierluigi Sarti, Facebook. High-Efficiency Server Design, 2011

Your IDEAS to meet Your Needs…

Mentor Graphics is committed to improving product user experience. Naturally, listening to user feedback is a vital part of this, so we really value your ideas for new product features and enhancements. With this in mind, Mentor IDEAS provides users with the ability to provide direct feedback for all Mechanical Analysis products, allowing you to post your suggestions for product improvements, and vote on other users' suggestions: mentor.brightidea.com/mechanical

The suggestions with the most votes are those that our engineering and development teams will look at first. While it may not be practical to implement every top vote-getter, it will help us to understand your priorities. Understandably most people want this to be a two-way process so we do provide feedback on your top suggestions at the "BLOG HOME" link.

Some users may think that categorizing the suggestions on Mentor IDEAS is an art, so we'd like to reassure you that there is science behind the statuses.

So here is what you can expect from Mentor Graphics on responding to top ideas:

RECEIVED: This is the initial status of any idea. Once the idea garners enough votes (the number of votes may vary from product to product), a Product Manager will review the idea for inclusion into an upcoming release.

ARCHIVE: This status is used for housekeeping on the Mentor IDEAS site. It is important that ideas with few votes are periodically removed so ideas remain current and the site does not become too cumbersome to navigate.

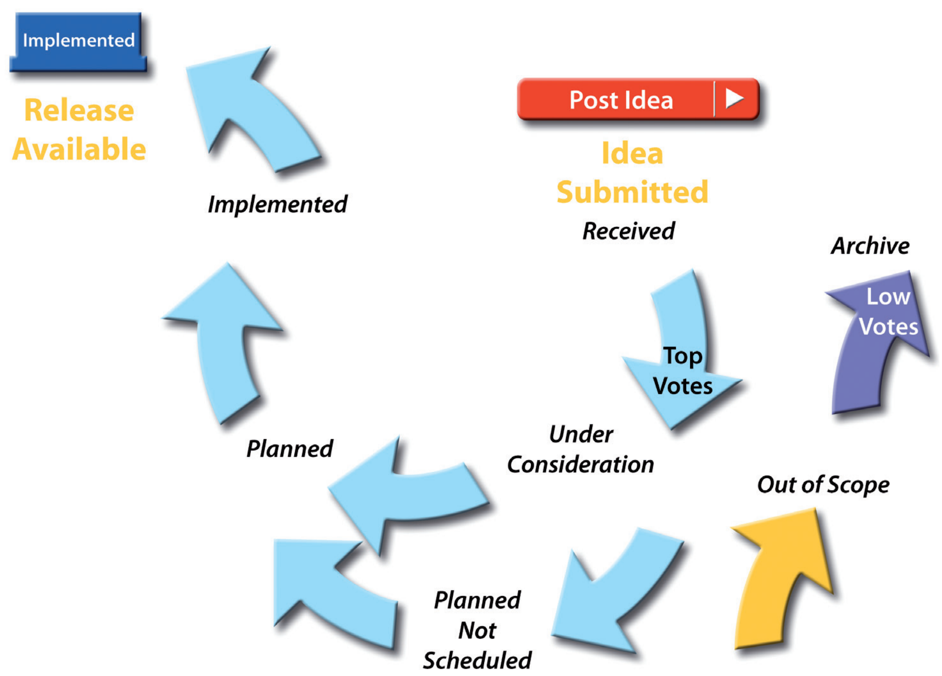
OUT OF SCOPE: The idea may have reached a vote threshold, however it is outside the product roadmap.

UNDER CONSIDERATION: The idea has reached a vote threshold and is being evaluated for inclusion in the product release.

PLANNED NOT SCHEDULED: This is a new status to indicate that the idea is in the product's longer term planning, but not yet committed to a release. These will be reviewed during the normal planning cycle for future release assignment.

PLANNED : The idea is scheduled into an upcoming release and the planned release is added as a tag to the idea.

IMPLEMENTED: The idea is currently available in a release and the tag indicates the release name. The release is available on SupportNet for download.
Finally, we should point out that Mentor IDEAS is not a replacement for technical support or SupportNet which can be accessed through http://supportnet.mentor.com. We look forward to hearing your ideas!



Bromley Post-Sochi Update: You don't learn if you're standing still

By John Murray, Industry Manager, Mentor Graphics

For athletes, there are few comparable stages to the Olympics in terms of either prestige or exposure. Like the Football (Soccer) World Cup or Wimbledon, it is a spectacle that draws in a wide audience, one that may not engage with any of the events in question at any other time. For those at the sharp end of the competition, the pressure to deliver upon years of preparation is therefore immense.

Having participated at Sochi 2014 as both athlete and supplier to many of the other teams in the Skeleton, Kristan Bromley understands the nature of this pressure all too well. Post-Sochi, what are the main lessons learnt? "What we do works", says Kristan "There were consistent indications that our sleds are performing as we needed them to". These indications – hard numbers from reams of split time data – allow the team at Bromley Technologies to unpick how their sleds are performing independently of the idiosyncrasies of each individual rider.

That the approach worked wasn't a surprise, the methodical approach taken by Bromley in designing and manufacturing their sleds not only required that they employed cutting edge tools, it also necessitated that the approach itself be consistently scrutinised and questioned. They weren't just learning, they were learning about learning as they went along.

Figure 1. Bromley Sports at Whistler Blackcomb, Canada

Such an approach is essential in an environment where performance is under constant and merciless scrutiny. "Skeleton is a small community, meaning that underperforming equipment is not only discovered quickly, it's rapidly communicated through the ranks."

Figure 3. Bromley Baseboard™

Little wonder that Kristan regards knowledge as one of Bromley Technologies key assets. However, without action, knowledge is not only academic but quickly reaches its sell by date. In order to harness and refresh it, Bromley integrate advanced tools and methods throughout the design and manufacture process. Laser metrology of athletes is used in conjunction with FloEFD in order to produce simulations upon which design decisions can confidently be drawn.

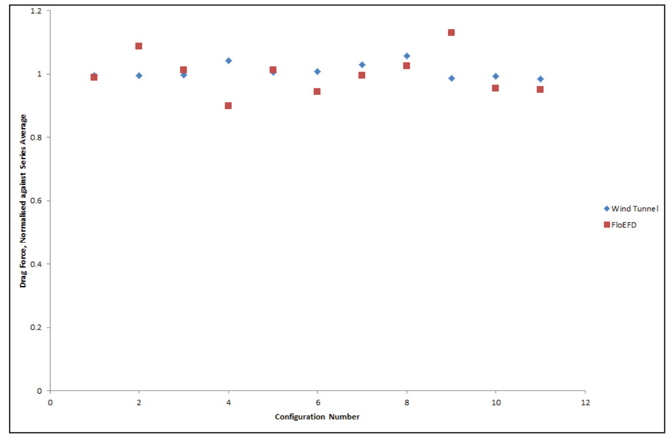


Figure 2. Windtunnel results vs. FloEFD simulation data

Engineering and competitive experience is systematically and continuously captured in the design process. Ultimately, this will be harnessed in the sleds that will compete in PyeongChang in 2018.

"FloEFD is an essential part of the process. It's not just the accuracy – we know from wind tunnel testing that the results are accurate – it's the ability to turn out these results quickly on my laptop. This gives me the freedom to virtually tweak and revise designs throughout the design and testing phase." (Figure 2)

So much for those at the cutting edge of sliding sports; what about us mere mortals who are never likely to go near an Olympic track?

The answer is the Baseboard (Figure 3). Launched at the Whistler resort in Canada last year with over 1,000 people trialling it in six days, it returns to the World Ski and Snowboard Festival this year with its own dedicated track.

Serving such diverse markets effectively is only possible because of this knowledge based ethos in combination with tools that can add value to the design process. Distilling the data from testing, simulation and design down to core concepts means that Bromley Technologies can hit very different design requirements without compromising on either.
For more information visit: bromleysports.com

Model Based System Engineering at the Aeronautical Development Agency

By V Krishna Prasad, Deputy Project Director, General Systems

Designing modern aircraft under stringent regulations for the military is a challenge the ADA in India face head-on with Flowmaster™

Figure 1. Squadron of Light Combat Aircraft LCA) Tejas Series

The design of modern aircraft remains an extremely challenging undertaking. A combination of stringent and often conflicting requirements, expensive equipment with long lead times and highly co-dependent and integrated systems present engineers with problems of almost unimaginable complexity. Consider, for example, how a change to the design of the fuel system has implications for the flight dynamics of the aircraft; its structure; hydraulic systems and potentially even cooling and avionics.

These constraints are felt all the more keenly for those designing modern combat aircraft. Not only are the packaging requirements more stringent, both the range of operating conditions and the rate at which they are covered during operations is much more extreme.

The Aeronautical Development Agency (ADA) of India was established in 1984 to wrestle with such challenges during development of the Light Combat Aircraft (LCA), an extremely ambitious project aimed at producing an indigenously designed and built aircraft.

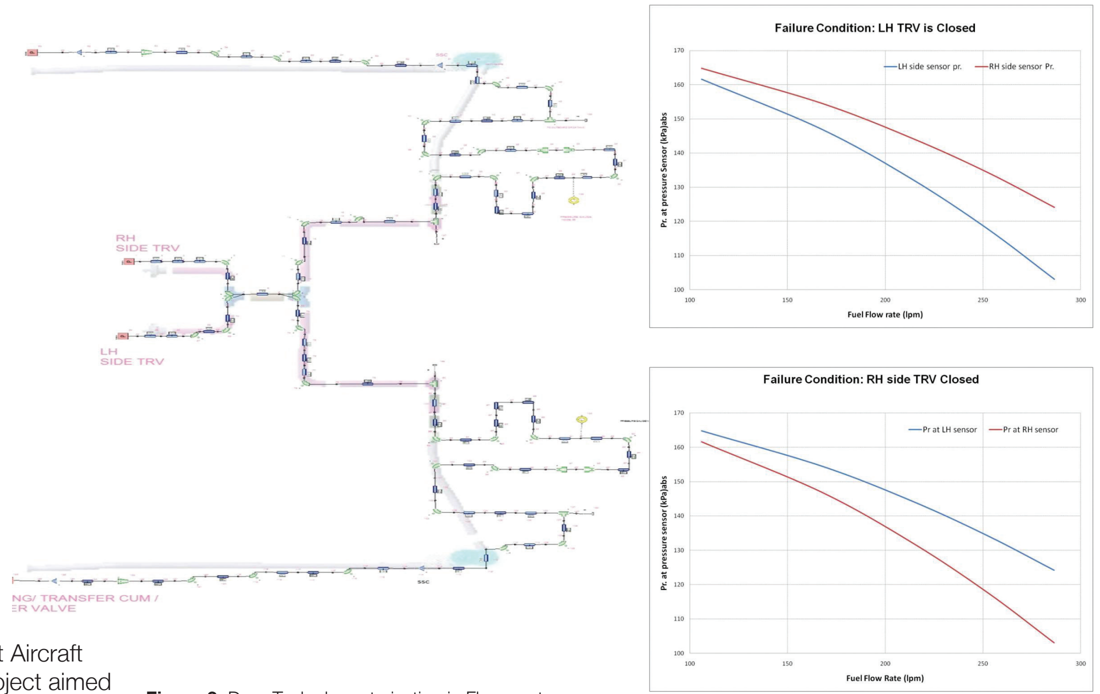


Figure 3. Drop Tank characterization in Flowmaster

The task before the fuel systems group was a daunting one: while the most obvious requirement is to ensure reliable fuel feed to the engine, this must be met while ensuring that the stability of the aircraft isn't compromised as tanks begin to empty. Meaning that the fuel tank pressurization and venting lines must be adequately sized and routed and the dynamic response of the system is well understood across a range of challenging mission profiles.
In order to meet these challenges, Mentor's Flowmaster® 1D CFD software was brought in by ADA as a complementary tool to existing theoretical and physical test procedures. Flowmaster allowed the group to achieve more accurate predictions of system performance at all stages of the design loop. This increase in accuracy translates to less uncertainty and consequently the ability to finalize on an appropriate configuration sooner. As a consequence, the overall design cycle can be significantly shortened.

Figure 2. Tejas cockpit

However, while significant, the benefits of using system simulation extended further than allowing the group to accomplish the same tasks to a higher degree of fidelity. A key benefit offered by Flowmaster was the ability to interrogate the virtual system in regions not easily accessible by instrumentation in physical prototypes. This ability streamlines the trouble-shooting of the snags that inevitably arise during the design of such complex systems. This in turn further reduces the physical test burden.

These high level benefits are the result of incremental improvements at each stage of the design process. For example, an accurate characterization of the drop tank circuit enables you to arrive at the pressure range of the Pressure Transducer intended to be used for monitoring the health of the drop tank fuel transfer system. This allows component specification to begin, not only for the Pressure Transducer itself, but a range of up and downstream system components.

Perhaps not as obvious, but equally significant, is the fact that the impact of any mid-design changes can be readily assessed and accounted for. Where any work must be revisited, options can be explored and assessed quickly and with confidence.

Fourteen squadrons of the LCA, now in production as the 'Tejas' ('radiance'), will ultimately enter service with the Indian Air Force (IAF), while a further 40-50 aircraft will enter service with the Navy as part of their carrier based air arm. Such a commitment underlines the capabilities of the Tejas and indicates that the design will continue to evolve as operational demands change. Flowmaster will continue to play a role throughout this evolution at ADA.

Driving Flanders to Electric Powertrain Innovation

Voxdale BVBA and Flanders' DRIVE delivering on the demand for innovation in the Automotive Industry.

By Koen Beyers, Voxdale BVBA, Belgium

Figure 1. Range Rover Evoque at Flanders' DRIVE media day with proposed driveline, April 2013

The not-for-profit organisation, Flanders' DRIVE, was set up in 1996 as an automotive industry initiative by an assortment of companies in Belgium to cope with the increasing demand for innovation in the sector. Activities started in 2001 with the support of the local Flemish Government and by 2004 the building and infrastructure of Flanders' DRIVE in Lommel, Belgium, came into operation.

At first, Flanders' DRIVE focused solely on product innovation. Since 2005 however, it expanded its focus to include process innovation for production and assembly companies as well. Over the past few years, Flanders' DRIVE has developed into a research center for the Belgian vehicle industry, which supports the sector with a hands-on approach and a permanent and flexible focus on the actual needs of the sector. For this, Flanders' DRIVE has a team of 45 employees and state-of-the-art infrastructure available for innovation support and application-oriented research together with and for the Belgium automotive industry. It now has over 170 Partners including Volvo, Tyco, Toyota, Bombardier, Alcatel-Lucent, Continental, DAT Trucks, Ford, IVECO, Johnson Controls, Siemens, NXP, and TI Group to name a few.

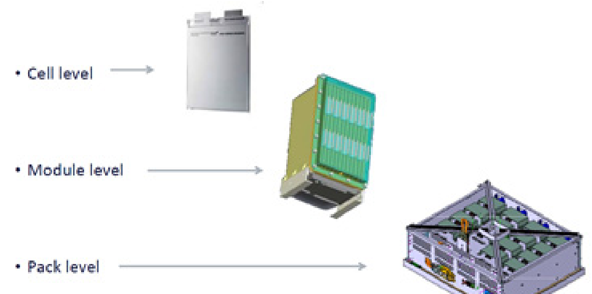


Figure 2. EV Battery Pack component levels

Flanders' DRIVE has in its aims targets for technological solutions in the fields of Advanced Manufacturing Processes, Clean & Energy Efficient Vehicles, Lightweight Solutions, Intelligent Driver and Traffic Systems and Intelligent Development Tools. In the years ahead, Flanders' DRIVE wants to play a leading part in the transformation of the vehicle industry towards a green and smart mobility industry. This will be done through focused development of strategic competences and knowledge diffusion, creation of an increase in scale through strategic and application-driven cooperation with other research centers, and further integration in European clusters and participation in international projects. Recently, Flanders' DRIVE through an "Electric Powertrain" project (with 12 partners*) wanted to prove an innovative conceptual EV drive train on a typical Range Rover Evoque car.

The project involved:

1. Developing further knowledge on state of the art battery systems (Lithium titanate oxide anode)
2. Designing, developing and integrating a full functional innovative battery pack
3. Special attention for energy management, the battery housing and thermal management so that the:
   a) Power pack would cover regenerative braking
   b) Development of an electrical ABS, leading to significantly shorter braking distances.

Originally the project targeted an 800V Battery Pack but eventually it opted for a 400V pack due to space reasons in the Evoque. We were aiming for Maximum Power in = Maximum Power Out which would be good for regenerative braking. Each Pack would have 12 cells per module and 15 modules per pack and the 180 cells would take up 235 liters of space in the car with a total mass of 225 kg. Each elementary cell would be made up from six layers repeated n/6 times. Heat transfer in the battery would be predominantly by conduction. Voxdale chose the FloEFD 3D CFD package that's embedded in PTC Creo as the simulation tool for designing thermal aspects of the Battery Modules because of its ease of use and easy meshing methodology for complex repeated geometries like in this example.

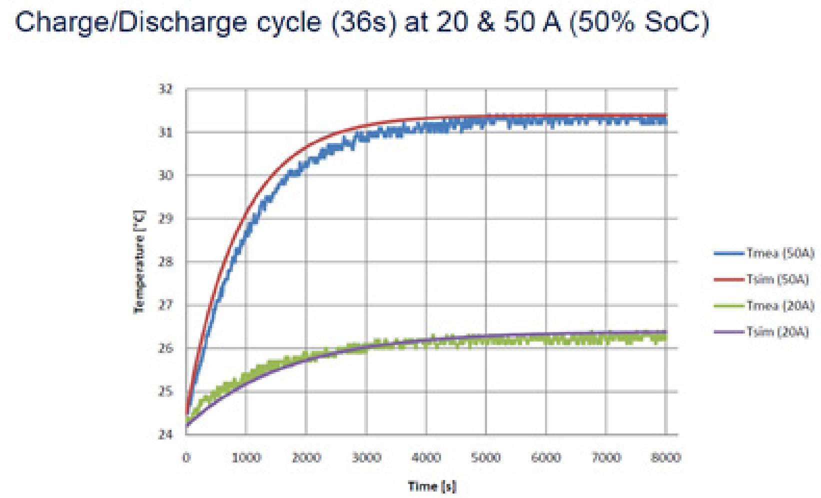


Figure 3. CFD thermal simulation versus experimental measurements.

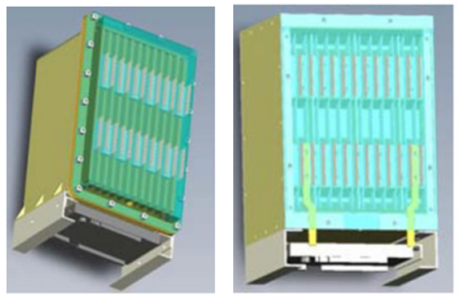


Figure 4. Battery Pack "Wet Module" (left) and "Dry Module" (right)

We initially validated our CFD thermal simulation approach versus experimental measurements in the laboratory and we got good agreement. (Figure 3).

The two Battery Pack Module concepts were investigated in the study are illustrated in Figure 4.

1. Wet Battery Module
   a) Cells submerged in cooling liquid
   b) Inlet and outlet for forced liquid cooling/heating
2. Dry Battery Module
   a) Aluminium cooling ribs between cells
   b) Cooling ribs connected to the base plate
   c) Base plate cooled/heated by Peltier elements.

The fluid flow and heat transfer predictions revealed complex flow fields in the Wet Battery Module channels which we were able to rapidly assess with FloEFD. (Figure 5)

Parametric FloEFD predictions for the Dry Battery Module channels also showed that a set of Peltier elements were able to cool the module adequately whereas the Wet Module created considerable packaging challenges. In addition, unknown longer

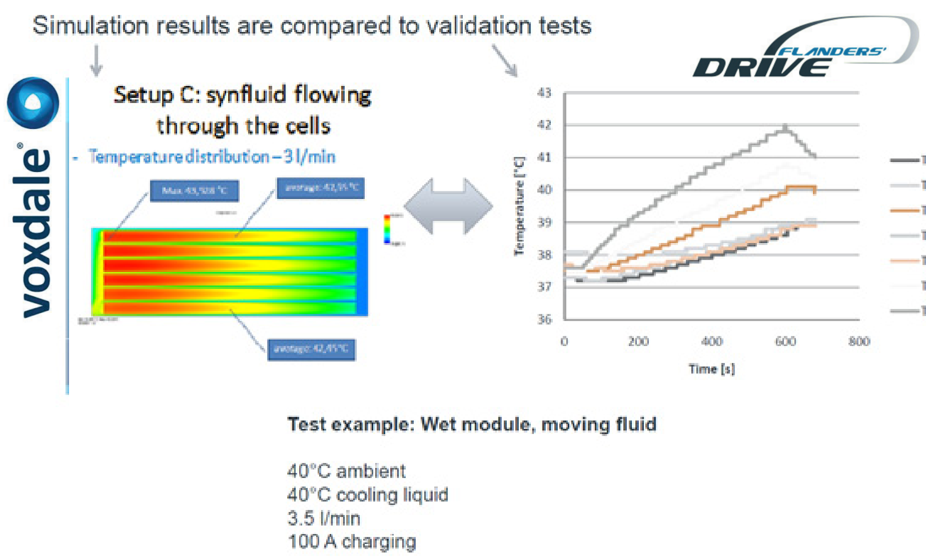


Figure 5. FloEFD simulation results versus experimental measurements for Wet Module

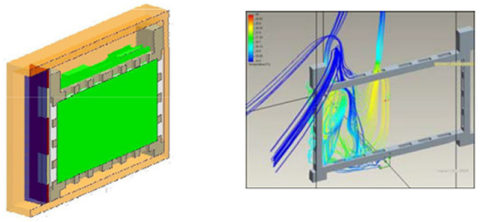


Figure 6. Geometry and detailed FloEFD thermal predictions for parts of the Dry Module

term effects on the cell packaging due to the cooling liquid meant that the Dry Module was our recommendation for the EV Battery being designed. (Figure 6)

Based on our work and that of the other consortia partners, Flanders' DRIVE set up a press and media day in April 2013 showing the new EV Powertrain design inside a two-wheel drive Land Rover Evoque's powertrain (Figure 1). It included four switched reluctance motors, one powering each wheel separately, thus eliminating the need for a differential between wheels. Powering each wheel with an independent motor should also lead to enhanced safety, speed and handling of the electric vehicle. Cornering would also be improved because the car's outer wheels would spin faster than the inner wheels as the car turns. This in turn improves the car's overall torque because the power generated by the batteries would be sent to where it is needed most. The Flanders' DRIVE motors also did not use magnets – thus potentially reducing the price and helping to generate additional power for the engine through a regenerative braking system. The next step for Flanders' DRIVE researchers will be to optimize the powertrain technology in conjunction with its European Partners which include Jaguar Land Rover and Skoda so that they can be applied to all hybrid and electric vehicle combinations.

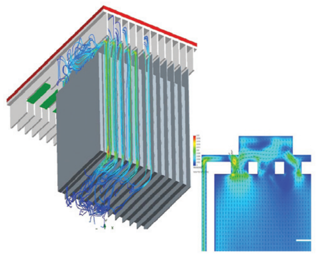


Figure 8. Aquilo concept car battery pack cooling simulation in FloEFD

Finally, my colleague at Voxdale, Wouter Remmerie, and I decided to see if we could think through what we had learnt from the initiative to facilitate some "blue sky" thinking related to electric vehicles with novel battery locations, a patented 3D printed chassis monocoque concept, and thermal management (via FloEFD), all inside PTC Creo. We called our Project "Aquilo" and decided to look at a fundamental new conceptual aerodynamic design process with CFD simulation prototyping related to cooling and heating of battery packs, cooling of powertrain (Figure 8), cooling of electronics, and simulation of battery cooling media, plus lightweight casings for a generic two door EV sports car chassis design (Figure 9). The battery casings were designed with FloEFD and fabricated in the laboratory to validate them.

Figure 7. Voxdale concept electric vehicle chassis

Our final sports car design with novel monocoque, FloEFD aerodynamic styling and battery driveline was visualized in PTC Creo (Figure 9). A very interesting exercise and something that illustrates the power of tools we have available to us inside PTC Creo.

For more information visit:
http://bit.ly/1kWdC9M

* The Flanders' DRIVE Electric Powertrain project was a consortium of 12 companies including Arteco, CTS, DANA, EIA Electronics, Imec, Inverto, LMS, NXP, Punch Powertrain, Triphase, Umicore and Voxdale: flandersdrive.be/en
voxdale.be/en

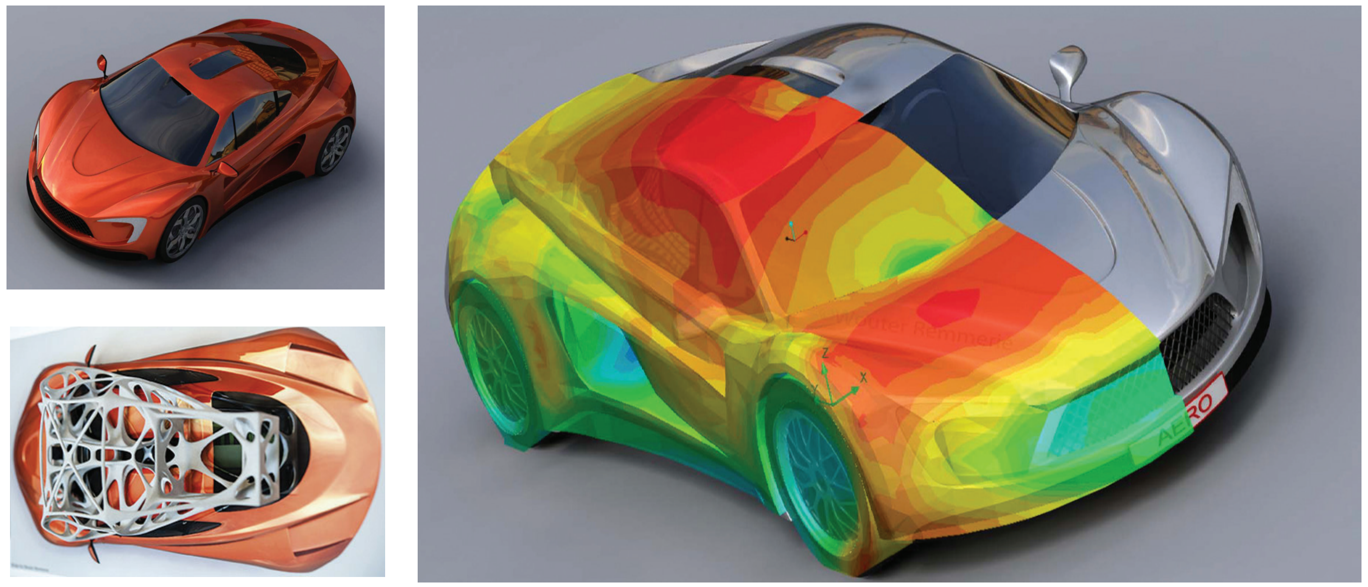


Figure 9. Aquilo concept car design in PTC Creo with external aerodynamics pressure predictions from FloEFD Simulations

Accurate 1D Thermo-Fluid Simulation in Real-Time Environments

By David Hunt, Flowmaster RDI Manager & Product Architect, Mentor Graphics

Control Systems are being increasingly used in complex engineering systems. Where testing cannot easily or safely be done in a real operating environment then development of these control systems requires robust, portable, real-time models of the engineering systems to facilitate:

- Failure mode analysis
- Trade off studies
- Design validation
- What-if studies
- Hardware-in-the-loop (HIL) testing
- In operation simulators

Flowmaster is able to accurately model a wide range of thermo-fluid systems but these simulations are often not able to run natively in real-time, making them unsuitable for coupling with an HIL environment. However, Flowmaster can generate Response-Surfaces that characterize the behavior of its models. Mentor Graphics collaborated with EnginSoft to implement this capability and the Response-Surfaces can be exported as C++ code or as MATLAB™ S-Functions.

These Response-Surface Models (RSM) provide robust, portable, real-time models which are suitable for Control System development, including HIL testing. Additionally, RSMs can be used in any model based environment; they can be passed to design and operational teams and used by non-experts to review the results of a simulation model analysis and understand a system's behavior more easily. The main application areas for hardware-in-the-loop simulation are in the design of Electronic Control Units where the controller is connected to a real-time simulator. This provides a way of testing control systems over the full range of operating conditions (including failure modes) both cost effectively and safely.

This article will look at a simplified automotive engine cooling system (Figure. 1) and how a robust, portable, real-time Response-Surface Model (RSM) can be generated using Flowmaster. In this example the engine is represented by a heat source transmitted into the cooling system via a thermal bridge component. The flow passes through a heat exchanger and there is a bypass line controlled by a set of globe valves that represent the thermostat.

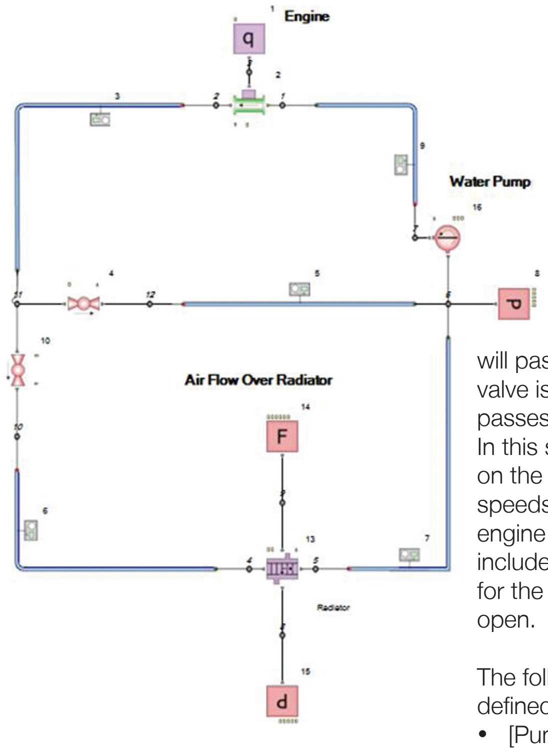


Figure 1. Simple automotive cooling system

The primary circuit consists of a pump, a heat source, a set of globe valves, a cross-flow heat exchanger and a pressure source that pressurizes the system. The bypass line includes a globe valve, component C4, which controls the amount of fluid that passes through the heat exchanger by modulating between position 0 and 1. If the valve is in position 0, then a quantity of flow will pass through the bypass line and if the valve is in position 1, then the entire flow passes through the heat exchanger.

In this study, we need to model the impact on the cooling system of varying pump speeds, air flows over the radiator and engine heat outputs. We also want to include the effects of various valve positions for the bypass line from fully closed to fully open.

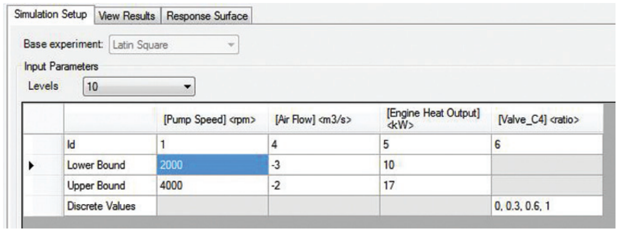
The following four input parameters are defined for the network:

- [Pump Speed] Mixed Flow Pump, C16
- [Air Flow] Flow Source, C14
- [Engine Heat Output] Heat Flow Source, C1
- [Valve_C4] Valve Opening, C4

The output parameters are defined as:

- Top Hose Temperature (Thermal Bridge C2, Node 2)
- Pump Flow Rate (Mixed Flow Pump, C16)

To generate the Response-Surface, Flowmaster runs simulations for this model over the range of the input parameters. It is not possible to run every possible combination of input parameters. Instead, a set of parameters are chosen which give a uniform distribution of combinations. The user sets up the input parameters using the Design of Experiments feature in Figure 2.



	[Pump Speed] <rpm>	[Air Flow] <m3/s>	[Engine Heat Output] <kW>	[Valve_C4] <ratio>
Id	1	4	5	6
Lower Bound	2000	-3	10	
Upper Bound	4000	-2	17	
Discrete Values				0, 0.3, 0.6, 1

Figure 2. Experiment input values

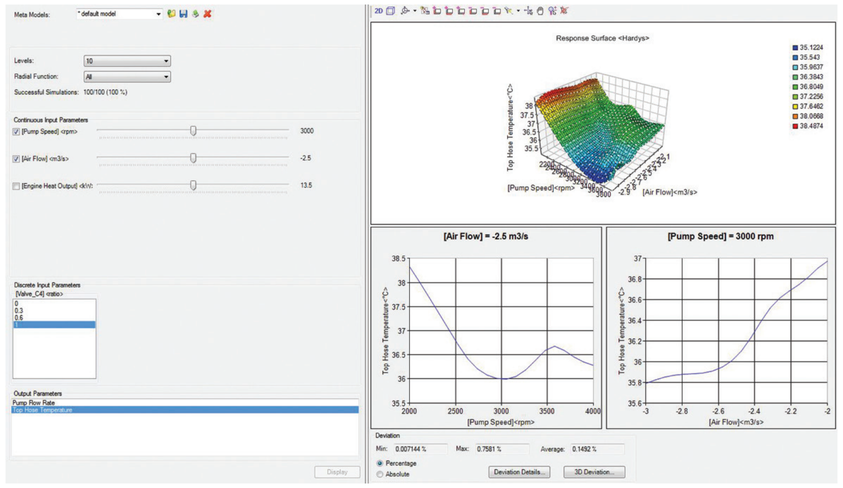


Figure 3. Deviations of Response Surface for the flow rate through the pump

Here a Latin Square of ten levels is considered which generates 100 simulations i.e. n2 simulations, where n is the number of different levels. Using four discrete values for the valve component C4 of 0, 0.3, 0.6 and 1 will produce a total of 400 steady state simulations. More levels, n, leads to more simulations and means that the Response-Surface has a higher fidelity – but takes longer to generate.

In fluid systems, discrete values (like valve position) can lead to radically different flows and a single response-surface would be inaccurate. So, separate Response-Surfaces are created for each combination of discrete values to increase accuracy of the RSM. Once the 400 simulations are completed, response surfaces for each output variable can be created and reviewed by the user. The Response-Surfaces are generated using "Radial Basis Functions" (RBF). Flowmaster offers different types of RBF but will select the best fit while offering the user the flexibility to customize the RBF. The result of applying a RBF to the simulation results is shown in Figure 3. The Deviation Details tool provides an immediate and simple evaluation of the goodness-of-fit of each response surface on the basis of its deviation. As shown in Figures 4 and 5 the best response surfaces for the flow through the pump and through the heat exchanger are those computed with Gaussian RBF while the best Response-Surface for the temperature in the primary circuit is the one computed with Hardy's MultiQuadrics.

Once the user is happy with the level of fidelity in each Response-Surface, then they can be exported to a Response-Surface Model (C++ code or MATLAB™ S-Functions) suitable for use in a real-time simulation or as a portable model for other designers or operators.

The product of the collaboration between EnginSoft and Mentor Graphics in the latest version of Flowmaster V7 now allows for robust, portable, real-time models to be generated using a Design of Experiments approach. These Response-Surface Models can be exported as C++ code or as MATLAB™ S-Functions suitable as the backend code to a runtime model of the system or for use in an HIL environment. The ability to characterize a system's behavior in exported code opens up a wide range of possibilities, such as creating a simple dashboard that allows non-expert users to understand and predict system performances in Flowmaster, inserting the code into a hardware-in-the-loop logic, or embedding the code into other codes for co-simulations.

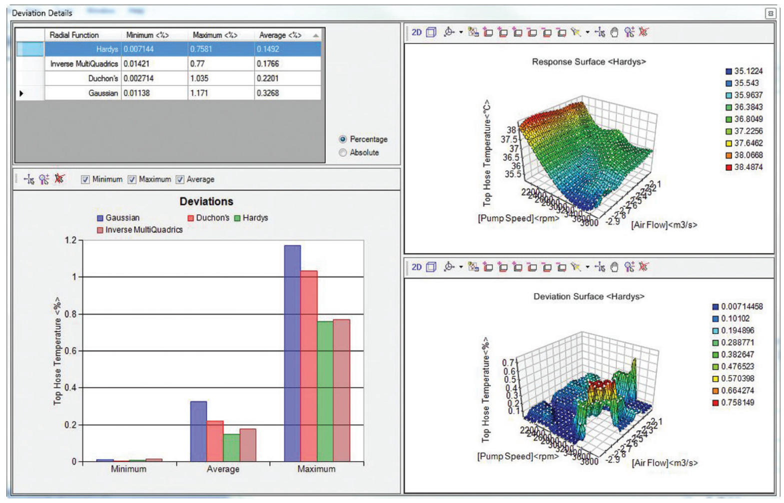


Figure 5. Deviations of Response Surface for temperature downstream of heat source

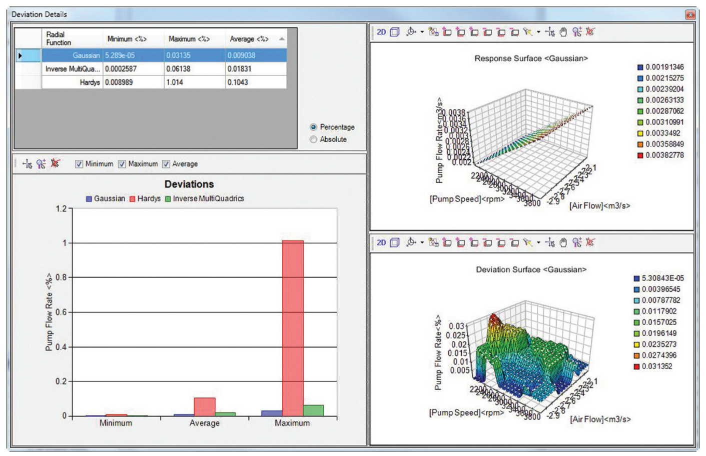


Figure 4. Response Surface view

References:

[1]. McKay, B., and Rogoyski, E. 1995, Latin Squares of Order 10, Electronic Journal of Combinatorics, 2(3), 1
[2]. Fisher, R., and Yates, F. 1934, The 6 x 6 Latin Squares, Proceedings of the Cambridge Philosophical Society, 30, 492
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[4]. Buhmann, M. D., Radial Basis Functions: Theory and Implementations, Cambridge University Press, 2003.
[5]. Rippa, S., An algorithm for selecting a good value for the parameter c in radial basis function interpolation, Adv. in Comp. Math., 11, pp. 193-210.

Upgrading a Biomass Furnace: A Simulation Driven Approach

By D. Hasevoets, Cofely Fabricom E&E & Wouter Remmerie, Patrick Vlieger, Voxdale

Cofely Fabricom GDF SUEZ is a leading multi-disciplined engineering, project management and construction organization in the oil, gas, power and allied industries. Part of the global energy group GDF SUEZ, Cofey Fabricom employ over 5,500 people worldwide who strive for the improvement of energy efficiency, durable development and quality of life.

The Cofely Fabricom, Energy & Environment Division specializes in turnkey Engineering, Procurement, Construction and Commissioning (EPC) projects in the renewable energy sector emphasizing on balance-of-plants, flue gas treatments, and cogeneration plants.
In April 2013, Cofely Fabricom E&E was awarded a turnkey revamping contract to improve the reliability and performance of the biomass furnace of the cogeneration unit in Sart-Tilman, Liège, Belgium, which is part of the central heat production and distribution across the Université de Liège (ULG) and the CHU University Hospital. The project was centered around the improvement of a number of failures experienced by the two institutions, specifically:

- Insufficient instrumentation for proper combustion control;
- Reduced performance due to a lack of recirculation of smoke gases in nominal operation;
- Incomplete coverage of grid with pellets, leading to primary air bypass non-uniform combustion; and
- Refractory damage caused by extremely high local temperatures.

In order to address these issues, a completely new combustion control philosophy was investigated.

The approach would involve:

- A mixture of 50% re-circulated smoke gases into primary and secondary air to improve performance;
- Optimizing, by means of Computational Fluid Dynamics (CFD) calculations, secondary air injections to respect legal emission limits;
- Installing new fans, frequency drives and electrical cabinets; and
- Implementing superior instrumentation, including ultrasonic flow meters and infrared cameras.

Cofely Fabricom E&E first performed the necessary process calculations for optimized combustion, accounting for flow rate, temperature, oxygen content and pressure drop, which sized the primary, secondary and recirculation fans as well as the duct diameter and valves.

The next step was to ensure the optimal configuration of the secondary air injections. Since the main objective of the project was to achieve an increase in performance, the oxygen concentration at the furnace outlet had to be reduced from its current value of 13% while respecting the legal emission limits. The secondary air injection therefore had to ensure that all produced CO was recombined to CO_2. This would be achieved by obtaining an optimal level of turbulence inside the narrowest section of the furnace, referred to as the "furnace neck".

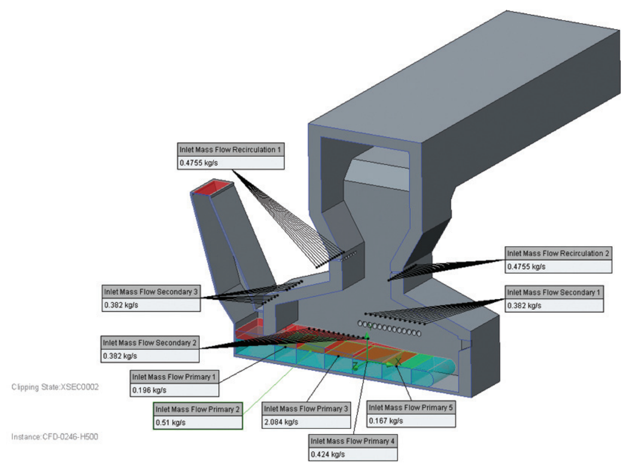


Figure 1. FloEFD simulation geometry

To gain sufficiently high velocities at the tube outlet, the secondary air injection nozzles were divided into two rows: an upper and lower ramp of 2 x 14 tubes each at the front and back end of the furnace, 112 tubes in total. At lower flow rates, the two lower rows were isolated in order to maintain a minimum velocity of 20m/s at the remaining tube outlets.

Physically building and testing different prototypes of an installation of this size would be time consuming and prohibitively expensive. In order to understand the response of the system and arrive at the optimum configuration of nozzles, Computational Fluid Dynamics (CFD) simulations were carried out using Mentor Graphics' FloEFD by project partners Voxdale.

The first step was to create a model of the existing furnace and simulate its behaviors. This approach would allow simulation parameters and boundary conditions to be adjusted to obtain a good match between a well-known system and the simulation model. During this phase confidence in the simulation approach is established and the first insights into the system are generated.

Combustion processes weren't directly modeled in the simulation, instead, air temperatures and flow rates were adjusted to obtain comparable behavior. This reduced the time required for each simulation without appreciably affecting accuracy, which in turn allowed for CFD to cover a large number of design iterations in a reasonable time.
Figure 1 illustrates the original setup of the furnace with wood pellets that are fed into the system, forming a layer on the moving grid. Below this grid, five distinct supplies of primary air, provide the oxygen required for the combustion process. In addition, secondary air is supplied through nozzles on both the front and lateral walls. At the furnace neck, exhaust gases are injected into the furnace, providing the system with recirculation air.

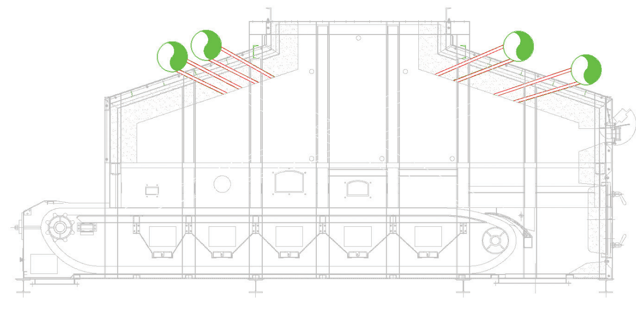


Figure 2. Secondary air nozzle detail results

In the second phase, different design proposals were set up and simulated in FloEFD. Three-dimensional turbulence plots and velocity patterns were used to assess the various configurations. One of the earlier setups is illustrated in Figure 2, in which the secondary air nozzles were moved closer to the furnace neck and the number of nozzles was greatly increased. Although this solution offered some benefits, it resulted in insufficient turbulence intensity across the furnace neck.

Based on the insight offered by such simulation and analysis, further design iterations could intelligently evolve. For example, it became apparent that offsetting the recirculation nozzles slightly with respect to each other created the desired amount of turbulence in the furnace neck.
The positioning and layout of the secondary air jets were similarly optimized in order to ensure sufficient turbulence in the adiabatic chamber (Figure 3). As the simulations were performed without combustion, it could reasonably be assumed that an even higher level of turbulence, higher velocities and better mixing would occur in practice. The resulting design is shown in Figure 4.

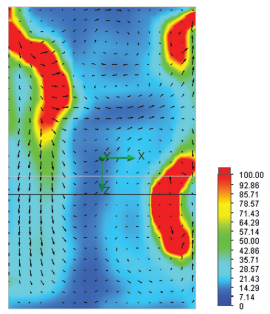


Figure 3. Turbulence intensity in the adiabatic chamber

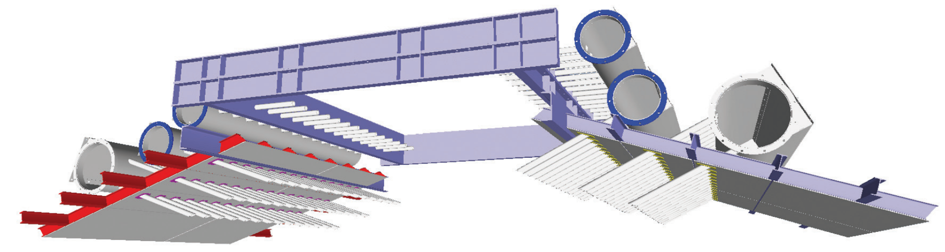


Figure 4. Furnace neck resulting design

Disassembly of the old furnace began in May 2013, with installation works running from June to September 2013. Start-up and combustion optimization took place in October - November 2013. During cold commissioning of the new installation the simulated velocity distribution was verified inside the furnace and comparable flow patterns were observed.
Integrating CFD in to the design process helped Cofely Fabricom E&E deliver the project successfully and within a short time frame. Virtually prototyping various designs in FloEFD provided a reliable and inexpensive means by which different parameters could be assessed and adjusted. Ultimately, all project objectives have been fulfilled.

- Performance was increased by 8.4% (actual efficiency 89.3%);
- The furnace represents a considerable improvement over the previous design (see Table 1) and operates well below legal limits, e.g. for both carbon monoxide and nitrous oxides.

The process followed demonstrated the value of fluid simulation for such projects. It is therefore an approach which will be used for future projects, where appropriate. The installation has been in reliable operation since November 2013.

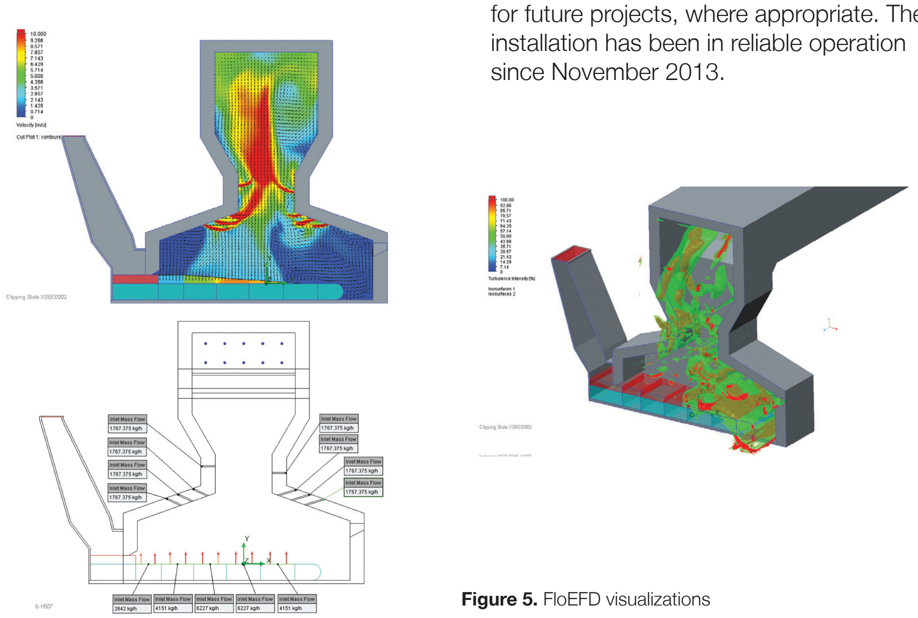


Figure 5. FloEFD visualizations

Table 1 Emission figures

Species	Old Furnace (Nm^3)	New Design (Nm^3)
CO	106	11
NO_x	406	203

How To...

Get Hot Lumens in situ from FloEFD's unique LED Module

By Joe Proulx, Application Engineer, Mentor Graphics

Just occasionally a software product or module comes along that stimulates interest in a new technical area and can even prove to be a game changer. The LED Module for the 3D CFD product, FloEFD, is looking like such a capability.

It emerged two years ago from two separate technical strands within the Mechanical Analysis Division; the MicReD T3Ster & TeraLED hardware for thermal and optical/radiometric characterization of LED lights, along with the 3D CFD FloEFD software that permits accurate thermal simulation of LEDs within complex geometries easily.

The big problem with simulating LEDs in a traditional CFD approach, however, is that as temperature increases inside an LED, its forward voltage changes leading to heat dissipation changes and ultimately the quality of its light output changing. Hence, modeling an LED as a simple heat source is just not accurate enough. This can be a bit like a dog chasing its tail! Figure 2 illustrates this complex interconnectivity beautifully. So how does the LED module help solve this problem? Let's consider that we have an LED geometry (Figure 3) with a datasheet of manufacturer's properties (boundary conditions) and we have access to Mentor's tried and proven combination of T3Ster & TeraLED to characterize the LED (using JEDEC JESD51-1 and CIE 127-2007 compliant techniques). We could measure the LED under a range of conditions to produce a set of data for the FloEFD LED Module. The LED geometry itself could be input into FloEFD via your favorite MCAD tool (FloEFD is embedded within most of the popular CAD tools available today) and the luminaire it is attached to can also be added so that the LED is modeled in situ. T3Ster/TeraLED measurements will yield for a given LED, the current and temperature

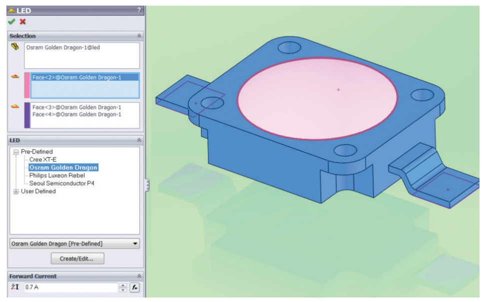


Figure 1. Typical LED geometry inside the FloEFD LED Module

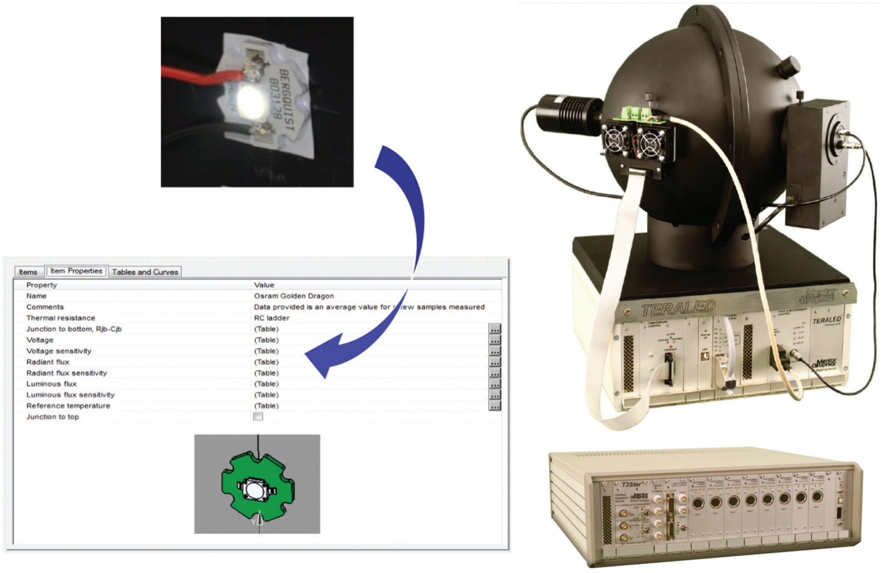


Figure 3. Inputs for an LED analysis in the FloEFD LED module utilizing the T3Ster/TeraLED thermal characterization and optical measurement devices

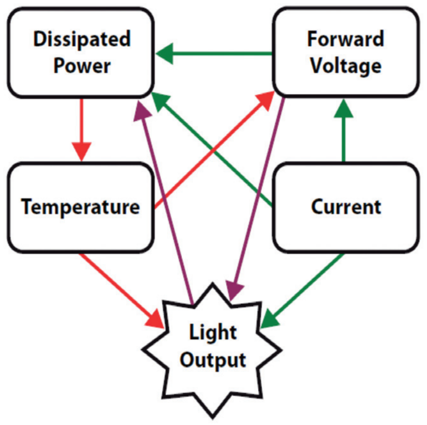


Figure 2. Interaction between temperature, forward voltage, power, current and light output for LEDs

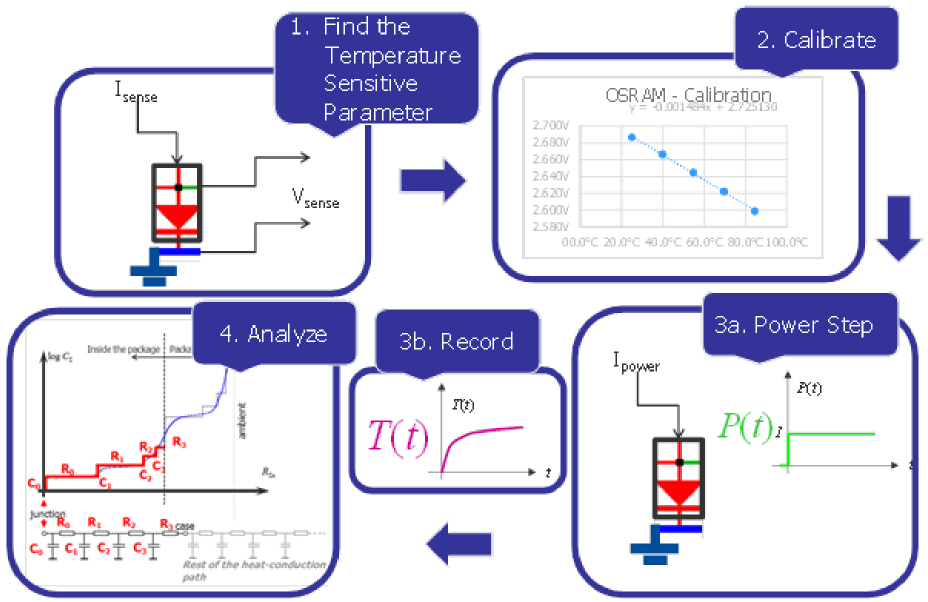


Figure 4. Four step process to create the cumulative thermal structure function.

dependence by way of R-C Structure Functions, Diode Characteristics, Optical Power (mW), Radiant Efficiency (Popt/Pelect), Luminuous Flux (lm), Efficacy (lm/W), Scotopic Flux (lm), and Optical Color Coordinates (X,Y,Z tristimulus values). As a result of the combined thermal/optical measurement, this data can be displayed based on the LED junction temperature. This process is illustrated in Figure 4, where the Temperature Sensitive Parameter (TSP), i.e. the diode forward voltage in the case of an LED, is measured to calibrate the LED. It is then powered up to steady state, allowing the temperature, light output, and power draw to stabilize. Measurement is made by suddenly powering down the LED to a very small measurement current that is used to record the TSP as the part cools. The T3Ster software is used to convert the temperature vs. time response into a cumulative thermal structure function – a graph of thermal capacitance vs. thermal resistance to reveal the thermal structure of the LED package.

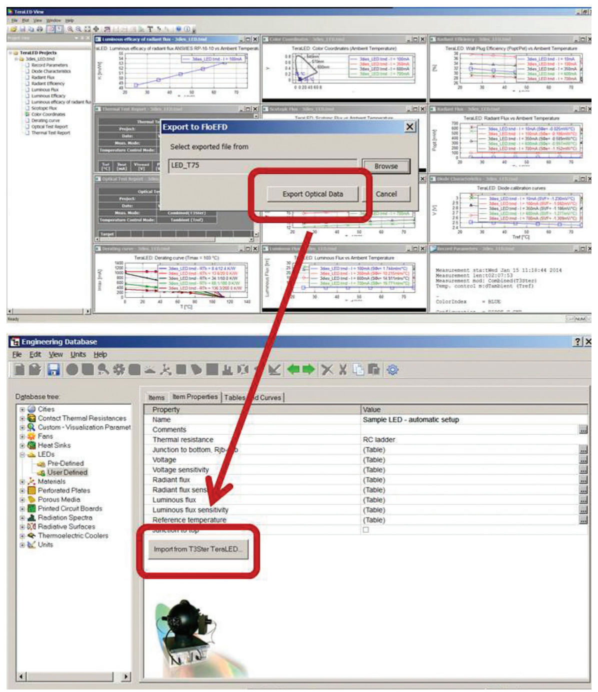


Figure 5. Two Clicks to enter all the LED characteristic data.

FloEFD's LED Module has a standard, premeasured set of typical LEDs in its Engineering Database. Alternatively, you can add a characterized LED yourself from your own hardware measurements (Figure 5). An LED Package Cumulative Thermal Structure Function can also be used to create a Resistance-Capacitance (RC Ladder) Model as shown in Figure 4 step 4, and then imported into FloEFD's LED module (Figure 6). These models determine junction temperature accurately, without the overhead of requiring the LED package internal geometry to be modeled, and can be used in transient situations. Less accurate, 2-Resistor (2-R) models can also be used but have the limitations of being steady-state only, use an assumed heating power as input, and give no information about the light output.

The LED Module user can select Native CAD faces and bodies to apply LED boundary conditions within their favorite MCAD packages; PTC Pro/ENGINEER and Creo Parametric, CATIA V5, Siemens NX or standalone (Figure 7).

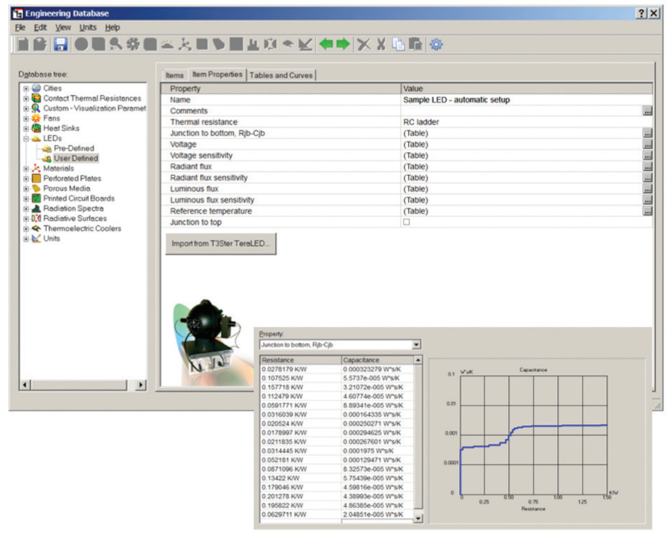


Figure 6. One click entry of the cumulative structure function.

The net effect of this LED Module approach is to allow the user to use FloEFD's accurate CFD solver to calculate the actual thermal impact of the LED inside its luminaire geometry, yielding real-world useful data for the LED Junction Temperature, the LED Heat Generation Rate and, uniquely, the LEDs light output, or 'hot lumens' in situ (Figure 8). This allows for the most accurate predictions of an LED's operational thermal performance in any given product and application environment.

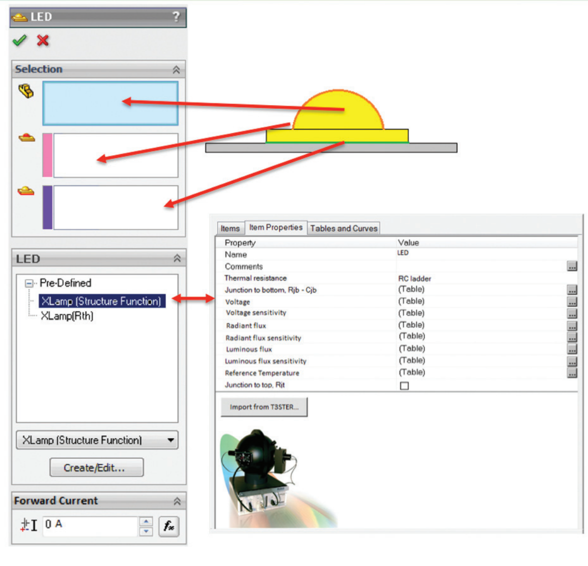


Figure 7. Applying the LED characteristics to the geometric boundary conditions

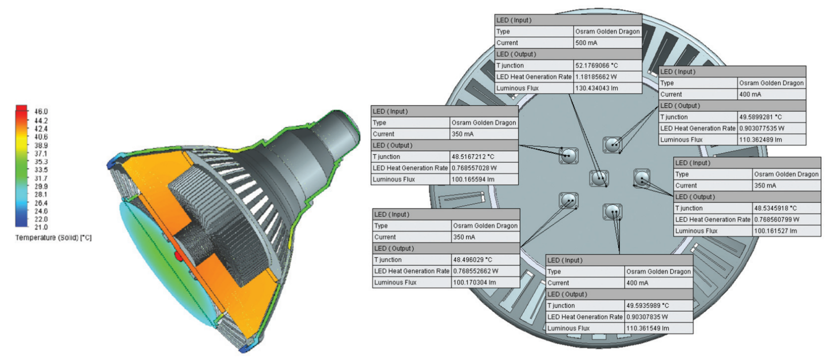


Figure 8. Accurate in situ performance simulation of the LED

There's an App for that!

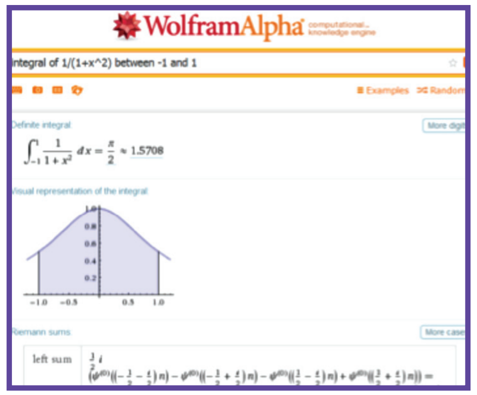
Now that our phones are to the guidance computer used on the NASA Apollo missions, as a flick-book is to a high definition television, it follows that there are more and more mobile applications with the potential to make the life of the average engineer easier. From an extensive trawl of the options out there, I've selected the following apps over which to cast a sceptical eye. Given that engineering is such a broad church, I've tried to select apps that are as general as possible and given them a roadtest and rating.

By John Murray, Industry Manager, Mentor Graphics

Smart Tools

Smart Tools® is a complete package of five app sets; **Smart Ruler Pro** (Length, Angle, Slope, Level, Thread), Smart Measure Pro (Distance, Height, Width, Area), **Smart Compass Pro** (Compass, Metal detector, GPS), **Sound Meter Pro** (Sound level meter, Vibrometer), and **Smart Light Pro** (Flashlight, Magnifier, Mirror). I loved this as it gives users many useful "rule of thumb" tools all in a handy App for your Smartphone to use with its camera. A must for every engineer!

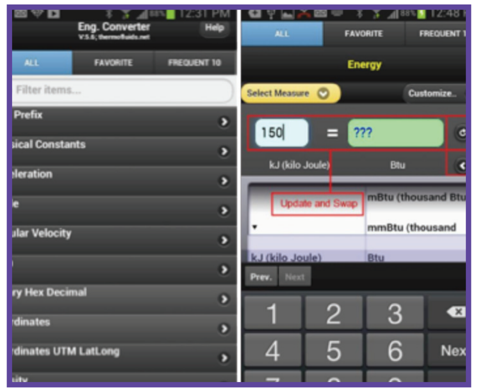
Cost: Most are free and some cost $1 **Rating:** ★★★★★



Wolfram Alpha

Despite comparing itself to the computer from 'Star Trek', Wolfram Alpha doesn't seem to have made any great strides on the road to quantum teleportation. It is, instead, a 'computational knowledge engine' a title with the air of a 19th Century curiosity about it. But what does that actually mean? The easiest way to sum it up is that were you to ask it 'What is teleportation?' You'd get a fairly unremarkable dictionary entry. So far, so sub-par Wikipedia. However, if you ask 'What is the integral of one over e to the minus x between one and two?', you get something a whole lot more impressive: it only goes and gives you the answer expressed algebraically, as a number and an x-y visualization of the result. Very impressive. It also does a range of more applied problems such as material properties and statistics. If you're not convinced, you could always try the web page first, wolframalpha.com.

Cost: $3 **Rating:** ★★★★½

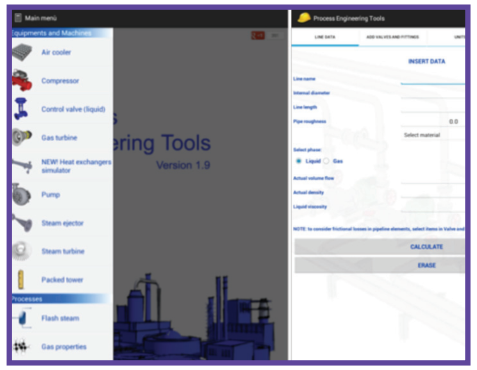


Engineering Unit Converter

No-one could argue that this isn't a function that's likely to get many excited. If we wanted excitement we'd have become accountants, not engineers, right? So let's get down to the details: to be useful, this app is going to need to cover a wide range of parameters quickly and easily.

On this basis, it's job done here. The front screen lets you select from a huge range of potential parameters, from which you find yourself looking at a rotating bezel of potential units. Very comprehensive, very easy to use. You can even set favorites. Highly recommended.

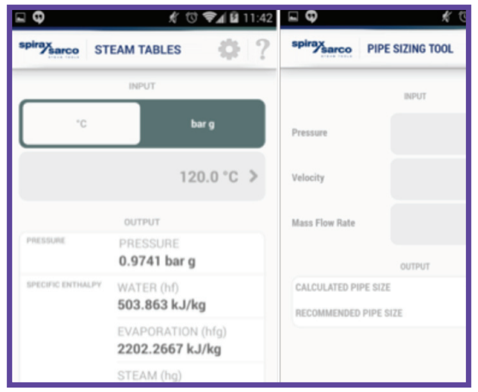
Cost: Free **Rating:** ★★★★☆



Process Engineering Tools

This is a decent little app that calculates some basic properties for common pipeline components. My only question would be, how often engineers find themselves needing to do these kind of calculations on an app, rather than a more sophisticated program or spreadsheet? Someone obviously thought the answer was frequently enough to make it worth writing one, so who am I to argue?

Cost: $5.50 **Rating:** ★★★½☆



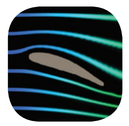
Spirax Sarco Steam Tools

This one is a little more parochial to those dealing with steam. It is a nicely designed app, so if you do happen to find yourself needing to know what the saturation temperature is for steam at a given temperature or pressure, you could do a lot worse. It also gives specific volume and enthalpies at the derived point as well. The app features a pipe sizing component as well.

By the way, if you're wondering if Wolfram Alpha could be used for the same job, the answer is yes. The advantage with this app is that it has a clear interface and doesn't need an internet connection to work. Which can only be a good thing if you really need those numbers in a flash (pun intended) when you're off-site.

Cost: Free **Rating:** ★★★½☆

Get your Geek On!



We loved **Wind Tunnel Pro HD** with its cool CFD-like visualization of 2D objects inside a wind tunnel geometry that you can move with your fingers (admittedly for $5.99)!

Fluid Automata 1.1 has some interesting colorful and very artistic visualization of fluid domains ($2.99).

HVAC Professional has some neat engineering features beloved of heating, ventilation and air conditioning engineers ($7.99)

Failing that, you could always try **Angry Birds** (for its aerodynamic features) and **Candy Crush Saga** (because of its discrete element modeling)…both are free!

Getting Heat Out

Cooling the Next Generation of Embedded Military Computing Products

By Darryl McKenney, VP, Engineering Services, Mercury Systems, Inc,

Mercury Systems is a publicly listed company based in Chelmsford, MA, USA and is a leading supplier of commercially developed, open sensor and Big Data processing systems for critical commercial, defense and intelligence applications. We design and build end-to-end, open-sensor processing subsystems. Our product set spans the entire ISR (Intelligence, Surveillance, and Reconnaissance) sensor processing chain, from acquisition to dissemination, helping customers address a broad range of sensor processing. Mercury Systems have worked on over 300 programs, including Aegis, Patriot, SEWIP, Gorgon Stare and Predator/Reaper.

If we examine typical military electronics CPU Modules and Mezzanines over the last few decades (Figure 1), what is very clear is that their Power levels have increased dramatically. The VPX, formerly known as VITA 46, is an ANSI standard (ANSI/VITA 46.0-2007) that provides VMEbus-based (Versa Module Europa bus) systems for CPUs with support for switched fabrics over a new high speed connector. It was defined by the VITA (VME International Trade Association) working group, that includes Mercury Systems, and it has been designed specifically with defense applications in mind, with an enhanced module standard that enables applications and platforms with superior performance. Basically, all CPU boxes in ISR applications must comply with this standard and its successor VITA 48.

We are finding that devices such as microprocessors and FPGAs (field-programmable gate arrays) have been running ever faster while their size has been constantly shrinking, which obviously has increased heat densities and threatened product reliability. But after nearly a decade of honing our Design for Reliability (DfR) thrust we have produced new design processes and implemented new procedures such that we have reduced the number of engineered change orders by over an order of magnitude. This demand for higher and higher functionalities in defense electronics has led to conflicting demands for more heat management, more sensitive signals, shorter design cycles, higher test coverage and all within ever tighter defense budgets. To add to all this, our products have to be highly reliable with years of operational run time in a wide range of harsh environments. You can imagine the challenges this poses for test engineers, signal-integrity engineers and mechanical engineers when it comes to designing new PCBs and enclosures. Many of today's high powered modules cannot be cooled using legacy cooling approaches. The bottomline is that in our business heat is the primary enemy of module reliability.

At Mercury we offer three types of products to our customers, Air-cooled (A/C) Modules, Conduction-cooled (C/C) Modules and what we call Air Flow-By (AFB) Modules.

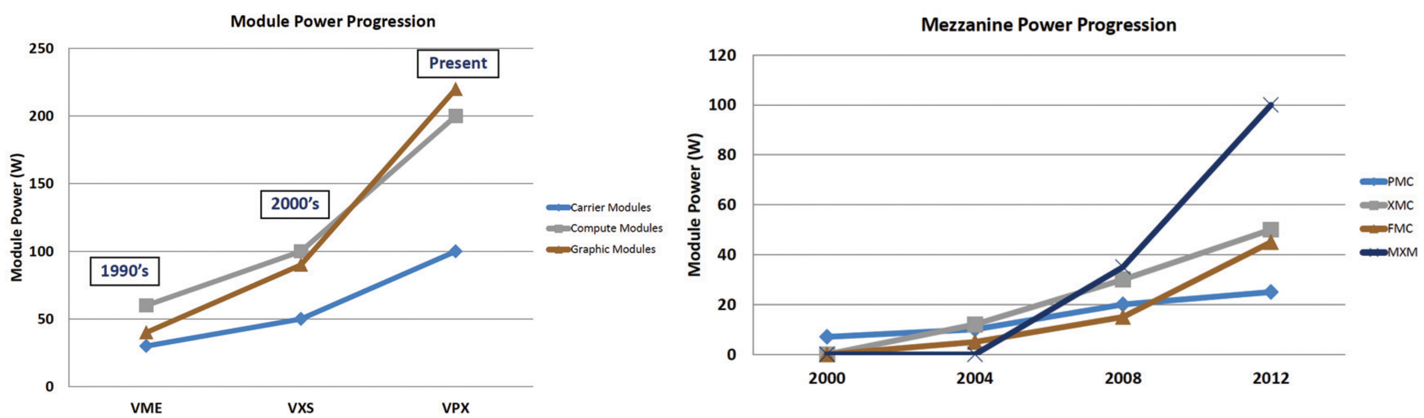


Figure 1. Defense CPU Modules and Mezzanine Power Module Evolution over time

In all cases we go through detailed design and testing processes to design the units for our customers. Our evaluation of each technique's cooling efficiency is highlighted in Figure 2. For our thermal CFD simulation needs we use Mentor Graphics' FloTHERM product which helps expedite our design process.

Air-cooling provides easy access to module debug connectors, front panel I/O and mezzanine modules. This combination simplifies system development and configurability while the system is in its greatest state of flux and requirements are not all identified. A major drawback is that air-cooled modules are not typically designed to be deployed in rugged environments. Conduction-cooling has been the preferred method of cooling for deployed systems for many years.

The modules are designed to handle the rugged shock and vibration levels, while the systems seal the modules away from harmful elements. A major challenge with conduction cooling is that it is heavier than air-cooled and thermally challenged with higher power modules. Air Flow-By – a new cooling technology designed by Mercury – delivers the best of both worlds. It provides the efficient point source cooling of an air-cooled module with the rugged deployment capabilities of conduction-cooling.

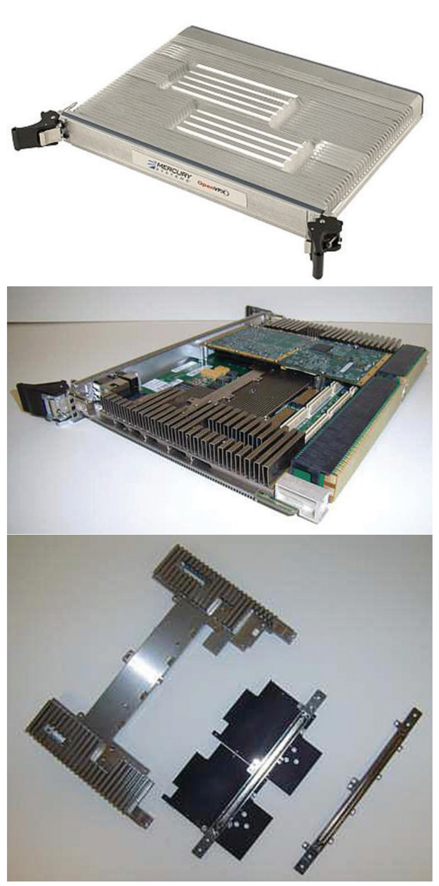


Figure 3. Typical Mercury Systems Integrated XMC Air-Cooled Thermal Solution showing details of Thermal Bridge Hooks

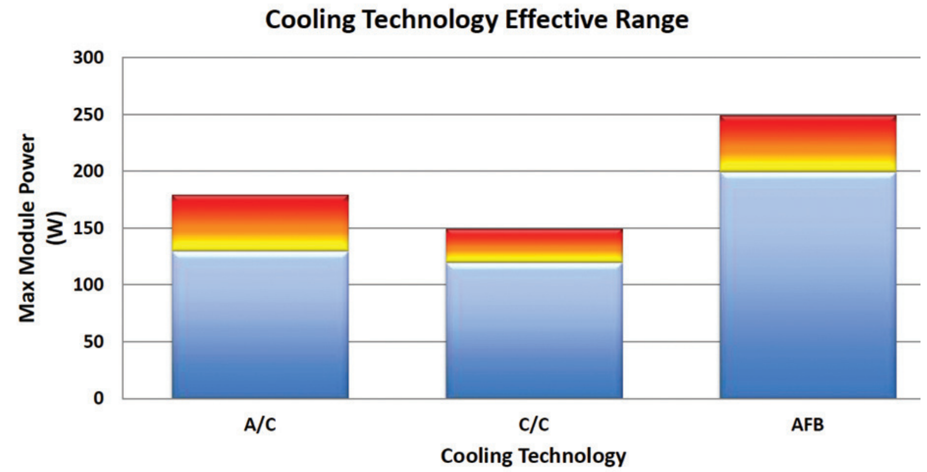


Figure 2. Air-Cooled, Conduction-Cooled and Air Flow-By Cooling Technology Ranges

To give a simple example of how we apply FloTHERM to one of our XMC-Air-Cooled products (Figure 3), we employed a standards based approach to bring heat from the mezzanine modules to the carrier module's heatsink. We discovered via CFD simulation (Figure 4) that we could do this by adding "hooks" for a thermal bridge between the carrier module heatsink and the mezzanine module heatsink. The net effect was a thermal solution that was compliant to standards and allowed for a wide range of mezzanine modules to be placed on a host while limiting any potential changes to a single component. We discovered with FloTHERM that we could get a 5°C Processor thermal reduction - half an Order of Magnitude. This leads to significant impact on mean time between failures (MTBF) too.

In summary, our new thermal-management solutions are capable of dissipating tremendous amounts of thermal energy, while still meeting the same or smaller size, weight and power requirements for the overall solution. By understanding the thermal profile for each specific component that makes up a system using FloTHERM, we created innovations in the mass transfer of thermal energy that work at the individual component, module and subsystem level.

References:

[1]. "We Need More Power Scotty! Getting the Heat Out: Innovations for Cooling the Next Generation of Embedded Computing Electronics" by Dan Coolidge & Darryl McKenney, Embedded Technology Trends, Long Beach, CA, January 21-23, 2013
[2]. December 2012, "Mercury Computer Systems Announces Cold Plate Technology for Embedded and OpenVPX Technologies": http://www.coolingzone.com/index.php?read=162&onmag=true&type=press#sthash.wssfl7Hp.dpuf
[3]. Test & Measurement World, Nov 2008, "Quality by Negotiation", pp32-35

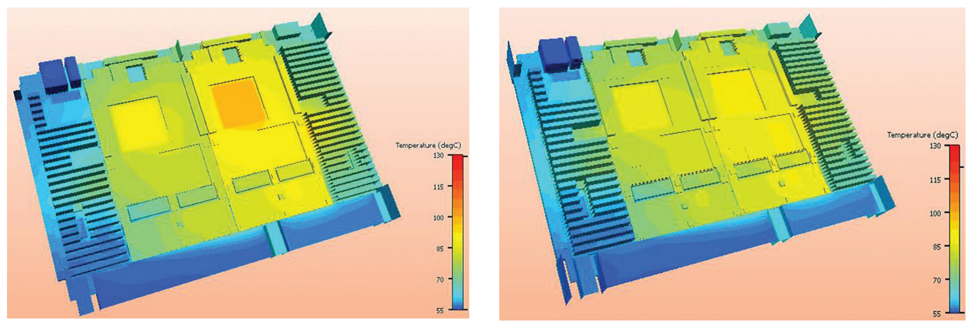


Figure 4. FloTHERM thermal analysis (L) without Integrated thermal bridge (R) with Integrated thermal bridge

Seiko Epson Corporation - Empowering Engineers since 1989

By Mr. Hiroshi Abe, Mr. Naoki Ishibashi, Mr. Shigeki Kikuchi, &
Mr. Fumio Yuzawa, Seiko Epson Corporation;
Ms. Hideko Murano, Syuzaiya;
Ms. Hiromi Sugihara, Kozo Keikaku Engineering Inc.

EPSON

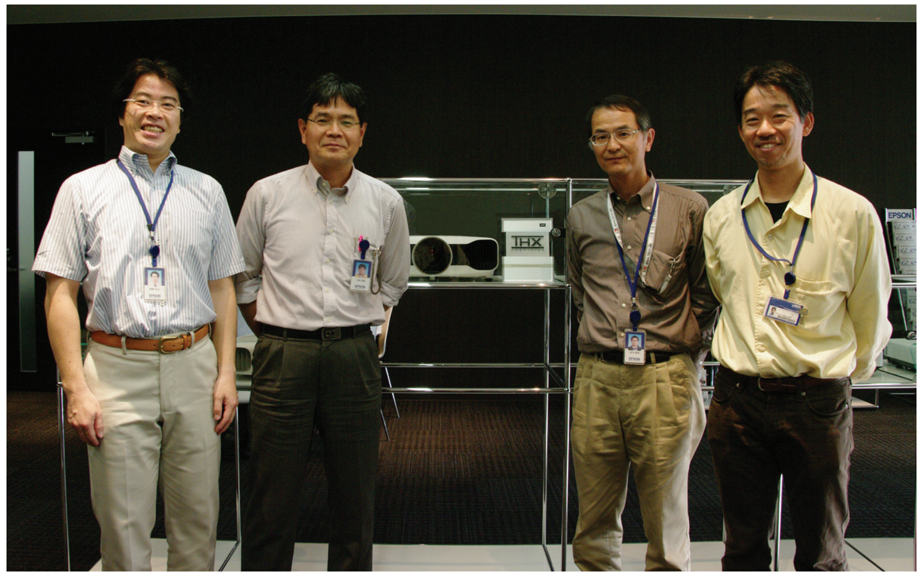


Figure 1. Seiko Epson Corporation in Toyoshina,, VI Planning & Design Department

The Seiko Epson Corporation in Toyoshina, Japan, is home to the VI Planning & Design Department. In March 1989, the Visual Instruments Operations Division was established, with liquid crystal televisions and liquid crystal projectors as its core products.

Epson used its liquid crystal projectors to develop an entirely new market that the company continues to lead: data projectors as multimedia presentation tools. It is here that they developed the technology for the world's first compact, full-color liquid crystal video projector. The first Epson branded projector, the VPJ-700, was built here with revolutionary technology that allowed the projector to use liquid crystal panels instead of a traditional 3-gun CRT to present a picture, thus showing the world a brand new application for liquid crystal displays. With the release of the VPJ-700, Epson became the company to watch in the visual instruments field, where it combined liquid crystal panel technology with optics to develop new products.

Epson's 17 year period with top market share for the Japanese projector market has been achieved by empowering engineers and having an efficient design lifecycle. Today, projectors are used for business, education, and for home entertainment. With each application there is a need for these products to be compact, light-weight, portable and most importantly durable. The challenge with all these attributes is of course thermal.

Heat sources in projectors, like power supplies and lamps, result in high temperatures inside the projector housing. As smaller, more compact portable projectors are continuously being developed the first consideration for the designers at Epson is always making heat sources smaller. By the nature of the design and materials used, the units tend to retain heat in their body unless it is vented into the air or through other parts. Radiant heat transfer is the most important consideration in the development of projectors.

The Thermal Challenge

Previously projector models did not require intense brightness and therefore didn't radiate high temperatures. With only a few models available on the market at the time, Epson could afford a lengthy development cycle. If any problems arose during testing they were able to simply redesign the units. When LCD technology was introduced, the development period halved as there was now a demand for projectors that were brighter, had more functionality, and were smaller.

As with many miniaturized devices, the path for heat radiation is limited, nevertheless air cooling is required within the housing. As well as this, development timescales are sometimes underestimated and can prove costly if they overrun.

Empowering Analysis Engineers

Thermal analysis simulation started at Epson in the 1990's by a team of in-house analysts. This team analyzed all of the products in SEIKO EPSON, including projectors and other electronic devices. Despite the new challenges faced in thermal analysis there was still a requirement to reduce development times and costs. The solutions tended to be focused on each type of device Epson manufactured in order to solve the more complex problems for physics analysis. Hence a new team of dedicated analysts was established to analyze projectors in 2007. It soon became apparent that with the need to speed up development time it was difficult to complete development within the developing phase. Meanwhile designers found it frustrating that they had to wait for the result of analysis by analysts, thereby squeezing the time they had in the design cycle to design and change geometries as necessary. Consequently, SEIKO EPSON started to use FloEFD for Creo in 2009 in order to empower designers to analyze their own designs and to speed up productivity.

Why FloEFD for Creo was the right choice for Epson

According to Mr Hiroshi Abe, "The most important consideration in selecting an analysis software tool was that all team members could use it regardless of their level of ability. We

	**VPJ-700** (1989) World-first 3CCD LCD projector Brightness: 100lm Weight: 7.6kg Pixel number: (320×320) Price: US$ 4,670
	**ELP-3000** (1994) World-first data projector Brightness: 250lm Weight: 7.7kg Pixel number: VGA (640 ×480) Price: US$ 8,650
	**ELP-730** (2002) Brightness: 2000lm Weight: 1.9kg Pixel number: XGA (1024×768) Price: US$ 3,400
	**EB-1775W** (2010) Brightness: 3000lm Weight: 1.7kg Pixel number: WXGA (1280×768) Price: US$ 970 ～ 1,750

Figure 2. LCD Projector history.

evaluated the following three criteria:
1.The people who don't have much experience of analysis can use it easily. In particular, meshing, as this is one of the most difficult processes. FloEFD's automatic meshing enables you to just set a specific area of a model. As for workflow, we only needed to select "yes" or "no" by using the wizard and then we can also learn what we should set in the analysis process by habit.
2. It was important that the tool integrated with Pro/ENGINEER. We didn't want to have to create another model for analysis and being CAD-embedded we could validate various analysis models repeatedly. We also wouldn't have any difficulty in switching between processes (from design to analysis).
3. A comprehensive database. FloEFD has a world-standard database. Especially, we are able to use other databases in the Mentor Graphics suite of products, such as FloTHERM. It has real benefits for users."

Improving Electronics Cooling Simulation

Mr Naoki Ishibashi at Epson notes that often the challenge when a company purchases a new tool is the adoption of its use within established teams with established processes. When Seiko Epson employed FloEFD the take up was swift. The product's intuitive environment was a contributing factor that quickly saw the number of license requests spread. "Actually, I didn't have confidence in the growth of users in the early days. After we tried one license as a test, there were many people who wanted to use it because a good reputation from other users had already spread. Now, we have six licenses. Sometimes I tried to say to some people, 'this software is really comfortable. You can use it anytime. Give it a try', and then the number of users increased. I didn't force them to use it at all."

By adopting FloEFD, Seiko Epson designers were able to affect designs as they developed, with the confidence that any discrepancies in results would be picked up by the analysis team during testing. FloEFD users found new ways to solve difficulties with their newly acquired skill set in analysis. Something the analysts weren't able to deliver as they serviced all the products in the company. Simulation is an essential part of the product development cycle at Seiko Epson so the usability by engineers of any tool is crucial.

"Computational Fluid Dynamics (CFD) is difficult for me even though I've been experienced in analysis for 20 years! However, the first time I tried to use FloEFD, I was amazed by its simplicity," said Mr. Fumio Yuzawa.

"Typical so-called 'high end CFD' software uses really complex meshing techniques. FloEFD requires you only select the resolution level between one and eight. However appropriate the mesh resolution levels are, an adequate number of cells is entrusted to the operator so we have accumulated know-how. If we have a lot of time and a high spec machine, is it better to use high level mesh? I think that's not necessarily so."
"One day, I had some difficulties with the analysis of fan air cooling. The difficulty was solved by using FloEFD for Creo. I didn't consider creating a one-to-one relationship between the characteristic of P-Q curve and the cooling system. I finally succeeded after trying to analyze the fan of air cooling." Mr. Fumio Yuzawa.

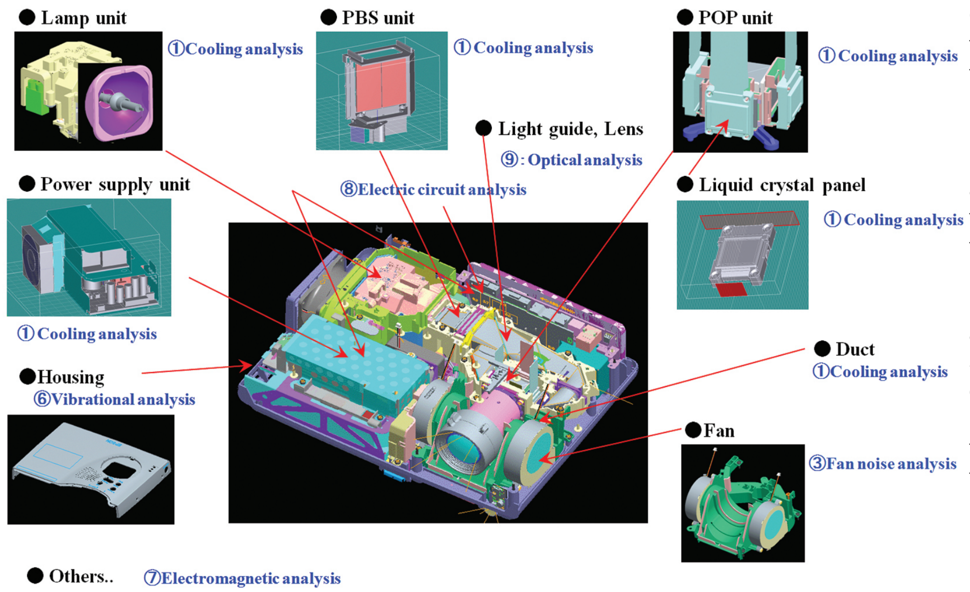


Figure 3. Analysis required for the improvement of design quality

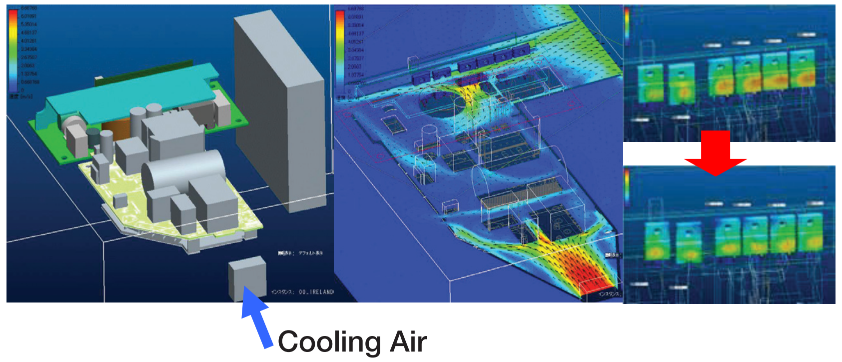


Figure 4. Verification of cooling airflow after changing a geometry path.

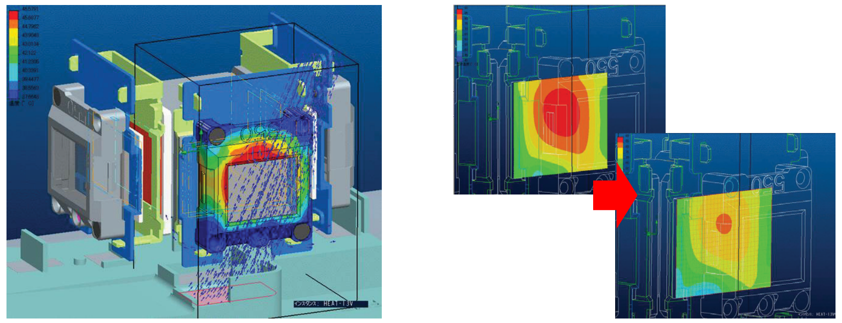


Figure 5. Design study based on a deflecting panel's temperature.

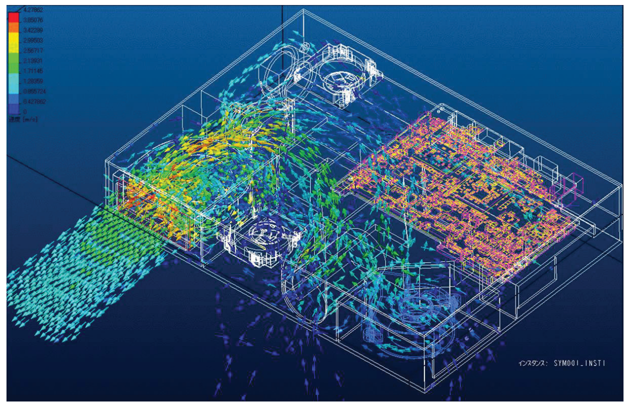


Figure 6. Cooling airflow verification inside of the whole enclosure.

FloEFD was able to assist in the challenges the team faced with design of semiconductors in projectors. Semiconductors reach high temperatures with natural air cooling and are typically designed under the 60% attainment of industry standards. Designer knowledge and experience will not achieve this level of attainment easily, so FloEFD proved to be the key to solving this challenge. "As well as ease of use and versatility, FloEFD is accurate" said Mr. Fumio Yuzawa, "while some complex parts still require specialist analysis knowledge there are others, such as enclosure air cooling, that can by-pass testing altogether as we are extremely confident in the accuracy of the results we are getting. FloEFD is essential in our daily work. In many cases, we can't predict the results of analysis but FloEFD leads us to correct results automatically."

The Future brings its own Challenges

"We want to tackle the problem of projector noise. Our projectors are spread worldwide, not only in Japan. There are some countries with high temperatures, humidity and elevation. We have to design to accommodate different environments as these variables cause the projector to be louder, which is inconvenient for the customer" said Mr. Shigeki Kikuchi. "The difficulty lies in the ability to attach larger fans into modern compact projectors. We use five or six small fans for cooling. A countermeasure for noise is absolutely needed so I joined this team as a sound analyst. We started to measure unpleasant noise over the recent few years and reflect these results in our products."

The world of technology is constantly evolving but Seiko Epson is at the forefront of projector innovation. The company is in the privileged position of being the pioneers as well as the leaders of their market space. Epson's projectors are widely utilized in offices, schools, retailers, museums, movie theaters, and living rooms. Most recently in 2011, Epson developed the Moverio BT-100. This revolutionary product is the world's first* standalone see-through mobile viewer that allows users to enjoy the big-screen experience anywhere and at any time. Moverio signaled Epson's intention to create a new visual communications culture. Going forward, Epson aims to leverage its original projection technology to create more original products that will deliver a big screen experience to all kinds of customers worldwide.

* According to Epson research as of November 25, 2011. The world's first civilian-use see-through mobile viewer that allows users to view video contents without being connected to another device.

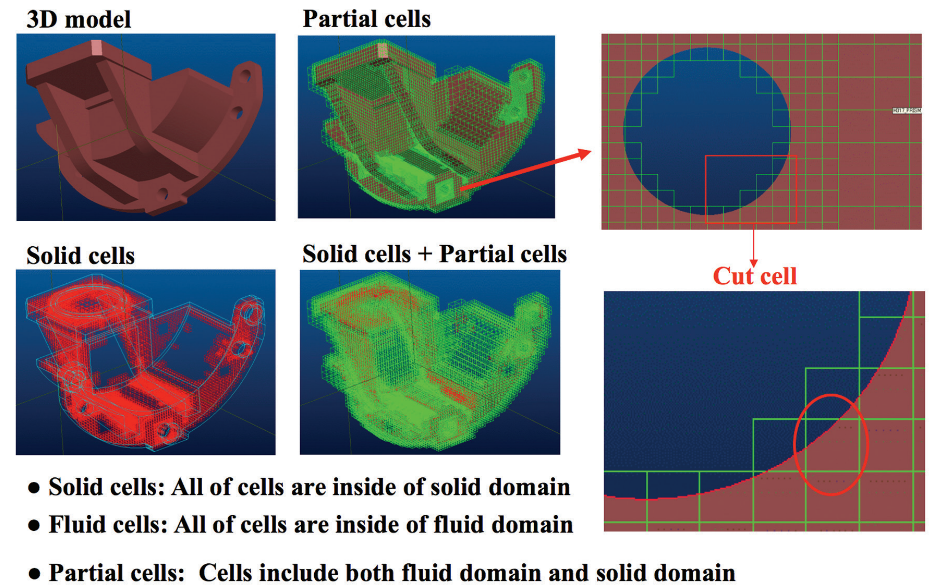
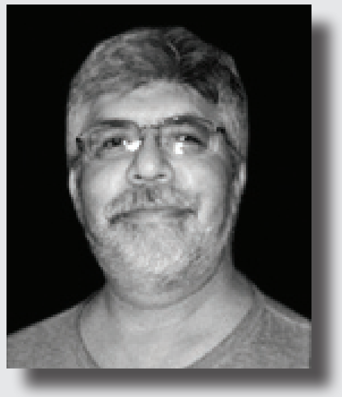


Figure 7. Optimization of mesh calculation.



Bill Maltz is the CEO of a dynamic Silicon Valley consulting company, Electronics Cooling Solutions Inc., in San Jose, California. Specializing in electronics thermal solutions, Bill is a veteran of the electronics cooling industry with nearly 30 years of experience in the field. He has also been an active member of the program committees for the Semiconductor Thermal Measurement, Modeling, and Management Symposium (Semi-THERM) and the International Microelectronics and Packaging Society (IMAPS) Advanced Technical Workshop on Thermal Management. He has also chaired technical sessions for Semi-THERM, IMAPS, the ASME InterPACK Conference and the I-Therm Conference; and played an active role in the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE).

Q. What was your earliest exposure to Computational Fluid Dynamics (CFD) for electronics cooling?
A. The earliest version of FloTHERM I can remember using was V1.2. I recall using the old pull-down menus in FloTHERM that were similar to the menus in Lotus 123. In the early days I was heavily involved with testing and analysis especially benchmarking of CFD codes. I spent a lot of time on the thermal design of forced convection boxes when I first started to work in the electronics industry. I also gained experience with Icepak when it came out in the mid-1990s.

Q. How does CFD software today for electronics cooling compare to that you used in your younger days?
A. I would say that CFD software can be used far more effectively today. 20 years ago we could use it to pick up flow and thermal trends. But now we can use it to make more accurate temperature predictions. We only had 64Mb of memory to work with in the mid-1990s. Today we have up to 32 Gb to play with. This means we can now have multi-million cell simulations. And of course solvers are commensurately quicker. The timescales involved in modern consumer electronics prototyping are such that it would be impossible to do benchmarking in electronics cooling these days using a general purpose CFD tool because the market moves too quickly.

Q. How has electronics cooling design workflows changed over the last 25 years?
A. It took us four to five years to design a computer system 20 years ago. Today the design cycle is much shorter. 25 years ago we relied mainly on physical testing. But with shorter design cycles the amount of time available for testing has been significantly reduced and we now rely heavily on CFD simulation tools during the design cycle.

Q. Are colleges producing enough mechanical graduates for electronics cooling simulation industry needs today?
A. Definitely not. In addition, I would add that most colleges and universities are not preparing their students to be effective in a product design environment. Students that complete advanced degrees and acquire a good understanding of CFD fundamentals typically lack practical exposure to product design requirements. At the same time there are many engineers with good product experience who lack the background to work successfully with CFD applications.

Q. What is peculiar to Electronics Industry design flows in your opinion?
A. In my view, the electronics industry is not a mechanical engineering centric industry. It is more focused on software and electrical driven product features. If you compare electronics to the automotive or aerospace industry for instance, the product features in these other industries have far more mechanical engineering content.
An electronics enclosure used to house leading edge electronics may be priced at $1,000. The electronics and software housed in the enclosure on the other hand may be valued at over $250,000. Since it is the electronics and software that give the product value, the mechanical design is driven at best by the hardware requirements. In some cases it is treated as an after-thought.

At the same time the trend to package more electronics in smaller volumes, means that the thermal design has become a more important part of the product design. Higher power density requires that more attention be paid to the cooling of the electronics.

Q. How important is multiphysics simulations in the consumer electronics space?
A. The electronics industry for the most part has not adopted a multiphysics simulation approach. Design parameters such as structural, thermal, acoustics, electromagnetic compliance, and safety are often addressed by different sets of engineers using different methodologies. While thermal engineers make extensive use of simulation tools, several of these disciplines place more reliance on hand calculations and rule of thumb methodologies, engineering experience and empirical testing.

Q. What do you see as the future for electronics cooling?
A. American companies are still at the cutting edge of electronics innovation in both the consumer as well as the commercial space. However, we will need to pay more attention to total power of products, lack of space for dissipating heat, better heat spreading technologies, and the use of new materials for thermal management.
In consumer products "more bang for the same battery space" is needed. The real game changers will be new battery technology and new materials. Phase change materials will help to mitigate some transient heat dissipation concerns. However, the amount of functionality delivered to the end user will always be restricted by Newtonian physics. We will also continue to weigh the pros and cons of natural convection versus forced convection cooling. Manufacturing has largely moved to Asia in the last 20 years but high end design has mainly stayed in North America, Europe and Japan. I expect more design to move to Asia. This will be especially true as products become commoditized. But we can also expect to see new technologies coming along such as hologram TVs, and TV wallpaper on our walls. There will also be other new horizontal markets that will require thermal design such as wearable consumer electronics.

We can expect to see incandescent and even fluorescent lighting disappearing as LEDs become the more predominant source of lighting in the future. This too will create new thermal design challenges. In short, new opportunities for electronics thermal will emerge in the future and the electronics cooling market will remain large.

Further Reading:

1."Thermal Management Challenges in the Passive Cooling of Handheld Devices" by G. Wagner and W. Maltz, 25-27 Sept 2013, THERMINIC 19, Berlin, Germany.
2."Validation Studies of DELPHI-type Boundary-Condition-Independent Compact Thermal Model for an Opto-Electronic Package" by G. Wagner, W. Maltz, A. P. Raghupathy, A. Aranyosi, 7-9 Oct 2009, THERMINIC 13, Leuven, Belgium.

Comparing Tablet Natural Convection Cooling Efficiency

Consumers are rapidly switching from desktop computers and laptop computers to tablets and smart phones for their computing, gaming and communication needs.

By Guy R. Wagner & William Maltz, Electronic Cooling Solutions

Handheld devices are increasingly capable of running applications that used to require high performance PC systems. With a smaller form factor, this presents significant challenges, especially when one considers that passive cooling is almost an absolute requirement.

With the rapidly increasing performance of tablets and smart phones, the result is increased power consumption leading to devices that are uncomfortably hot to hold. This is especially true after watching videos or playing games on these devices has become very popular. These types of operations are both CPU and graphics intensive which involve much higher power dissipation than viewing a relatively static screen. The thermal design of the next generation handheld tablet device and smart phone will need to address both a comfortable surface touch temperature and maximum temperature limitations of critical internal components while also meeting aggressive industrial design requirements.

The limits of cooling for handheld devices explored in this study are based on both testing and simulation under various conditions, and provides a method for evaluating the quality of the cooling options for these devices. Factors affecting the maximum possible power dissipation are: surface area and emissivity; outer shell materials; thermal interface materials; heat spreader properties; and air gaps. The limiting factor in the thermal design of these devices is generally the touch temperature of external surfaces. There have been studies that address the maximum allowable touch temperature of a handheld device. This article discusses the effect of maximizing the heat spreading within these devices which aids in keeping the touch temperatures of these devices within comfortable limits.

Performance Expectations

Handheld devices are increasingly capable of running applications that used to require their more powerful predecessors. The user expects these devices to provide similar performance to the notebook and desktop computers that were commonly used in the past. This presents significant challenges, especially when one considers that passive cooling is almost a requirement in these small form factor devices. Several studies have focused on the cooling challenges of hand-held devices; Brown et al [2], Lee et al [5], Mongia et al [6], Huh et al [4], and Gurrum et al [3].

Maximum Power Dissipation

The maximum possible power dissipation by natural convection and radiation has been calculated for this study using FloTHERM® CFD simulations and is shown in Figure 1.

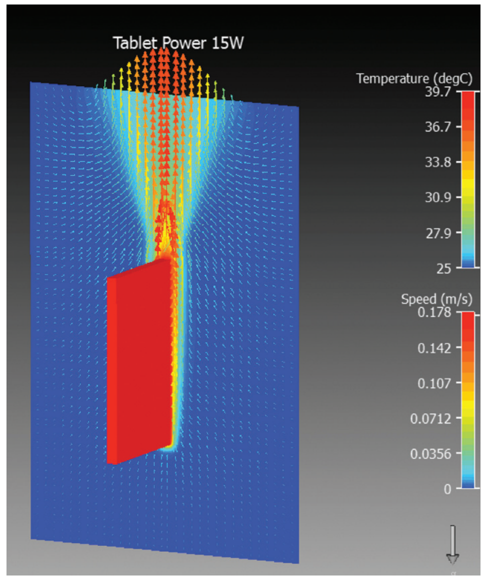


Figure 1. FloTHERM® CFD Model of a 10 Inch Tablet in a Vertical Orientation

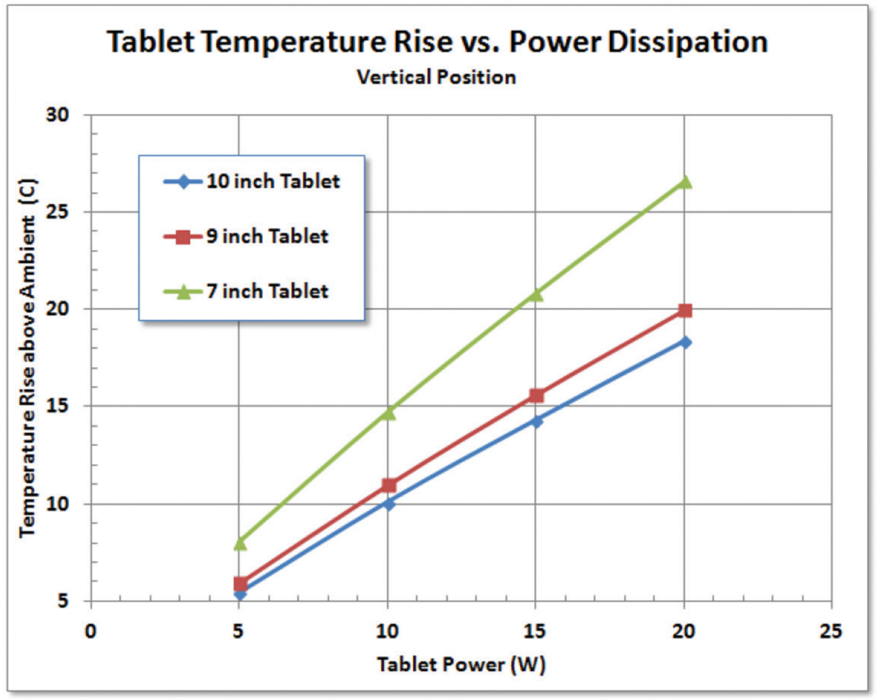


Figure 2. Temperature Rise Above Ambient as a Function of Tablet Power

In a 25°C ambient condition, the maximum total power dissipation is calculated with the requirement that the surface temperature does not exceed a touch temperature of 41°C. This is the maximum aluminum enclosure comfort touch temperature as presented by Berhe [1].

It can be seen that the theoretical maximum total power dissipation is 17.1 watts when a 10 inch tablet is suspended vertically in mid air with conduction and radiation occurring from all surfaces. When the device is placed on a horizontal adiabatic surface, heat transfer occurs from the sides and front surface only. These values establish bounds for the maximum amount of heat that can be dissipated by the device for different orientations in still air.

In order to calculate the total power dissipation for a full-size tablet, the following assumptions were made as inputs to the FloTHERM model with 610k elements: a typical 10 inch tablet size of 180 mm (w) x 240 mm (h) x 10 mm (d) with an ideal condition of uniform surface temperature. The tablet was simulated as a very high thermal conductivity block (k = 10000 W/mK) with uniform internal heat generation to yield an essentially isothermal surface. With an ideal surface emissivity of 1.0, the radiant heat transfer component accounts for a surprising 9.9 watts of the 17.1 watts total power while the convective heat transfer component is 7.2 watts. Since radiation can account for more than half of the total power dissipation at an ambient temperature of 25°C, the use of high emissivity surfaces finishes is very important.

In order to achieve maximum power dissipation, design parameters need to be considered carefully. It is important to design the device to be as isothermal as possible to maximize the amount of heat transfer from all surfaces to the surroundings. If a surface is no longer available for heat transfer, such as when the device is placed on a blanket, the amount of power that can be dissipated is almost cut in half.

The power dissipation at 41°C maximum touch temperature is calculated using CFD for three devices ranging from smart phone size through to mini and full-size tablet, the power dissipation versus surface area is shown in Figure 3, for the device in both the vertical and horizontal positions with an adiabatic lower surface. There is a high probability that the tablet will be used in the horizontal position with a near-adiabatic

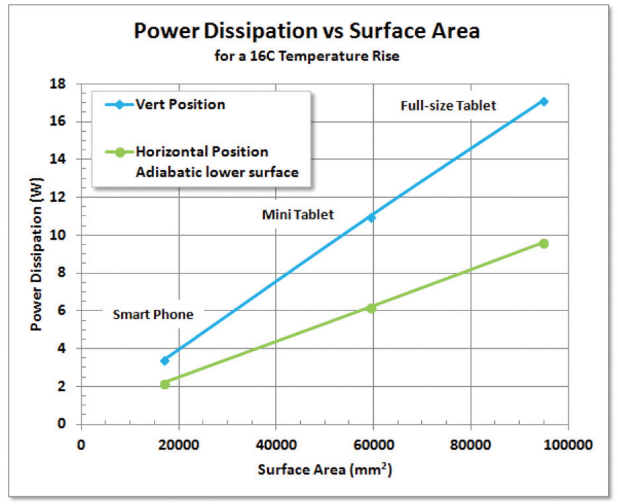


Figure 3. Power Dissipation vs. Surface Area for a Device with a 41°C Skin Temperature

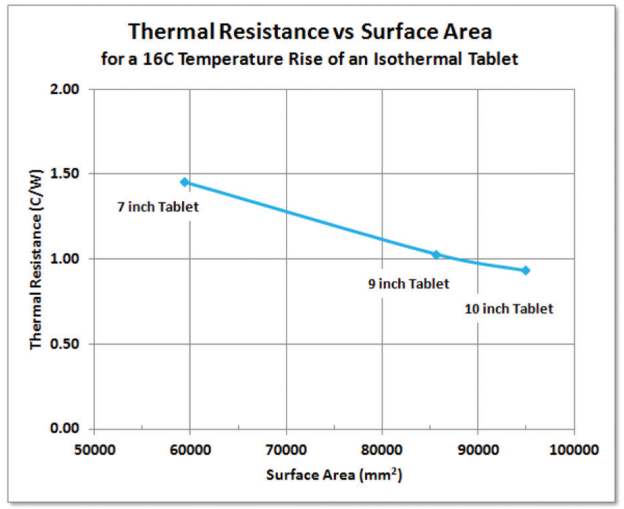


Figure 4. Thermal Resistance vs. Surface Area for a Vertical Isothermal Device with a 41°C Skin Temperature

lower surface while the smart phone will rarely be run in this orientation. From the power and temperature rise computations, it is now possible to calculate the thermal resistance of a vertical, isothermal tablet as a function of the exposed surface area as shown in Figure 4.

Numerical Models

In order to analyze the impact of different thermal management techniques, a detailed Computational Fluid Dynamics (CFD) thermal model was constructed using FloTHERM XT™. Since the thermal characterization data for the main processor in the tablet may not be known, the thermal characteristics of the actual processor can be measured with a high degree of accuracy using Mentor Graphics' T3Ster® hardware to determine the thermal resistance from the processor IC to the case and the PCB; Wagner et al [7]. This allows accurate capture of heat flow from the top and bottom of the processor. The thermal model of the processor can be directly dropped into the tablet CFD model. The adaptive mesh in FloTHERM XT allows the fine features of the internal components of the tablet to be included in the model while keeping the mesh count to a reasonable size as shown in Figures 5 and 6 (overleaf).

With the CFD thermal model, the following questions can be addressed:

1. How much do high-conductivity heat spreaders improve heat dissipation while reducing the touch temperature?
2. What is the best way to move the heat from the heat-producing components to the surfaces of the tablet where it can be safely dissipated?
3. How can air gaps be strategically used in the thermal management process?
4. How important it is to account for radiation in addition to convection?
5. Should the dissipated power be spread at the source or at the surface?

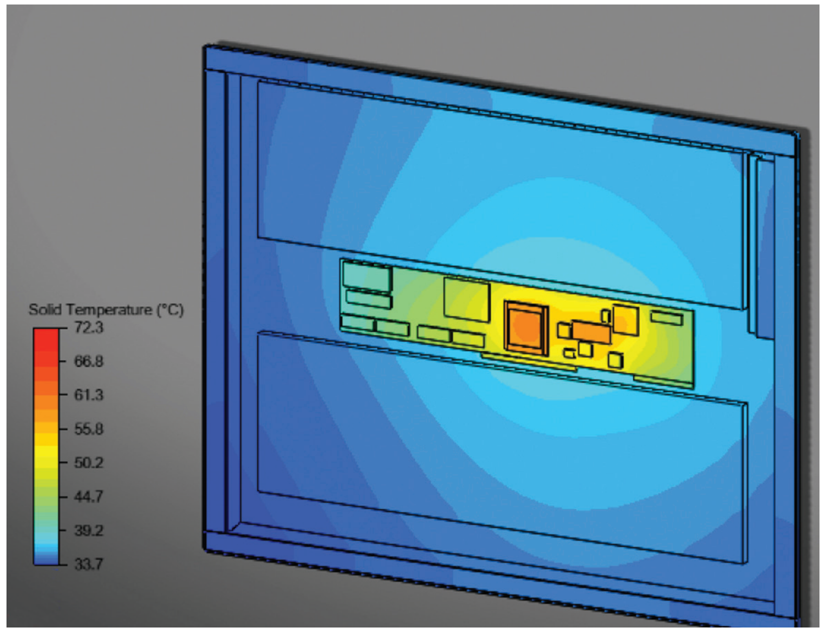


Figure 5. FloTHERM XT Model of the Internal Component Temperatures of a Tablet

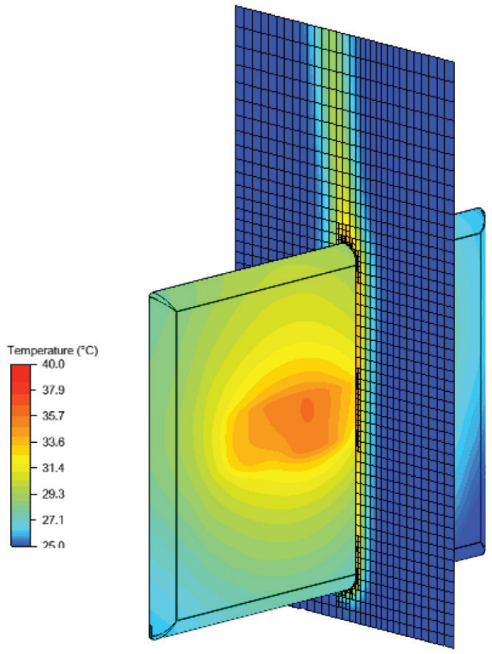


Figure 6. FloTHERM XT Model Showing the Hot Spot and the Natural Convection Airflow around the Back of a Tablet

6. How does designing the tablet with a plastic case compare to an aluminum or magnesium case?

Since we have a goal of keeping touch temperature at or below 41°C, answering question #1 has a large impact on the design.

Temperature uniformity can be achieved by either providing a high conductivity heat spreader inside the case of the tablet or by making the case itself out of a high conductivity material; Wagner et al [8]. One must keep in mind that the maximum touch temperature is a strong function of the conductivity of the heat spreader or case. As the conductivity of the case goes down, the maximum comfortable touch temperature increases. For example, if the case is made of plastic with a thermal conductivity in the range of 0.2 W/mK, the case temperature that the user senses feels lower since the low thermal conductivity of the plastic conducts less heat to the user's skin. The apparent touch temperature decreases as the product of thermal conductivity, density and specific heat (k.ρ.Cp) of the case material decreases. When this product is low, the touch temperature may be increased by approximately 5°C over that of a solid metal case. Since the surface area of the case is large relative to the thickness of the plastic, heat transfer to the air is not reduced significantly over that of an aluminum case. This assumes that the heat is spread across the inside surface of the plastic housing using a high-x-y conductivity aluminum plate or graphite sheet.

Infrared Images

When evaluating the effectiveness of heat spreaders, whether internal or through the use of high conductivity case material, it is very useful to take infrared images of the units under test while they are performing at their maximum computation levels. It has been found that graphic intensive processes also require considerable computation and will exercise the tablet at maximum power. In general, it takes a minimum of 30 minutes for the tablet to reach a steady state temperature. Figure 7 shows three tablets running the same game during thermal testing.

Since the emissivities of the tablet surfaces are not always known, thermocouples are placed at various locations on the front and back of the tablet to read the temperatures at selected locations. The emissivity setting of the image from the IR camera is adjusted until the difference between the thermocouple readings and the IR image is minimized.

Figure 8 consists of infrared images of the back side of four different models of tablet. The tablets were running a game called Riptide GP, while the graphics and computational capabilities of mobile devices were measured. Ambient air temperature at the time of the test was recorded for each tablet to determine the temperature rise of the hot spot. The dark area running up the center of tablet A is from the support that was holding that tablet in the vertical position.

Note how the location of the hot components inside "print through" the case forming a hot spot.

Figure 7. Images of three Different Tablets Running Riptide GP while Temperatures are being Monitored with Thermocouples.

Figure of Merit for the Quality of the Thermal Solution

Since heat spreading is the most important factor for dissipating heat from the outer surface of the tablet and reducing the temperature of the hot spots, the authors propose the following figure of merit to determine the effectiveness of the thermal design of the tablet.

The thermal heat spreading efficiency of the tablet can be defined as the ratio of the ideal thermal resistance of an isothermal tablet divided by the measured or simulated thermal resistance of the actual tablet. The thermal resistance of an isothermal tablet with emissivity equal to 1.0 is the very best that can be achieved on a theoretical basis. The isothermal thermal resistance is calculated by dividing the temperature rise above ambient by the dissipated tablet power for an isothermal tablet. The actual thermal resistance is calculated by dividing the temperature rise of the hot spot above ambient by the dissipated tablet power.

Heat Spreading Efficiency = R_i/R_a

$R_i=\Delta T_i/Q_i$ Thermal resistance of an ideal isothermal tablet

$R_a=\Delta T_a/Q_a$ Thermal resistance of an actual tablet

Where

ΔT_i = Temperature rise above ambient for an ideal isothermal tablet with emissivity = 1.0

Q_i = Power dissipation of the ideal isothermal tablet

ΔT_a = Temperature rise of the hot spot above ambient for the actual tablet

Q_a = Power dissipation of the actual tablet

The table below summarizes the results of the testing for the four tablets and calculates the heat spreading efficiency of the thermal design for each tablet.

Summary

In summary, building an accurate thermal model of the tablet allows the designer to rapidly test the effect of design and material changes without incurring the cost and schedule delays of testing prototypes. This speeds time to market and lowers development costs.

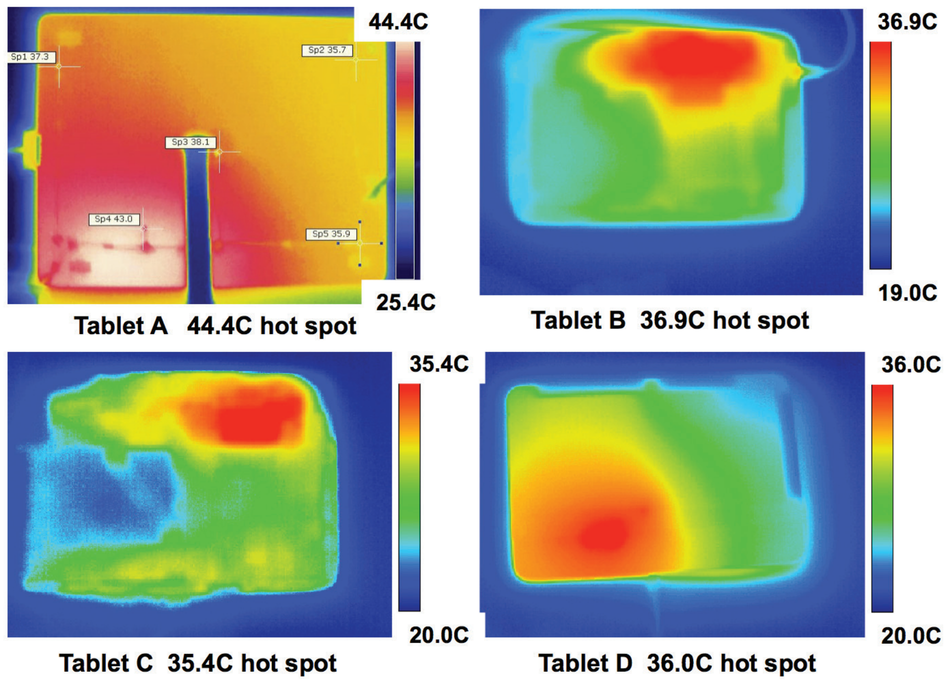


Figure 8. Infrared Images of the Back Side of Four Different Tablets Running Riptide GP

The maximum power dissipation of the internal components is not only governed by the size of the tablet but is a strong function of how well that heat is spread internally to reduce hot-spot temperatures. Few engineers realize the importance radiation plays in dissipating the heat from the exposed surfaces of a tablet. It is not until precise calculations are made that the importance of radiation in the thermal design of tablets really becomes apparent. If the emissivities of the various surfaces are high, over half of the heat transfer is due to radiation.

Introduced is the Heat Spreading Efficiency figure of merit which measures the actual cooling efficiency of a tablet against the theoretical maximum cooling efficiency. The perfect thermal design for a tablet cooled under natural convection would have a Heat Spreading Efficiency of 1.0. However, tablet thickness and weight have to be traded off against efficiency.

Heat Spreading Efficiency

	Tablet			
	A	B	C	D
Ambient Temperature (C)	25.4	19.0	20.0	20.0
Hot Spot Temperature (C)	44.4	36.9	35.4	36.0
Actual Delta T (C)	19.0	17.9	15.4	16.0
Power (W)	8.8	6.9	7.2	5.2
Ra (C/W)	2.16	2.60	2.14	3.05
Delta T iso (C)	16.0	16.0	16.0	16.0
Power-isothermal (W)	17.1	17.1	17.1	15.5
Ri (C/W)	0.94	0.94	0.94	1.03
Heat Spreading Efficiency	**0.43**	**0.36**	**0.44**	**0.34**

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Implementing Practical Fan Curves in Datacenter Simulations

Datacenters are among the most energy consuming facilities. The current trend is continuously increasing to satisfy the growing needs of E-commerce and other revolutionary technologies such as cloud computing. We use CFD, to model variable flow devices that exist in a typical datacenter.

By Sami Alkharabsheh, State University of New York at Binghamton

Mechanical Analysis Division's FloVENT® product has been the simulation engine for a datacenter modeling for 25 years. In a new track at the IEEE SEMI-THERM conference in 2013 a technical paper presented [1] that investigated the validity of a common modeling assumption when using Computational Fluid Dynamics (CFD) to predict and analyze air flow and temperatures in datacenters.

It is often assumed by CFD practitioners when performing datacenter simulations that the volumetric air flow rates provided by a Computer Room Air Conditioning (CRAC) unit and a server are constants. The rationale for this approach is the assumption that the resistance to air flow within a CRAC unit and a server will be far larger than any other air flow resistance present in the datacenter. If that's true, then the system impedance curve of the CRAC unit can be used with the CRAC blower performance curve to read off the operation point of the unit. A similar approach can also be applied to servers. Figure 1 shows the representative datacenter considered in this study.

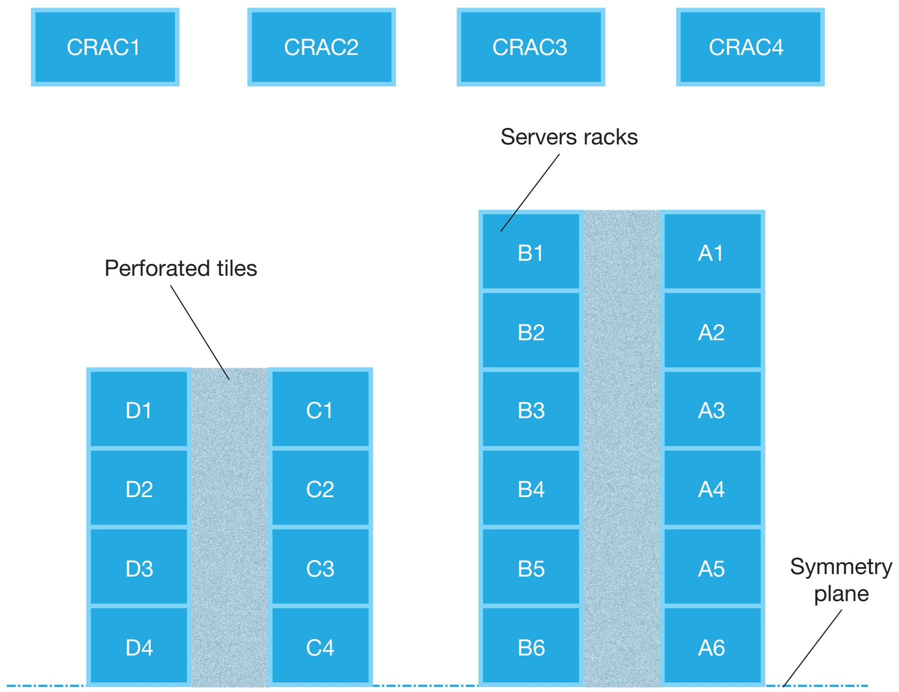


Figure 1. Plan view of the datacenter layout being considered

The internal elements of CRAC units include filters, cooling coils, baffles, ducting, and is generally a very cluttered and restrictive piece of equipment to move air through. The other sources of pressure drop in the datacenter are all external to the CRAC unit: movement of air throughout the datacenter space, under the raised floor, through the perforated tiles and in and around the electronics equipment. The assumption investigated in our paper was how large is the ratio of 'external' to 'internal' losses in a datacenter, and what impact could this have on the commonly used fixed flow rate in the modeling method of the CRAC units and the servers. The chart in Figures 2 & 3 demonstrates the potential impact on the expected flow rate from the CRAC unit blower if the 'external' losses are 10% and 25% of the 'internal' losses.

The change in CRAC unit flow rate by considering the external losses are indicated by the horizontal arrows. For this chart, the impact of including the external loss in the impedance curve is not large as the blower performance curve has a steep slope in the vicinity of the operating point. If the operating point was near a flatter portion of the blower curve, then the CRAC flow rate would be more sensitive to changes in the external static pressure contributions that would be caused by adding or removing electronics equipment, partitions or floor tiles.

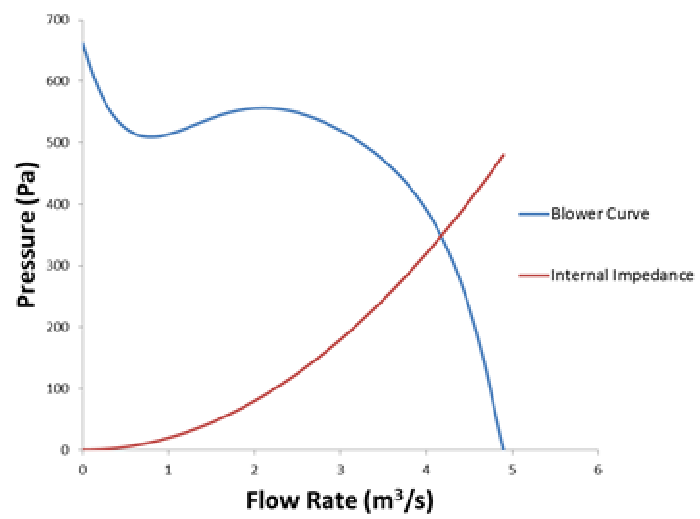


Figure 2. Blower curve used with a typical system impedance curve.

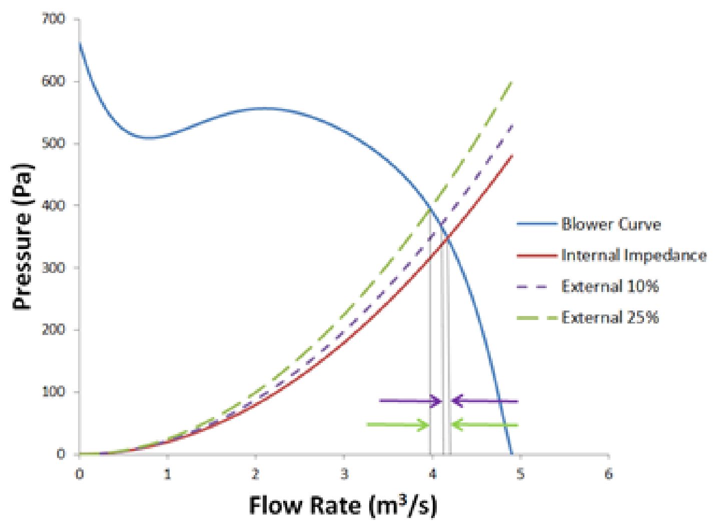


Figure 3. Effect of the external static pressure on the operating point of the CRAC blower

With an application specific simulation tool like FloVENT we can investigate such assumptions in real environments as was done in the paper. FloVENT has SmartParts for various objects commonly needed for a datacenter analysis, such as CRAC units, racks, perforated tiles, fan curves, flow resistances, as well as a parts library for easy retrieval of previously defined parts. Each of these SmartPart objects has a specific set of tailored data available after a solution. For a fan curve definition, this tailored data includes the operating point of the fan, and thus the static pressure observed by the fan in the model.

The methodology[1] to evaluate the CRAC fixed flow rate assumption involves the creation of a datacenter model and using the object specific results reporting in FloVENT to extract the external system impedance for each CRAC unit, followed by calibration of the internal flow resistance definition to match the observed flow rate with the manufacturer's blower performance curve. For the final calibrated operating point, in the paper[1], the external static pressure was 0.22 inches of H_2O and the internal static pressure was 2.82 inches of H_20, a ratio for external/internal of 7.8%. The CRAC unit models with calibrated fan curves were placed in a simulation for an approximately 1,723 ft^2 datacenter with a typical hot aisle, cold aisle rack layout. The variation in flow rates from the calibrated fan curve CRAC models was less than 120 ft^3/min, which is less than 1% of the average CRAC unit flow rate. This data suggests that the common fixed flow rate assumption for CRAC units would produce satisfactory results in this model. This was the expected result with the datacenter model in question being considered fairly open. It was suggested in reference 1 that future work from the authors could explore the sensitivity of this approach in datacenters where the external impedance curve is expected to be more significant, such as in containment systems.

Reference:

[1]. S. Alkharabsheh, B. Sammakia, S. Shrivastava, R. Schmidt, "Utilizing Practical Fan Curves in CFD Modeling of a Data Center", SEMI-THERM 2013, pp 208-212.

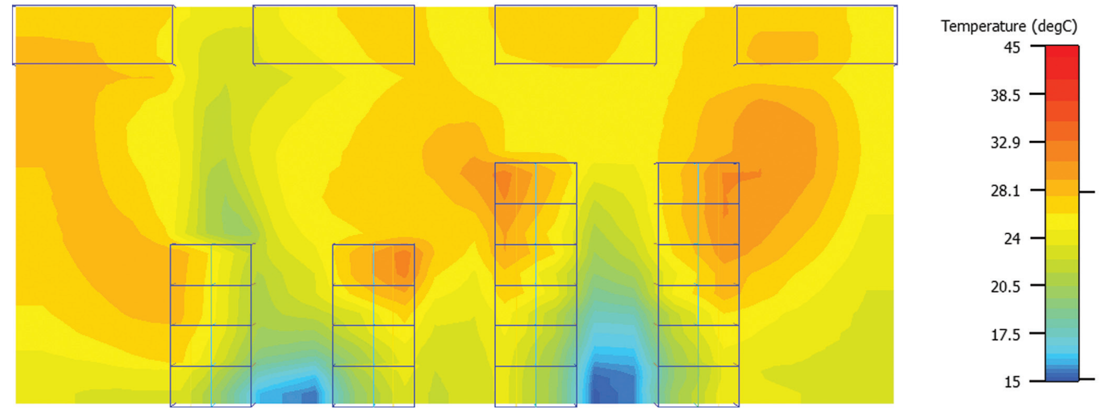


Figure 4 . Plan view of the datacenter layout being considered with FloVENT predicted temperature contours

More Power Please!

What do Tim, the Toolman, Taylor in the TV-Series "Home Improvement" and Raul Cano at Stanley Black & Decker have in common? The need for "More power!!"

By Boris Marovic, Industry Manager, Mentor Graphics

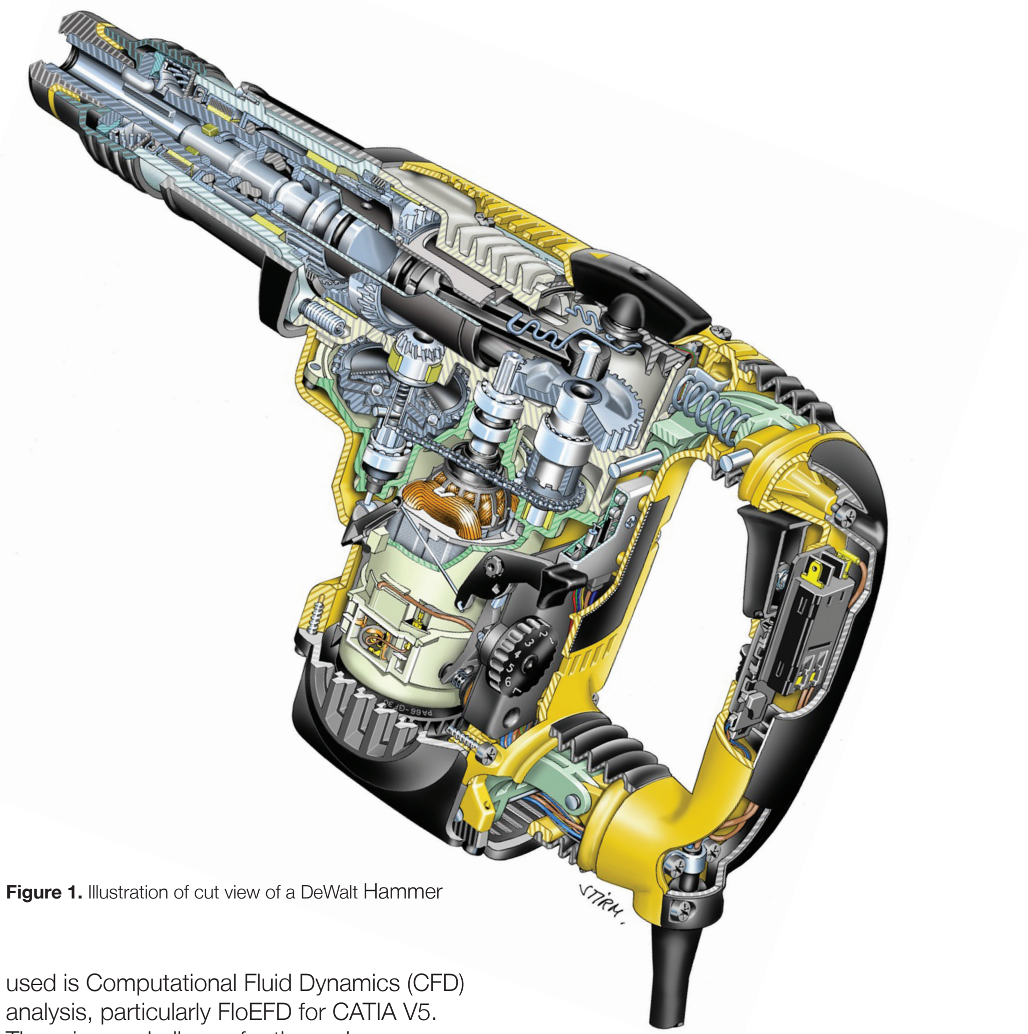


Figure 1. Illustration of cut view of a DeWalt Hammer

Unlike Tim, Raul Cano is a professional and is the Lead Project Engineer CAE for Stanley Black & Decker's DeWALT Professional Tools brand. He and his team are responsible for optimizing the performance of their hammer tools, namely the Rotary Hammer, Demolition Hammer, and Hammerdrills as well as concrete saws and dust extraction for large hammers.

DeWALT's reputation in the power tools and construction tools industry is unsurpassed. For almost 80 years DeWALT has earned a name for designing, engineering and building the toughest industrial machinery. The company incorporates their long standing tradition of state-of-the-art engineering into every product of their broad range of high performance portable electric power tools and accessories. Making DeWALT tools the number one selling brand of professional power tools in North America, and the fastest growing professional power tool brand in the world for the past five years.

The mission for professional tools from DeWALT is to deliver optimum performance and reliability. In order to achieve this, Raul's team investigate several numerical simulations including drop, stress and thermal simulations. One of the methods used is Computational Fluid Dynamics (CFD) analysis, particularly FloEFD for CATIA V5. The primary challenge for thermal simulations is the need to process complex geometries such as the narrow spaces inside a handheld power tool where the motor, gearbox, and electronics are situated. This housing is built with stiffening ribs that not only makes such a power tool so robust but also complex. As with many, if not all, tools of this nature, the challenge is thermal. The use of FloEFD in their design process helps Raul to test design variations for venting, fan position and geometries, as well as housing changes for better airflow. In the case of the metal housings of the gear box, FloEFD is used to improve the cooling performance of the gear box.

Raul comments, "The capabilities of FloEFD to handle complex geometries allows us to simply switch between different component designs such as different fans and then let the software automatically mesh and calculate several variants over the weekend, is an enormous advantage for us."

By having the ability to test so many variations of geometry it is possible to find the best solution for optimum airflow, both for quantitative flow rate and noise. With FloEFD, Raul is able to determine if a certain geometry change has a positive influence on the volume flow rate through the tool as well as find areas with very high velocities which can be indicative of a high noise source in the design.

The primary role of the airflow in the power tool is of course, thermal management. The better the airflow the more efficiently the motor can be cooled, thus allowing the power of the tool to be increased. One study showed that an existing bearing housing design that contained fins for better thermal management, although it made the part more expensive and heavier, was still justified when compared to a housing version without the fins (Figure 2) as simulations have shown. In case of the housing without the fins, the surface temperature of the external housing of the tool increases by 30°C in some regions (Figure 3).

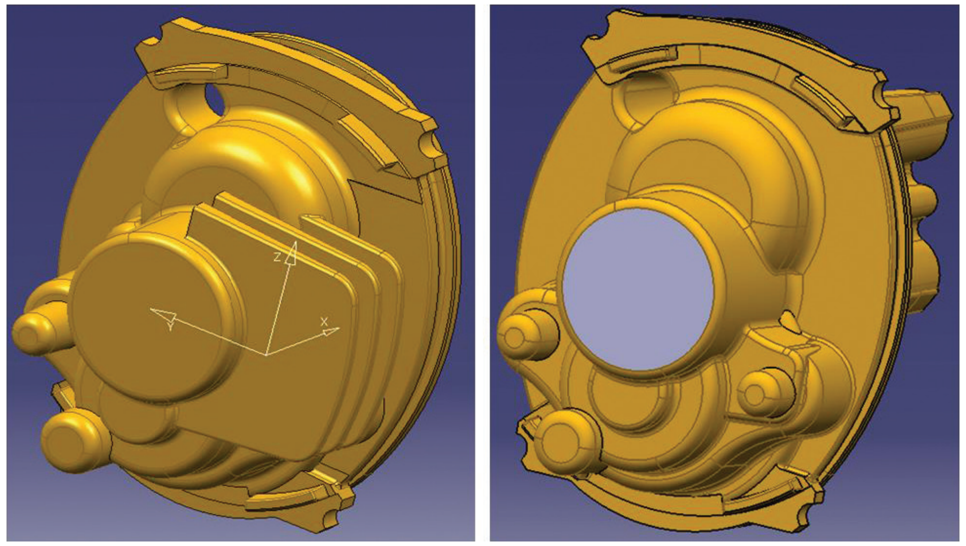


Figure 2. Bearing housing variants with (left) and without (right) cooling fins

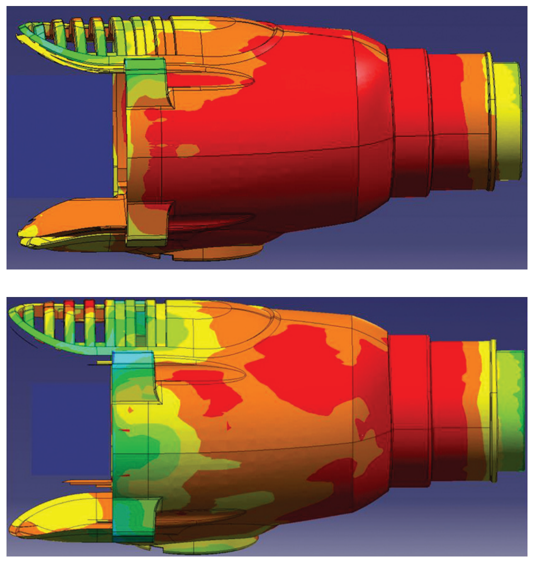


Figure 3. Temperature profile of external housing of a hammer showing the influence of the bearing housing without (top) and with (bottom) cooling fins

In the case of the Large Hammer Dust Extraction – Hole Cleaning tool, the team at Stanley Black & Decker were able to reduce the wear of the hose attached to the unit and the vacuum cleaner. The wear at the hose was caused by the high concentration of concrete particles from the drilling of a hole that impacted the hose at a certain location causing a high abrasion rate. Just by optimizing the airflow path and its bends to reduce the impact of the particles, Raul was able to reduce the wear by around 60%. As a result the lifetime of the hose increased by a factor of two.

In another case, a range of simulation variants with different components of the Alligator Concrete Saw was conducted (Figure 4) to optimize the performance. The goal was to optimize the flow rate by makings changes to the fan, fan RPM and other components. The measurements in the lab at the end showed that even the noise was reduced by 10dB. A reduction of 10dB of noise is equivalent to around an eighth of the original noise (3dB equal half the noise).

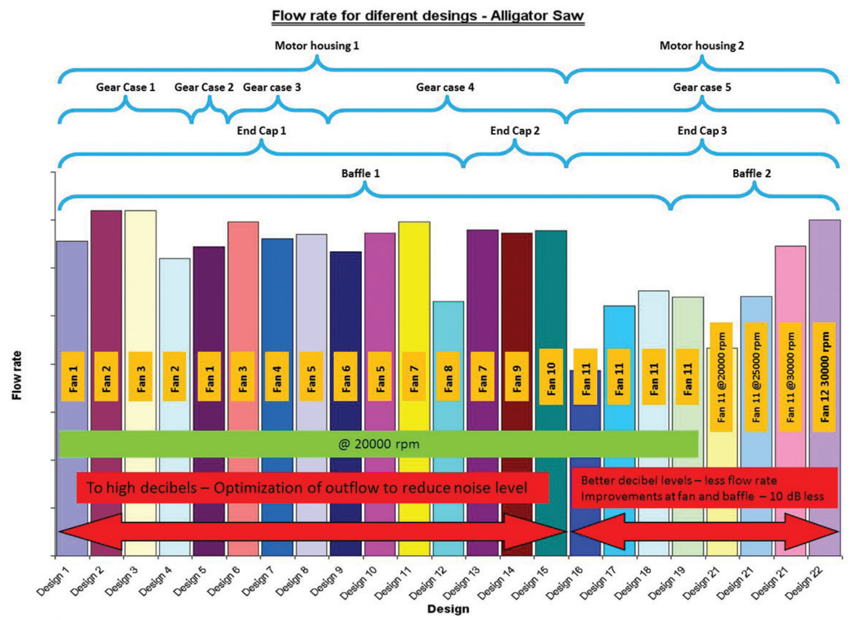


Figure 4. Flow rate variation of different component design iterations of the Alligator Concrete Saw

The design of the power tools at Stanley Black & Decker are influenced by several departments and requirements. "If the drop test simulations don't go well we have to redesign the housing which might make it necessary to change locations of venting openings. On another occasion the marketing department played with the rapid prototyped sample and found it is too thick or too long at a certain area of the housing which means we need to try to change it if possible and that often influences the flow paths in the tool that might reduce the flow rate due to too high pressure losses." explains Raul. "All the desired changes have to be evaluated by multiple factors which might increase the price, the weight or size in one way or another. At the end of the process, the design has to perform at its best and the thermal simulations with FloEFD provide us reliable results to make sound judgments on the design changes we make."

"Stanley Black & Decker uses several FloEFD licenses in our development centers in the US, UK and Germany and I have personally used it for over five years now with great success. We have several projects over a year and in each the number of simulation runs can vary from just a few to 20-30 simulations per project." says Raul.

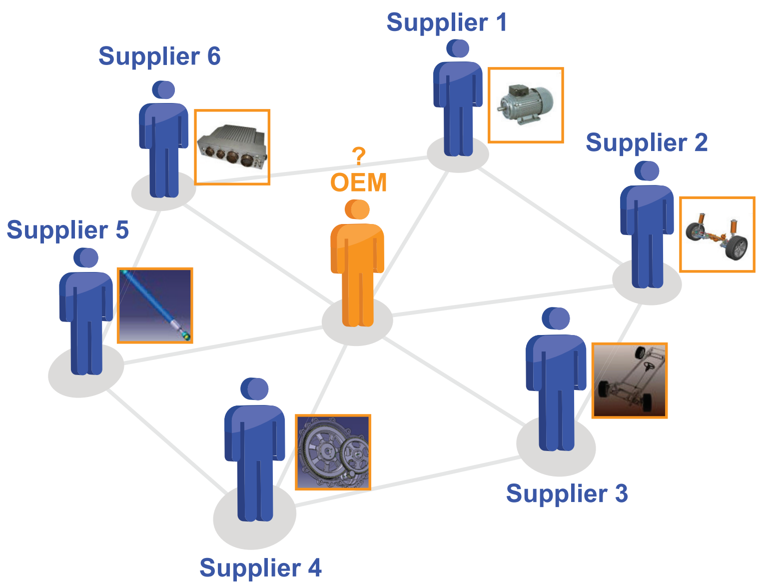
Co-Simulation capabilities from xMOD™

By Steve Streater, Flowmaster Product Manager, Mentor Graphics

It is almost universally recognized that simulation is a key factor in helping to reduce product development costs. In particular 1D models are an excellent basis for collaborative development, not only by the nature of their relatively small file sizes and fast run times, but by allowing virtual prototyping to be carried out much earlier in the design process before any CAD geometry is available.

As key enabler of collaborative development, co-simulation platform tools (also known as coupling environments or middleware), are finding growing popularity as a means of solving the ever more technically complex challenges that face automotive and aerospace system designers. However, co-simulation brings its own challenges and so we must recognize two fundamental co-simulation dichotomies. Firstly, coupling different simulation tools can be technically difficult, but conversely, large monolith models are unwieldy and computationally intensive.
Secondly, coupling via co-simulation platforms makes this task much easier, as it removes the need for the user to create a bespoke adapter, and provides a user-friendly environment for managing the co-simulation, but can mean significantly increased license costs. So these conflicting requirements inevitably mean that compromise is needed.

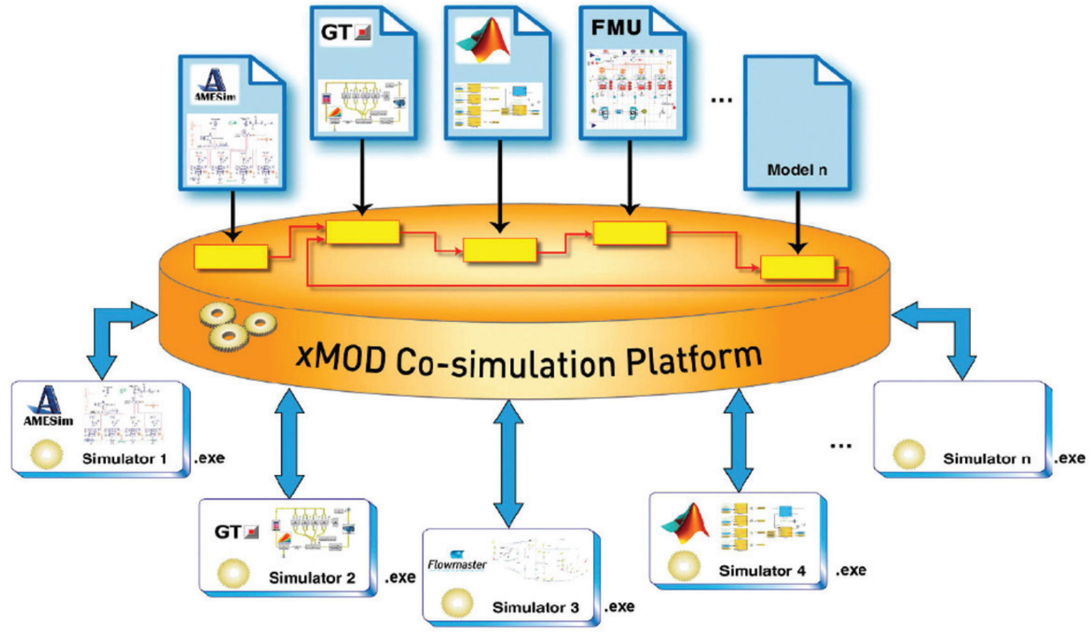
Against this industry backdrop, D2T's xMOD™ product is the latest co-simulation platform tool to add a Flowmaster link to its compatibility list. This important development was the result of a collaboration with D2T under the Mentor Graphics OpenDoor Program, allowing a development license to be granted to D2T early in 2013, followed by market release of the Flowmaster® link for xMOD last October. The over-arching concept for xMOD is that it is intended to link heterogeneous models through a versatile and efficient coupling process. This is achieved by optimising model execution through multi-cored and multi-threaded processing with individual solvers, and by providing a standalone model execution capability thus avoiding the need for separate application licenses. However, xMOD also provides some additional benefits, including compatibility with emerging standards through the integration of new simulation methodologies such as Functional Mock-up Interface (FMI), as well as continuity in the transition from Software-in-Loop (SiL) to Hardware-in-Loop (HiL). Finally, xMOD allows customization of graphical user interfaces which can be essential when facilitating 'non-expert' end user access.

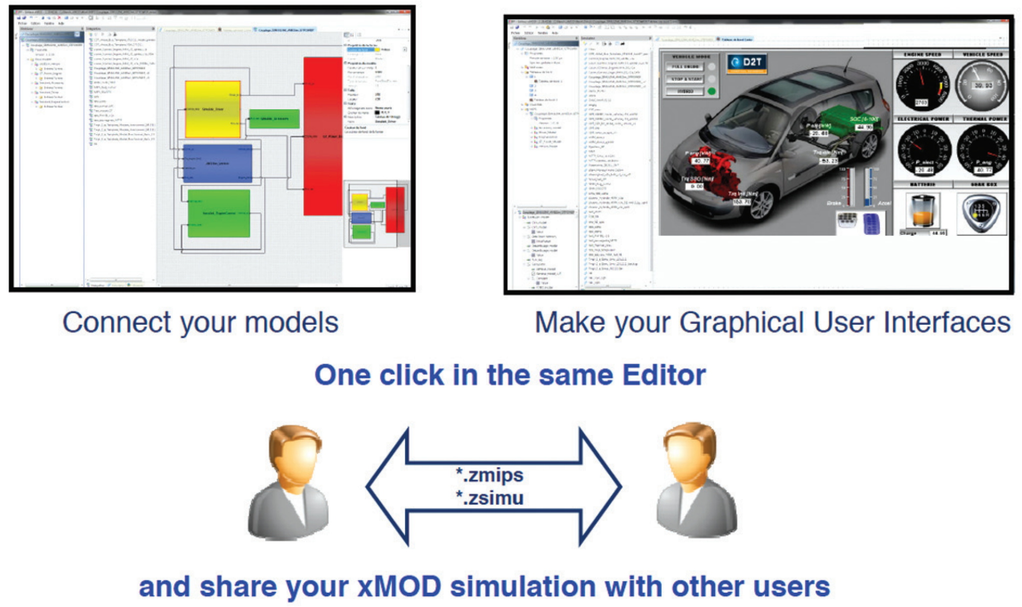


xMOD is capable of running two principal simulation types. The first is Tool Coupling Co-simulation which is a conventional on-line simulation using separate processing for xMOD and each of the coupled applications. The second is Standalone Co-simulation which means an executable model is supplied to the xMOD simulation platform with the key difference being that the co-simulation is executed using a single computational process.

Not surprisingly, the Tool Coupling approach is higher cost, both in terms of CPU time and of course the application license requirements, but significantly it does provide the user with the flexibility to internally change the models. However, if the workflow is such that a Tier 1 supplier is providing models to its OEM customer, or indeed vice versa, this may not be an issue and indeed may be a distinct advantage! Furthermore the ability to select the 'best tool for the job', mean that this platform-based approach to vehicle development is increasingly finding favor with large OEMs, and complements Flowmaster's product positioning. Consequently, the increasing popularity of the co-simulation platform, and its important role in facilitating supplier collaboration makes it an attractive alternative to the 'one tool does everything' methodology.

D2T's compatibility table clearly illustrates the various tools that can now be linked to xMOD, and it can be seen that the new Flowmaster capability allows Tool Coupling Co-simulation, which was the stated priority of the lead customer. Going forward, D2T believe that extending the Flowmaster link to include Stand Alone Co-simulation is a feasible next step but like most enhancements will be driven by market demand…watch this space!





All images: D2T

FloEFD™ for Cyclone Simulation

Air cyclones are a popular method for separating out particulates due to their simple design and low capital and running costs.

By John Murray, Industry Manager, Mentor Graphics

The simple operating principle belies the complexity of the air motion inside the cyclone. This is characterized by high levels of turbulence, strong anisotropy and an unsteady, swirling airflow.

The lack of a stable theory of fluid motion in an air cyclone tends to favor either incremental alteration of existing designs and/or expensive physical prototyping. However, computational fluid dynamics (CFD) can be used to have a better understanding of the intricate flow field structure of the cyclone and help designers understand important features such as hydraulic resistance, central vortex stability and cyclone efficiency, as described by the degree of air purification. Obviously, the usefulness of any such results depends upon the trust that can be placed in the CFD tool for a given application. Mentor Graphics FloEFD addresses this issue directly by continually looking for industrial benchmarks or suitable experimental data against which it can be compared.

This FloEFD CFD study is particularly interesting as the k-ε turbulence model is generally regarded as not being suitable for the swirling flow that obviously plays such a prominent role in a cyclone. It therefore provides an excellent dataset against which to judge FloEFD's enhanced k-ε turbulence model. [1]

Two separate experiments were considered: the first relates to a Stairmand High Efficiency cyclone [2], the second to a cyclone with a bin [3] (see Figure 1 & 2).

As well as the lack of a bin, the Stairmand HE cyclone differs by not having a flow straightening device at the end of the outlet pipe. Beyond geometric considerations, the two experimental datasets emphasized differing aspects and so allowed a broader range of FloEFD outputs to be assessed. Comparison with the Stairmand data will provide a good benchmark of how FloEFD handles the pressure differential between inlet and outlet. The Lorenz cyclone with bin data will allow an assessment of how accurately FloEFD is tracking the motion and settling of particles of various diameters to be simulated.

Stairmand HE Cyclone

A range of cyclone operating conditions were considered, covering inlet velocities of 5-25m/s. A comparison of the FloEFD predictions with the experimental results (Figure 4) show excellent agreement for calculated pressure drop between inlet and outlet.

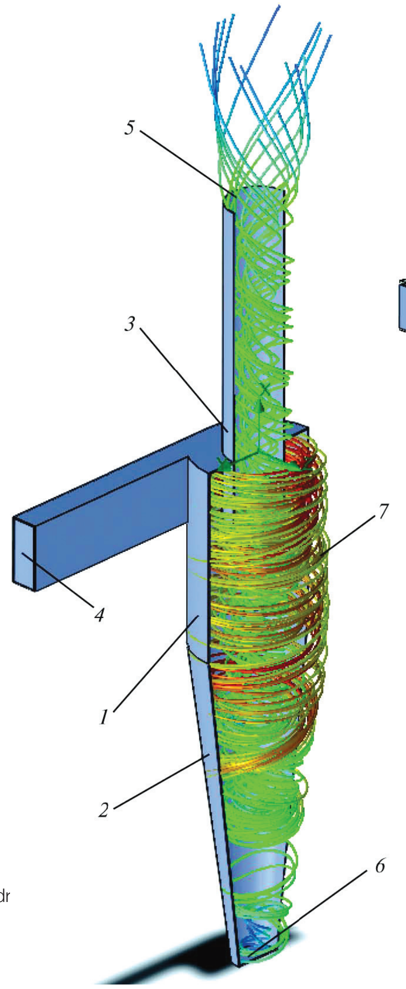


Figure 1. Design of Stairmand HE cyclone: 1) cylindr part; 2) conical part; 3) outlet pipe; 4) inlet pipe; 5) expulsion; 6) dust expulsion; 7) current lines

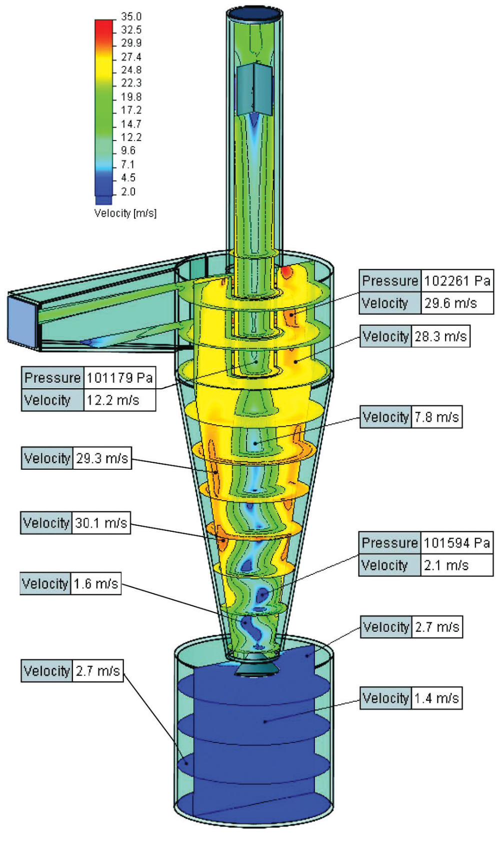


Figure 2. Velocity distribution in cyclone.

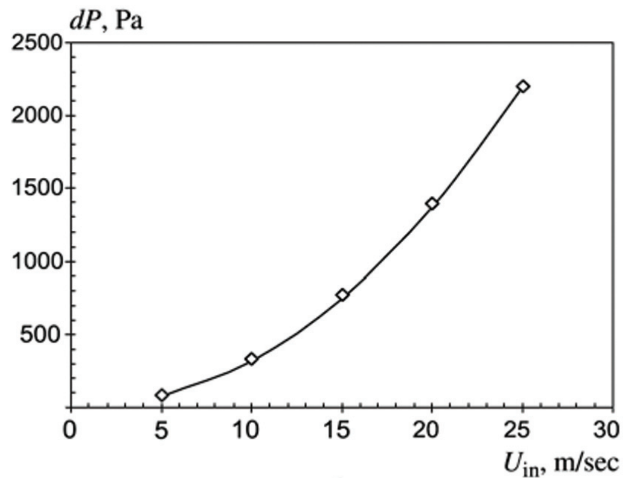


Figure 3. Dependence of hydraulic resistance of Stairmand HE cyclone on air velocity at cyclone inlet

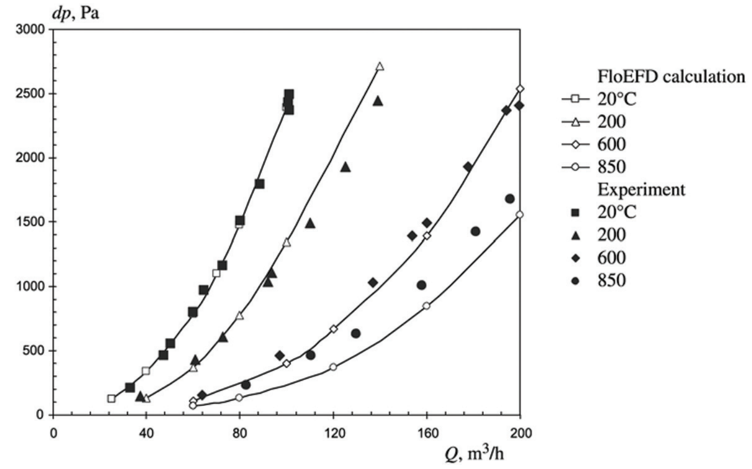


Figure 4. Dependence of hydraulic resistance *dP* of cyclone with bin on throughput *Q* at various gas temperatures

Lorenz Cyclone with a Bin

In contrast to the above, the experimental data for a cyclone with a bin are distinguished by a wide variety of conditions and temperatures. In addition, an evaluation of the cyclone efficiency which FloEFD replicated via an assessment of the motion and settling of particles. In order to do this, the inlet surface discharged 500 particles of a given diameter, across a range of diameters, from the inlet pipe. The trajectory of each particle was then tracked and the cyclone efficiency determined as the ratio of the number of captured to the number of discharged particles of each size. In common with the Stairmand HE case, the first step was to compare predictions of the hydraulic resistance across a range of flow rates with the experimental dataset. In this case, the experimental dataset included points for a range of gas temperatures, which was in turn calculated by FloEFD, (Figure 4).

It can be seen that there is again excellent agreement between experiment and simulation for this cyclone geometry. While the error does increase at higher temperatures, even at 850°C it is little over 10%. In practice, gas flows in cyclones rarely exceed 400°C. The calculated cyclone efficiency is shown Figure 5.

Since the flow pattern in a cyclone is unsteady, the probability of particle drop-out for each diameter was calculated by averaging the results of five discharges of particles. The vertical bars at each point represent the maximum and minimum probability of drop-out of a particle with a definite diameter over five particle discharges. While the calculated cyclone curves have a slightly steeper gradient relative to the experimental data, the agreement between FloEFD and the dataset is very good, particularly below 200°C.

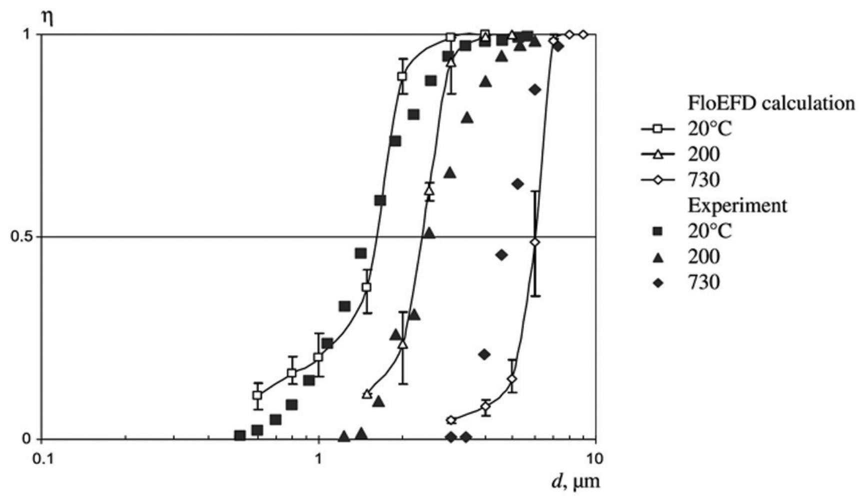


Figure 5. Dependence of gas purification degree η on particle size at various gas temperatures at 60 m³/h cyclone throughput

Conclusions

This work demonstrates that the modified k-ε turbulence model used in FloEFD is well suited to highly swirling flows. Considering the low computational overhead associated with FloEFD (the largest mesh was generated for the cyclone with a bin case, which only came to 380,000 cells) it is clearly the case that FloEFD can offer much to engineers and designers involved in the design of such systems.

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This article was adapted from an article published in Petroleum and Engineering Journal, Vol. 49, Nos. 3–4, July, 2013. Computerizing Calculations and Designing a Numerical Modeling Software Package for Computing Aerodynamic Characteristics of Air Cyclones. A. V. Ivanov, G. E. Dumnov, A. V. Muslaev, and M. V. Popov

Geek Hub

Our team are passionate about all things CFD and love sharing their findings. In this issue, FloEFD's Investigation of the Unexpected Scorching Effect on one of London's Skyscrapers

By Dr. Svetlana Shtilkind, Dr. Andrey Ivanov & Maxim Popov, Mentor Graphics

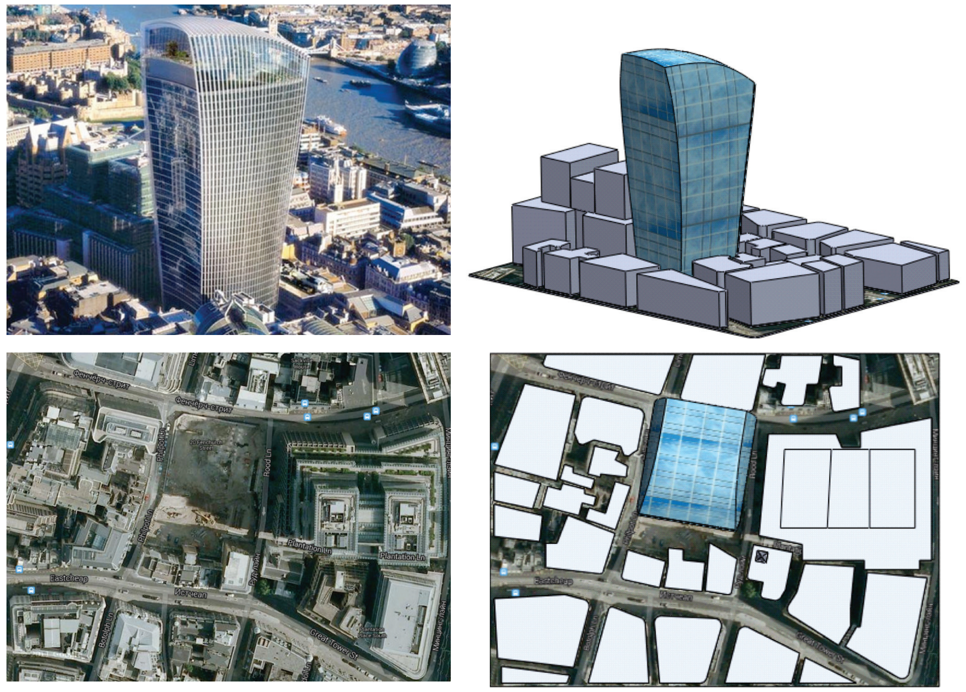


Figure 1. 20 Fenchurch Street Skyscraper and corresponding CAD-model

Sometimes even the most deeply considered engineering creations such as architectural structures can exhibit unpredictable behaviors. One such example, is the commercial skyscraper in the center of London, 20 Fenchurch Street. Nicknamed The Walkie-Talkie Building or The Pint because of its distinctive top-heavy shape, this impressive building provides 680,000ft^2 of exclusive office space that offers unrivalled panoramic views of London. The only problem is that the £200million skyscraper has a dazzling effect on passers-by. As a result of its unusual shape, the architectural structure reflects blinding rays of sun onto the street below, damaging the vehicles parked beneath it.

In the summer of 2013, the United Kingdom experienced unusually hot and sunny weather. On the 29th of August, Martin Lindsay, director of a tiling company, parked his Jaguar XJ for one hour opposite The Walkie-Talkie Building only to return to find a rancid smell of burning plastic and that parts of the car, including the wing mirror and side panels had melted or warped. We later calculated that Mr Lindsay had, by coincidence, parked in the 30m area with the most intensive sunlight exposure from Walkie-Talkie. This article investigates this phenomenon with the aid of Mentor Graphics' FloEFD analysis software.

To begin a full-scale CAD-model of building and the surrounding landscape was reconstructed with the maximum correspondence to its parabolic surface (Figure 1). The area topology data is taken from Google maps and the solar radiation parameters (location and actual time) were defined in FloEFD automatically.

As a first step in the investigation we estimated the ray exposed area dynamics as a result of the sun's position in 29th of August. Distribution of the calculated solar

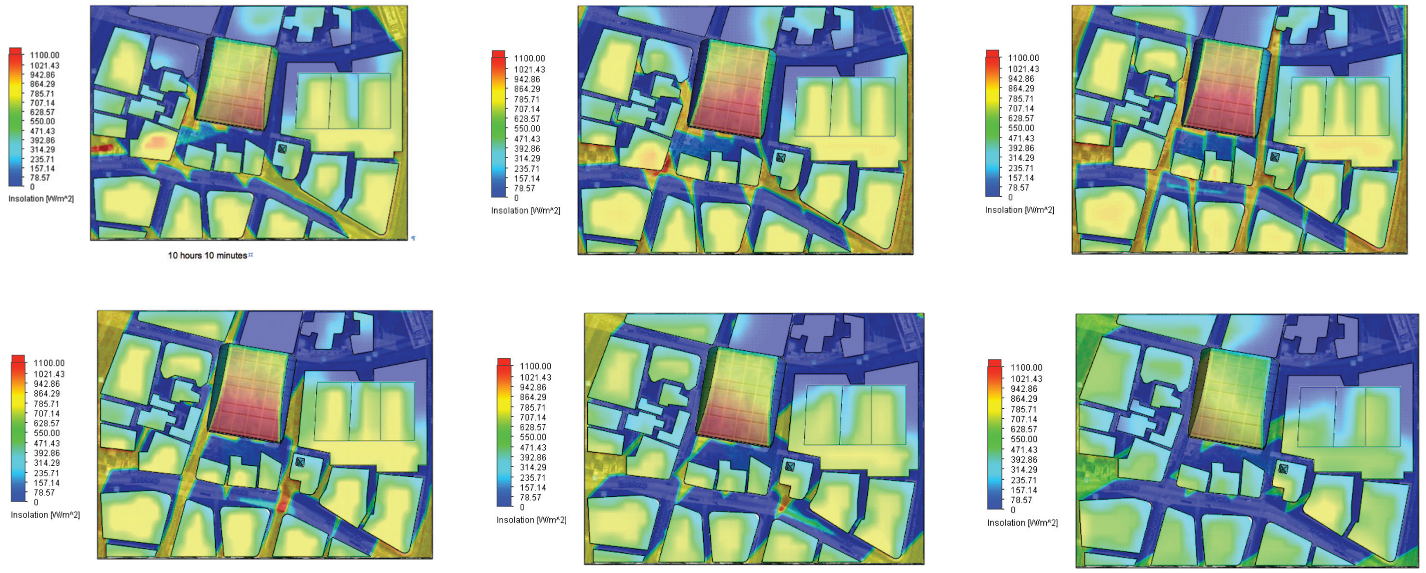
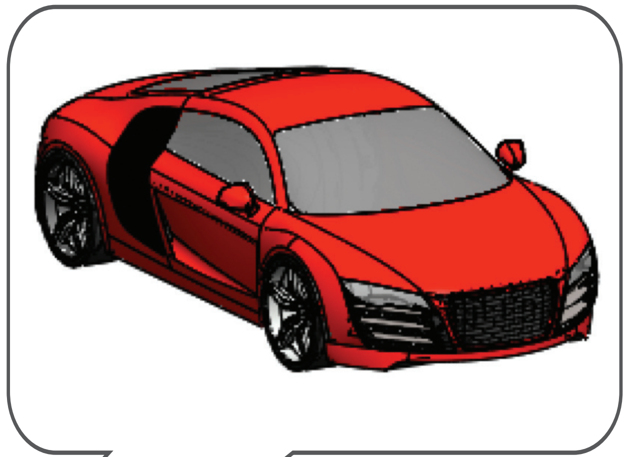


Figure 2. Solar net radiation flux (insolation) as a function of time. Hourly simulation from 10:10 to 15:10, 29th Aug, 2013

net radiation flux, W/m^2 (indicated here as Insolation), for the expanded time interval from 10:10 to 15:10 is shown in Figure 2. We can see the complicated shadow distribution changing its configuration as the rays shift. The sunlight focus spot illustrating via insolation maximum moves from west to east heating the pavement and any objects on it.

By analyzing the results obtained, one can see that the most heated area at the time of incident (between 12:00 and 14:00) is the section of Eastcheap between St. Mary-in-Hill Street and Botolph Lane (Figure 3). The next step in the calculation, was to place



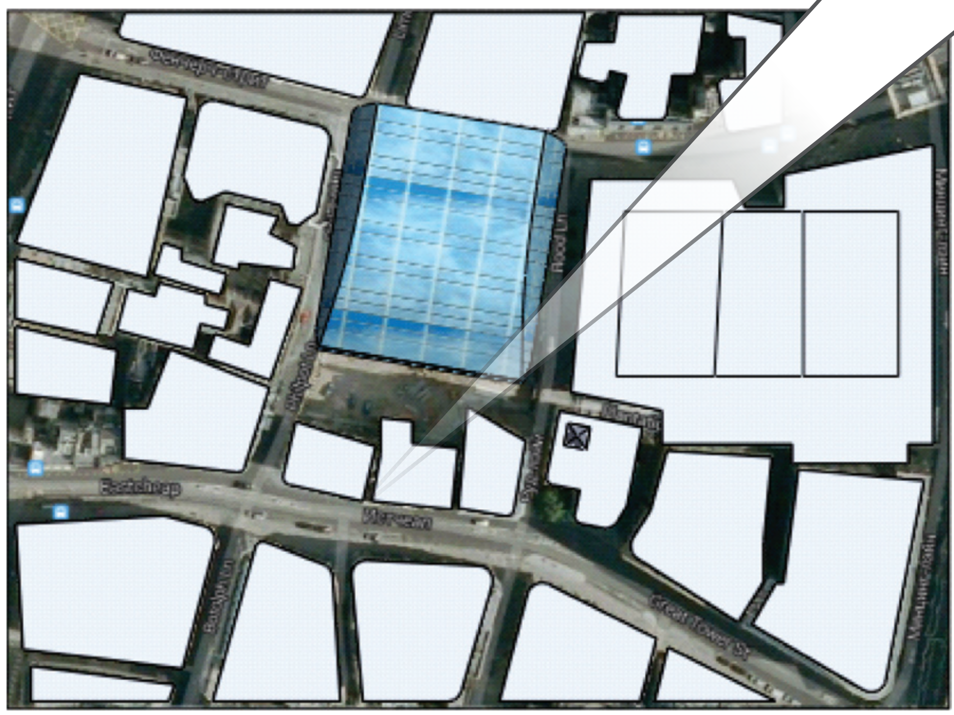


Figure 3. Spread of probable Jaguar positions between of 12.00 and 14.00

the sunlight focus area in the CAD model. (Figure 3)

A more exact car position was defined by the focus trajectory analysis. For a deeper understanding of the optics specific to this case, we compared the results of the solar radiation flux calculation both with and without reflection. In the first case, the parabolic surface of the skyscraper was defined as reflecting glass and at the second case as absorbent concrete. Figure 4 illustrates that the parabolic reflecting surface is a necessary condition to focus the sunlight.

In order to simulate the melting effect of the wing mirrors, their materials were defined as plastic. For the car's shell material, steel was used. Figure 5 illustrates the solar radiation influence on the car parked on the southern side of Eastcheap near the crossing with Botolph Lane at 12:40. The focused insolation maximum reaches the car's bonnet (hood) and left wing mirror shell at this point.

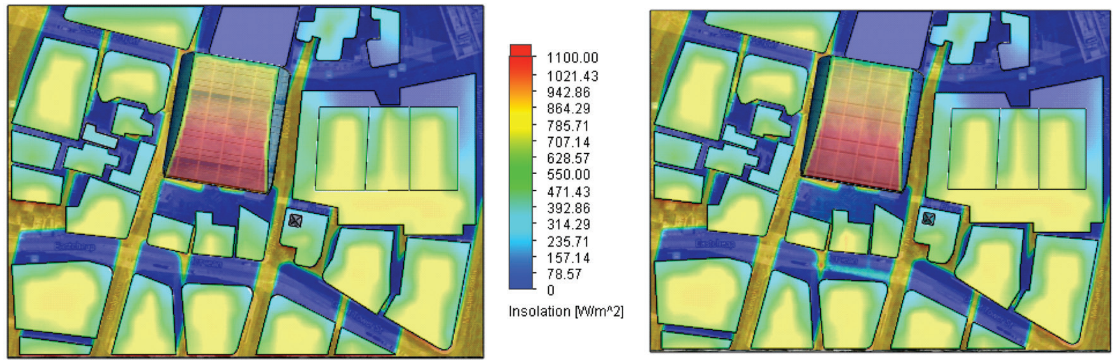


Figure 4. Comparison of solar radiation influence with or without focusing effect at 12:40.

Its value is around 1300 W/m² which is about 1.5 times higher than the average solar radiation flux value (about 850 W/m²) relative to current location, day and time. According to the calculations, the focused insolation maximum is reached within the morning hours of the time period of 10:00 and 15:10. It is an incredible feat of luck for pedestrians that the focused area (about 2600 W/m²!) is occupied by buildings which is preventing more dramatic damage.

The temperature distribution shows the hottest area on the left wing mirror shell. The solar influence on the wing mirror surface lasted just ten minutes. This short time is enough to cause a considerable heating effect. Typically, a wing mirror has a hollow construction with thin plastic outer shell. Given these variables it is rather difficult to remove the heat inside the construction and therefore the plastic shell is forcibly heated. The softening temperature of the typical plastic materials used for wing mirror shells is around 100ºC, with the melting temperature at around 220ºC. The result in the simulation model exactly mimics the effect on Mr Lindsay's Jaguar: the most heated parts of wing mirror are hot enough to change shape or even melt. (Figure 5). The measurement of the pavement temperature at the focused rays area was reported by local press as being around 59.5ºC. This fact was obtained in FloEFD calculations (see Figure 6).

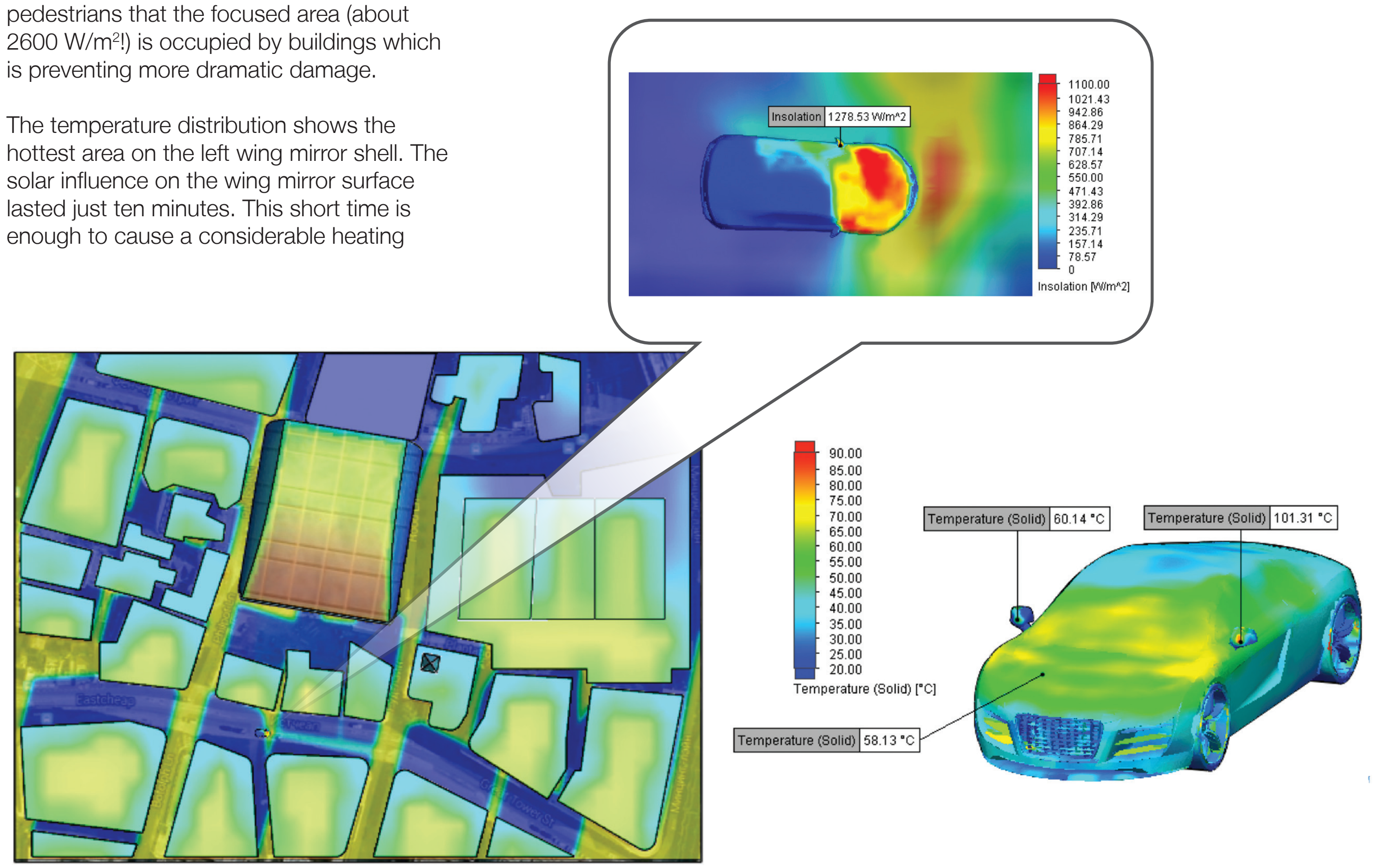


Figure 5. Insolation of all model surfaces and the temperature distribution on the car.

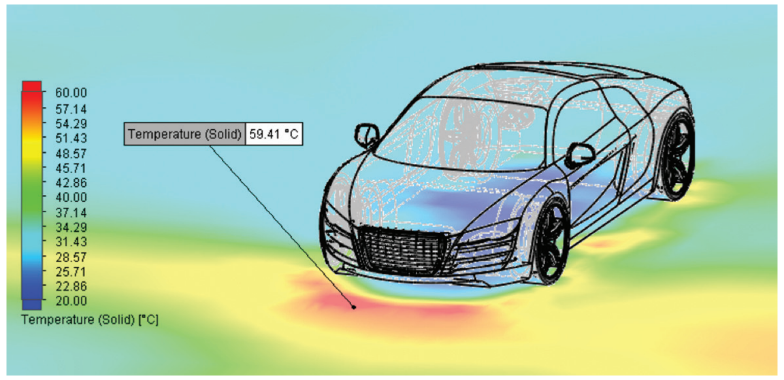


Figure 6. The pavement temperature distribution.

The retrospective of the focus position and intensity was obtained under the assumption that the skyscraper front surface is made of ordinary glass. Its reflective properties are dependent on the incidence angle and other factors. Glass reflection forms a complex interaction pattern which is defined by ray optics principles. Perhaps this consideration was not completely taken into account in the design of the skyscraper. If even the ordinary parabolic glass surface working as a giant mirror can scorch plastics, then how dangerous could it be with more reflecting materials?

Let us consider the extreme situation where the solar radiation flux value in focus reaches its physically feasible maximum. Obviously this is a case of total or mirror reflection. The FloEFD simulation of total reflection shows that maximum of insolation at 12:40 is about 6000 W/m² (Figure 7). No doubt the consequences of such exposure would be more dramatic.

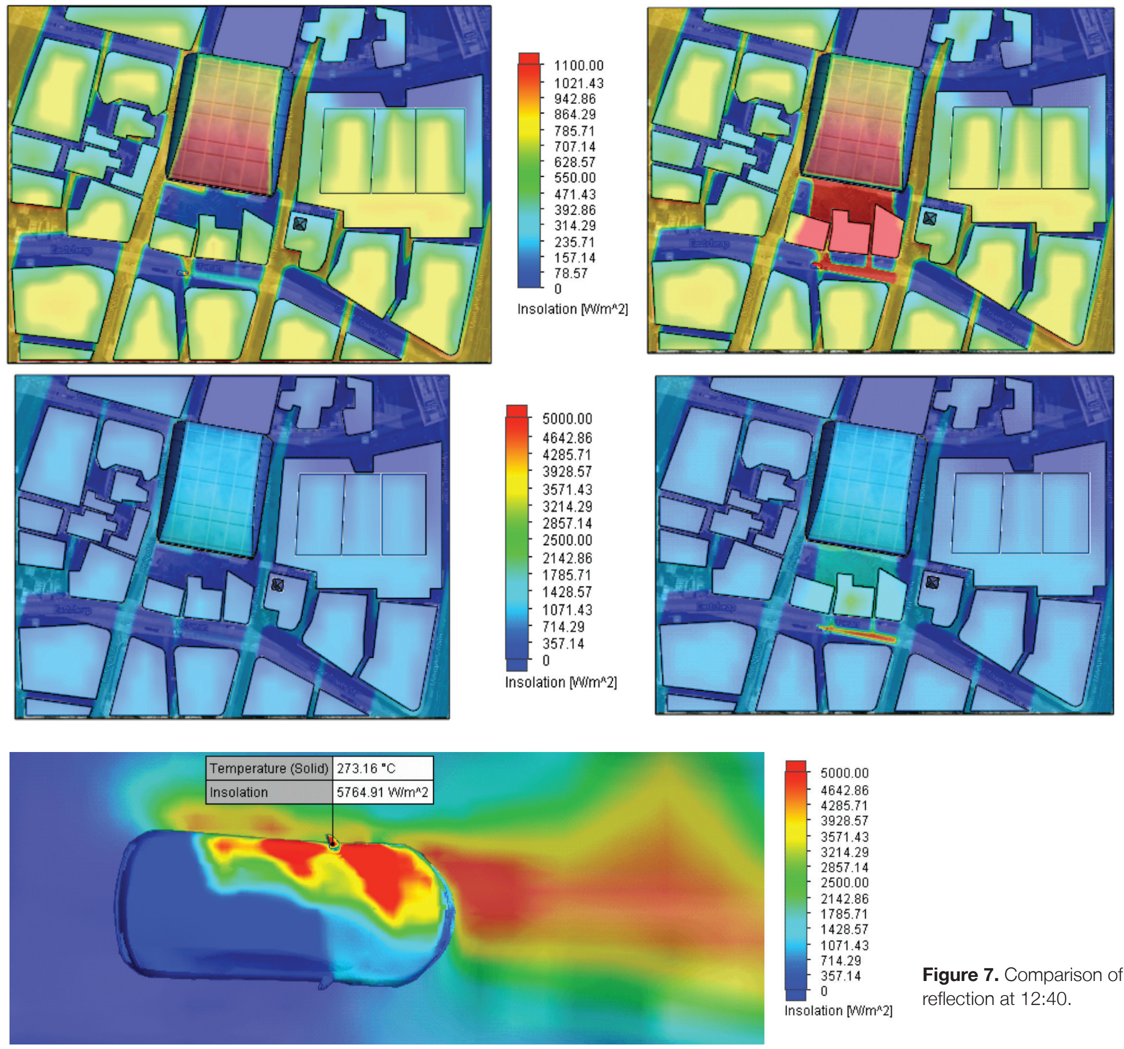


Figure 7. Comparison of ordinary glass and mirror reflection at 12:40.

Conclusions

This example effectively illustrates designers and architects should not neglect the CFD engineering analysis when designing complex structures. While designing an embedded item the interference of all components becomes a very important factor that can have an influence in all assembly operations. Using FloEFD, it is quite simple to explore various constructions under different conditions in details. The reliable results of calculations are based on a consideration of geometrical optics as well as heat transfer specific data.

The amount of engineering reference data that is available in FloEFD makes the designer's task easier. For example in this task the parameters of solar radiation as well as the material's physical properties were defined by means of FloEFD's database. The use of FloEFD in the design of new structures is an effective way to prevent costly failures in the future.
Read the article online: bbc.co.uk/news/uk-23945767

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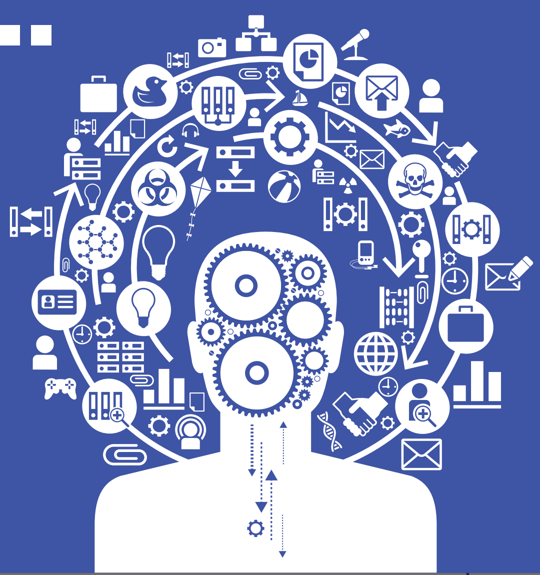
Brownian Motion...

The random musings of a Fluid Dynamicist

Brownian motion or **pedesis** (from Greek: πήδησις Pɛdeːsɪs 'leaping') is the presumably random moving of particles suspended in a fluid (a liquid or a gas) resulting from their bombardment by the fast-moving atoms or molecules in the gas or liquid. The term 'Brownian motion' can also refer to the mathematical model used to describe such random movements, which is often called a particle theory.



Cyber Revolt!

Will Robots Take Over the World?

I spend a lot of my life in front of a computer. A lot. So that admittedly may skew my view of the world, and that frame is already a bit wonky thanks to watching Terminator at a younger age than I really should have. But does anyone else get the feeling that the world is getting a bit…well, Skynet?

I'm as impressed as the next person that computers can now write news stories (get ready for a lot of headlines about how humans suck at chess), but I'm increasingly uneasy about the whole thing.

Computers are so useful that in both work and play I'm spending increasing amounts of time on my backside, mentally and physically. That type of preparation is going to hurt come the man vs machine war. Secondly, we humans are largely irrational beings, computers aren't. We fall foul of many logic traps simply because our mushy mammalian brains aren't naturally very adept at dealing with statistics. I don't think we can win if we try to go toe-to-toe in a battle of wits.

So, the way I see it is that the future of humanity rests on three lines of defense:

1. Stairs. Robots seem pretty rubbish at stairs. They can fly though, so that could be a problem;
2. Laziness. What if at the exact moment the first computer became conscious it simultaneously learns to procrastinate? So that rather than destroying humanity it instead gets lost in Angry Birds;
3. Take the fight to them. Scientists are already capable of mapping thoughts, deleting memories, downloading memories to disc and even uploading false ones. Admittedly, only with lab rats to date, but that in itself is pretty amazing.

I'll leave it to the reader to decide which of the above should form the basis of humanity's grand strategy. Having said that, I think we can probably rule out stairs: I've seen people in my local library wait for an elevator rather than stand on an escalator.

This tends to suggest that the plain old staircase isn't our sweet spot either. Personally I'd go with number three. Quite apart from the potential to be able to download virtual kung-fu, it may lead to a new and significant way to treat neurological and psychological afflictions such as dementia and post-traumatic-stress-disorder. Which, it must be admitted, are also great things to highlight on the funding submission form right after 'beat terminators in their own back yard'.

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