Ansys

Engineering What's Ahead:

# Electric Mobility

e-book

**Winning the Race to Electric Mobility**

The Critical Role of Engineering Simulation

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# Electrification is Moving the World Forward.

Efficiently transporting goods drives the global economy. People need to move for business and pleasure. With the global population expected to swell to 10 billion people by 2050, these forces are combining to cause an exponential increase in mobility.

At the same time, the planet needs to heal. Governments and consumers increasingly connect the ways mobility impacts the environment and are demanding change.

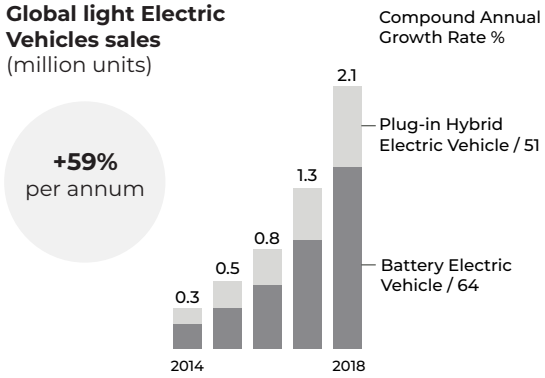
Electric vehicles – whether traversing land, sea, or air – offer the potential to solve this dichotomy of rapidly increasing mobility while simultaneously reducing environmental impact.

Companies – established and new – are racing to capture the electric mobility market opportunity and they know that their future success depends on the critical technology decisions they make today.


Engineering teams are the key to unlocking the potential for their organizations. This e-book details the technical challenges they face, identifies simulation as a common best practice adopted by electric mobility leaders to tackle these challenges, highlights the resulting benefits, and details the critical simulation capabilities required to realize them.

# Electrification is Growing Globally.

While economic conditions, policy and sentiment may influence adoption patterns, the rapid and inexorable global rise and impact of electric mobility is undeniable. As proof, a snapshot of recent studies revealed:




Source: EV-Volumes.com; McKinsey analysis.

## *What Consumers Want[1]*

**75%**
of global consumers expect to own an electric vehicle

**60%**
of consumers would ride in an electric plane, believing it better for the environment

**63%**
of consumers think about emissions generated by their own travel

## *What Electrification Can Deliver*

**35%**
fuel savings by using hybrid-electric ferries versus traditional vessels[2]

**35%**
reduction in hourly operating energy costs for a NASA demonstrator aircraft[3]

**30%**
reduction in greenhouse gas emissions from electric vehicles versus gasoline or diesel fuels, according to the EU[4]

[1] Data collected through a consumer survey. Ansys enlisted Atomik Research and its team of MRS-certified researchers to conduct the online survey in March 2020. The sample included 16,037 adults 18-and-over, from the U.K., U.S., DACH (Austria, Germany and Switzerland), France, Sweden, Japan, China and India. See more survey results at https://www.ansys.com/electrification-survey
[2] https://www.rivieramm.com/news-content-hub/news-content-hub/how-hybrid-electric-ferry-achieves-35-fuel-savings-57636
[3] https://www.businessinsider.com/nasa-developed-fully-electric-plane-x-57-maxwell-2020-4?r=US&IR=T#besides-testing-new-technology-the-x-57-allows-nasa-to-test-an-aircraft-with-decreased-noise-and-fuel-emissions-however-the-x-57-will-likely-only-serve-as-nasas-technology-research-platform-because-there-arent-many-commercial-uses-for-a-plane-that-only-has-one-seat-while-the-rest-of-the-cabin-is-occupied-by-the-instruments-and-batteries-according-to-clarke-10
[4] https://www.eea.europa.eu/highlights/eea-report-confirms-electric-cars

# Electrification is Poised to Soar, as Engineers Clear the Path.

The landscape before electric mobility innovators appears wide open, but critical market demands must be overcome by those who want to win the race to market.

### COST REDUCTION

Batteries alone play a major role in inflating the cost of electric vehicles by as much as $10,000 over their internal combustion engine competitors[1]

### RANGE & PAYLOAD IMPROVEMENT

Range anxiety, speed of charging and availability of charging infrastructure are leading concerns for ground-based vehicles. Electric aircraft must also overcome payload limitations to become commercially viable, requiring batteries with at least twice the energy density of today's most advanced batteries.[2]

### PERFORMANCE ENHANCEMENT

Estimates suggest that current electric drivetrains can suffer 20% energy loss.[3] Delivering the performance that consumers and business demands – whether range, payload capacity or speed – means that every percent counts. Improving the efficiency of the overall electrified powertrain is key.

### SAFETY & SECURITY

Technologies for electrification are in large part behind the anticipated doubling of the automotive electronics and software market by 2030. To capture the enormous market potential, advanced electronics, embedded software and battery management systems across all modes of electric mobility must prove functionally safe and cybersecure.[1]

[1] https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/making-electric-vehicles-profitable
[2] https://www.rolandberger.com/publications/publication_pdf/roland_berger_aircraft_electrical_propulsion.pdf
[3] https://www.fueleconomy.gov/feg/atv-ev.shtml#:~:text=An%20EV%20electric%20drive%20system,75%25%20for%20a%20gasoline%20engine.&text=See%20All%2DElectric%20Vehicles%20for,efficient%2C%20depending%20upon%20drive%20cycle.

# Critical Engineering Challenges Explained.

### Power Electronics

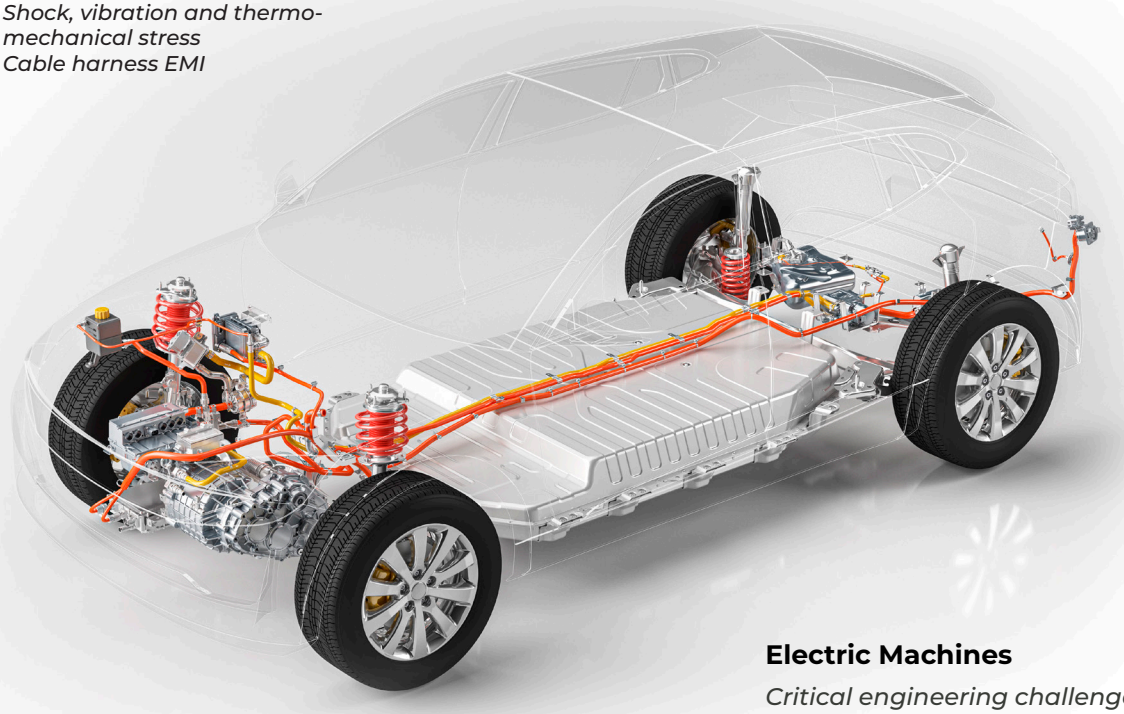
*Critical engineering challenges:*

- *High switching frequencies create more losses and additional electromagnetic interference/ electromagnetic harshness (EMI/EMC) challenges*
- *Signal integrity and power integrity*
- *Thermal management, temperature prediction and effect of temperature on performance*
- *Controls integration*
- *Reliability and failure mitigation*
- *Shock, vibration and thermo-mechanical stress*
- *Cable harness EMI*

### Electrified Powertrain System Integration

*Critical engineering challenges:*

- *Internal and cross supply chain collaboration of multi-disciplinary teams*
- *System-level design trade-offs and optimization*
- *Integration of hardware systems with control software*
- *Functional safety and embedded software certification*



### Battery & Battery Management Systems

*Critical engineering challenges:*

- *Performance sensitivity to temperature, particle size, material properties, design parameters, surface reaction at solid-electrolyte interphase (SEI) interface*
- *Electrochemical aging*
- *Thermal management, abuse and safety*
- *EMI/EMC*
- *Noise propagation due to high-frequency switching*
- *Structural integrity and safety in a noise vibration & harshness (NVH) environment*
- *Safe charge and discharge cycles*
- *Charge balancing*
- *Functional safety and embedded software certification*

### Electric Machines

*Critical engineering challenges:*

- *Maximizing torque and power density*
- *Reducing size and weight*
- *Material selection*
- *Determining motor performance, efficiency and control strategy over the complete drive cycle*
- *Thermal management to achieve performance requirements avoiding short circuits, demagnetization, structural deformation, and reduced part life*
- *Robustness and fault tolerance, accounting for spatial and temporal harmonics, tilt and skew*
- *Reducing torque ripple and cogging*
- *Noise and vibration control*

# Simulation is *the* Electrification Solution.

Leaders in the electric mobility revolution are reporting significant impact in the race to market and technology advancement through simulation. This impact cannot be ignored and typical statistics include:

**50%**
**reduction in overall electric vehicle development time[3]**

**75%**
**reduction in AC drive development time[2]**

**12%**
**improvement in power density and energy efficiency[1]**

1. https://www.ansys.com/en-in/about-ansys/advantage-magazine/volume-xi-issue-2-2017/electrifying-vehicle
2. https://www.ansys.com/-/media/ansys/corporate/resourcelibrary/casestudy/sherlock-danfoss-case-study.pdf
3. https://www.youtube.com/watch?v=GpJaVUs0UH4

**GOING BEHIND THE STATISTICS.**
The real story of simulation driving innovation can be found behind the statistics. These case studies highlight the impact of simulation in real world electric mobility situations.

### Accelerating Development of Lower-Cost Batteries at A123 Systems, Inc.

A123 SYSTEMS

Knowing that producing less expensive lithium-ion batteries is essential to make electric vehicles more competitive, a 48-volt mild hybrid electric vehicle system can be used as integrated starter and generator to improve fuel efficiency and cut CO2 emissions. Engineering such a system can increase development costs and delay time to market, however.

A123 Systems, Inc. used Ansys to reduce simulation time from days to seconds, without reducing accuracy. Ansys helped A123 determine thermal dependency on electric performance, design cooling supply, calculate temperature distributions, predict battery life, and simplify complex 3D thermal simulation, while maintaining required accuracy.

### Making Electric Aircraft a Reality at Zunum Aero

ZUNUM Aero

Zunum Aero focuses on closing the vast regional transport gap between small- and mid-sized cities through electric propulsion technology, enabling a door-to-door air system very different from today's jet-driven hub-and-spoke model. To provide aircraft suitable for short-distance travel while reducing emissions, Zunum Aero is turning to electrification to create hybrid-electric systems.

With Ansys simulation, validating these aircraft can be done in half the time, while saving Zunum Aero millions of dollars in hardware tests.

Zunum Aero's senior principal engineer, who has relied on Ansys throughout his 20-year aerospace career, says they could not have come this far without Ansys simulation software.

### Breaking Records at Volkswagen Motorsports

With less than a year to produce, test, and race an all-new electric car to compete in the Pikes Peak International Hill Climb, Volkswagen Motorsport engineers had to design battery modules with enough stored energy to reach peak speeds for the course, while ensuring sufficient energy to complete the race.

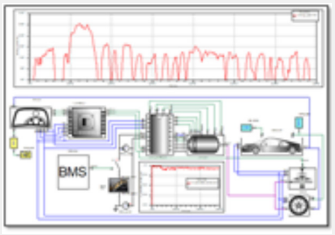
Using Ansys, they conducted a multiphysics simulation involving electrical and thermal parameters to design and validate the battery model within this abbreviated time frame.

Racecar driver Romain Dumas negotiated the 156 sharp bends on the 12.42-mile course in the Volkswagen I.D. R Pikes Peak car in less than 8 minutes at 7:57:148, smashing not only the electric vehicle record by more than a minute but also the overall record by more than 16 seconds.

# Ansys Comprehensive Electrification Simulation Solution.

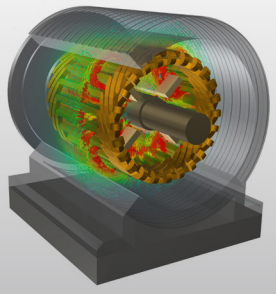
Ansys provides a pervasive simulation solution leveraging high-fidelity multiphysics from the component to the system, including automatic generation of safety certified embedded software and functional safety analysis, in an open environment for optimization, simulation data and process management, workflow customization, access to cloud and HPC, and that supports third-party integration for deployment across the enterprise. This solution is backed by the world's leading center of simulation expertise, providing customer enablement through technical support, services and training.

## *Electrified Powertrain System Integration*

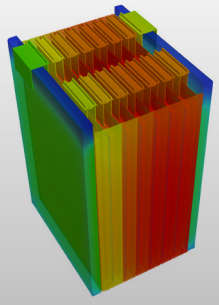



Increased Accuracy: Integrate high-fidelity physics and system level simulations

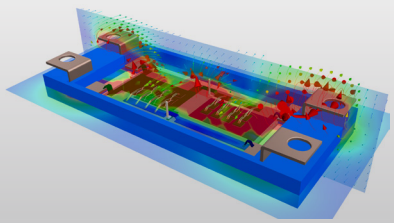
***Electric Machine Simulation***



***Battery and Battery Management System Simulation***



***Power Electronics Simulation***



*Optimization* | *Simulation & Process Data Management* | *Cloud & High-Performance Capacity (HPC)* | *Workflow Customization* | *Third-Party Tool Integration* | *Customer Enablement*

# *Making It Real:* Subaru

**Applying Ansys Electrification Simulation Solution: Electrified Powertrain System Simulation.**

Critical engineering challenges:

- *Internal and cross supply chain collaboration of multi-disciplinary teams*
- *System level design trade-offs and optimization*
- *Integration of hardware systems with control software*
- *Functional safety and embedded software certification*

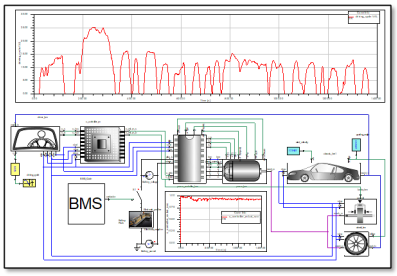
Creating accurate control systems that balance safety, performance and energy efficiency in electric vehicles falls to the electronic control unit (ECU), which is supported by millions of lines of code and subject to strict regulatory oversight.

For nearly a decade, Subaru has relied on Ansys SCADE solutions to help its engineers quickly and accurately generate this mission-critical ECU code, no matter how complex their technology architecture.

***"As Subaru's engineering team improved its internal processes by using Ansys SCADE, the amount of automation increased to 95% for the code underlying the e-BOXER," said Yuji Kawakami, senior electronics engineer at Subaru.***

"In Subaru's experience, SCADE generates such a highly reliable code that a manual review is no longer required, resulting in a great reduction of tasks," Kawakami added.

## *Electrified Powertrain System Simulation*




## *Solution Capabilities*

Architecture Selection
- Modelica libraries for EV powertrain
- Customized libraries, wizards and templates

High-Fidelity and Multilevel Model Libraries:
- Built-in libraries for devices, subsystems and components
- High-fidelity models based on 3D physics

Embedded Software:
- Auto generation of certified code (including ISO 26262, DO-178C, IEC 61508, EN 50128, IEC 60880)

Functional Safety
- Automated analysis and verification for electronic control systems

System Integration
- Complete multidomain, multiphysics workflow
- Integrated high-fidelity physics and reduced order models

## *Key Outputs & Benefits*

Technical Outputs
- Automatic generation of certified embedded software
- System simulation integrated with control software
- Twin model for offline compute and edge/cloud deployment
- Functional mock-up unit (FMU) for simulation workflows
- Traceability

Technical Benefits
- Ease of use
- Speed & accuracy
- Design optimization of the system
- Design efficiency: Modularize and reuse proven designs and architectures

# *Making It Real:* magniX

**Applying Ansys Electrification Simulation Solution: Electric Machines Simulation Solution.**

Critical engineering challenges:

- *Maximizing torque and power density*
- *Reducing size and weight*
- *Material selection*
- *Determining motor performance, efficiency and control strategy over the complete drive cycle*
- *Thermal management to achieve performance requirements avoiding short circuits, demagnetization, structural deformation and reduced part life*
- *Robustness and fault tolerance, accounting for spatial and temporal harmonics, tilt and skew*
- *Reducing torque ripple and cogging*

The lack of air or rail connections among smaller U.S. cities not only limits movement of people and goods, hampering economic growth, but it also contributes to increased emissions. Addressing these issues will require new, more powerful and lightweight electric-powered flights.

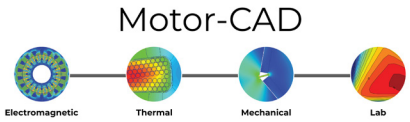
Ansys simulation solutions helped magniX develop an electric motor as powerful as traditional internal combustion engines, but significantly lighter. Embedded software development tools from Ansys for the motor's control code can streamline qualification requirements, allowing it to get to market faster.

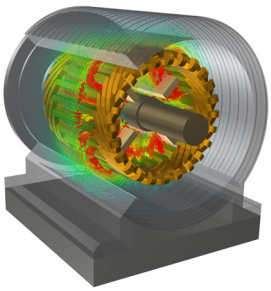
***"Simulation allows us to try out different ideas, from fluid dynamics to stress to structural properties to electromagnetics in a multiphysics environment to take into consideration all the simultaneous forces at play when an electric motor is working," said Roei Ganzarski, CEO of magniX.***

"If we had to build every motor design to test each one, it would take us years before we ever had anything to even try on the ground, let alone in the air. When you are revolutionizing an industry like we are, time is of the essence," noted Ganzarski.

## *Electric Machines Simulation Solution*

Ansys delivers an integrated design to validation multiphysics workflow.



## *Solution Capabilities*

Preliminary Design
- Electromagnetic and thermal sizing
- Structural assessment
- Optimization

Advanced magnetics:
- 2D & 3D finite element analysis (FEA)
- Advanced material modeling (demagnetization, core loss, 3D vector hysteresis modeling, magnetostriction)
- Motion modeling (sliding, rotation, translation)
- Reliable materials data

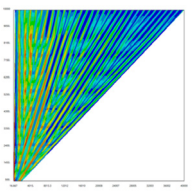
Thermal Analysis:
- All methods of cooling and heat transfer

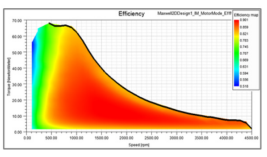
Structural & NVH Analysis
- Structural analysis
- Acoustic modeling

## *Key Outputs & Benefits*

Technical Outputs
- Accurate loss estimation (core, eddy current, copper)
- Efficiency maps
- Torque speed characteristics
- NVH
- Waterfall contour maps
- Control strategy determination

Technical Benefits
- Design optimization
- Improved machine performance and robustness





# *Making It Real:* NEVS (National Electric Vehicles, Sweden)

**Applying Ansys Electrification Simulation Solution: Battery and Battery Management System Simulation Solution.**

Critical engineering challenges:

- *Performance sensitivity to temperature, particle size, material properties, design parameters, surface reaction at solid-electrolyte interphase (SEI) interface*
- *Electrochemical aging*
- *Thermal management, abuse and safety*
- *EMI/EMC*
- *Noise propagation due to high-frequency switching*
- *Structural integrity and safety in an NVH environment*
- *Safe charge and discharge cycles*
- *Charge balancing*
- *Functional safety and embedded software certification*

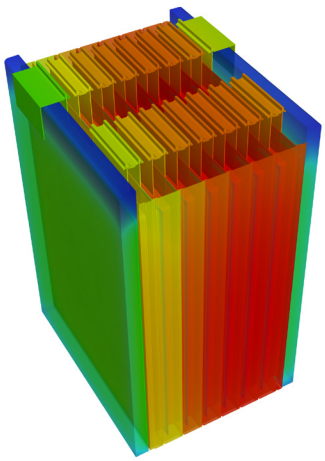
An electric vehicle's battery management system (BMS) optimizes performance by conserving the charge to prolong battery life and respond to unsafe operating conditions. A commonly used BMS development tool unfortunately requires extensive manual verification, validation, and back-to-back testing.

By using the Ansys SCADE end-to-end model-based development solution, the need for costly code reviews and low-level testing verification was eliminated, leading to a 30% productivity gain.

***"The SCADE model allows them to detect errors in their specification early in the design process instead of during integration testing," said Christian Fleischer, NEVS Manager Software Architecture, Advanced Battery Technology.***

## *Battery and Battery Management System Simulation Solution*

Ansys delivers an integrated simulation solution from the cell to the management system.



## *Solution Capabilities*

Cell and Electrode Performance:
- LI-ion battery template

Module and Pack Thermal Management:
- Electrochemistry models including Newman, NTGK and ECM
- Reduced order models
- Integrated ECM and thermal simulation

EMI Analysis

Thermal Management
- All methods of cooling and heat transfer

Structural Reliability
- Thermal stress
- Impact and drop testing
- Random vibration and fatigue

Battery Management System
- Integrated functional safety analysis
- System architecture
- Textual requirements for software controller
- Controller prototyping, design, and verification

## *Key Outputs & Benefits*

Technical Outputs
- Performance of different electrochemistry
- Impact of temperature and C-rating
- Cell current, voltage, and temperature distributions
- Test drive cycles
- Failure propagation
- Selection and placement of filters
- Abuse tolerance determination
- Standard compliant management system
- Automatic generation of safety certified code

Technical Benefits
- Optimize the cooling system and housing design
- Avoid thermal runaway
- Early detection and mitigation of EMI/EMC effects
- Ensure operational safety
- Software design and requirements traceability

# *Making It Real:* Integrated Micro-Electronics, Inc.

**Applying Ansys Electrification Simulation Solution: Power Electronics Simulation Solution.**

Critical engineering challenges:

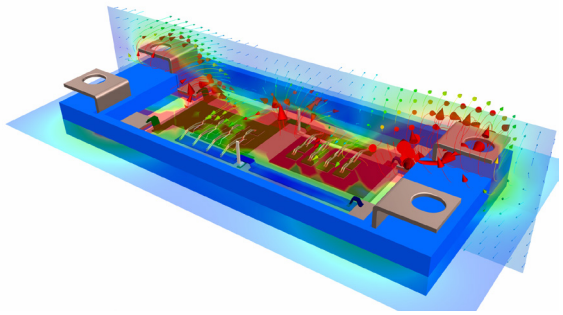
- *High-switching frequencies create more losses and additional EMI/EMC challenges*
- *Parasitics*
- *Multidomain effects including circuits, controls, and power semiconductor*
- *Thermal management, temperature prediction, and effect of temperature on performance*
- *Controls integration*
- *Reliability and failure mitigation*
- *Shock, vibration, and thermo-mechanical stress*
- *Cable harness EMI*

When a new power-steering module failed under testing, engineers at Integrated Micro-Electronics were faced with spending eight months using trial-and-error to determine the cause and find a workable solution. They found that a power-steering power module frequently cracked down the centerline of the epoxy molding compound package and experienced solder remelting during the reverse battery test. Using cross-platform, multiphysics analysis, engineers solved these issues in only four months.

Simulation helped engineers to develop a solution that did not increase manufacturing costs — in about half the time that would have been required using physical experiments alone. Without simulation, it would likely have taken at least eight months to solve the problem, and the contract might have been lost.

## *Power Electronics Simulation Solution*

Ansys delivers a multiscale, multiphysics simulation solution for power electronic systems.



## *Solution Capabilities*

Multilevel models (electronics, semiconductors and thermal)
- Electronics circuit and system simulation
- Power semiconductor characterization wizard
- Losses and temperature simulation
- Bus bar and cable thermal prediction

Reduced Order Models (ROMs):
- Magnetics
- Workflows for electric machines and equivalent circuits

Embedded controls and software:
- System-level models
- Import/export functional mock-up interface (FMI)/FMU

EMI/EMC

Electronics reliability
- Workflow automation
- Integrated electrical, mechanical and thermal reliability analysis

## *Key Outputs & Benefits*

Technical Outputs
- Temperature prediction
- Determination of motor impedance
- Prediction of over voltages and EMI/EMC

Technical Benefits
- Ease of use
- Increased accuracy of system models
- Mean time to failure
- System behavior model and digital twin creation
- Eliminate insulation breakdown

# Engineering Security into Electrification.

***Every vehicle is, at its essence, a computer in motion.***

The increased amount of software in vehicles, and their greater levels of internal and external connectivity, have made them vulnerable to cyberattacks. Well-publicized hacking events have demonstrated the real potential for hackers to override software systems and interfere with safe operation.

That's why cybersecurity remains a major concern as electronic systems become exponentially more complex. Ansys medini analyze for Cybersecurity is an easy-to-use modeling and analysis tool that streamlines the complex task of generating and verifying a cohesive, safe, secure, system-level architecture that is impervious to outside attacks.

This solution allows engineers to quickly identify and address vulnerabilities with key security analysis methods in a model-based environment, to:

- *Deliver analysis context establishment, asset identification, threat identification, attack trees, and threat assessment and treatment all in one integrated tool*
- *Analyze and design cybersecurity-related functions and systems according to standards like SAE J3061, HEAVENS and the upcoming ISO 21434*
- *Integrate architectural/functional design models with cybersecurity analysis methods*
- *Capture and management of cybersecurity requirements*
- *Support complete end-to-end traceability*
- *Customize work product/document generation*
- *Enable seamless collaboration between teams*

With Ansys medini analyze for Cybersecurity, engineers can deliver safe and secure products, reduce time-to-market, maximize profit margins, and comply with upcoming regulations surrounding cybersecurity.

**Click here** to learn more about Ansys medini analyze for cybersecurity.

Contact us to learn more about
Ansys solutions for Electrification.

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*Is your startup poised to make the next*
***breakthrough in Electrification?***

**Click here** to see how Ansys supports startups

## About Ansys

If you've ever seen a rocket launch, flown on an airplane, driven a car, used a computer, touched a mobile device, crossed a bridge or put on wearable technology, chances are you've used a product where Ansys software played a critical role in its creation. Ansys is the global leader in engineering simulation. We help the world's most innovative companies deliver radically better products to their customers. By offering the best and broadest portfolio of engineering simulation software, we help them solve the most complex design challenges and engineer products limited only by imagination.