Using Simulation to increase reliability of Electronics

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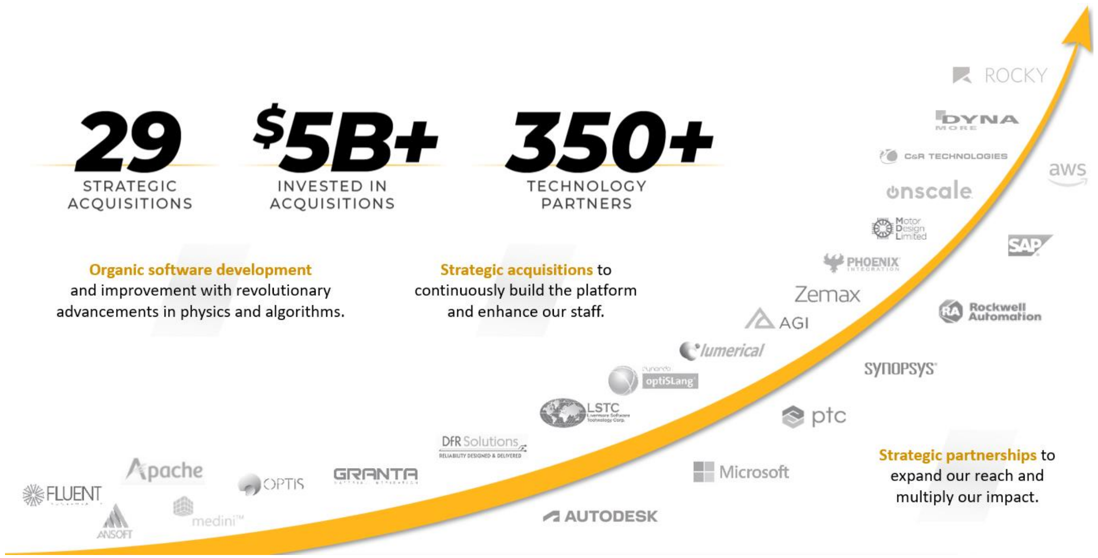
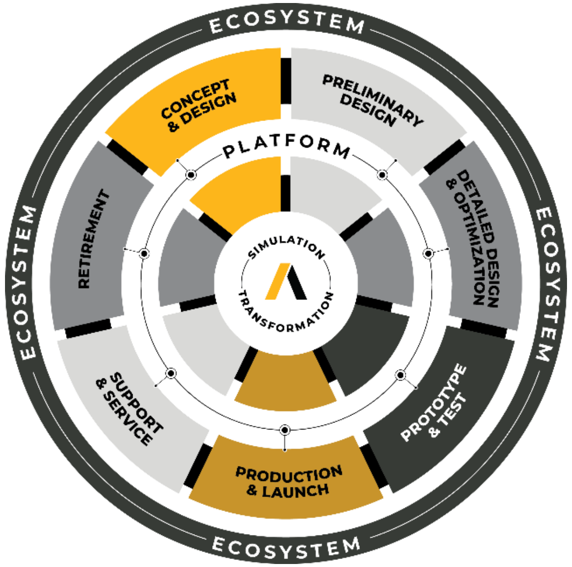
50 Years of Simulation Innovation and Leadership

Ansys ongoing investment in critical simulation capabilities



- ✓ **High Investments in R&D** – on average ~20% of annual revenue ($1.68B in 2020) as R&D budget.
- ✓ **Gold Standard** – Comprehensive best-of-breed simulation portfolio across all physics. **#1 in Engineering Simulation & Virtual Validation.**
- ✓ **Open ecosystem for total integration** – CAD/PLM/IoT agnostic, open to 3rd party simulation tools.

Digital Ecosystem to reduce physical prototypes



CONNECTED DIGITAL THREAD
Connects people, processes, technology and data by leveraging simulation through your digital pipeline

ACROSS THE ENTIRE PRODUCT LIFECYCLE
Understand the cost & ecological impacts of material selections from design to retirement

SHIFTING LEFT
Improves speed to market
Considers supply chain risks
Meet sustainability initiatives

Accelerate Time-to-Market	Exponentially Innovate	Reduce Cost
Create productivity gains that accelerate new products and industry advancements.	Gain competitive advantage with highly accurate product development practices.	Meet size, weight, cost, and sustainability goals while staying within budget.

Digital Transformation

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Almost 75% of R&D costs are spent in failure mode elimination

% OF PRODUCT DEVELOPMENT SPEND

	TODAY	IDEAL STATE
Initial design	2%	10%
Engineering	15%	60%
Eliminate failure modes	73%	10%
Product demonstration	10%	20%

INCREASE SIMULATION

More upfront design exploration

60%
of failure modes created in initial design stage

$$$
high costs to fix late stage

shift failure mode identification left with simulation

IMPACT

- ✓ Significant cost & time reduction
- ✓ Monetizing digital transformation

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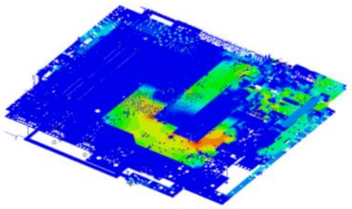
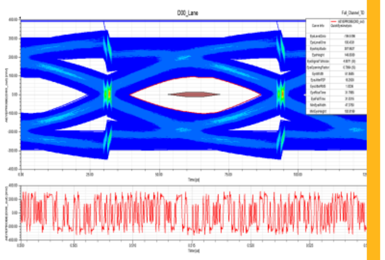
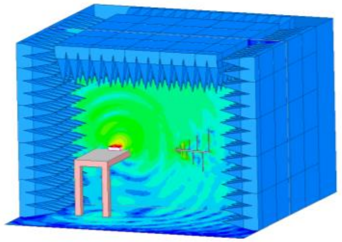
Ansys Multiphysics Solutions for Electronics Systems

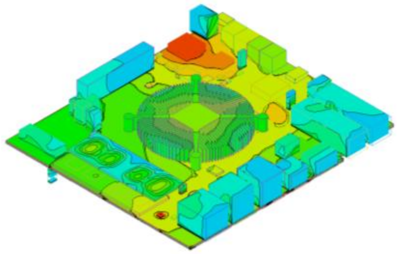
Complete Electronics System Analysis

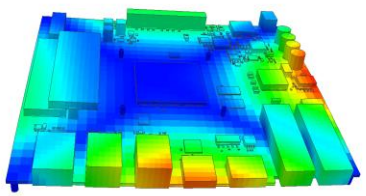
Power Integrity | **Signal Integrity** | **EMI/EMC** | **Thermal Integrity** | **Mechanical Reliability**











High Speed SI/ PI Team | EMI/EMC Team | Design Reliability Team

Ansys

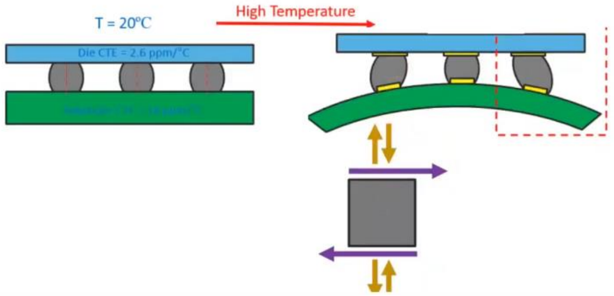
Mechanical Reliability

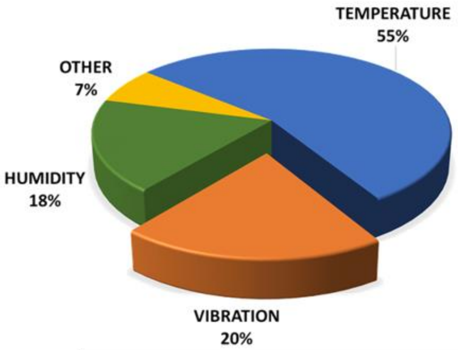
Andreas Rydin

Ansys

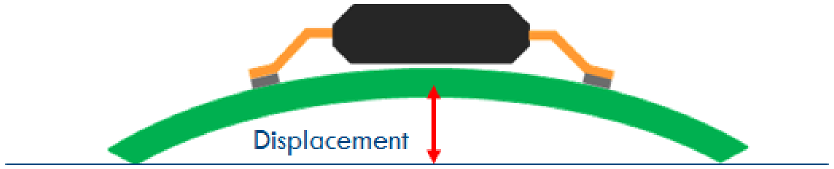
Concerns for Reliability?

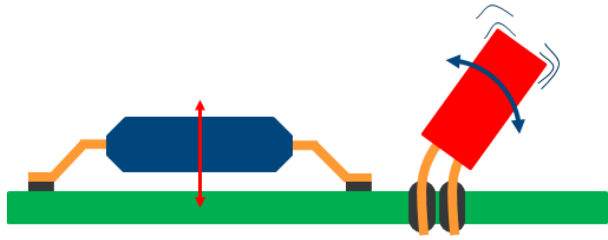
- Some of the most common failure modes for electronics assemblies
  - Temperature cycling
    - Solder Joint Fatigue with/without system level effects
  - Vibrations
    - Harmonic (Sine) / Random Vibration / Shock
  - Environment

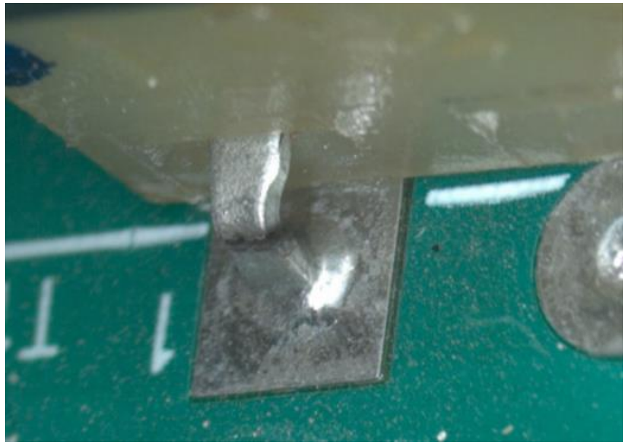


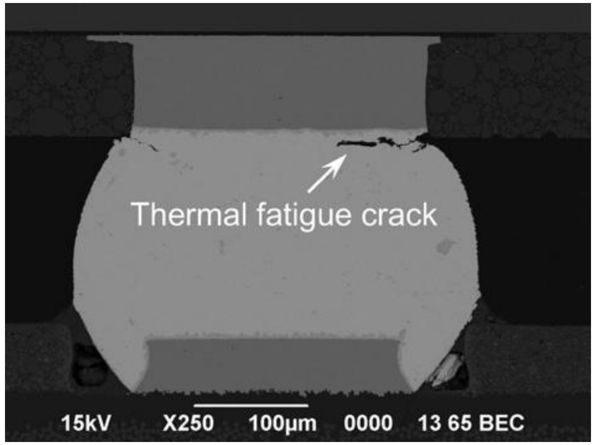


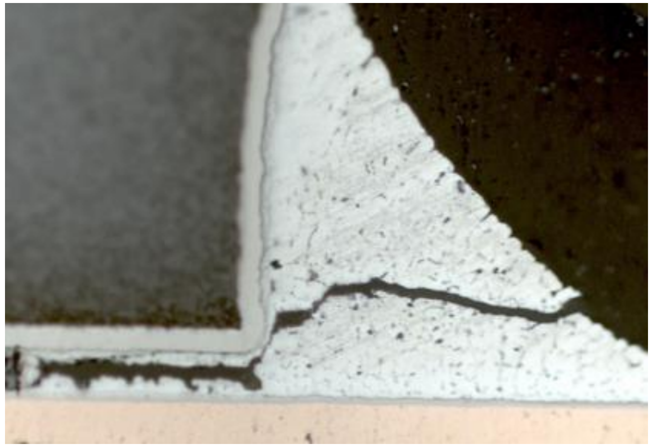
Steinberg D.S. Vibration analysis for electronic equipment. John Wiley & Sons, 2000.









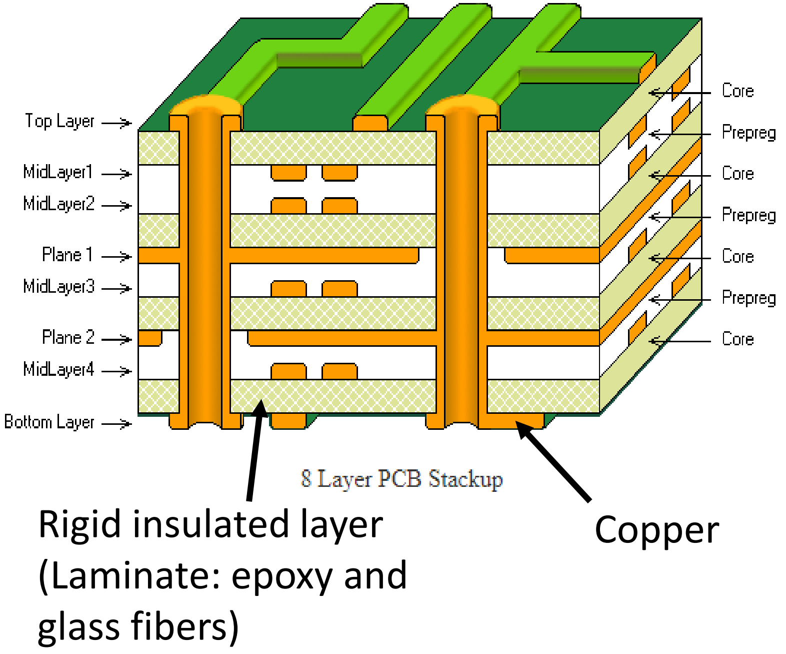


Printed Circuit Board (PCB) Background and Challenges

- As electronic devices have become smaller and find themselves in evermore applications, PCB designers are faced with developing more complex PCBs which are to be used in a wide range of use environments.
- To ensure product reliability, functionality, and a quick time-to-market, accurate and detailed simulation methods are necessary.
  - Simulation is often much quicker than physical testing and can be used early in the design process to ensure reliability, minimizing the amount of qualification testing needed.

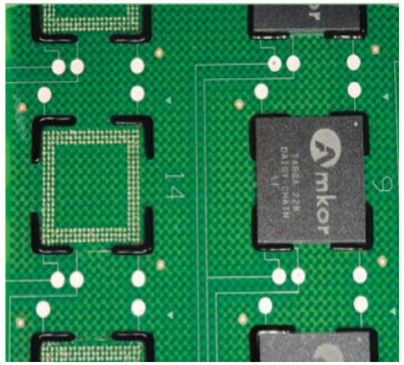
- **PCBs Geometrically complexity:**
  - Large number of components with complex details.
  - Each PCB layer is unique with different copper and laminate geometries (e.g., traces and vias).

- **Material Complexity:**
  - Components and PCB often comprise several materials, each with different properties (composite structure).
  - Some materials exhibit creep and/or have temperature-dependent properties.
  - Fatigue and fracture are common concerns.



PCB

Parts/Components

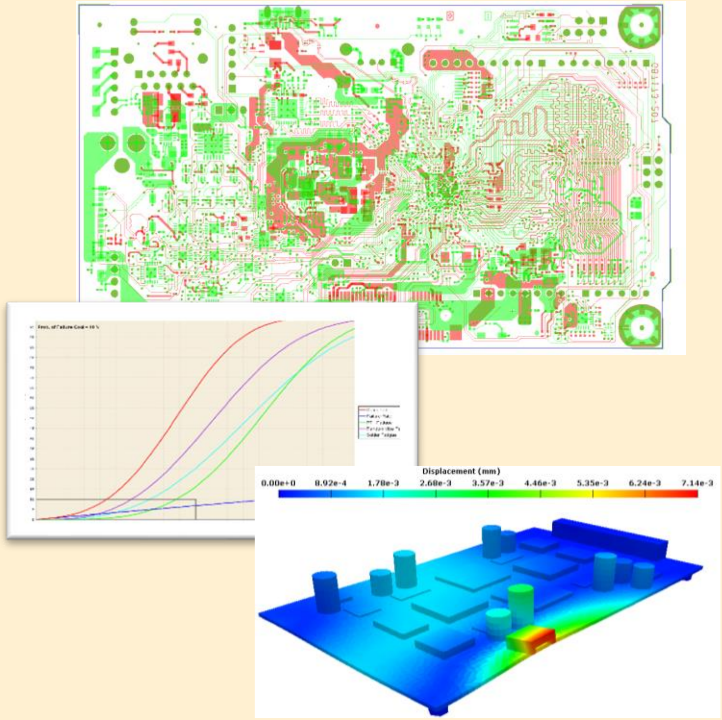


Potting & Underfill

Levels of Electronics Reliability Testing

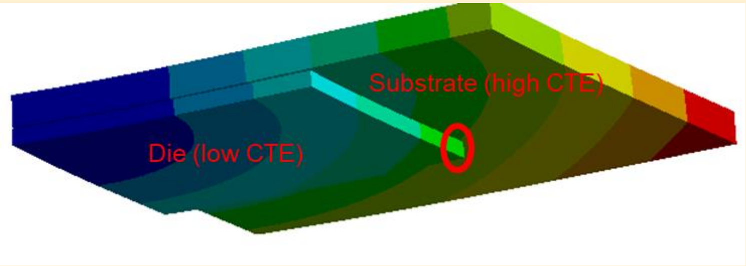
Board Level

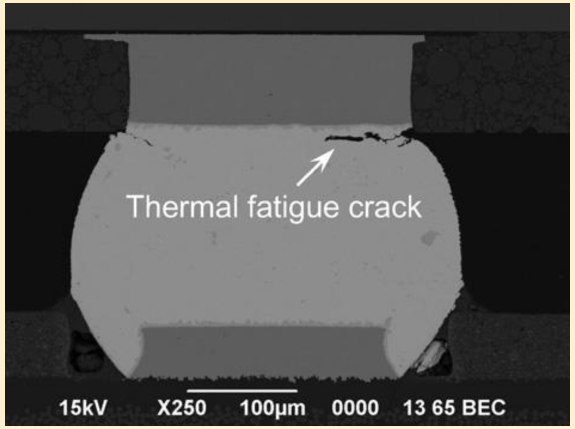
- Pre-Processing Solutions
  - Libraries (Components, Solders, Materials)
- Post-Processing Solutions



Detailed Modelling

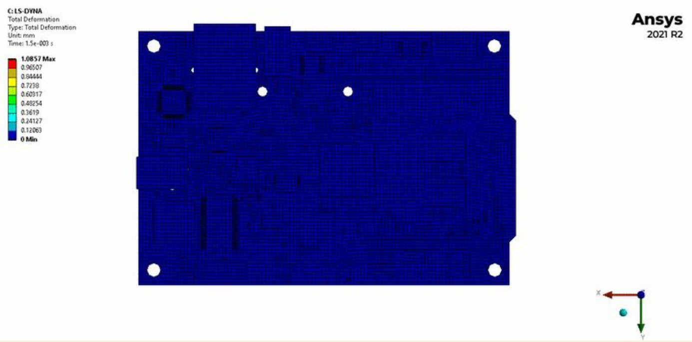
- Structural and Thermal Analysis

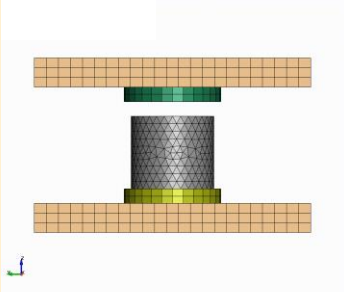


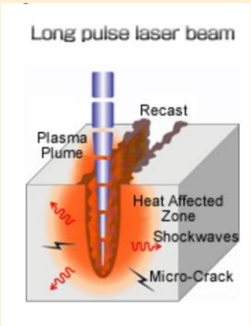


Special Applications & Manufacturing

- Drop tests, tumbling
- Solder Reflow & TIM Distribution





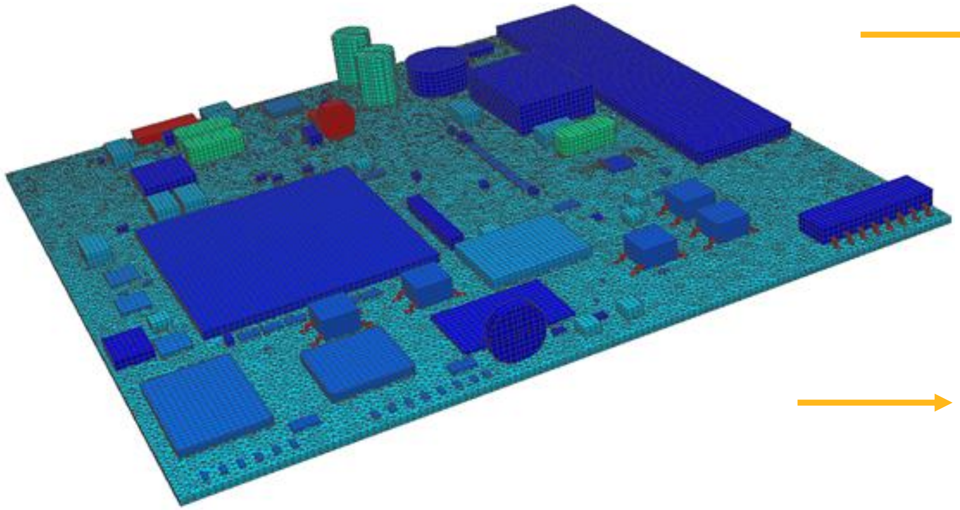


Efficient End-To-End Workflows focusing on ECAD

Pre-processing

Automated Workflow to convert ECAD to 3D FE model

- **Save time**
- Democratize electronic reliability simulations
- Perform what-if studies

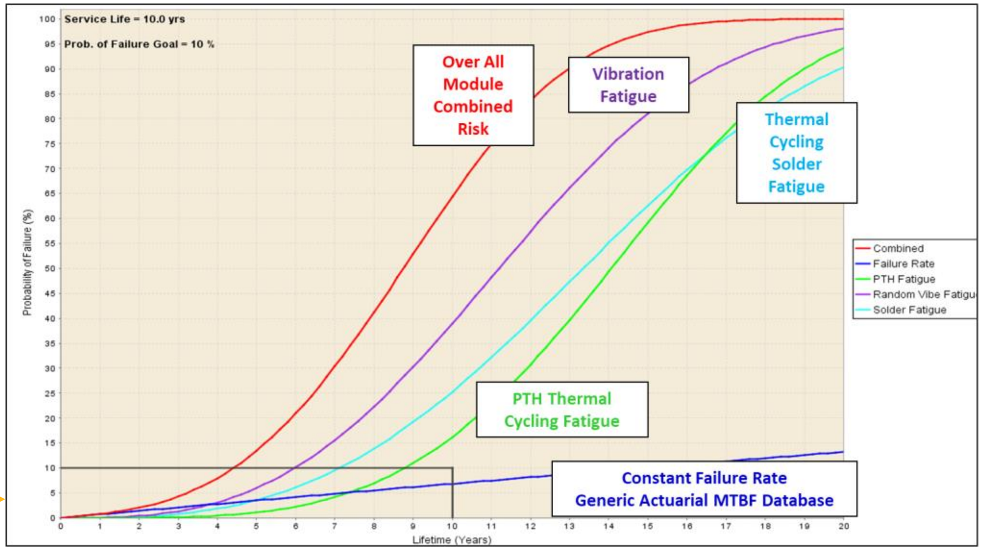


Seamless inside of Sherlock

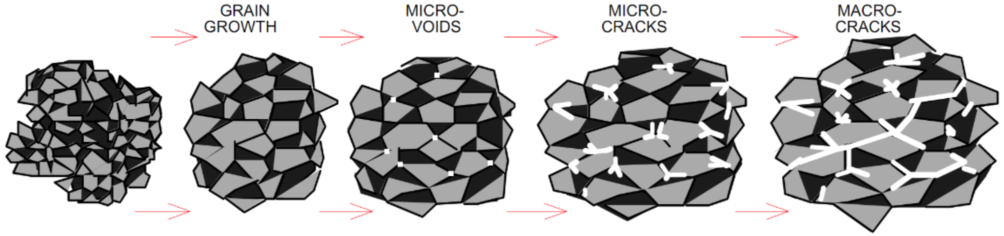
Use external solver for the simulation

Post-processing

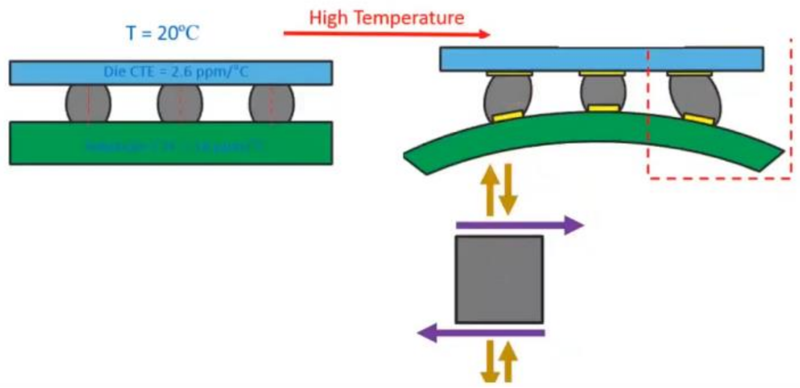
Convert Stresses, Strains and temperatures to Life Curves



Solder Joint Fatigue – Introduction



Source: Werner Engelmaier, Engelmaier Associates, L.C.



- Mismatch in CTE & Stiffness between package and PCB causes thermal stresses during thermal/power cycling
- Damage is accumulated for each cycle ultimately causing failure
- Constitutive Models & Damage indicator
  - Due to homologous temperature being high, creep effects are expected to be dominant for power/thermal cycles
  - A wide range of different constitutive equations for the creep behaviour have been investigated and show similar creep behaviour over expected stress ranges
  - Suggested life model (A. Syed) for lead free solders (SnAgCu) on the form of
    - $Nf = (C * w_{acc})^{-1}$
    - Where w_{acc} corresponds to creep strain energy density within a cycle

Example of Creep Material Models

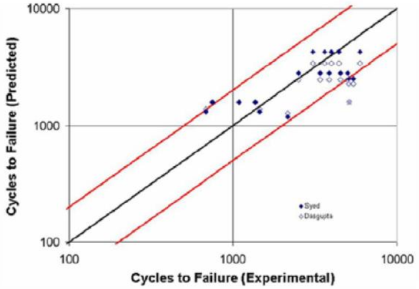
Generalized Garofalo	$\dot{\varepsilon}_{cr} = C_1[\sinh(C_2\sigma)]^{C_3} e^{-C_4/T}$	$C_1>0$
Exponential form	$\dot{\varepsilon}_{cr} = C_1 e^{\sigma/C_2} e^{-C_3/T}$	$C_1>0$
Norton	$\dot{\varepsilon}_{cr} = C_1 \sigma^{C_2} e^{-C_3/T}$	$C_1>0$

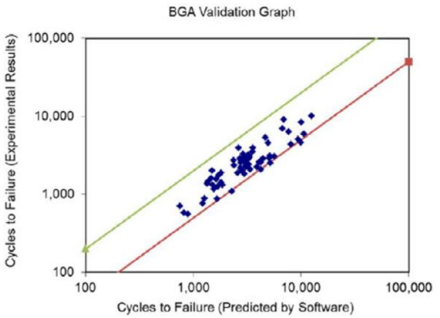
Typical Failed SnAgCu solder joint cross section. Ref: Accumulated creep strain and energy density based thermal fatigue life prediction models for SnAgCu solder joints, A Syed, ECTC 2004

Solder Joint - Examples

- **Ansys Sherlock**
  - Analytical approach
  - Shear stress dominating fatigue process
    - Blattau model to calculate strain energy ranges

$$\text{Cycles to Failure}_{\text{corner}} = \frac{1}{\text{Strain Energy Coefficient} \times \text{Strain Energy}_{\text{corner}}}$$





- Solder shape study

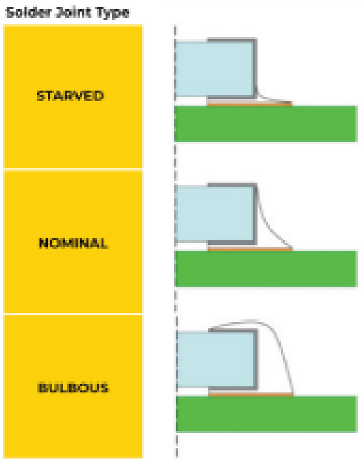


Figure 1. Different solder joint geometry modeled.

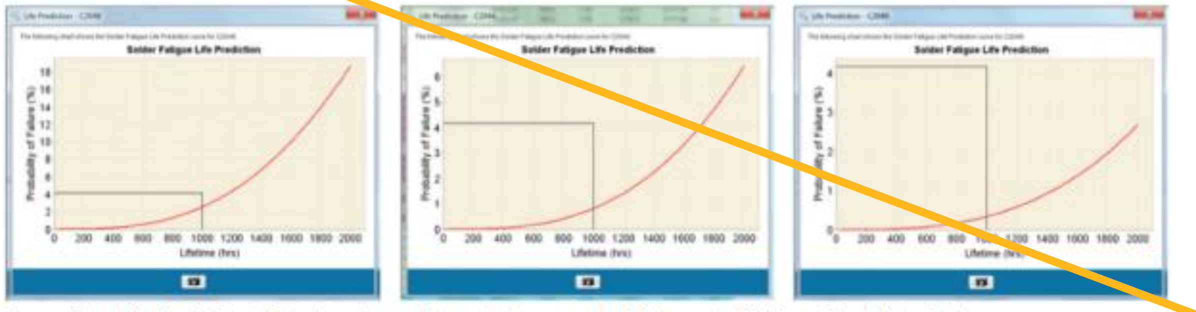
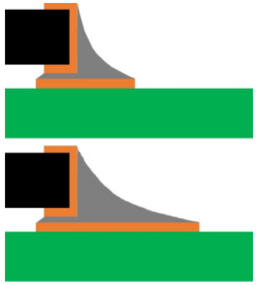
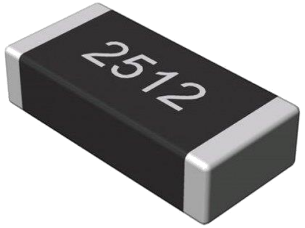
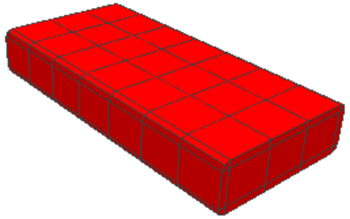


Figure 3. The Life Prediction of the starved, nominal and bulbous solder joints under 1210 Capacitor (left to right).

Solder Fatigue Mitigation





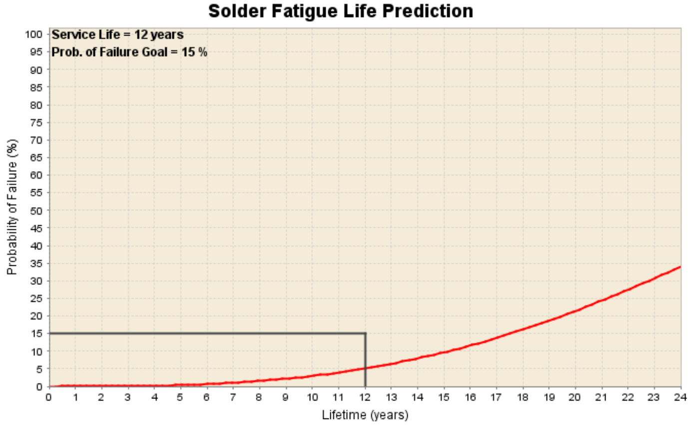


CTExy: 17.440 ppm/C
CTEz: 67.308 ppm/C
Exy: 27,973 MPa
Ez: 3,681 MPa

→

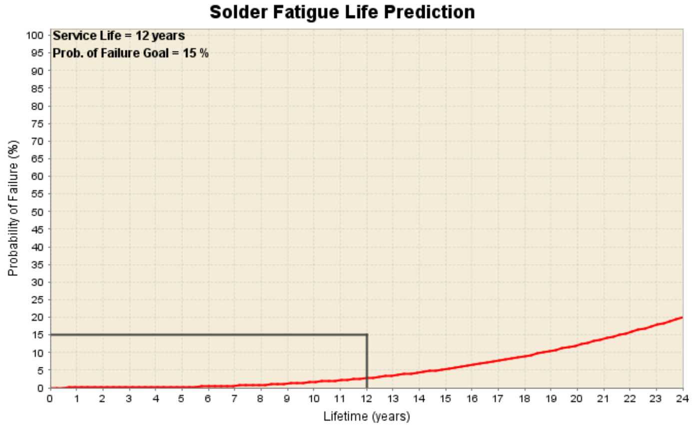
CTExy: 13.471 ppm/C
CTEz: 43.975 ppm/C
Exy: 29,260 MPa
Ez: 3,681 MPa

The following chart shows the Solder Fatigue Life Prediction curve for R500.



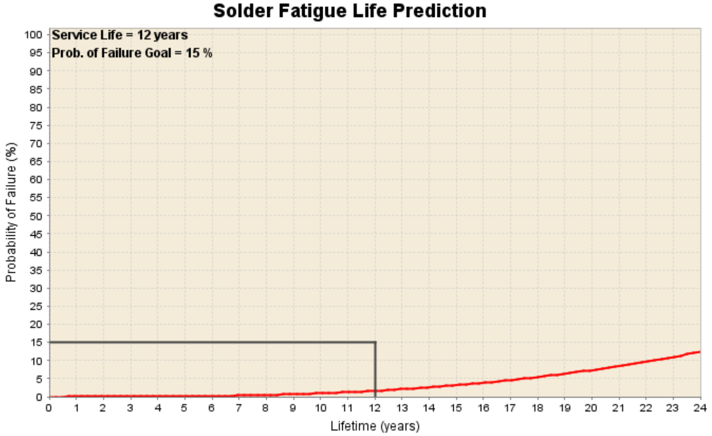
Change Pad Size?

The following chart shows the Solder Fatigue Life Prediction curve for R500.



Switch Package?

The following chart shows the Solder Fatigue Life Prediction curve for R500.



Change Laminate?

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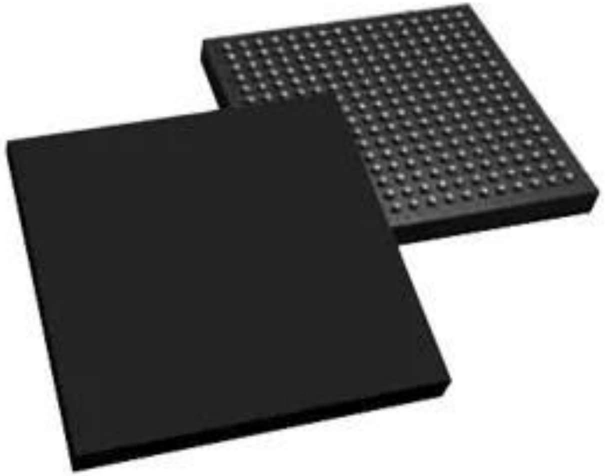
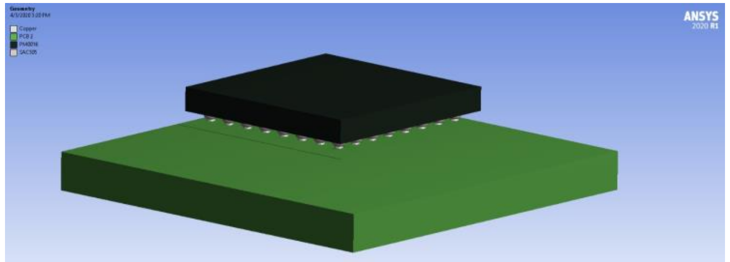
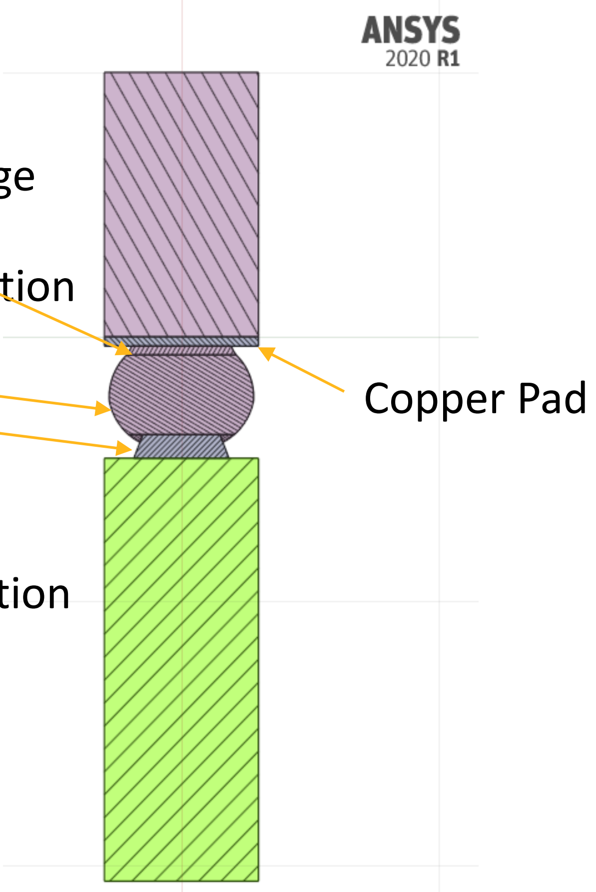
Solder Joint Fatigue - Examples



- BGA 17x17
- Temperature cycling (-40,120) degrees
- Materials
  - Package CTE 13.444 ppm/°C
  - PCB CTE_{XY} 18.533 ppm/°C
  - Underfill manufacturing data

Below Tg	35
Above Tg	131
Glass Transition Temperature (Tg) by TMA, °C	125





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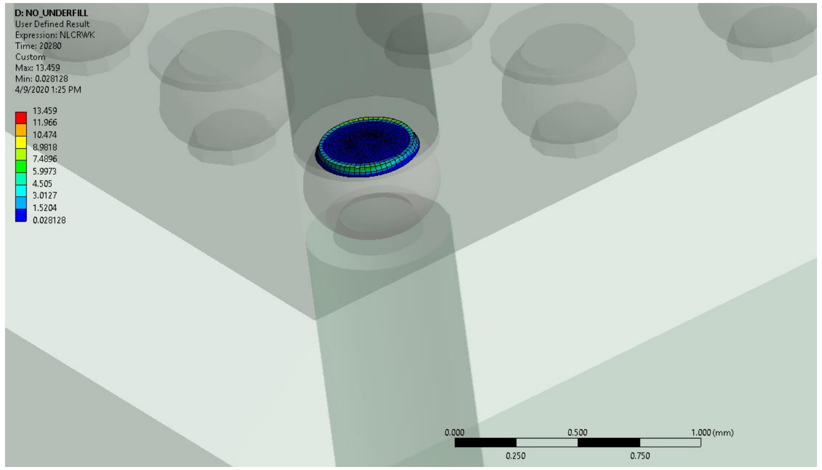
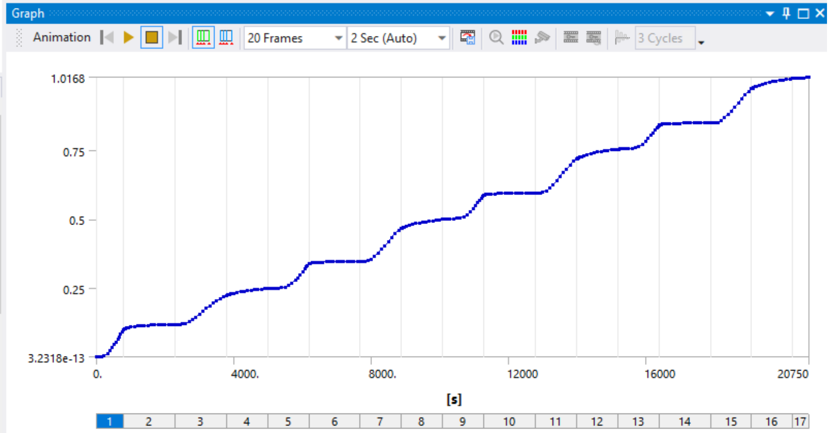
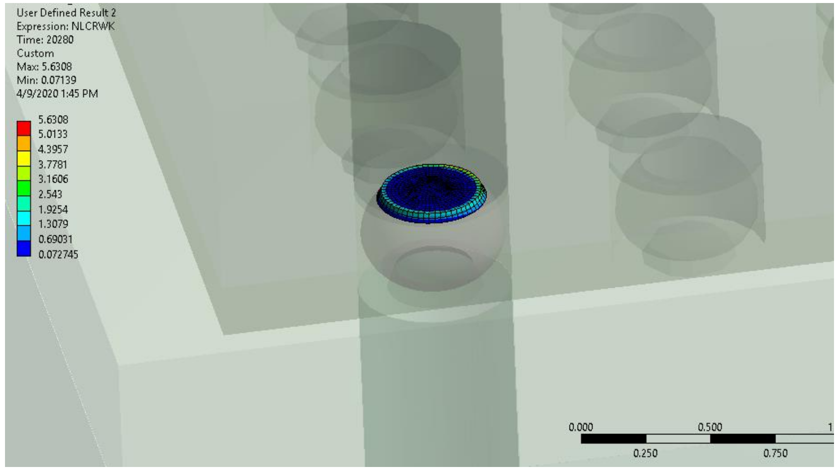
Solder Joint Fatigue - Examples

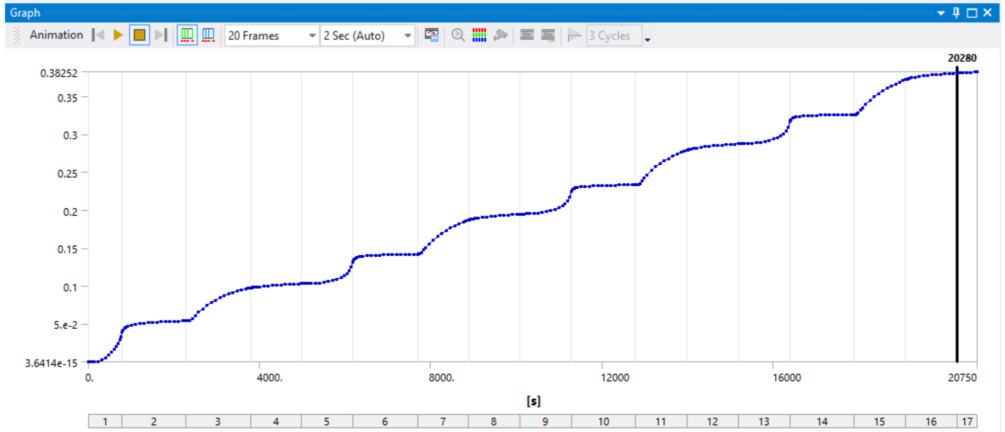
- Without Underfill – Time to Failure – **2050 cycles**





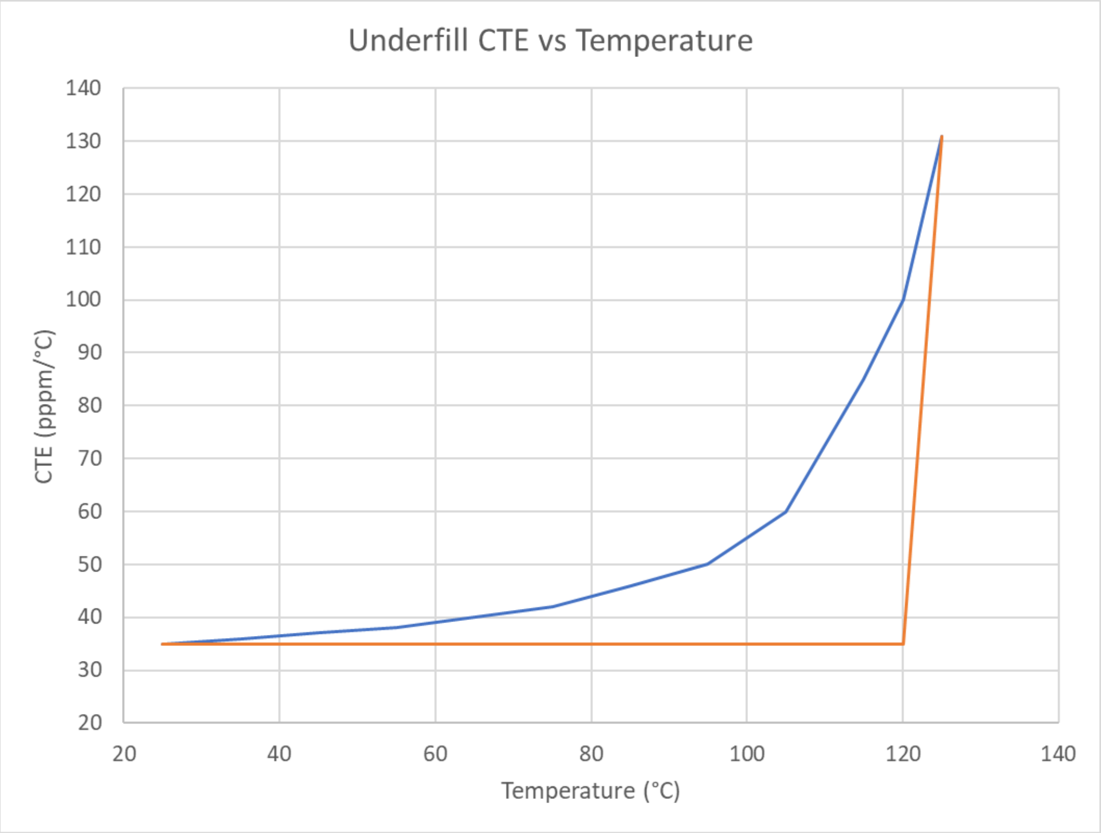
- With Underfill – Time to Failure – **5600 cycles**



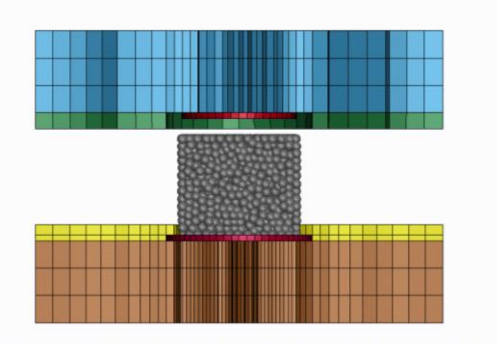


Solder Joint Fatigue - Examples

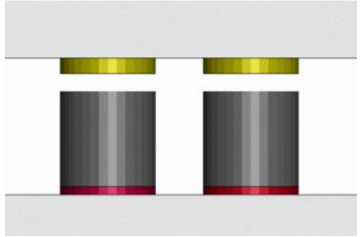
- Adding underfill to the BGA increased life of the component with a factor of 2.75 for the given thermal cycle profile
- Physical testing showed failures occurring significantly earlier. Why?
  - Glass transition temperature for underfill was closer to 110 degrees (compared to 125 provided by manufacturer)
  - Huge increase in CTE in the temperature range for the thermal cycle
- Revised simulations including new temperature dependent material for the underfill material
  - New, revised, life of the component 3200 cycles
  - Corresponds to a factor 1.5 life increase



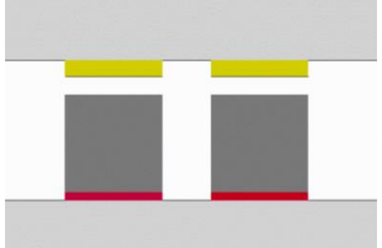
Including the manufacturing process



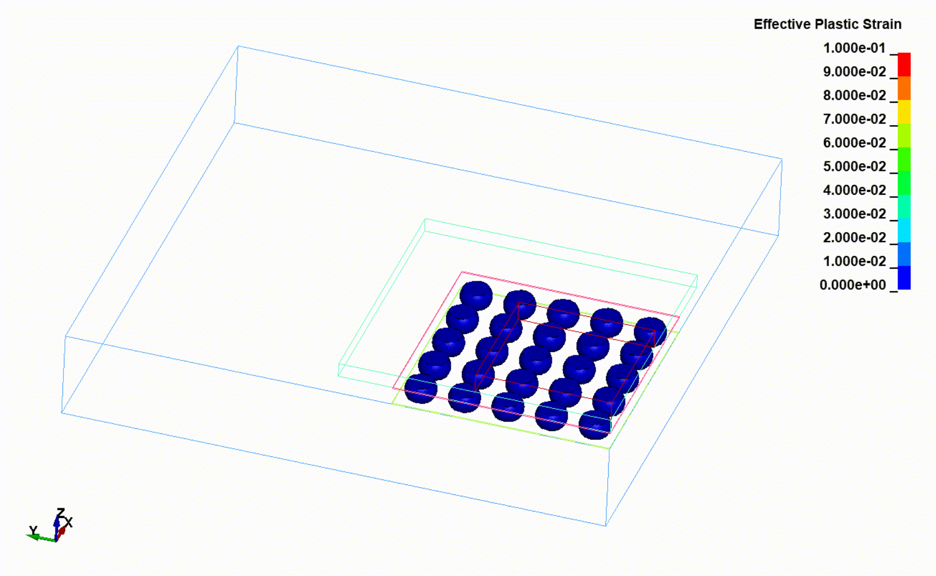
- Virtual testing of solder reflow manufacturing process
  - Predict defects before manufacturing (HoP, bridging, etc)
  - Include solder shape in downstream (virtual) testing

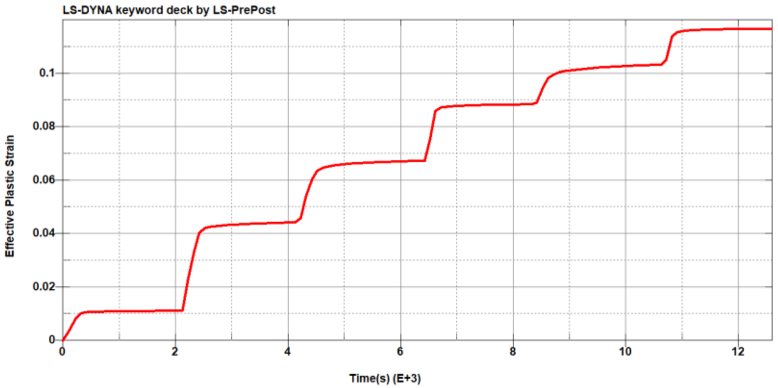


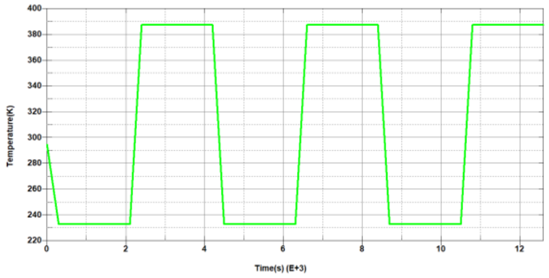
Front View



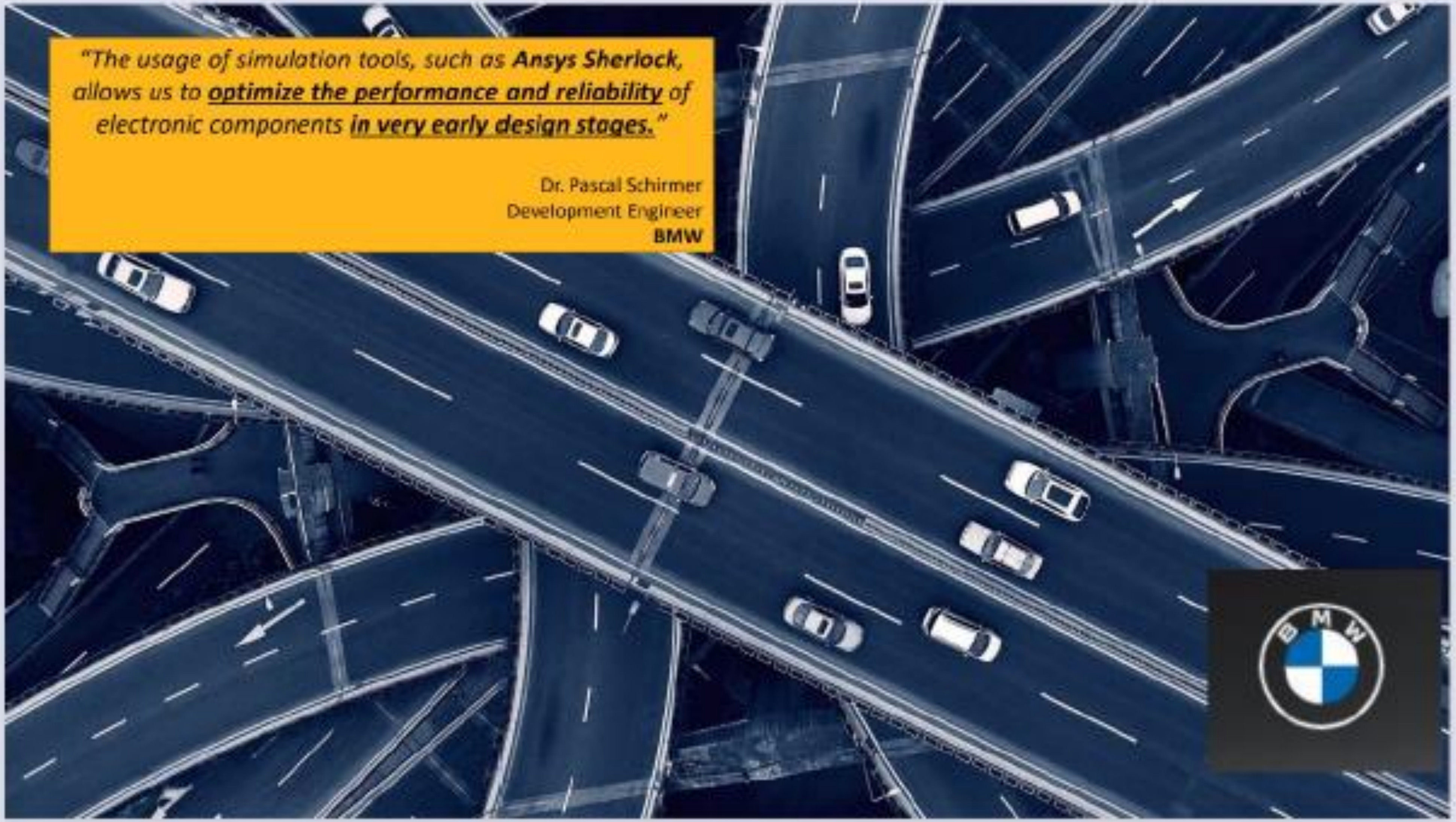
Section Cut View







Customer quote:



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Electromagnetic Compatibility and Discharge

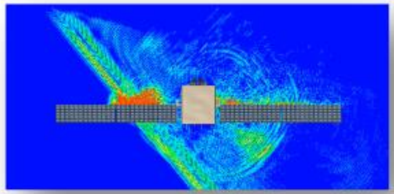
Jens Albrektsson

Ansys

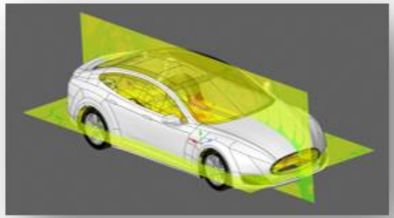
Ansys EMC Plus Addresses Many EMC Requirements

- Electrostatic Discharge (ESD)
- Radiated Immunity
- Signal/Power Integrity (SI/PI)
- Conducted Emissions
- Radiated Emissions
- Transfer Impedance
- Conducted Immunity

Ansys Electronics Plus Solutions

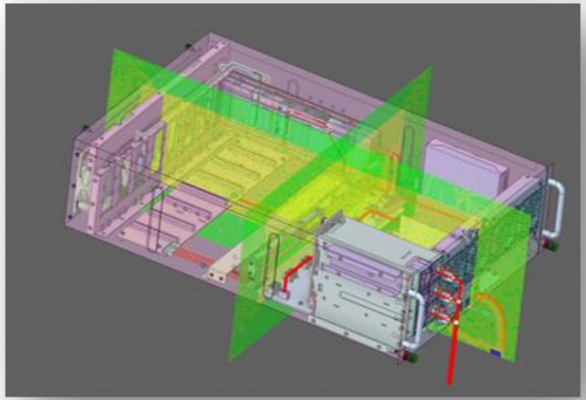


E3

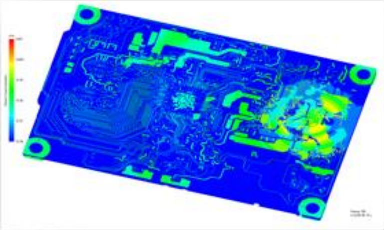


Cables

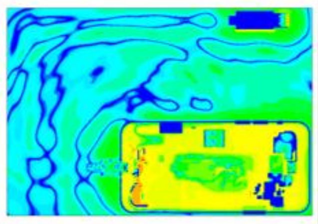
Ansys EMC Plus



Ansys EMC Plus is a platform-level electromagnetic cable modeling and simulation tool that delivers a design-to-validation workflow for EMC

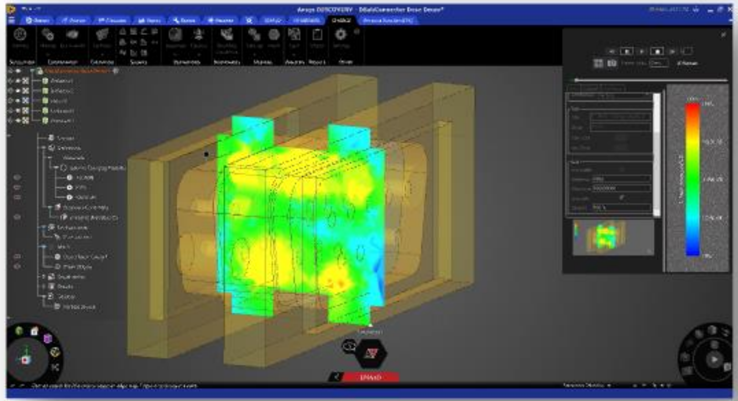


EMI/EMC



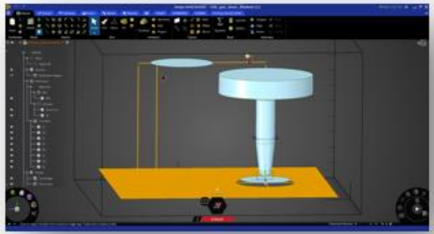
RF De-sense

Ansys Charge Plus

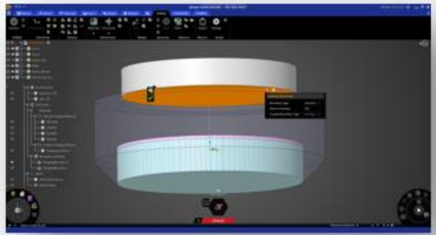


EMA3D Charge combines electromagnetic solvers, fluid solvers, and particle physics solvers to provide easy-to-use Multiphysics simulation.

Lightning Strike



ESD



Semiconductor Plasma

Arc Extinction

ePowertrain EMC/EMI EV Impact

Engineering Goals

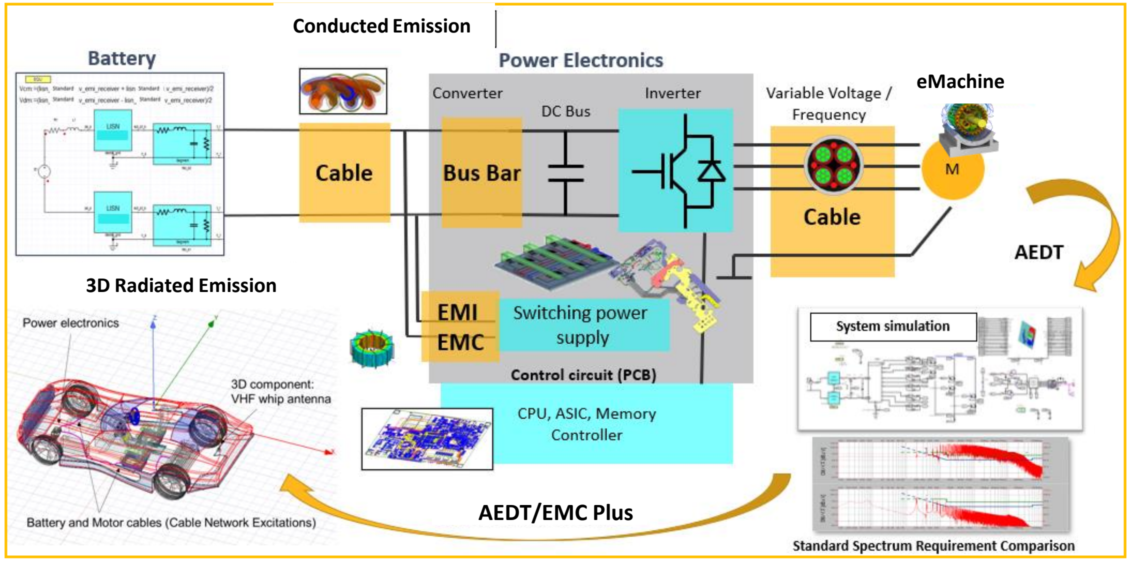
- **Virtual prototyping of e-Powertrain EMC impact** on the whole Electric Vehicle (**EV**).
- **Accelerate GTM** (Go-To-Market) for the Conducted and Radiated Emission (**CE/RE**) of Electromagnetic Compatibility/Interference (**EMC/EMI**) normative.
- **Save** high **prototyping costs.**

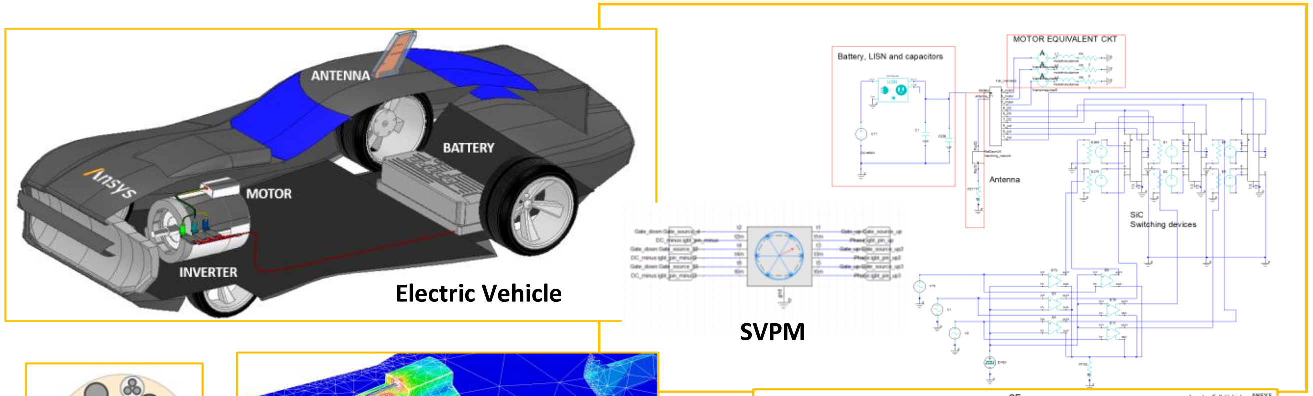
Solution

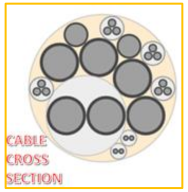
- **High-Fidelity 2D/3D Component and 3D Vehicle EM Simulation:** Industry leading for parasitic extraction of electronics components (**Control/Power PCBs, power modules, busbar, common mode chokes, eMotor** and its command) for CE and **integration in full EV for RE**. *(Electronics Enterprise Suite: Maxwell, Q3D, SIwave, HFSS, Twin Builder, Circuit, EMC Plus, Charge Plus)*
- **Circuit/System:** Advanced technology based on Ansys Circuit solver which combines robust Spice models import capability with advanced 3D/2D frequency domain models to state space conversion for non-linear time domain simulation. *(Twin Builder, Circuit)*
- **Model Coverage:** Analysis workflow configurable for all power electronics components: Inverters, battery chargers, DC-DC converters, control units for different car chassis and antennas. *(Electronics Enterprise Suite: Maxwell, Q3D, SIwave, HFSS, Twin Builder, Circuit, EMC Plus, Charge Plus)*

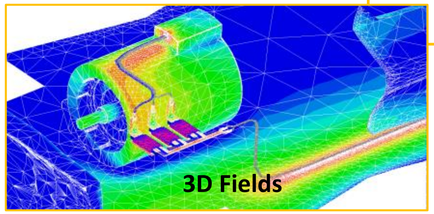
Benefits

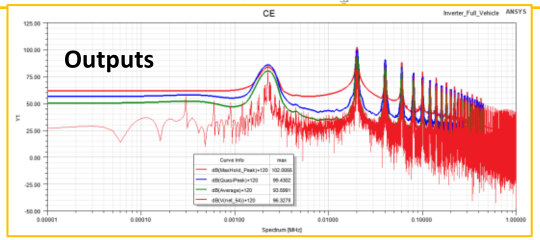
- Reduce **prototyping cost by 30%** and **risk of delaying projects by 20%** in complying with the CE/RE EMC automotive normative.











Virtual EMI/EMC Test for Full Vehicle

Engineering Goals

- **First -pass electromagnetic compatibility (EMC) certification** such as CISPR12/25/36, ISO11451-2.
- **Reduce** cost to compliance and time to market.
- Understand **safety critical** aspects in the vehicle.

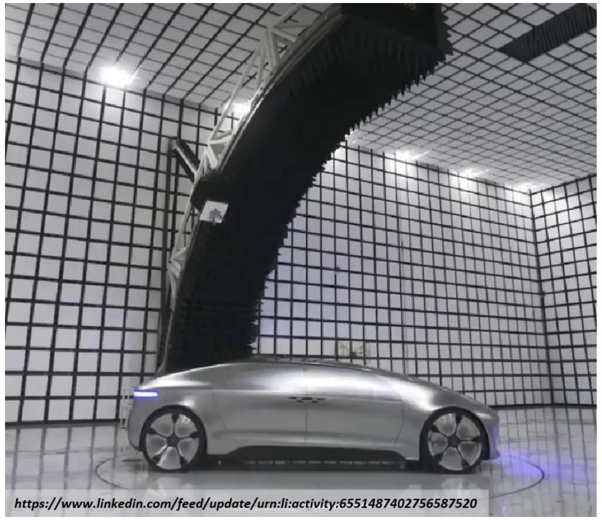
Solution

- **Virtual EMC compliance:** Accurately mimic test chamber to easily create virtual EMC tests.
- **Solver technology and integrated workflow**: Simulation toolchain integrated to provide compete EMC solution for ECUs -> EDS -> Antennas -> Vehicle in EMC chamber. (*SIwave, HFSS, EMC Plus*)

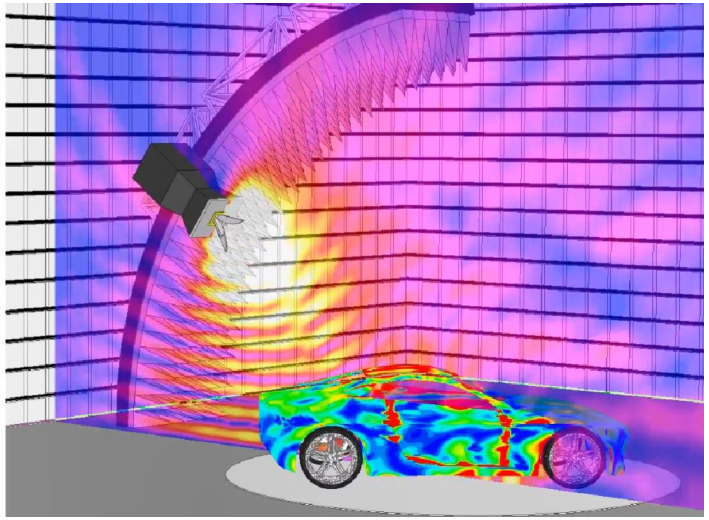
Benefits

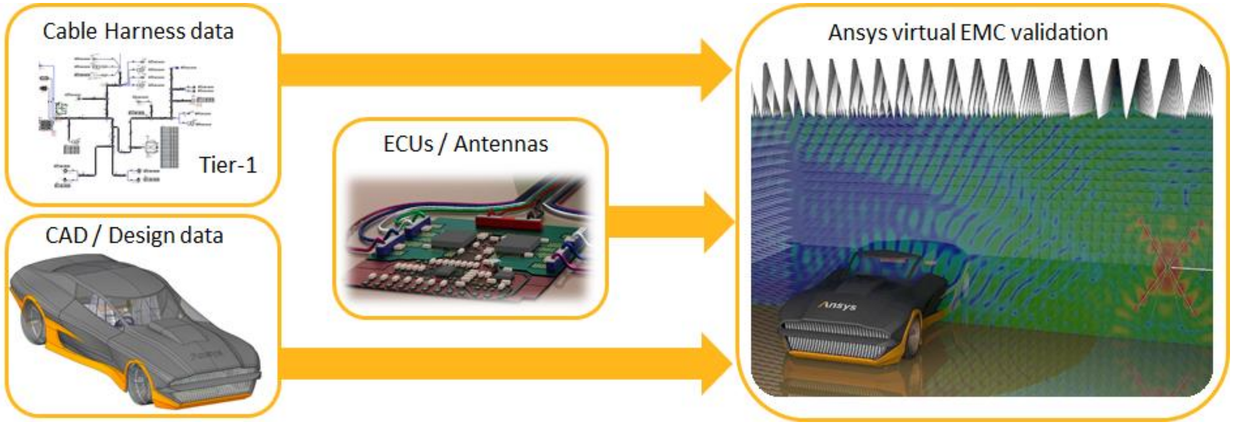
- **Reduced** time to market by **30%** for EMC compliance.
- **Lowers** testing and design **costs** up to **~50%** by reducing lab testing iterations during pre-compliance.
- **Early detection** of EMC issues at vehicle level before the physical prototype is ready.

New Mercedes EMC Facility (2019)



Ansys virtual EMC test





Radiated Emissions Case Study

/ CHALLENGES

Ansys and EMA Help Intel Achieve the Impossible: EMI Simulation of an Entire Server

“The impact of this joint program on Intel has been that we went from not being able to even consider simulating a whole server to now having something that is doable,” says Mendez-Ruiz. “It was a three-way effort and that what makes this story so compelling. Intel, Ansys, and EMA invested whatever effort was necessary to make it happen. It’s a big win for all of us.”

Cesar Mendez-Ruiz
Signal Integrity Engineer / Intel

whatever effort was necessary to make it happen. It’s a big win for all of us.”

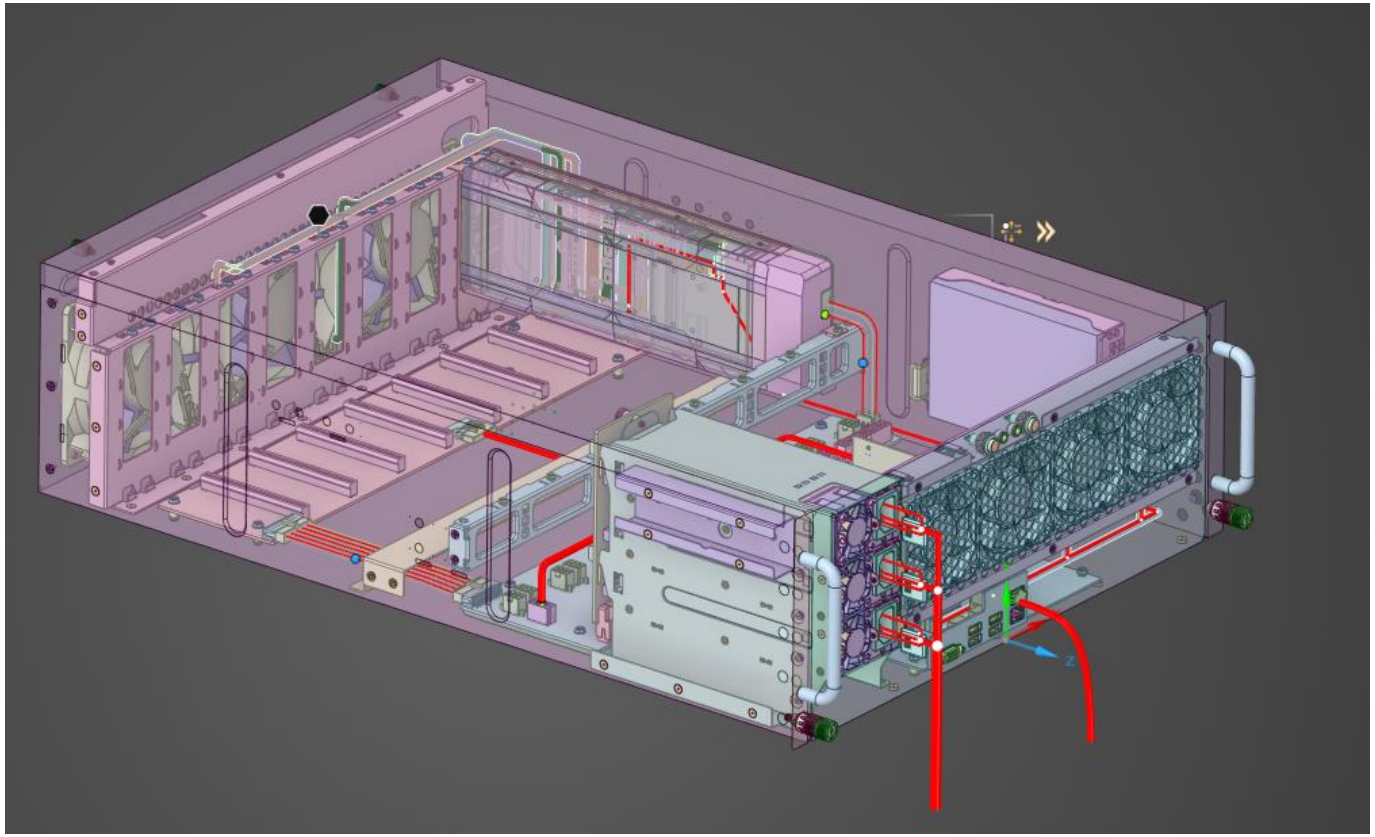
Cesar Mendez-Ruiz
Signal Integrity Engineer / Intel

multi-conductor transmission line theory for the cables. This combination yields a one-dimensional line that shows the cable placement and a 2D cross section that reveals what's inside that one-dimensional line.

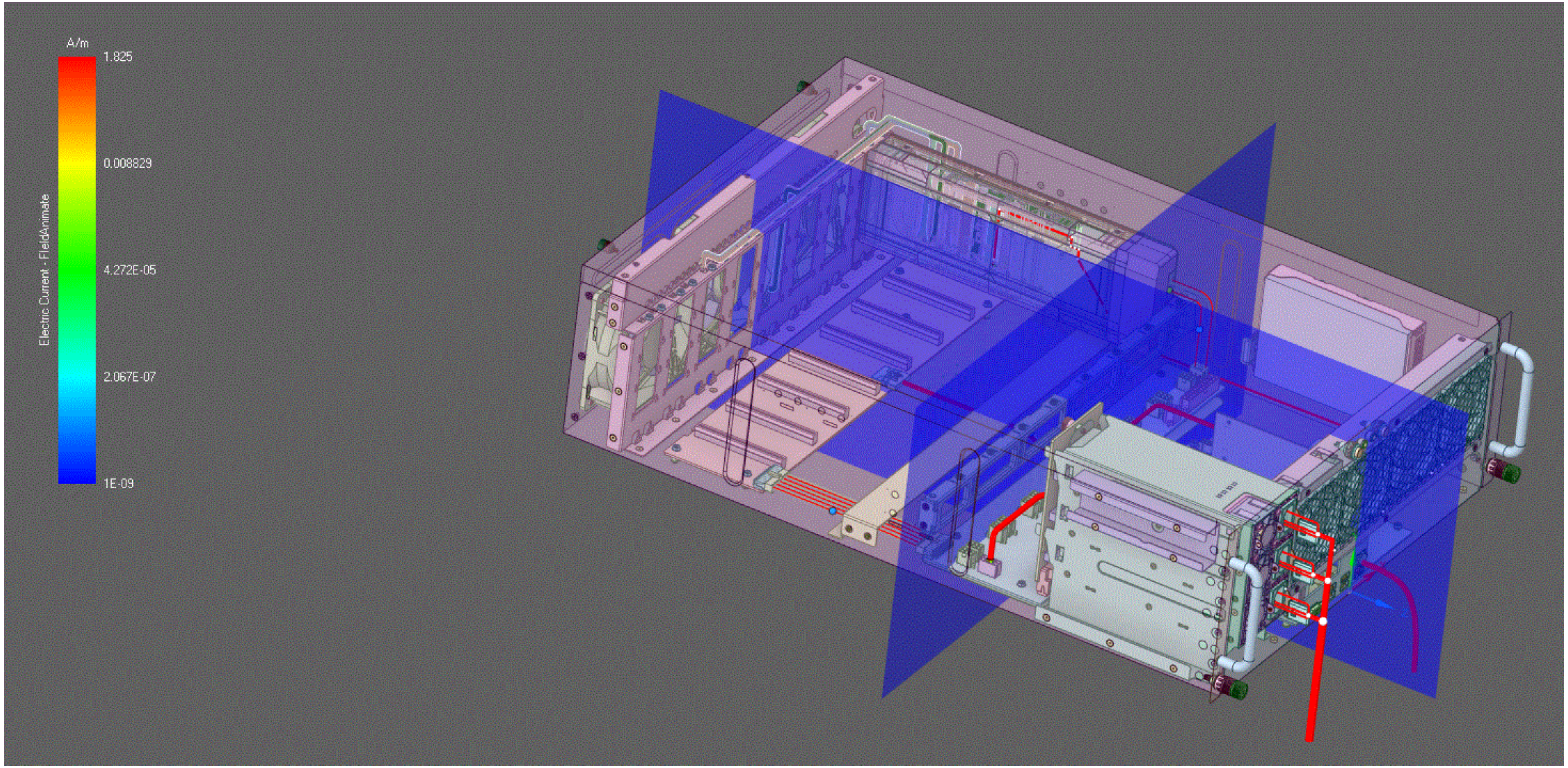
https://www.ansys.com/resource-center/case-study/ansys-and-ema-help-intel-achieve-the-impossible-emi-simulation-of-entire-server

Full-Device Radiated Emissions Modeling

- Power Supplies
- Motherboard with CPU
  - Field Source for Motherboard and SODIMM from SIwave
- HDD
- GPU
- Cooling Fans
- Ethernet output
- Power Input

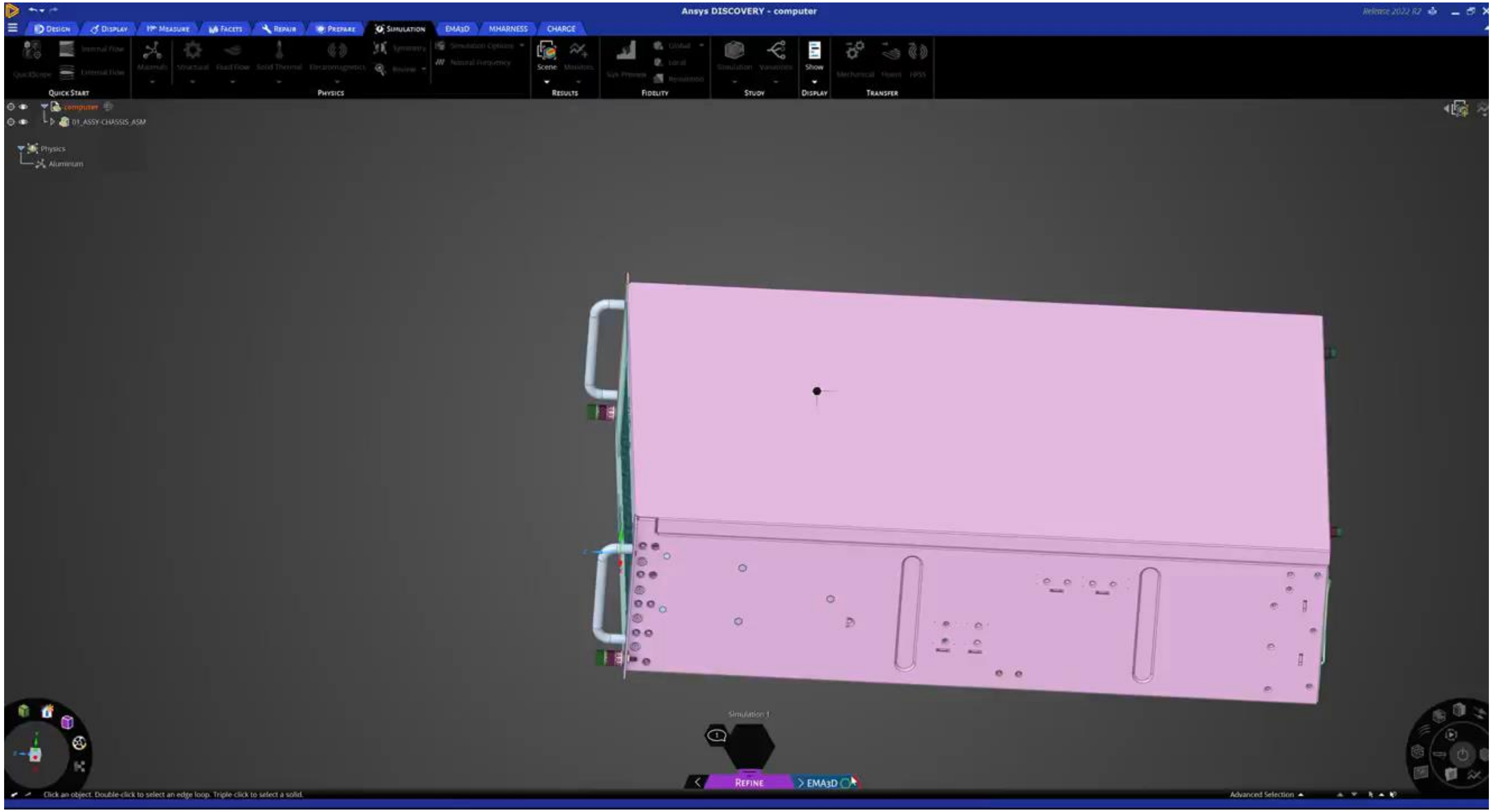


Internal Fields



EMC simulations – Keeping up with Design Changes

You can get the **Shielding Effectiveness** of an enclosure **with a single click**! You just import the geometry and click one button. Simple as that.



Conclusion

- Reliability, EMC/EMI and ESD Simulation can now practically be used in early in product development due to the capacity to analyze industry size models, full systems and ease of use.
- Virtual testing can be used to replace or significantly reduce physical tests by understanding what would be the key conditions to test.
- Maximize the chance to pass certification test.
- Avoid late changes and find tradeoffs early to mitigate problems at significantly lower cost and risk.

Ansys