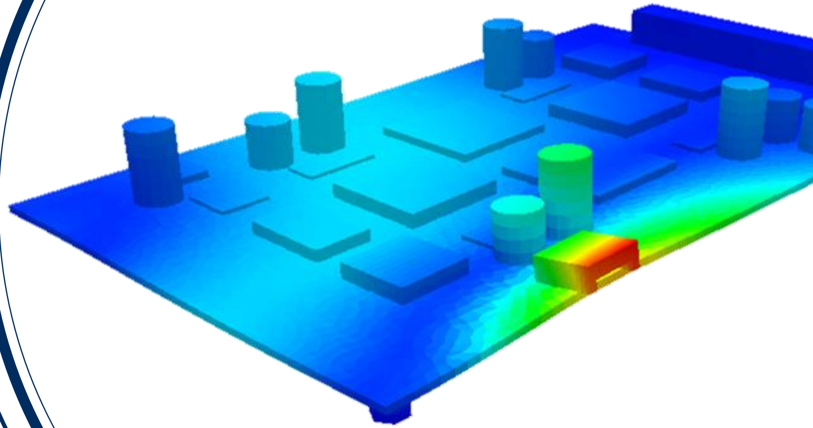
Zuverlässige Baugruppen entwickeln – Design for Reliability of PCB

Technologietag Leistungselektronik

18. Juni 2021

Frank Weiand, CADFEM GmbH



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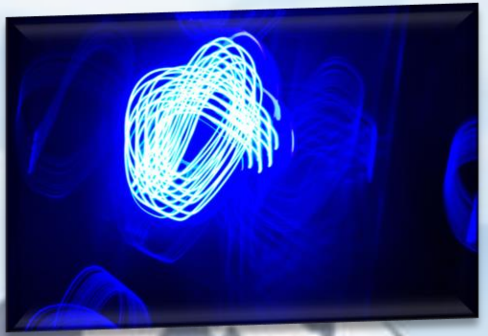
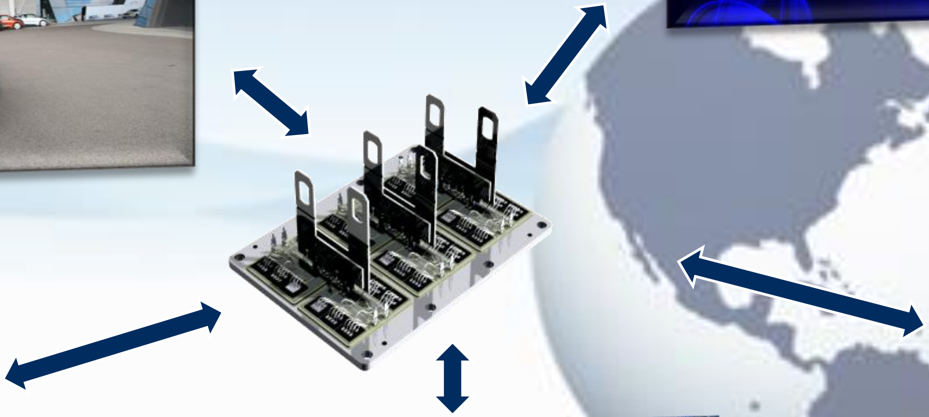
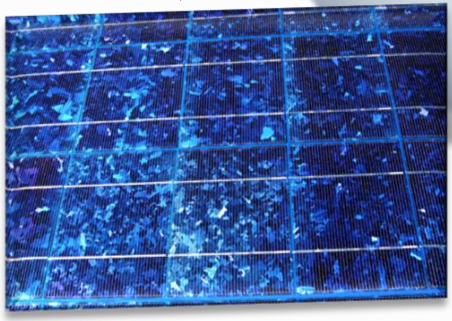
Agenda

- Simulation for Reliability – Overview
- Electronics Design Simulation Workflows
- Example Reliability Study
  - DC-IR Drop – Thermal – Mechanical
- Summary

Power Electronics as Enabler for an Energy Efficient World







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Simulation for Reliability

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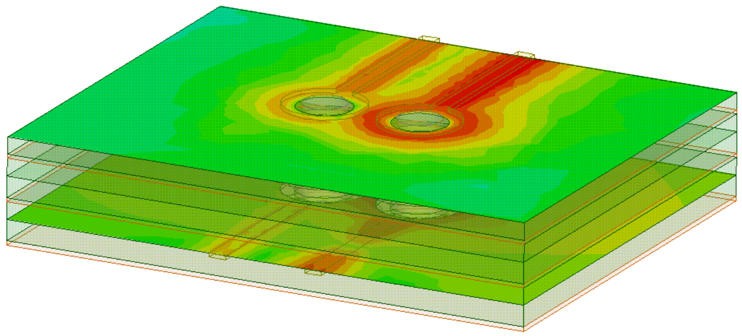
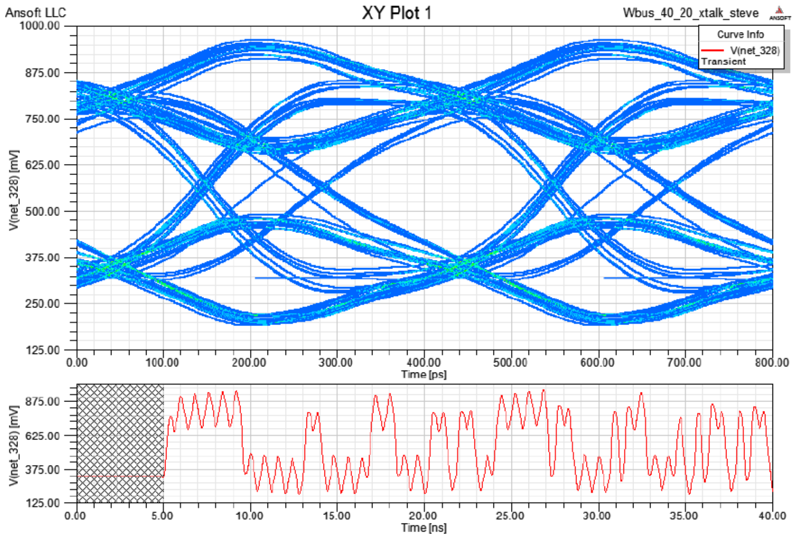
- Electrical Reliability
  - Power Integrity
  - Signal Integrity
- Thermal Reliability
  - Excess of Junction Temperatures
  - Effect on Electrical Behavior
- Mechanical Reliability
  - Operating Loads (Temperature, Vibration, Misuse&Shock)
  - Manufacturing Process (Assembly and Joining technology, Packaging)





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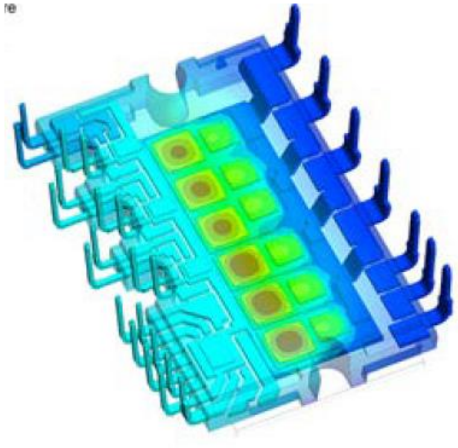

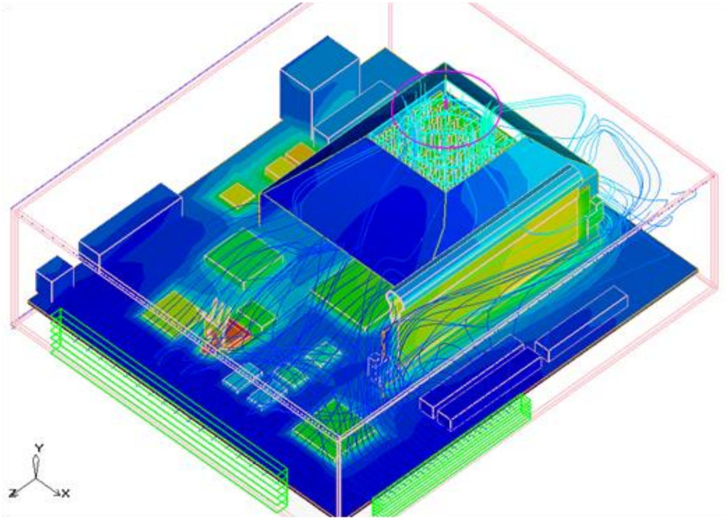

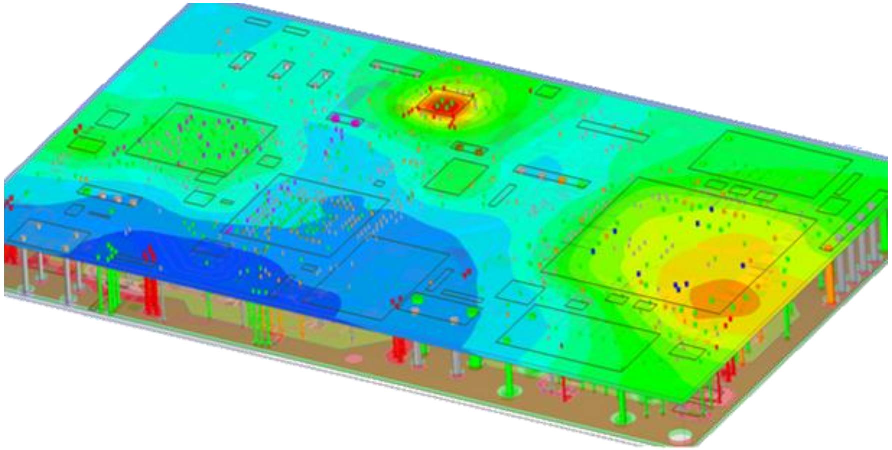

Simulation for Reliability

- Electrical Reliability
  - Power Integrity
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- Thermal Reliability
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  - Operating Loads (Temperature, Vibration, Misuse&Shock)
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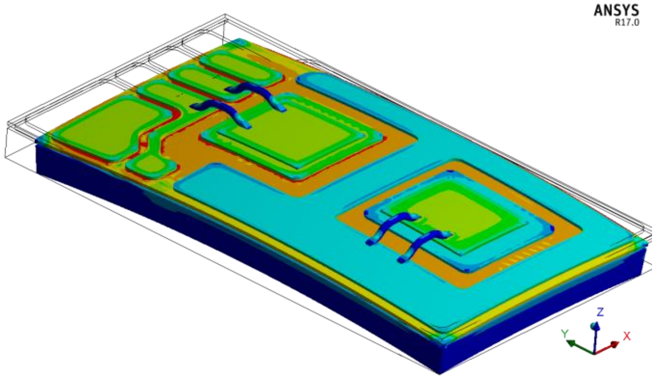

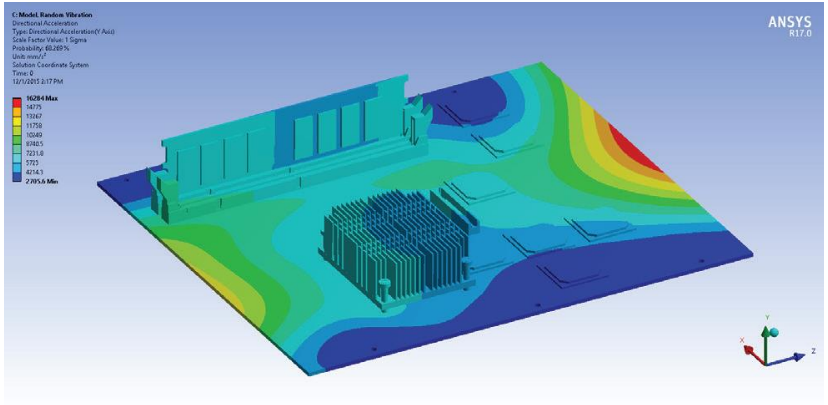

Electronics Design Simulation Workflows

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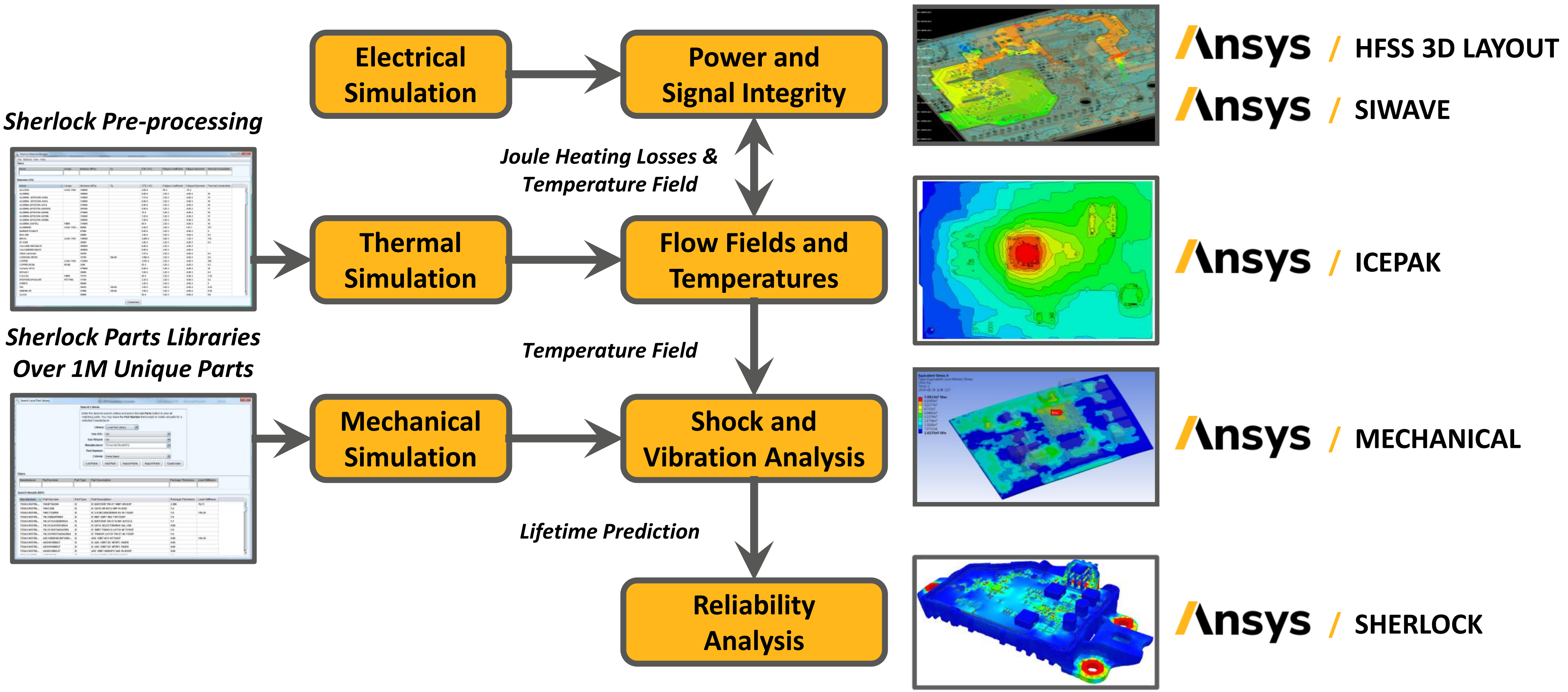

Ansys PCB Reliability Workflow

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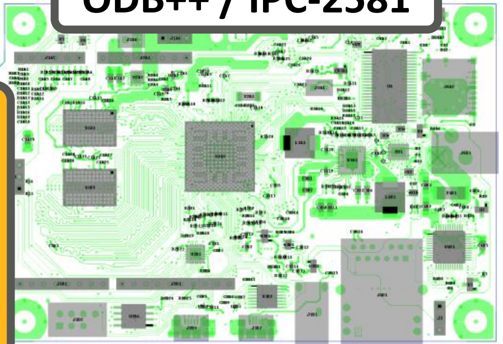
Pre-Processing

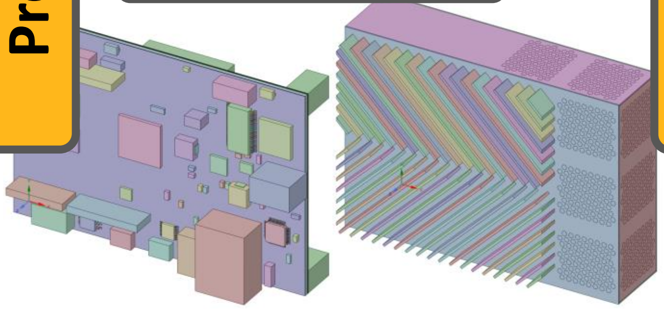
Ansys Sherlock

ODB++ / IPC-2581



Ansys SpaceClaim

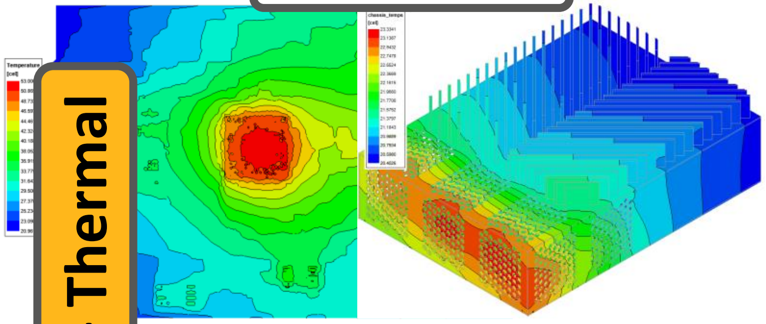
PCB + Chassis + HS



Electrical + Thermal

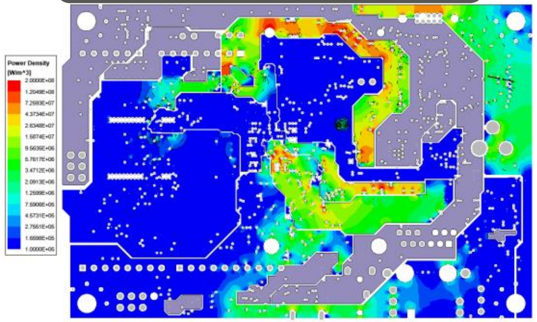
Ansys Icepak

CFD Thermal



Ansys HFSS 3D Layout

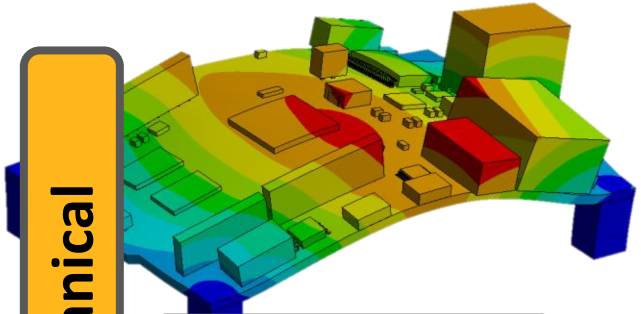
PCB DCIR Losses



Mechanical

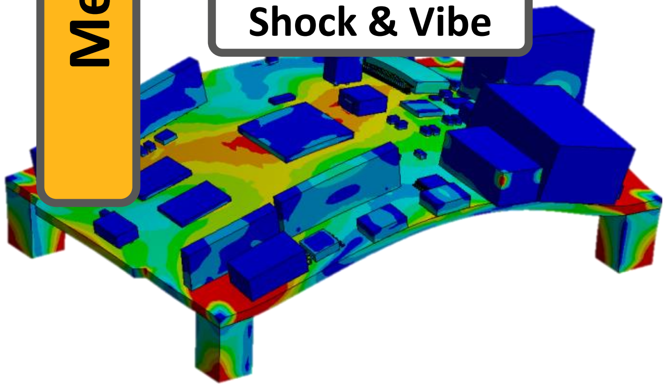
Ansys Mechanical

Thermal Stresses

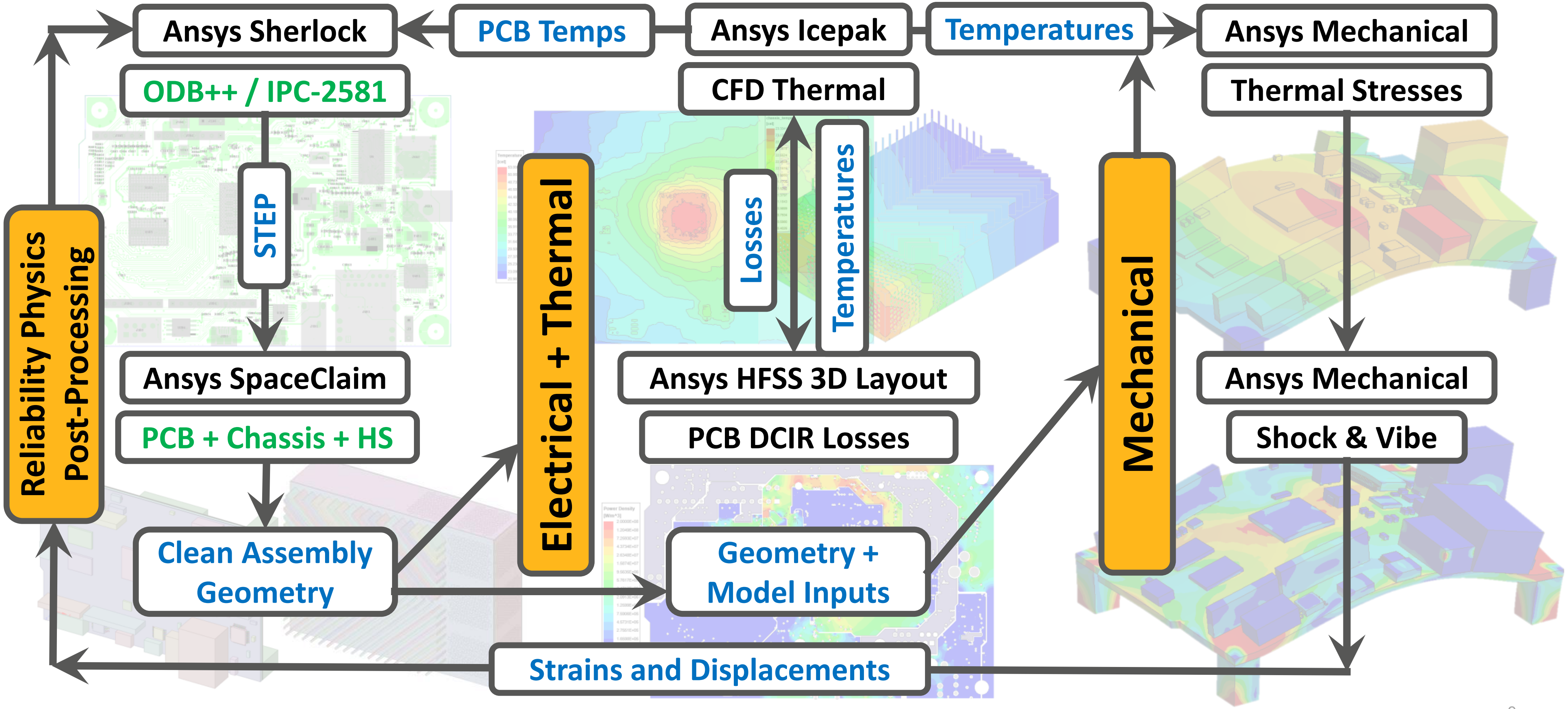


Ansys Mechanical

Shock & Vibe



Ansys PCB Reliability Workflow



Example Reliability Study – Autonomous Vehicle

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- Sherlock, HFSS 3D Layout, Icepak, and Mechanical used together to mitigate risk of failure.
- PCB inside an aluminum chassis within a larger housing on top or inside autonomous vehicle.
- Vehicle is assumed to be operational everyday for 15 hours.
- Reliability goal is less than 5% failure rate over a period of two years.

Analysis not affiliated with Waymo or Mercedes in any way.

Example Reliability Study – Autonomous Vehicle

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Open-source Intel Galileo PCB.

Two cooling solutions:
Forced and Natural convection.

Three 3.0 CFM fans.

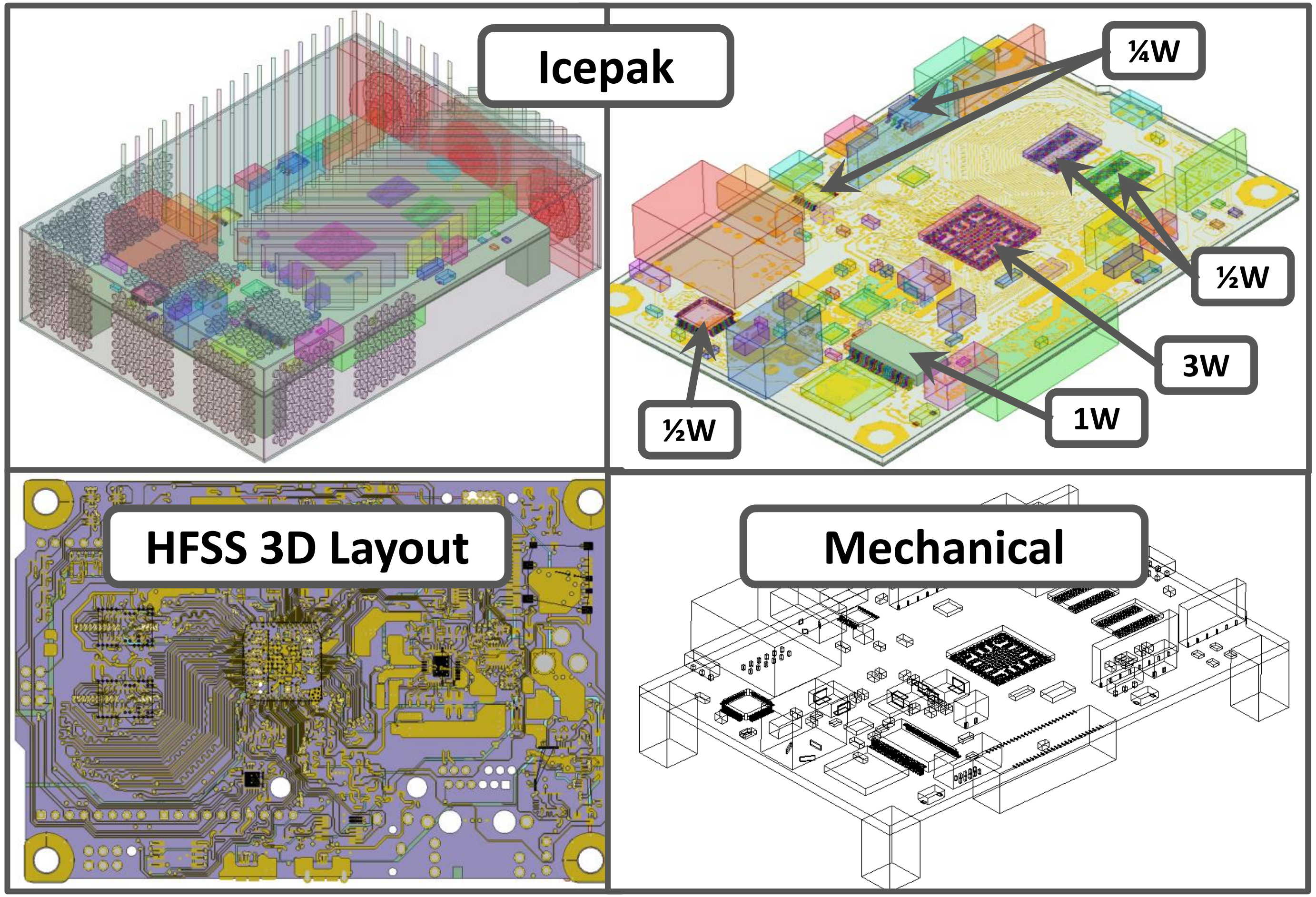
No heatpipes or heatsink standoffs inside chassis.

Ambient temperature of 20°C.

Total power dissipation without DCIR = 6W.

Three potholes per hour of mechanical shock.

Leads and solder balls modeled explicitly for critical heat dissipating components.



Proposed Cooling Solutions – Natural or Forced Convection

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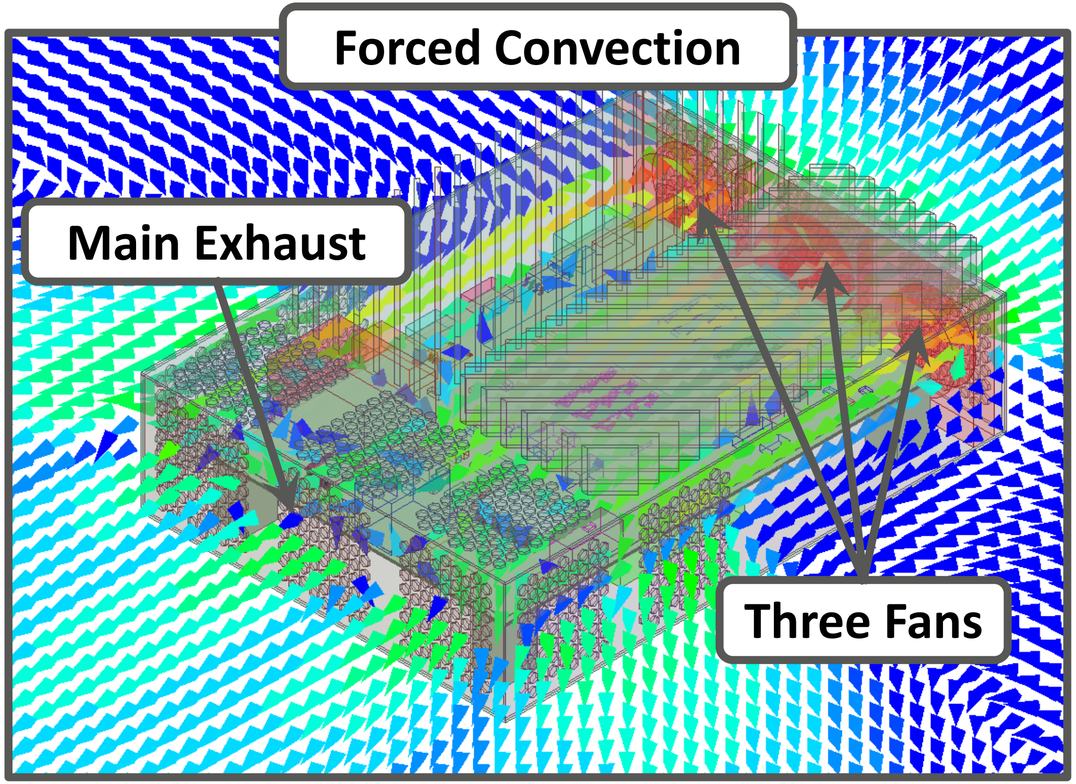
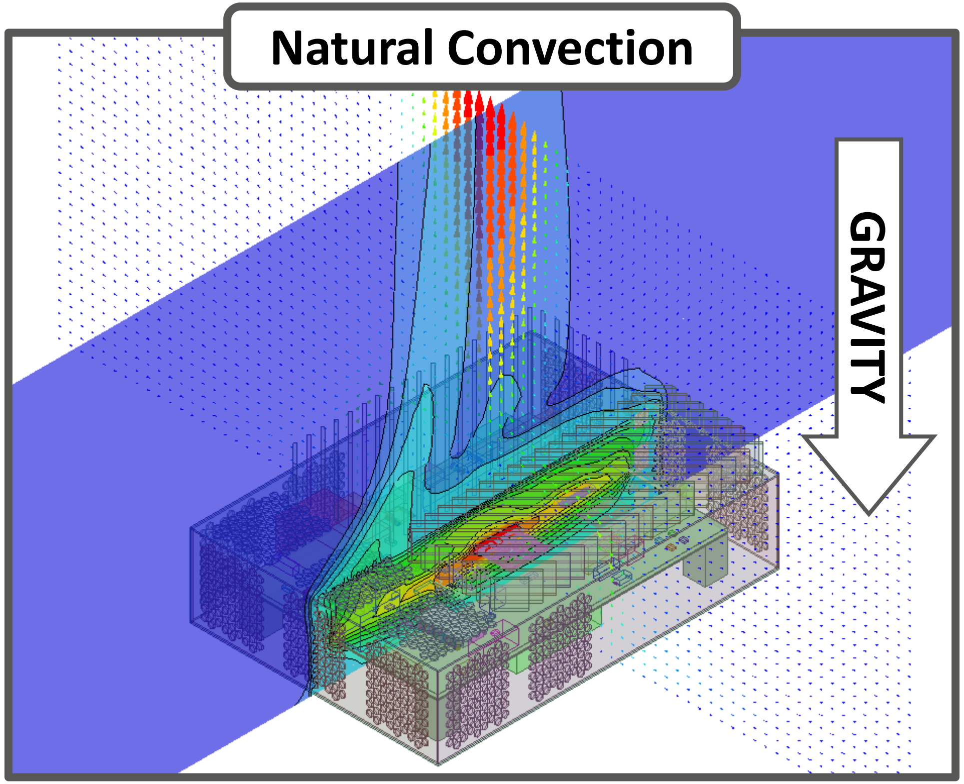
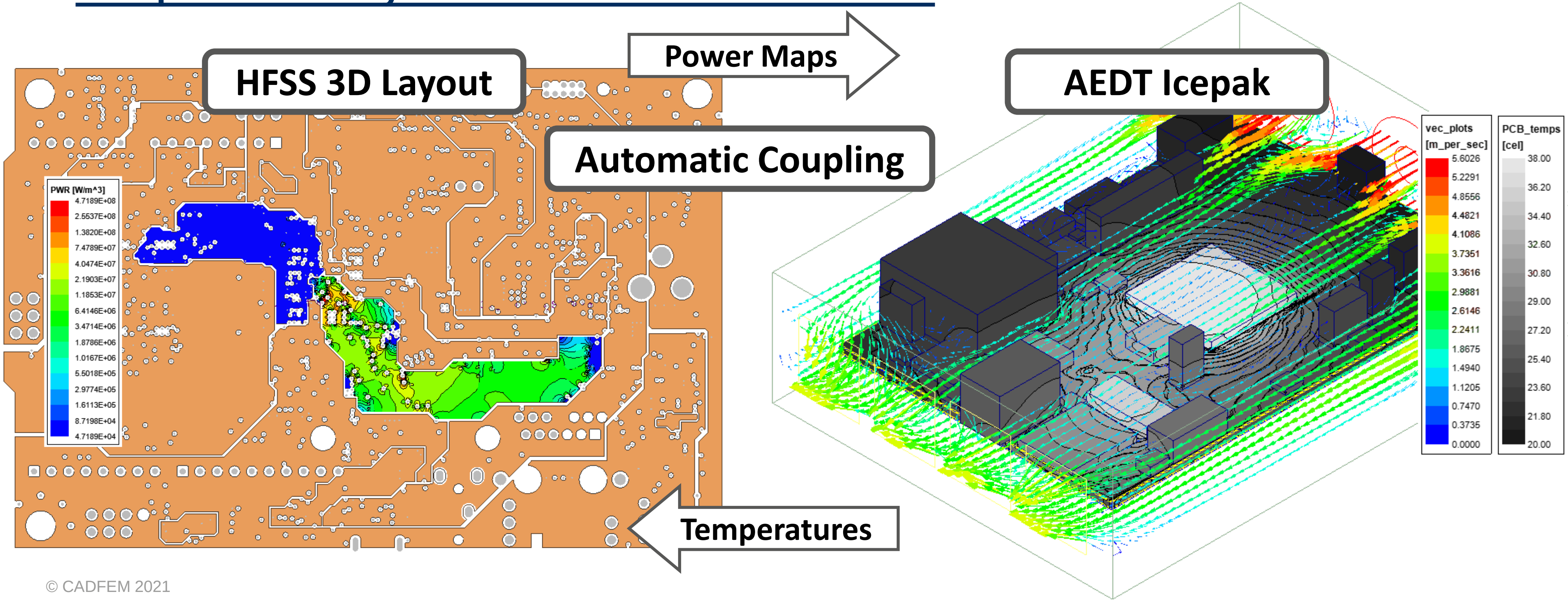
- Natural convection cooling can be desirable for low power devices to avoid the cost of fans.
- Fans can also be noisy and could reduce overall reliability due to potential failures.





Electro-Thermal Analysis: HFSS 3D Layout – Icepak in AEDT

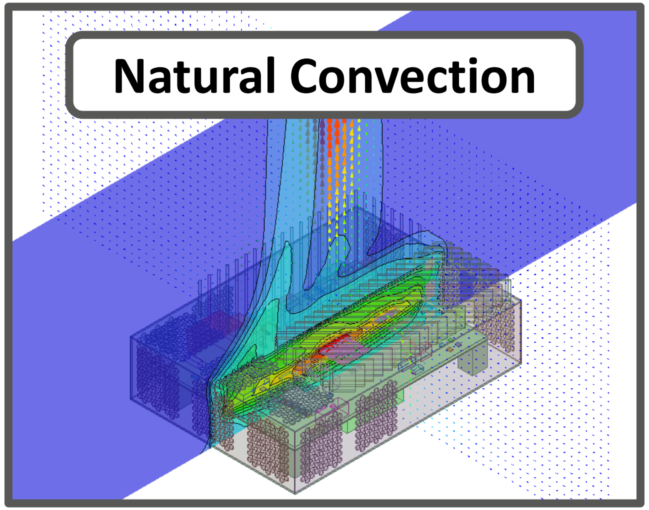
- Fully automated two-way workflow embedded in a single GUI for both DCIR and Thermal.
- **Compare reliability results with and without DCIR.**



Scope of Reliability Analysis

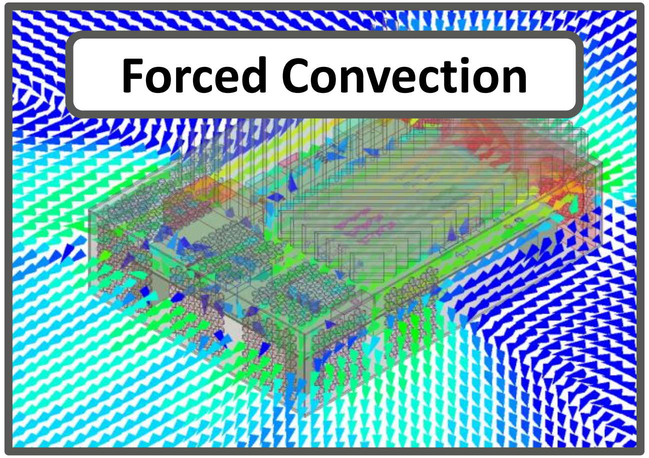
Natural Convection

1. Without DCIR
2. With DCIR for added accuracy



Forced Convection

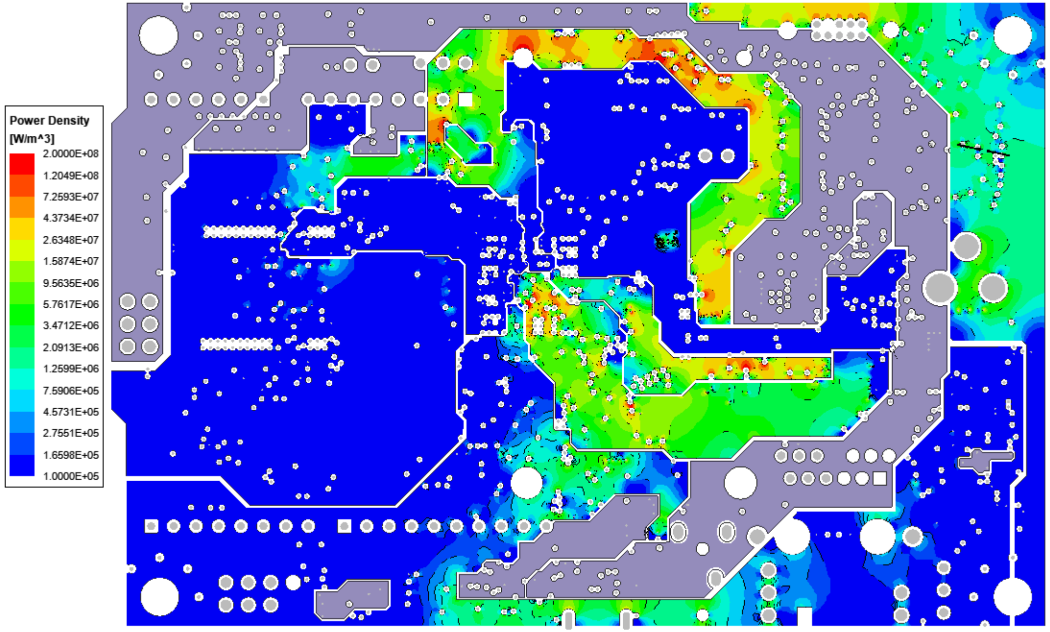
3. Without DCIR
4. With DCIR for added accuracy



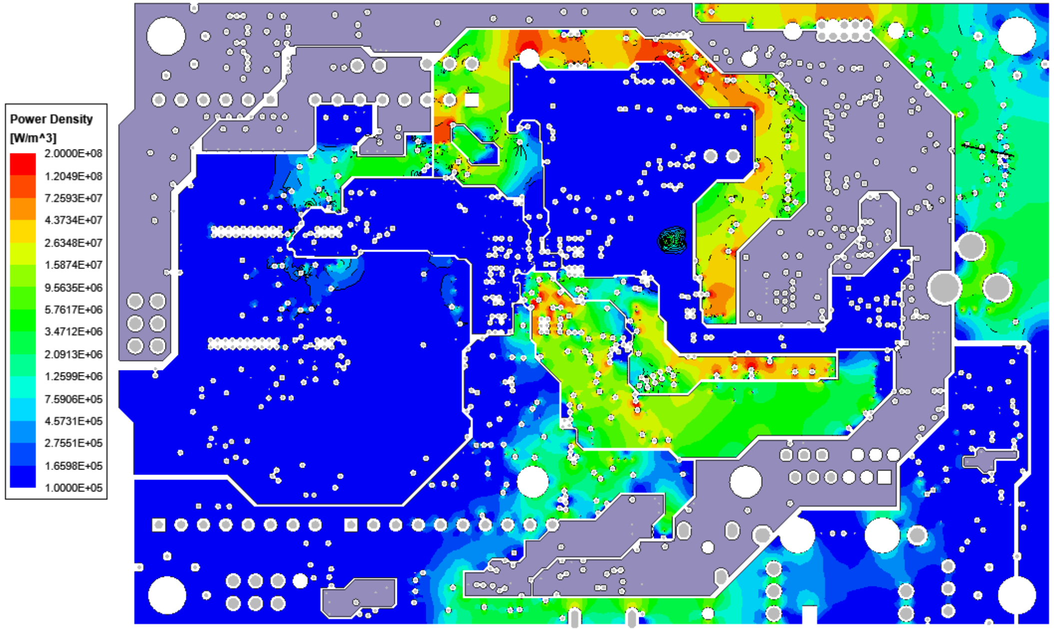
HFSS 3D Layout – DCIR Losses in PCB

- Temperature dependent losses inside the PCB are computed using Ansys HFSS 3D Layout.
- These losses are mapped as heat loads in Ansys Icepak and coupled to the thermal solution.

PWR Layer @ 20°C ≈ 0.5W

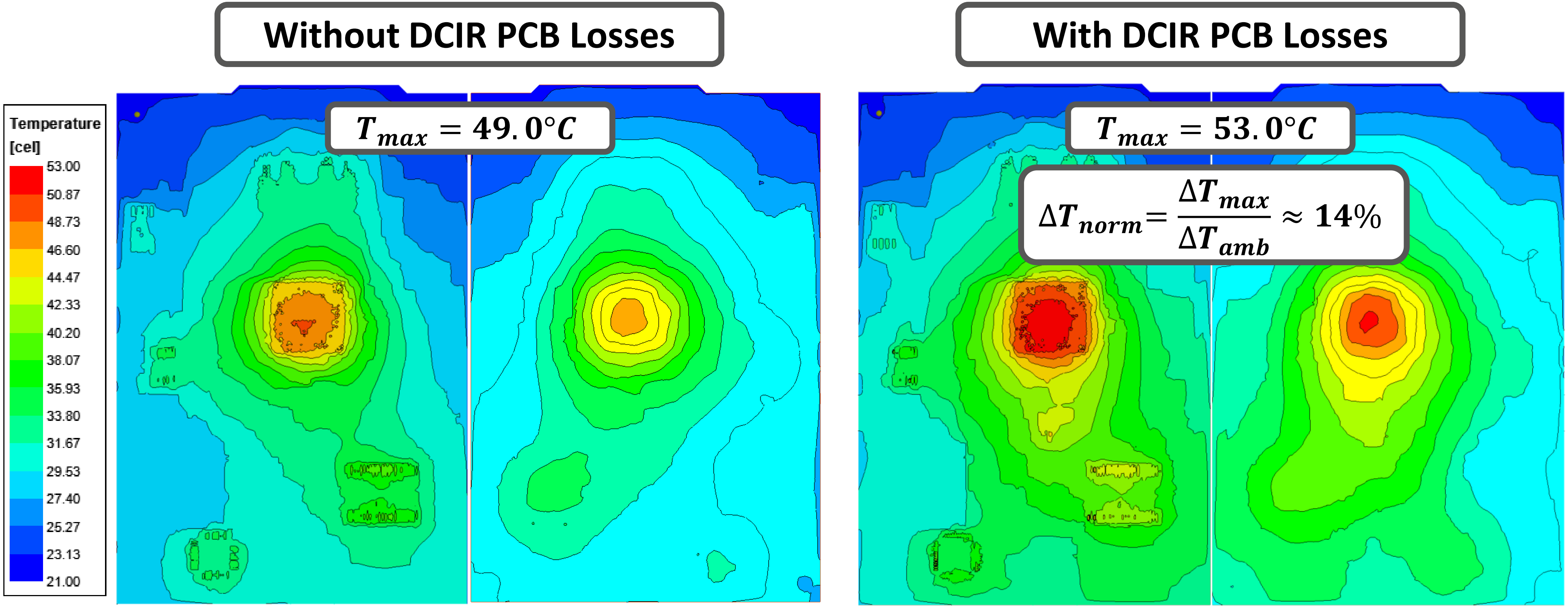


PWR Layer @ 100°C ≈ 0.67W



DCIR Losses in PCB: Effect on Temperatures – Forced Convection

- DCIR losses due to current crowding can increase hotspot temperatures on the PCB.

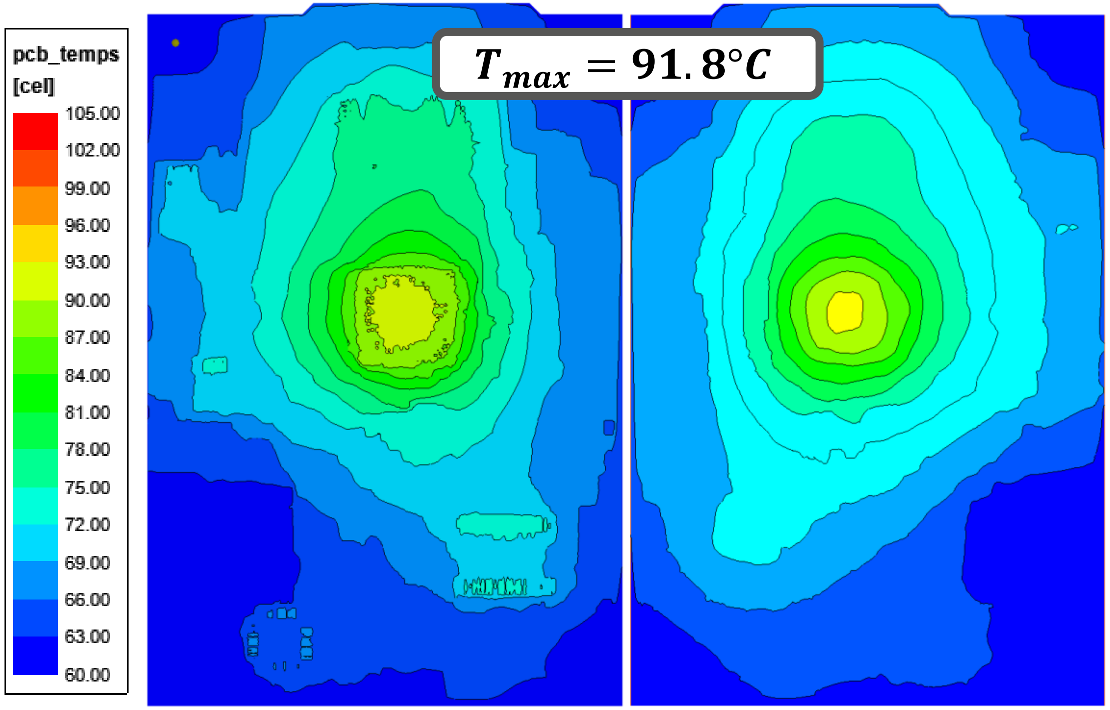


DCIR Losses in PCB: Effect on Temperatures – Natural Convection

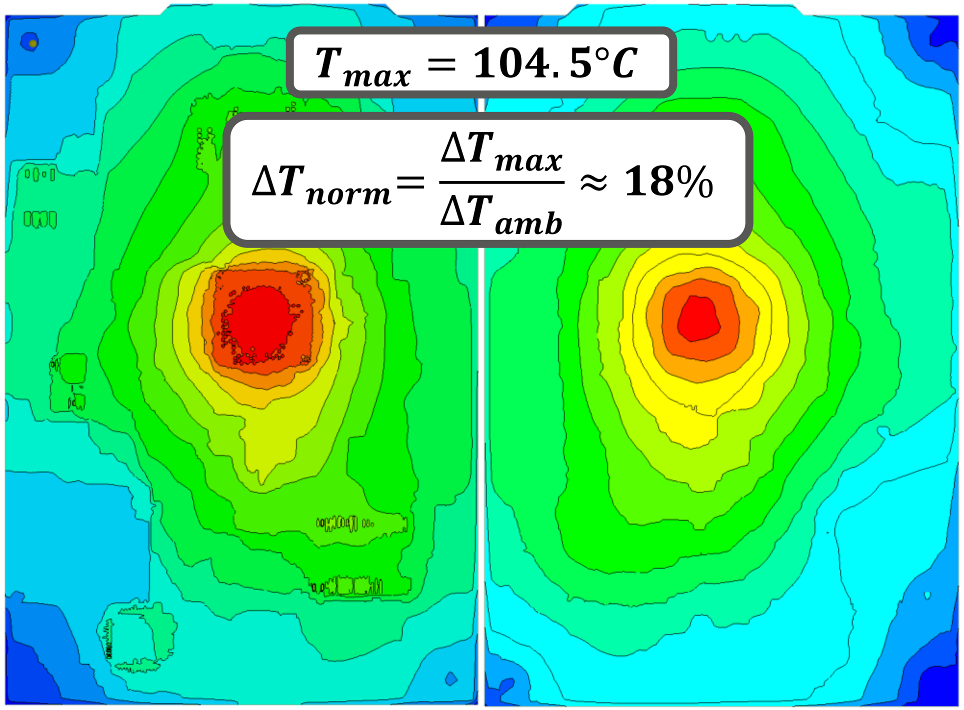
CADFEM

- DCIR losses due to current crowding can increase hotspot temperatures on the PCB.

Without DCIR PCB Losses



With DCIR PCB Losses



Ansys PCB Reliability Workflow

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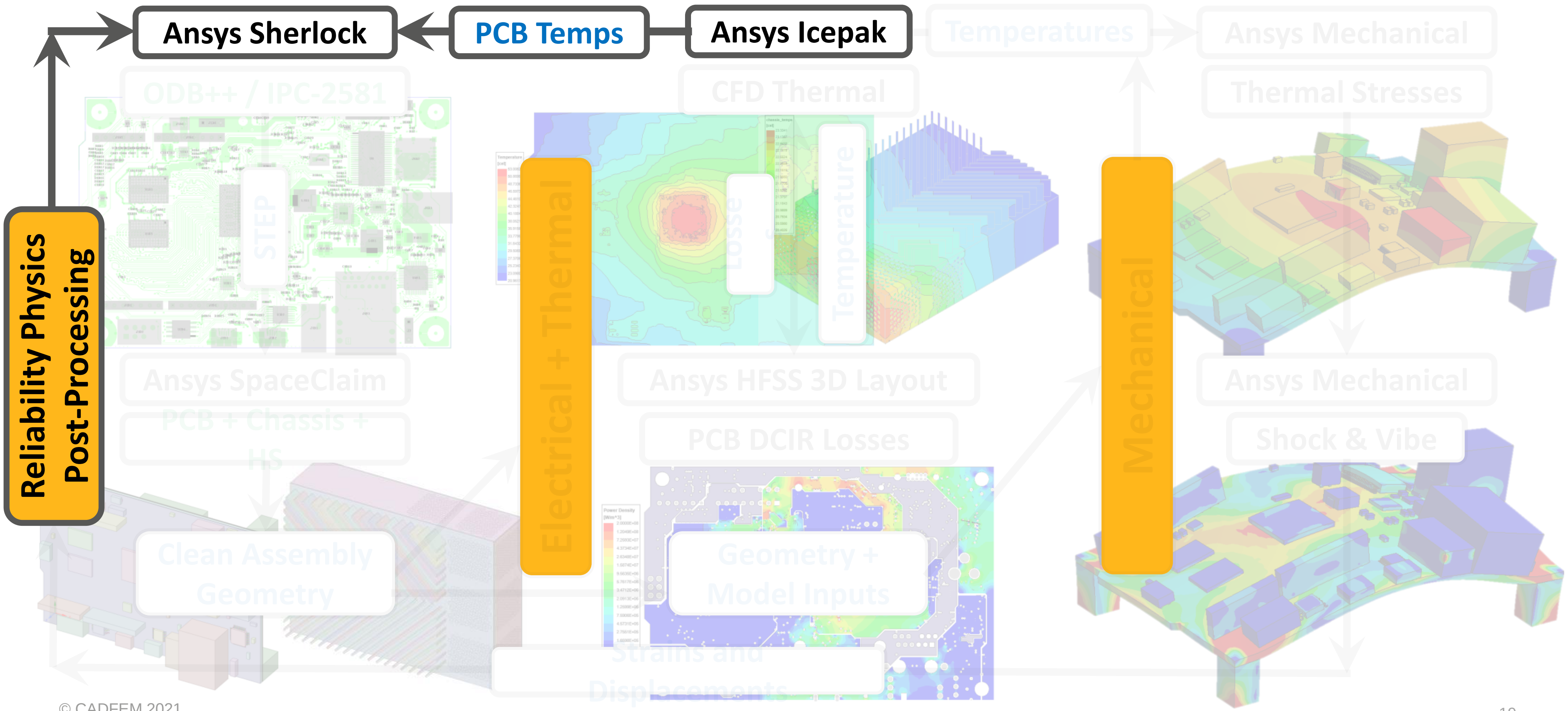

Thermal Derating Analysis – Natural Convection

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- Quickly check which components exceed their maximum allowable temperature.
- The DCIR analysis identifies additional failures that would otherwise have been missed.

Natural Convection without DCIR

$$T_{max} = 91.8°C$$

RefDes	Part Number	Part Type	Package	Min Rated	Max Rated	Min Temp	Max Temp	Score
C3L9	RMJMK105BJ105KVEF	CAPACITOR	0402	-55.0	85.0	20.0	85.2	0.0
C3L10	RMJMK105BJ105KVEF	CAPACITOR	0402	-55.0	85.0	20.0	85.4	0.0
C3L11	RMJMK105BJ105KVEF	CAPACITOR	0402	-55.0	85.0	20.0	90.6	0.0
C3L14	RMJMK105BJ105KVEF	CAPACITOR	0402	-55.0	85.0	20.0	90.0	0.0
C3L15	CL03A105MR3CSNH	CAPACITOR	0201	-55.0	85.0	20.0	90.6	0.0
C3L17	CL03A105MR3CSNH	CAPACITOR	0201	-55.0	85.0	20.0	90.6	0.0
C3L18	CL03A105MR3CSNH	CAPACITOR	0201	-55.0	85.0	20.0	90.6	0.0
C3L20	CL03A105MR3CSNH	CAPACITOR	0201	-55.0	85.0	20.0	90.6	0.0
C3L21	RMJMK105BJ105KVEF	CAPACITOR	0402	-55.0	85.0	20.0	90.1	0.0
C3L22	CL05A106MR5NRNC	CAPACITOR	0402	-55.0	85.0	20.0	90.6	0.0
C3L24	CL03A105MR3CSNH	CAPACITOR	0201	-55.0	85.0	20.0	90.6	0.0
C3L26	CL03A105MR3CSNH	CAPACITOR	0201	-55.0	85.0	20.0	90.6	0.0
C3L28	CL03A105MR3CSNH	CAPACITOR	0201	-55.0	85.0	20.0	90.6	0.0
C3L29	CL03A105MR3CSNH	CAPACITOR	0201	-55.0	85.0	20.0	90.6	0.0
U3B2	MAX3232CUE+	IC	HTSSOP-16	0.0	70.0	20.0	70.7	0.0
S1A1	TL1015AF160QG	SWITCH	SON SW	-20.0	70.0	20.0	67.3	1.4

Natural Convection with DCIR

$$T_{max} = 104.5°C$$

With increased CFD fidelity, more components fail!

RefDes	Part Number	Part Typ				Min Temp	Max Temp	Score
C2L1	RMJMK105BJ105KVEF	CAPACI				43.4	97.0	0.0
C2L4	C2012X5R0J226M	CAPACITOR	0805	-55.0	85.0	42.3	90.5	0.0
C2L5	RMJMK105BJ105KVEF	CAPACITOR	0402	-55.0	85.0	43.4	90.5	0.0
C2L6	C201							0.0
C2L8	GRM							0.0
C2L10	RMJ							0.0
C2L11	C201							0.0
C2L12	GRM							0.0
C2L13	RMJ							0.0
C3B1	C2012X5R0J226M	CAPACITOR	0805	-55.0	85.0	41.3	87.5	0.0
C3B5	RMJMK105BJ105KVEF	CAPACITOR	0402	-55.0	85.0	43.5	93.7	0.0
C3B7	C2012X5R0J226M	CAPACITOR	0805	-55.0	85.0	39.1	87.3	0.0
C3B10	CL10A226MQ8NRNE	CAPACITOR	0603	-55.0	85.0	39.0	86.9	0.0
C3L8	RMJMK105BJ105KVEF	CAPACITOR	0402	-55.0	85.0	44.8	90.5	0.0
C3L9	RMJMK105BJ105KVEF	CAPACITOR	0402	-55.0	85.0	43.4	97.0	0.0
C3L10	RMJMK105BJ105KVEF	CAPACITOR	0402	-55.0	85.0	43.8	97.0	0.0
C3L11	RMJMK105BJ105KVEF	CAPACITOR	0402	-55.0	85.0	50.0	103.2	0.0
C3L12	C1608X5R0J225KT00...	CAPACITOR	0603	-55.0	85.0	39.1	90.5	0.0
C3L14	RMJMK105BJ105KVEF	CAPACITOR	0402	-55.0	85.0	48.7	100.2	0.0
C3L15	CL03A105MR3CSNH	CAPACITOR	0201	-55.0	85.0	50.0	103.2	0.0
C3L16	C1608X5R0J225KT00...	CAPACITOR	0603	-55.0	85.0	39.1	90.5	0.0
C3L17	CL03A105MR3CSNH	CAPACITOR	0201	-55.0	85.0	50.0	103.2	0.0
C3L18	CL03A105MR3CSNH	CAPACITOR	0201	-55.0	85.0	52.1	103.2	0.0

Thermal Derating Mitigation – Natural Convection with DCIR

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- Many problematic components are X5R dielectric capacitors rated to 85˚C. If replaced with X7R capacitors that are rated to 105˚C, none will exceed their maximum ratings.
- Given the Icepak maximum temperature of 104.5˚C, and the maximum allowable temperature of 105˚C , the margin of error might be too close for comfort.

X5R Capacitors, rated to $85°C$

$T_{max} = 104.5°C$

RefDes	Part Number	Part Type	Package	Min Rated	Max Rated	Min Temp	Max Temp	Score
C2L1	RMJMK105BJ105KVEF	CAPAC				43.4	97.0	0.0
C2L4	C2012X5R0J226M	CAPAC				42.3	90.5	0.0
C2L5	RMJMK105BJ105KVEF	CAPAC				43.4	90.5	0.0
C2L6	C2012X5R0J226M	CAPACITOR	0805	-55.0	85.0	42.5	90.5	0.0
C2L8	GRM21BR61C106KE1...	CAPACITOR	0805	-55.0	85.0	41.2	89.5	0.0
C2L10	RMJMK105BJ105KVEF	CAPACITOR	0402	-55.0	85.0	43.4	90.5	0.0
C2L11	C2012X5R0J226M	CAPACITOR	0805	-55.0	85.0	42.5	90.5	0.0
C2L12	GRM21BR61C106KE1...	CAPACITOR	0805	-55.0	85.0	41.2	88.7	0.0
C2L13	RMJMK105BJ105KVEF	CAPACITOR	0402	-55.0	85.0	43.4	97.0	0.0
C3B1	C2012X5R0J226M	CAPACITOR	0805	-55.0	85.0	41.3	87.5	0.0
C3B5	RMJMK105BJ105KVEF	CAPACITOR	0402	-55.0	85.0	43.5	93.7	0.0
C3B7	C2012X5R0J226M	CAPACITOR	0805	-55.0	85.0	39.1	87.3	0.0
C3B10	CL10A226MQ8NRNE	CAPACITOR	0603	-55.0	85.0	39.0	86.9	0.0
C3L8	RMJMK105BJ105KVEF	CAPACITOR	0402	-55.0	85.0	44.8	90.5	0.0
C3L9	RMJMK105BJ105KVEF	CAPACITOR	0402	-55.0	85.0	43.4	97.0	0.0
C3L10	RMJMK105BJ105KVEF	CAPACITOR	0402	-55.0	85.0	43.8	97.0	0.0
C3L11	RMJMK105BJ105KVEF	CAPACITOR	0402	-55.0	85.0	50.0	103.2	0.0
C3L12	C1608X5R0J225KT00...	CAPACITOR	0603	-55.0	85.0	39.1	90.5	0.0
C3L14	RMJMK105BJ105KVEF	CAPACITOR	0402	-55.0	85.0	48.7	100.2	0.0
C3L15	CL03A105MR3CSNH	CAPACITOR	0201	-55.0	85.0	50.0	103.2	0.0
C3L16	C1608X5R0J225KT00...	CAPACITOR	0603	-55.0	85.0	39.1	90.5	0.0
C3L17	CL03A105MR3CSNH	CAPACITOR	0201	-55.0	85.0	50.0	103.2	0.0
C3L18	CL03A105MR3CSNH	CAPACITOR	0201	-55.0	85.0	52.1	103.2	0.0

X7R Capacitors, rated to $105°C$

$T_{max} = 104.5°C$

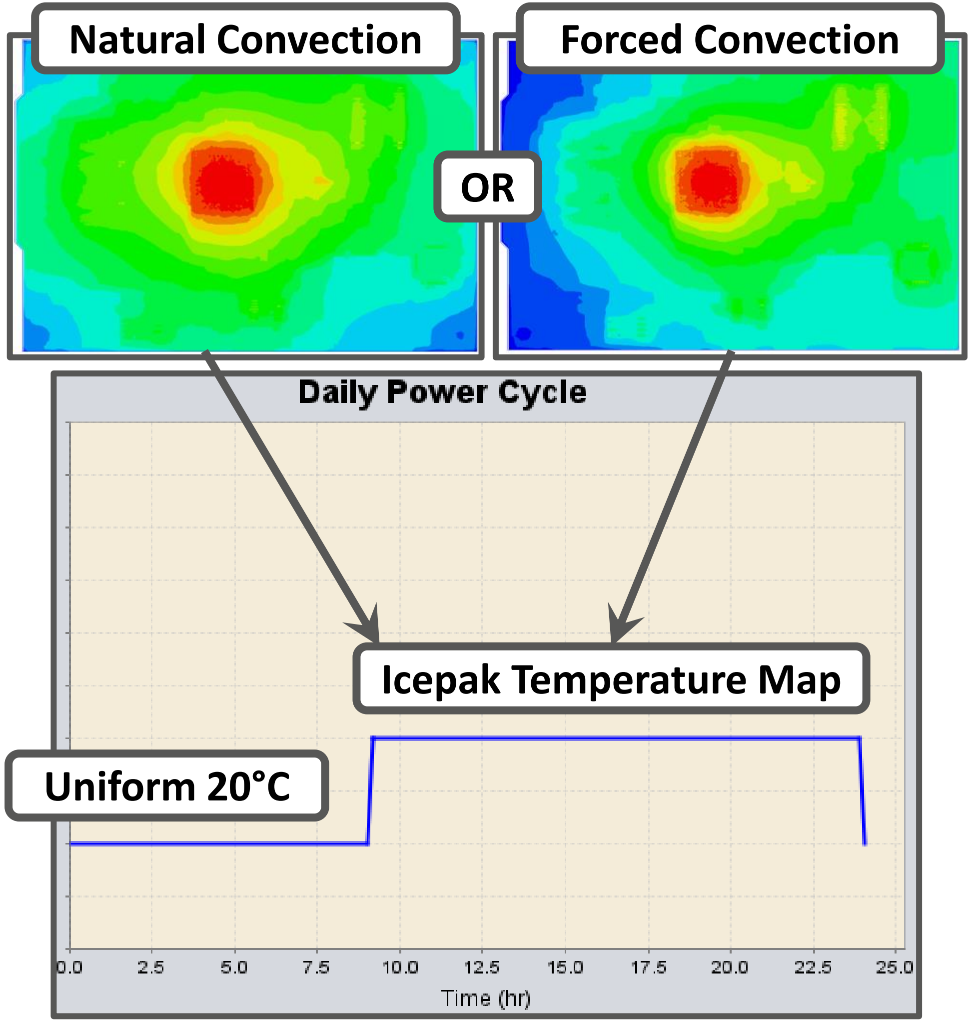
RefDes	Part Type	Package	Min Rated	Max Rated	Min Temp	Max Temp	Score
C3L15	CAPACITOR	0			0	103.2	0.9
C3L17	CAPACITOR	0			0	103.2	0.9
C3L18	CAPACITOR	0			0	103.2	0.9
C3L20	CAPACITOR	0201	-55.0	105.0	20.0	103.2	0.9
C3L24							0.9
C3L26							.9
C3L28							.9
C3L29							.9
C3L11							.9
C3L19							.9
C3L22							.9
C3L25							.9
C3L27							0.9
C3L30	CAPACITOR	0402	-55.0	105.0	20.0	102.9	1.1
C3M1	CAPACITOR	0402	-55.0	105.0	20.0	102.4	1.3
C3L14	CAPACITOR	0402	-55.0	105.0	20.0	100.2	2.4
C3L13	CAPACITOR	0402	-55.0	105.0	20.0	100.2	2.4
C3L21	CAPACITOR	0402	-55.0	105.0	20.0	100.2	2.4
C3M2	CAPACITOR	0402	-55.0	105.0	20.0	100.2	2.4
C3M5	CAPACITOR	0402	-55.0	105.0	20.0	98.3	3.3
C2L1	CAPACITOR	0402	-55.0	105.0	20.0	97.0	4.0
C2L13	CAPACITOR	0402	-55.0	105.0	20.0	97.0	4.0

Very small margin of error, highly likely that forced cooling will be necessary.

Sherlock Solder Fatigue Analysis

CADFEM

- The Icepak temperature fields are used in Sherlock to quantify solder fatigue failure risk associated with power cycling.
- A daily power cycle is applied to the PCBA to account for the system powering up and staying on during its 15 hours of drive time.
- Need to know the ramp time:
  - A transient analysis in Icepak could be done to compute the exact time to steady state.
  - For simplicity, a lumped capacitance hand calculation yields 22 minutes to achieve steady state.
- Ramp times tend to be more critical to solder fatigue when they are under 5 minutes.
- Ramp time is not expected to influence solder fatigue reliability for this PCBA.



Sherlock Solder Fatigue – Natural Convection with and without DCIR

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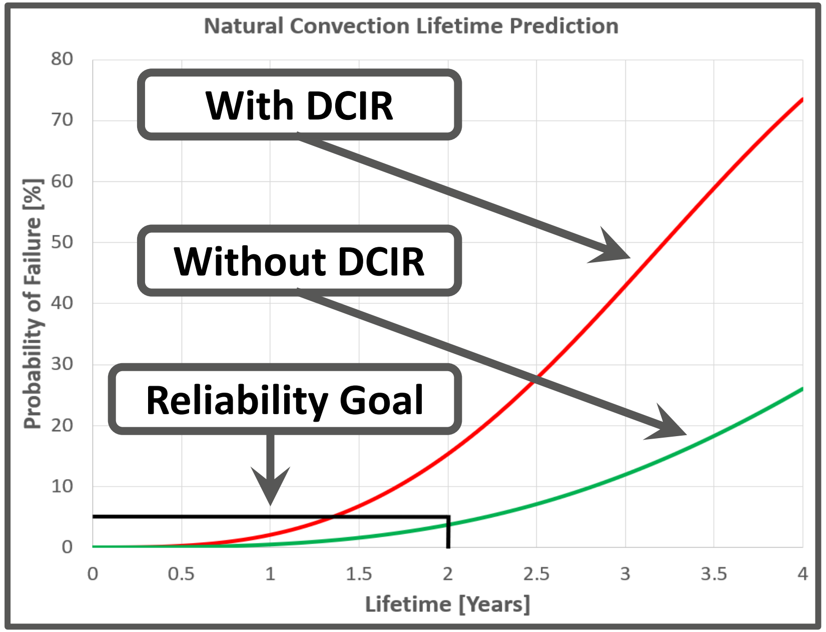
- Without DCIR losses, the PCBA passes the reliability goal, but with a very slim margin.
- With DCIR losses the PCBA does NOT meet its reliability requirement. The additional heating is enough to push the U2A5 component prediction to failure. Two additional BGAs are also identified as borderline.



Without DCIR All Components Pass

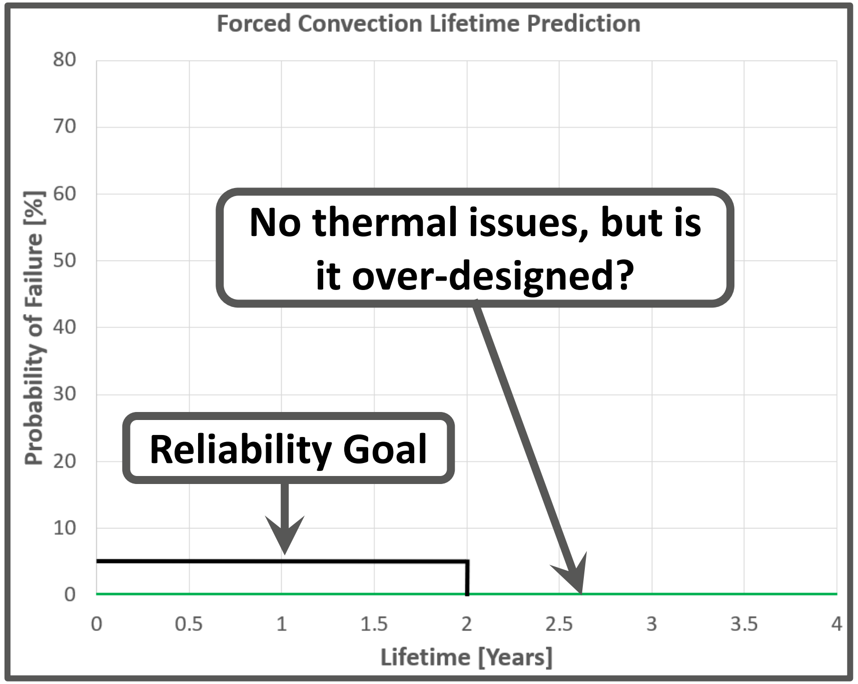
RefDes	Package	Part Type	Model	Side	Material	Solder	Max dT (C)	Damage	TTF (years)	Cycles To Fail	Score
U2A5	CBGA-393	IC	CBGA	TOP	LAMINATE-BGA	SAC305	69.3	3.0E-1	6.58	2,405	2.6
U1B5	BGA-78	IC	BGA	TOP	LAMINATE-BGA	SAC305	56.2	1.6E-1	12.22	4,463	10.0
U1A1	BGA-78	IC	BGA	TOP	LAMINATE-BGA	SAC305	55.6	1.6E-1	12.58	4,595	10.0
Y3L1	0000	OSCILLATOR	CC	BOT	ALUMINA	SAC305	57.5	1.0E-1	19.37	7,073	10.0
Y2A1	0000	OSCILLATOR	CC	TOP	ALUMINA	SAC305	56.1	3.7E-2	>20	19,510	10.0
U2L1	BGA8	IC	BGA	BOT	SILICON	SAC305	58.4	3.3E-2	>20	22,401	10.0
U2M1	BGA8	IC	BGA	BOT	SILICON	SAC305	57.8	3.2E-2	>20	23,160	10.0

With DCIR Some Components Fail / Borderline

RefDes	Package	Part Type	Model	Side	Material	Solder	Max dT (C)	Damage	TTF (years)	Cycles To Fail	Score
U2A5	CBGA-393	IC	CBGA	TOP	LAMINATE-BGA	SAC305	81.7	5.1E-1	3.92	1,430	0.0
U1B5	BGA-78	IC	BGA	TOP	LAMINATE-BGA	SAC305	63.7	2.4E-1	8.35	3,048	5.6
U1A1	BGA-78	IC	BGA	TOP	LAMINATE-BGA	SAC305	63.6	2.4E-1	8.40	3,068	5.7
Y3L1	0000	OSCILLATOR	CC	BOT	ALUMINA	SAC305	67.4	1.0E-1	12.30	4,493	10.0
Y2A1	0000	OSCILLATOR	CC	TOP	ALUMINA	SAC305	69.8	7.0E-2	>20	10,495	10.0
U2L1	BGA8	IC	BGA	BOT	SILICON	SAC305	70.5	5.8E-2	>20	12,646	10.0
U2M1	BGA8	IC	BGA	BOT	SILICON	SAC305	70.5	5.8E-2	>20	12,646	10.0

Sherlock Solder Fatigue – Forced Convection with and without DCIR

- With forced convection, the PCBA meets its reliability goal with significant margin.
- However, with and without DCIR, there are big differences in cycles to failure.



Without DCIR All Components Pass

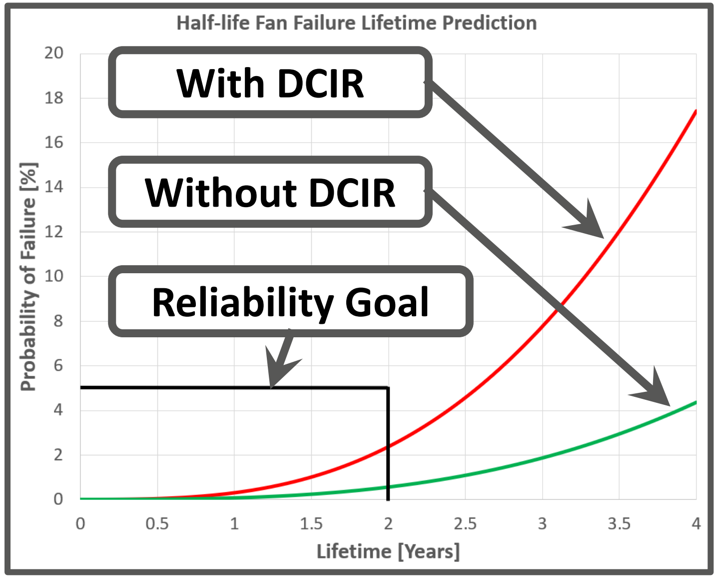
RefDes	Package	Part Type	Model	Side	Material	Solder	Max dT (C)	Damage	TTF (years)	Cycles To Fail	Score
U2A5	CBGA-393	IC	CBGA	TOP	LAMINATE-BGA	SAC305	26.7	2.1E-2	>20	35,283	10.0
Y3L1	0000	OSCILLATOR	CC	BOT	ALUMINA	SAC305	15.0	3.9E-3	>20	187,992	10.0
U1A1	BGA-78	IC	BGA	TOP	LAMINATE-BGA	SAC305	11.9	3.1E-3	>20	239,042	10.0
U1B5	BGA-78	IC	BGA	TOP	LAMINATE-BGA	SAC305	11.8	3.0E-3	>20	243,298	10.0
Y2A1	0000	OSCILLATOR	CC	TOP	ALUMINA	SAC305	16.6	1.9E-3	>20	390,344	10.0
U2L1	BGA8	IC	BGA	BOT	SILICON	SAC305	18.8	1.6E-3	>20	462,058	10.0
U2M1	BGA8	IC	BGA	BOT	SILICON	SAC305	18.1	1.4E-3	>20	505,566	10.0
F4B1	0000	FUSE	CC	TOP	ALUMINA	SAC305	11.0	1.2E-3	>20	592,831	10.0

With DCIR All Components Pass

RefDes	Package	Part Type	Model	Side	Material	Solder	Max dT (C)	Damage	TTF (years)	Cycles To Fail	Score
U2A5	CBGA-393	IC	CBGA	TOP	LAMINATE-BGA	SAC305	30.3	2.9E-2	>20	25,497	10.0
Y3L1	0000	OSCILLATOR	CC	BOT	ALUMINA	SAC305	17.3	5.4E-3	>20	136,176	10.0
U1A1	BGA-78	IC	BGA	TOP	LAMINATE-BGA	SAC305	12.6	3.5E-3	>20	208,528	10.0
U1B5	BGA-78	IC	BGA	TOP	LAMINATE-BGA	SAC305	12.3	3.3E-3	>20	221,745	10.0
U2L1	BGA8	IC	BGA	BOT	SILICON	SAC305	23.4	2.7E-3	>20	268,565	10.0
U2M1	BGA8	IC	BGA	BOT	SILICON	SAC305	23.4	2.7E-3	>20	268,565	10.0
Y2A1	0000	OSCILLATOR	CC	TOP	ALUMINA	SAC305	19.1	2.6E-3	>20	282,218	10.0
U3A1	QFN-40 (MO-208HHEA-H)	IC	QFN	TOP	OVERMOLD-QFN	SAC305	20.0	2.2E-3	>20	335,752	10.0

Sherlock Solder Fatigue – Fan Failure

- What would happen if the fans were only working for 50% of the time? For example, over a 2 year lifetime the fans failed at 1 year, or over a 4 year lifetime the fans failed at 2 years.
- Half the time cooling would be forced, the other half cooling would be by natural convection.
- Both analyses with and without DCIR predict the board to meet its solder fatigue reliability goal, although the margin is slim when the DCIR losses are included.



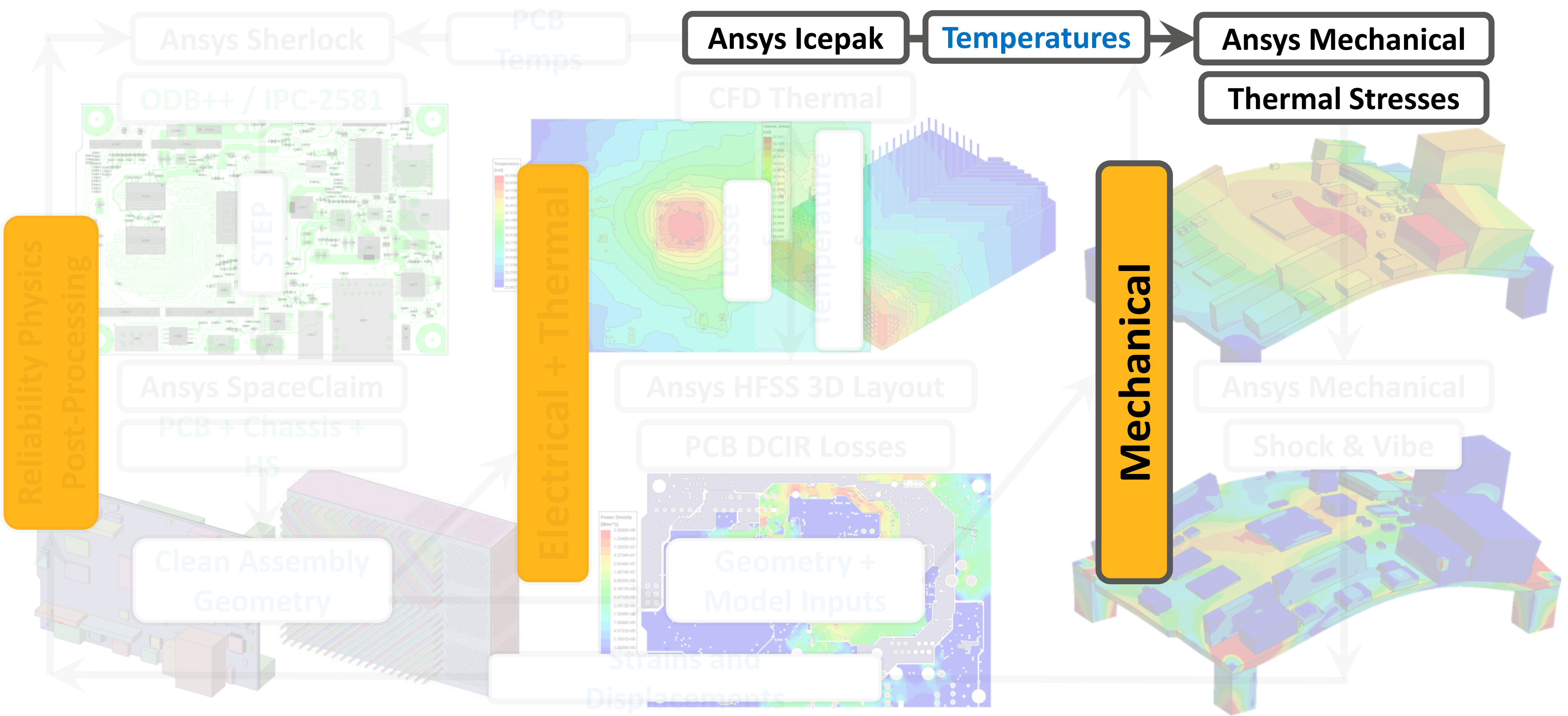
Without DCIR All Components Pass

RefDes	Package	Part Type	Model	Side	Material	Solder	Max dT (C)	Damage	TTF (years)	Score
U2A5	CBGA-393	IC	CBGA	TOP	LAMINATE-BGA	SAC305	69.3	1.6E-1	12.29	10.0
U1B5	BGA-78	IC	BGA	TOP	LAMINATE-BGA	SAC305	56.2	8.3E-2	>20	10.0
U1A1	BGA-78	IC	BGA	TOP	LAMINATE-BGA	SAC305	55.6	8.1E-2	>20	10.0
Y3L1	0000	OSCILLATOR	CC	BOT	ALUMINA	SAC305	57.5	5.4E-2	>20	10.0
Y2A1	0000	OSCILLATOR	CC	TOP	ALUMINA	SAC305	56.1	2.0E-2	>20	10.0

With DCIR Large BGA is Borderline

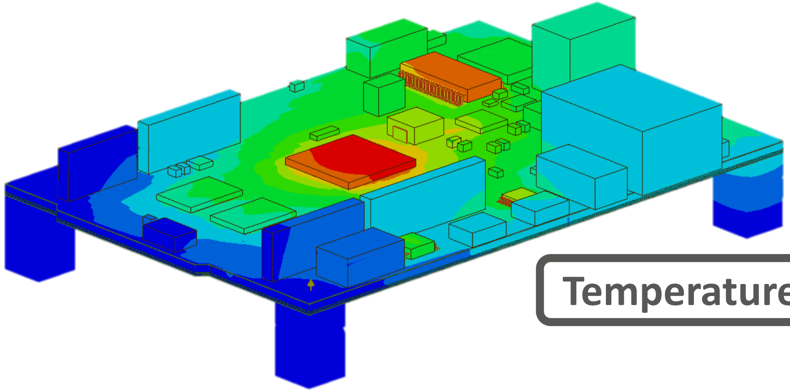
RefDes	Package	Part Type	Model	Side	Material	Solder	Max dT (C)	Damage	TTF (years)	Score
U2A5	CBGA-393	IC	CBGA	TOP	LAMINATE-BGA	SAC305	81.7	2.7E-1	7.39	4.1
U1B5	BGA-78	IC	BGA	TOP	LAMINATE-BGA	SAC305	63.7	1.2E-1	16.44	10.0
U1A1	BGA-78	IC	BGA	TOP	LAMINATE-BGA	SAC305	63.6	1.2E-1	16.53	10.0
Y3L1	0000	OSCILLATOR	CC	BOT	ALUMINA	SAC305	67.4	8.4E-2	>20	10.0
Y2A1	0000	OSCILLATOR	CC	TOP	ALUMINA	SAC305	69.8	3.6E-2	>20	10.0

Ansys PCB Reliability Workflow

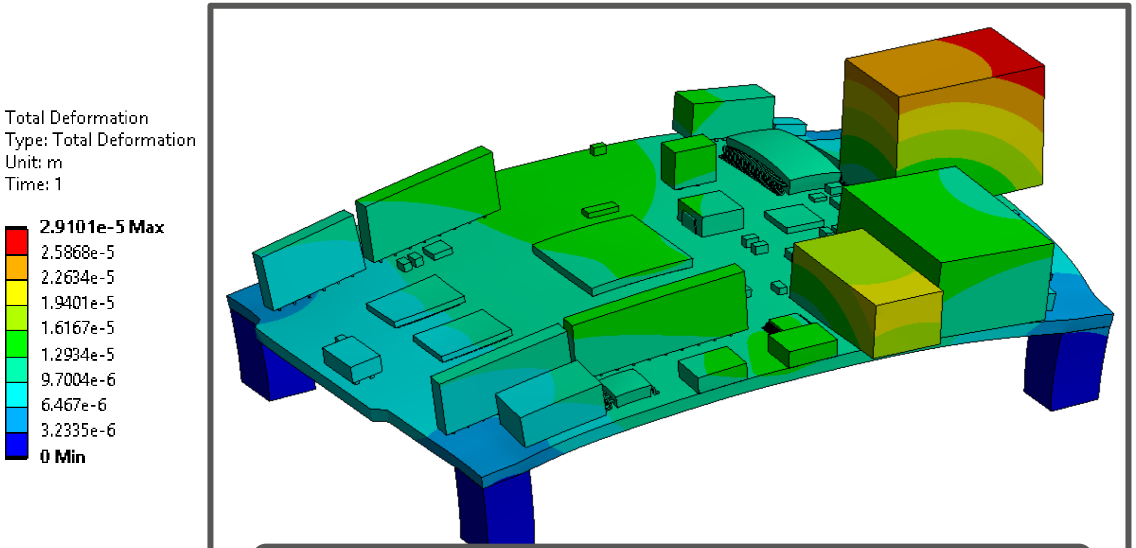


Thermal Expansion

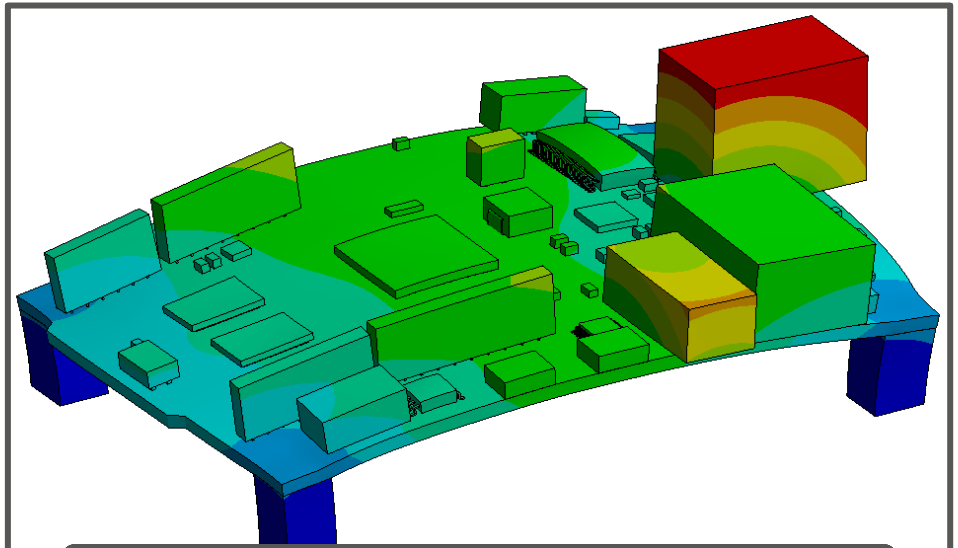
- Temperature rise during power cycling creates thermal expansion. As the board expands and contracts, it can bend and buckle resulting in board strain during operation.
- This system-level effect can accelerate solder fatigue, shock, and vibration failures over a PCBA’s lifetime or even create single event failures on its own.



Temperatures

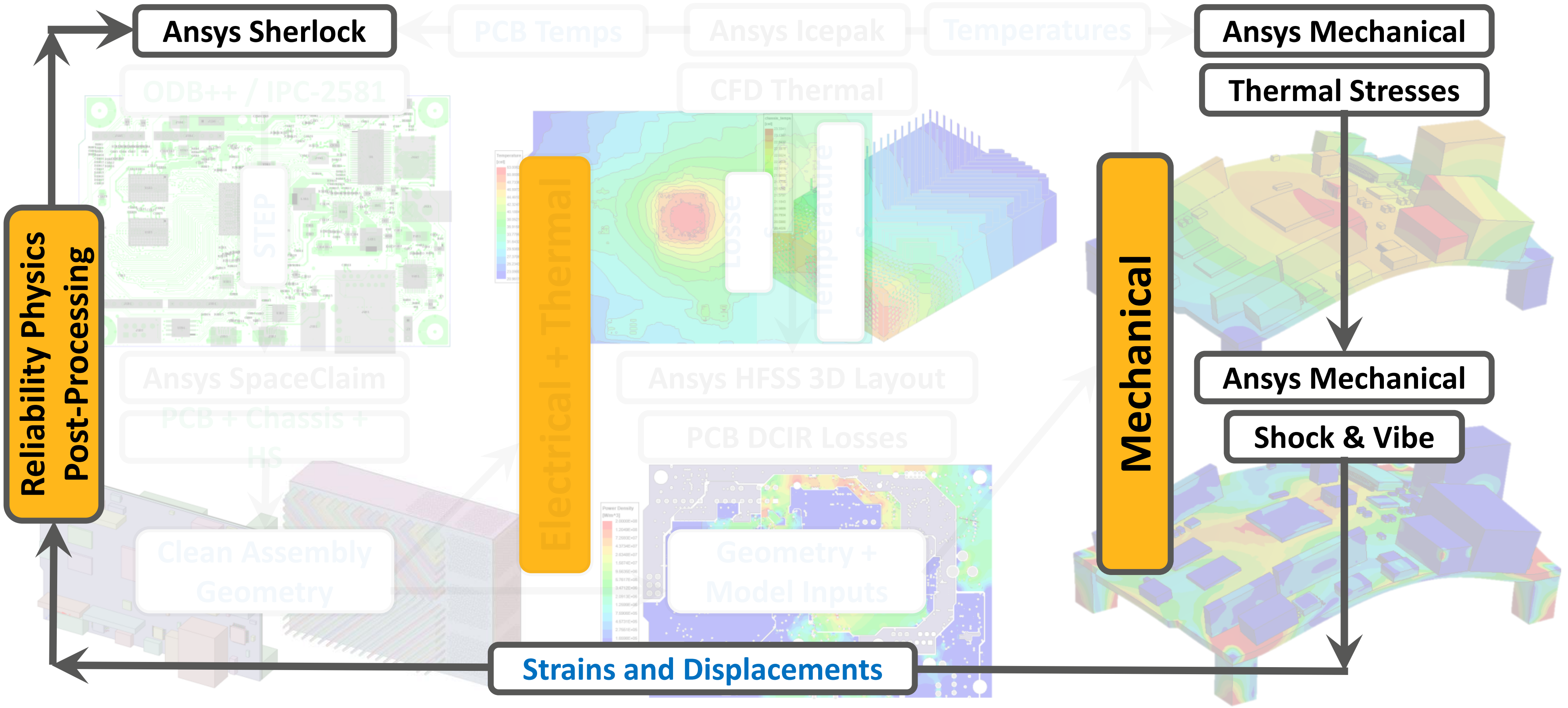


Thermal Deformation without DCIR Losses



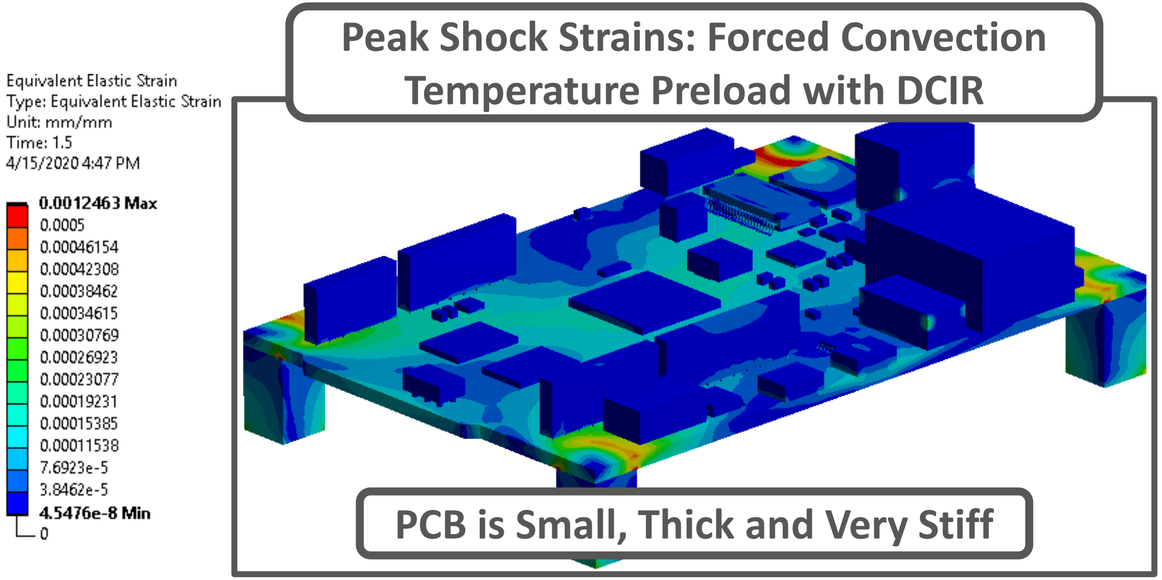
Thermal Deformation with DCIR Losses

Ansys PCB Reliability Workflow



Mechanical Shock & Sherlock Reliability

- The thermal expansion is treated as a preload in a Mechanical shock simulation.
- A 25G, 10ms half-sine pulse is applied 3 times per hour over the desired two-year lifetime to estimate the effect of the vehicle running over potholes.
- Strain and displacement results are imported to Sherlock to generate a reliability prediction.



No Risk of Failure Due to Mechanical Shock

RefDes	Package	Part Type	Side	Max Disp	Max Strain	TTF (years)	Failure Prob	Failure Prob / Cycle
U2A5	CBGA-393	IC	TOP	4.6E-2	3.0E-4	>20	0.4	8.2E-6
J1B2	BOX CONN	PLUG CONNECTOR	TOP	1.7E-2	3.5E-4	>20	0.3	6.2E-6
J4B1	BOX CONN	JACK	TOP	3.9E-2	2.1E-4	>20	0.1	1.6E-6
U1A1	BGA-78	IC	TOP	2.7E-2	1.3E-4	>20	0.0	5.9E-7
S1	SON SW	SWITCH	TOP	1.3E-2	3.9E-4	>20	0.0	3.1E-7
L2M1	C-BEND	INDUCTOR	BOT	4.4E-2	2.4E-4	>20	0.0	3.0E-7
U8	SSOP-48 (MO-118...	IC	TOP	3.5E-2	1.7E-4	>20	0.0	2.8E-7
U1B5	BGA-78	IC	TOP	2.8E-2	1.2E-4	>20	0.0	2.6E-7
U2L1	BGA8	IC	BOT	4.6E-2	2.9E-4	>20	0.0	1.5E-7
U2M1	BGA8	IC	BOT	4.6E-2	2.6E-4	>20	0.0	7.9E-8
J2	SIP CONN	PLUG CONNECTOR	TOP	1.0E-2	2.7E-4	>20	0.0	7.0E-8
Q1	SOT-23 (TO-236AB)	TRANSISTOR	TOP	9.5E-3	3.2E-4	>20	0.0	5.0E-8
L3A1	C-BEND	INDUCTOR	TOP	4.5E-2	1.7E-4	>20	0.0	2.4E-8
Y3L1	0000	OSCILLATOR	BOT	4.3E-2	2.1E-4	>20	0.0	6.9E-9
U6	SON	IC	TOP	9.5E-3	3.3E-4	>20	0.0	3.8E-9
U3A1	QFN-40 (MO-208H...	IC	TOP	4.0E-2	1.7E-4	>20	0.0	2.3E-9
C3A18	0603	CAPACITOR	TOP	4.1E-2	1.6E-4	>20	0.0	3.3E-12
C3A19	0603	CAPACITOR	TOP	4.2E-2	1.5E-4	>20	0.0	2.5E-12
C3A10	0402	CAPACITOR	TOP	4.5E-2	1.3E-4	>20	0.0	1.1E-13
C3A11	0402	CAPACITOR	TOP	3.9E-2	1.3E-4	>20	0.0	1.2E-13

Summary

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- **Multiphysics simulation of printed circuit boards:**
  - DCIR simulation verifies power integrity and provides DCIR losses for thermal analysis.
  - Thermal simulation identifies hot spots and provides temperatures for DCIR, mechanical, and reliability solutions.
  - Mechanical simulation determines thermal deformation, and strains and displacements due to shock and vibration.
  - Sherlock combines all load cycles and computes overall PCB lifetime reliability.
- **Multiphysics simulation of PCBs offers high fidelity results, and improves electrical, thermal and mechanical reliability.**

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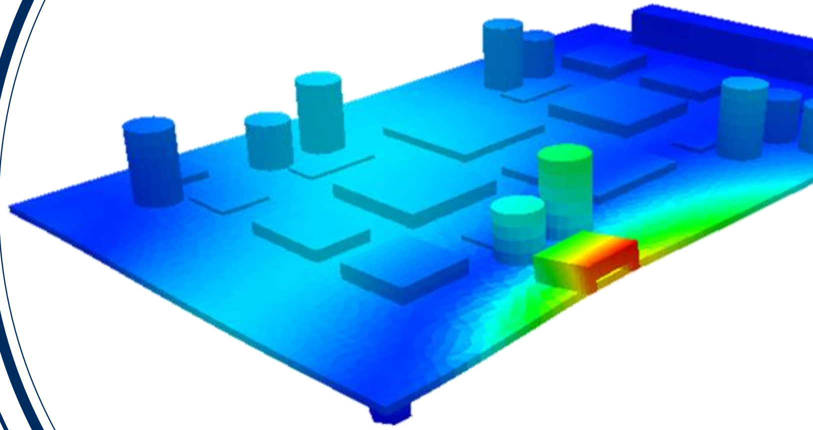
Simulation is more than Software



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