



Simulating Additive Manufacturing Material Extrusion Processes with Short Fiber-Reinforced Polymer Materials

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Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR):

- Robert Hein, Deputy Head of Structural Mechanics
- Maik Titze, Aviation Program Management
- Felix Winkelmann, R&D Engineer

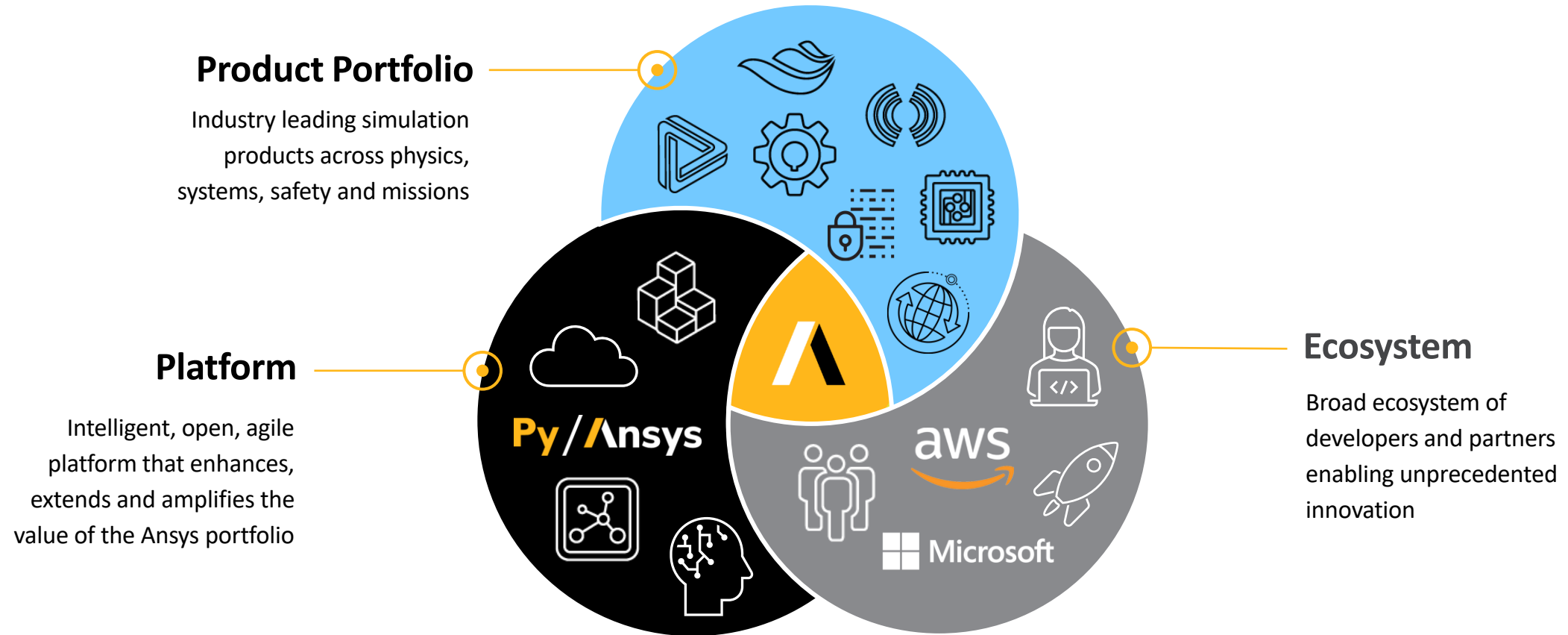
Synopsys:

- Thomas Hirche, Lead Application Engineer
- Haoliang Yu, Senior R&D Engineer
- Javier Vique, Team Lead Application Engineer



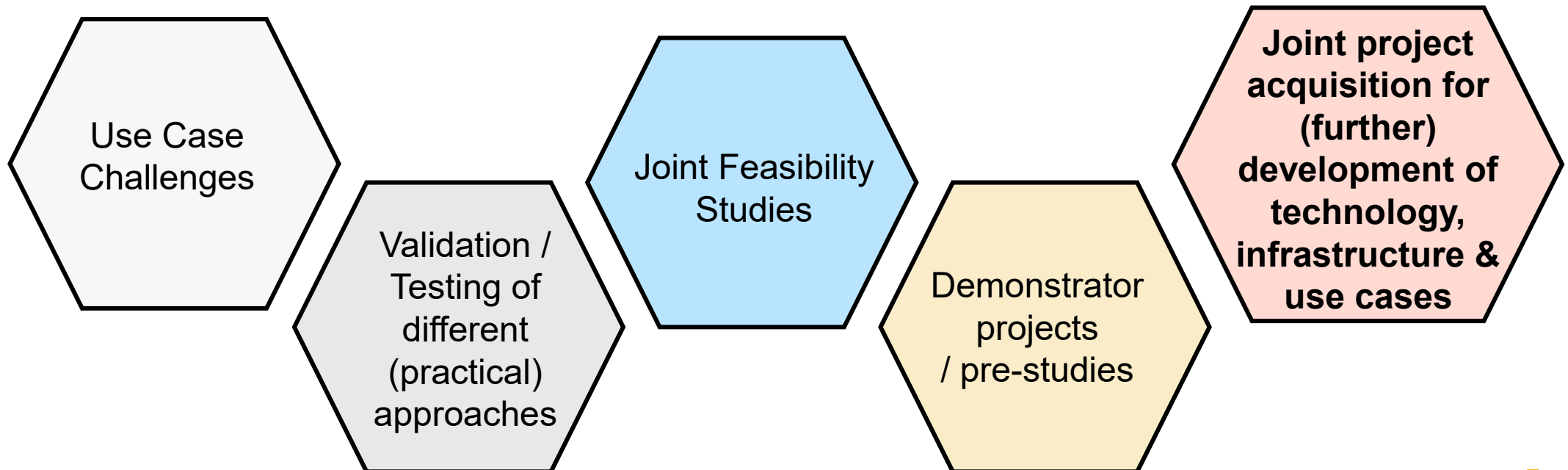
Redefining "Simulation"

The unique **combination** of the Ansys product **portfolio**, **platform** and **ecosystem** is redefining simulation in ways that enable people in every industry to **change the world**.



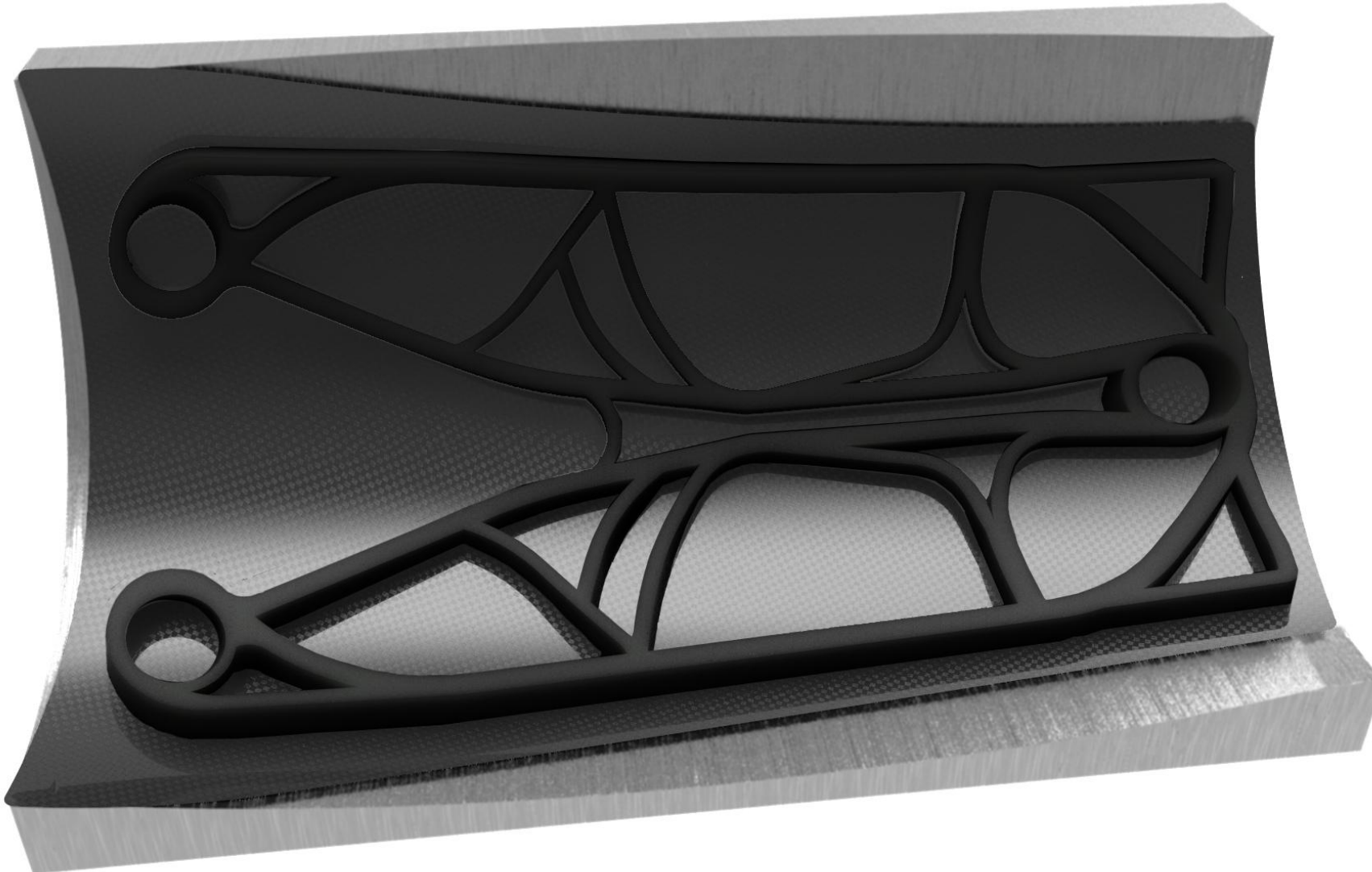
EmpowerAX is...

*... a place where we can try out together almost everything,
what drives the technology, infrastructure & use cases forward
and makes it accessible to the broad industry...*



EmpowerAX Demo Part

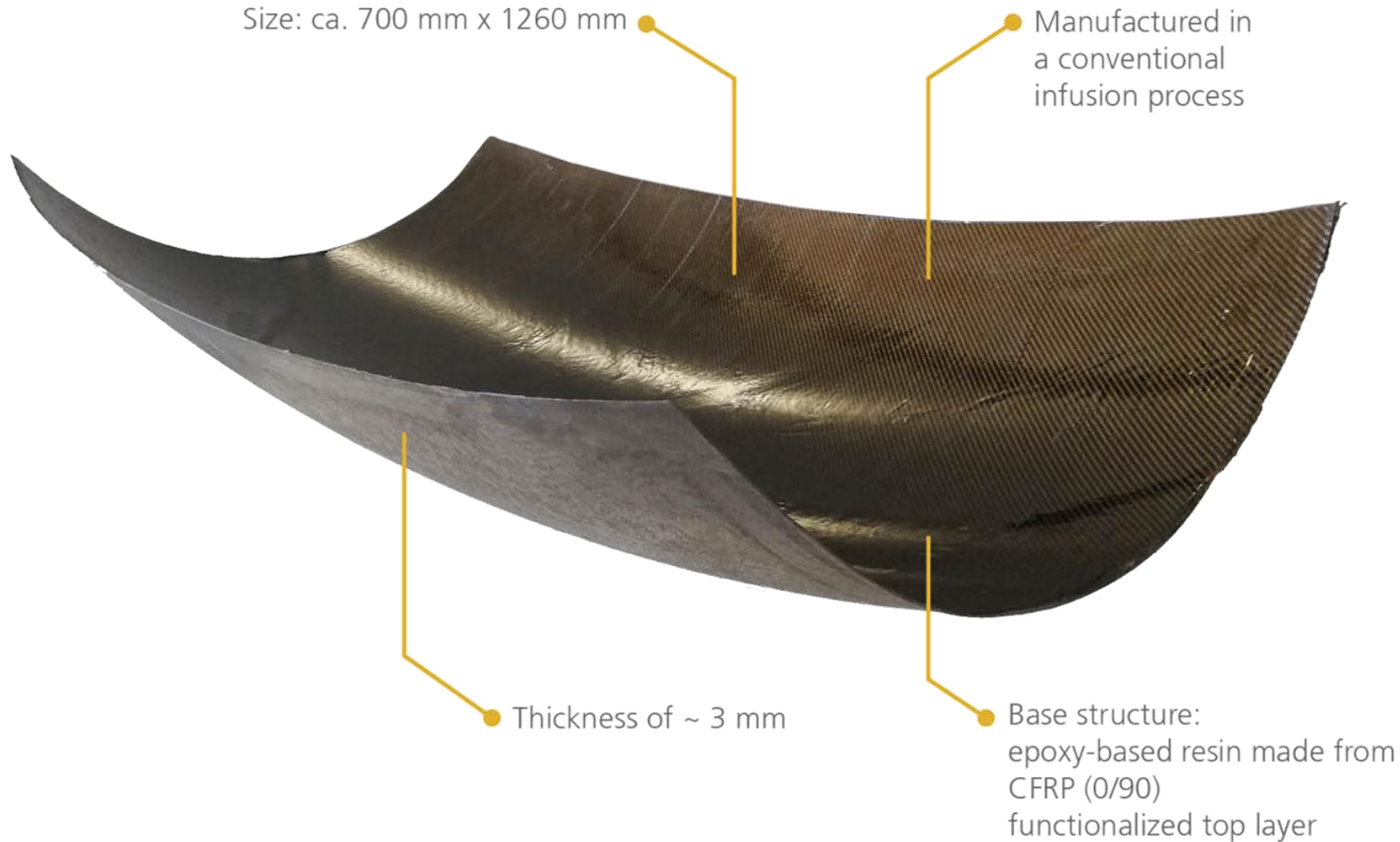
Experimental data courtesy of the
German Aerospace Center (DLR)



EmpowerAX Demo Part

The Basic Idea

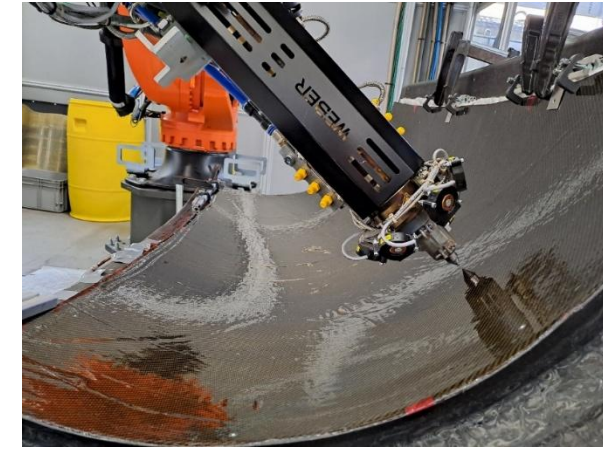
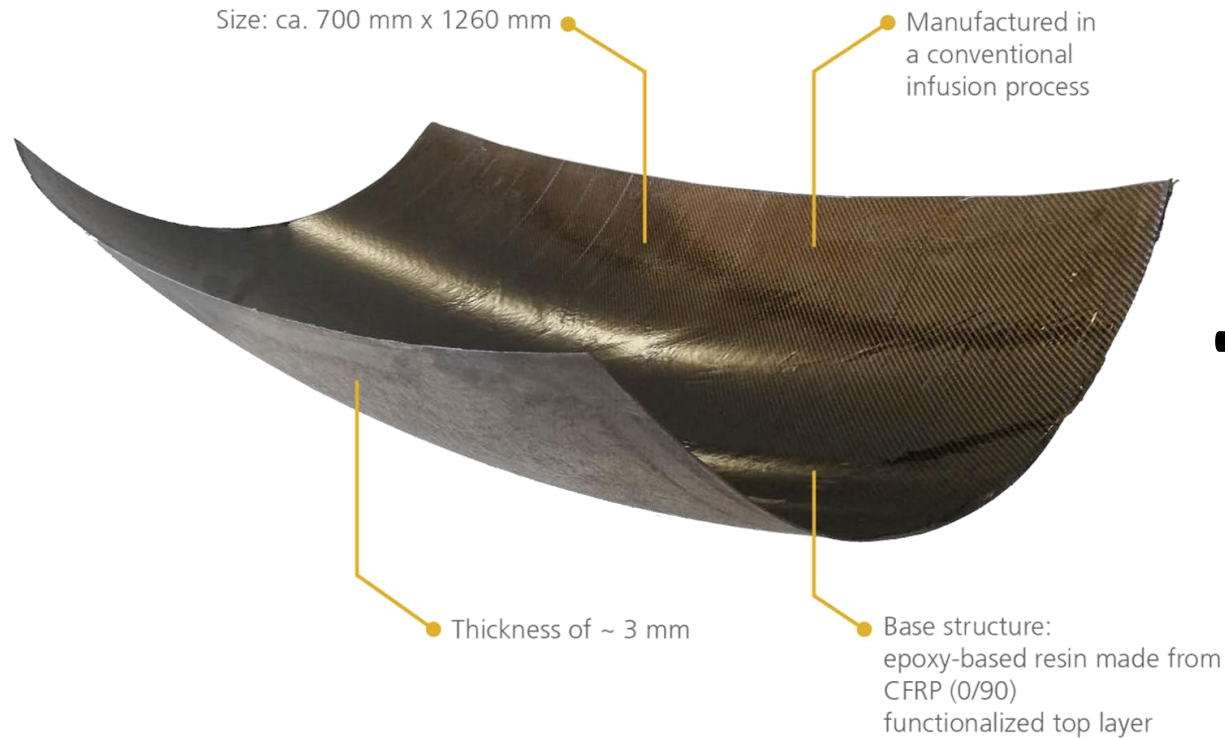
Experimental data courtesy of the
German Aerospace Center (DLR)



EmpowerAX Demo Part

The Basic Idea

Experimental data courtesy of the
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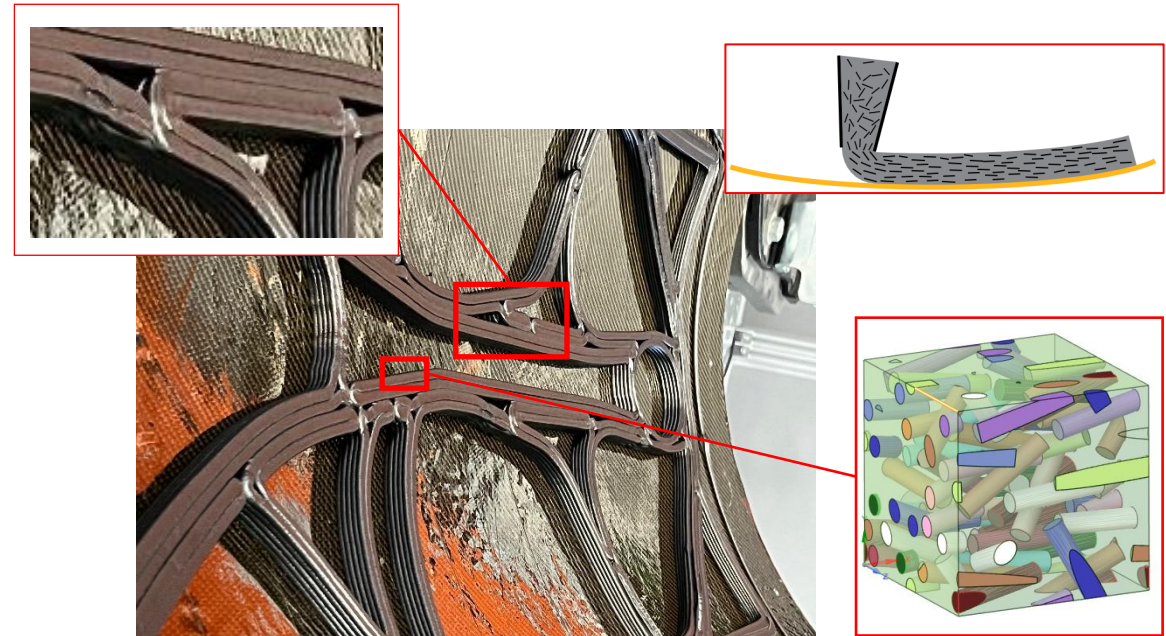
Simulation Challenges

Experimental data courtesy of the
German Aerospace Center (DLR)



Ansys partnered with the [DLR Innovation Lab EmpowerAX](#), which drives the adoption of Multi-Axis AM with fiber reinforced materials. The goals are:

- Simulate printed **geometry as manufactured** – it often does not match designed geometry.
- Enable print path **trajectories in 3D space**.
- Consider the **anisotropic properties** of Fiber-reinforced materials. These influence thermal and structural response of parts and affect geometric tolerances.

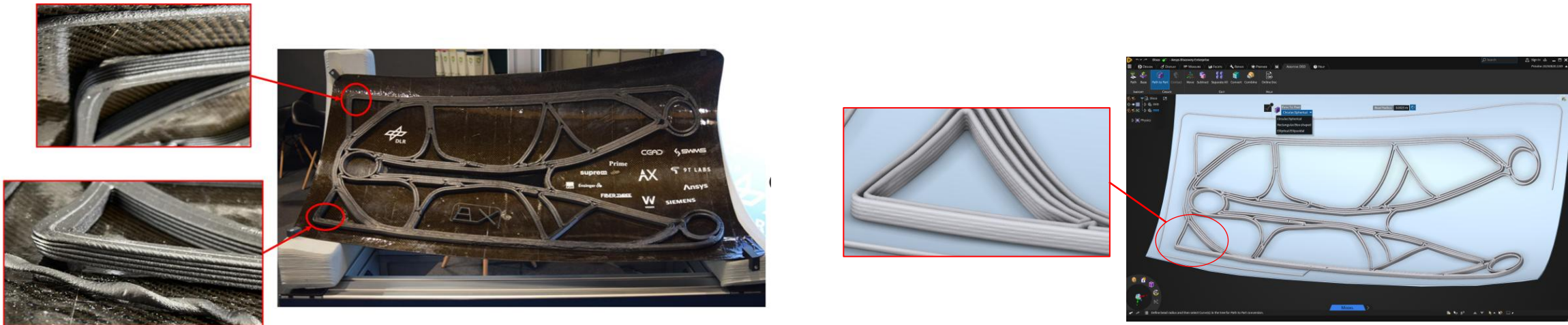




Approach taken – From G-Code to CAD Model

Additive DED in Ansys Discovery – Path to Part Modeling allows to generate geometry models directly from G-code for your simulations.

- Print bead cross sections and deposition volumes with greater accuracy in the simulation model (Available in 25R2)
- G-Code is the common data format for manufacturing and simulation processes. Differences between manufactured part and simulated part significantly decreased.

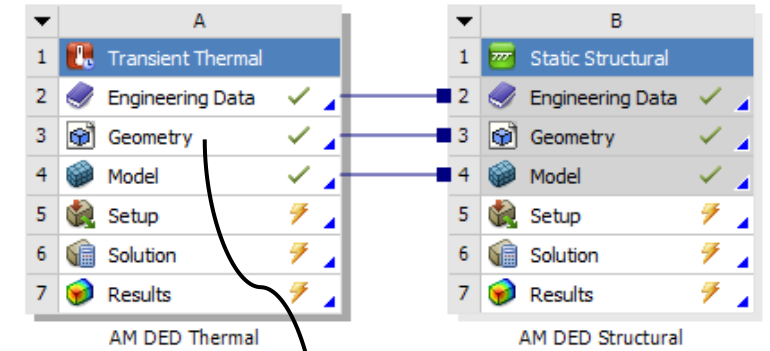


Path-based Geometry Generation Tool in Ansys Discovery

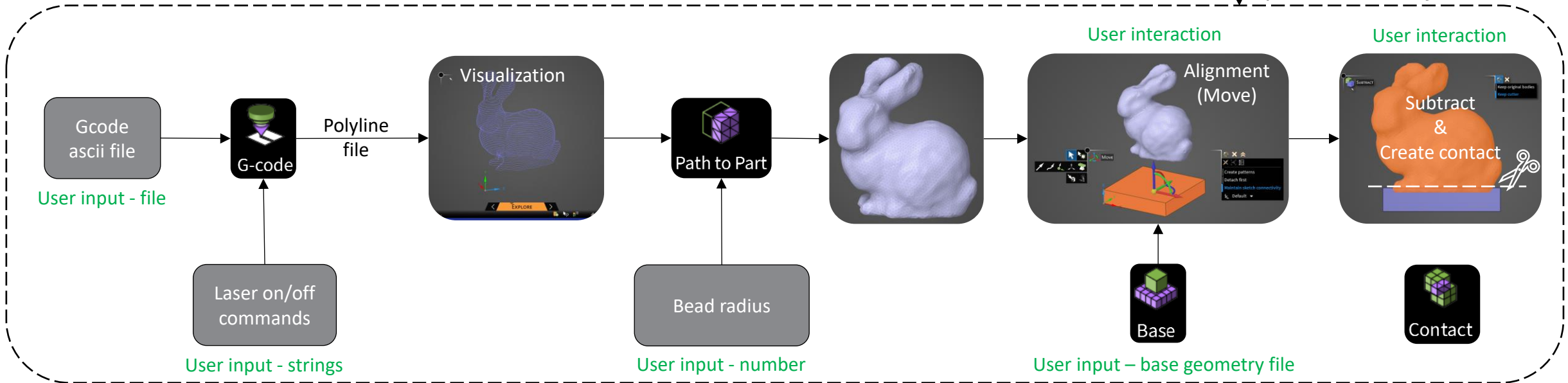
A new workflow in Ansys Discovery which considers:

- Different Laser On & Off command
- Various bead radii
- Part and base alignment
- Part and base contact generation for WB Additive simulations

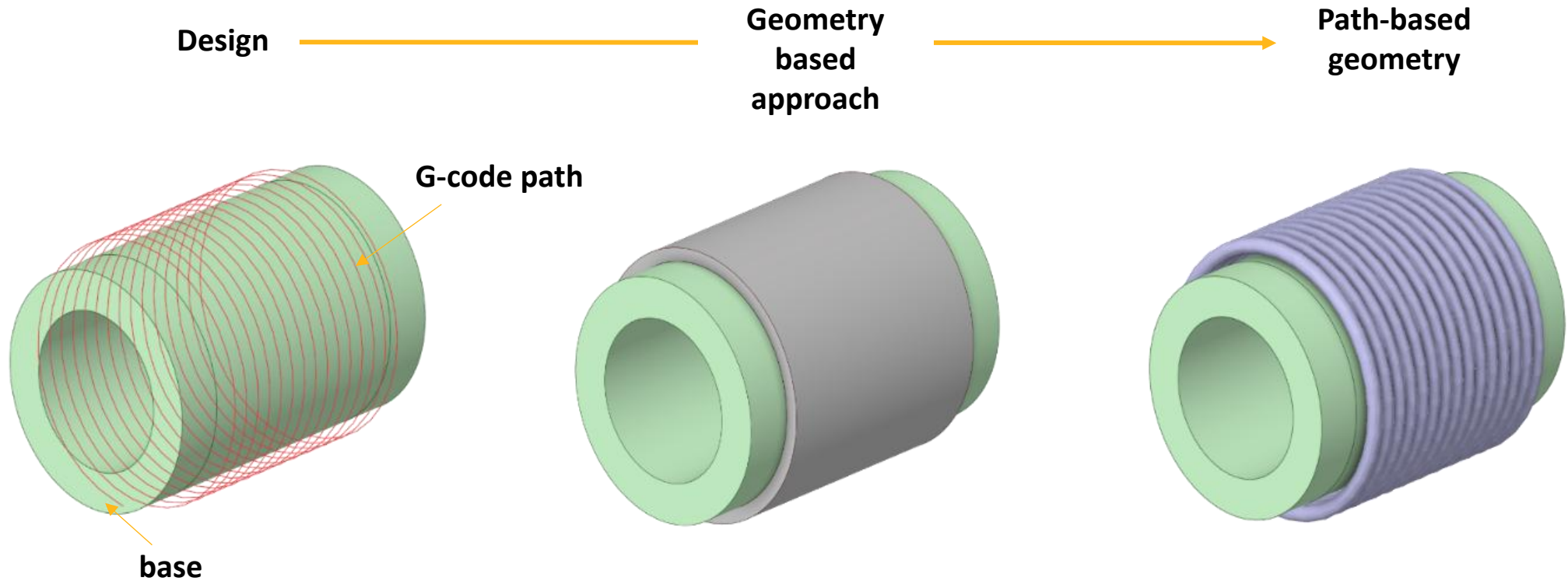
Schematic in Workbench



Open in Discovery



Path-based Geometry Generation Tool in Ansys Discovery



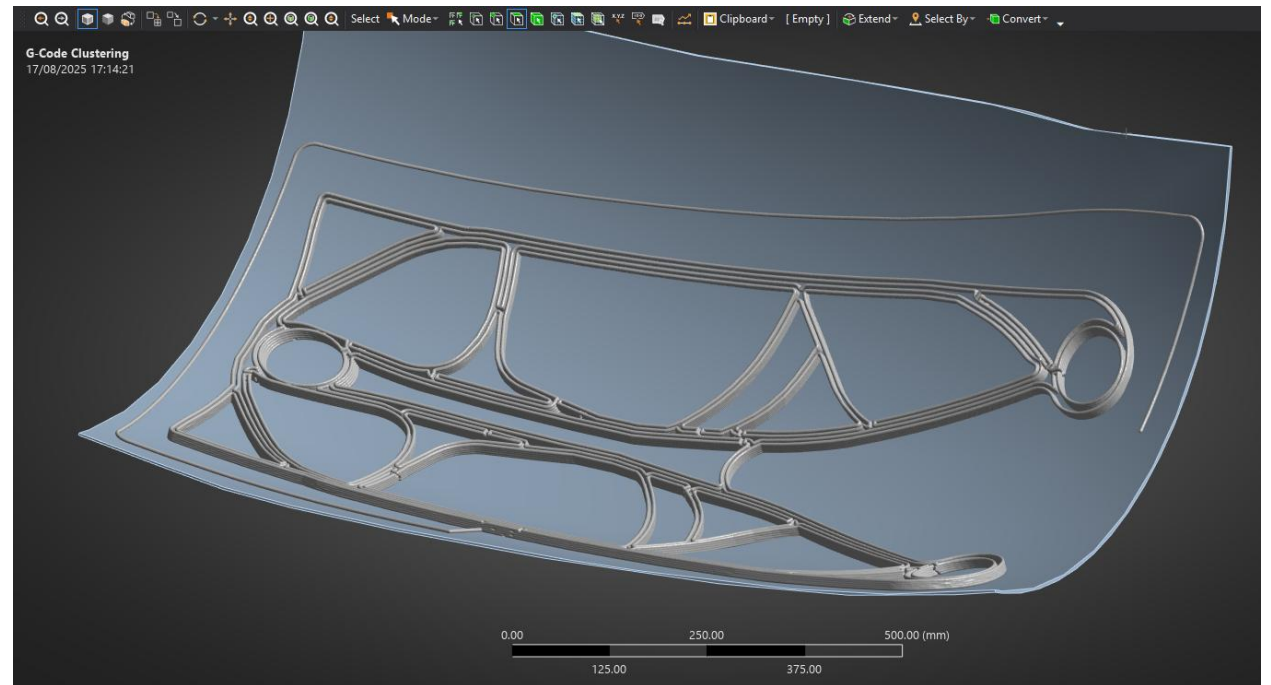
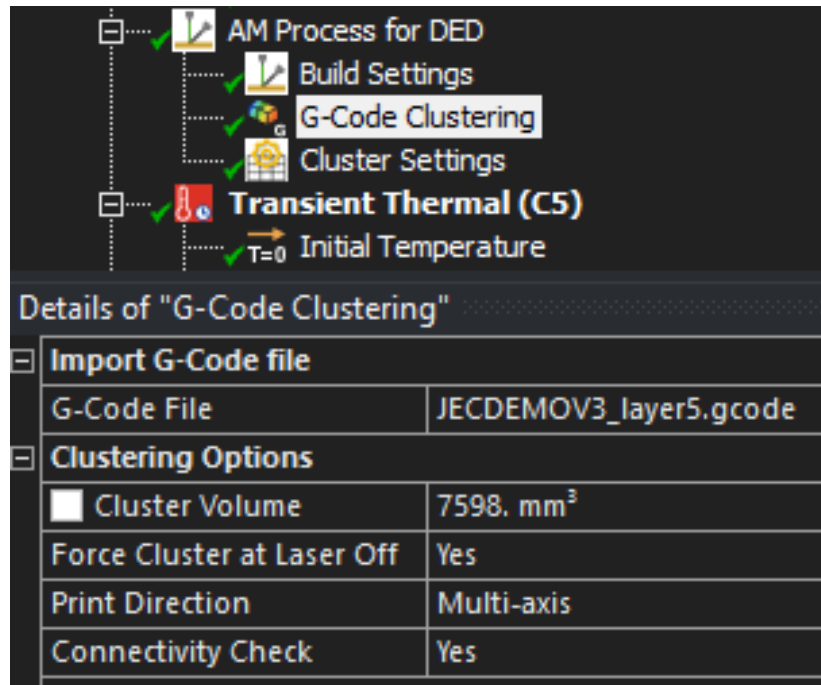
Path-based Geometry Generation Tool in Ansys Discovery



Approach taken – Multi Axis Material Deposition

Ansys Mechanical AM Process for DED – Allows Multi-Axis printing processes

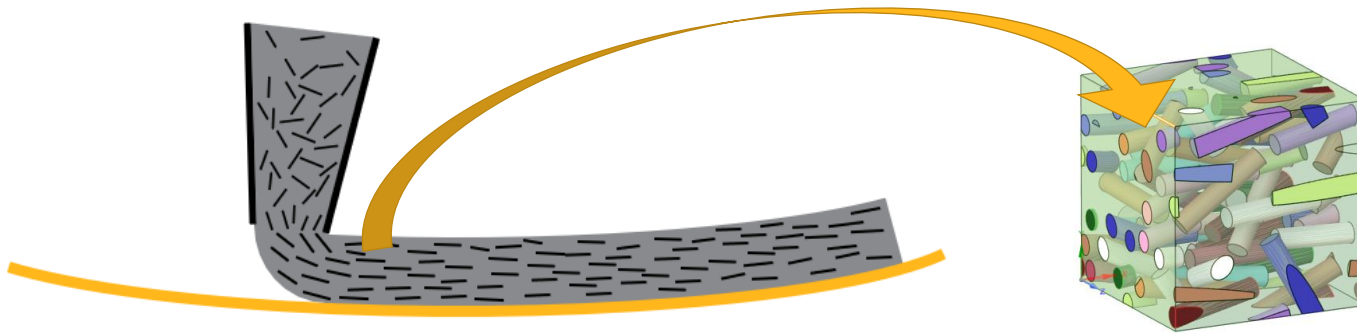
- Print head translates and rotates taking into account the curved print base. The 5-Axis G-code file contains required information.



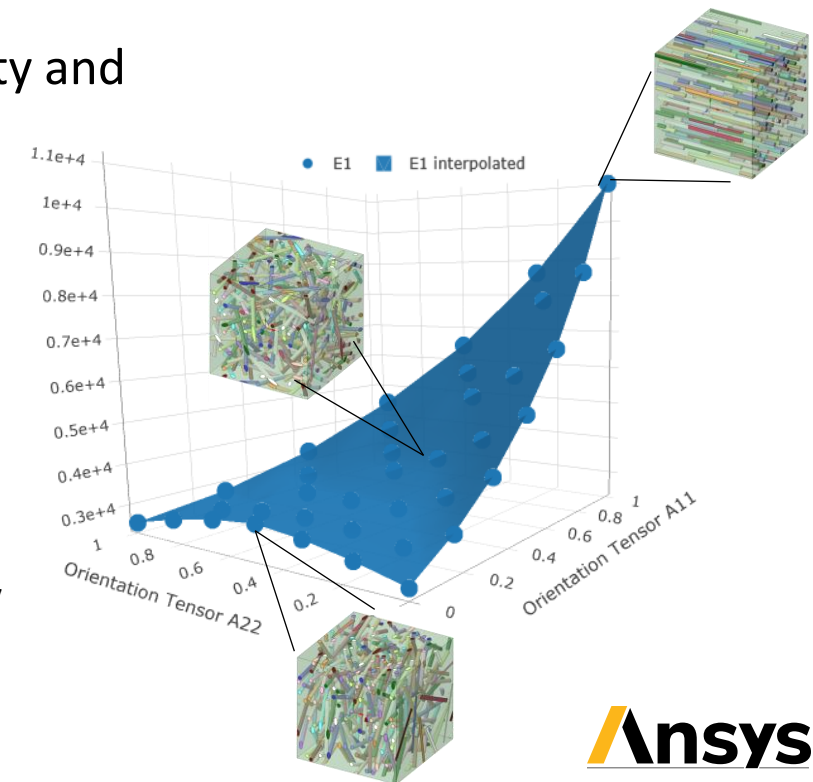
Approach taken – From G-Code to Material Anisotropy

Ansys Material Designer – Calculates Material Anisotropic Properties

- Research shows specific alignment pattern of fibers when passing through print head nozzle*
- Material properties are calculated based on commonly assumed Orientation Tensors for Short fiber materials e.g. $A_{11}=0.8$.
- Anisotropic Elastic Properties, Thermal Expansion, Thermal Conductivity and Specific Heat.



The stiffness and strength of the material depend largely on the fiber orientation with respect to the loading direction, due to the anisotropic nature of the fibers.



	X	Y	Z	Calculator	Calculator2	Calculator3
0	1.618175	-0.059042	1.904541	176.09	0	142.6063
1	3.236349	0.318082	3.809093	176.09	0	142.6063
2	4.854524	0.577105	5.427268	176.09	0	142.6063
3	6.472698	0.735568	7.045442	176.09	0	142.6063
4	8.090873	0.894031	8.663616	176.09	0	142.6063
5	9.709047	1.052494	10.281790	176.09	0	142.6063
6	11.327221	1.210957	11.899964	176.09	0	142.6063
7	12.945395	1.369420	13.518138	176.09	0	142.6063
8	14.563569	1.527883	15.136312	176.09	0	142.6063
9	16.181743	1.686346	16.754486	176.09	0	142.6063
10	17.800000	1.844809	18.372660	176.09	0	142.6063
11	19.418174	1.999999	19.990834	176.09	0	142.6063
12	21.036349	2.155189	21.609008	176.09	0	142.6063
13	22.654524	2.310379	23.227182	176.09	0	142.6063
14	24.272698	2.465569	24.845356	176.09	0	142.6063
15	25.890873	2.620759	26.463530	176.09	0	142.6063
16	27.509047	2.775949	28.081704	176.09	0	142.6063
17	29.127221	2.931139	29.699878	176.09	0	142.6063
18	30.745395	3.086329	31.318052	176.09	0	142.6063
19	32.363569	3.241519	32.936226	176.09	0	142.6063
20	33.981743	3.396709	34.554400	176.09	0	142.6063
21	35.600000	3.551899	36.172574	176.09	0	142.6063
22	37.218174	3.707089	37.790748	176.09	0	142.6063
23	38.836349	3.862279	39.408922	176.09	0	142.6063
24	40.454524	4.017469	41.027096	176.09	0	142.6063
25	42.072698	4.172659	42.645270	176.09	0	142.6063
26	43.690873	4.327849	44.263444	176.09	0	142.6063
27	45.309047	4.483039	45.881618	176.09	0	142.6063
28	46.927221	4.638229	47.499792	176.09	0	142.6063
29	48.545395	4.793419	49.117966	176.09	0	142.6063
30	50.163569	4.948609	50.736140	176.09	0	142.6063
31	51.781743	5.103799	52.354314	176.09	0	142.6063
32	53.400000	5.258989	53.972488	176.09	0	142.6063
33	55.018174	5.414179	55.590662	176.09	0	142.6063
34	56.636349	5.569369	57.208836	176.09	0	142.6063
35	58.254524	5.724559	58.827010	176.09	0	142.6063
36	59.872698	5.879749	60.445184	176.09	0	142.6063
37	61.490873	6.034939	62.063358	176.09	0	142.6063
38	63.109047	6.190129	63.681532	176.09	0	142.6063
39	64.727221	6.345319	65.299706	176.09	0	142.6063
40	66.345395	6.500509	66.917880	176.09	0	142.6063
41	67.963569	6.655699	68.536054	176.09	0	142.6063
42	69.581743	6.810889	70.154228	176.09	0	142.6063
43	71.200000	6.966079	71.772402	176.09	0	142.6063
44	72.818174	7.121269	73.390576	176.09	0	142.6063
45	74.436349	7.276459	75.008750	176.09	0	142.6063
46	76.054524	7.431649	76.626924	176.09	0	142.6063
47	77.672698	7.586839	78.245098	176.09	0	142.6063
48	79.290873	7.742029	79.863272	176.09	0	14

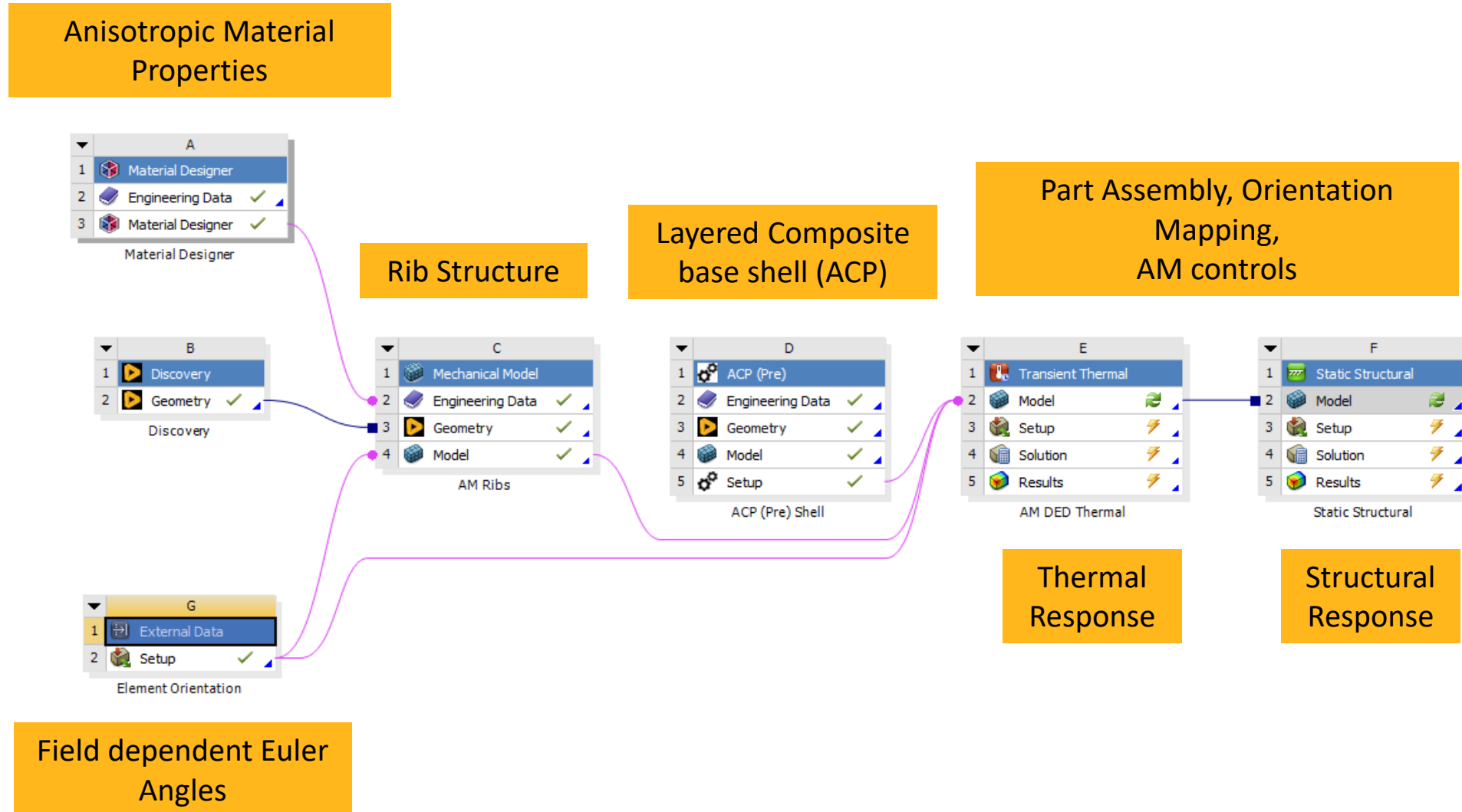
[illegible]

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The screenshot shows the ANSYS Workbench environment. On the left, the 'Project' tree is expanded to 'Mesh' for the 'Male' part, where 'Element Orientation' is highlighted. The central 3D view displays a mechanical part with red arrows representing the element orientation. A scale bar at the bottom right indicates a range from 0 to 20,000 mm. The top toolbar includes various simulation and analysis tools.

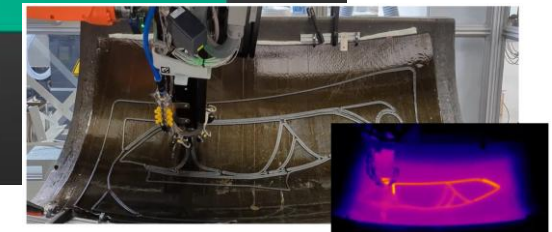
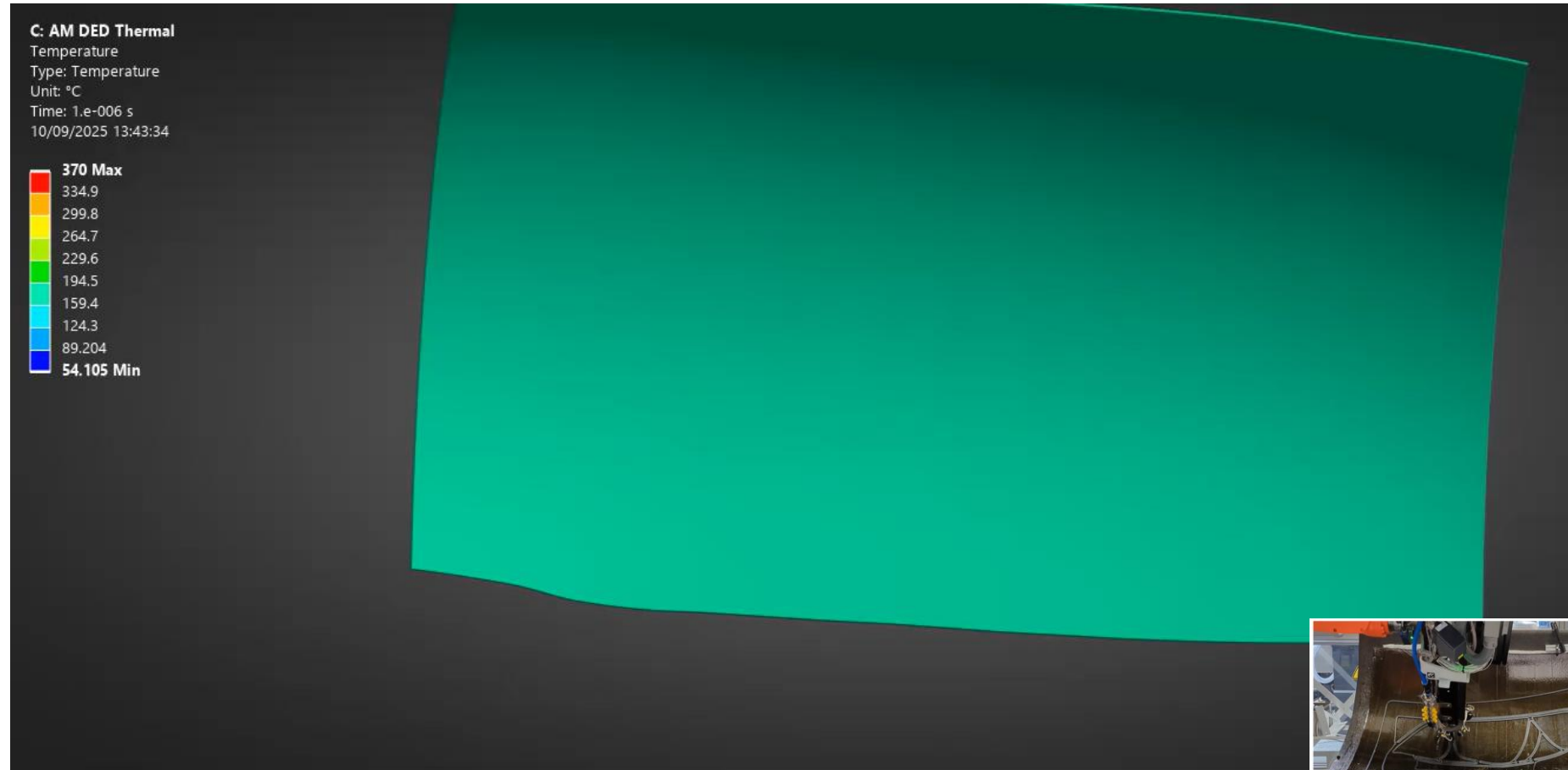
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Approach taken – Ansys Workflow Details

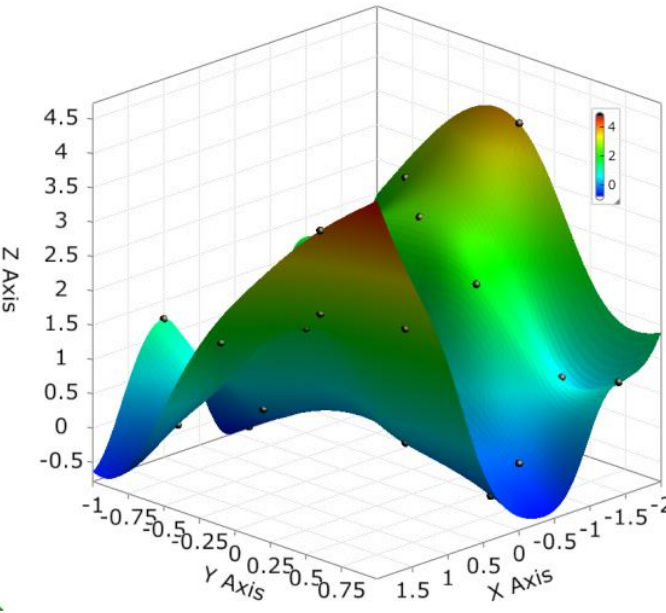
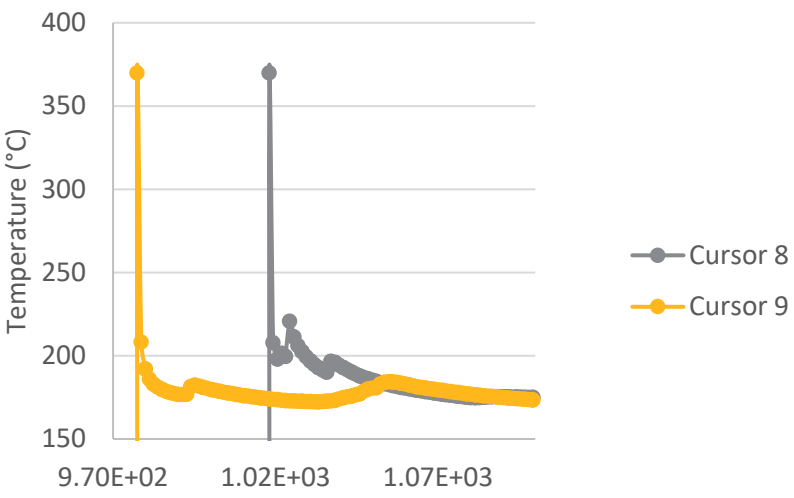
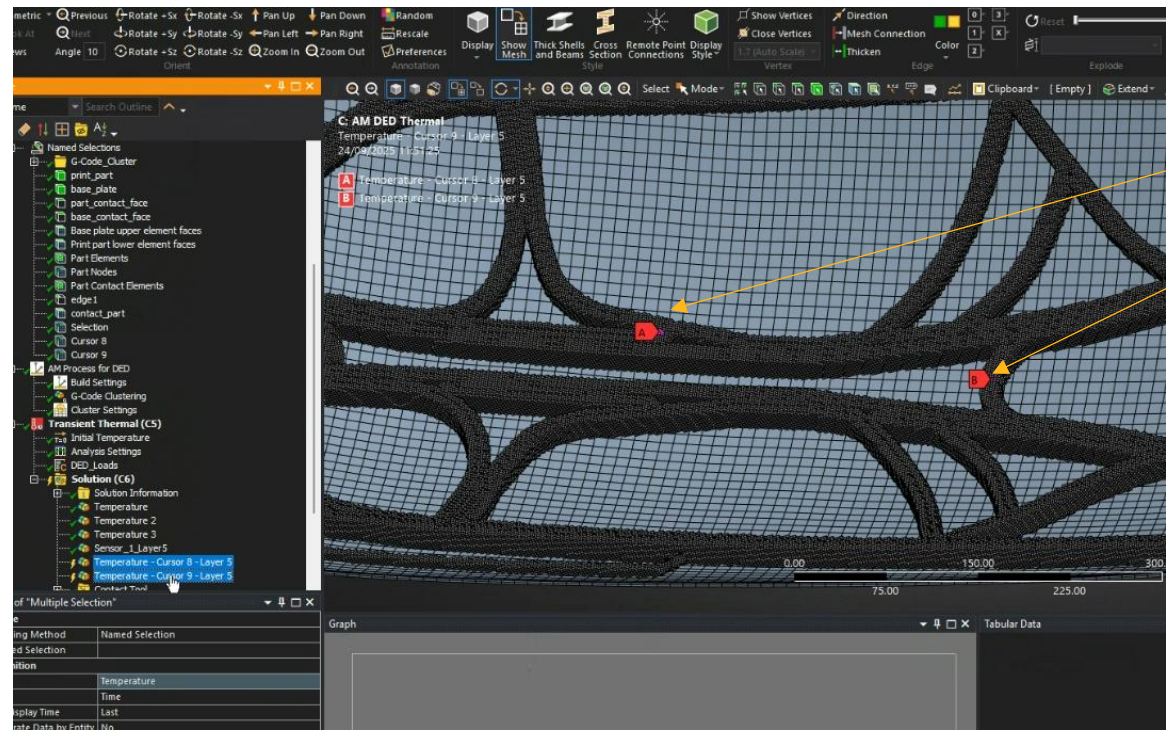


Ansys AM DED – Printing fiber reinforced polymer rib structure on a curved composite shell.

Experimental data courtesy of the
German Aerospace Center (DLR)



Sensor data and calibration



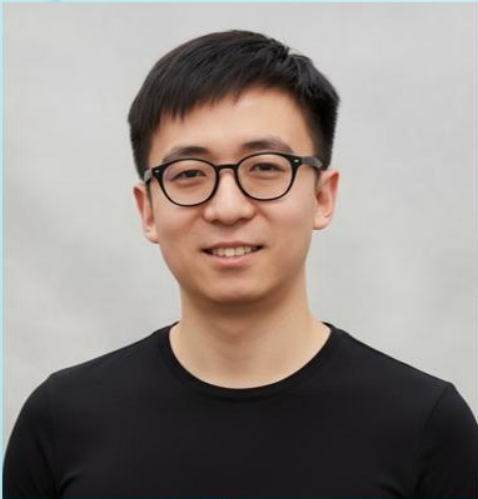
Optimization models can be used to fit FEA model parameters to experimental data.

Want to know more...



|ICAM25

OCTOBER 6-10 | LAS VEGAS, NV



Path-based geometry modeling tool for additive applications: A G-code driven advancement over design-based modeling
Oct 10th@Pavilion 01

Presented by Haoliang Yu
Senior R&D Engineer
Ansys – part of Synopsys

www.amcoe.org/icam2025

Summary

Further developments includes:

- Perform simulation validations based on thermal sensor data and structural analysis
- Enhance simulation workflows (meshing types, material models, etc)
- There is more than reinforced polymers ...Expand the use of this technology to other anisotropic manufacturing Additive Manufacturing processes that also depend on path deposition sequence

