

# Microchannel Cooling Optimisation

How Panejo's high-fidelity simulations and QUGATE's surrogate models turn computational effort into structured design insight

PARTNER	INDUSTRY	SIMULATION TOOL	DESIGN SPACE	TRAINING RUNS
Panejo	Engineering Consultancy	COMSOL Multiphysics	4 Parameters	< 50 runs

## THE CHALLENGE — PHYSICS, COMPLEXITY & COMPUTATION

**High-fidelity simulation is essential** to accurately capture the complex physics of microchannel cooling systems. However, even with a well-built COMSOL model, exploring the full design space remains computationally intensive.

Four key parameters namely **channel depth, coolant flow rate, heat sink conductivity and interface thermal resistance** interact in a strongly coupled manner. Changing one parameter simultaneously affects multiple performance metrics such as maximum temperature and pumping power.

A limited number of simulation runs provides reliable data points but not a complete understanding of the system. Identifying dominant effects, trade-offs and optimal regions requires a structured exploration approach, which quickly becomes time-intensive when relying on full simulations alone.

**This is where surrogate models come into play** enabling efficient exploration of parameter combinations without repeatedly solving the full numerical model.

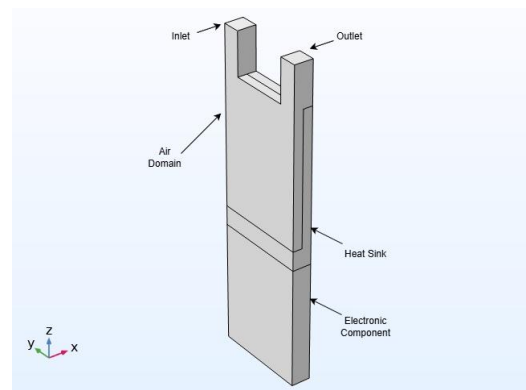


Fig 1. Model geometry including the air domain, heat sink & component

## FOUR PAIN POINTS EVERY DESIGN ENGINEER KNOWS

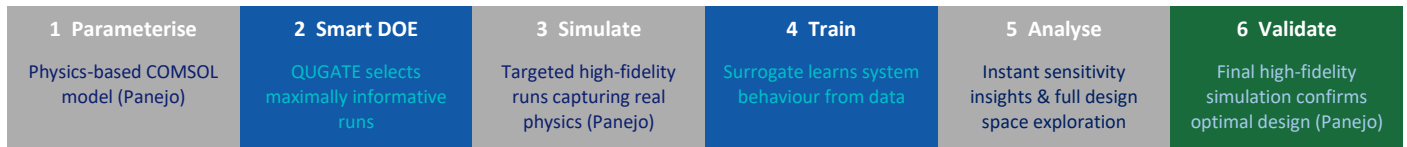
<p><b>1. Which parameter matters?</b> Multiple inputs affect multiple outputs simultaneously. There is no obvious starting point.</p>	<p><b>2. Everything is coupled</b> Change channel depth and both maximum temperature and pumping power move simultaneously.</p>	<p><b>3. Small samples, low insight</b> A handful of simulation runs provides data points and not a complete map of the design space.</p>	<p><b>4. Where to focus in QC?</b> Once manufactured, which dimensions need the tightest tolerance control to hit target performance?</p>
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## WITHOUT VS WITH THE PANEJO + QUGATE APPROACH

X Without Structured Surrogate Approach	VS	✓ With Panejo + QUGATE Workflow
<ul style="list-style-type: none"> <li>X Build high-fidelity COMSOL model</li> <li>X Manually define parameter variations</li> <li>X Run simulations → computationally expensive</li> <li>X Limited number of design points</li> <li>X Difficult to extract global sensitivities</li> <li>X Iteration remains slow and experience-driven</li> </ul>		<p><b>Panejo</b></p> <ul style="list-style-type: none"> <li>✓ Build validated high-fidelity COMSOL model</li> <li>✓ Systematically parameterise physics-based model</li> <li>✓ Run targeted simulations (&lt;50 high-quality runs)</li> </ul> <p><b>QUGATE</b></p> <ul style="list-style-type: none"> <li>✓ Design efficient sampling strategy (DOE)</li> </ul>

- ✓ Train surrogate model based on physical data
- ✓ Instant sensitivity analysis & design exploration
- ✓ Rapid identification of optimal design regions

PANEJO + QUGATE WORKFLOW



HIGH-FIDELITY SIMULATIONS & SURROGATE INTELLIGENCE

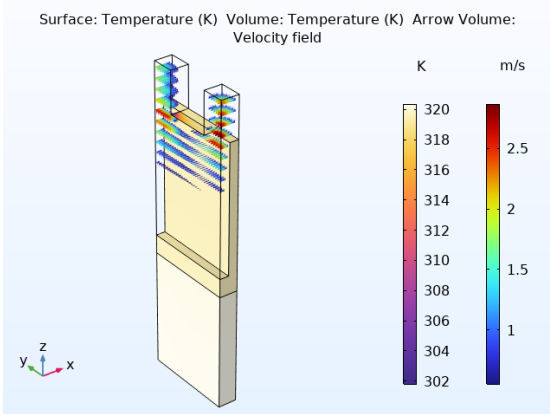


Fig 2. COMSOL velocity (m/s) & temperature (K) — Panejo's high-fidelity training data.

QUGATE Knows When to Stop

<b>99%</b> Prediction Accuracy <i>Max component temperature</i>	<b>93%</b> Prediction Accuracy <i>Pumping power</i>
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What the surrogate revealed:

- Flow rate accounts for 85% of the variation in component temperature being the single most important design lever
- Channel depth and flow rate jointly govern pumping power. Neither can be optimised in isolation
- Thermal contact resistance has minimal influence simplifying QC priorities
- 10,000 design candidates explored instantly

High-fidelity simulations generated by Panejo form the foundation of the surrogate model. These resolve detailed flow and thermal fields ensuring all derived insights remain physically accurate. QUGATE leverages a targeted subset of these computationally expensive simulations to learn system behaviour enabling rapid exploration without repeatedly solving the full numerical model.

A final high-fidelity validation run confirms the optimised design meets all physical and engineering requirements.

**QUGATE told us to stop at 20 runs.** The sensitivity results at 20 simulations were virtually identical to those at 45 or 180. Key drivers were already identified. The design space was already explorable. Running more would have added cost and not insight.




THE INSIGHT NOBODY TALKS ABOUT — UNTIL NOW

**WHERE IS QUALITY CONTROL CRITICAL?** Because flow rate controls 85% of temperature performance, manufacturing tolerances on the coolant delivery system matter far more than dimensional tolerances on the heat sink body itself. The analysis turns simulation insight into direct production guidance automatically.

OUTCOMES

<b>&lt; 45</b>	<b>~20 K</b>	<b>99%</b>	<b>10,000+</b>
Simulations for full accuracy (vs 180 typical)	Temperature reduction vs unoptimised baseline	Prediction accuracy for new design candidates	Design candidates explored in seconds

VALUE FOR EVERY STAKEHOLDER

 Design Engineers	 Engineering Managers	 Prospects & New Leads
Flow rate controls 85% of temperature behaviour and QUGATE identified that from just 20 simulation runs, not 180. Panejo's physics expertise ensures the model is right; QUGATE tells you when you already have enough data to act.	Fewer iterations, faster delivery. QUGATE identifies when enough data has been collected. In this case, 20 runs gave the same insight as 180. That is a direct reduction in simulation cost, time and engineering hours.	Already running expensive simulations? QUGATE tells you when to stop and what you already know. In this case, 20 runs delivered the same answers as 180. The Panejo + QUGATE partnership works with whatever tools you already use.

<p><b>QU</b> <b>GA</b>   QUGATE</p> <p><b>About QUGATE</b> Surrogate intelligence platform. Works with COMSOL, Ansys, Python models and more. <a href="mailto:support@qugate.com">support@qugate.com</a> <a href="http://qugate.nl">qugate.nl</a></p>	<p><b>panejo</b></p> <p><b>About Panejo</b> Engineering and simulation consultancy applying advanced data-driven methods across industrial challenges. <a href="mailto:office@panejo.com">office@panejo.com</a> <a href="http://panejo.com">panejo.com</a></p>	<p><b>Better together.</b></p> <p>Deep simulation expertise. Surrogate intelligence. One integrated approach. <a href="#">Reach out to either partner to get started.</a></p>
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