ESEngSim in partnership with GENERAC

Virtual prototyping and flow analysis of a generator enclosure using CONVERGE CFD

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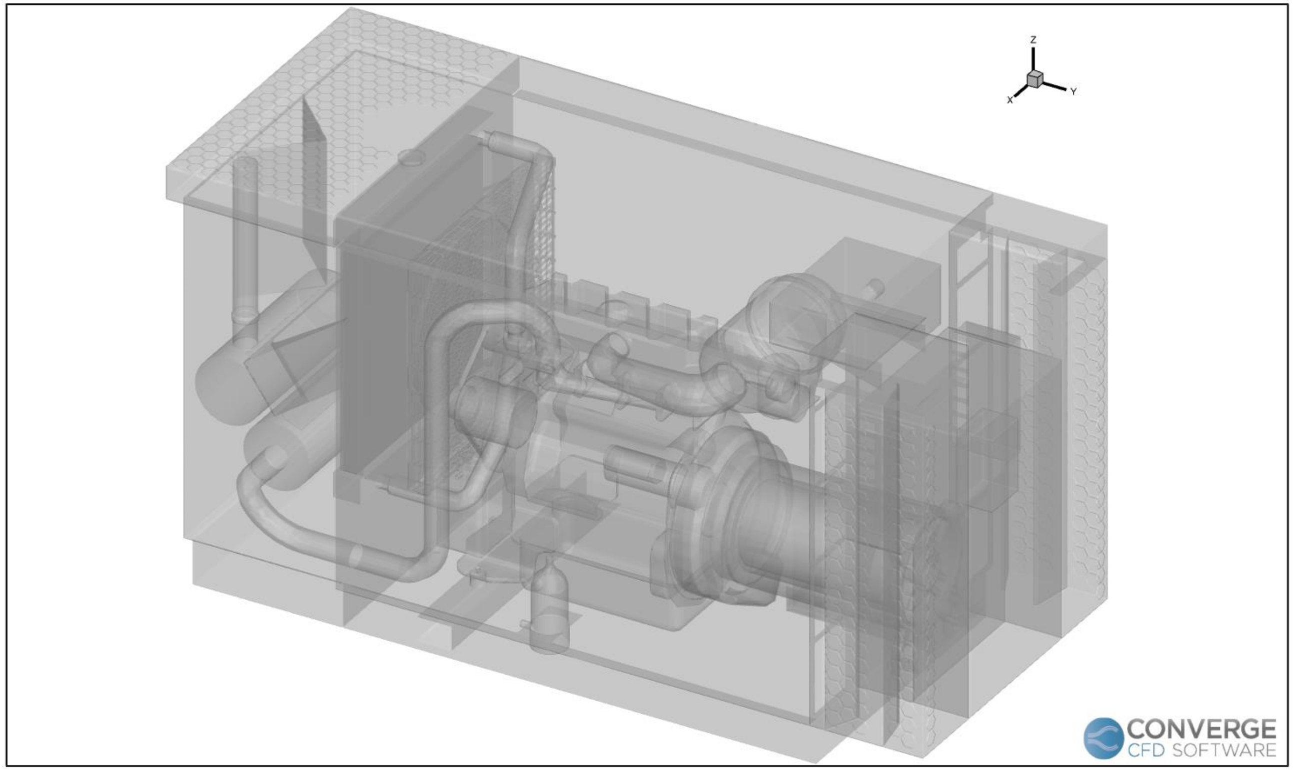
Objective

- Use 3D CFD simulation to virtually prototype generator enclosures
- Visualize flow velocities and air temperatures in the enclosure
- Quantify 2D and 3D results with changes in enclosure designs
- Technical targets:
  - Minimum flow rate through the enclosure (for desired heat transfer)
  - Maximum threshold of velocity magnitude (surrogate for noise)
- Minimize hardware iterations and physical test time, to yield faster development cycle

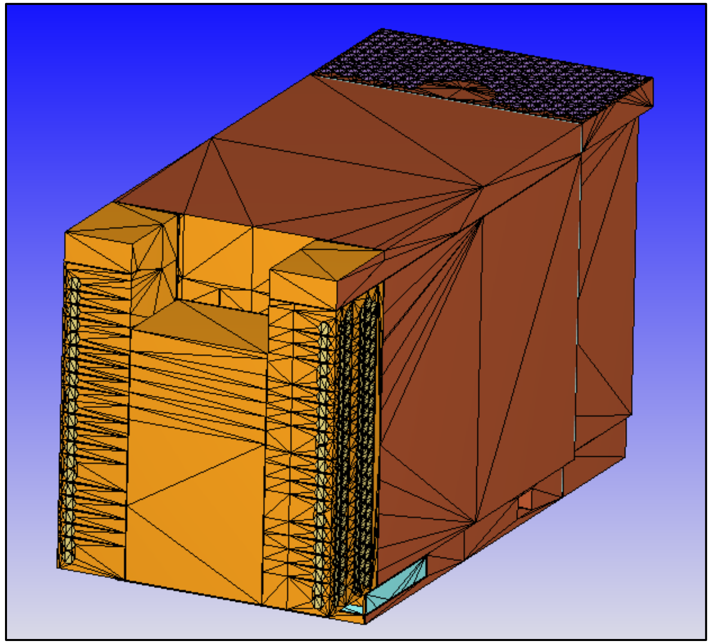


Phase 1: Cold Flow Simulation

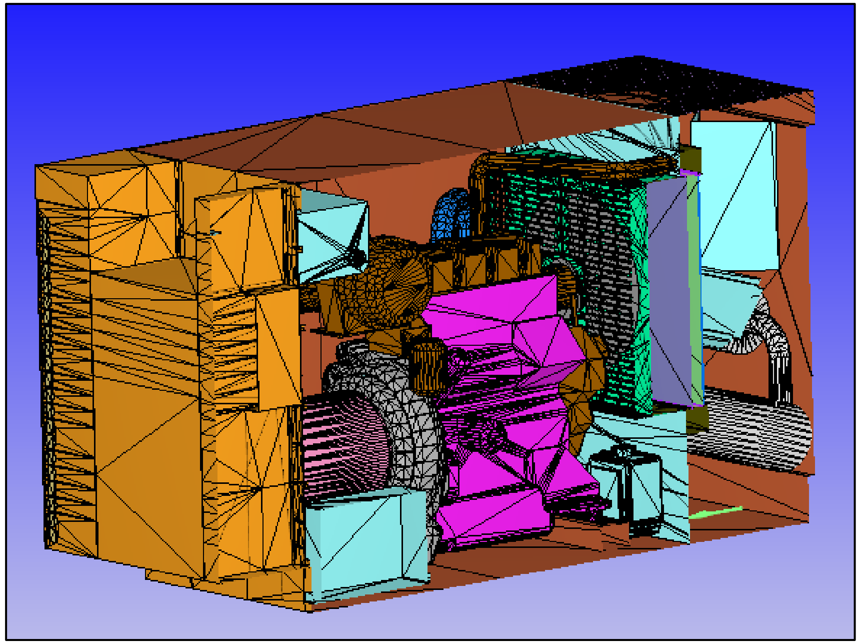
Simulation setup

Geometry and case-setup

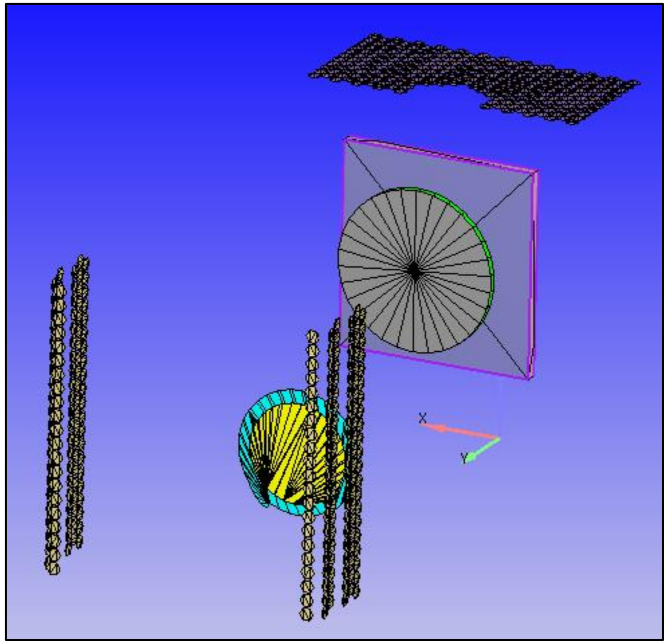
- A watertight CONVERGE model was created and prepared using STEP file provided by Generac



Enclosure geometry



Interior



Flow rate boundaries and unique modeling features

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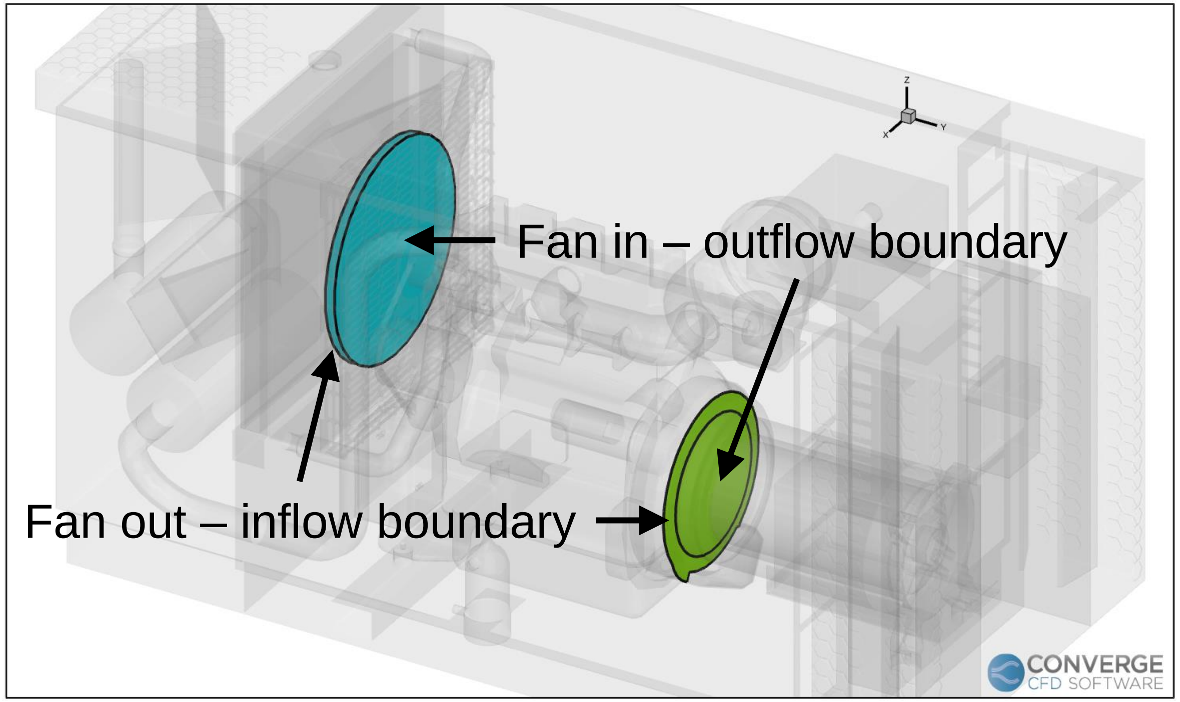
Modeling fans

- Options for modeling fans in CONVERGE:
  - Rotating fan model
  - Multiple Reference Frame (MRF) model
  - **Outflow-Inflow boundary**

- Fan inlet is represented as an outflow boundary
- Fan outlet is represented as an inflow boundary
- Imposed mass flow rate and temperature boundary condition

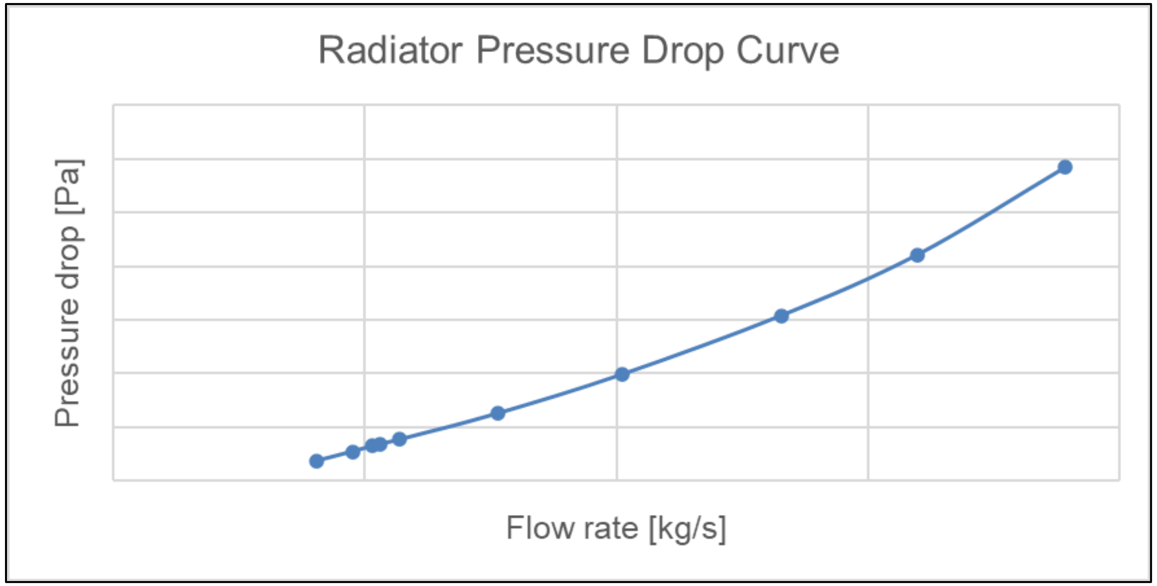


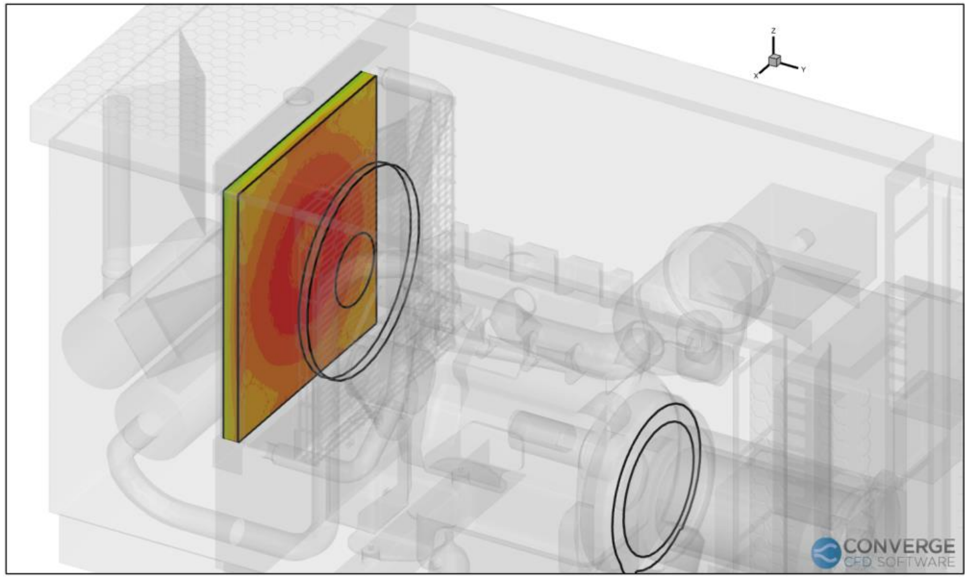
Modeling radiator pressure drop

- We used a *Source/Sink* model with a *Porous* source to characterize the radiator pressure drop
- In CONVERGE, delta P is calculated by the following formula:

$$\Delta P = -\left(C_{viscous}\mu u_i + \frac{1}{2}\rho C_{inertial}|u|u_i \right)$$

- Inertial and viscous coefficients were calculated using a curve fit





Phase 1: Cold Flow Simulation

Simulation targets and results

Cold flow simulation objectives and targets

Is the case and radiator pressure drop initialized correctly?

Calibrate engine fan flow rate to match system pressure with fan curve

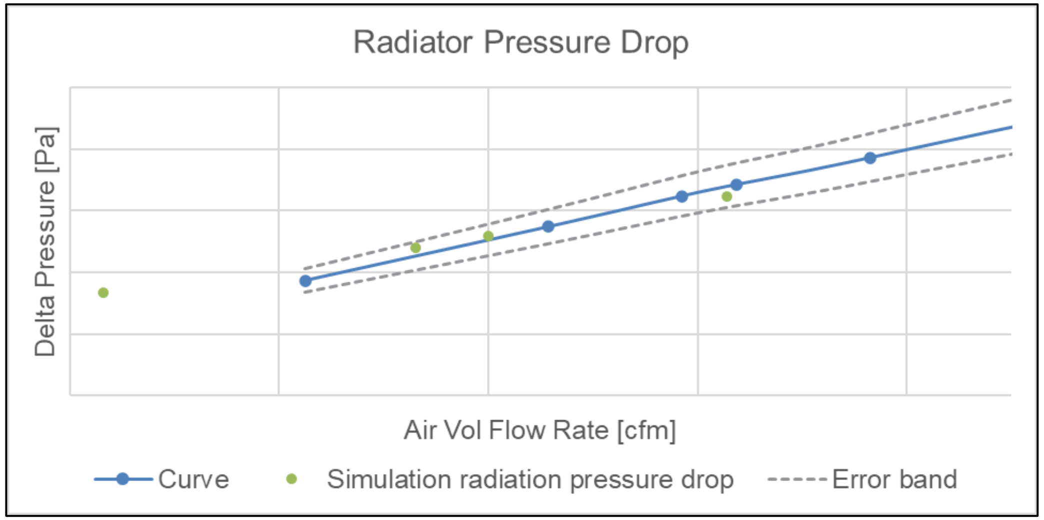
Is the calibrated flow rate higher than desired flow rate?

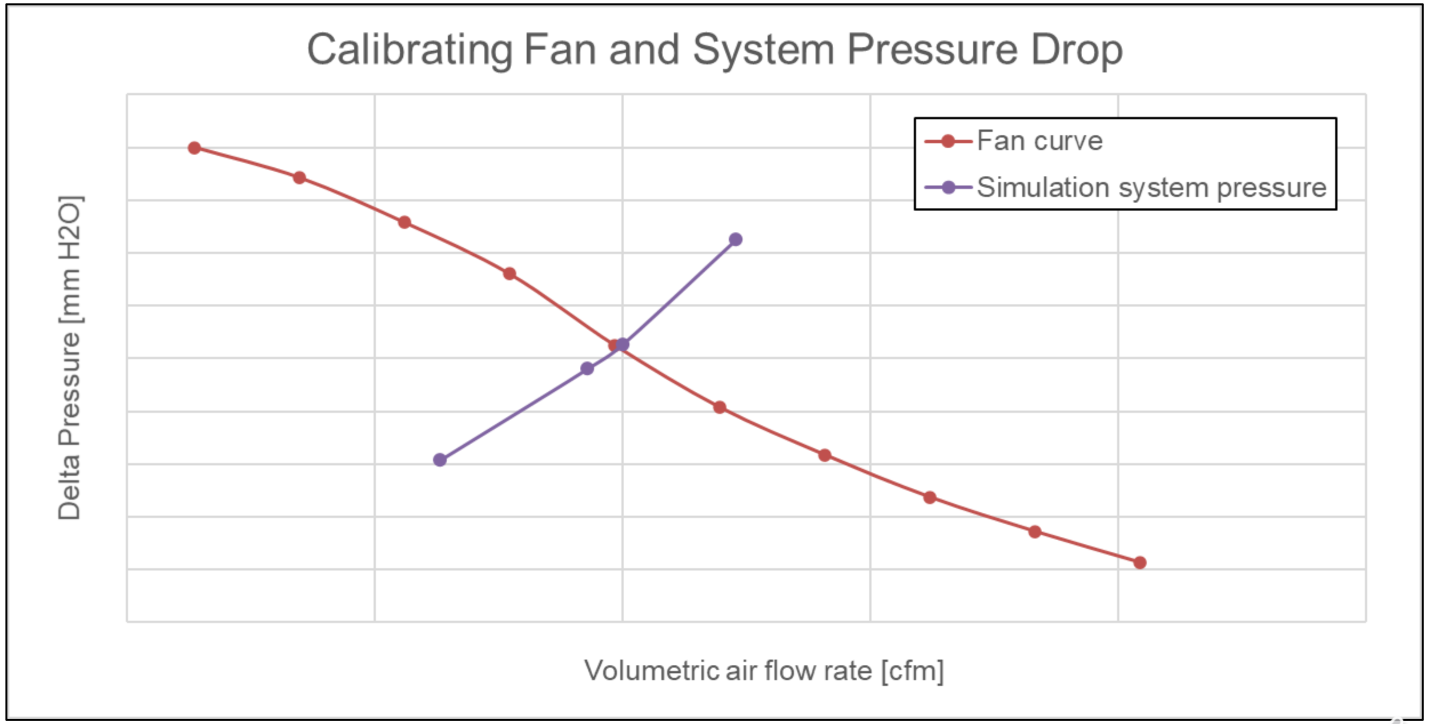
Determine if max system velocity is lower than the threshold

(surrogate for noise)

Validating radiator pressure drop and system calibration

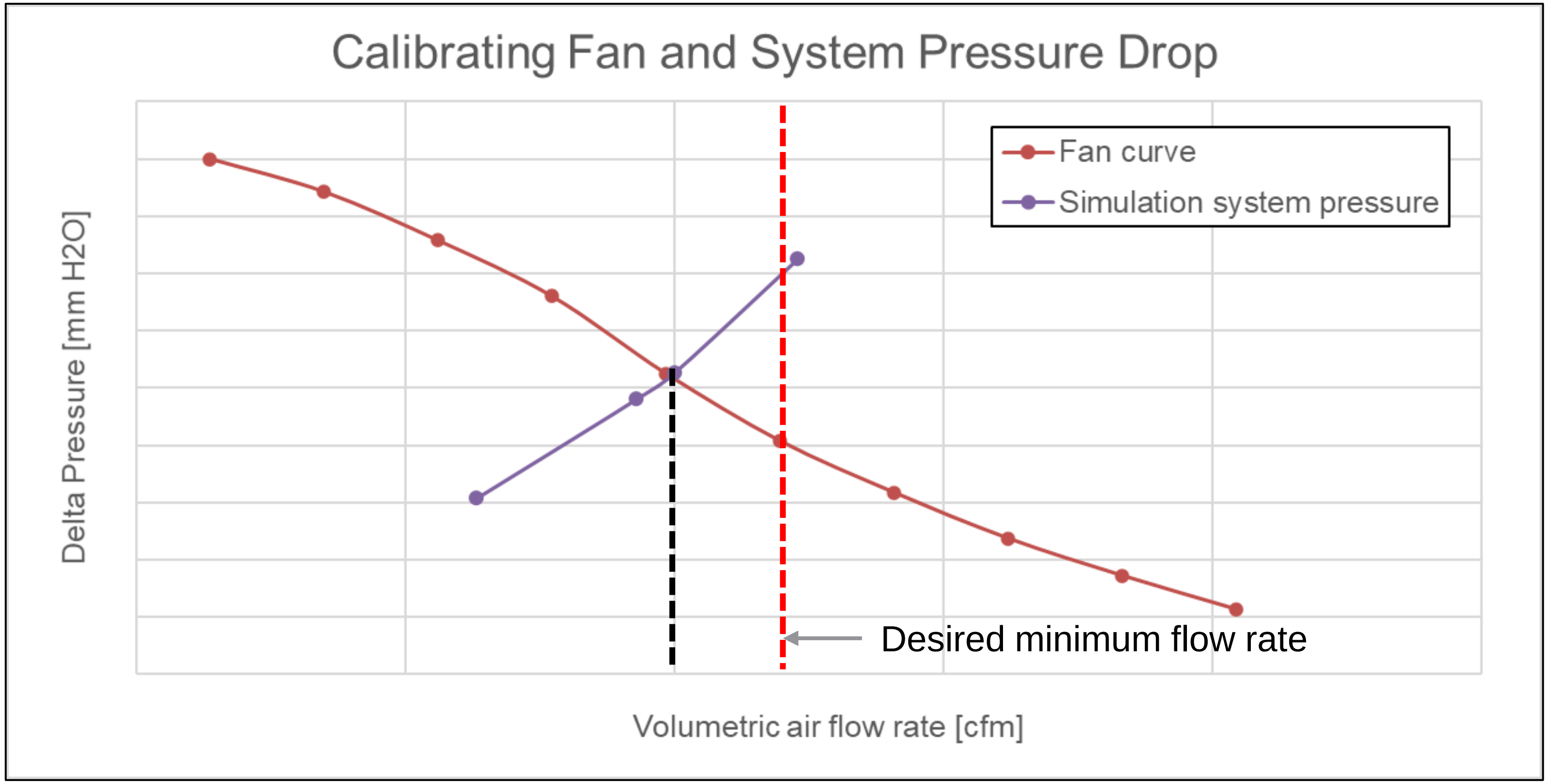
- We validated radiator pressure drop
- For every new geometry, we first calibrated the flow rate that matched the system ΔP to the test ΔP for the fan
- This allowed the team to know the possible air flow rate through the enclosure





Target 1: Comparing with target minimum flow

- Initial results showed that calibrated flow rate was lower than desired minimum flow rate
- Before an initial prototype was built



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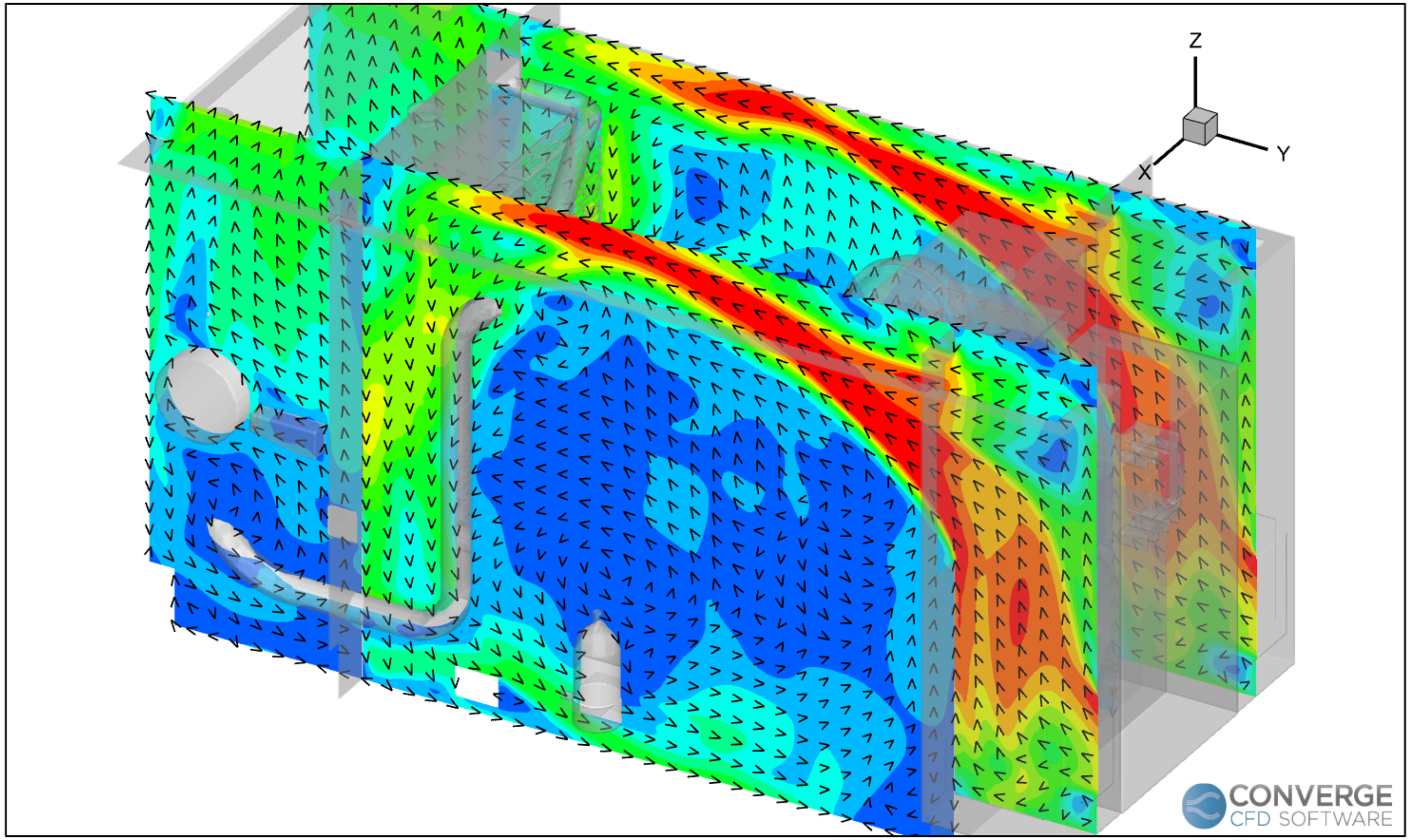
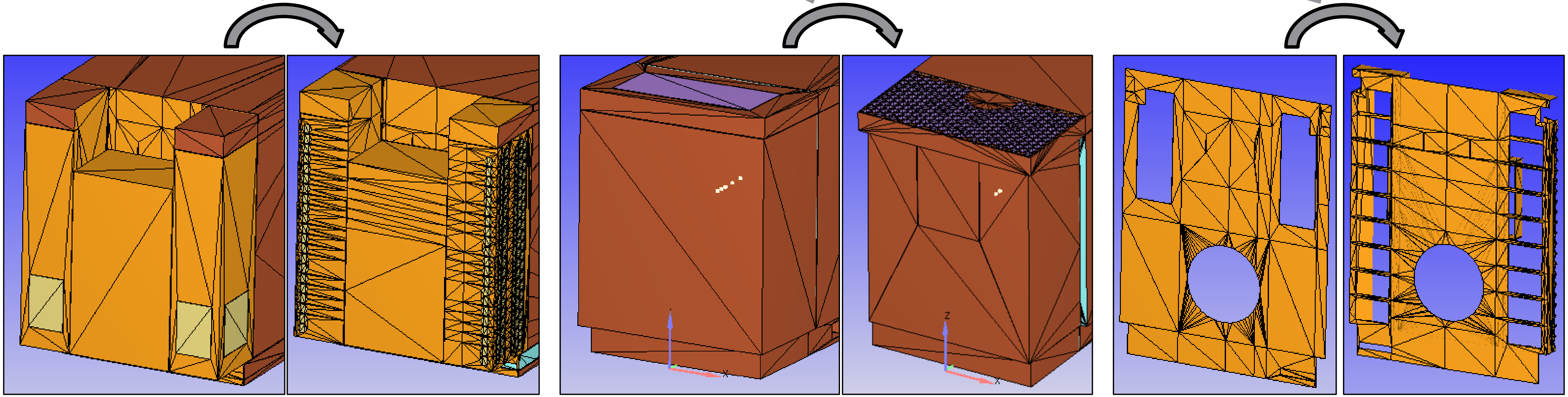
Target 2: Velocity magnitude threshold

- In the contour results, velocity magnitude in red are at undesirable levels
- Velocity magnitude threshold is a surrogate for noise limits



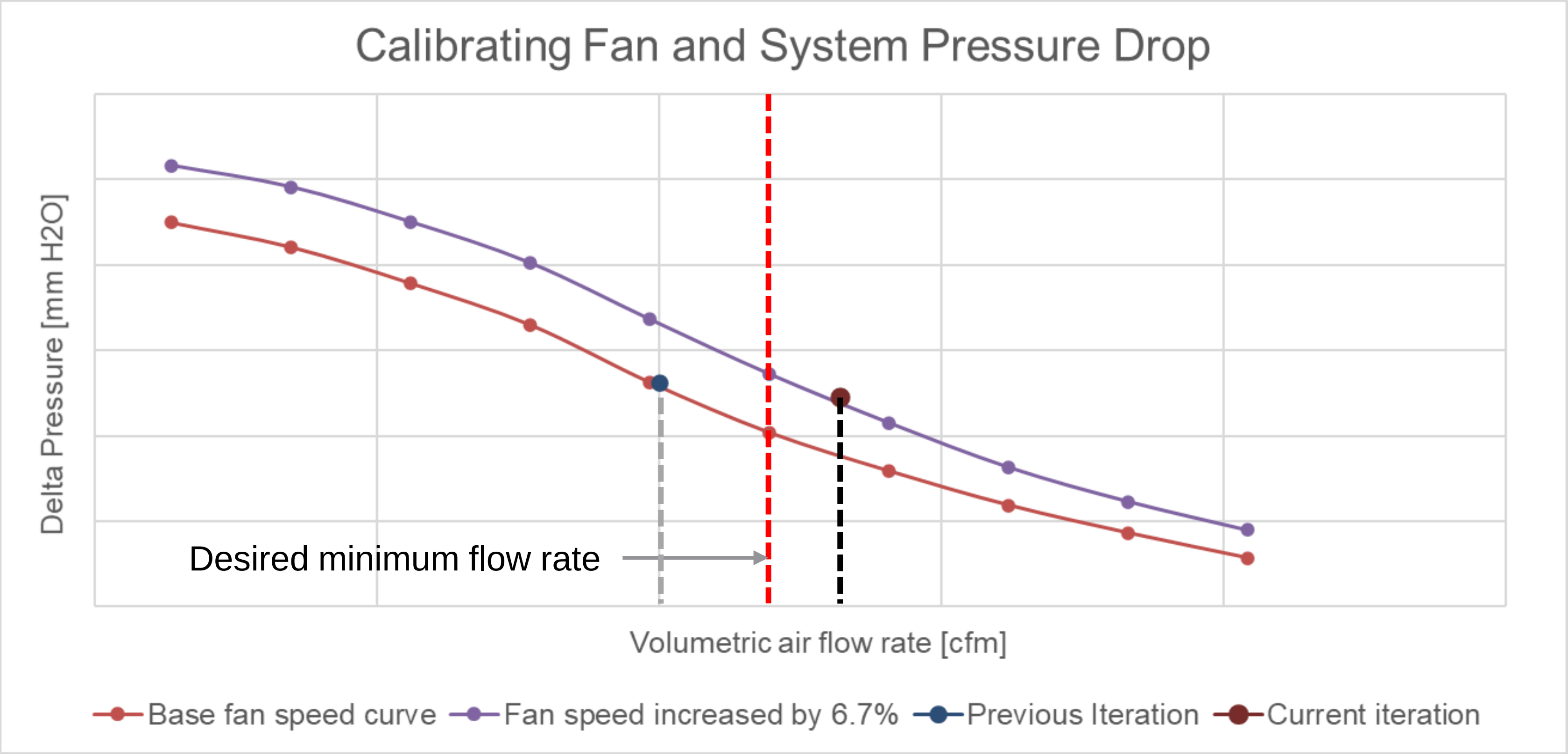
Decisions made to improve enclosure performance

Change inflow area → Change outflow area → Change opening area → Increase fan speed by 6.7%



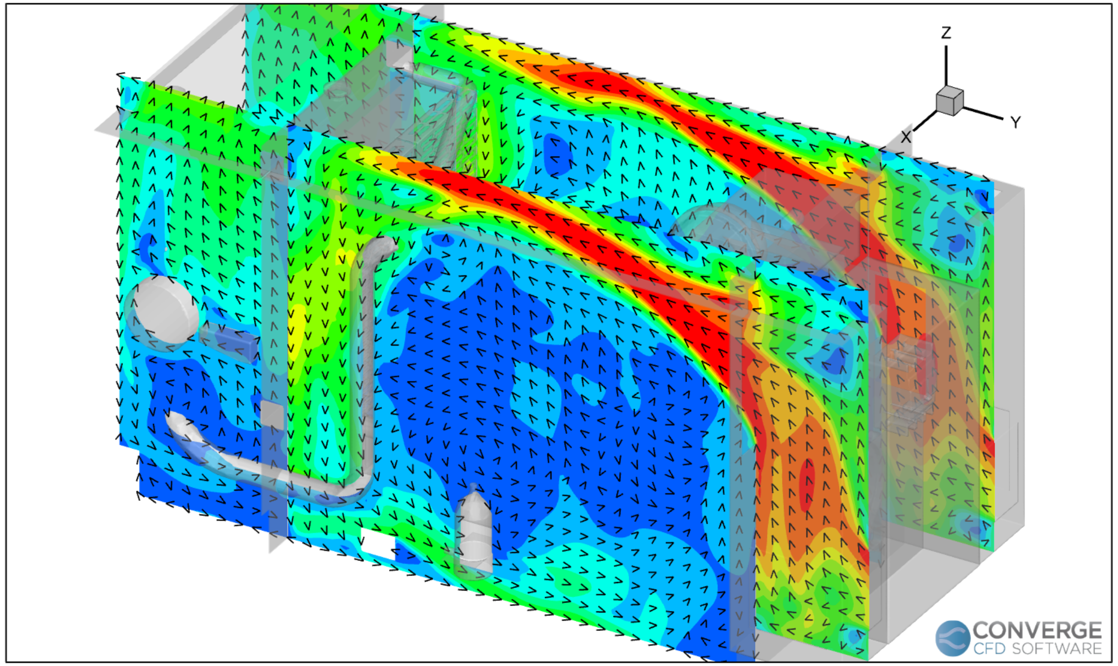
Comparing with target minimum flow

- Modified geometry surpasses the target minimum flow rate

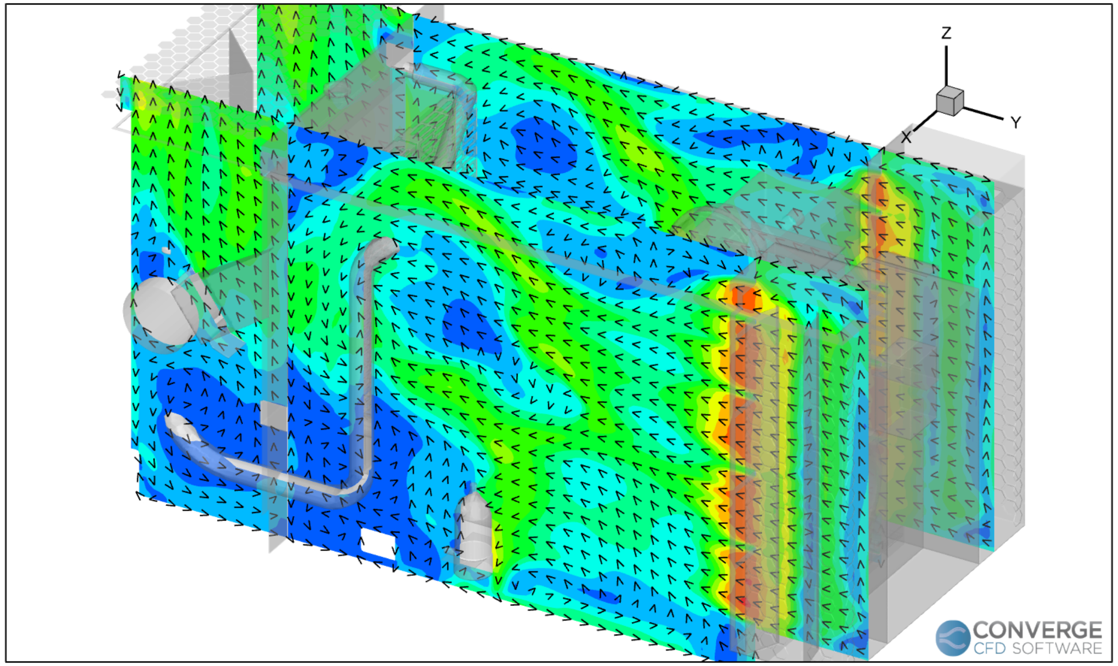


Velocity magnitude threshold

- In the contour results, velocity magnitude in red are at undesirable levels
- Modified geometry has velocity magnitudes lower than the threshold
- Resulting in confidence in cooling air flow and cooling related sound performance before physical testing



Previous iteration



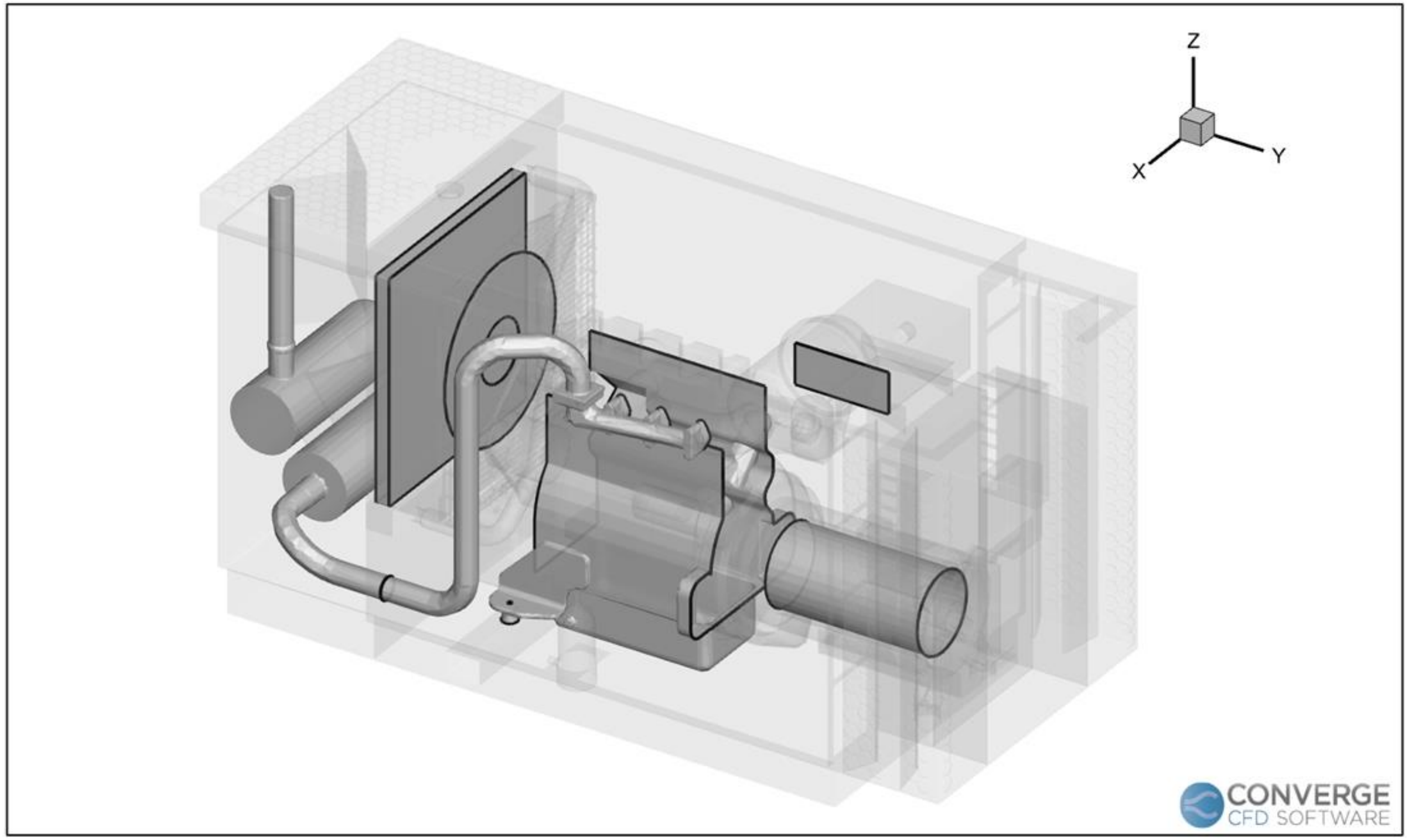
Current iteration

Phase 2:

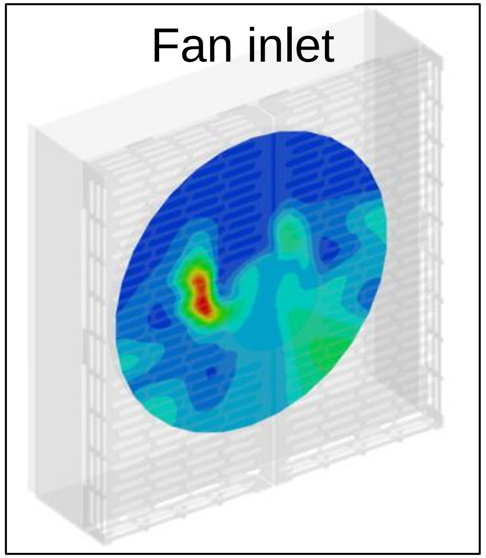
Hot Flow Simulation

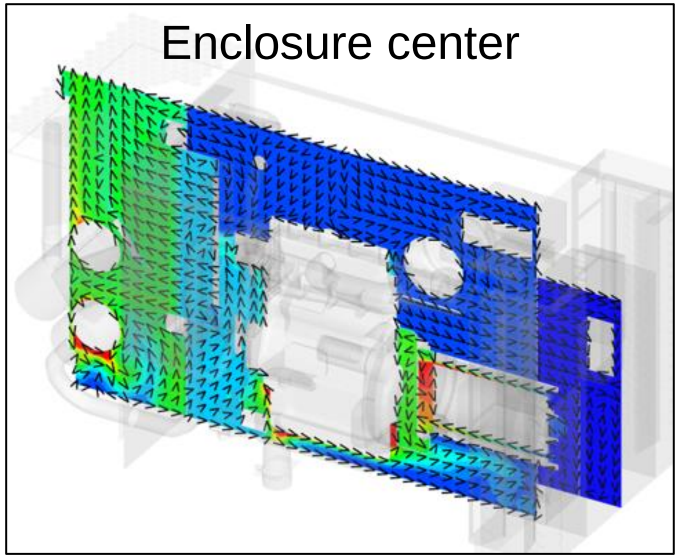
Adding heat into the system

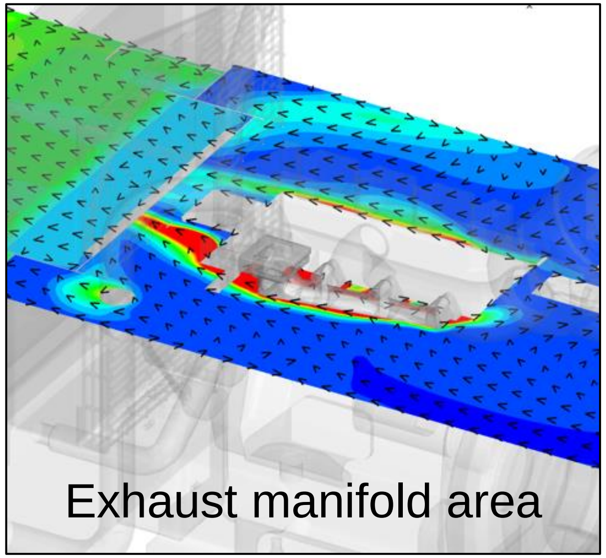
- Objectives:
  - Visualize air temperatures within the enclosure
  - Understand hot spots in the enclosure
  - Compare average air temperatures with design thresholds and test data
- Modeling:
  - Based on component heat rejection rate and component area, we impose a heat flux (W/m^2)
  - For the radiator, we use an *Energy Source* element in the same region as the *Porous Sink*

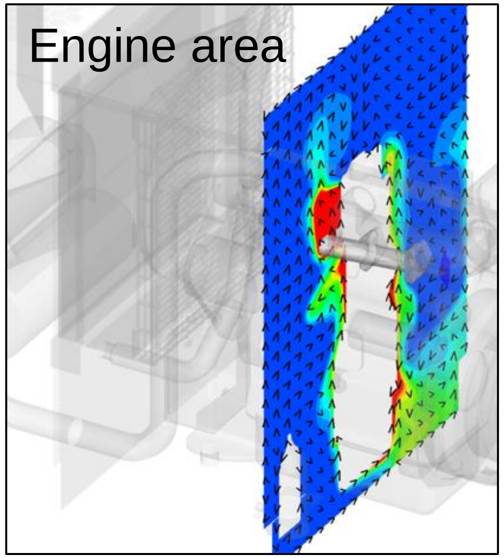


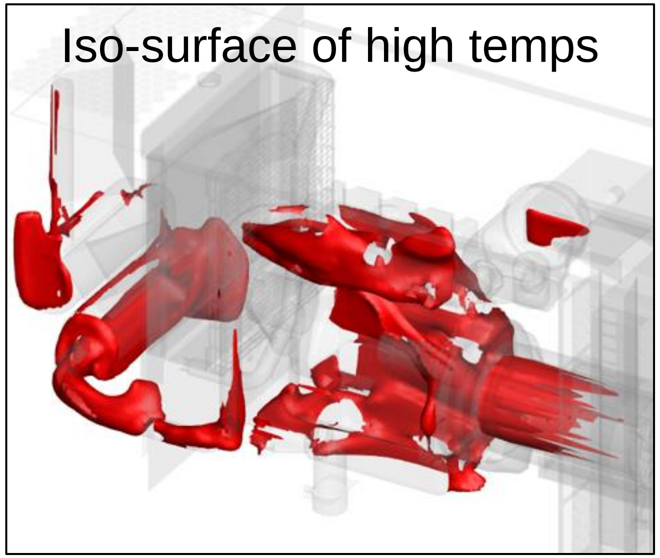
Air temperatures in the enclosure

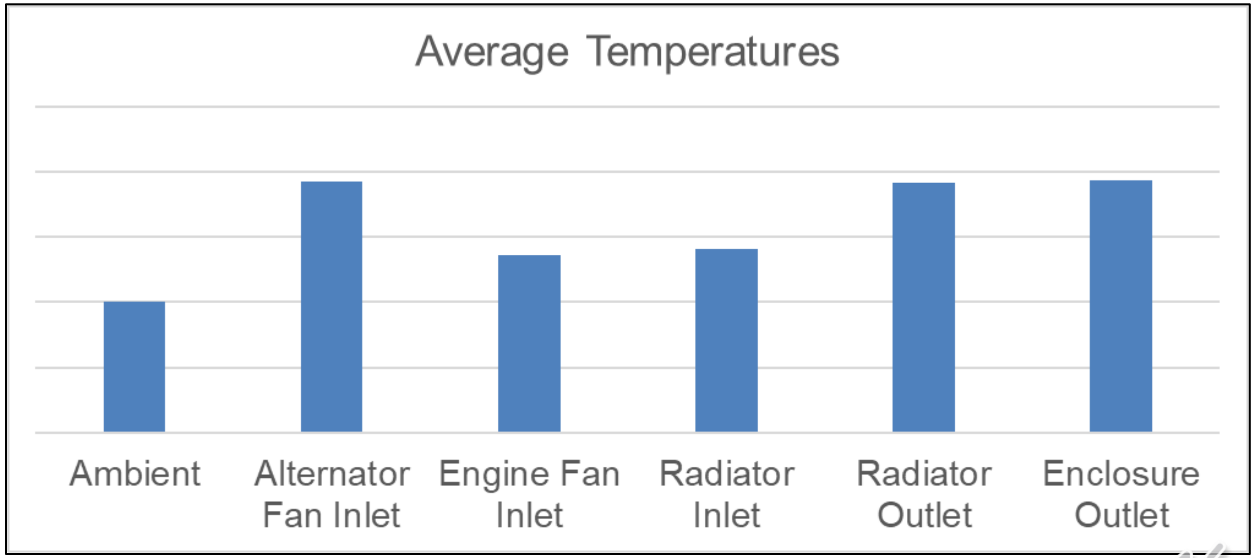












Conclusions

- Using CONVERGE CFD we were able to virtually prototype enclosure geometries before it was able to go on a test stand
- Resulted in minimal physical prototype iterations resulting in faster development cycle time
- With modified iterations we increased available flow rate through enclosure by 21.3%
- Velocity magnitude is reduced by 19.1% to achieve the design threshold
- Temperature contours and iso-surfaces help the team visualize air temperatures to decide thermocouple locations and be aware of hot zones

Acknowledgements

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Thank you for your attention