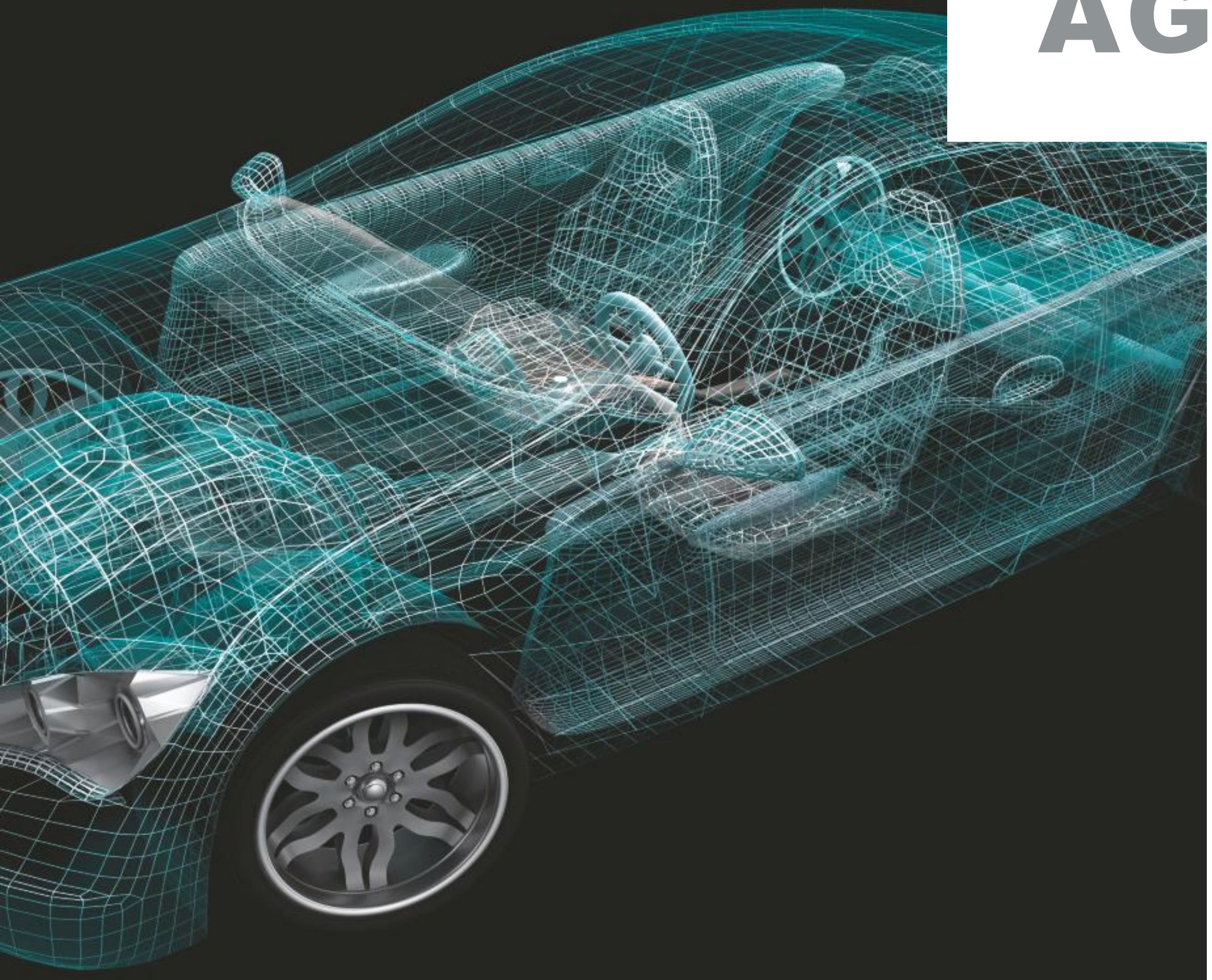
ADVANCES IN LIGHTWEIGHTING VALIDATION

Topics

- ≈ Material characterization of TPO & CFA’s
- ≈ CAD simulation capabilities
- ≈ Correlating CAD simulations to molded parts
- ≈ Supporting sustainable automotive designs

AVIENT



AGENDA

- Avient Automotive Solutions
- Chemical Foaming in Automotive
- Case Study & Results
  - Advances in CFA Simulation
  - Simulation Workflow / Execution
  - Future Directions
- Conclusions / Q&A

AVIENT

AVIENT AUTOMOTIVE

INTERIOR

OVER 14,000 APPROVED OEM FORMULATIONS

MASTER PLAQUE SUPPLIER

SMARTBATCH™ ADDITIVES

COLOR, MATERIAL, FINISH

COLORWORKS™ DESIGN CENTERS

COLOR DESIGN GUIDES

CHEMICAL FOAMING AGENTS (CFA) TO REDUCE WEIGHT AND DENSITY

EXTERIOR

PRE-COLOR FORMULATIONS FOR AESTHETICS, FUNCTION, AND HARMONY

SPECIAL EFFECTS TO PROVIDE CUSTOMIZED AND QUALITY AESTHETICS

PAINT REPLACEMENT SOLUTIONS FOR REDUCED VOCS

CHEMICAL FOAMING AGENTS (CFA) FOR LIGHTWEIGHTING AND IMPROVED MPG

UNDERHOOD

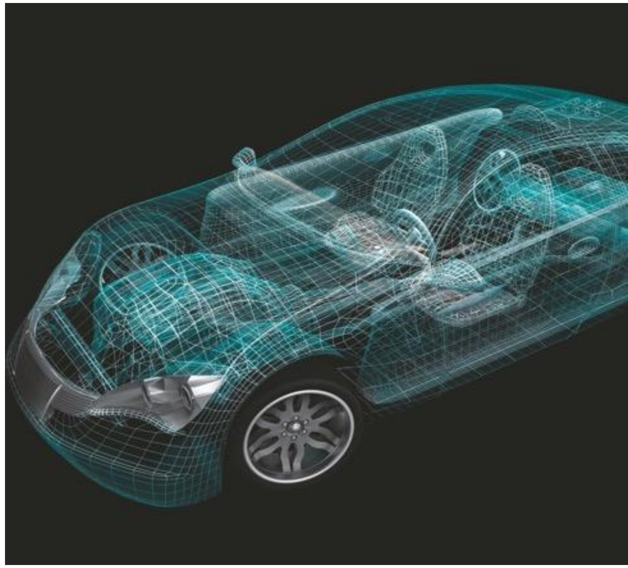
MRP COLLABORATION

FLAME RETARDANTS & UL APPROVALS

MOLDED-IN-COLOR (MIC) METALLICS FOR VISUAL ENHANCEMENT OF ENGINE COVERS

PERFORMANCE-ENHANCED DURABILITY FUNCTIONAL ADDITIVES

CHEMICAL FOAMING AGENTS (CFA) TO REDUCE WEIGHT AND DENSITY



BODY / STRUCTURAL

MOLDED-IN-COLOR (MIC) METALLICS FOR VISUAL ENHANCEMENT

SMARTBATCH ADDITIVES WITH COLORANTS FOR EE, PART LONGEVITY, AND EFFICIENCIES

CHEMICAL FOAMING AGENTS (CFA) TO REDUCE WEIGHT AND DENSITY

ADVANCED COMPOSITES COLLABORATION

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CFA VALUE

HYDROCEROL™ & EXCELITE™ CHEMICAL FOAMING AGENTS

Corporate Annual Fuel Economy (CAFE)

- ICE weight savings discussed in pounds
- EV engineers speak in ounces
- Reduced material potential (5 – 35%)

Key Considerations

- Early involvement
- OEM / Tier 1 buy-in
- Utilize OEM teams
- Application TDEs

20%
Reduction in weight of dashboards

20%
Reduction In Cycle Time/Energy

CO2
Reduced CO_2 emissions

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CFA SUCCESS STORIES

LIGHTWEIGHTING WITH EXCELITE & HYDROCEROL

Current Automotive Programs

- Standard injection molding and core-back process
- With / without gas counter pressure
- Class “A” appearance
- 5-20% weight reduction
- Cycle time reduction
- Dimensional stability


INTERIOR TRIM PANELS


IP CARRIERS/SUBSTRATES


GARNISH TRIM, PILLARS

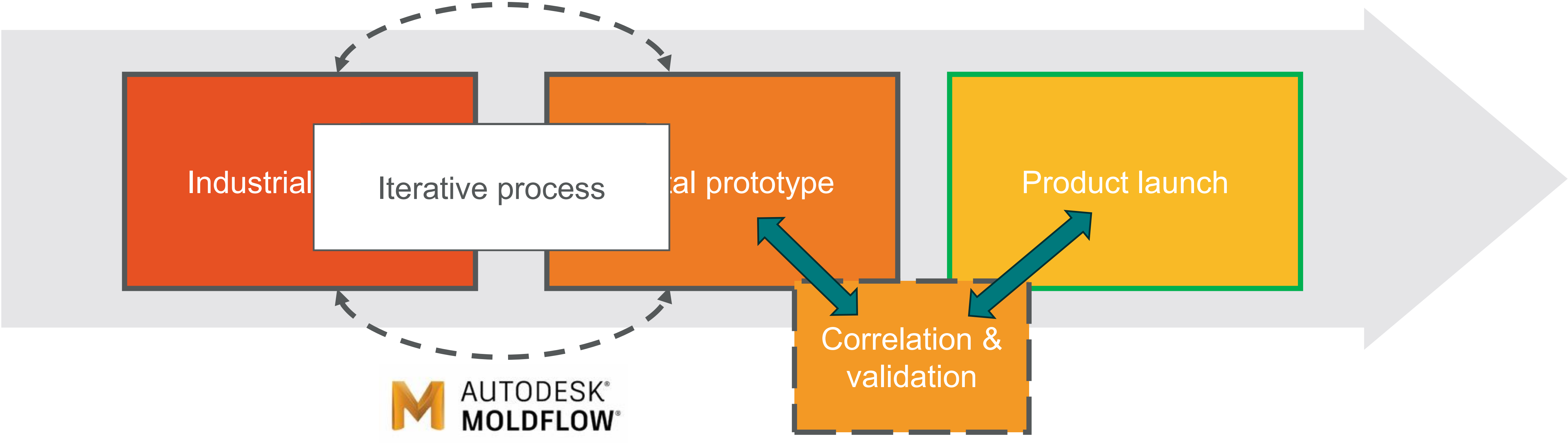

EXTERIOR COMPONENTS


INTERIOR GRAB HANDLES


HVAC COMPONENTS


REAR LIFTGATE, FRUNKS AND TRUNKS

PROCESS VALIDATION



→ **Product development support**
→ **Helps validate the process**

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ABOUT US

9,300
employees worldwide

35,000+
solutions

$3.3 billion
in 2025 sales

$19+ million
donated since 2007

100+
facilities in 35 countries

OUR PORTFOLIO

COLOR, ADDITIVES & INKS

Solid & liquid colorants and masterbatch

Performance additives

Plastisols

Inks

ENGINEERED POLYMER FORMULATIONS

Engineered formulations

Advanced composites

Protective materials

TPEs and urethanes

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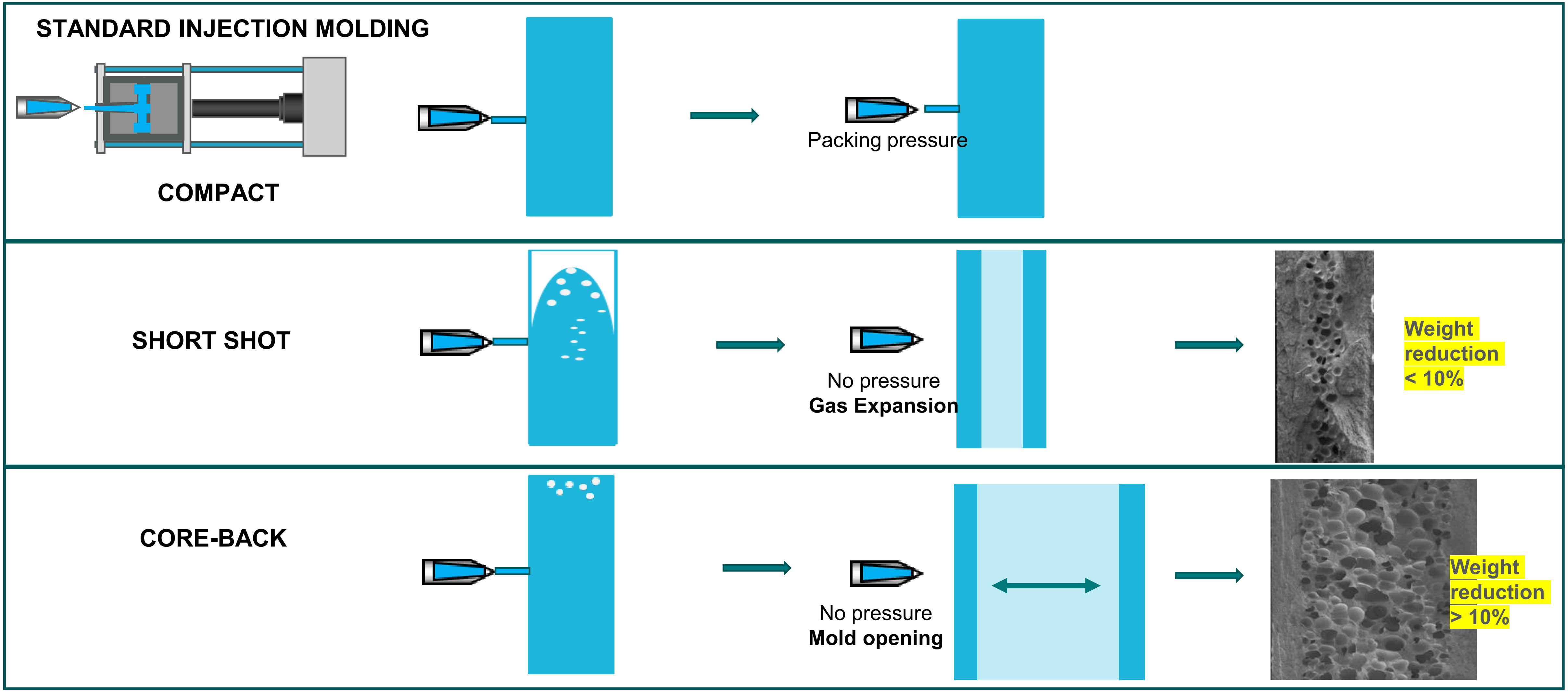
INJECTION MOLDING PROCESSES

COMPACT, SHORT-SHOT, AND CORE-BACK



CASE STUDY OVERVIEW

STRATEGY

- Correlate CAD simulation studies of Chemical Foaming Agents (CFAs) with the KPIs of Class A surface-approved polyolefin materials

PROCESS

- CAD simulation design of experiment (DoE); Injection molding of article; KPI measurements; Correlate & validate CAD simulation with molded part data

BENEFIT

- Advance Avient current CAD foaming simulation platform – utilize findings for future product development opportunities, speed to market

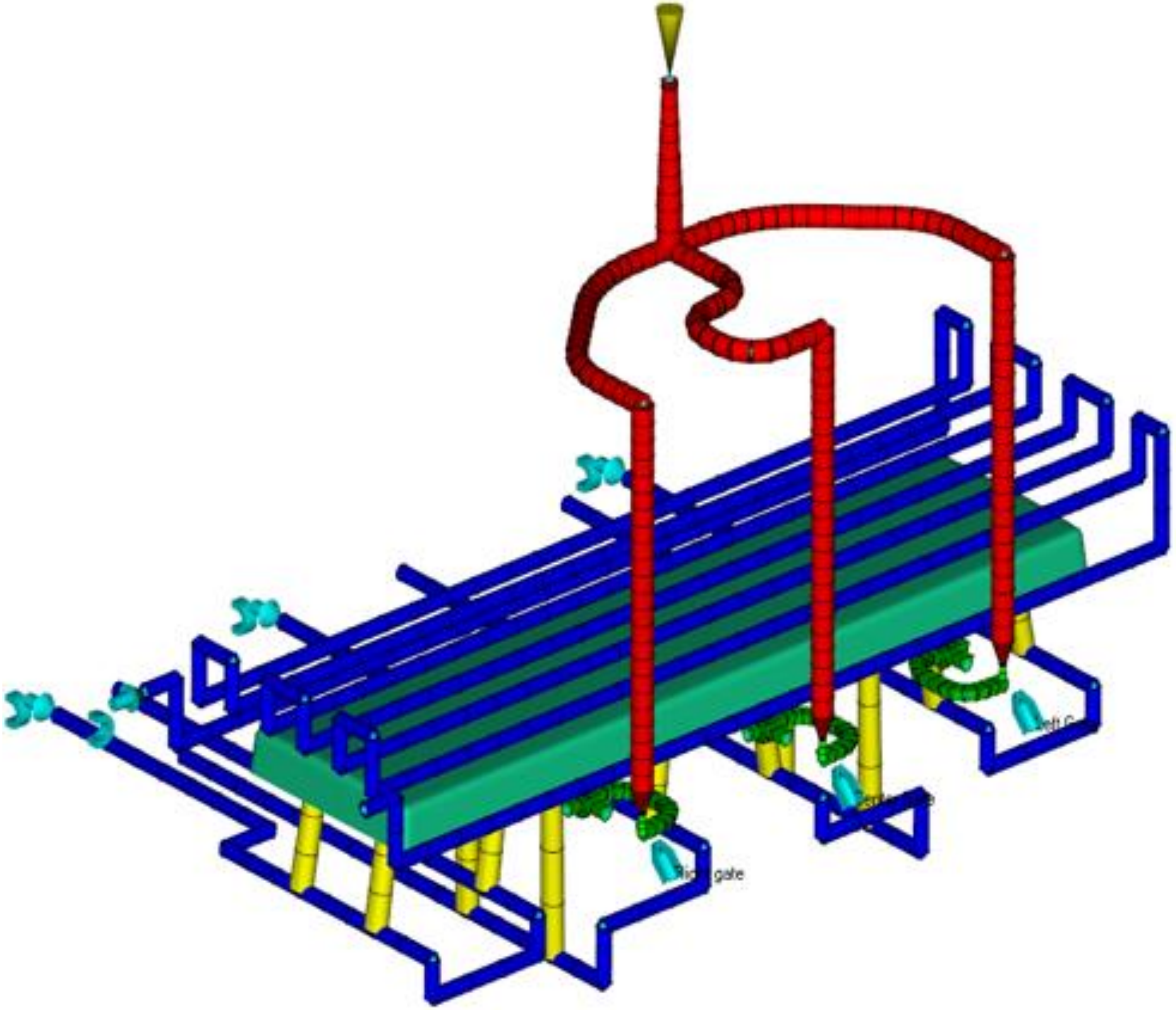
MATERIAL TRIAL SUMMARY

AUTODESK MOLDFLOW SIMULATION DETAILS

Tool Details
- Wall Thickness = 2.6mm
- Cold Runner Cashew Gates ~ Ø1.5mm
- Hot Runner & Manifolds
- Five Cooling Channels

Materials Used
- Five (5) TPO's
- Neat PP
- Glass-filled PP
- Three (3) Avient Hydrocerol CFA's
- Multiple Let-Down Ratios (0.5% - 2.0%)

Moldflow Process Settings
- Analysis Type: Microcellular Injection Molding
- Analysis Sequence: Cool + Fill + Pack + Warp
  - Injection + Packing + Cooling Time: Automatic
  - Filling Control: Flow Rate
  - V/P Switchover: By % Weight Reduction
  - Pack/Holding Control: Packing Pressure vs Time
  - Bubble Nucleation Model: Constant Nucleation Density

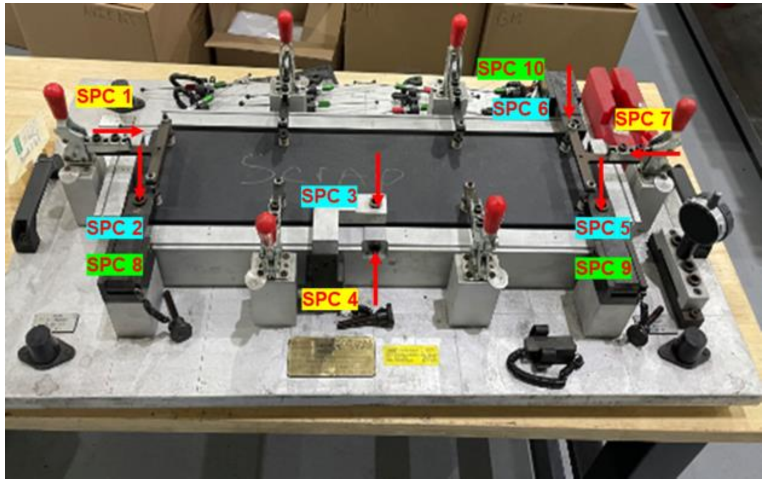


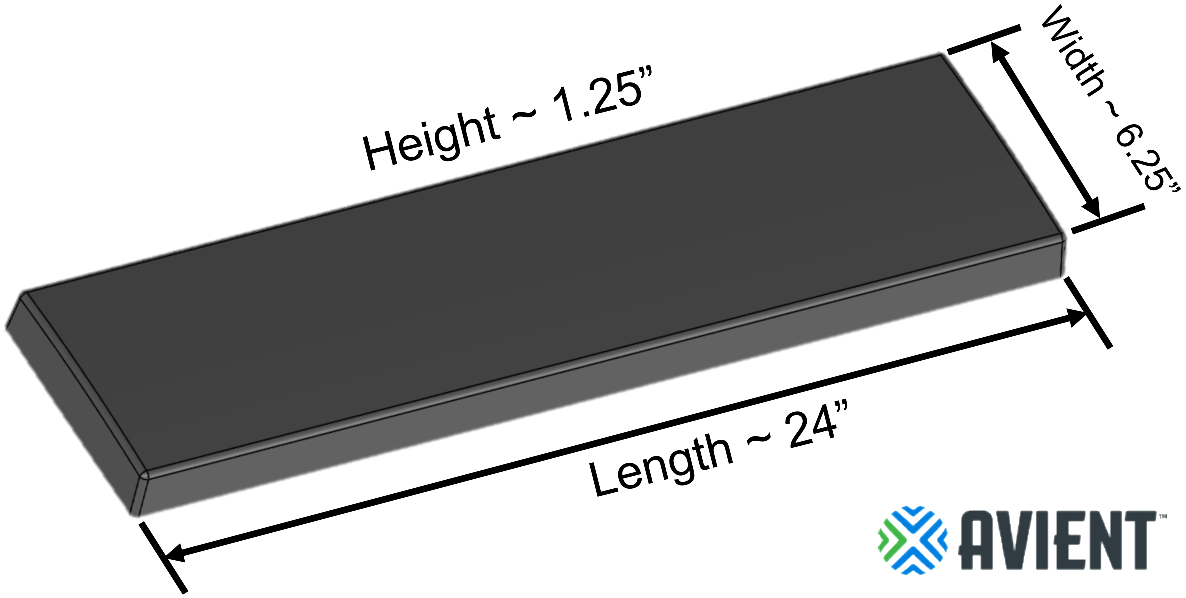
MATERIAL TRIAL SUMMARY

INTEGRITY TOOL TRIAL DOE DETAILS

25 Different Runs
- ✓ 168 parts
- ✓ 1680 total dimensional data points
- ✓ 250 weight measurements
- ✓ 500 wall thickness points

Data Collection (Correlation)
- ✓ Part Weight Reduction
- ✓ Shrinkage Prediction
- ✓ "Warpage" Prediction
- ✓ Cosmetics and Appearance Approvals





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MATERIAL TRIAL SUMMARY

COSMETICALLY APPROVED ITERATIONS

- Run 6A
  - Material - High-flow, high-stiffness interior TPO
  - Chemical Foaming Agent - Hydrocerol ITP 818
  - Let-Down Ratio = 0.5%

6A

- Run 11B
  - Material - Talc-filled, impact-modified TPO
  - Chemical Foaming Agent - Hydrocerol ITP 818
  - Let-Down Ratio = 0.75%

11B

- Run 14A
  - Material - Talc-filled, impact-modified TPO 2
    Chemical Foaming Agent - Hydrocerol ITP 818
  - Let-Down Ratio = 0.75%

14A

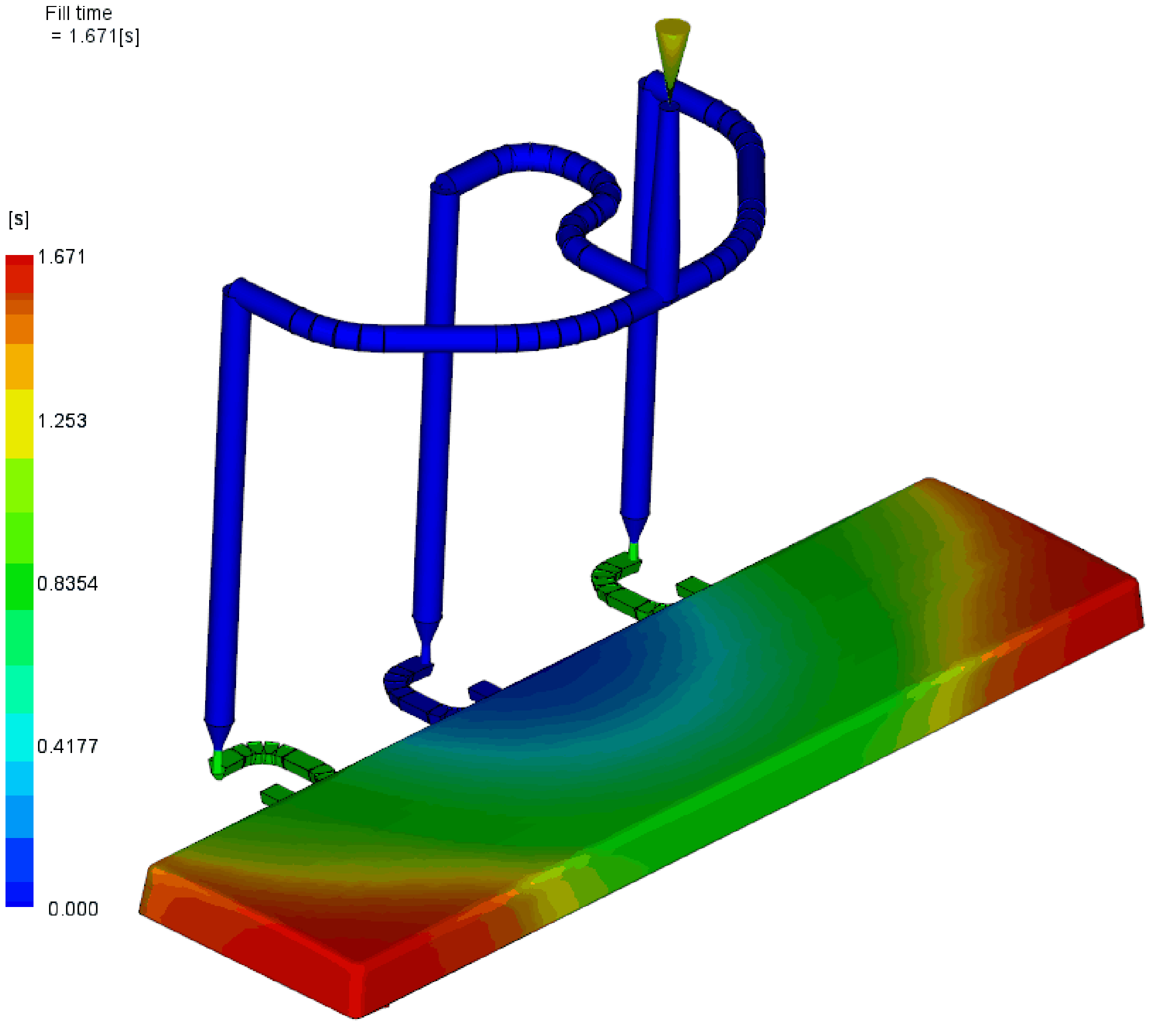
MOLDFLOW ANALYSIS COMPARISON

FILL TIME

Analysis 11B

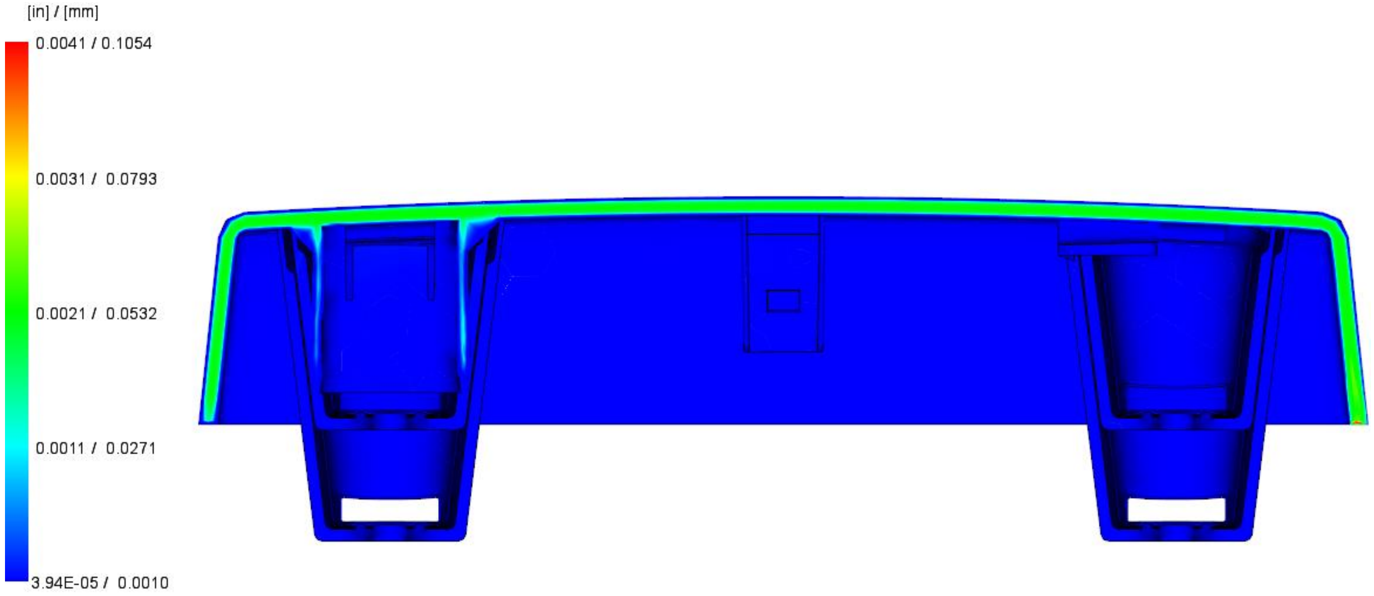
- Simulated Fill Time = 1.67 sec
- Trial Fill Time = 1.67 sec
  - % Error = 0%

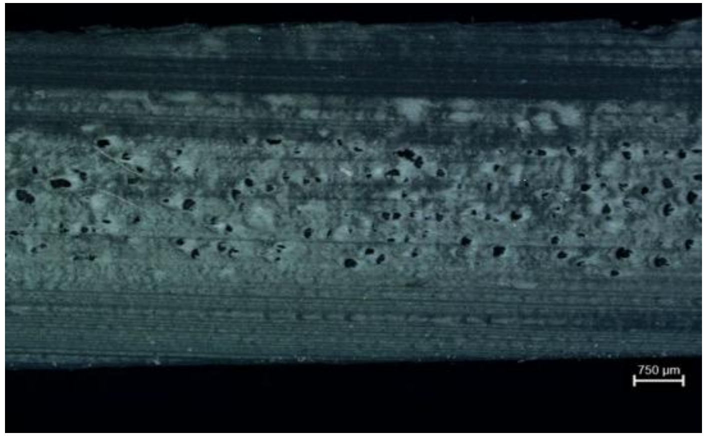
- Simulated V/P Transfer Pressure = 678 psi
- Trial V/P Transfer Pressure = 751 psi
  - % Error = 10.7%



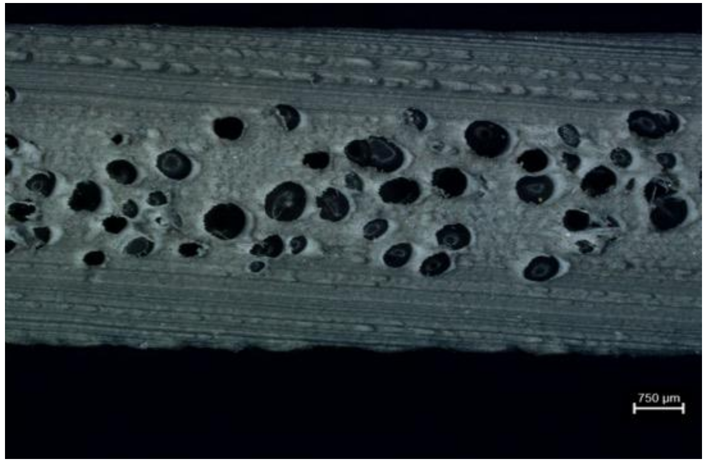
MOLDFLOW ANALYSIS COMPARISON

BUBBLE (CELL STRUCTURE) RADIUS





Part 8A: Injected with cavity counterpressure



Part 11B: Injected without cavity counterpressure

Bubble Nucleation Model: Constant Nucleation Density

- Assumes a pre-defined, uniform number of bubbles nucleate throughout the part once the saturation pressure drops below a critical point.

Bubble Nucleation Model: Variable Nucleation Density

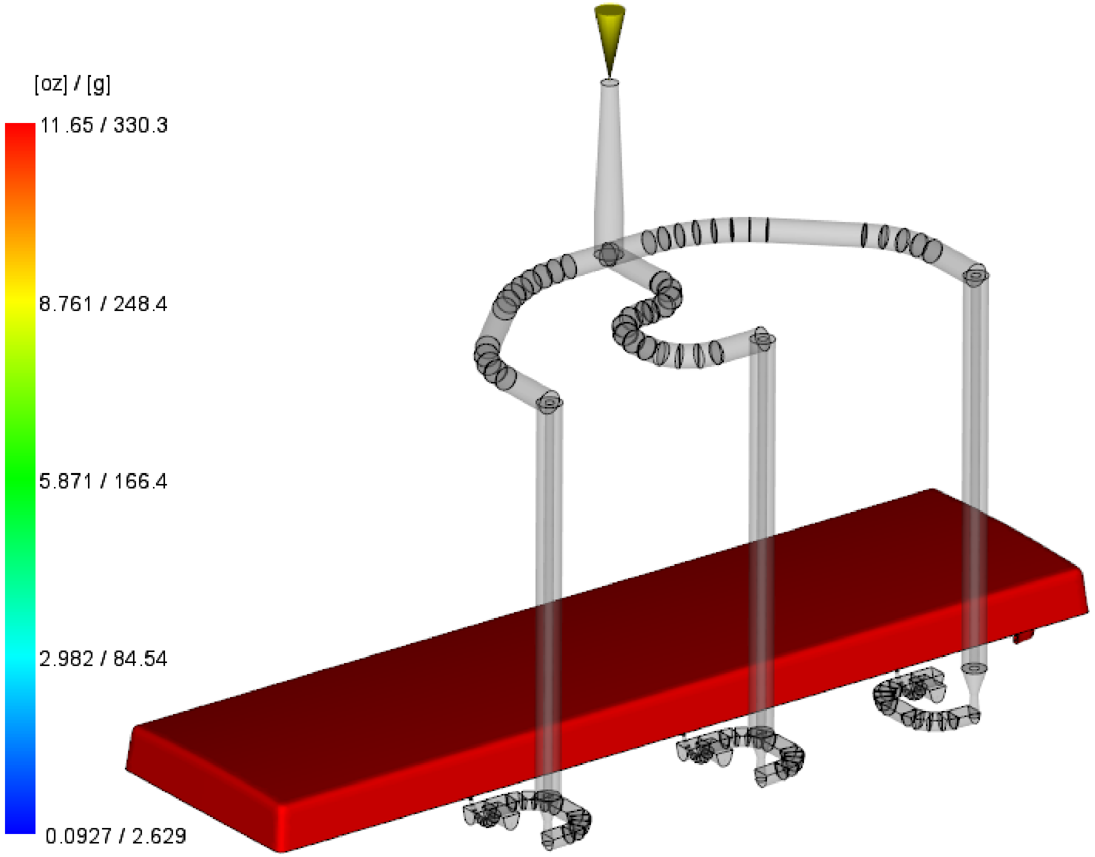
- Calculates the nucleation rate (bubbles per volume per time) dynamically based on local variables such as polymer-gas surface tension, temperature, and pressure.

MOLDFLOW ANALYSIS COMPARISON

PART WEIGHT ANALYSIS

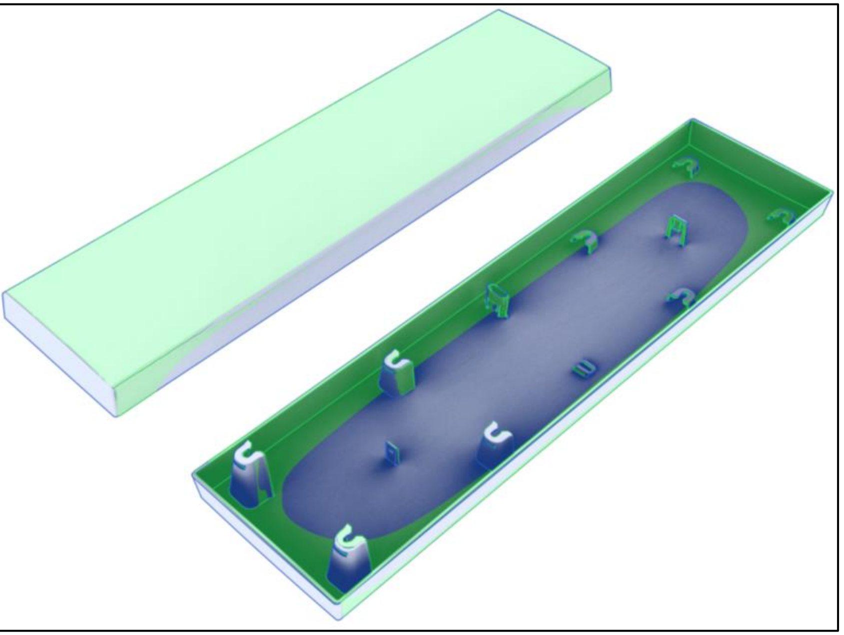
Trial #	Material	CFA LDR %	Trial Part Weight (g)	CFA Weight Reduction
9A	TPO #2	-	352	6.3%
11B		0.75%	330	

Trial #	Material	CFA LDR %	Moldflow Part Weight (g)	Weight % Error Moldflow vs Trial
9A	TPO #2	-	330	6.3%
11B		0.75%	316	4.4%



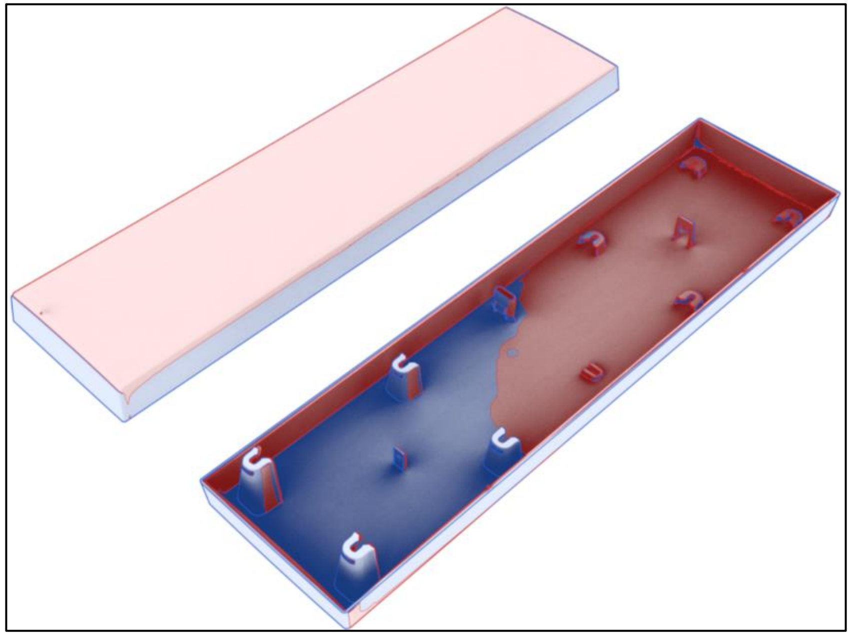
MOLDFLOW ANALYSIS COMPARISON

SHRINKAGE & WARPAGE ANALYSIS



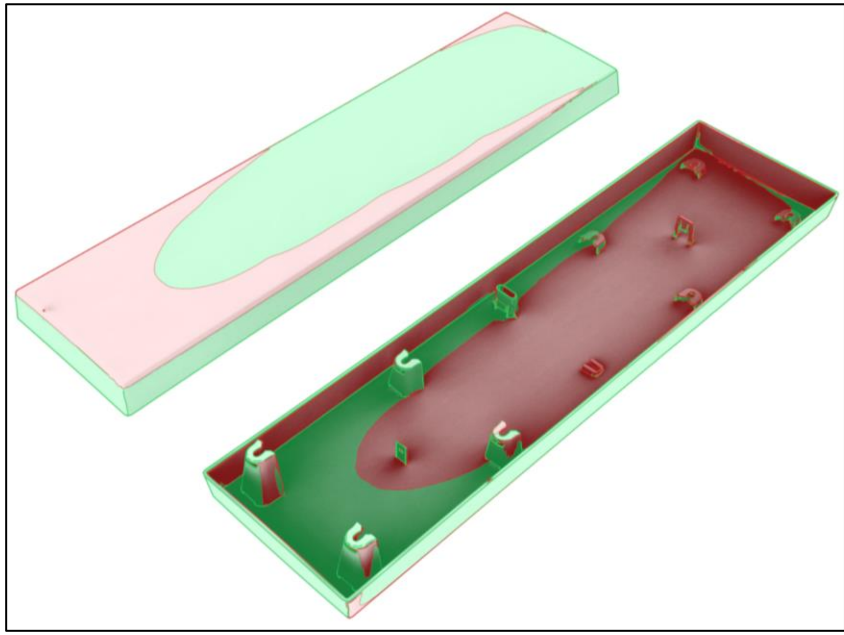
Original CAD

MoldFlow Analysis



Original CAD

3D Scan of Molded Part



MoldFlow Analysis

3D Scan of Molded Part

MOLDFLOW ANALYSIS COMPARISON

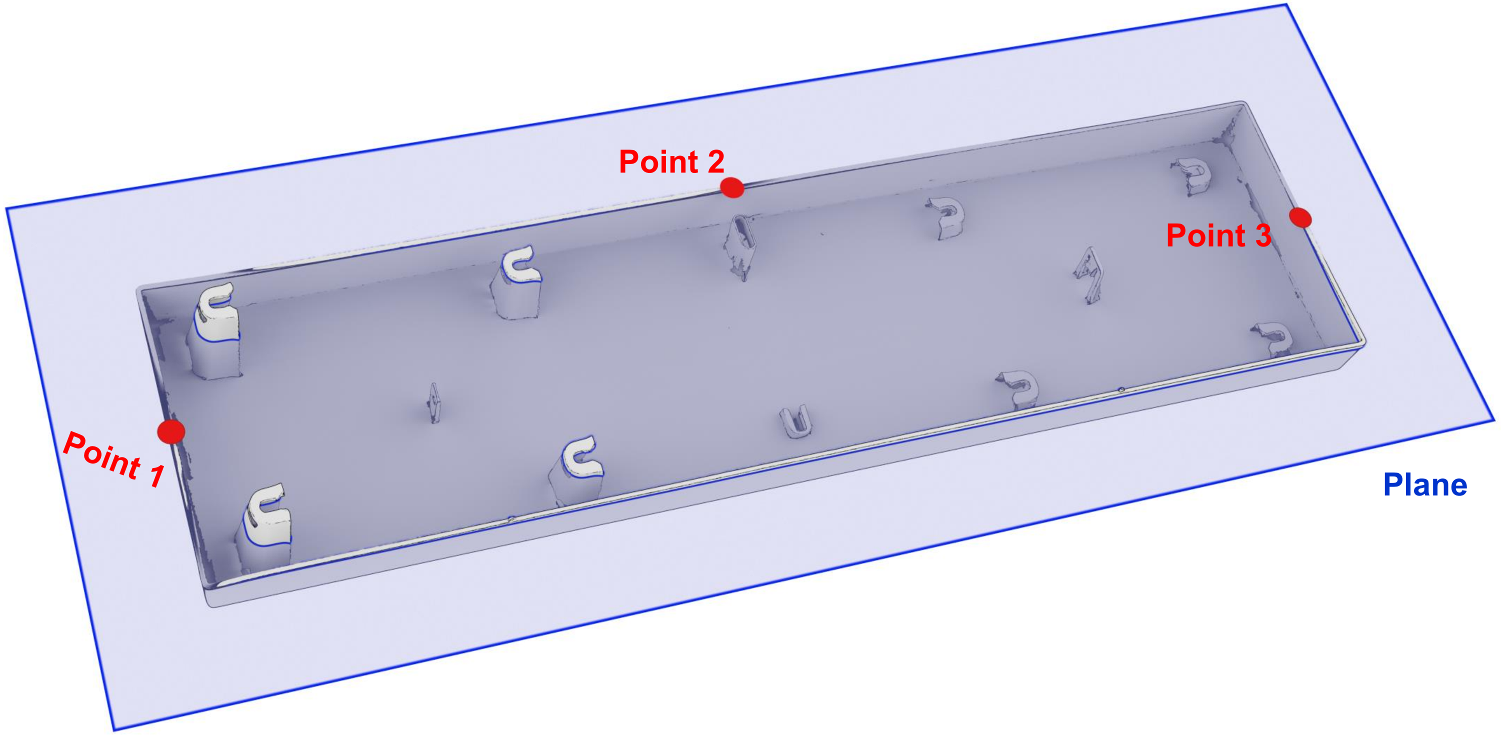
SHRINKAGE & WARPAGE ANALYSIS - METHODOLOGY

Creating 3D Scan 'Ground' Plane

- Points were chosen along 3 of the 4 sides of the part.
- A plane was created using these 3 points as reference.

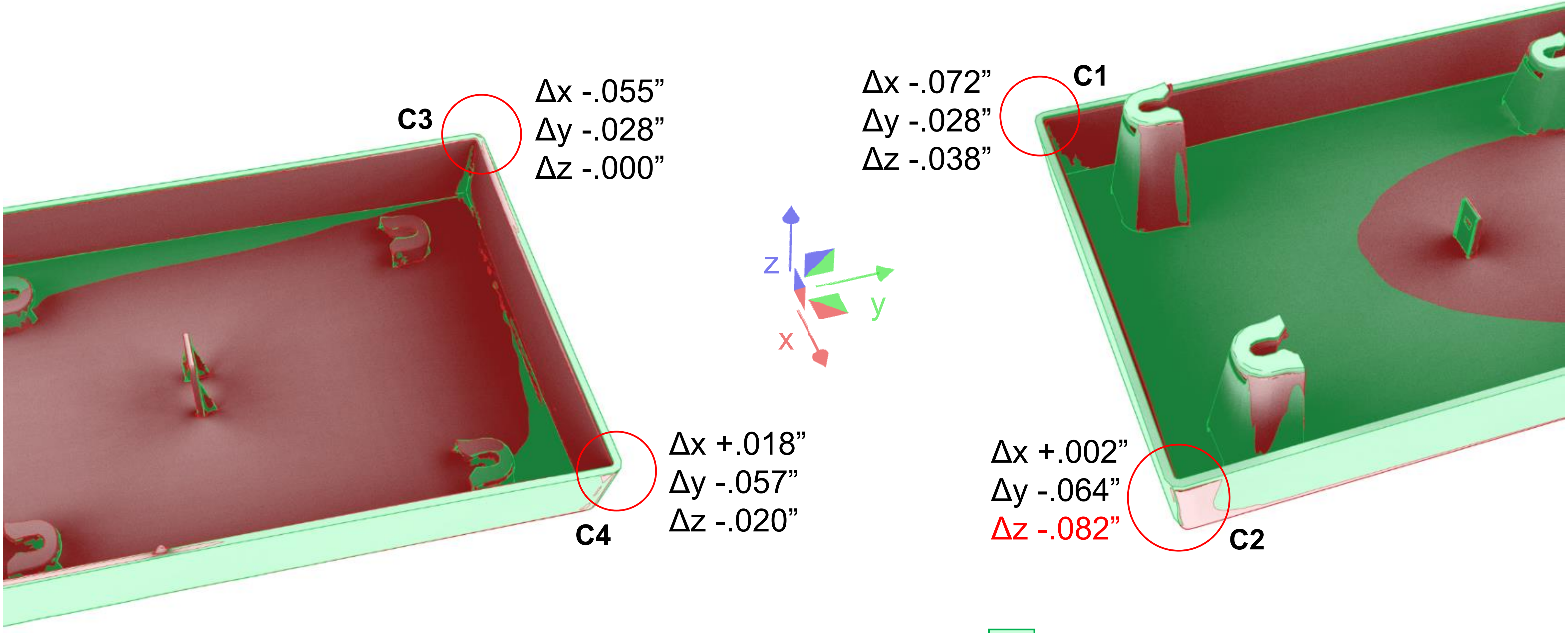
Comparing Geometries

- Using these points and this plane, and XYZ plane arrangement was created.
- XYZ planes were used to align 3D scan, Moldflow, and original CAD parts.
- Delta values were measured between parts to determine dimensional difference in CAD vs Moldflow vs 3D Scan



MOLDFLOW ANALYSIS COMPARISON

MEASUREMENT ANALYSIS – 9A (NO CFA)



MoldFlow Analysis

3D Scan of Molded Part

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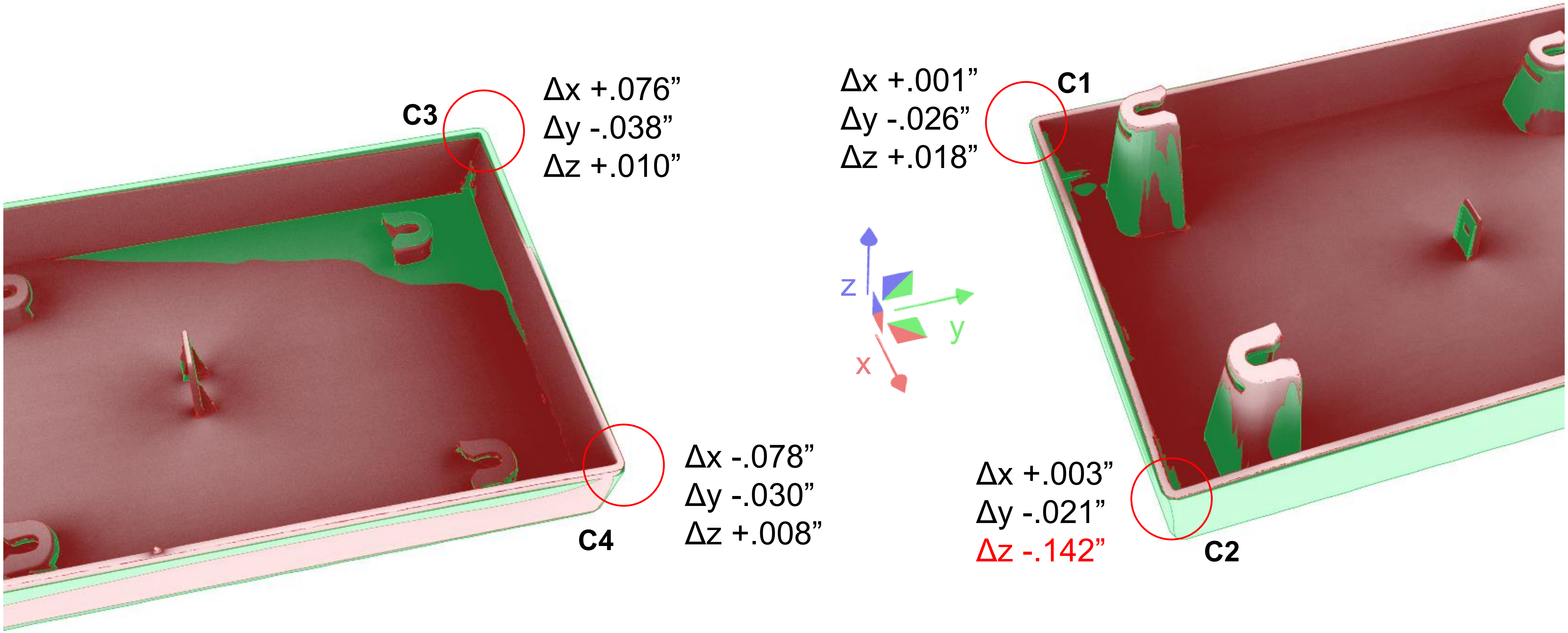
MOLDFLOW ANALYSIS COMPARISON

MEASUREMENT ANALYSIS – 11B (0.75% CFA + COUNTERPRESSURE)



MoldFlow Analysis

3D Scan of Molded Part

VARIABLES TO DIAGNOSE

Constant Nucleation Model vs Variable Nucleation Model

- Will getting the CFA + Material + Part Design characterized reduce the % error in shrinkage/warpage prediction?

Tooling

- The weight difference in the actual part vs simulated parts (without CFA) was 6.25%.
    - Moldflow was not able to achieve the actual part weight regardless of process settings.
    - Does the CAD reflect the steel tooling?
        - Wall thickness variations could be seen in molded parts from 2.6mm – 2.8mm.

Hand Mixing Masterbatch

- Did hand mixing the CFA lead to inconsistency during the 10 part molding?

SUMMARY & CONCLUSIONS

Case Study Results

- Moldflow was able to predict the 5% to 7% reduction in part weight within a 4.4% error.
- Class A surface appearance approvals are possible.
- Foaming simulation is predictable within an accuracy of 0.150” across a 24” long part.
  - Simulated Part vs Actual Part (No CFA) had a 0.082” inaccuracy when looking at shrinkage/warpage.

Advancing CFA Prediction and Correlation

- Can mechanical properties of molded articles using CFA be predicted?
- Can we optimizing 3D scanning and/or CMM measurements for warpage and shrinkage?
- Identify variable nucleation model work needed for CFA cell structure.
- Future material trials with a focus on reducing overall variables.

THANK YOU

QUESTIONS?