



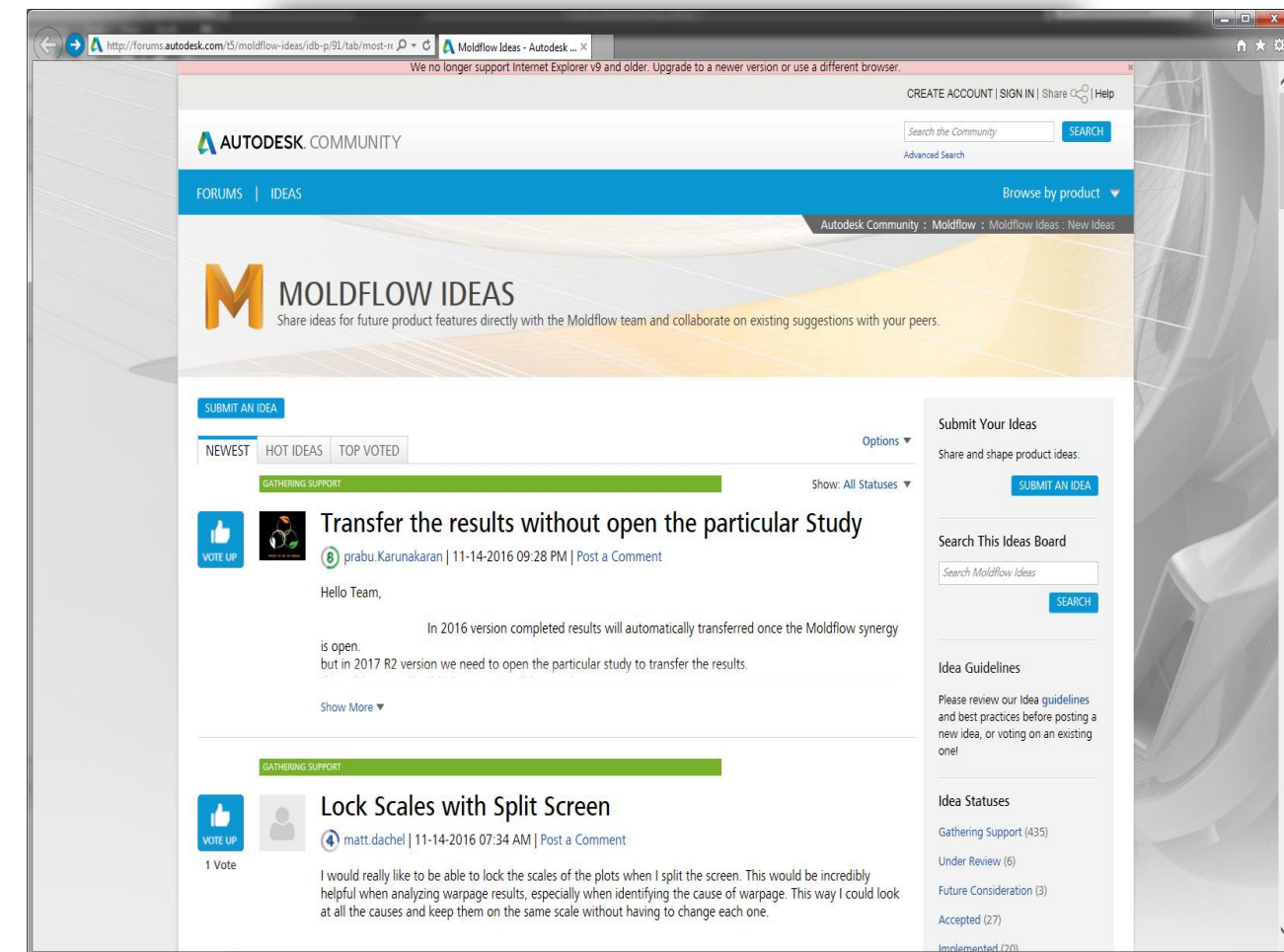
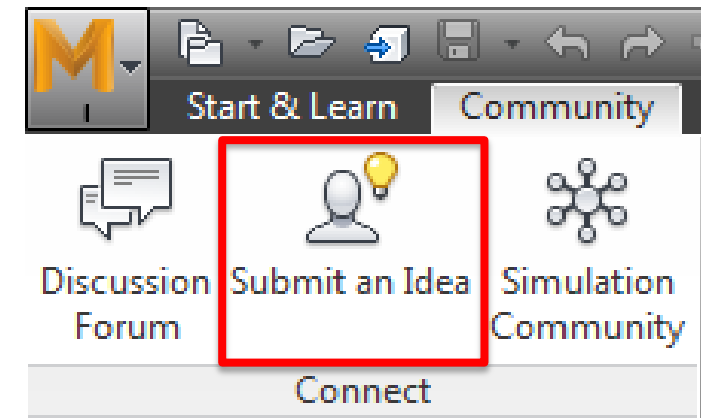
Moldflow Simulation Validation Case Study

Curt Randall – GE Appliances, a Haier company

Jeff Higgins – Autodesk, Inc.

Shape the future of Autodesk

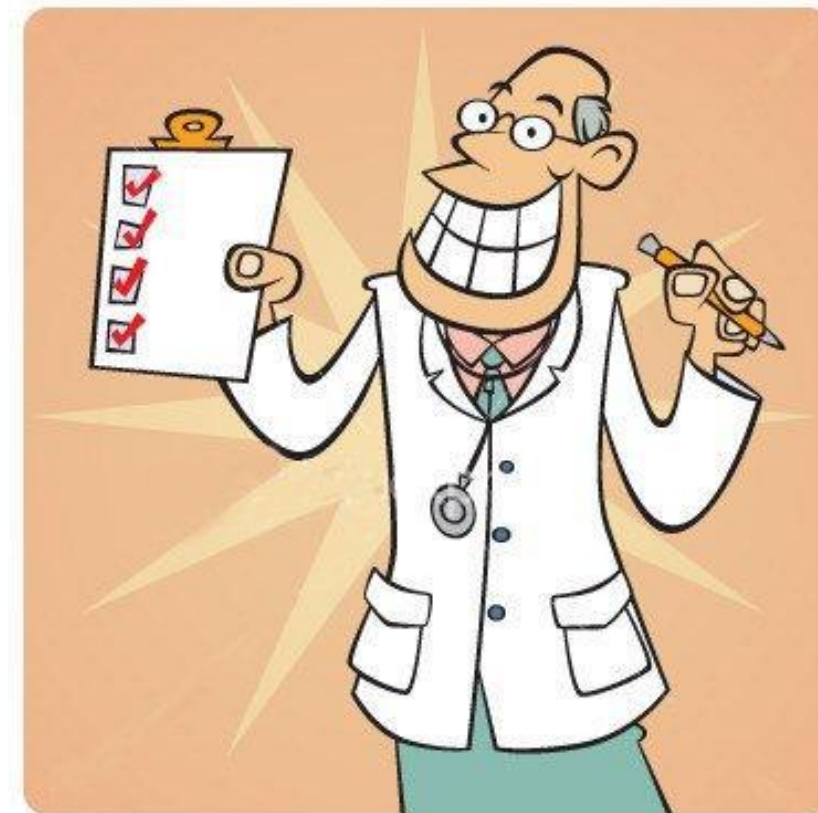
- Connect one-on-one with product managers, designers, and researchers at the **Idea Exchange**.
- Earn **Amazon gift cards** and enter our **GoPro 4 Sweepstakes**.
- **Open daily** – Sessions average 20 minutes. No appointment necessary. Walk-ins welcome!
- Located outside **Hall C, Level 2**.
- Don't Forget "Submit an Idea"



Simulation Validation

- Validate (Definition from the Oxford Dictionary)

“Check or prove the validity or accuracy of ... (something)”



The Million Dollar Question

- How accurate is that Moldflow simulation?
- As analysts we have all been asked this question at one time or another.



The 5¢ Answer

IT DEPENDS.

- This is the typical answer given to this question.
- The truth is that it does depend on a many items.



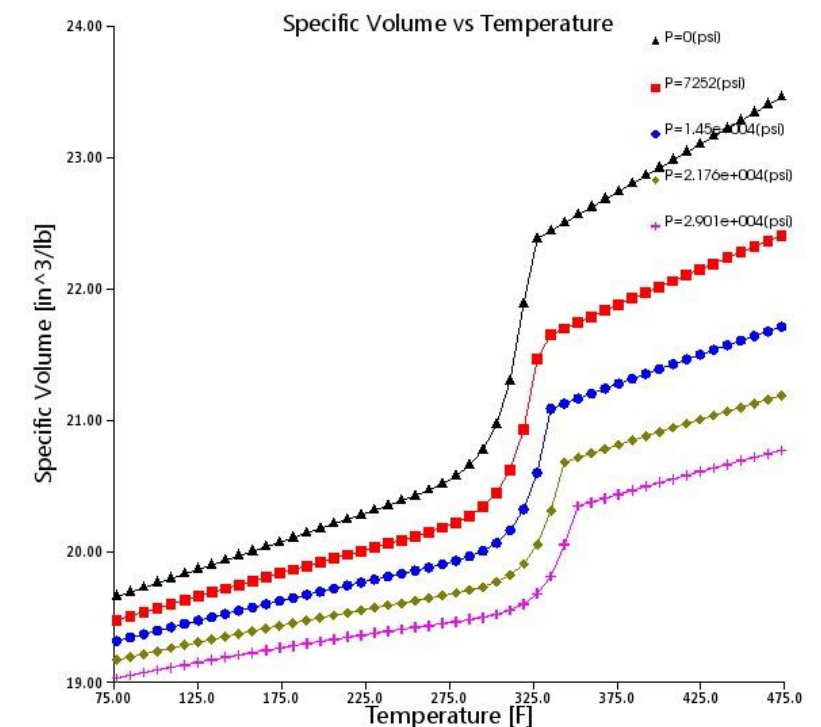
Key learning objectives

At the end of this class, you will understand:

- The importance of material characterization in simulation
- Utilization of cavity pressure sensors for simulation validation
- The use 3D scanning technology to validate part deflections
- The importance of process conditions and simulation setup
- How simulation predictions compare with a real life case study

Material Characterization

- The accuracy of the results depends on the quality of the material characterization.
- Material Quality Indicators
 - Filling
 - Packing
 - Warpage
- Three Levels



Material Quality Rating

	Gold	Silver	Bronze	Unknown
Fill Quality				
Packing Quality				
Warpage Quality				

- Gold Rating
 - High confidence in quality material data
- Silver Rating
 - Combination of well tested and supplemental material data
- Bronze Rating
 - Incomplete data sets and extensive use of supplemental data

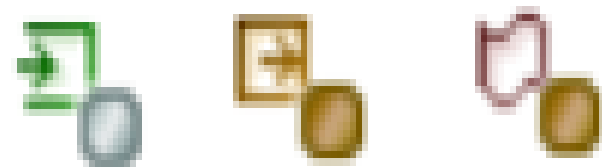
>>EXPERT TIP<<

- Use gold Level material data for accurate results
- Spend the money to get your material characterized
 - Contact Autodesk Moldflow Plastics Labs
mplmoldflow@autodesk.com



Test Your Knowledge!

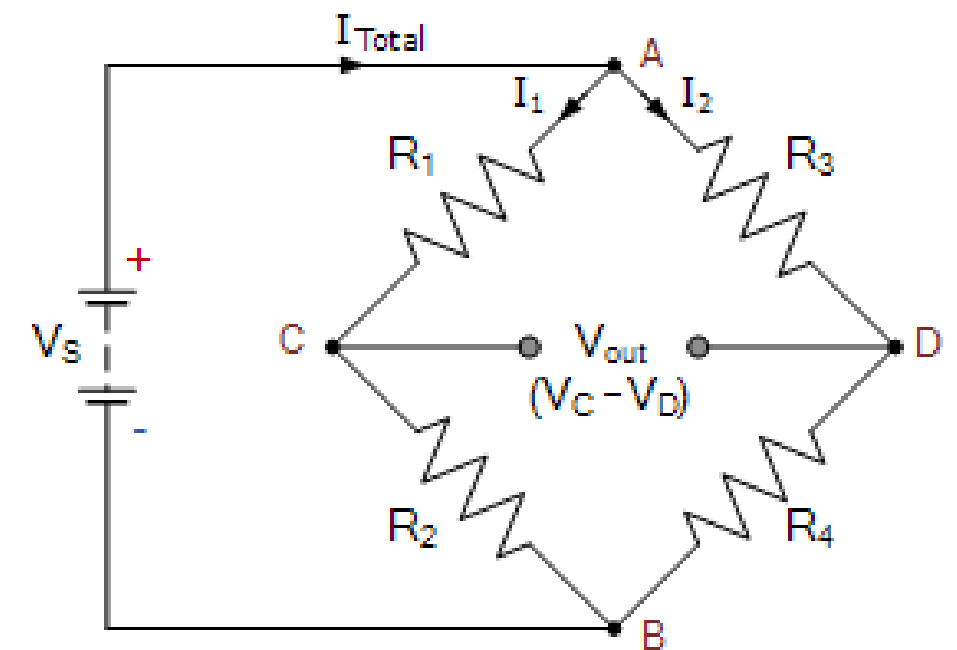
- Can a material in the database have silver level filling data, gold level packing data, and gold level warpage data?



No. The packing quality indicator cannot exceed the filling quality indicator.

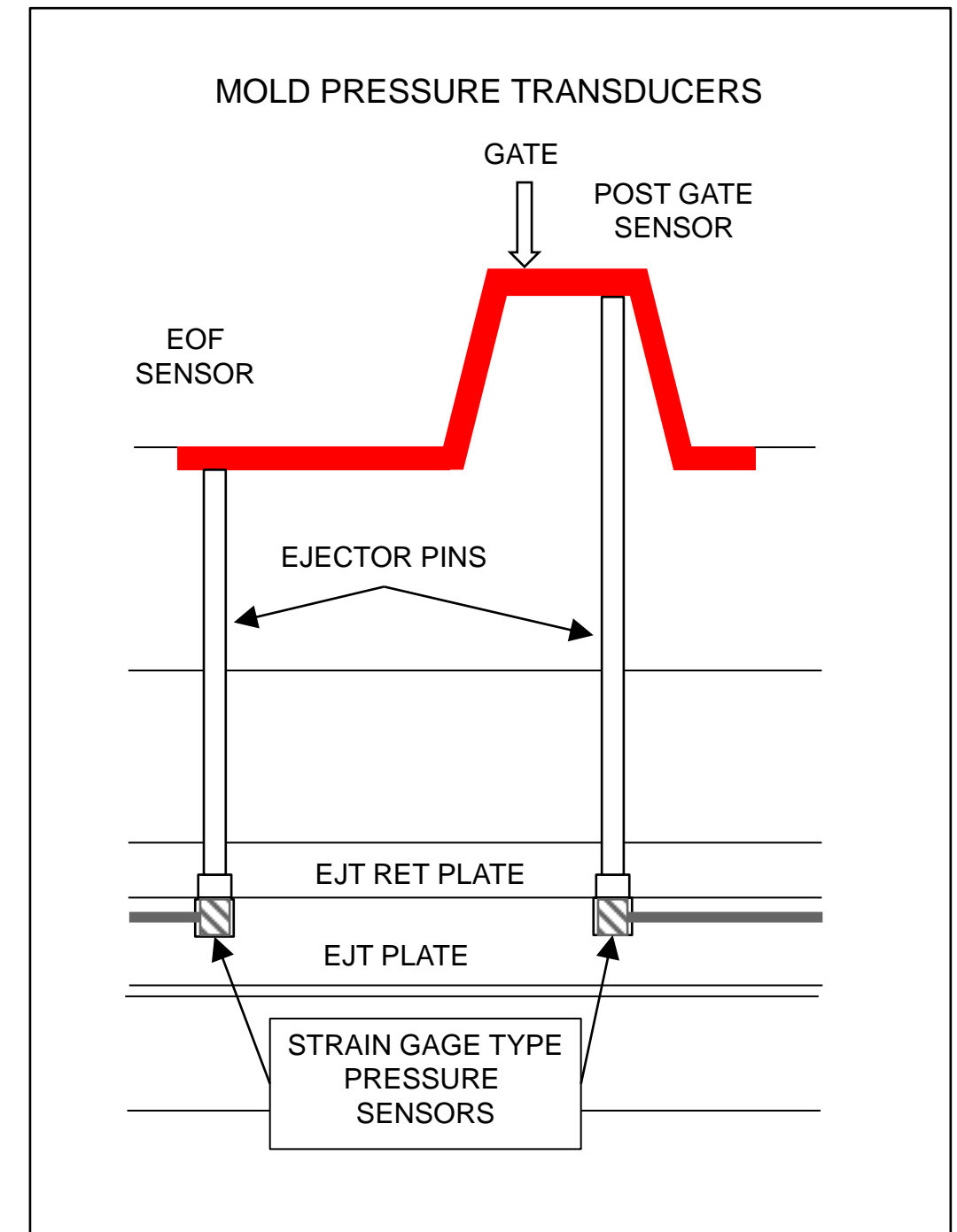
Using Cavity Pressure Sensors

- Process Control (V/P transfer)
- Process Monitoring (Mtl variation, short shots)
- Process Setup Transfer (Machine to Machine)
- Traceability / Genealogy
- Quality Control
 - Cavity Rejects/Containment
 - Sorting
- Pressure Validation

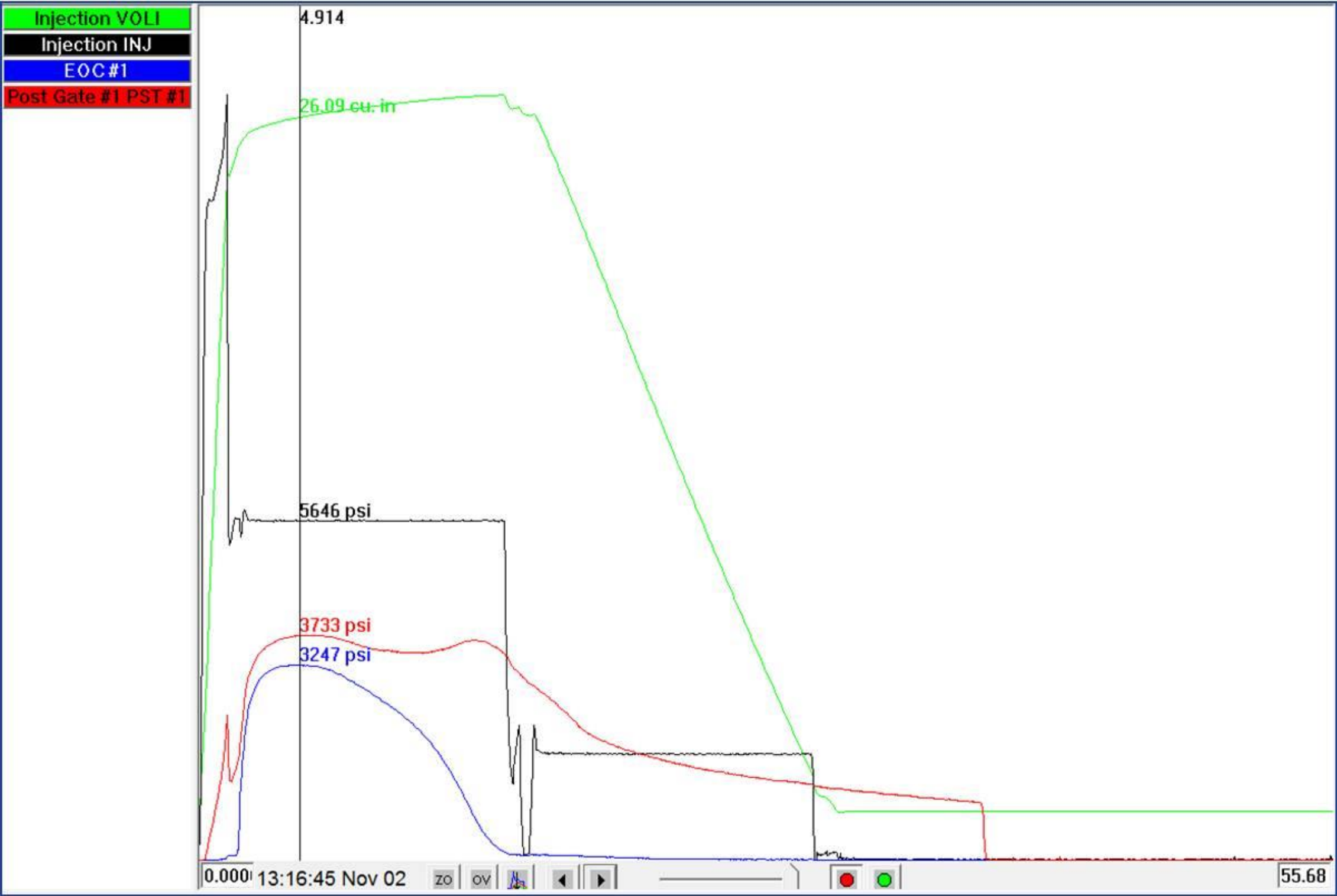


Pressure Sensor Locations

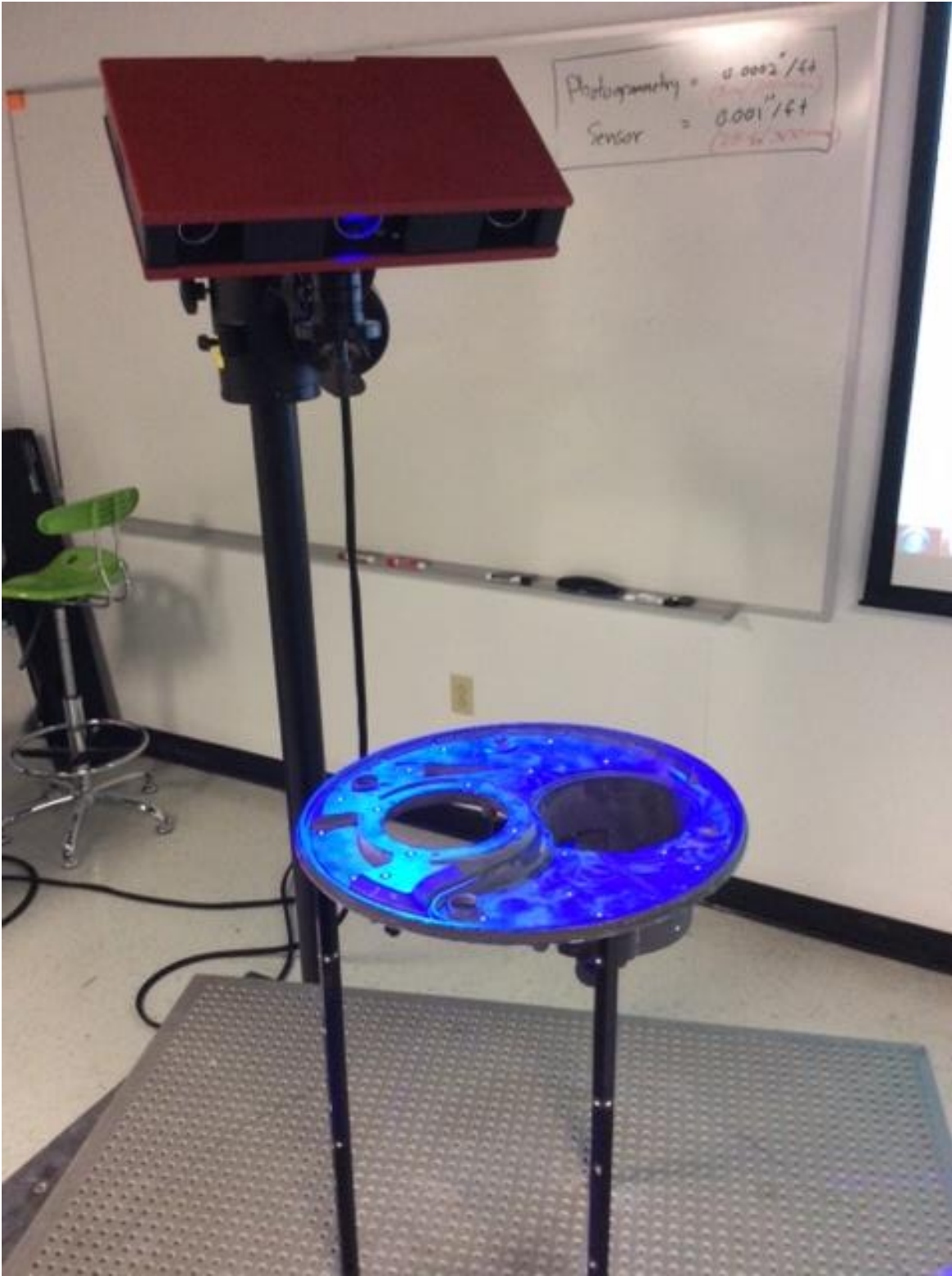
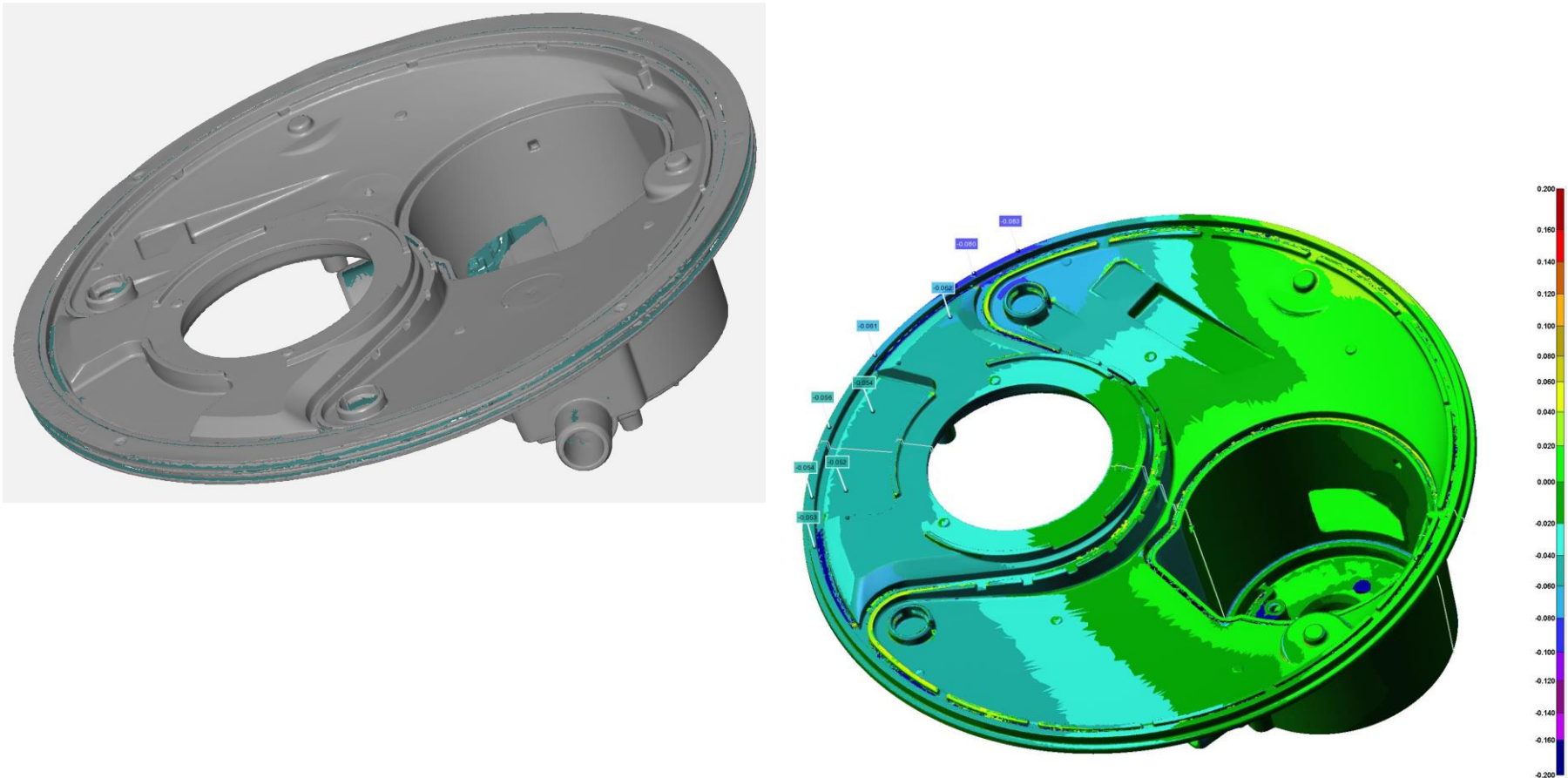
- Post Gate Sensor (PG)
 - As close to the gate as possible
- End of Fill Sensor (EOF)
 - As close to end of fill as possible



Pressure Trace



3D Part Laser Scanning



Scanning Setup

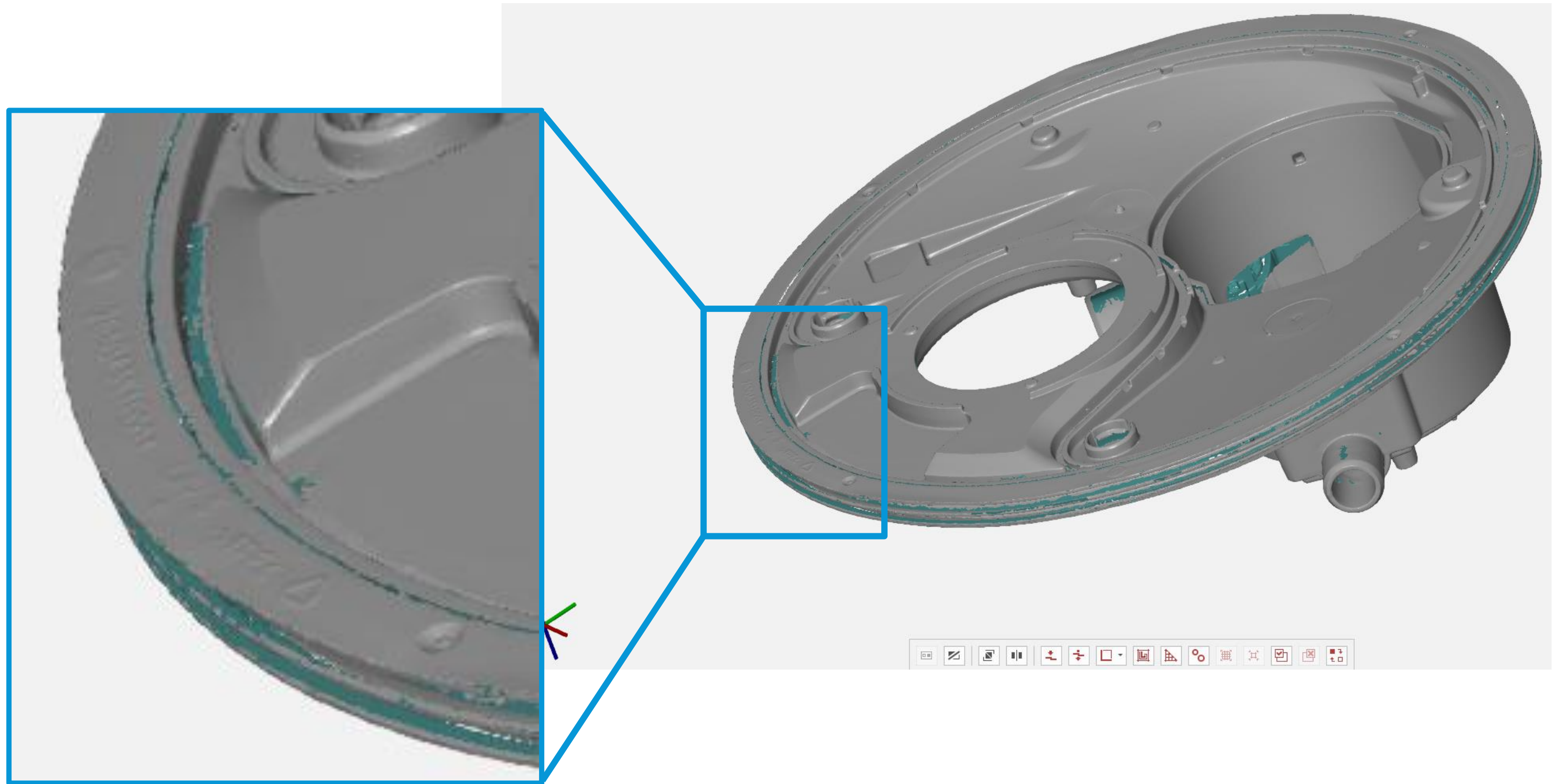


Targets applied to part



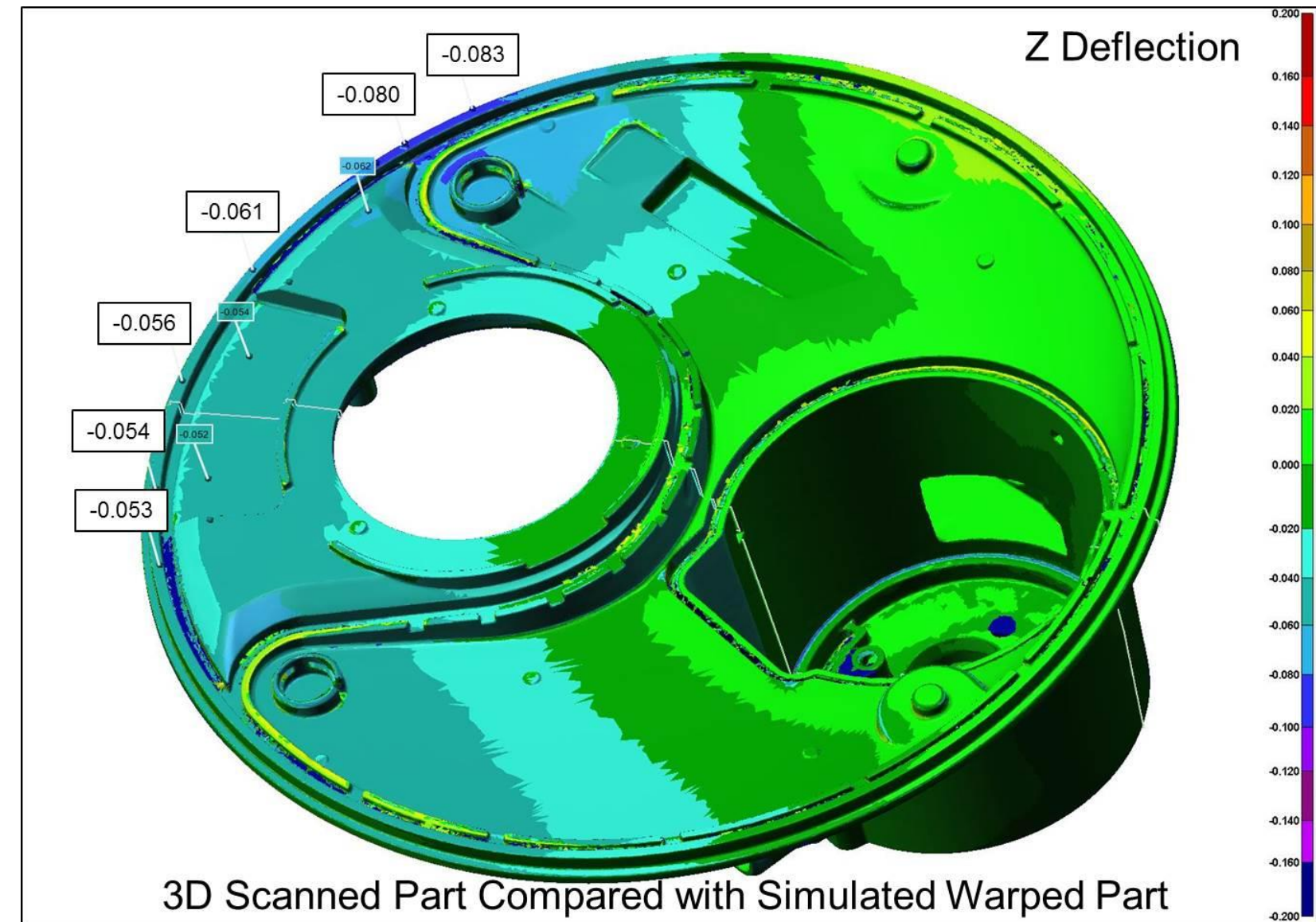
Blue Light Laser Scanning
Simple Fixture part in free state

3D Scanned Part

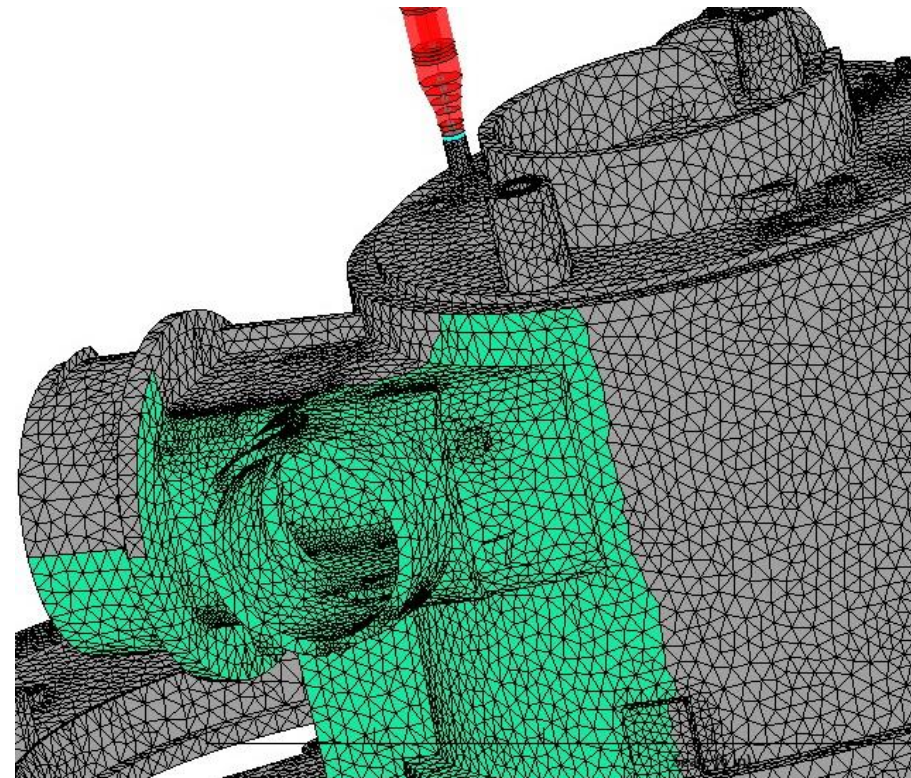
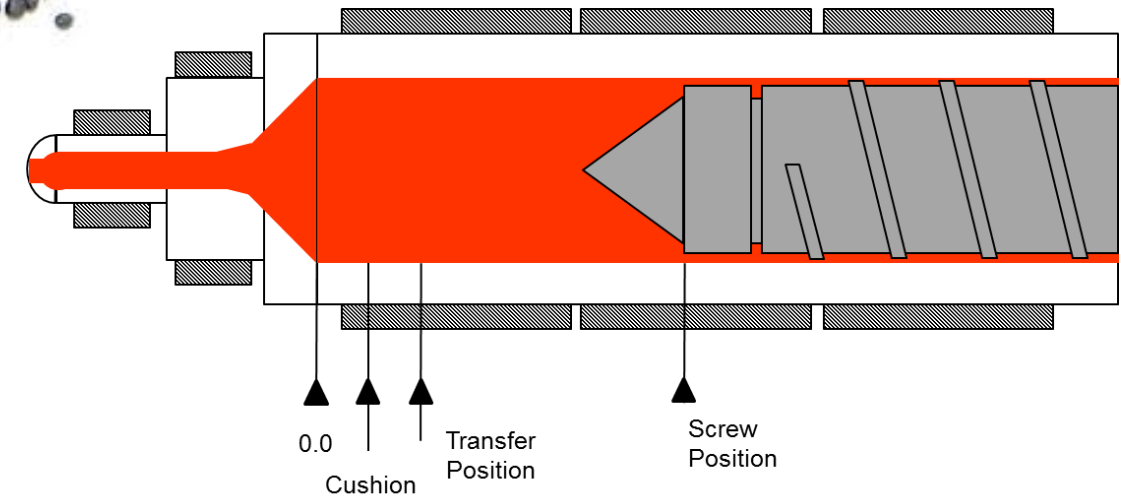


Part Deviation Analysis

- Data is compared to show deviations
 - Scanned part to CAD
 - Simulated warped part CAD to scanned part
- Allows use of custom anchor planes
- Uses GDT with custom reports from analysis

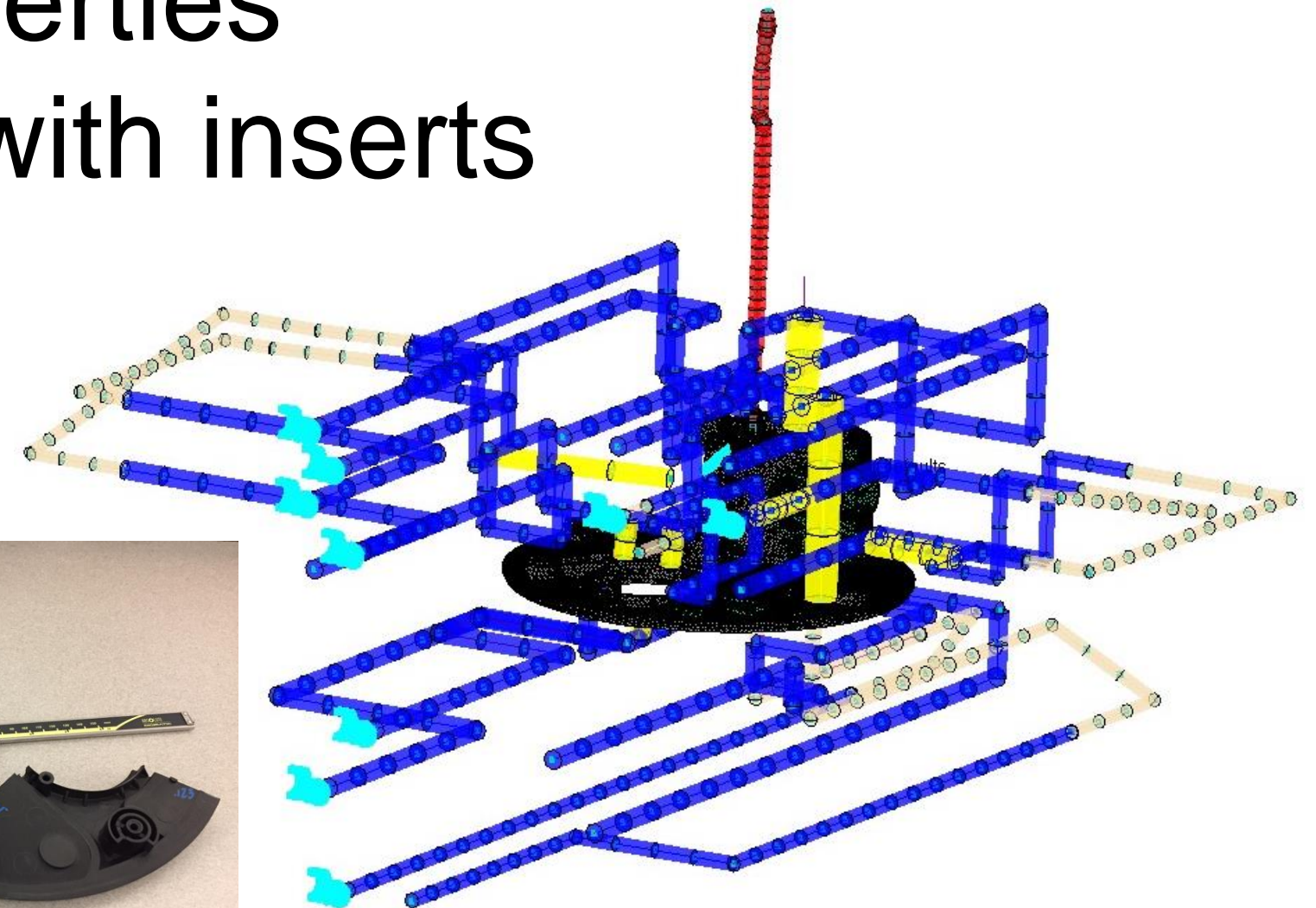


Process Conditions & Simulation Setup



Part/Mold Modeling & Mesh

- Use Theory & Concepts – Model Requirements
- Apply mold material properties
- Cooling Lines and mold with inserts
- Machine nozzle
- Accurate wall thickness
- Expanded Data



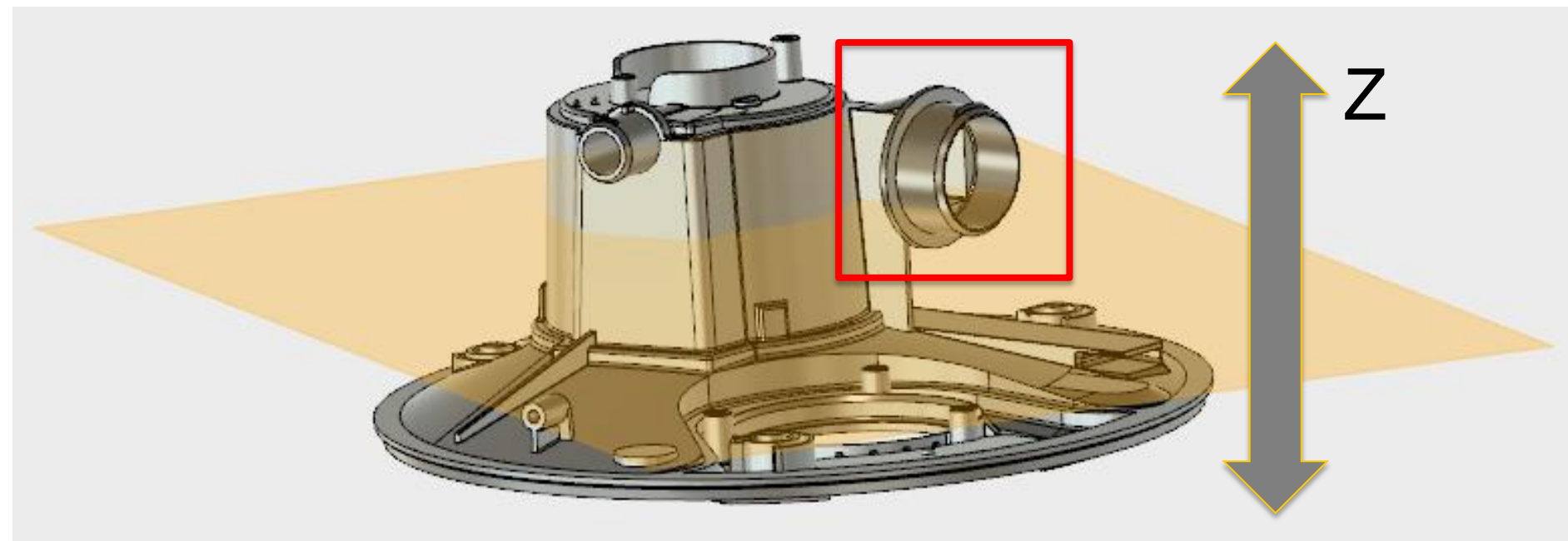
To Expand or not to Expand?

- That is the real question.
- Use expanded data for simulation validation.
 - Matches meshed mold and inserts
 - Matches cooling line geometry



Test Your Knowledge!

- How does the software calculate the projected area of a part mesh?



Sum of all surface areas projected onto X-Y plane

>>EXPERT TIP<<

- Use the “exclude from clamp force calculation” option in element properties
- This is especially true is you are conduction clamp force simulation validation



Process Conditions

- Machine settings
 - Fill & transfer
 - Pack/hold
 - Cooling
 - Mold open/close time
 - Part removal time
- Mold/melt temperature

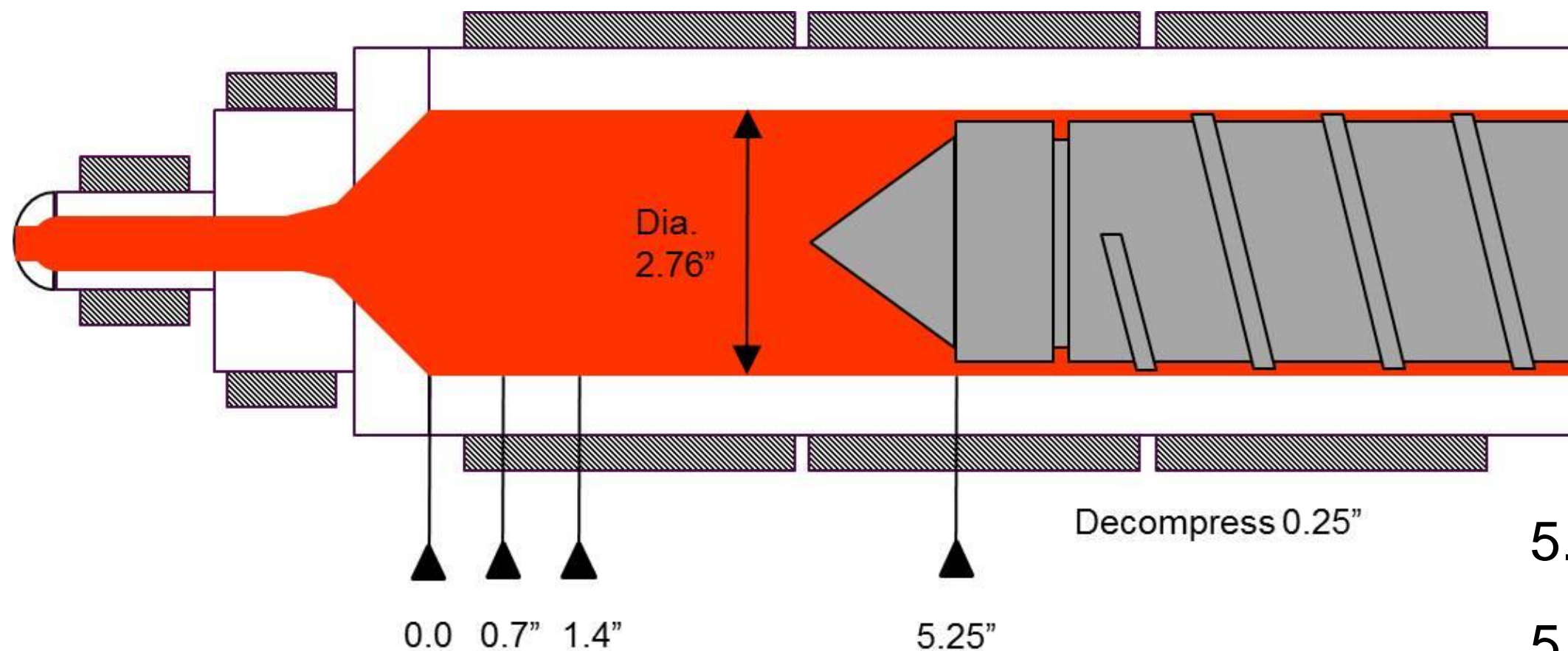
PRESS #: 510																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
PRESS #:		5-10		MOLD # :		Liner										PART REMOVAL:		Robot																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
TONNAGE:		2300		CAVITIES (#):		1												RJG TEMPLATE:		Yes																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
MATERIAL:		ABS Cheil HG-0760GP (WHITE)						MTL STK#:		STK44674		SILO #:		3		RUN MODE:		Auto																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
COLORANT:		N/A						COLOR STK #:		N/A		BOX #:		N/A		LDR %:		N/A																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
Clamp Close					Mold Protect					Injection					Process Data																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
Velocity					3		2		1		Vel					3		2		1		Cycle Time (s)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
					N/A		N/A		29.00		in/s					2.00		in/s		N/A		N/A		2.95		in/s		75.40																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
Pos					N/A		N/A		40.000		in					Pres					800		psi		N/A		N/A		18000		psi		Inj Fill Time (s)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
									Start MP		Pos					3.00		s		N/A		N/A		18000		psi																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
											Mold Touch					34.630		in		N/A		N/A		2.100		in		Cushion (in)		0.537																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
																								3.50		s		Transfer Pos (in)		2.000																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
Clamp Open					3		2		1		Mold Height					Pack / Hold					Stages		1						Recovery Time (s)		13.5																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
Velocity					N/A		25.00		1.50		in/s					Vel					3		2		1						Inj Peak Press (psi)		10951																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
Position					N/A		74.500		42.100		in					Prs					N/A		N/A		6200		psi				Mold Open Time (s)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
Open Dwell Time							0.0		s		Ejt Back Position					Time					N/A		N/A		12.00		s																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
Tonnage Setting							2000		tons																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		



Test Your Knowledge!



- What is the shot size of the following machine setup?



$$5.25 - .25 - .7 = \text{Shot Size} = 4.3"$$

$$5.25 - .25 - 1.4 = \text{Fill Stroke} = 3.6"$$

>>EXPERT TIP<<

- Use absolute ram speed profile and transfer position for accurate results
- Do not be tempted to use a fill time and 98% volume switch-over
- The actual switch-over may be only 87%

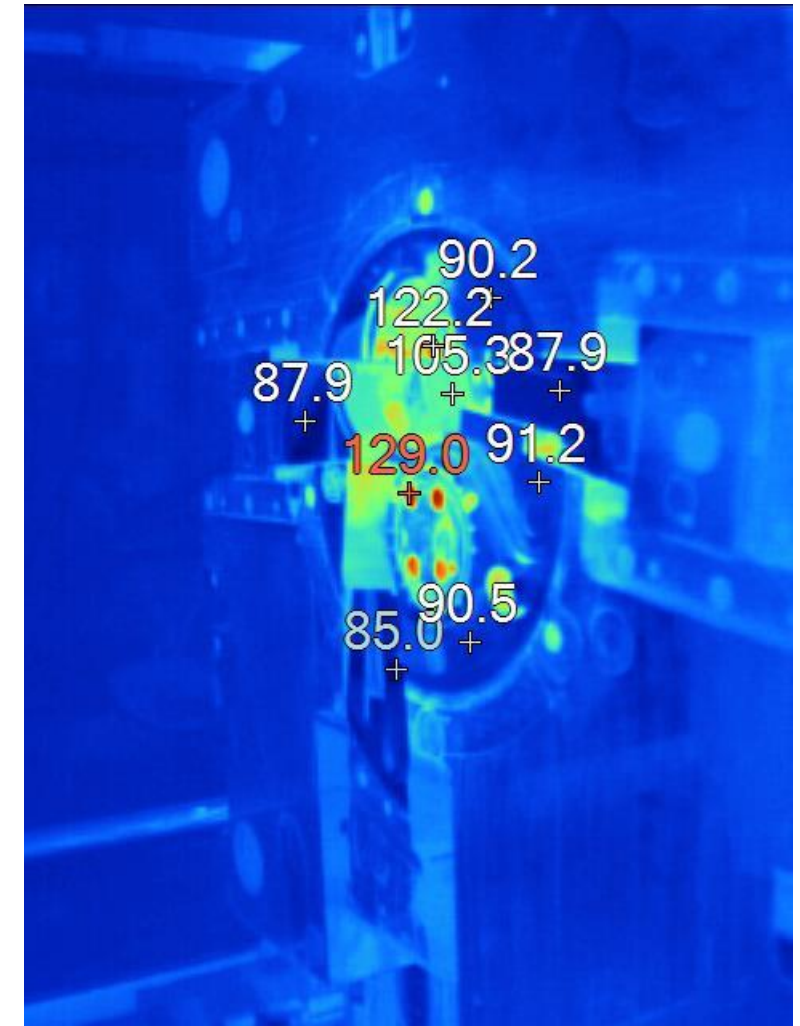


Decoupled MoldingSM DII (RJG, Inc.)

- Establish fill only part
 - Fill as fast as the machine, mold and part quality will allow without being pressure limited
 - 95-98% Full
- Transfer to pressure control to finish filling and complete packing
 - Packing pressure 50-80% of max fill pressure

Melt/Mold Temperature

- Obtaining accurate melt and mold temperature readings can be a difficult task.
- Handheld pyrometers
 - Use for melt temperature
- Thermal imaging cameras
 - Use for Mold/Part Temperature
- In mold thermocouples



Custom Injection Molding Machine Database

- Required for simulation validation
- Specific machine information is needed

Injection stroke

Injection rate

Screw diameter

of RPM speed steps

of pressure steps

Maximum injection pressure

Intensification ratio

Hydraulic response time

Maximum clamp force



Simulation Validation Case Study

Part: Appliance Part

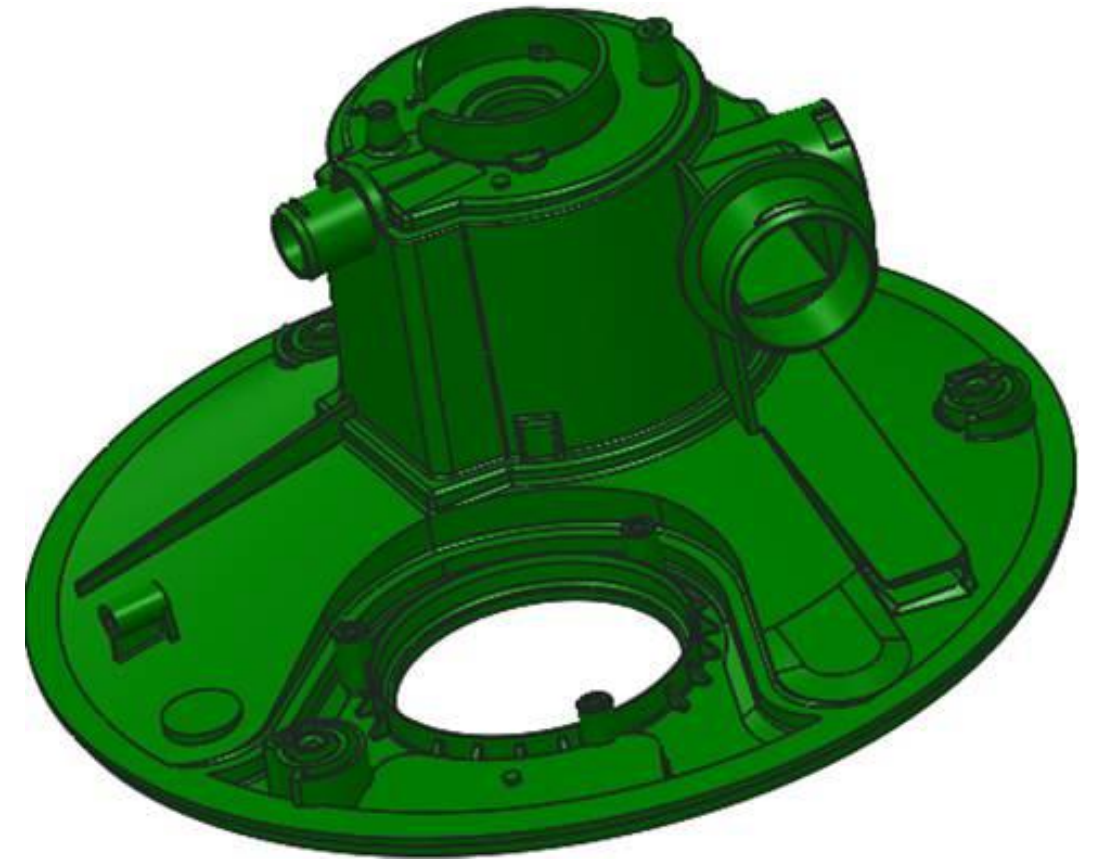
Material: Filled PP (Gold Data)

Gate: Valve Gate

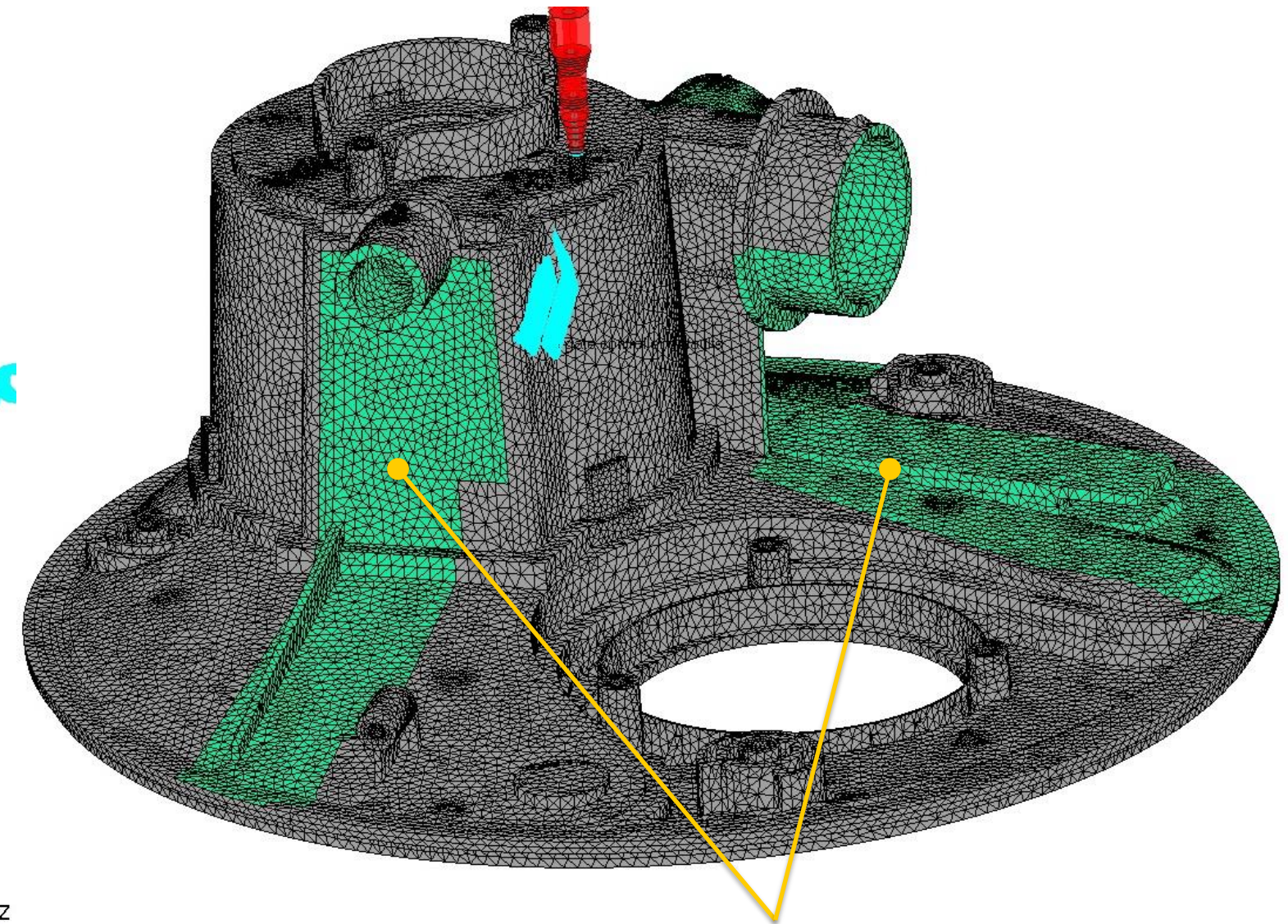
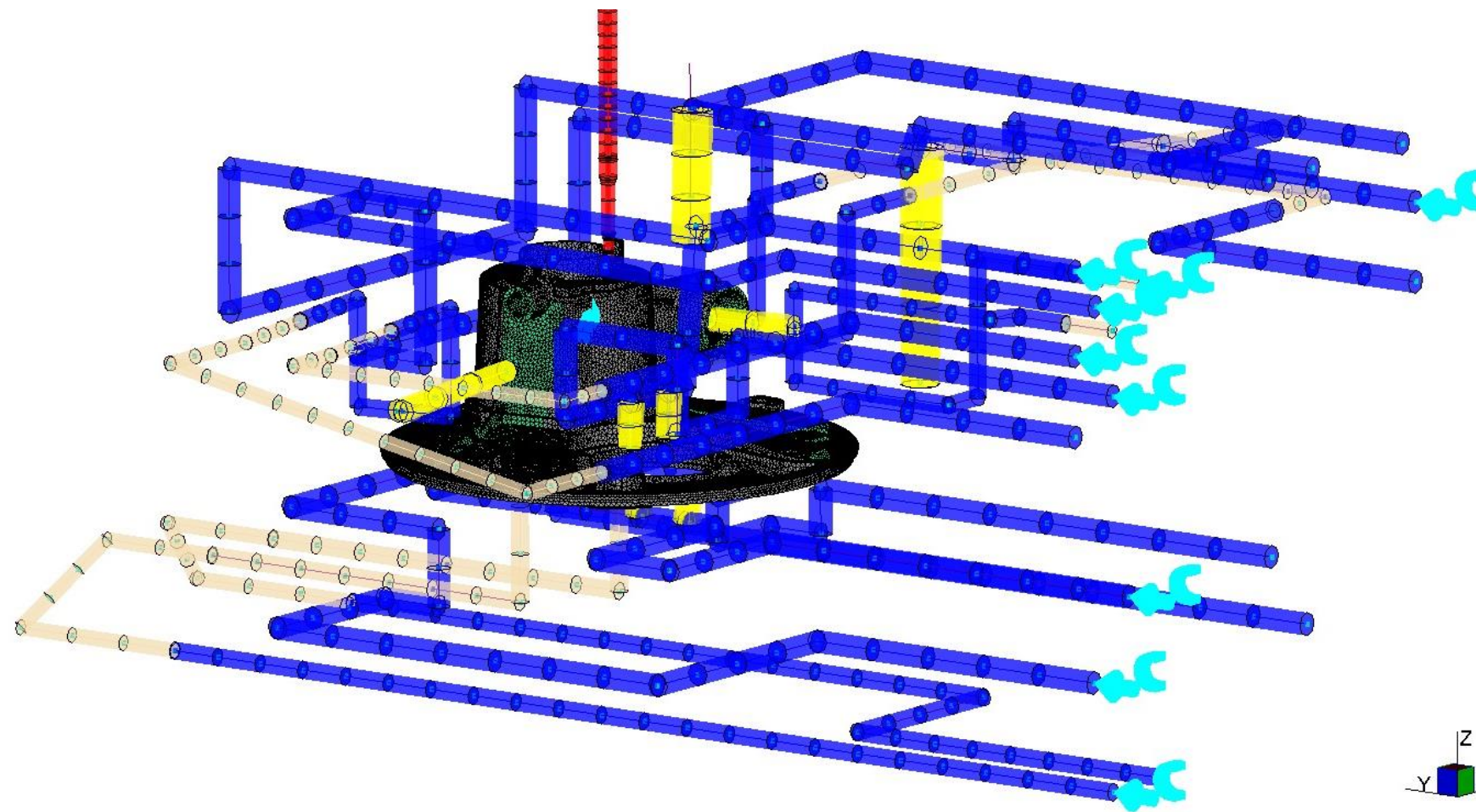
Analysis Type: Dual Domain & 3D mesh

Analysis Sequence: Fill, Cool, Fill, Pack, Warp

Mold Shrinkage: Cut to .012in/in

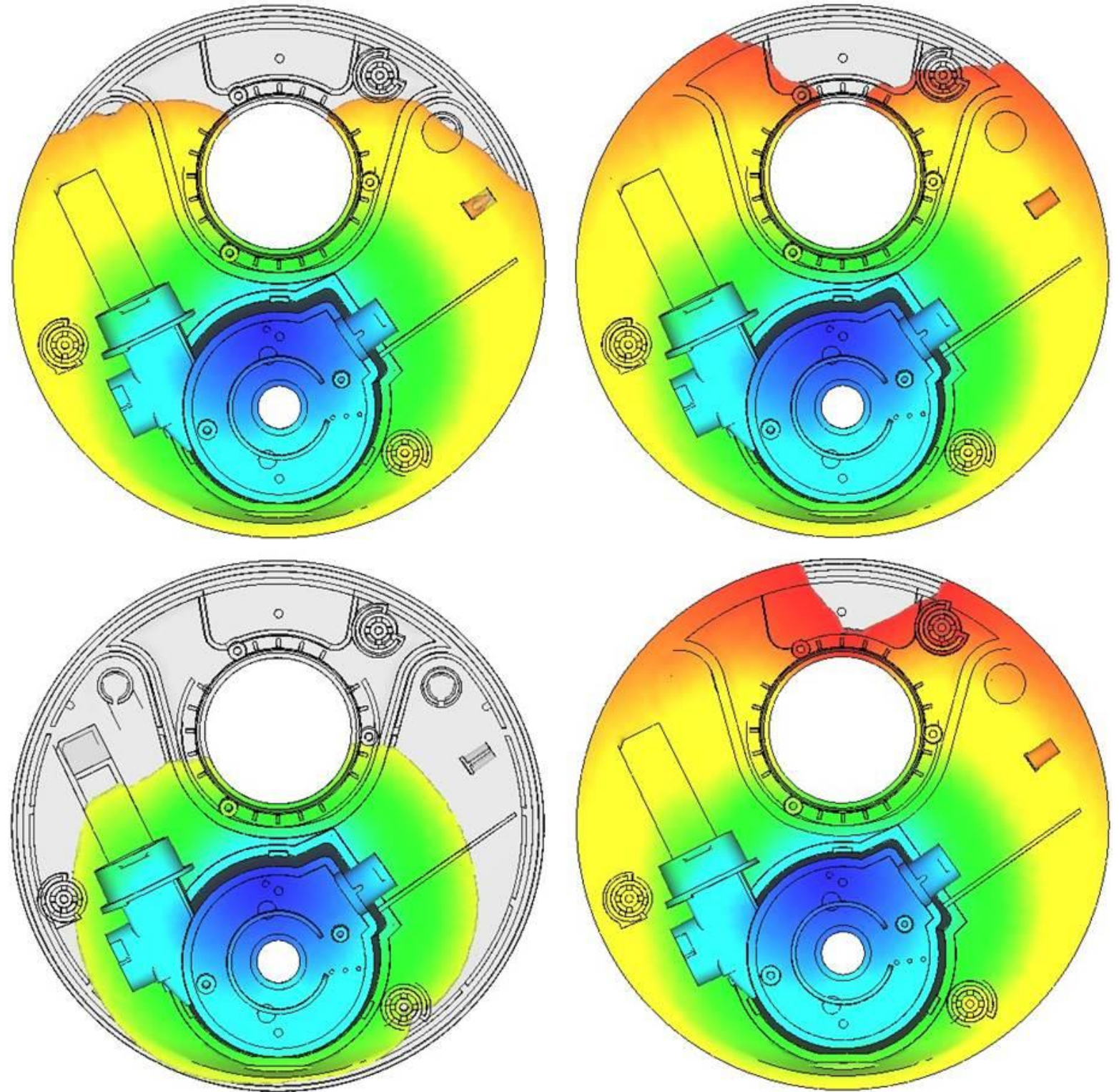


Model with Inserts and Cooling Lines

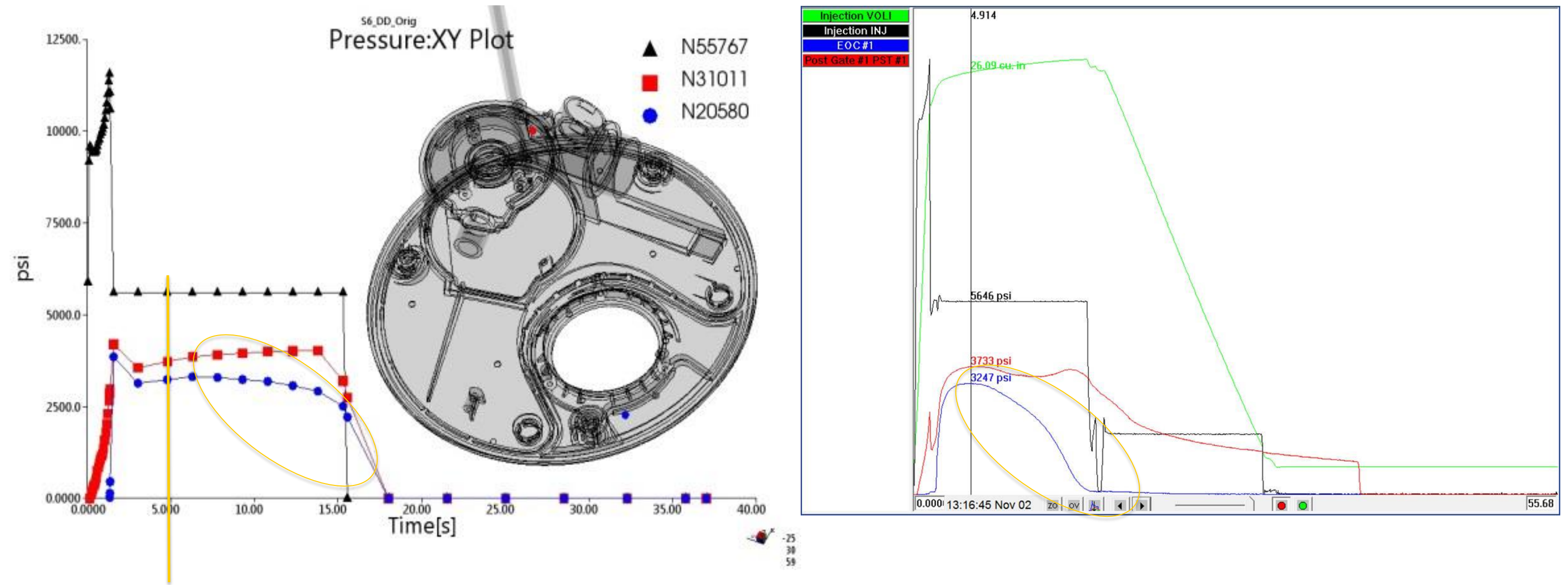


Assigned Moldmax Material
(part elements & water lines)

Short Shot Sequence



Pressure Trace vs. Simulation (Continued)



Pressure Trace vs. Simulation (Continued)

PLASTIC PRESSURE VALIDATION

	Actual	DD	DD w/ Nozzle*	3D
Nozzle (psi)	12,480	9,786	11,562*	10,067
Post Gate (psi)	3,733	3,757	3,757	4,002
End of Fill (psi)	3,247	3,246	3,246	3,710

5600 psi packing/hold pressure

Actual pressures from in cavity pressure sensors

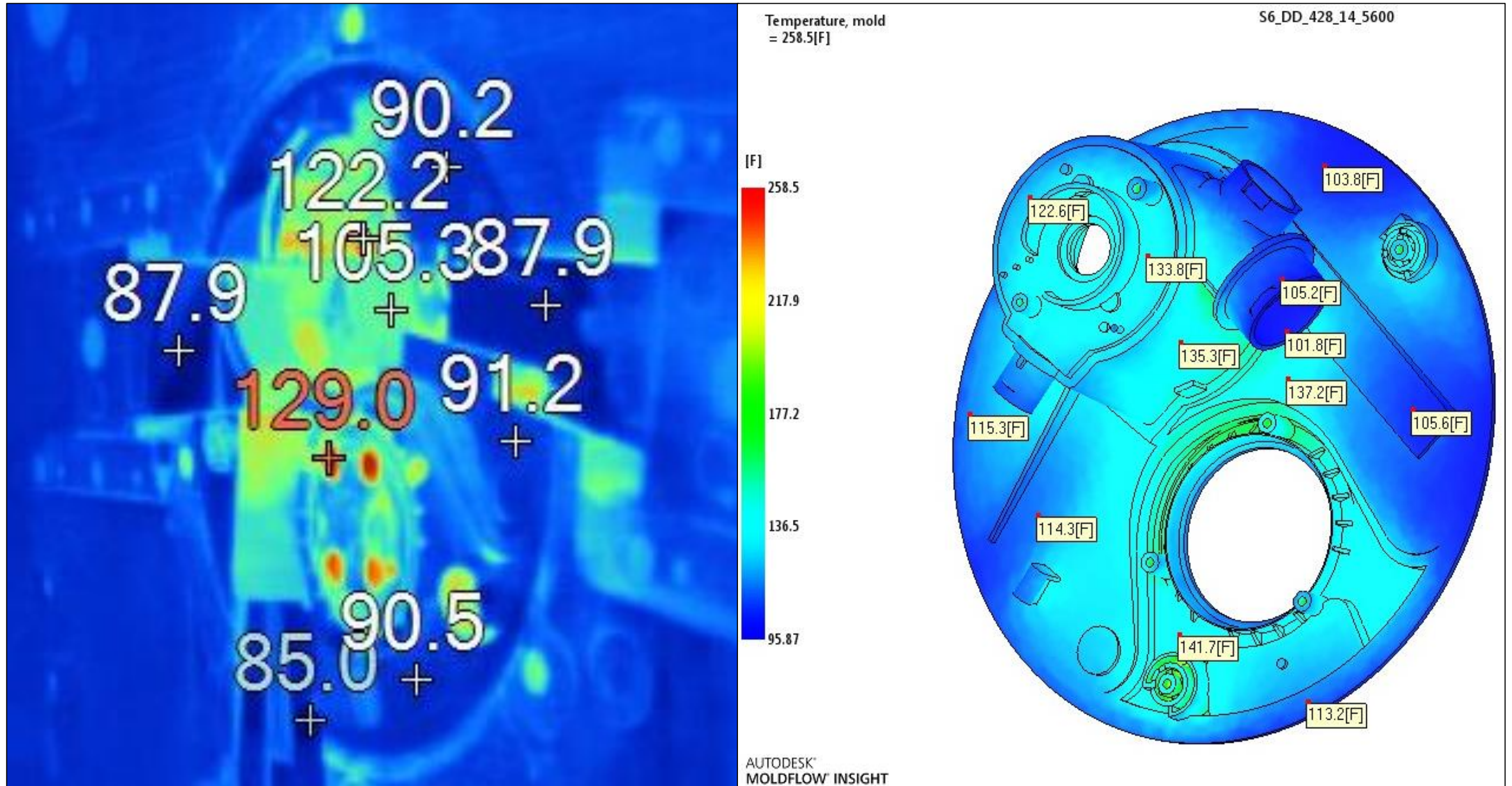
*Machine nozzle pressure loss = 1,776 psi

Part Shrinkage vs Simulation

	Actual	DD	3D
Dia (in)	11.2606	11.25	11.29
Shrinkage (%)	1.05%	1.21%	0.81%

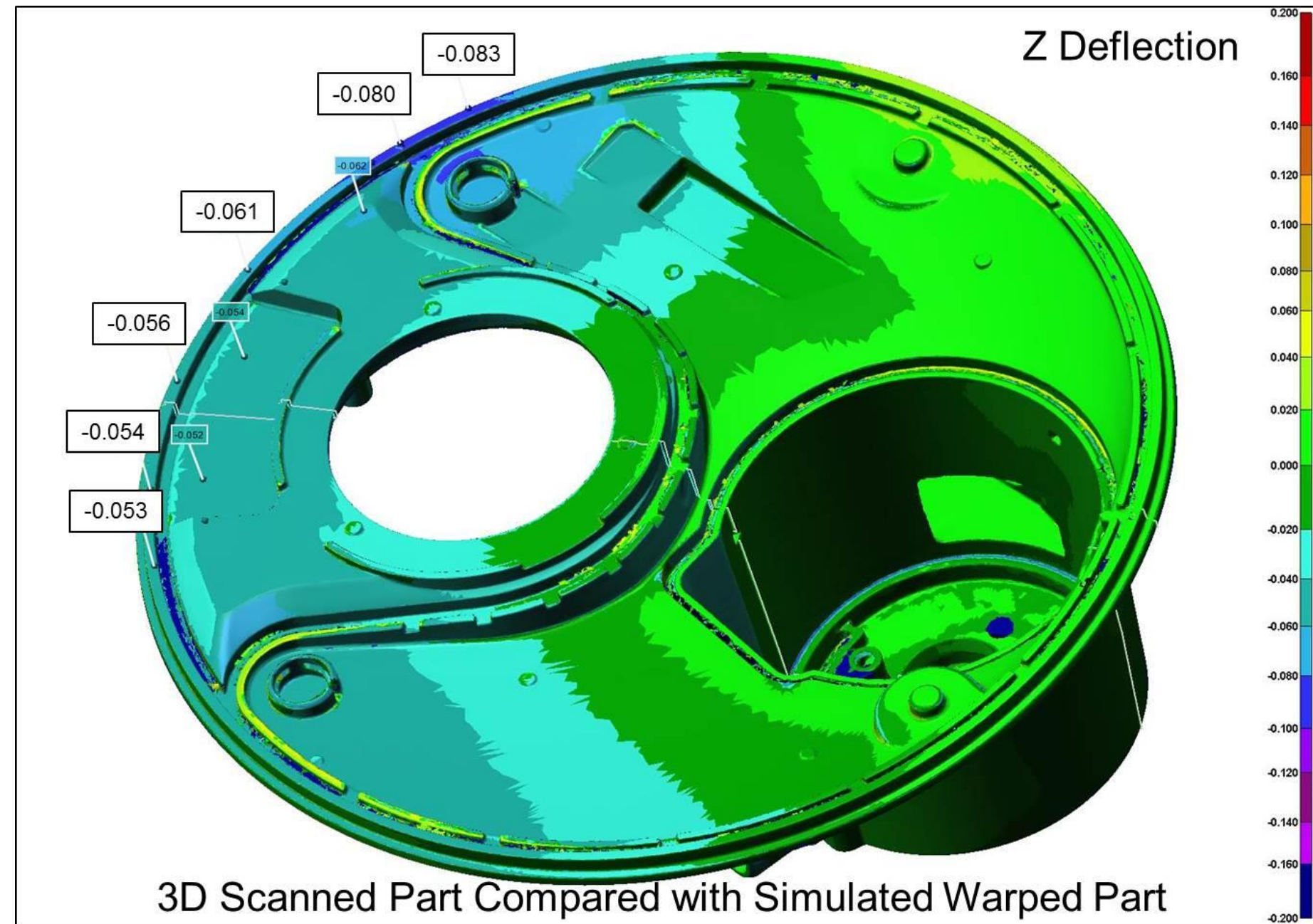


Mold Temperature vs Simulation

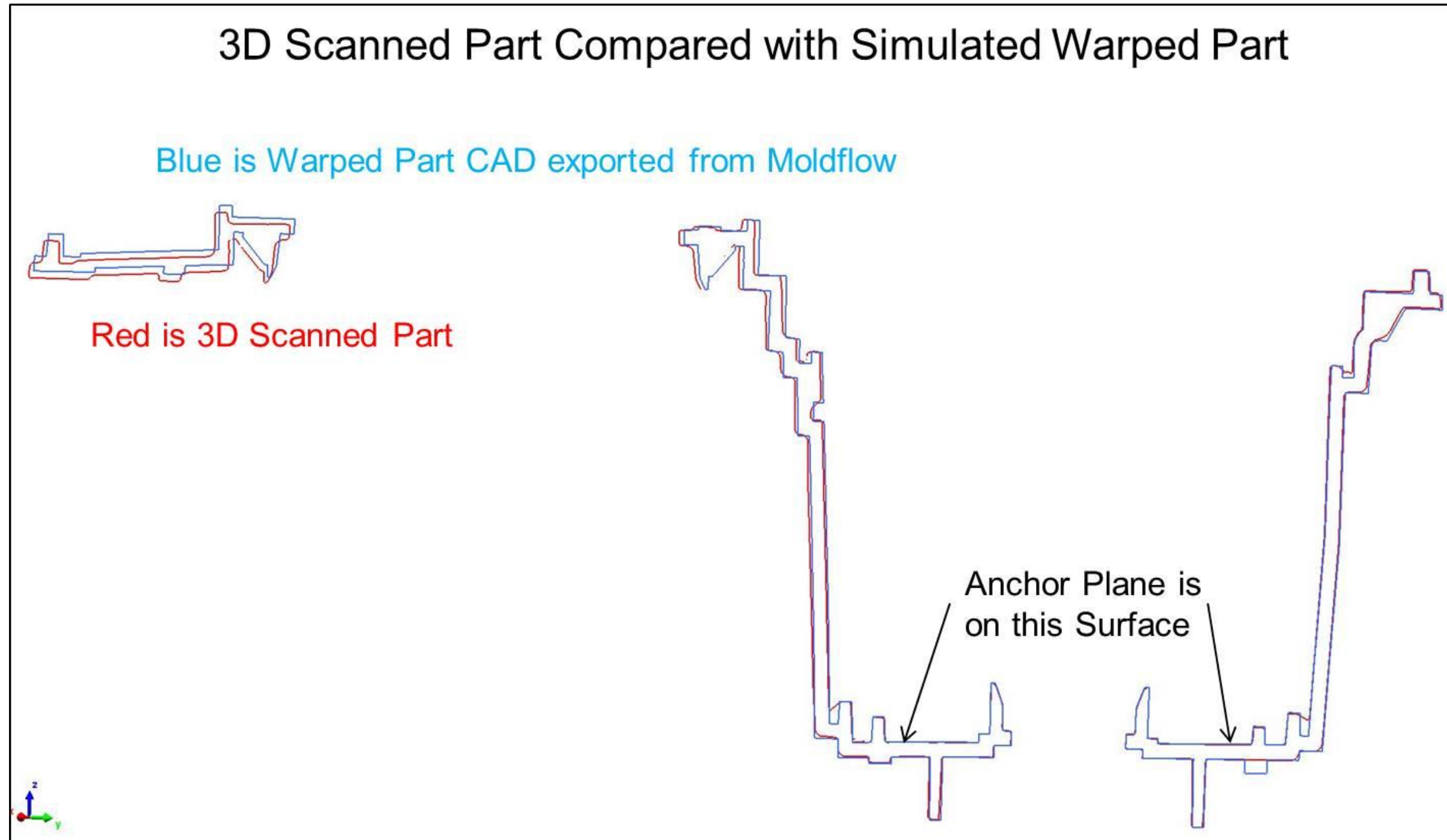


Part Deflection Validation

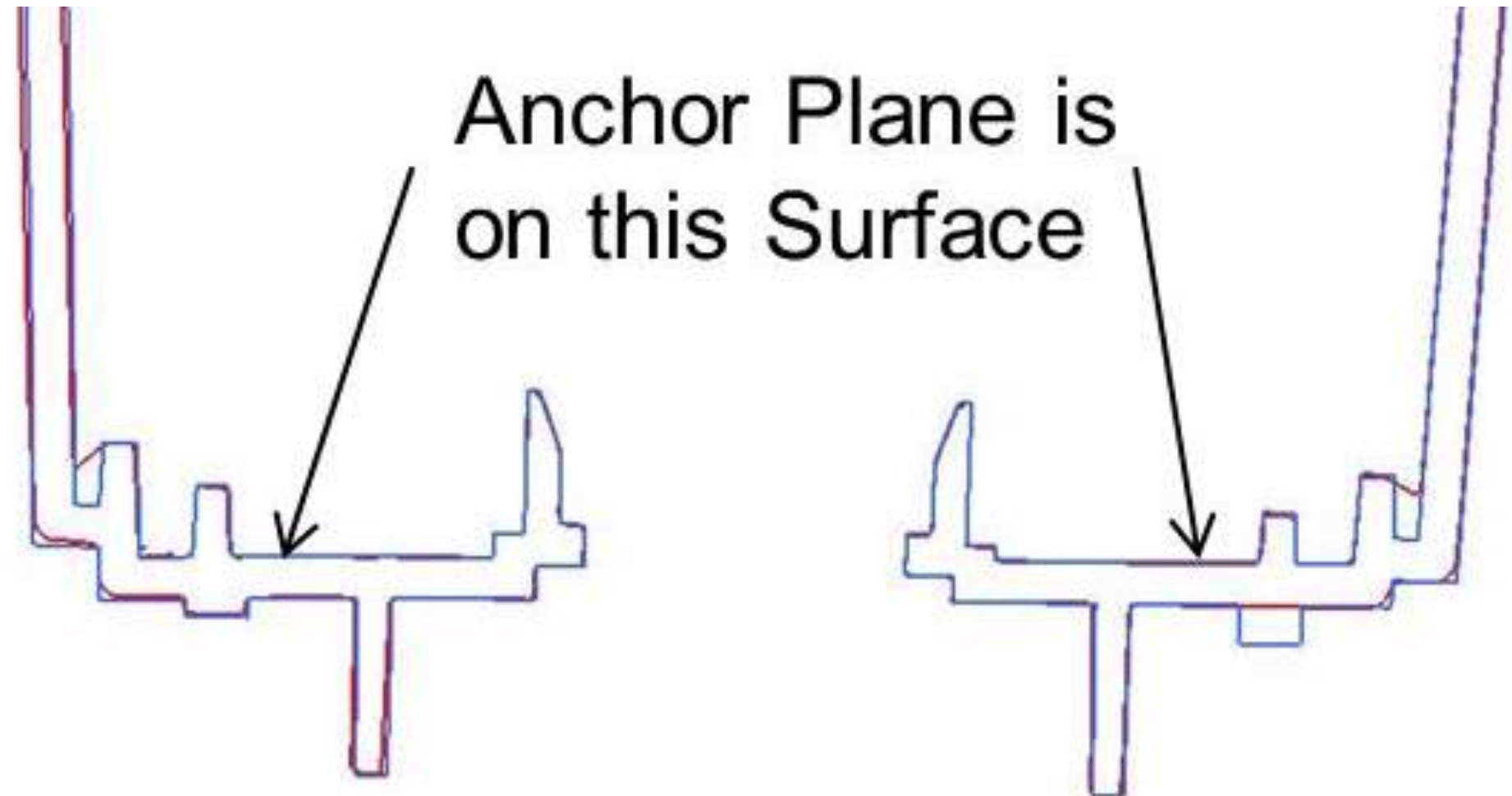
- Deviation analysis from Polyworks software
- Compares scanned molded part with exported warped CAD from Moldflow



Part Deflection Validation (continued)

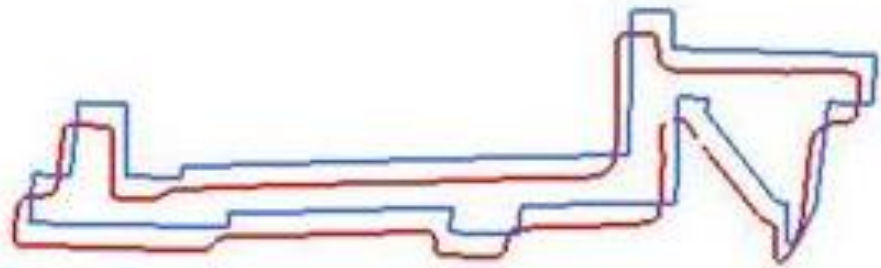


Part Deflection Validation (continued)

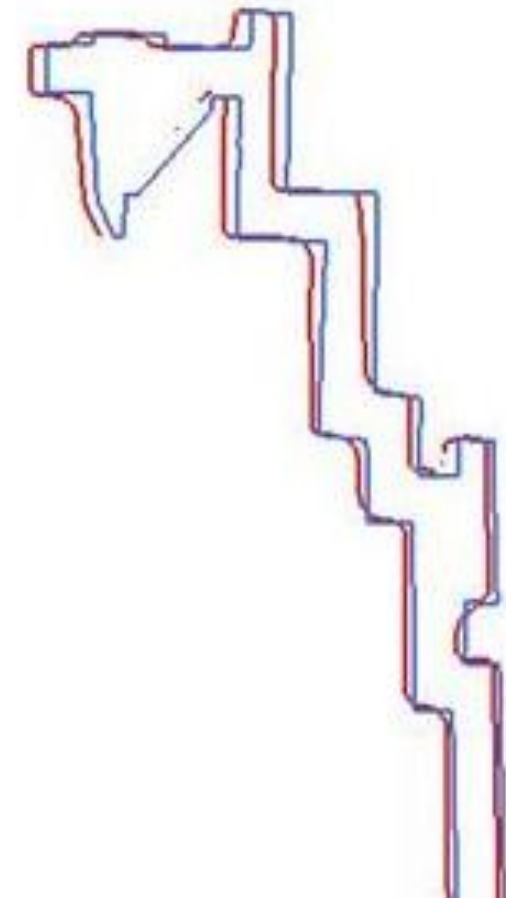


Part Deflection Validation (continued)

Blue is Warped Part CAD exported from Moldflow

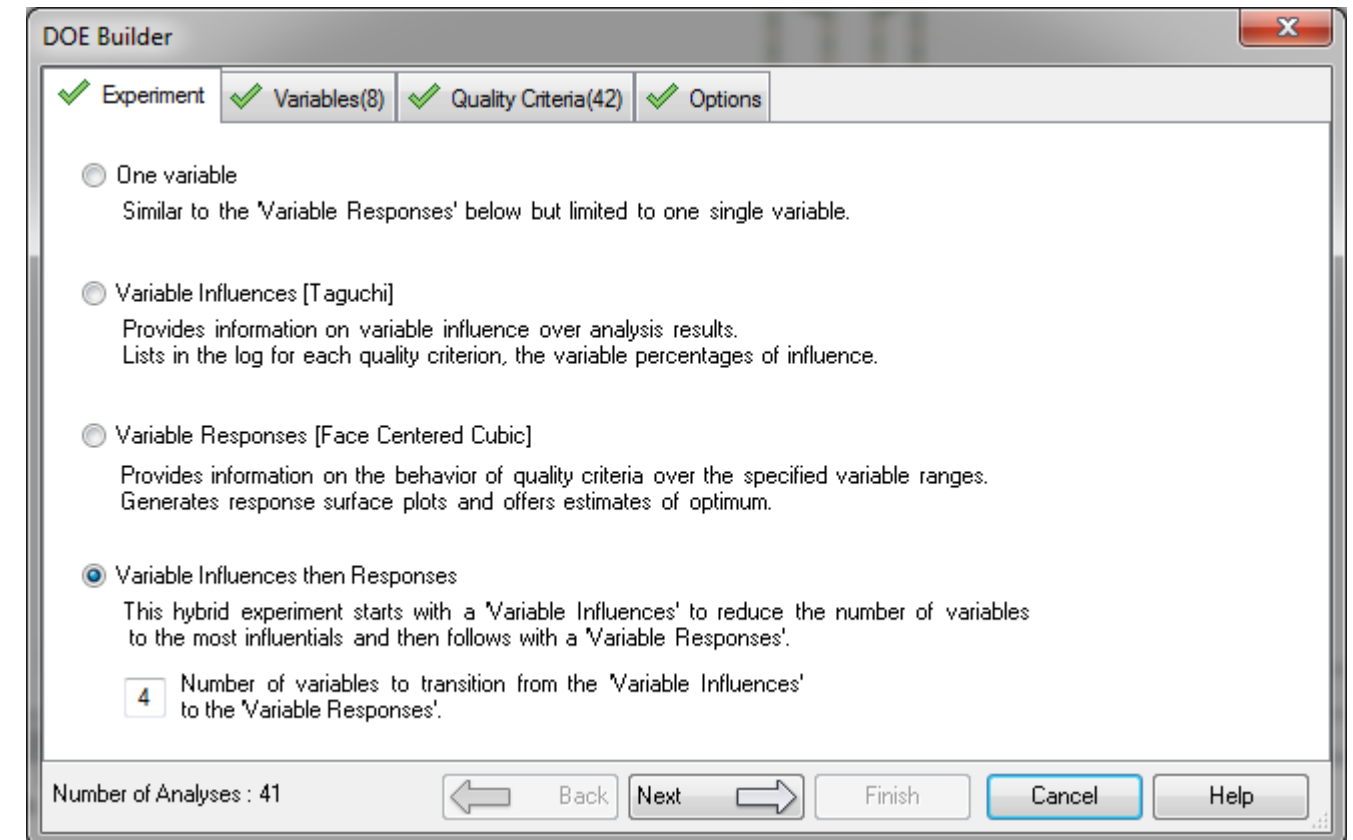


Red is 3D Scanned Part



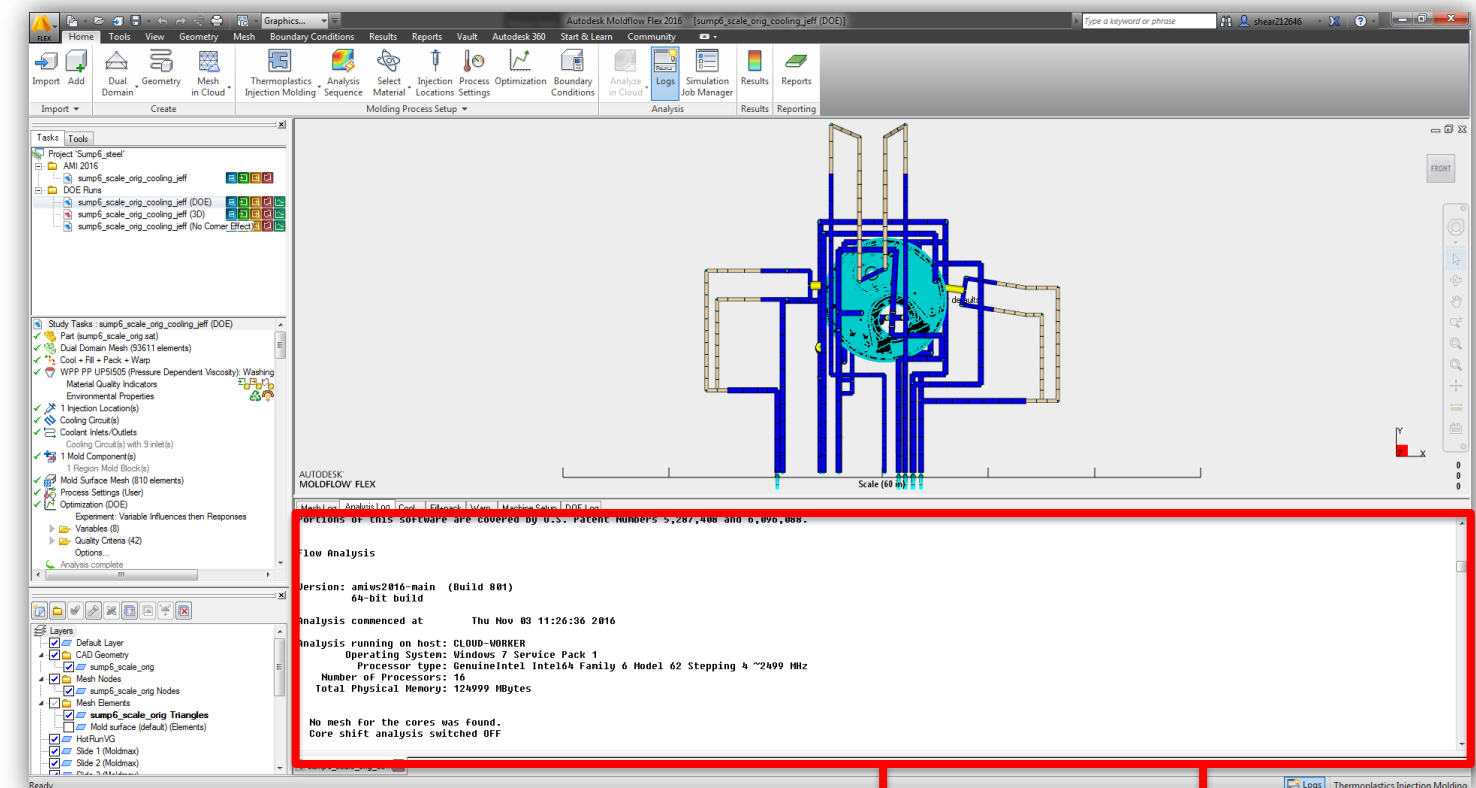
Find Process Sensitivity

- Moldflow Optimization (DOE)
 - Find Variable Influence on quality criteria
 - Evaluate Impact on the parts



Find Process Sensitivity – Influence Variables

- Moldflow Optimization (DOE)
 - What variables are having the largest impact?
 - What is impacting the part the most?



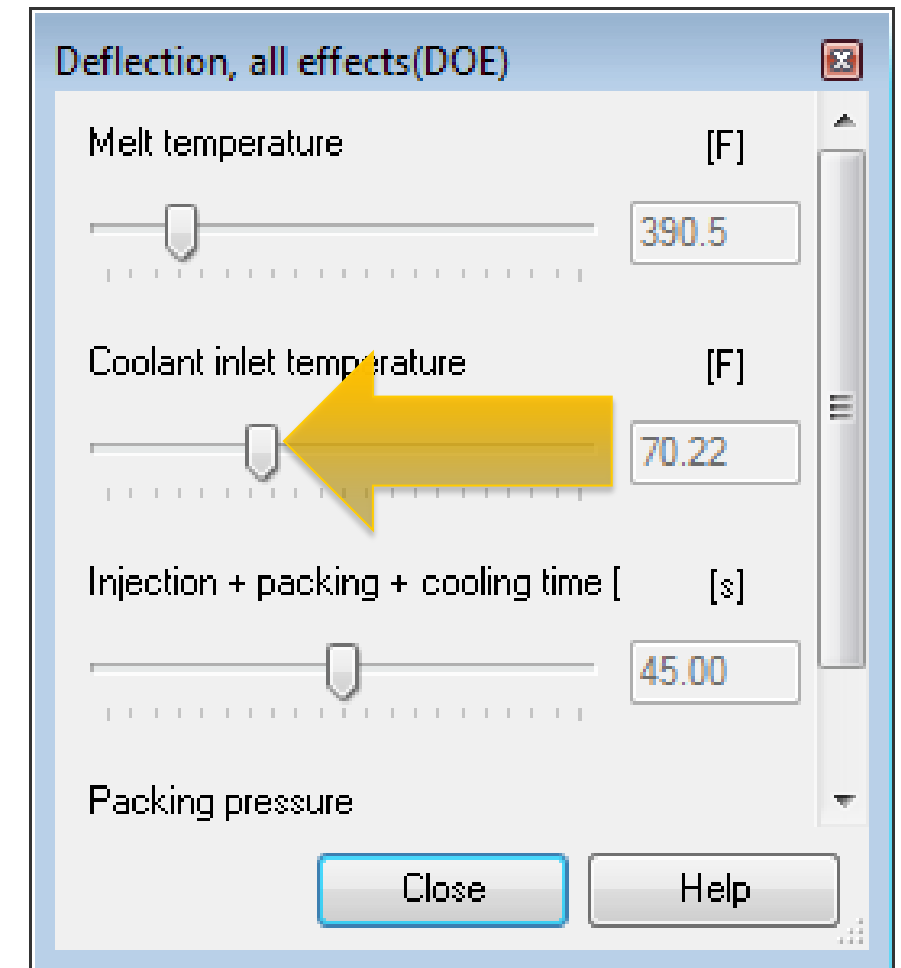
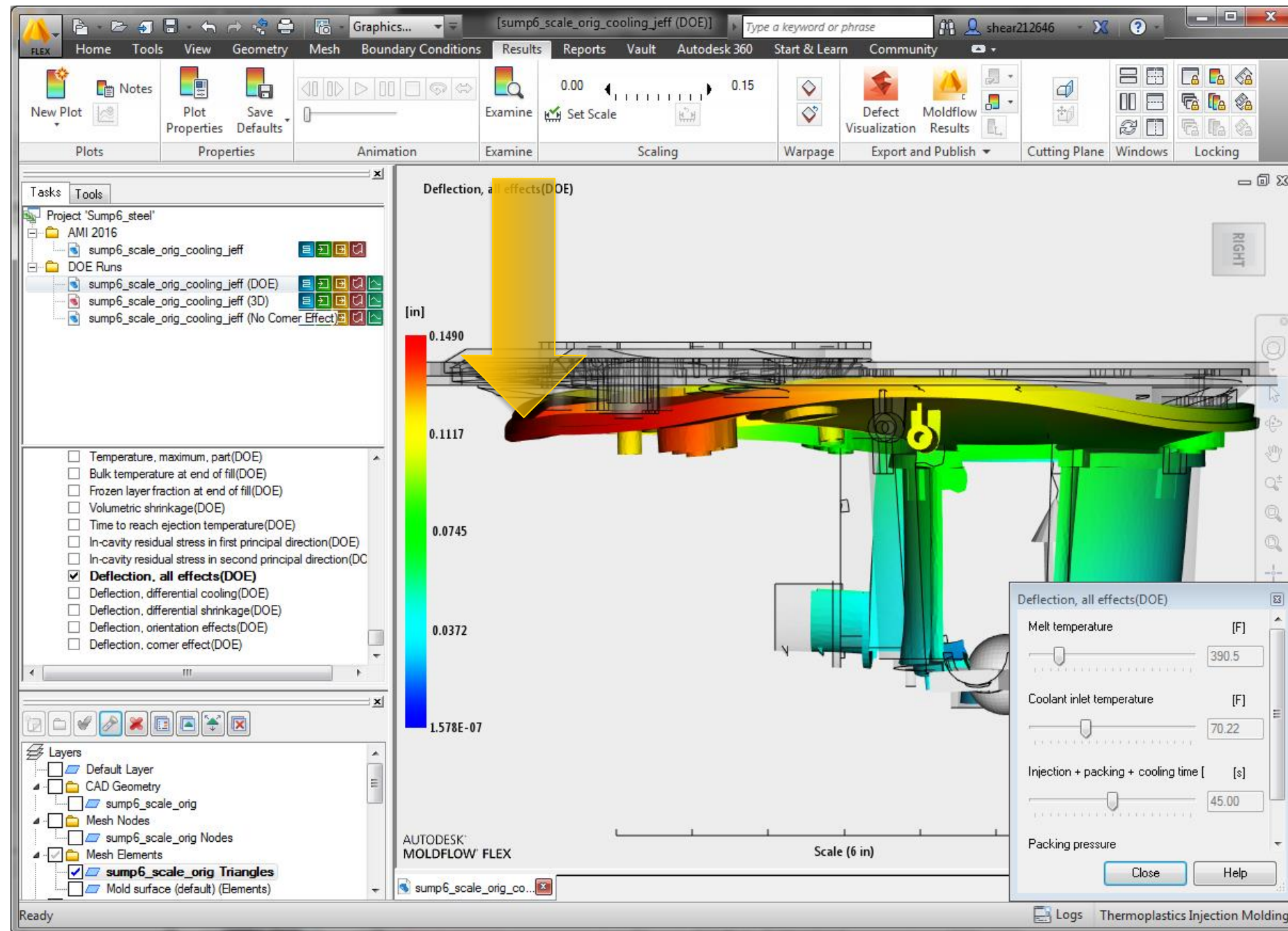
Influences on global weighted quality

6.92%	Filling control [Injection time]
33.18%	Melt temperature
20.53%	Coolant inlet temperature
3.32%	Mold-open time
3.73%	Velocity/pressure switch-over [By %volume filled]
9.18%	Duration
13.46%	Injection + packing + cooling time [Specified]
9.67%	Packing pressure

Influences on quality #23, Deflection, all effects:Deflection Calculate = Standard deviation

6.77%	Filling control [Injection time]
42.72%	Melt temperature
24.40%	Coolant inlet temperature
0.35%	Mold-open time
2.91%	Velocity/pressure switch-over [By %volume filled]
5.96%	Duration
0.55%	Injection + packing + cooling time [Specified]
16.34%	Packing pressure

Find Process Sensitivity – The impact of change



Conclusions

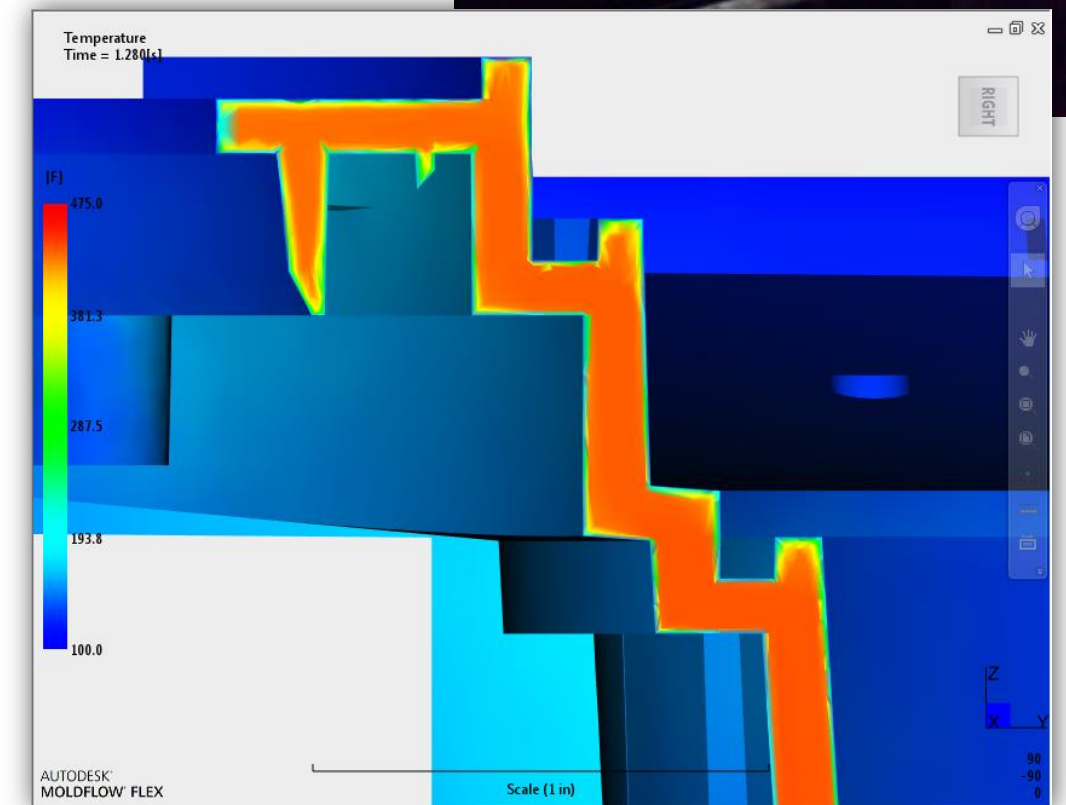
- The short shot predictions were very close to reality
- The pressure predictions were close (with the nozzle modeled)
- Mold temperature was over predicted *
- Mold shrinkage was over predicted for DD
- Deflection was under predicted *

* Need further study with 3D mold mesh & actual mold temperatures



Future Work

- Model & mesh mold in 3D
 - Core/Cavity
 - MoldMax Slides
- Run with Insight v2017
- Conduct 3D simulation with Cool (FEM)
- Conduct optimization analysis
- Work with Autodesk Moldflow Validation Team



How did I do?

- Your class feedback is critical. Fill out a **class survey** now.
- Use the AU mobile app or fill out a class survey online.
- Give feedback after each session.
- AU speakers will get feedback in real-time.
- **Your feedback results in better classes and a better AU experience.**



Questions & Answers



