SM6326:
Demystifying Optimization in Simulation

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Autodesk

Class Overview

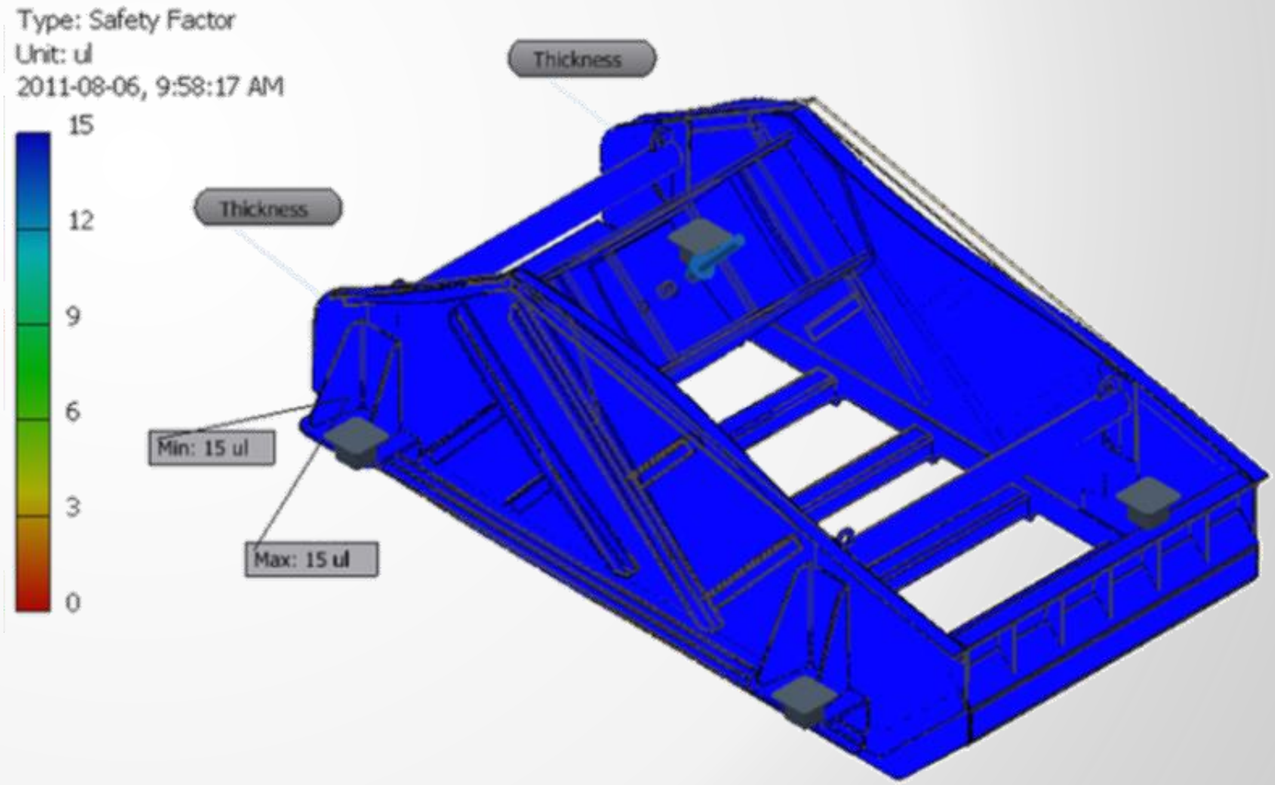
- Past
  - Inventor Optimization (2007)
  - Sim360 (2013)
- Present
  - Sim CFD (2002, 2009)
  - Sim Mechanical (2013)
  - Moldflow DOE (1990)
- Future
  - Topology Optimization (2014)
- Demos

Key learning objectives

- Learn about Optimization in products including Inventor Simulation, Sim360, Sim CFD, Sim Mechanical
- Performing Design of Experiments with Moldflow
- Learn about Topology Optimization in SimStudio

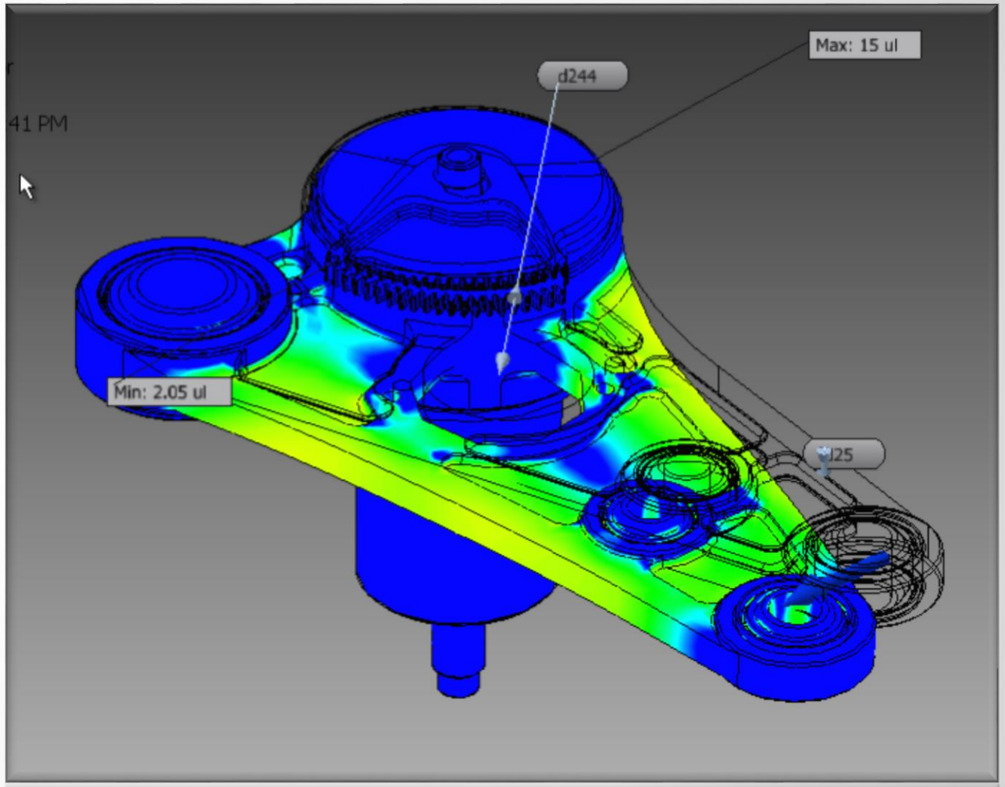
Optimization: Past

Past:
Inventor Optimization



Project Charter

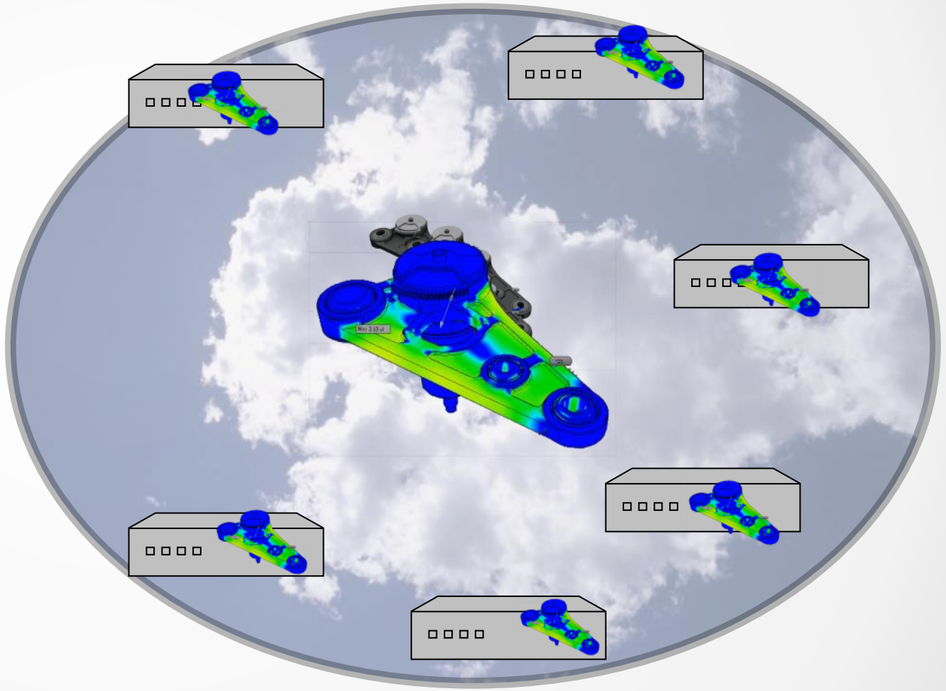
- Common customer need: Reduce weight while improving safety
- Simulate and Design Simultaneously
- Realize orders of magnitude better performance



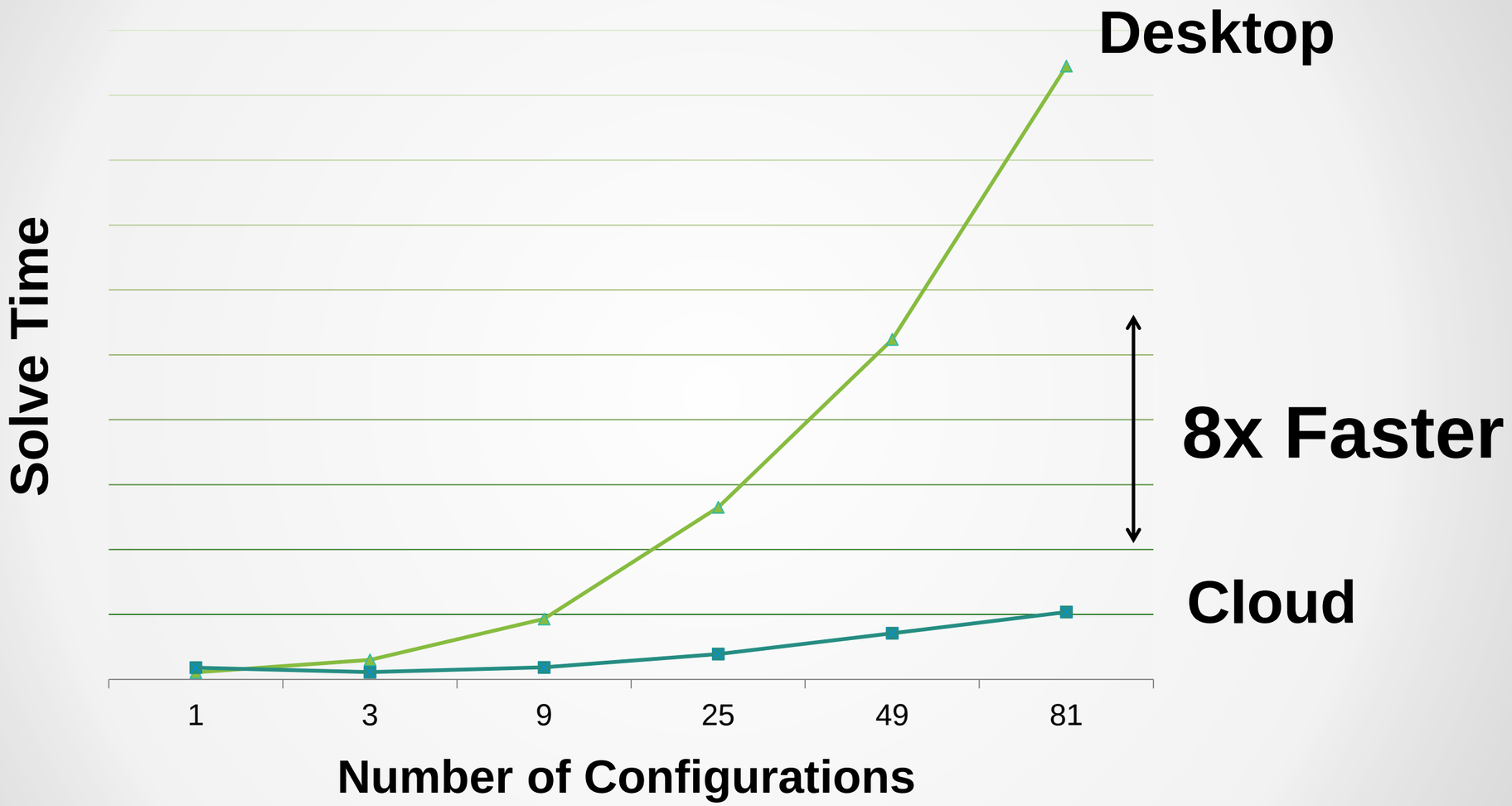
Early Cloud Adoption

Lightweight
Inventor Add-in

All processing happens
in the cloud



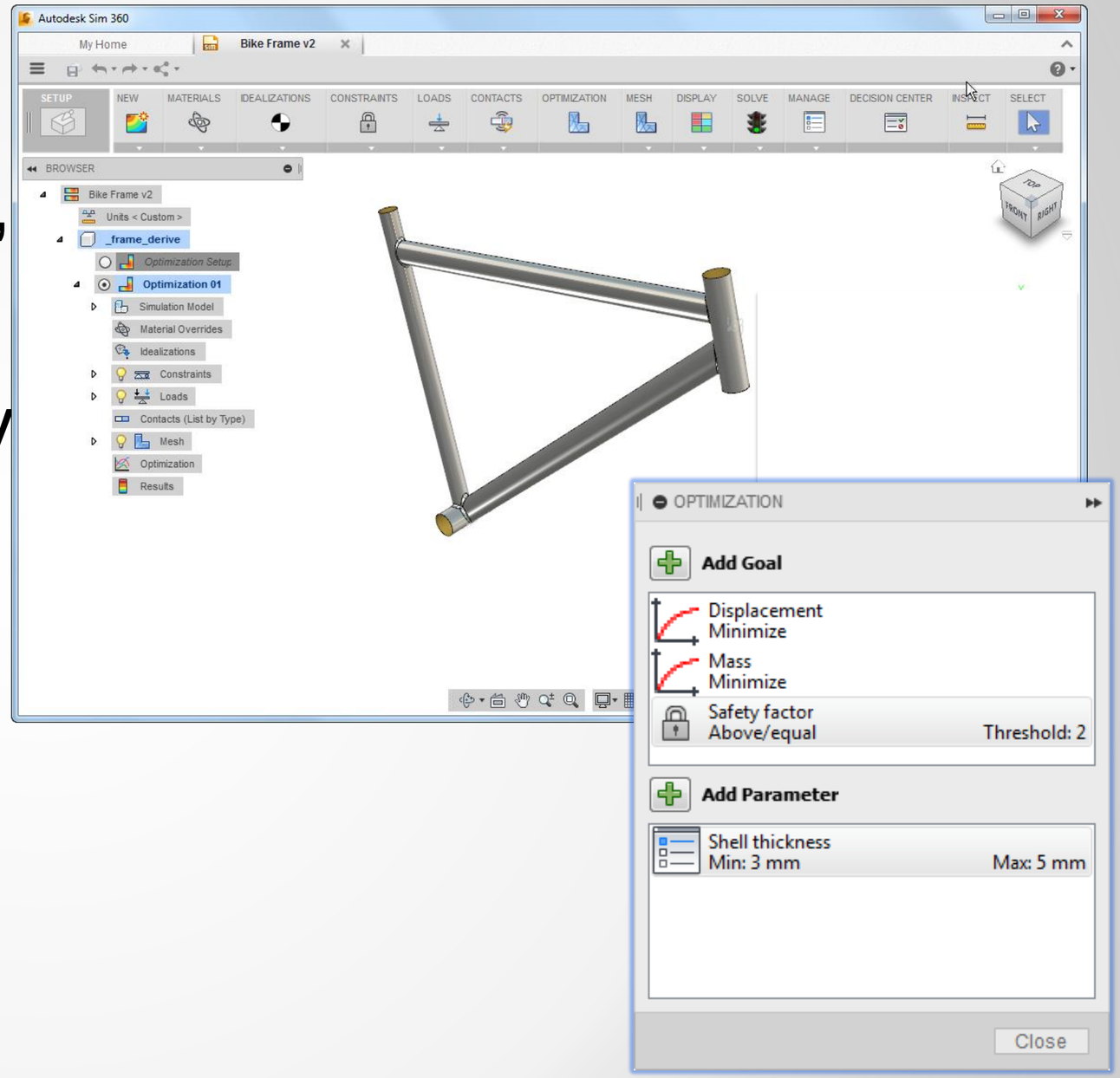
Performance Gains



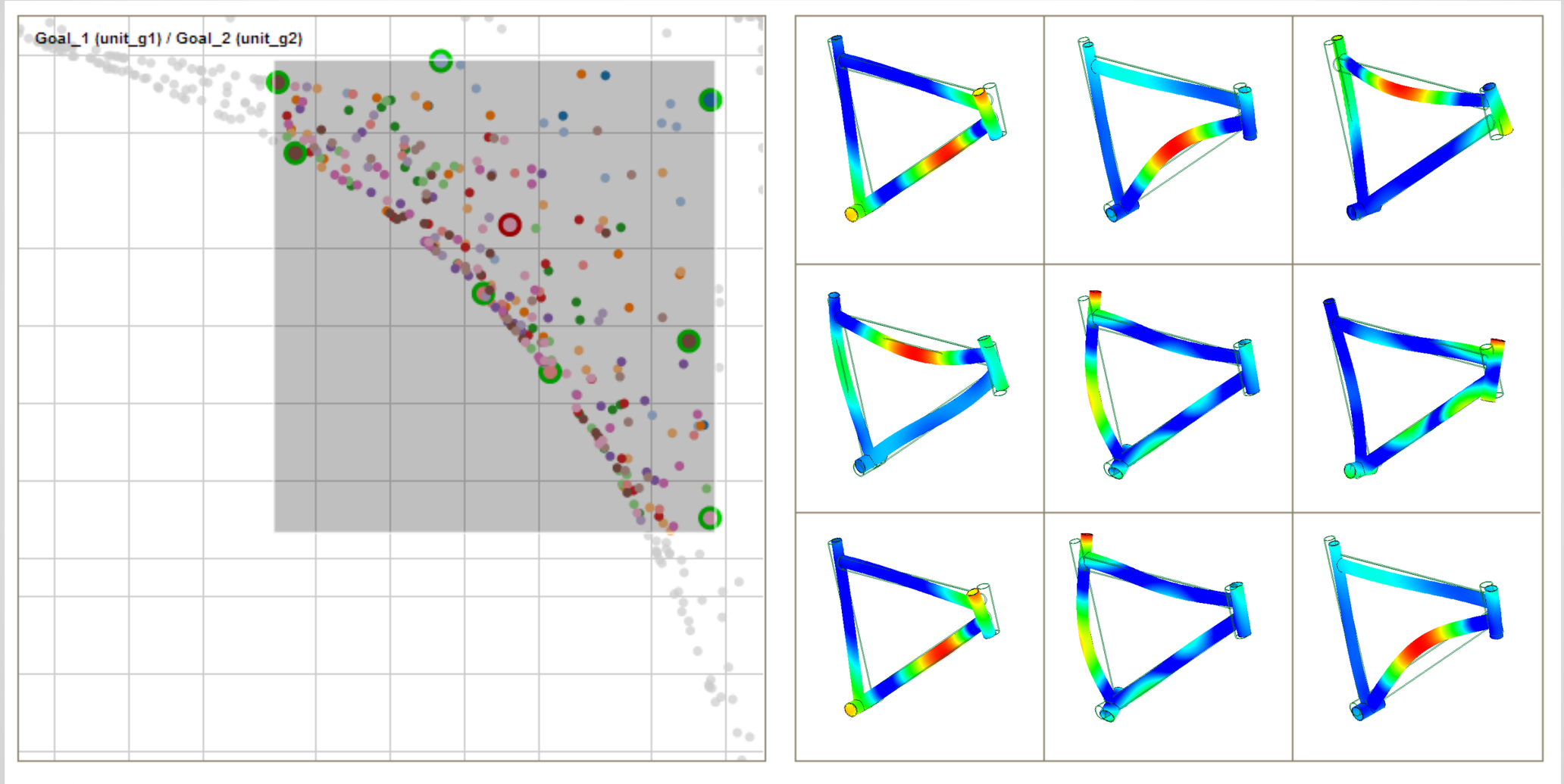
Past:
Sim 360

Project Charter

- Bring focus to Objectives, not optimization setup
- Arrive at results efficiently
- Make reasonable assumptions
- Encourage exploring far more alternatives than manually possible



Exploring Options



Optimization: Present

Present:
Simulation CFD (Fluids)

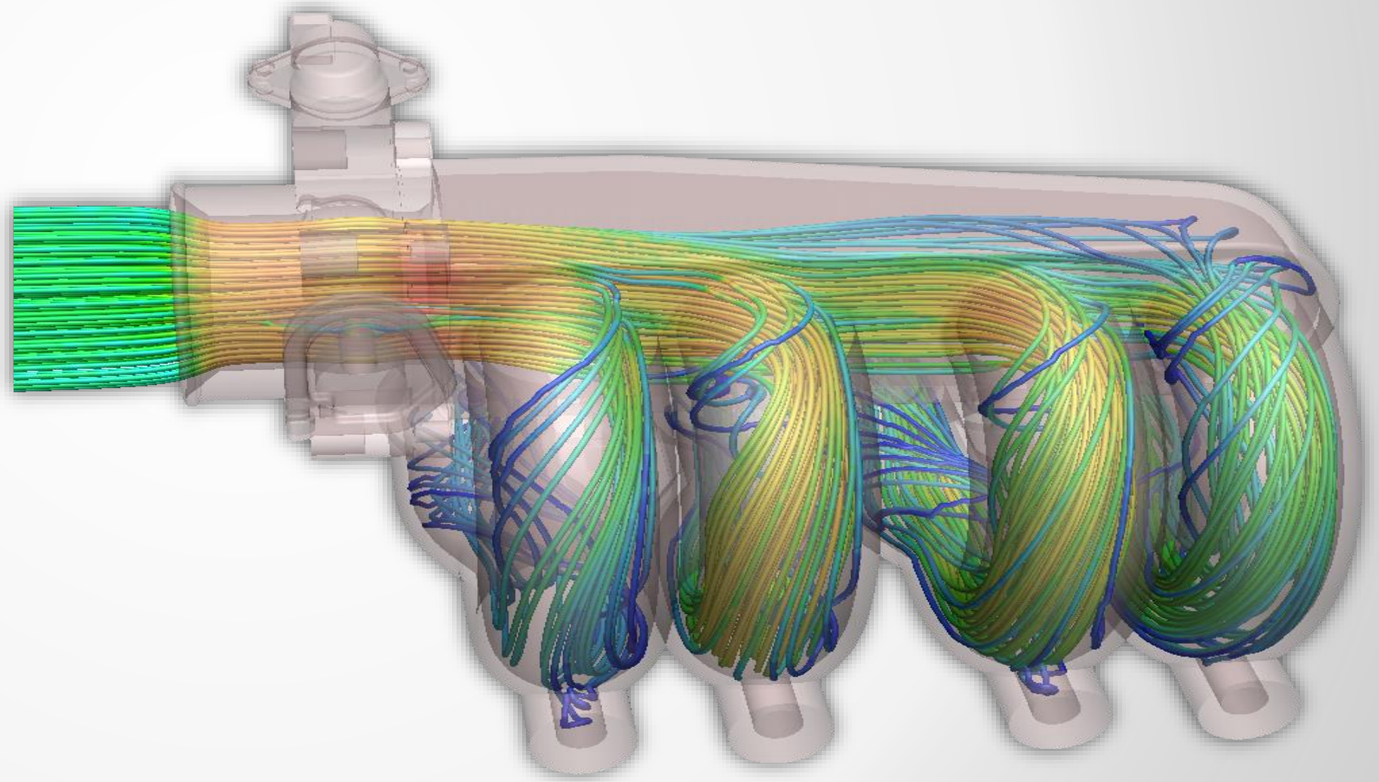
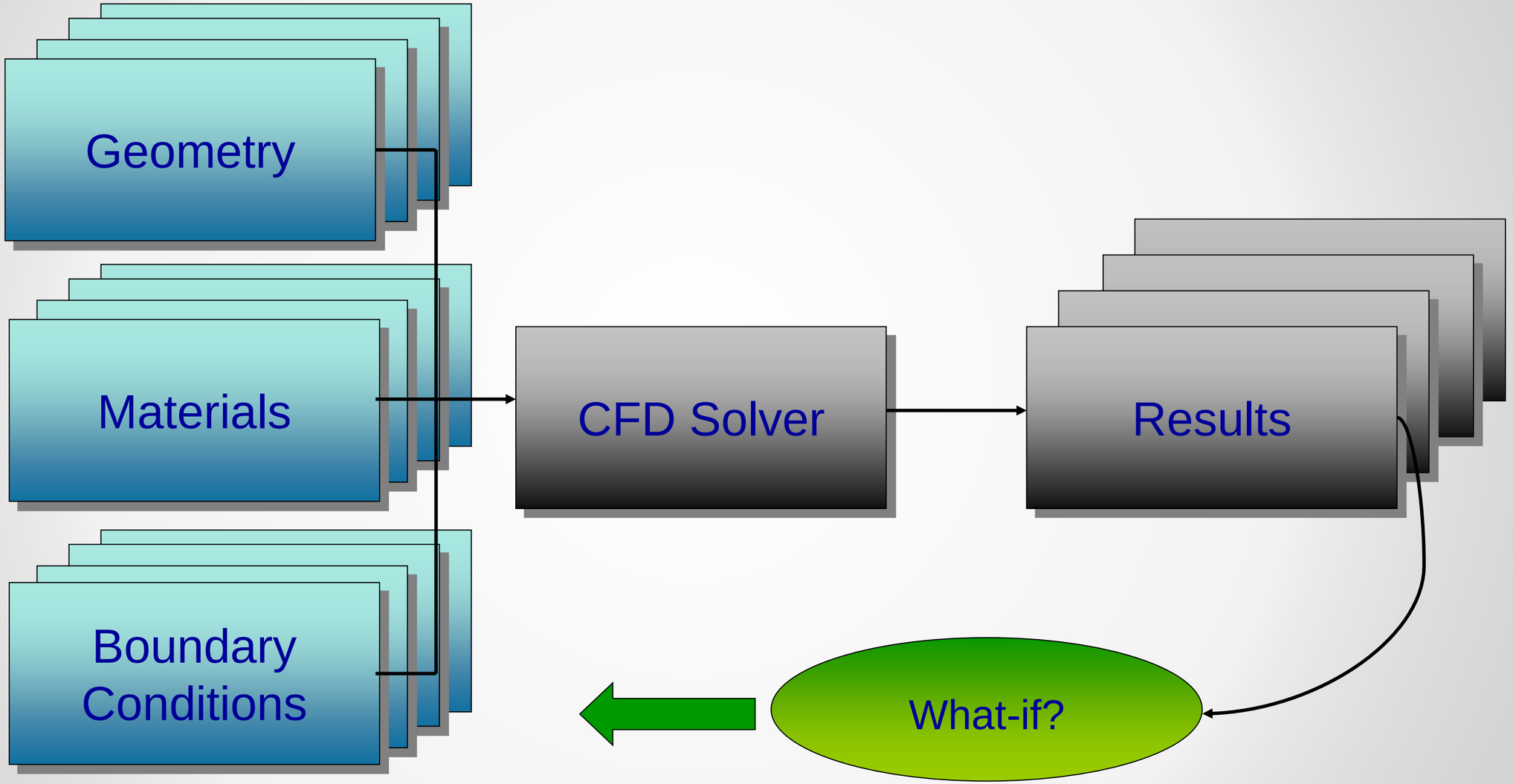
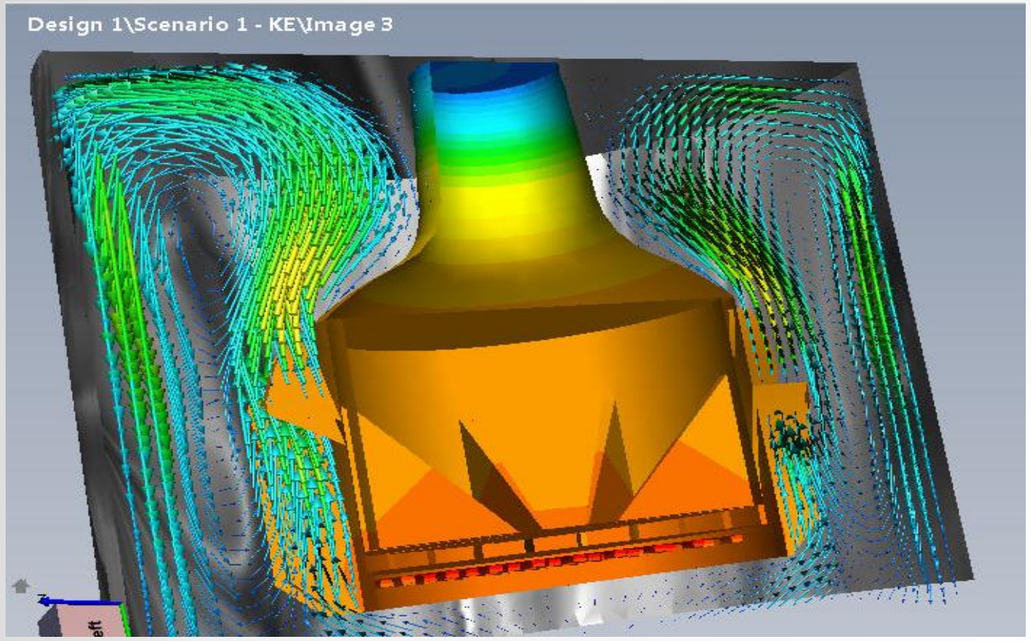


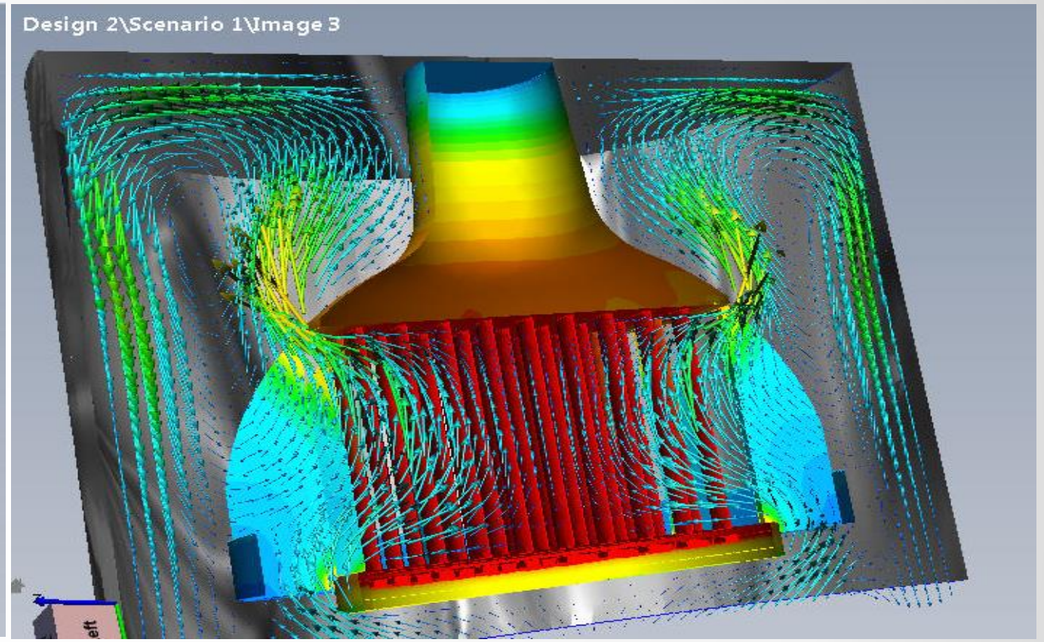
Image courtesy Oklahoma FSAE

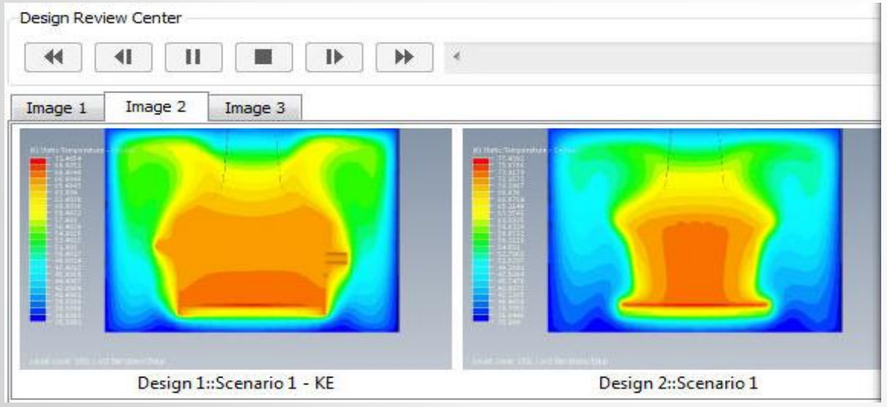
Simulation CFD Workflow

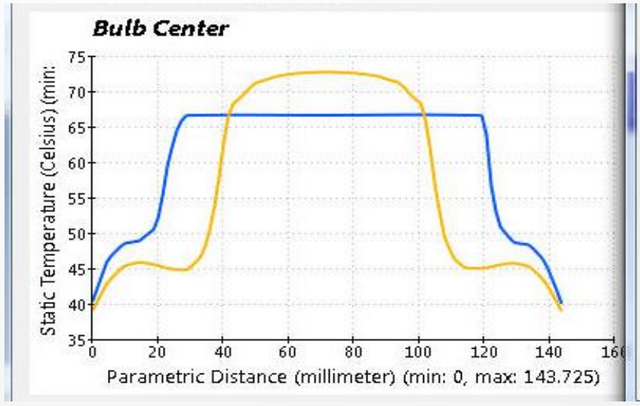


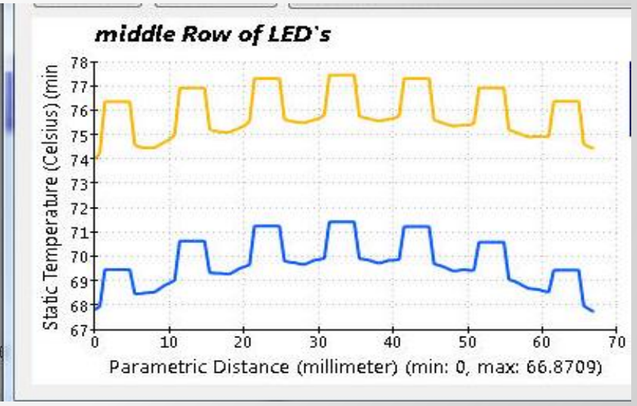
Design Study Environment



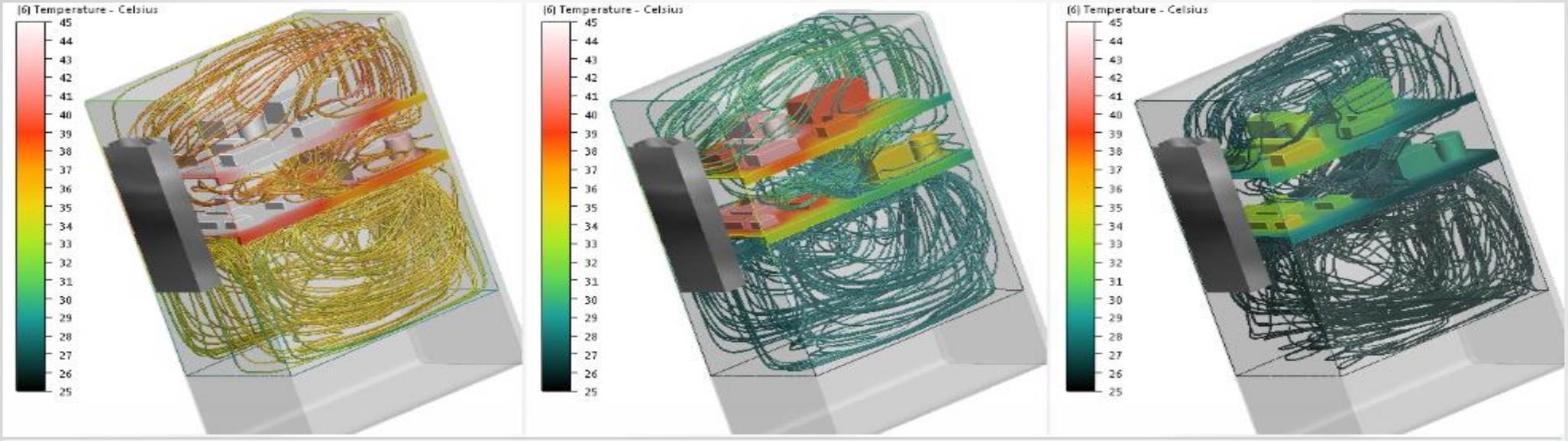


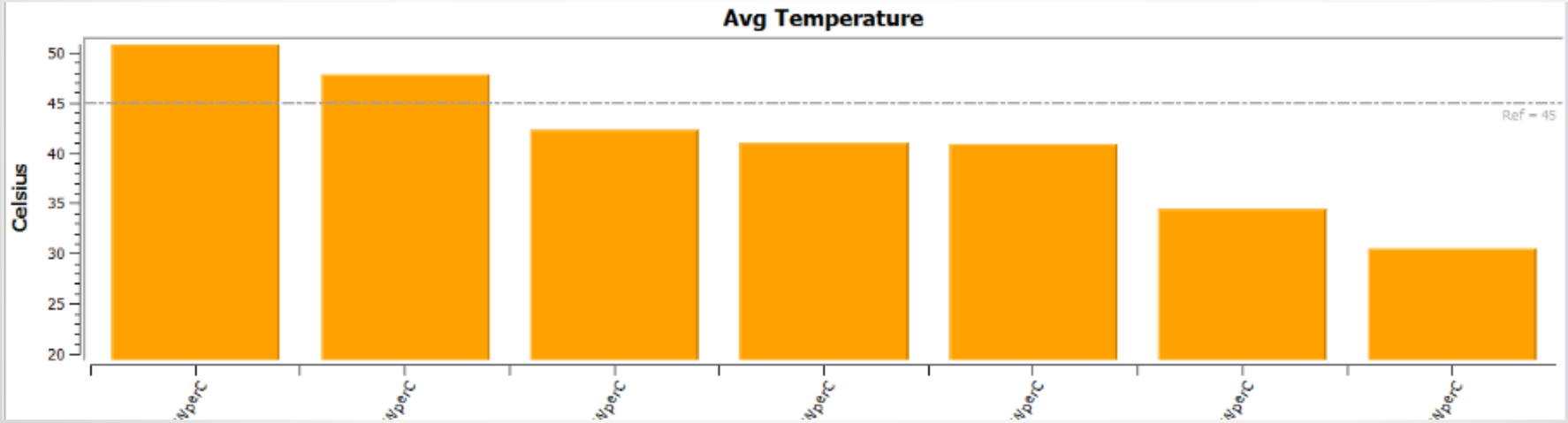






Design Study Environment





Present:
Simulation Mechanical

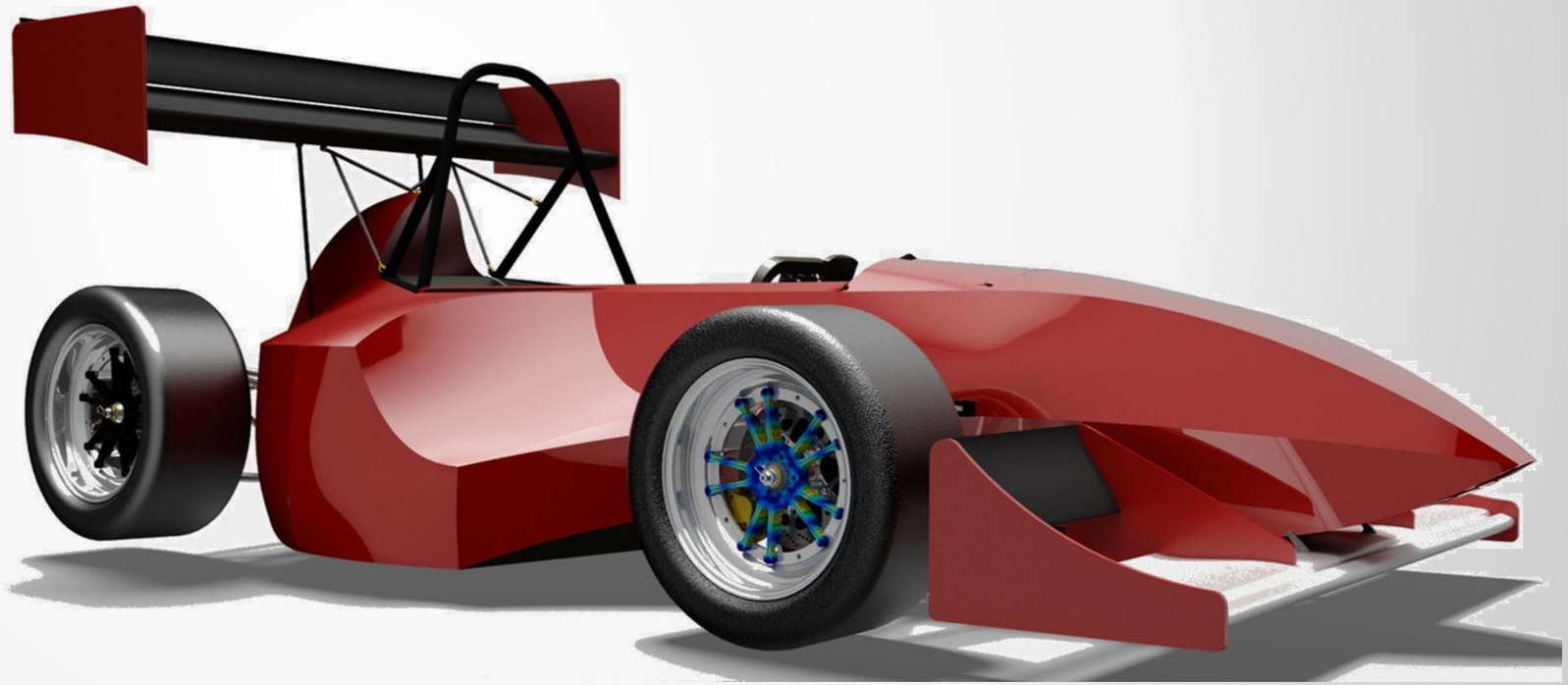


Image courtesy Oklahoma FSAE

Parametric Studies

- Access to CAD parameters
- Explore many shape options in batch

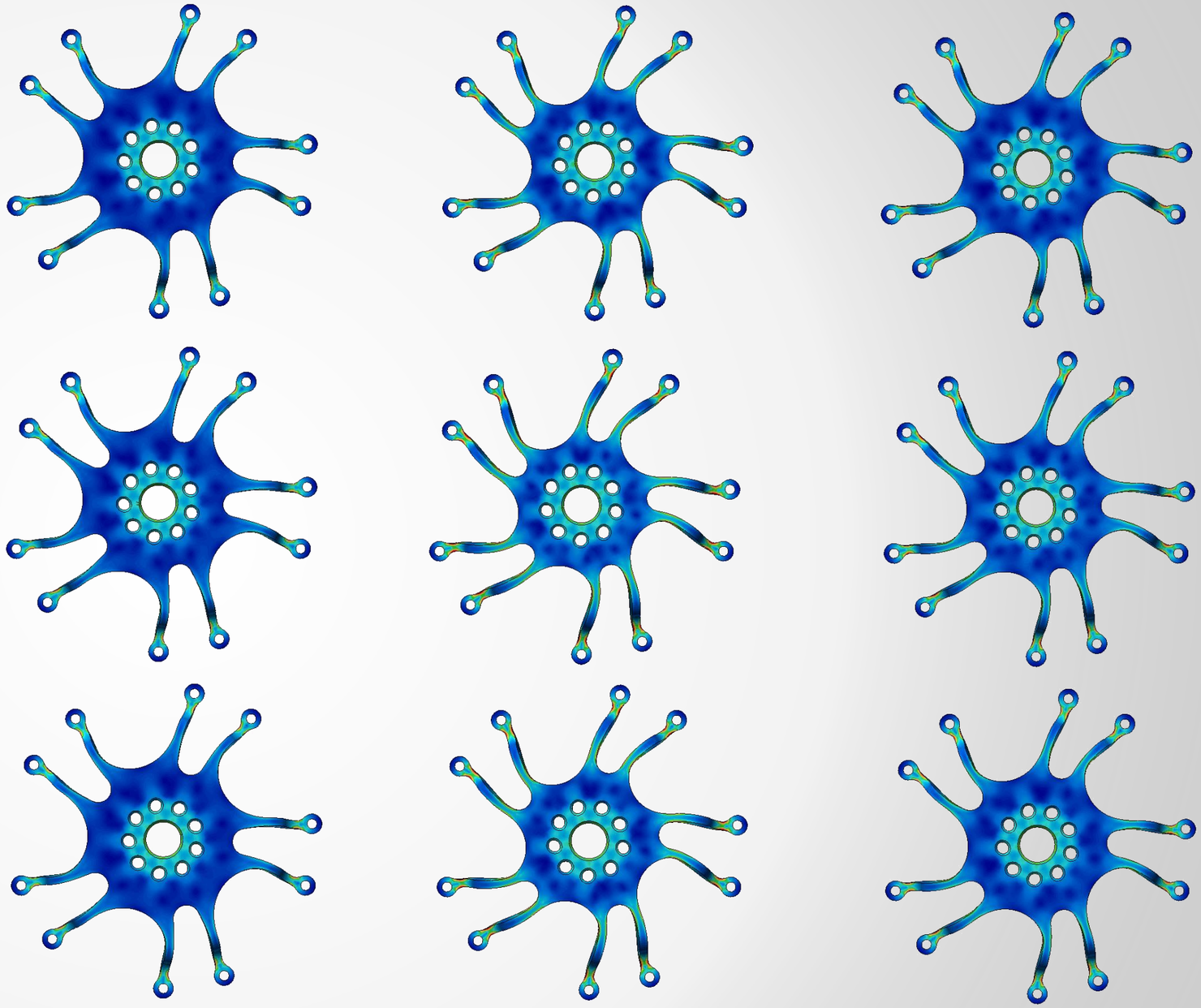
Vary major and minor radius

Parametric Studies

- Review all responses
- Find optimal

  - or -

- Determine critical parameters
- Repeat process with targeted values



Present:
Simulation Moldflow

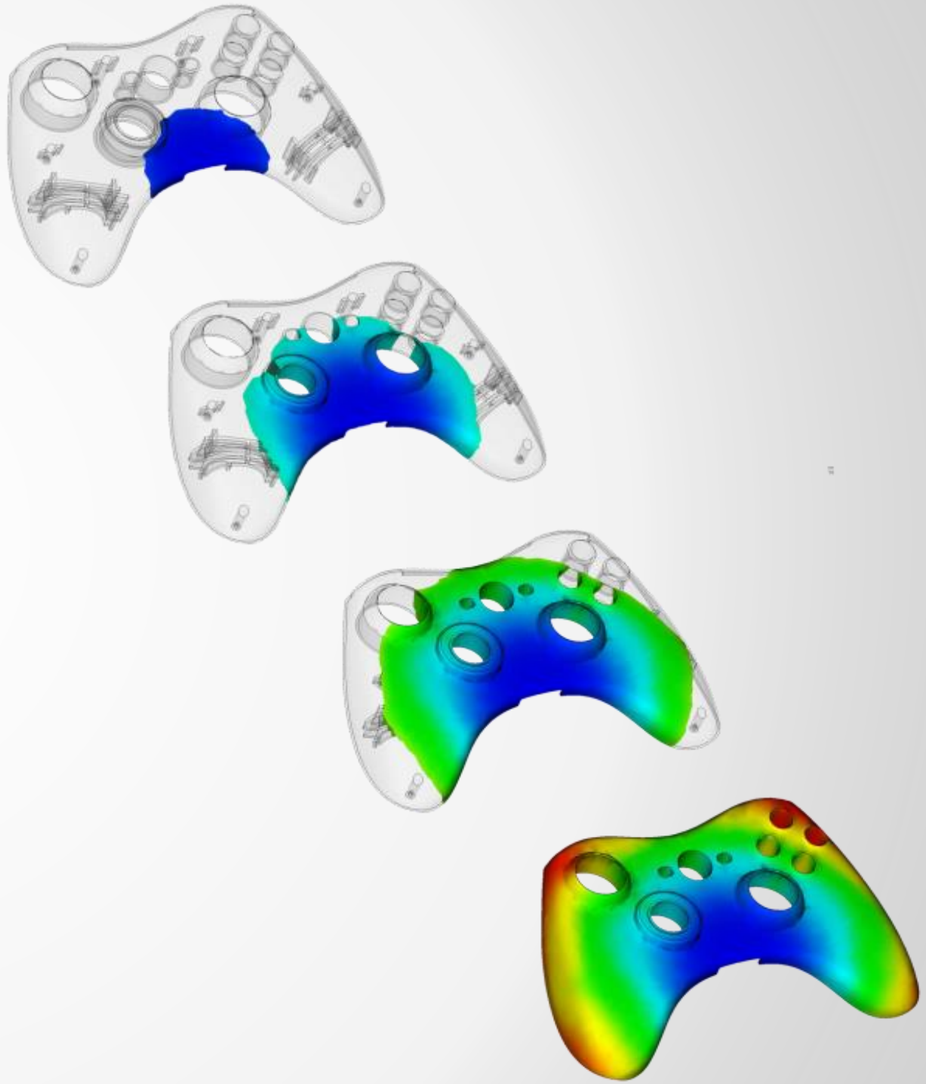


Image courtesy Oklahoma FSAE

Moldflow Optimization Agenda

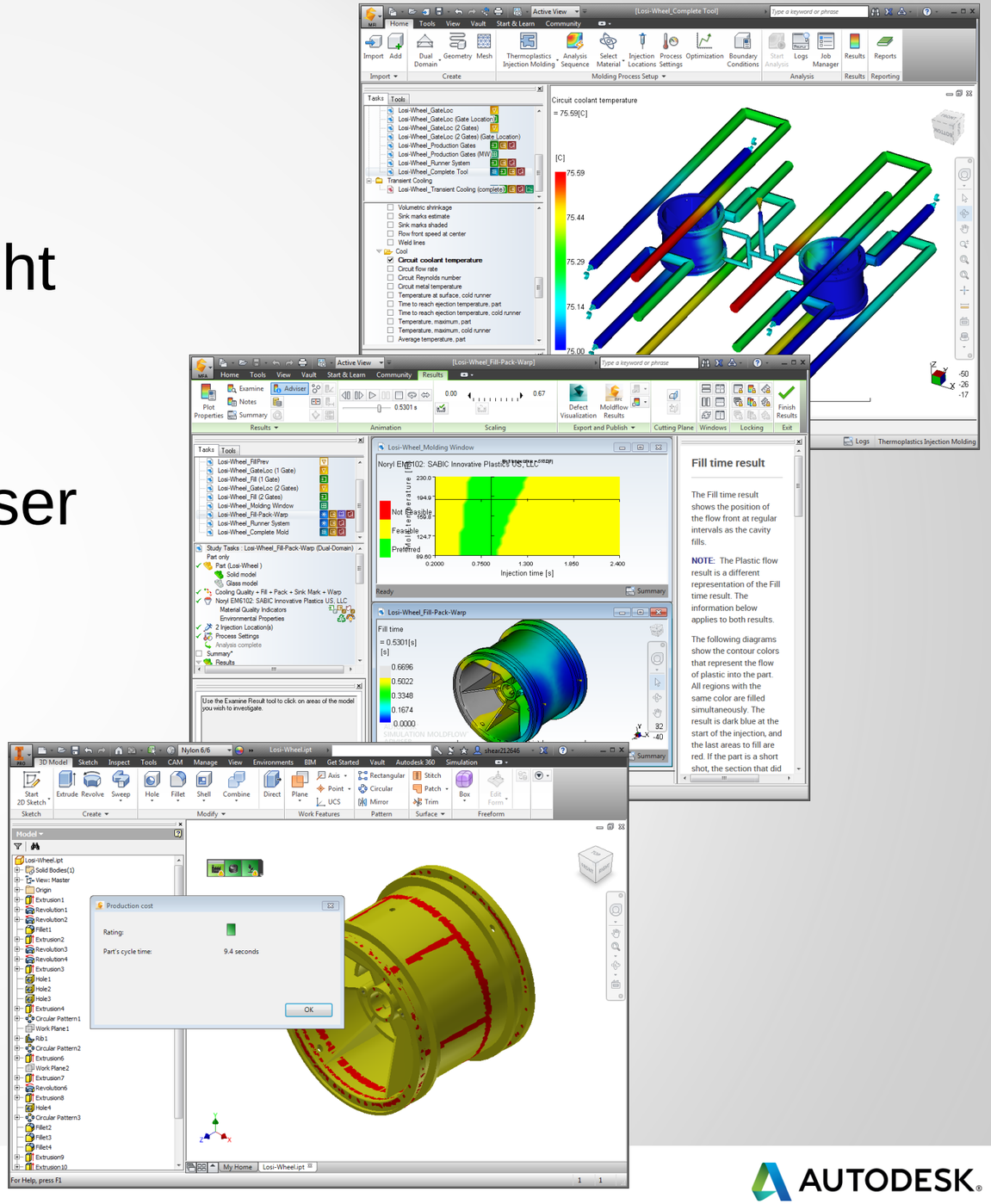
- Brief History of how Moldflow was used
- The Development of Workflows
  - Traditional Problem Solving
  - Legacy Process Optimization
  - Design of Experiments
- The Future???

Introduction to Moldflow Optimization

- Moldflow development started in 1978
  - Primarily an analytical tool
  - Targeted at replicating problems and simulating alternatives
- Moldflow has been steadily moving more toward influencing design
  - It's easier to effect change before physical tools or parts exist

Influence Design

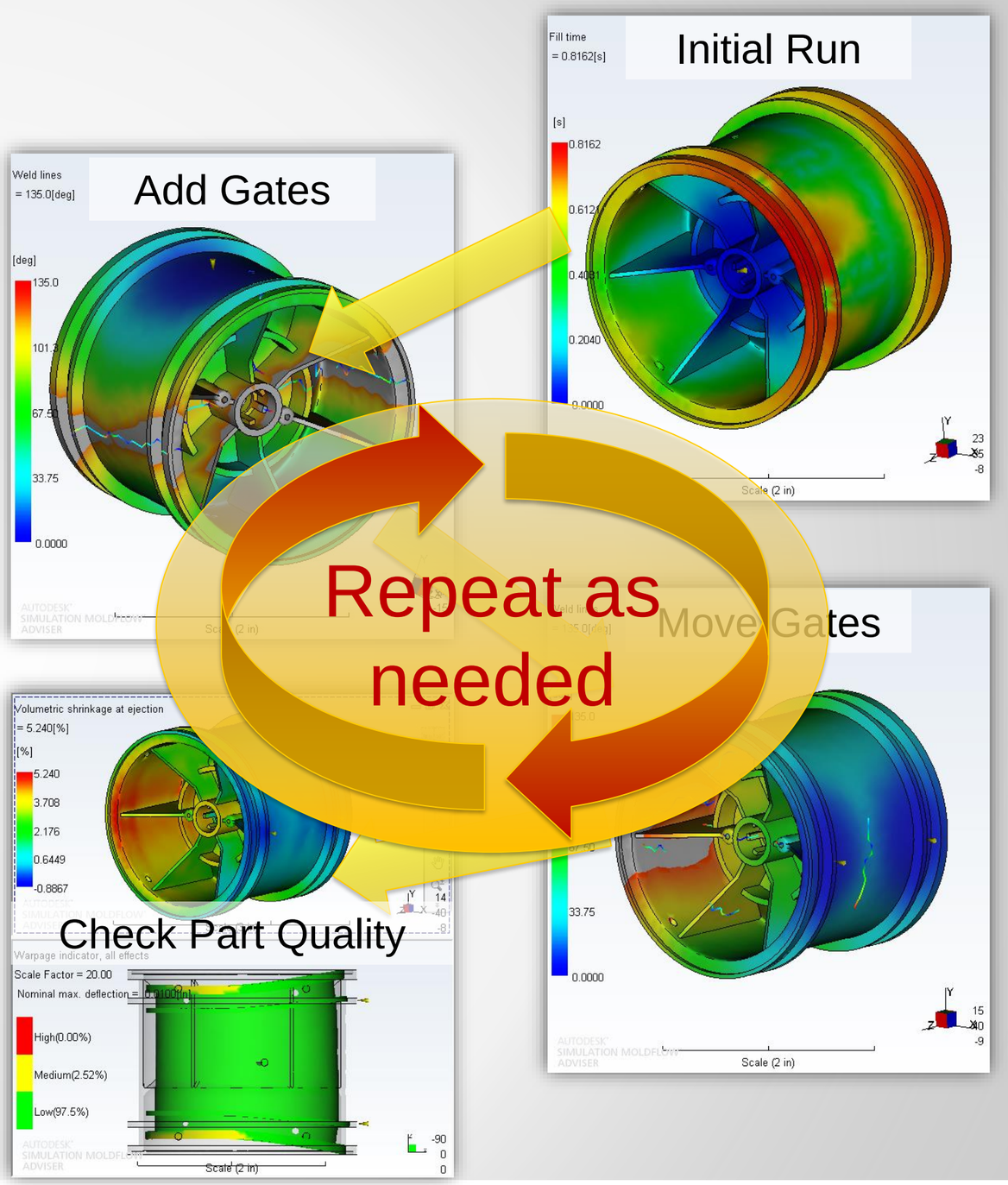
- Autodesk Simulation Moldflow Insight
  - In-Depth Simulation
- Autodesk Simulation Moldflow Adviser
  - Designer Based Simulation
- Autodesk Simulation DFM
  - Plastic Design Tool



Traditional Problem Solving

Manual Optimization

- Run Simulation
- View Results
- Diagnose Problem
- Make Modification
- Launch additional Analysis
- Repeat as needed

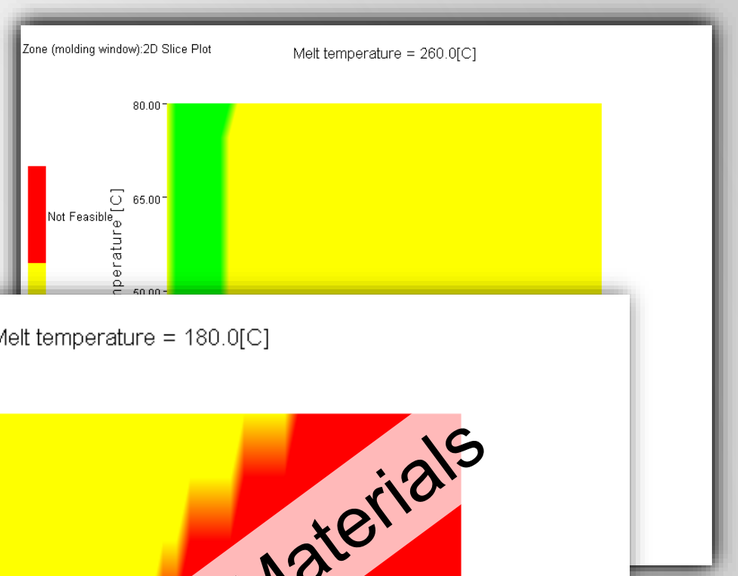


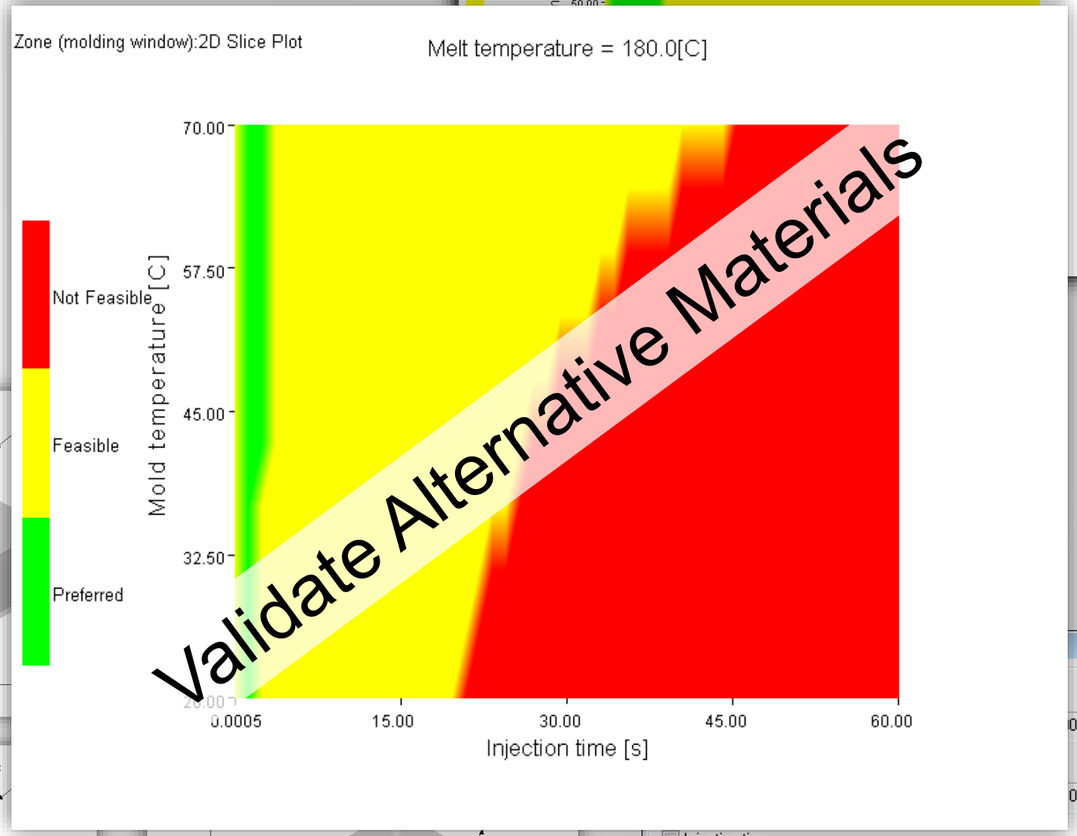
Legacy Optimizations

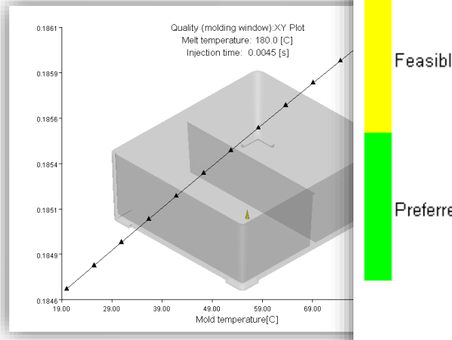
Molding Window

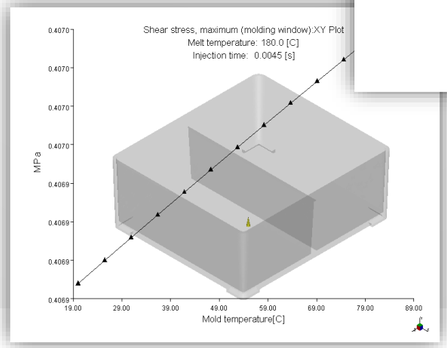
- Molding Process Window
- Quality Estimate
- Pressure
- Temperature
- Shear Rate
- Cooling Time
- Compare Materials

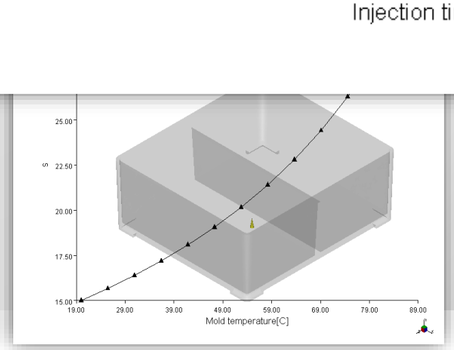
Dynamically
See influence
on the process

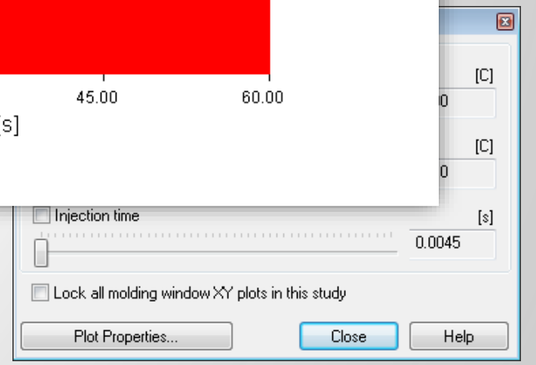






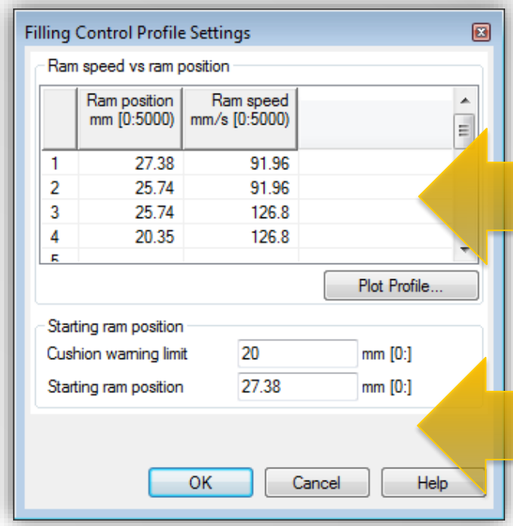


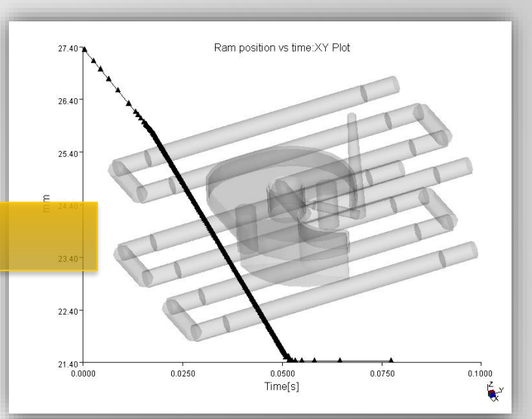


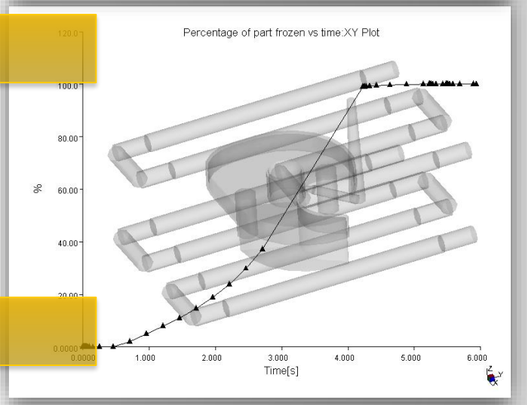


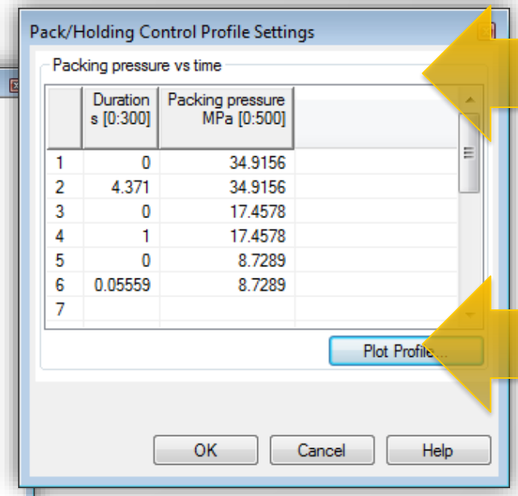
Process Optimization

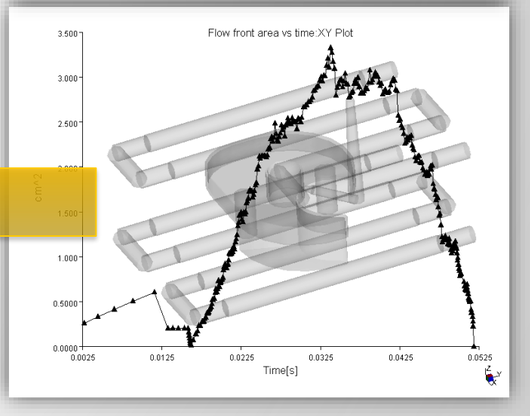
- Optimize the Injection Molding Process
  - Optimize Filling to maintain constant melt front velocity
  - Optimize Packing to Minimize Shrinkage

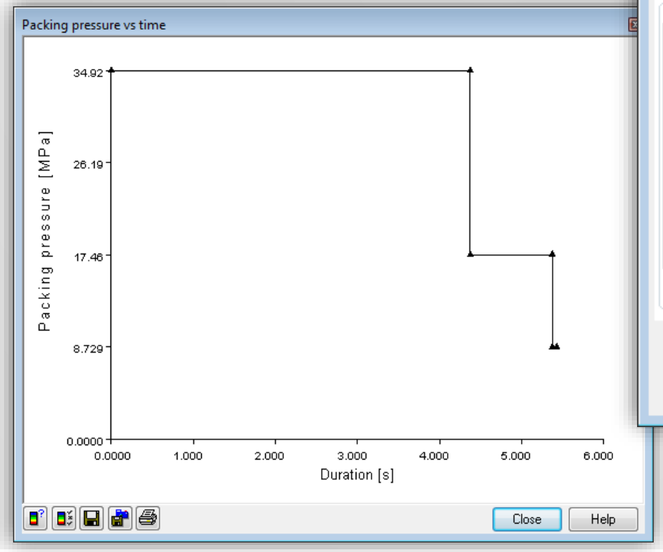








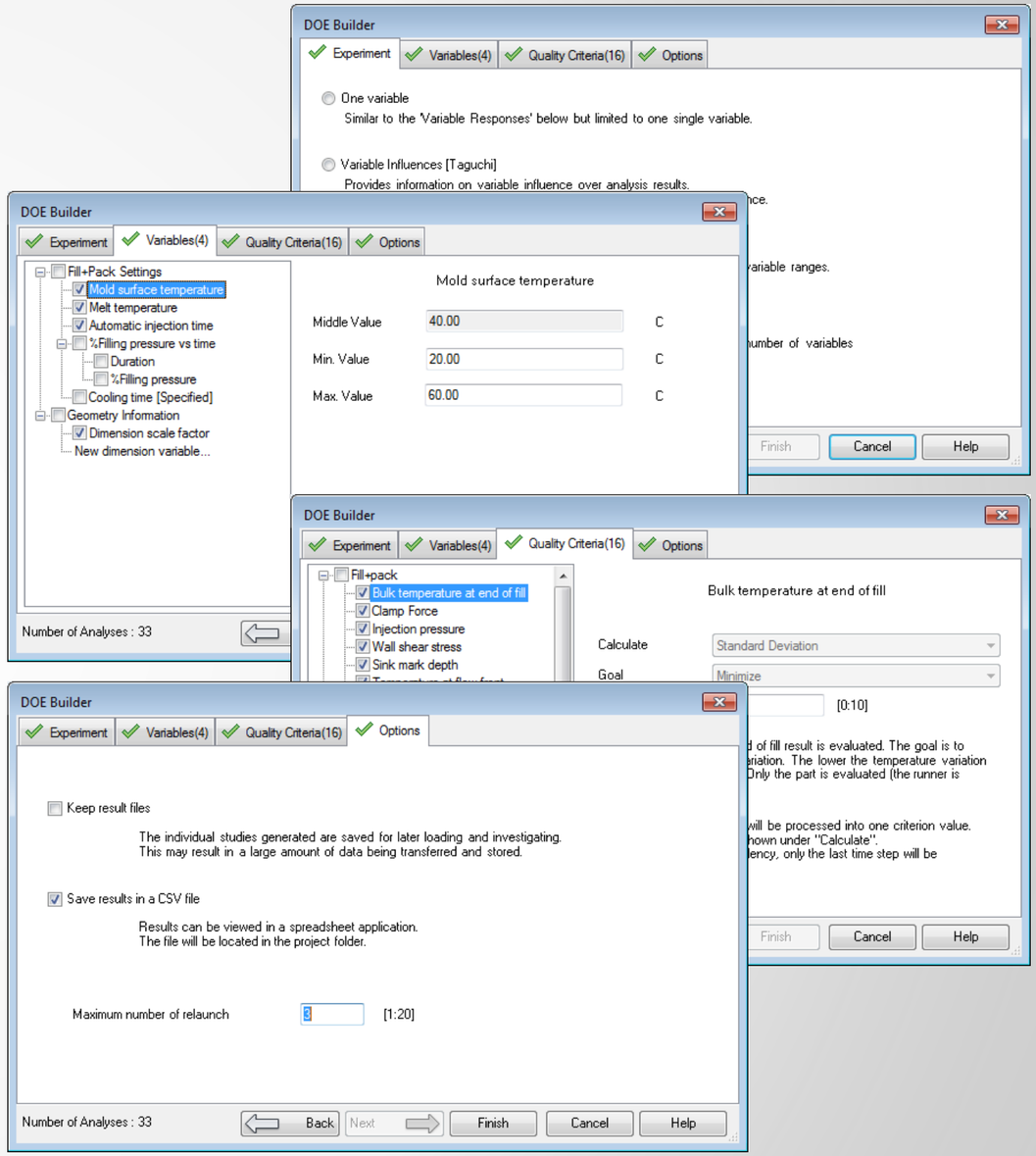




Interactive Optimization

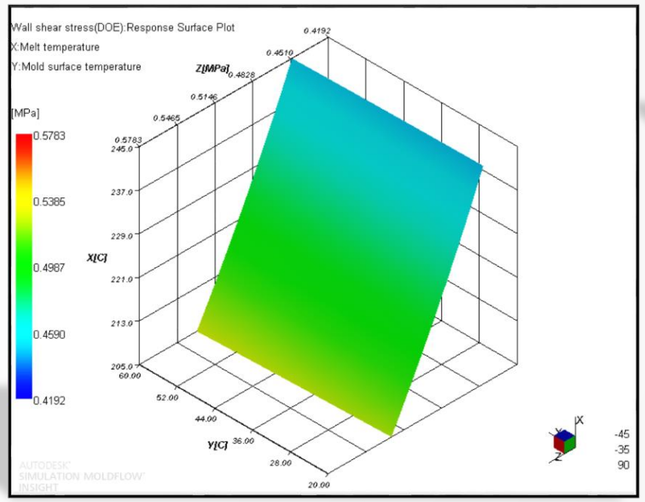
Design or Experiments (DOE)

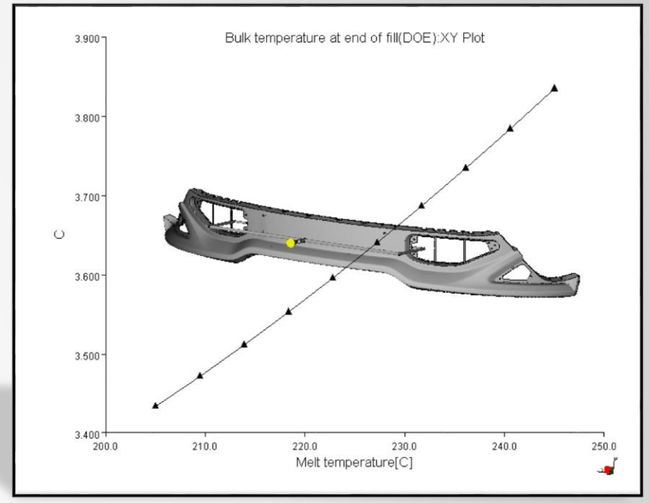
- Design of Experiments
  - Single Variable
  - Variable Influence (Taguchi)
  - Variable Responses (Factorial)
  - Variable Influence then Responses
    - Specified Influence Variables
- Define Variables
  - Specify Input Variables
- Define Quality Criteria
- Options

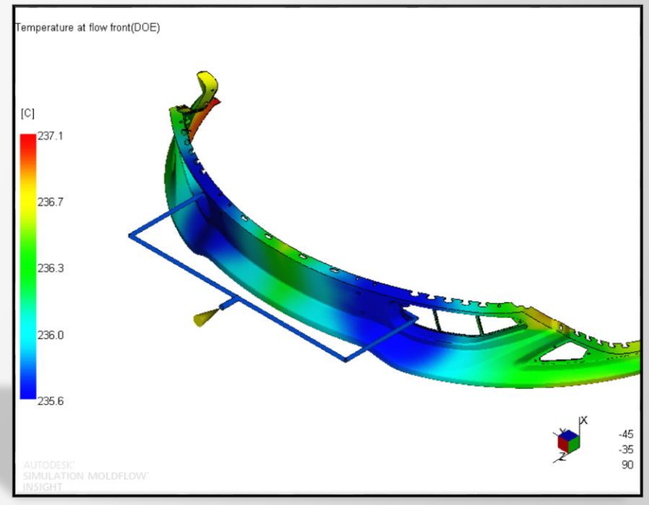


Design of Experiments (DOE) – cont'd

- XY Plots
- Surface Response
- Graphical Results Response

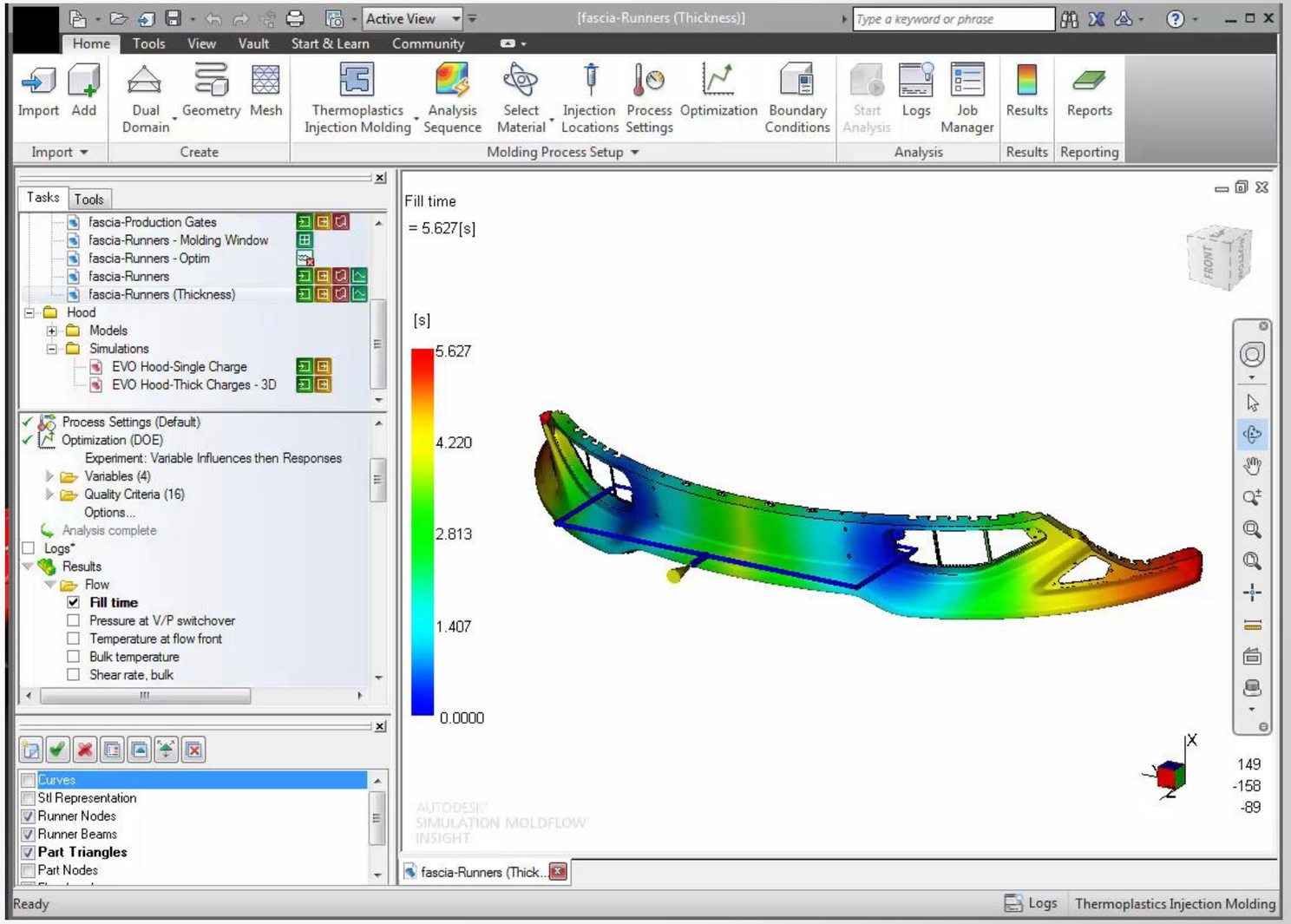




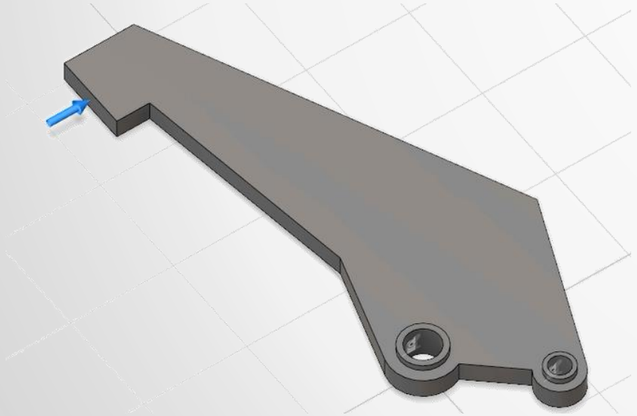


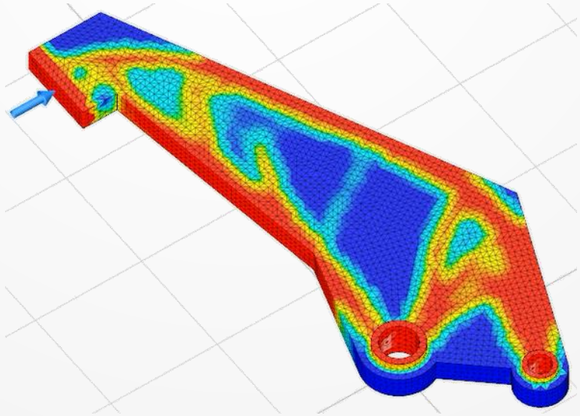
Design of Experiments (DOE) – cont'd

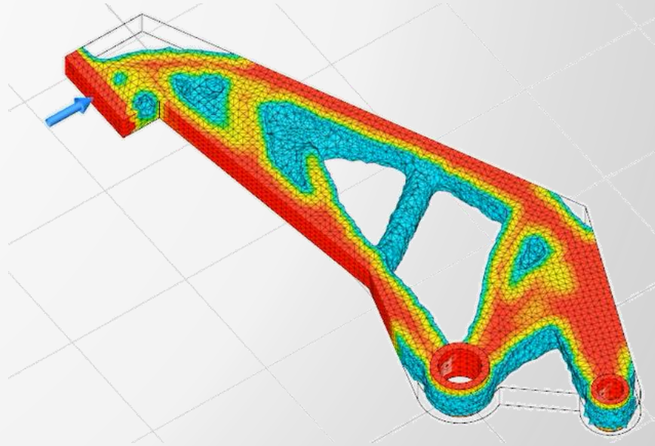
- Interactive User Optimization
- Direct Interactive Tools
- Direct Responses
  - Results Comparison Explorer
  - XY Plots
  - Response Surfaces
  - Graphic Plot



Optimization: Future







Autodesk SIMSTUDIO Platform

- Next generation Unified platform (Fusion)
- Geometry: Autodesk Shape Manager
- Optimization (Built-in)
- Intuitive Multiphysics
- Cloud-connected
- Automation Tools

Common Simulation Inputs

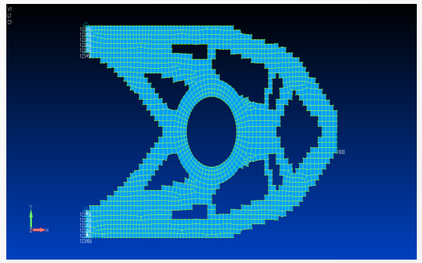
- Geometry
- Loads: Force, Pressure
- Constraints: Fixed, Frictionless
- Materials
- Settings

Parametric Optimization

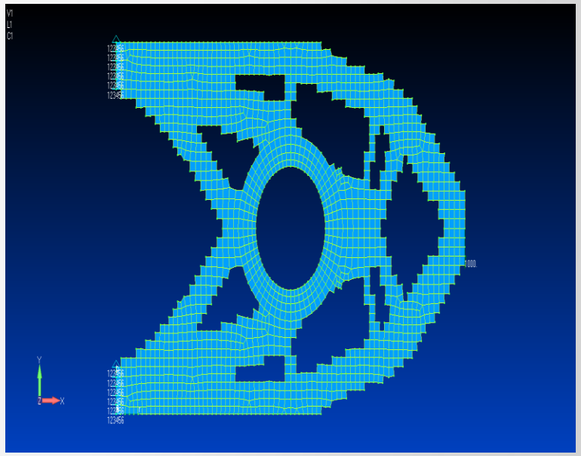
- **Concept**: Given a set of goals and constraints, vary parameters to find the variation/s that meets a set of performance targets.

- Also known as Size/Shape optimization

- **Stage**: Parametric Design



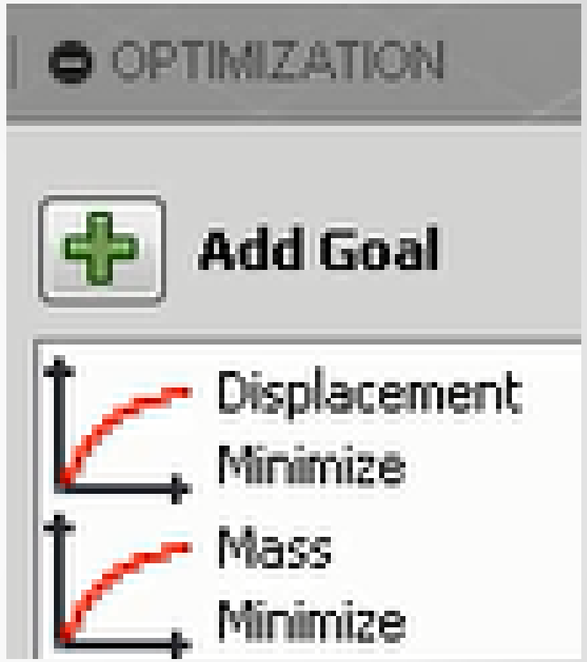
Small

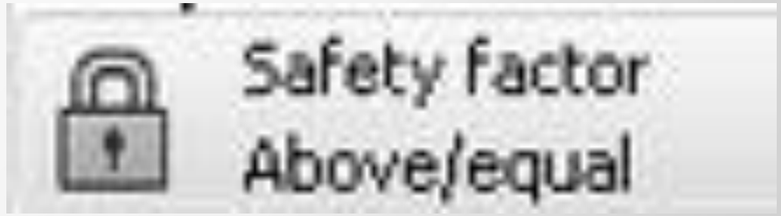


Large

SimStudio Platform – Parametric Opt

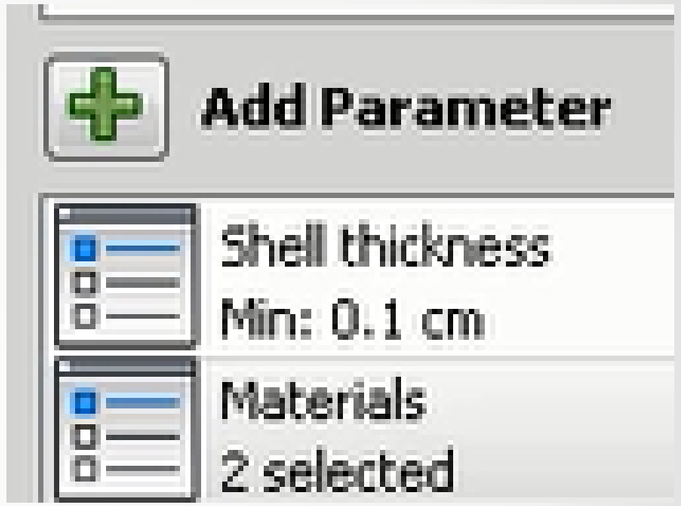
- **Inputs**
  - **Goal**: Objective
    - eg Minimize Displacement
    - eg Minimize Mass
  - **Constraint**:
    - Specify boundaries
    - Algebraic Formula
    - eg Safety Factor > 2





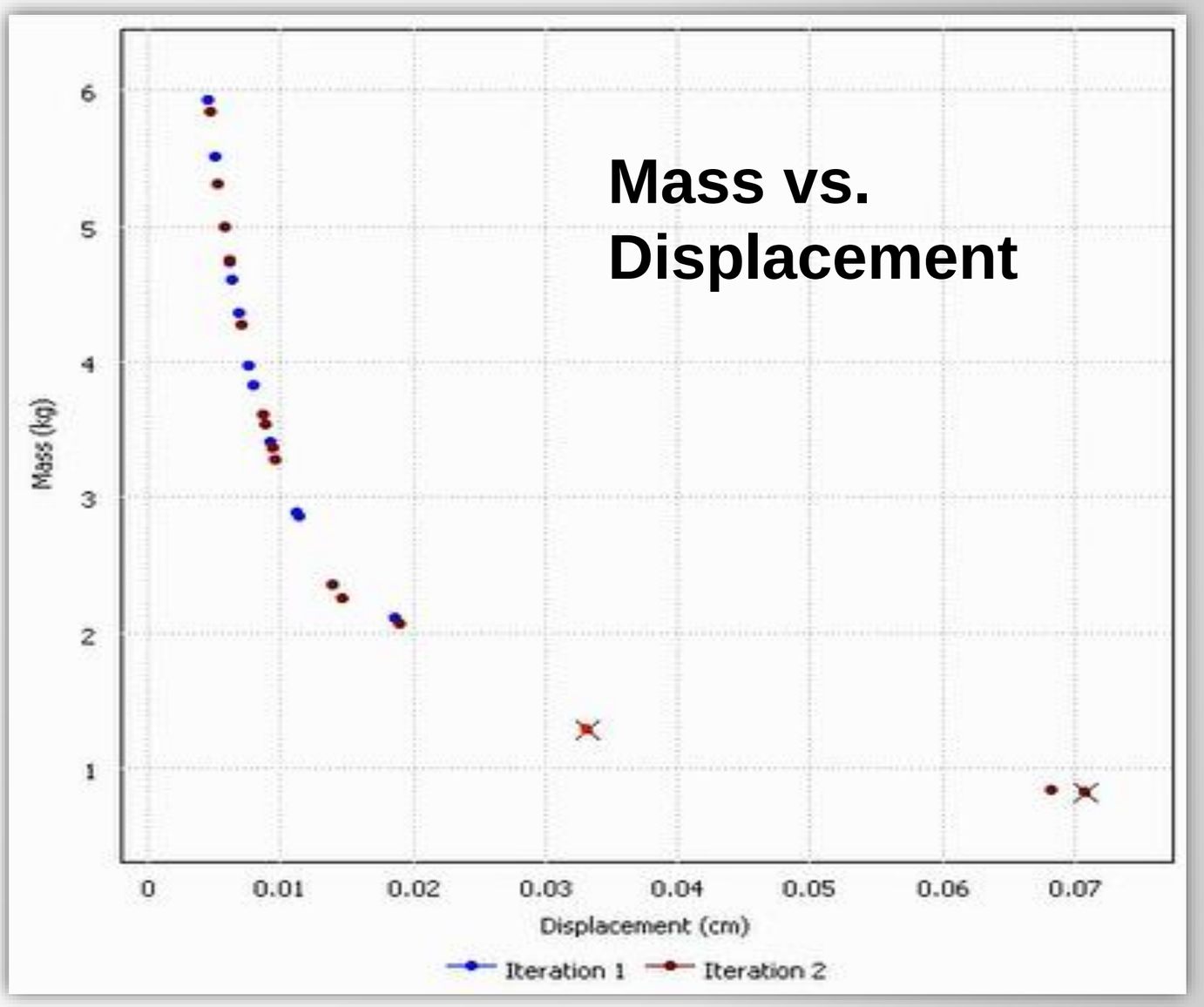
SimStudio Platform – Parametric Opt

- **Parameters**
  - **Continuous:**
    - Shell thickness [0.2 – 0.8, 0.1]
    - Force/Pressure
    - Extrusion length
  - **Discrete:**
    - Material [Aluminum, Steel]
    - Number of ribs in a pattern
- **Output:** Optimized shape/s

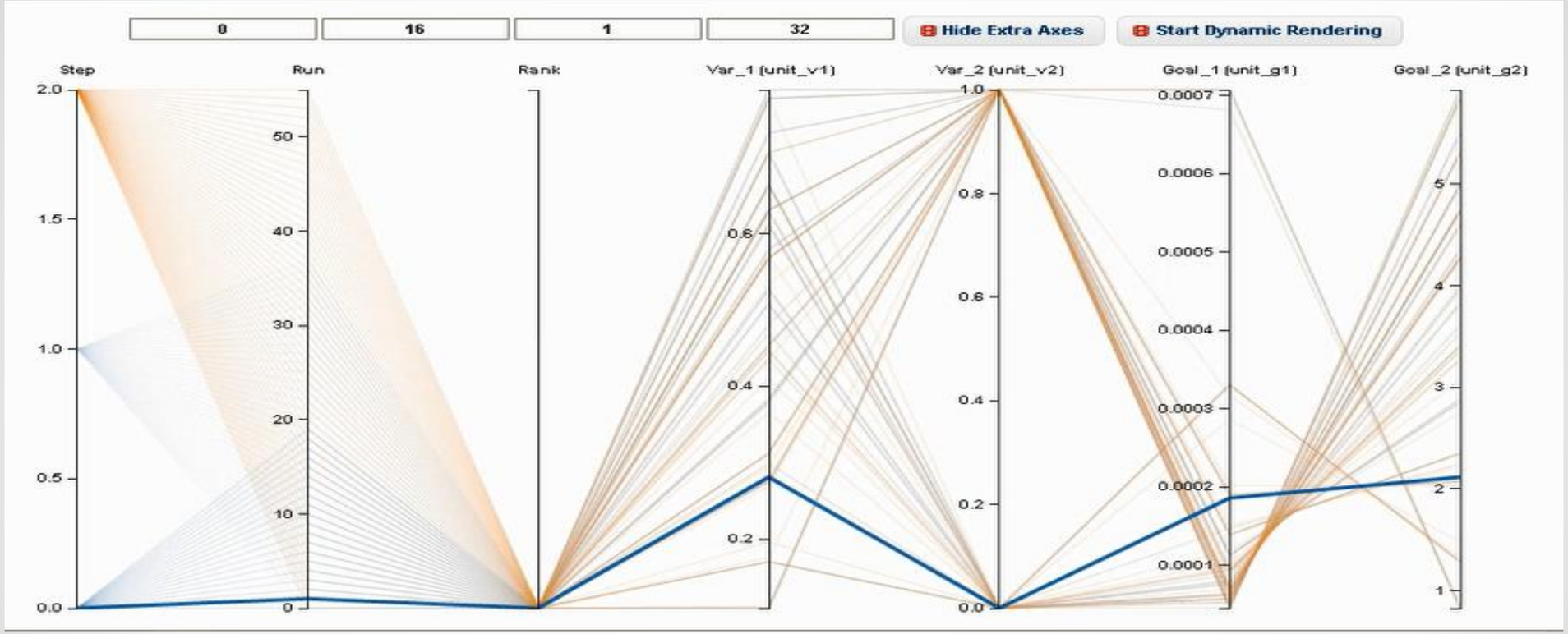


Optimization plots

- **Pareto**
  - Vilfredo Pareto, Economist
  - 80-20 rule
  - Trade-off analysis
- **Sensitivity**
- **Progress**
- **Scatter**



Parallel Coordinates



A spread on this input shows little influence

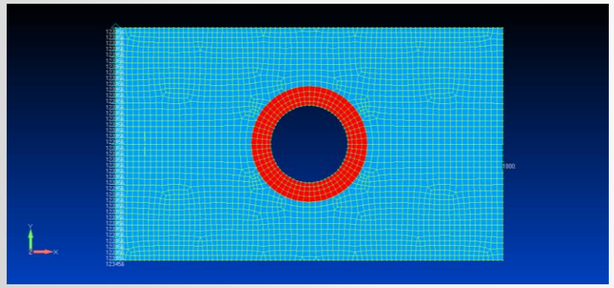
Most successful configs at two extremes for this input

SimStudio Platform: Topology Optimization (TO)

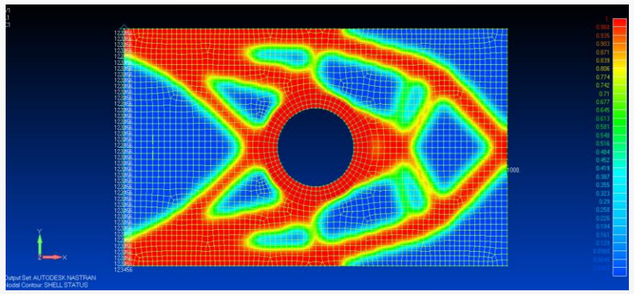
- **Concept**: Given a set of goals and constraints, find optimal mass distribution that meets a set of performance targets.

  eg. Varies topology, i.e. position and # of holes.

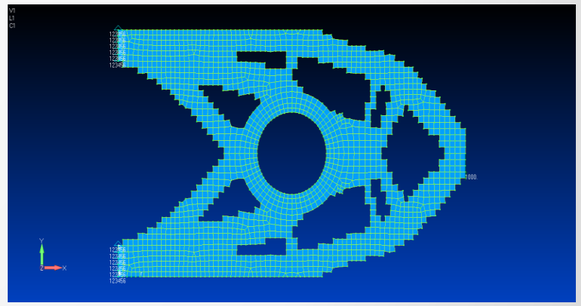
- **Stage**: Concept design



Cantilever (**Keep**)



Opt adds/removes elements (**Remove**)



Optimized result

Topology Optimization

- **Inputs**
  - **Goal**: Minimize compliance
  - **Constraint**:
    - Mass Target (%): The target mass in the model after the optimization
    - “Keep Out” regions: Do not optimize away these regions
  - Tolerances
- **Output:** Optimized mesh model/Solid
- Uses Nastran technology

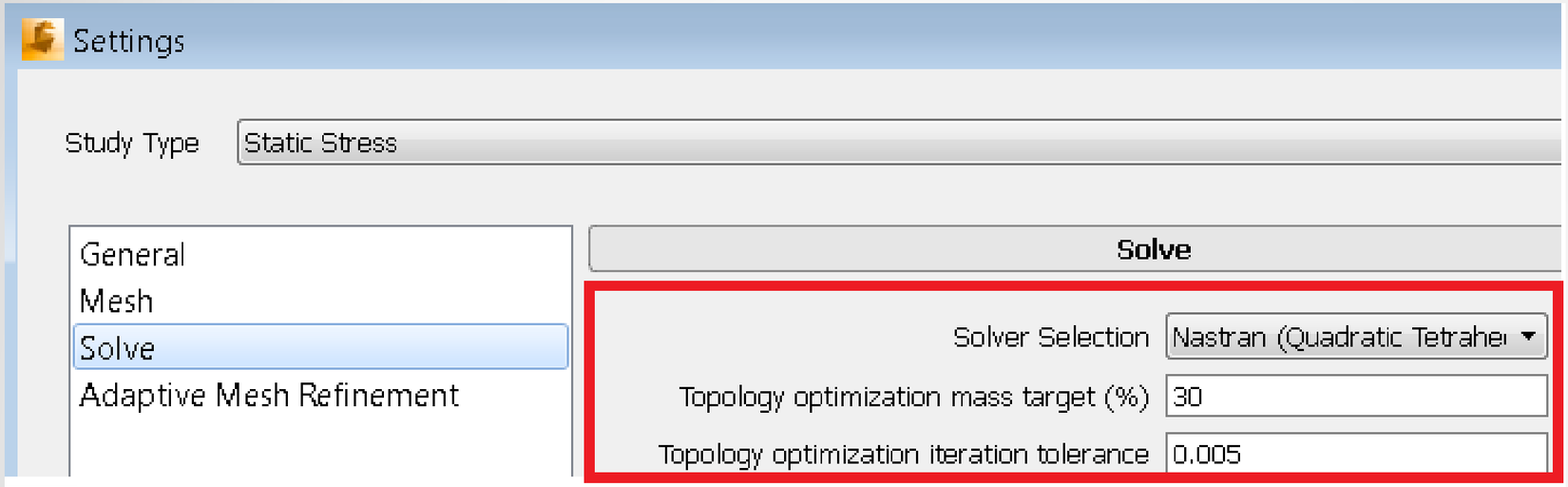
(Solid Isotropic Material Penalization (SIMP) with sensitivity filter)

Topology v/s Parametric Optimization

	Topology Optimization	Parametric Optimization
Design Stage	Concept	Parametric
Output	Mesh/Solid	Solid
Analysis & Solving	Desktop	Cloud
Technology	Autodesk Nastran Solver	Autodesk cloud-based optimization

- **Gains**: Reduce time, cost + improve performance

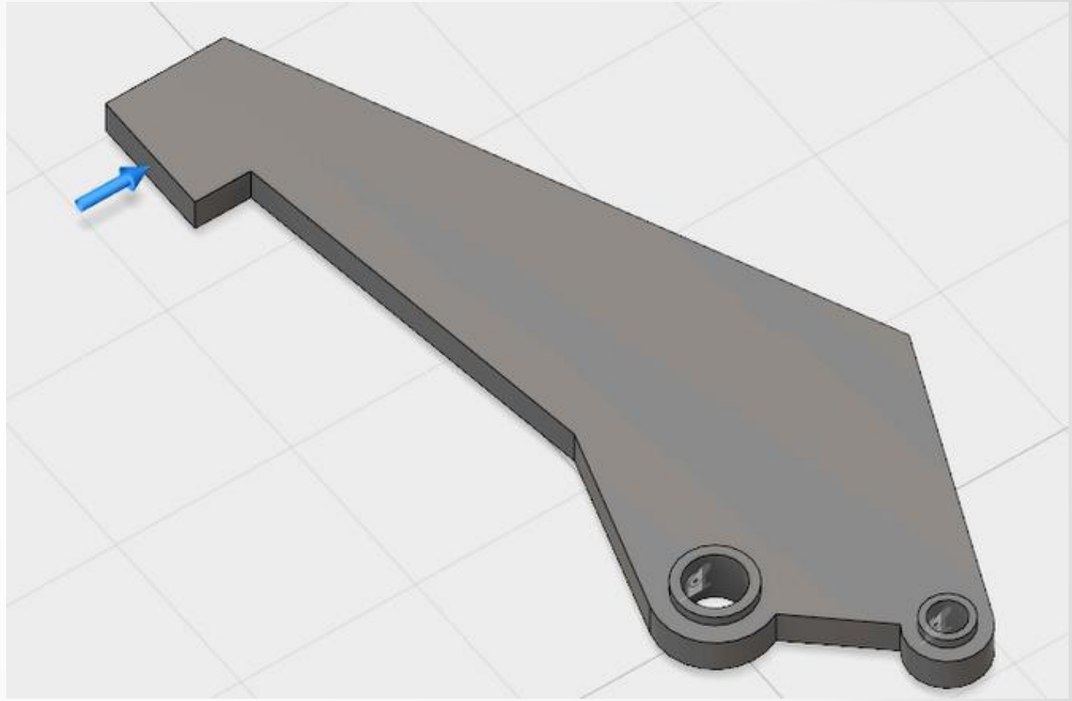
TO: Settings



- Create a Linear Static Stress(LSS) Study
- Right Mouse Button (RMB) on Study, Settings, Solve
  - Setting: Select Quadratic tets
  - Goal: Mass target (30%): Defines how much mass is remaining in the model

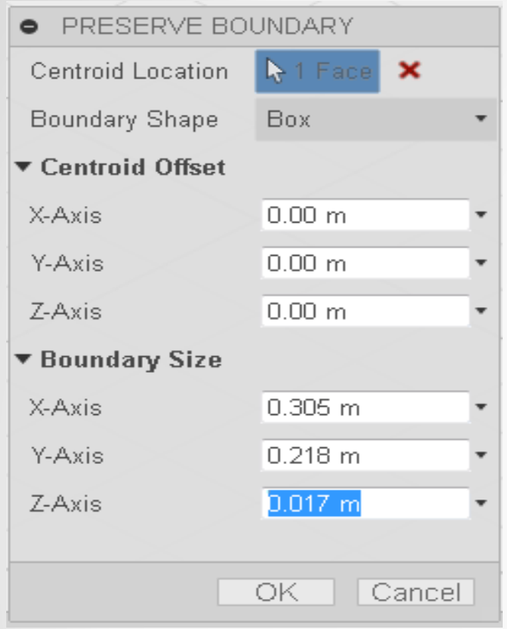
TO: Pre-Processing

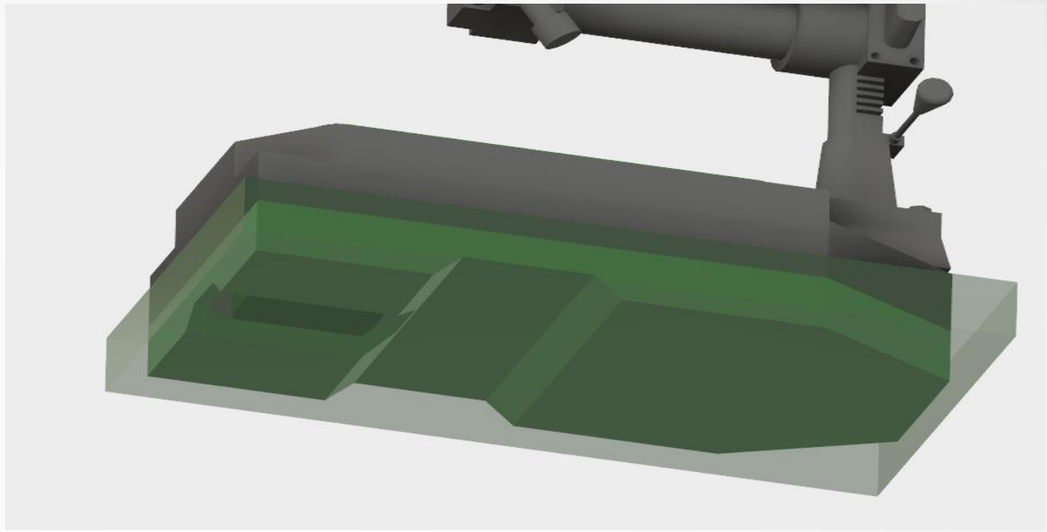
- Specify Common Inputs
- Specify TO goal
  - Mass target
- Specify TO constraints
  - Preserve Boundary



- Gripper Arm Design Challenge

TO: Pre-Processing - Preserve boundary

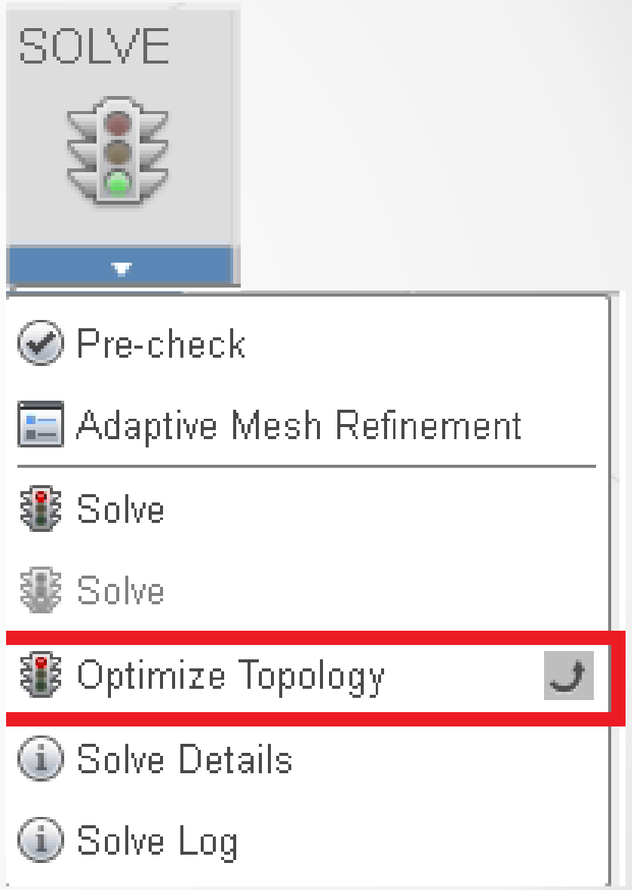




- Boundary volumes like **box, sphere, cylinder/faces** can be specified
- Regions of the model where loads, constraints and contacts applied are automatically kept (Keep-Out regions)
- Preserve Boundary Command
  - Boundary volume Center can be moved
  - Manipulators for sizing

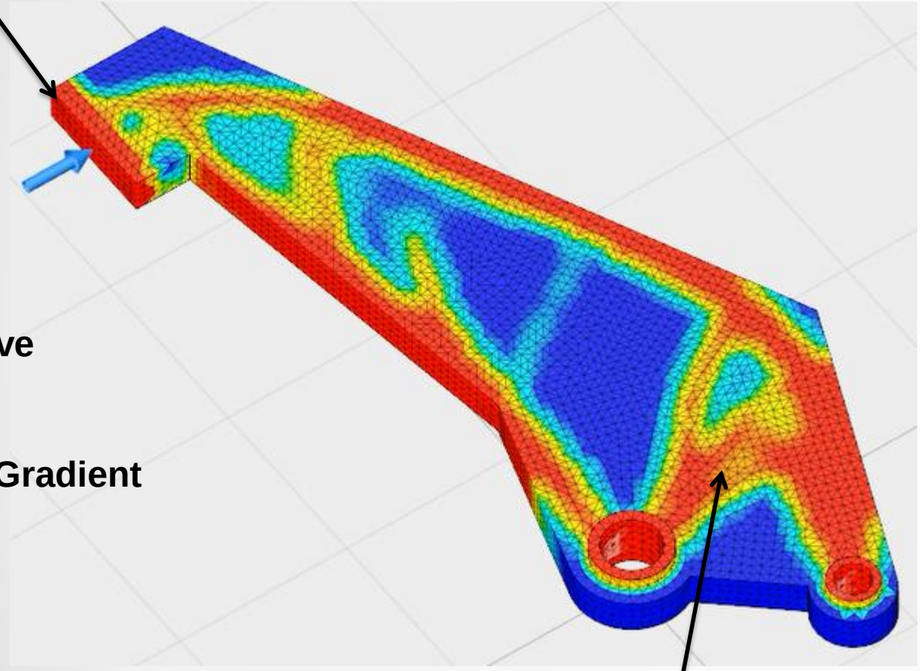
TO: Solve

- Solve, Optimize Topology
- Presented as a different type of solve
- Linear Solve
- Normal Modes & Linear buckling in wish list



TO Post-processing: Results

Non-Design Region



Color scheme

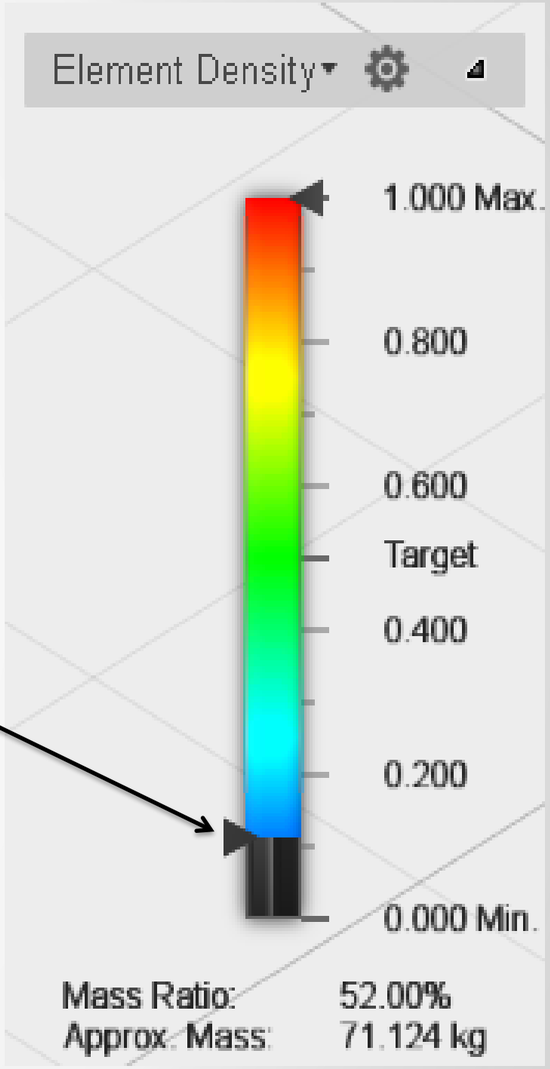
Remove

Keep

Other colors: Gradient

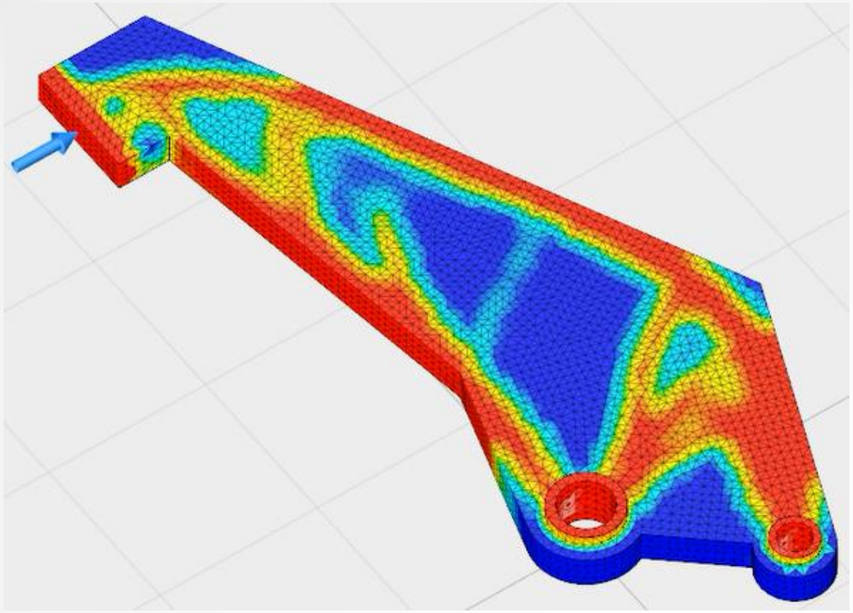
Design Region

Slider to control add/remove elements



Mass Ratio for a given slider position

TO Demo

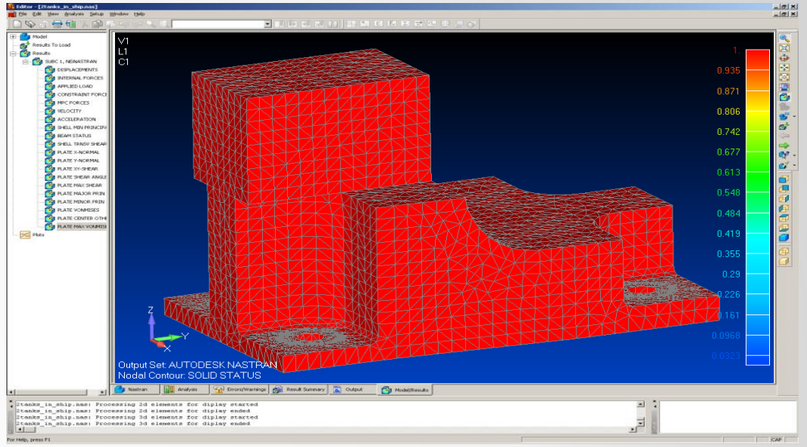


TopOpt.mp4

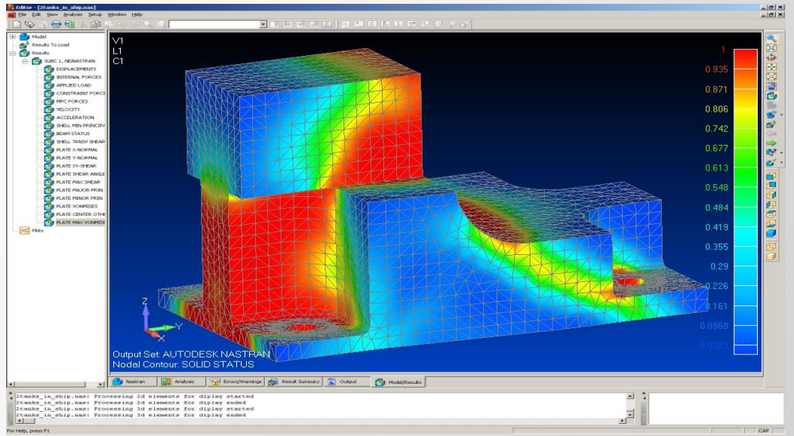
Topological Optimization With Angled Load.mp4

Nastran optimization capabilities

- All load and constraint types + Nastran SUBCASE structure for defining multiple load and constraint cases
- Use of linear contact, bolt preload, composite elements, other element types, features, etc.
- All shell and solid element types for design space
- All element types for non-design space
- Detailed status information gives progress of solution and each optimization iteration



Iteration 1



Iteration 2

Summary

- Optimization is a must in today's age
- Autodesk is committed to solutions covering a host of disciplines and needs

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