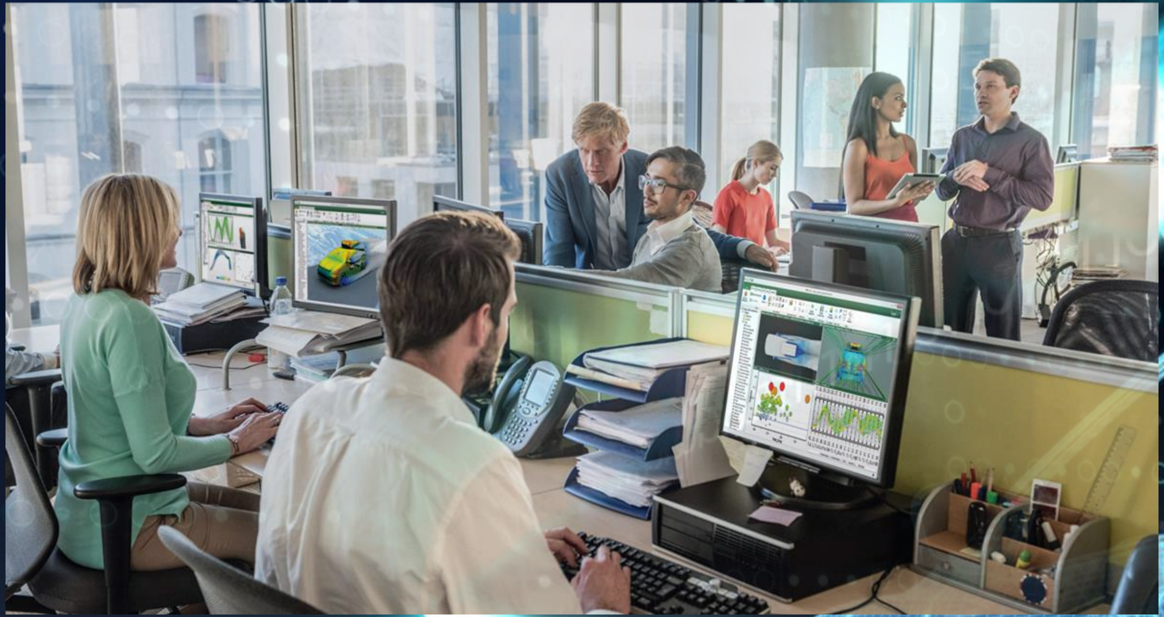

Discover Better Designs, *Faster!*

Driving Product Innovation Through Design Exploration

Realize Innovation.

Executive Summary

Chassis design is a complex, and often iterative process, aimed at maintaining the suspension deflection angles within acceptable limits, satisfying structural requirements, and reducing material cost.

Although simulation has long played a key role in validating designs, its usage to discover new, higher performing, innovative designs has been limited until now.

This presentation highlights how modern **Process Automation, Simulation** and **Design Space Exploration** can be used in a managed environment to consistently deliver high performance, low-cost designs.

Design of a wheel suspension assembly, including structural and multi-body dynamics considerations of a lower control arm component, is used to show how **HEEDS MDO**, deployed together with **Simcenter 3D, Motion and Structural** solutions, can enable engineers to **discover better designs, *faster!***

Case Study: Vehicle Suspension Assembly

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The Challenge (Objectives):

- Minimize *Mass (Lower Control Arm)*

Requirements (Constraints):

Motion:

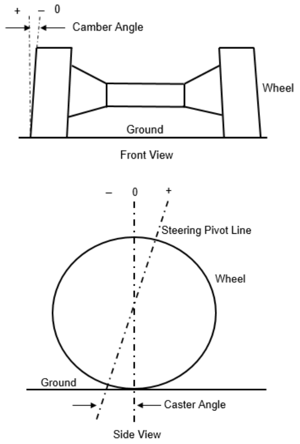
- -0.5° ≤ Maximum Camber Angle ≤ 0.5°
- -0.5° ≤ Maximum Caster Angle ≤ 0.5°

Structural:

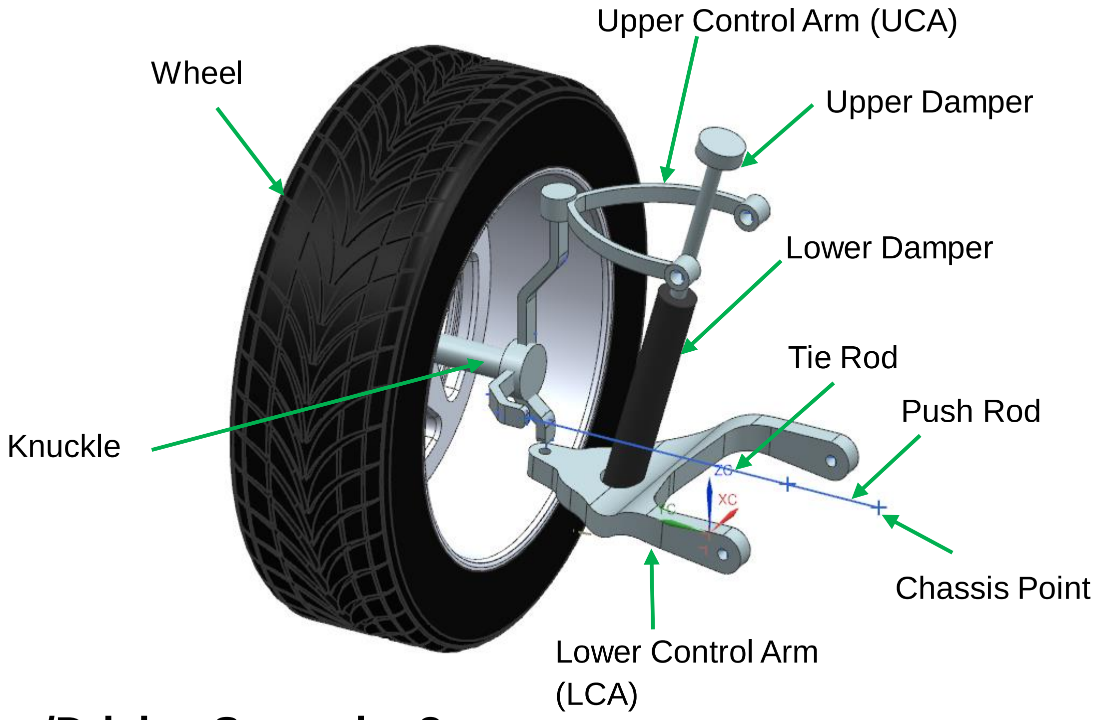
- Maximum Displacement ≤ 0.5 mm
- Factor of Safety ≥ 1.5

Design Variables:

- 11 LCA Shape Parameters
- 20 LCA & UCA Linkage Hardpoints



Simcenter 3D Model



Operational Conditions/Driving Scenarios?....

Case Study: Vehicle Suspension Assembly

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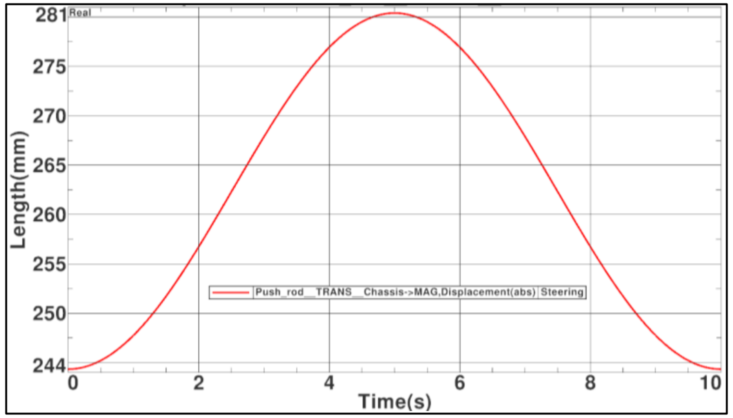
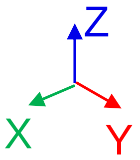
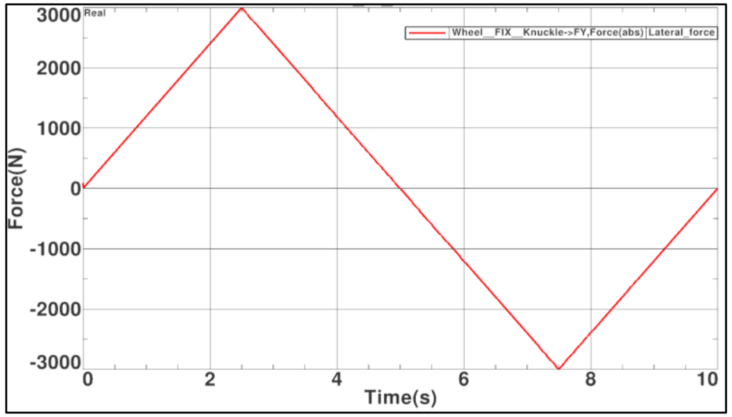
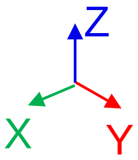
Steering



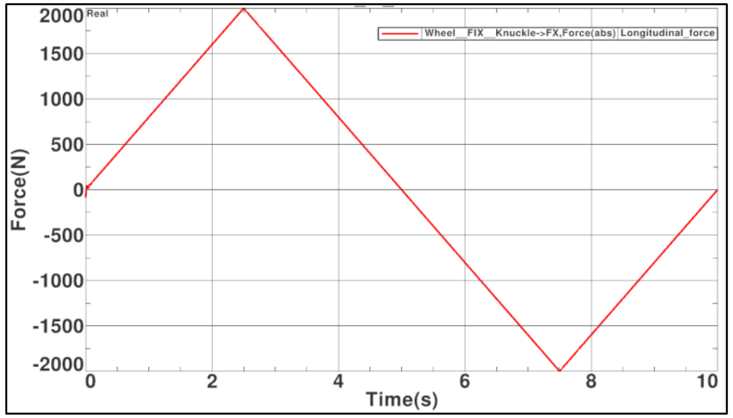


Drifting



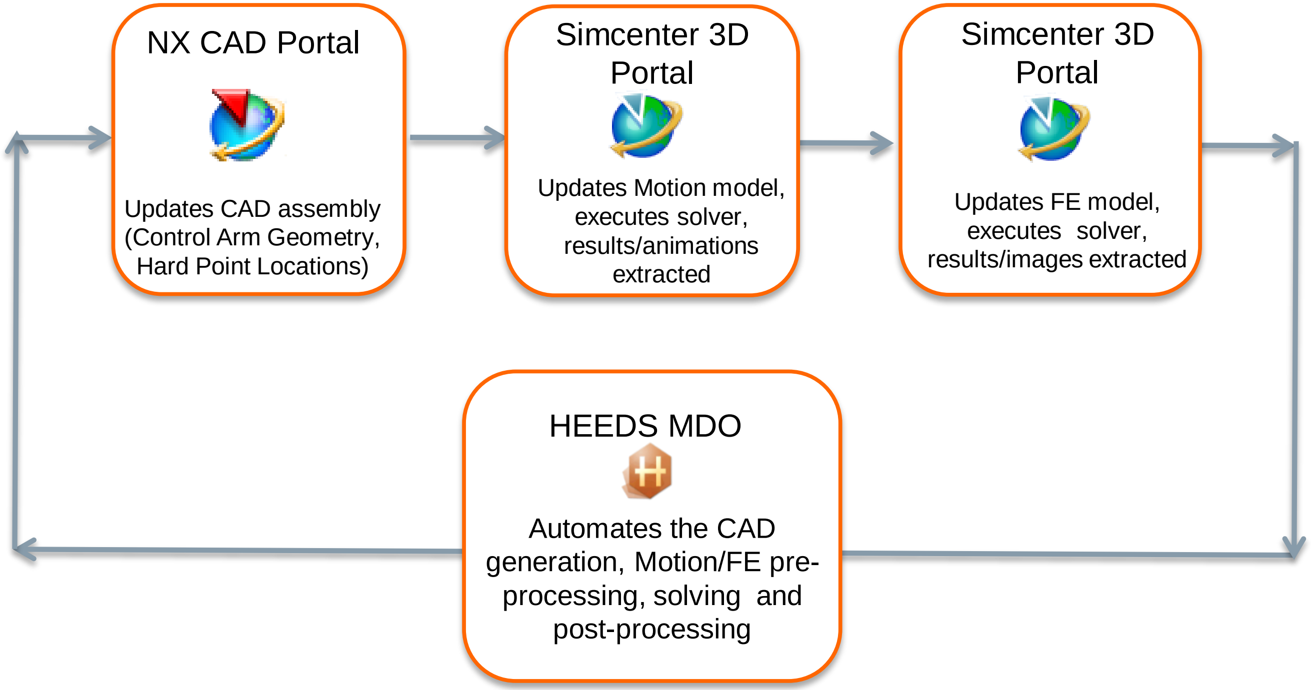


Braking



Case Study: Vehicle Suspension Assembly

Process Automation:



Process Automation

NX CAD Portal

A parametric CAD model was built in the Simcenter Modeling module

HEEDS drives the parametric Simcenter CAD model via the Expression Table in Simcenter

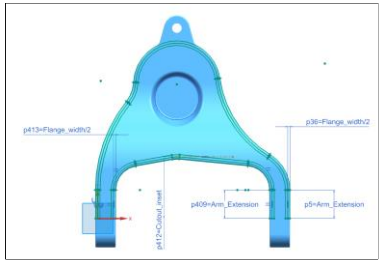
NX CAD

HEEDS

Tag

Expressions

	Name	Formula	Value	Units	Dimensionality	Type
24	AS_Arm_Extension	62	62	mm	Length	Number
25	AS_Arm_width	20	20	mm	Length	Number
26	AS_back_inner_radius	150	150	mm	Length	Number
27	AS_back_outer_radius	150	150	mm	Length	Number
28	AS_Cutout_inset	120	120	mm	Length	Number
29	AS_Flange_width	5	5	mm	Length	Number
30	AS_Front_Inner_Radius	200	200	mm	Length	Number
31	AS_Height1	40	40	mm	Length	Number
32	AS_Lower_Bend_Offset	74.6	74.6	mm	Length	Number
33	AS_Rear_Inner_Radius	127	127	mm	Length	Number
34	AS_Rear_Outer_Radius	382	382	mm	Length	Number
35	AS_rib_spacing	40	40	mm	Length	Number



Parametric CAD

Input Type	Name	Value
Expression	AS_Arm_Extension	Arm_Extension
	AS_Arm_width	Arm_width
	AS_back_inner_ra...	Back_inner_radius
	AS_back_outer_ra...	Back_outer_radius
	AS_Cutout_inset	Cutout_inset
	AS_Flange_width	Flange_width
	AS_Front_Inner_...	Front_Inner_Radius
	AS_Height1	Height1
	AS_Lower_Bend_...	Lower_Bend_Offset
	AS_Rear_Inner_R...	Rear_Inner_Radius
	AS_Rear_Outer_R...	Rear_Outer_Radius
	AS_rib_spacing	Rib_spacing

HEEDS NX CAD Input Portal

Updated Assembly

Process Automation
Simcenter 3D Portal

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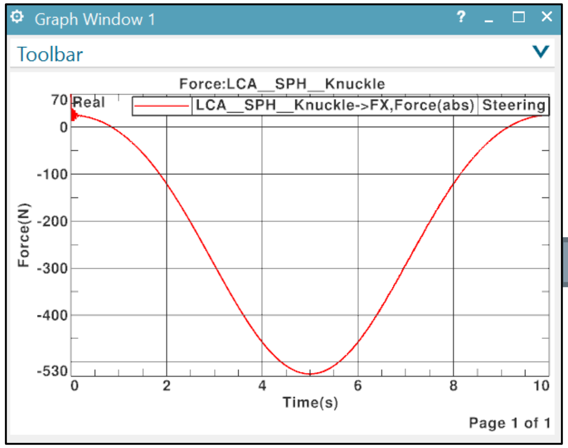
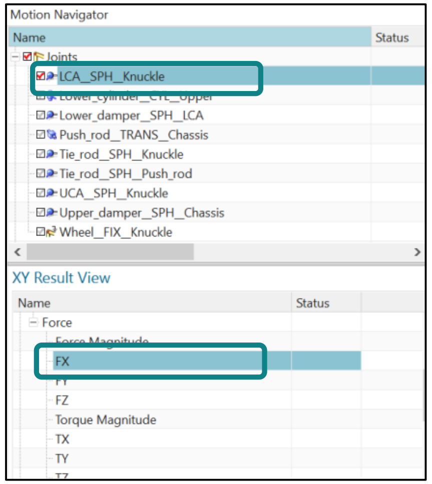
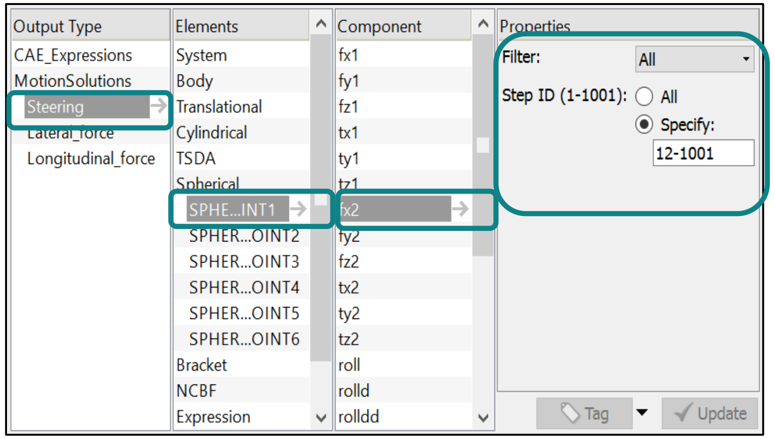


X component of force during steering at Knuckle-LCA spherical joint

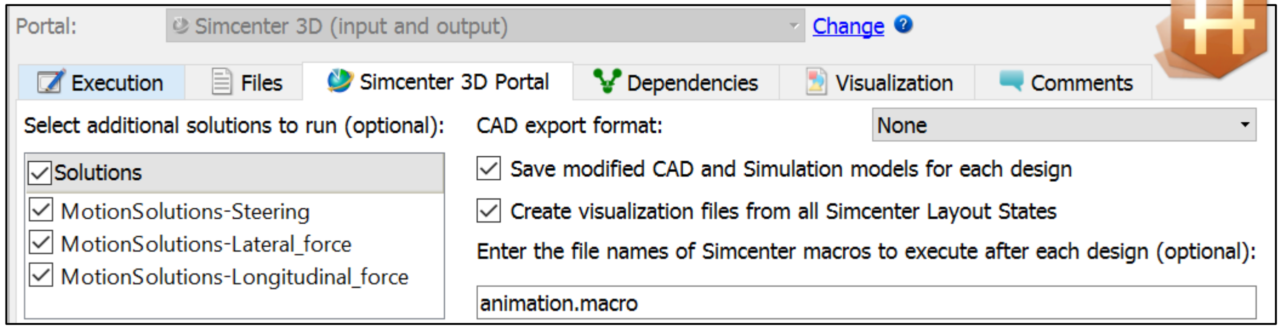


HEEDS

Tag



HEEDS Simcenter 3D Output Portal



Design Exploration

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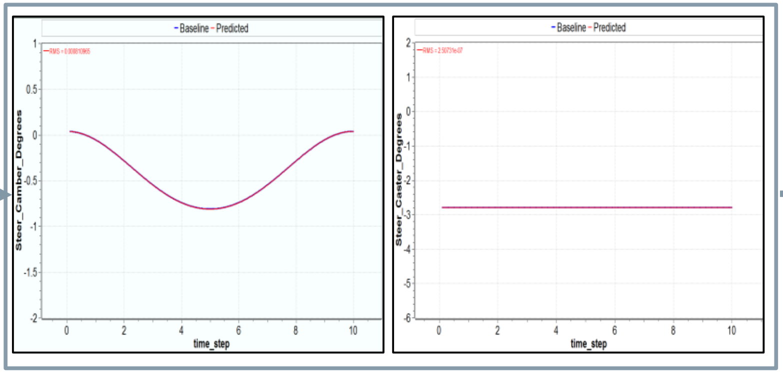
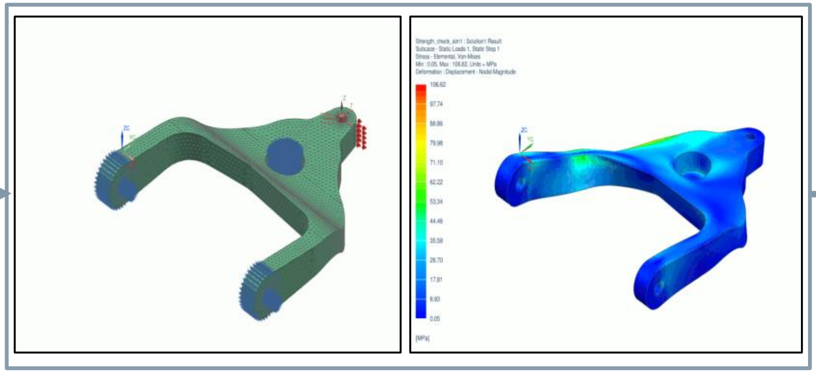
CAD Modeling

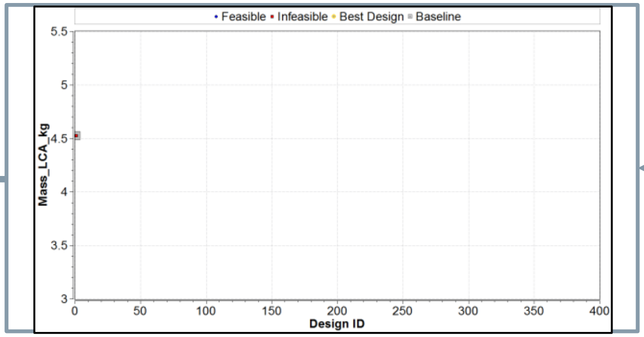
Directed Modification

Motion Simulation



FE Pre/Post-Processing & Solving





HEEDS' intelligent search algorithm SHERPA
- **Hybrid & adaptive functionality**
- **No model fitting or surrogates**

HEEDS Design Exploration

Design Exploration

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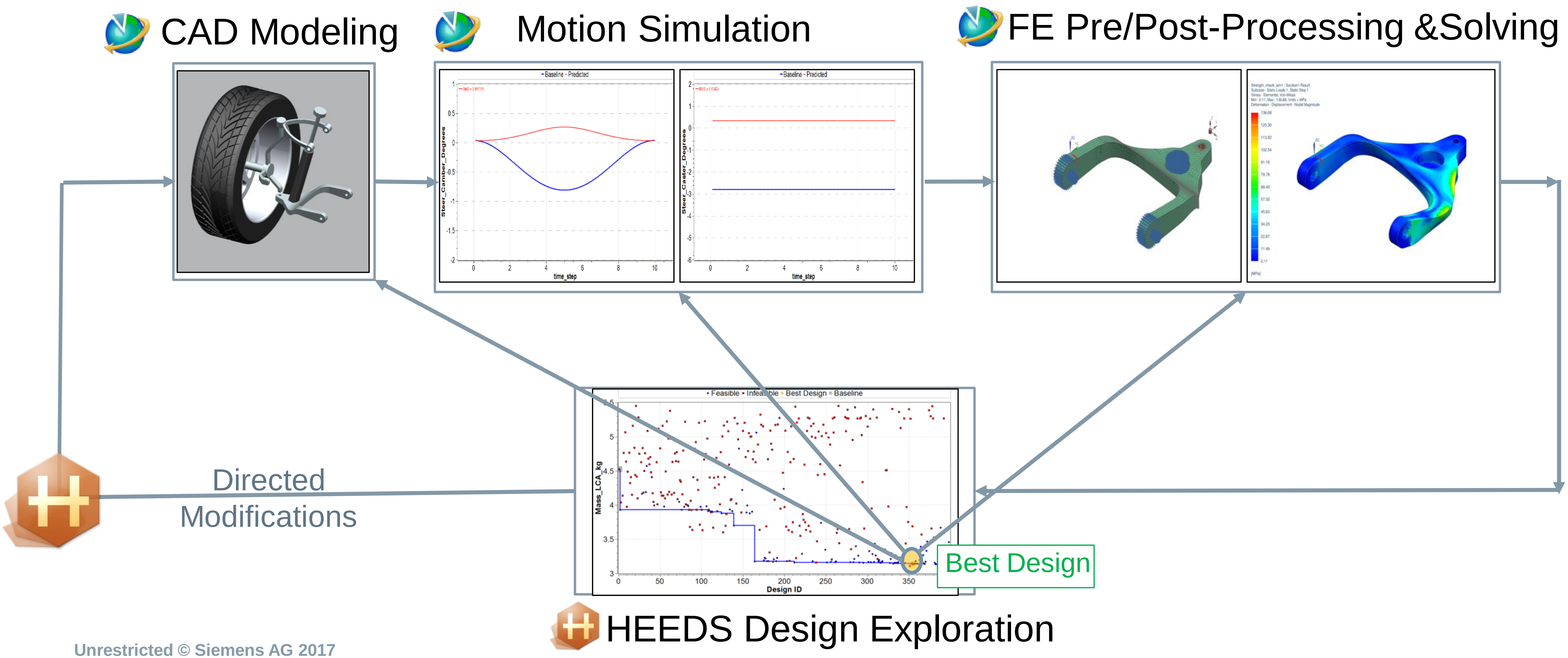
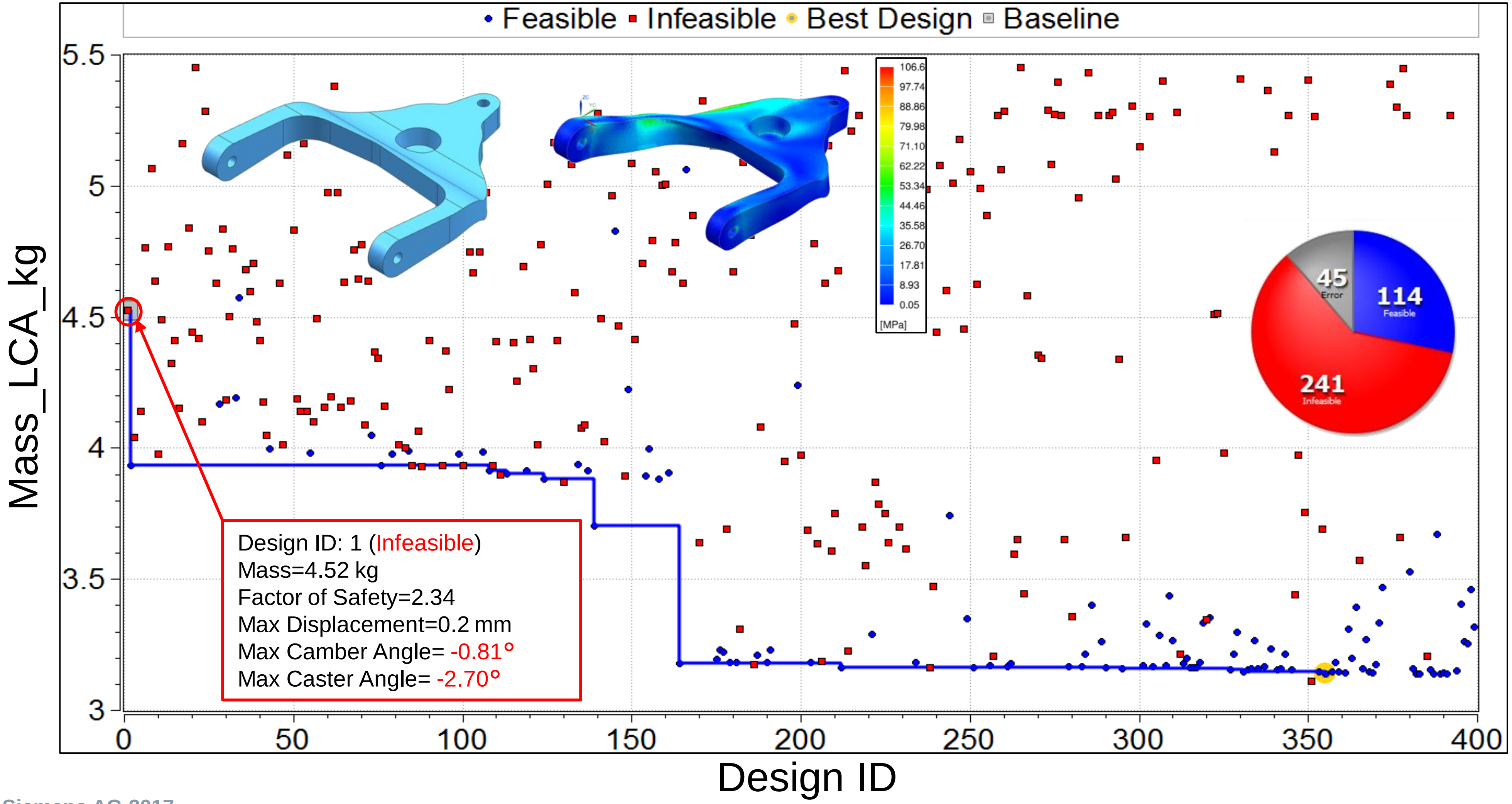


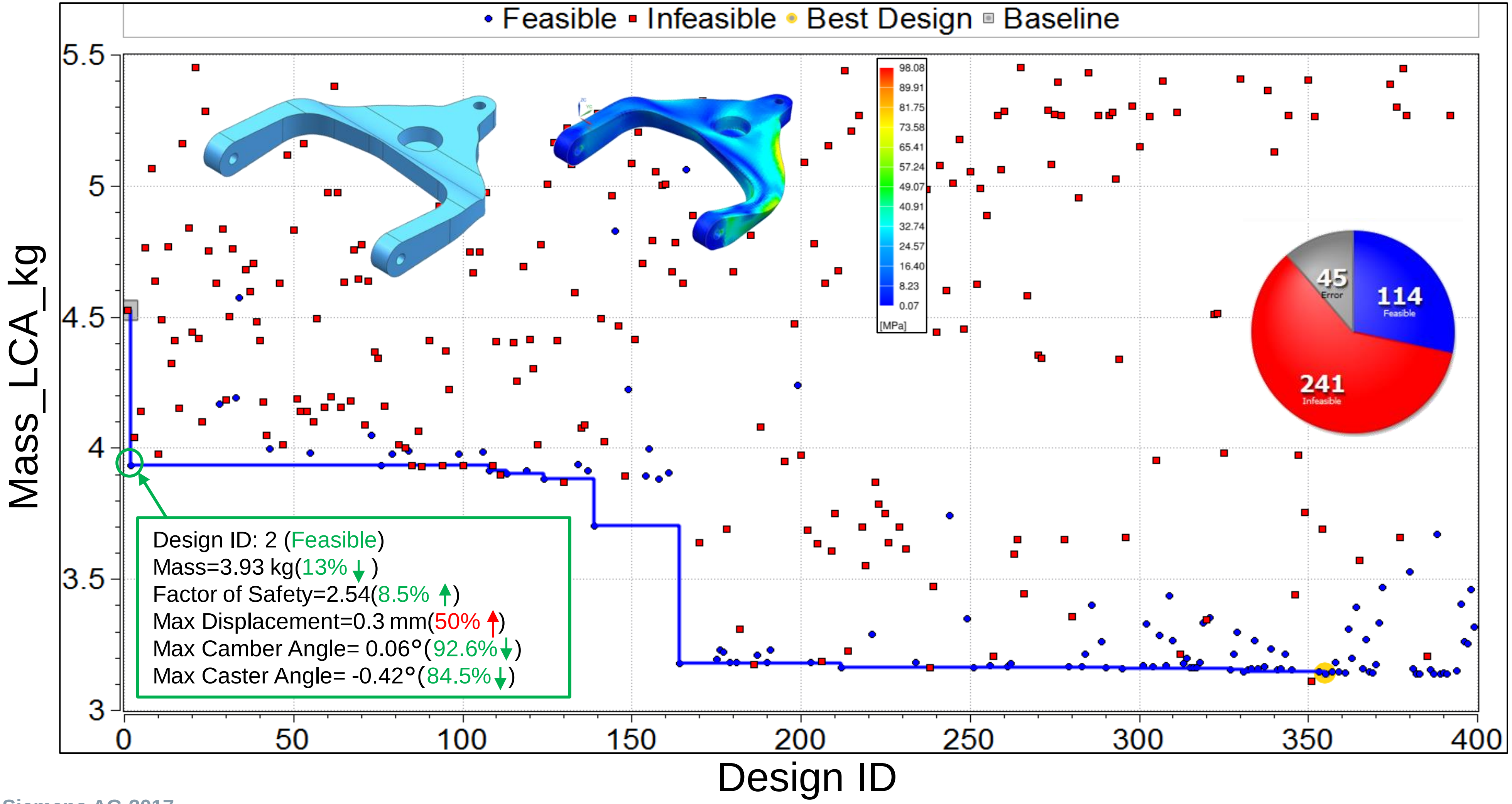
Design Exploration – Mass (Lower Control Arm)

Objective History Plot



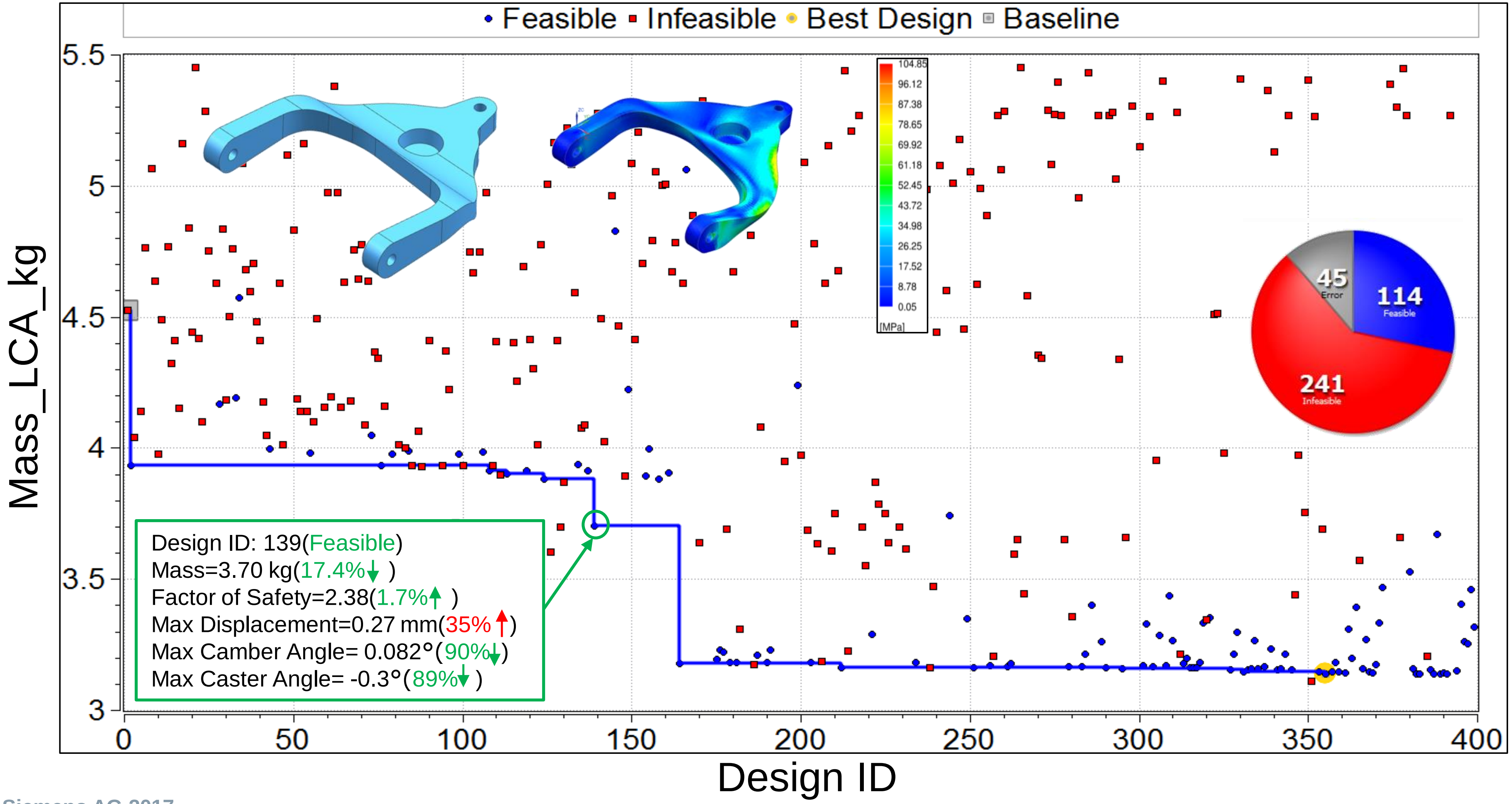
Design Exploration – Mass (Lower Control Arm)

Objective History Plot



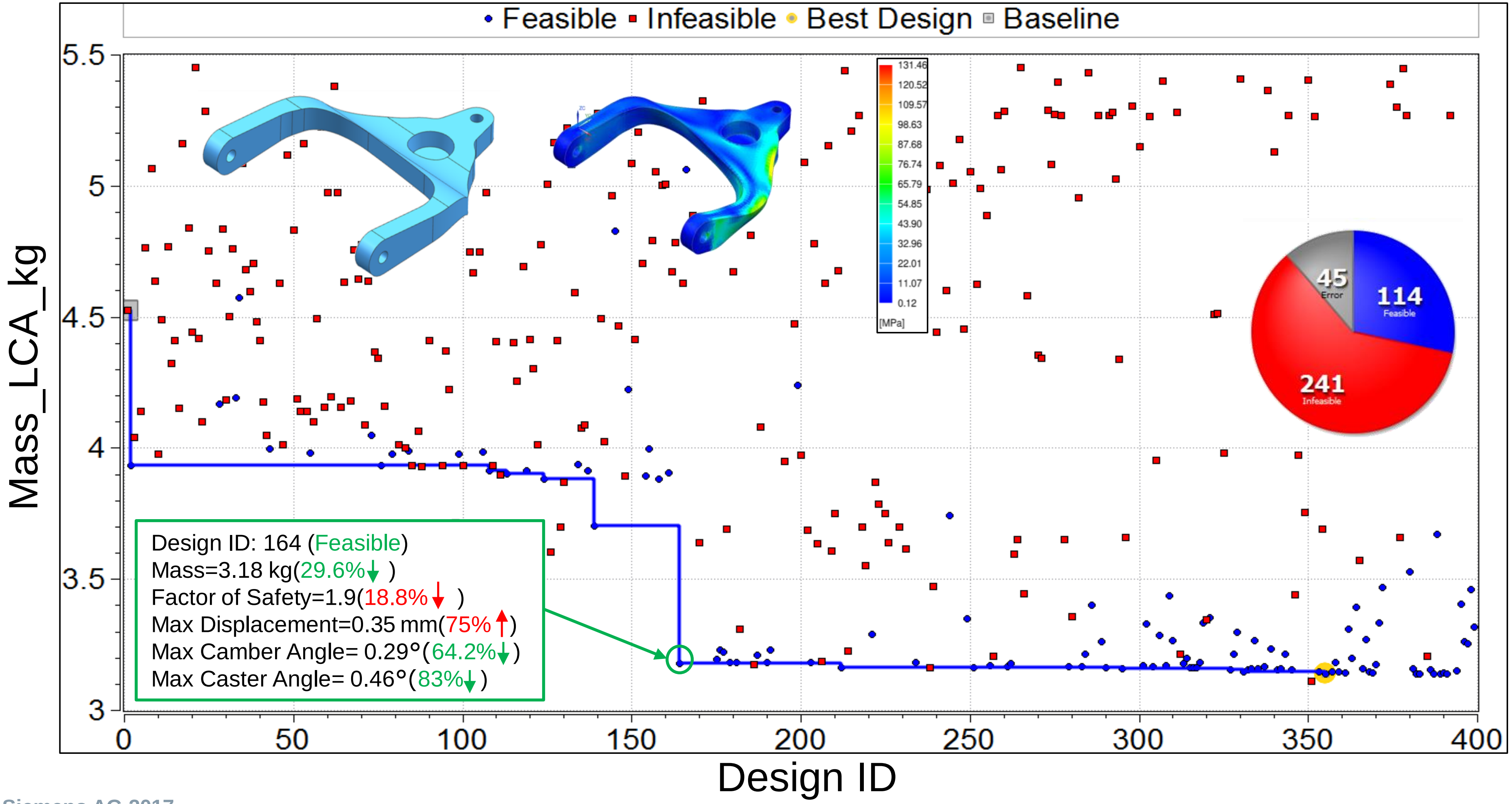
Design Exploration – Mass (Lower Control Arm)

Objective History Plot



Design Exploration – Mass (Lower Control Arm)

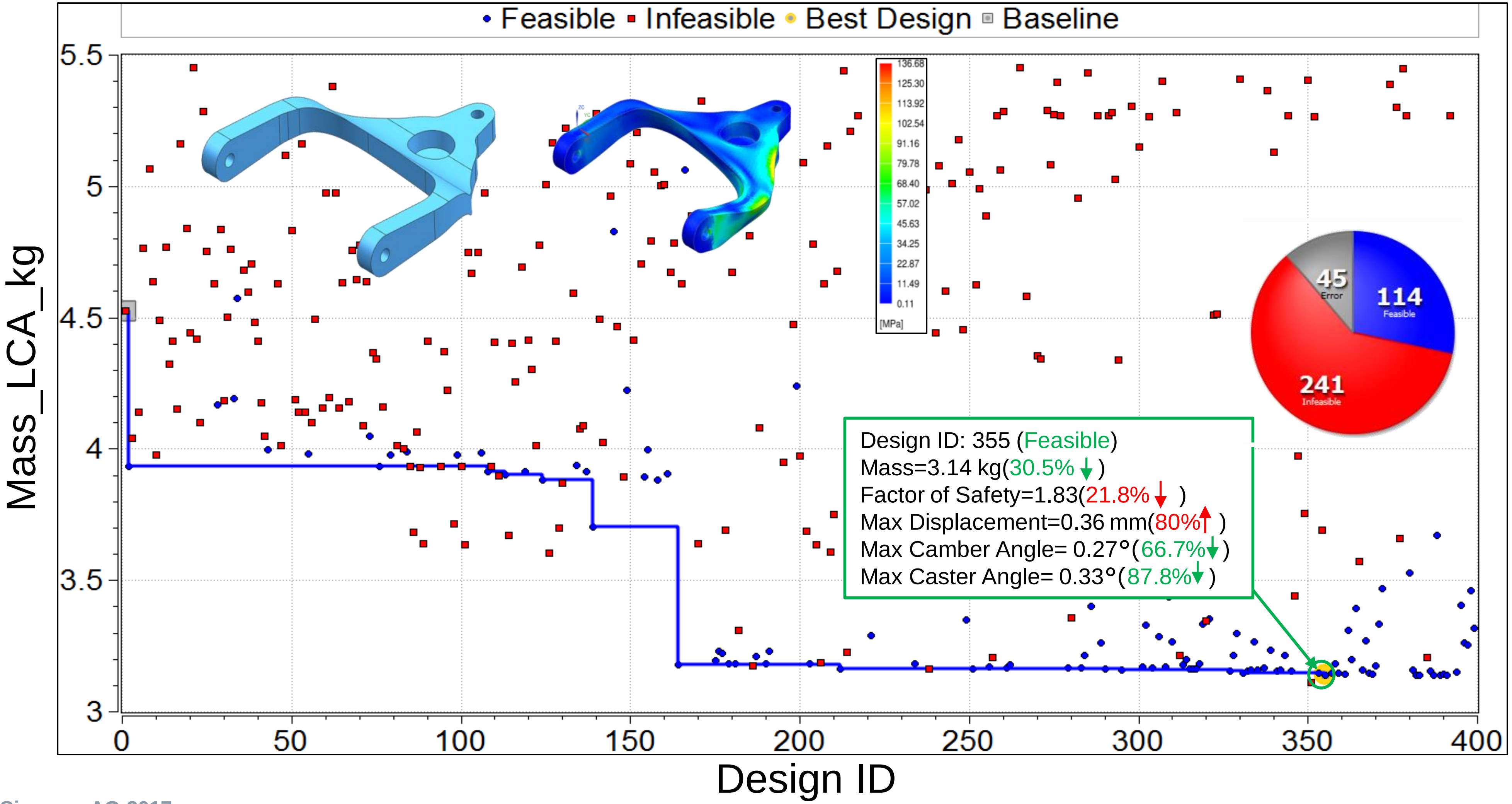
Objective History Plot



All percentages marked are with respect to the baseline values and considers absolute values only

Design Exploration – Mass (Lower Control Arm)

Objective History Plot



All percentages marked are with respect to the baseline values and considers absolute values only

Scalable Computation

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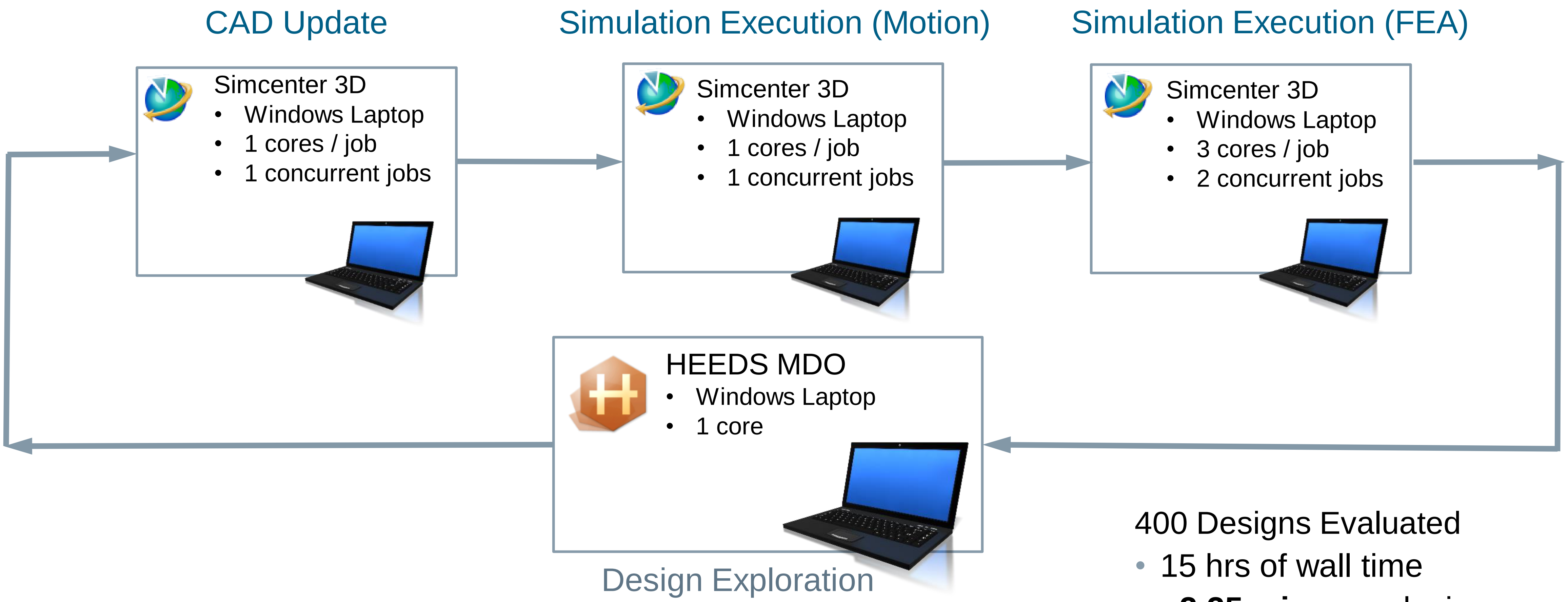

400 Designs Evaluated

- 15 hrs of wall time
- **~2.25 mins** per design

Constraint Analysis

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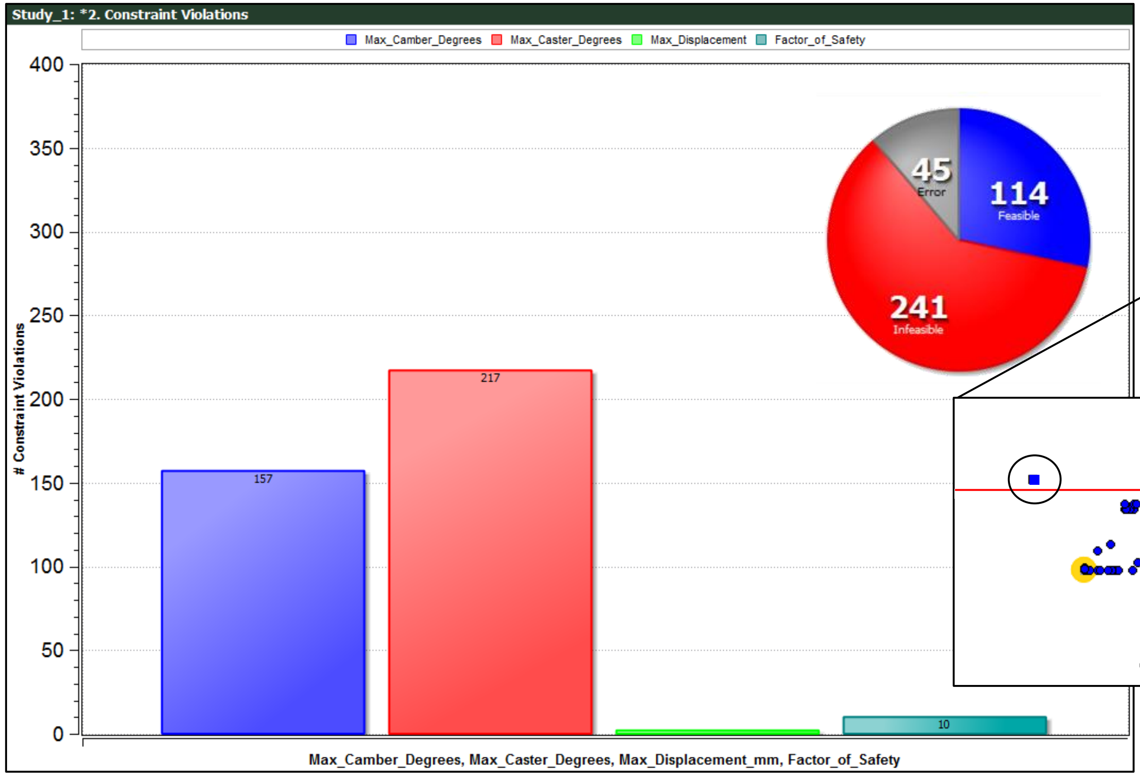

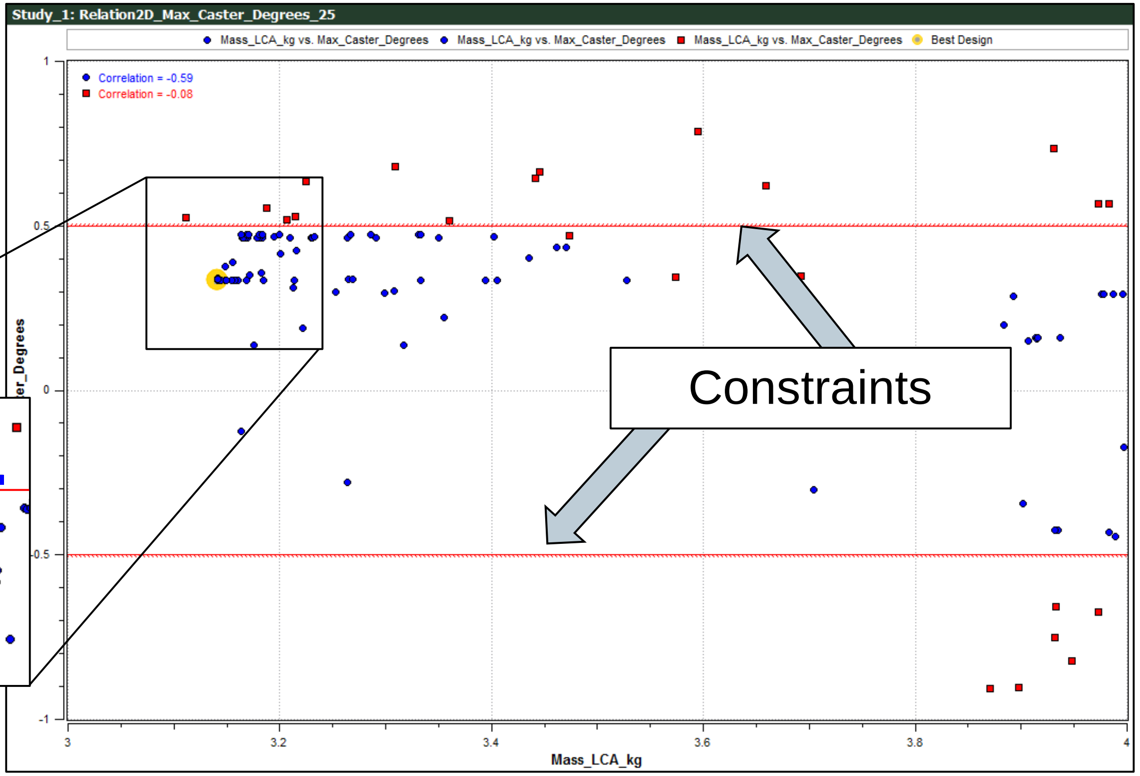

Assess Design Trends – Parallel Plot: Geometric Variables

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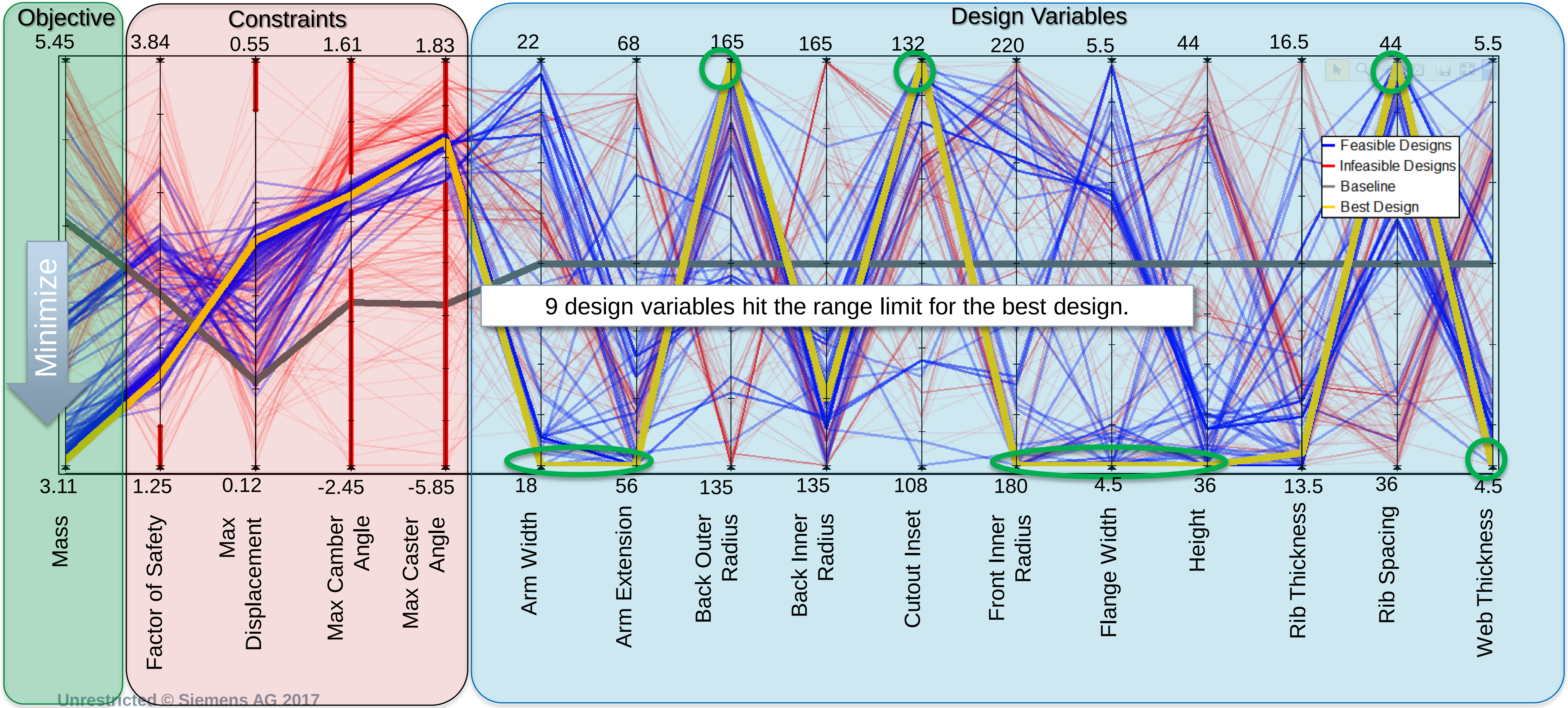

Assess Design Trends – Parallel Plot: LCA Hard Point Variables

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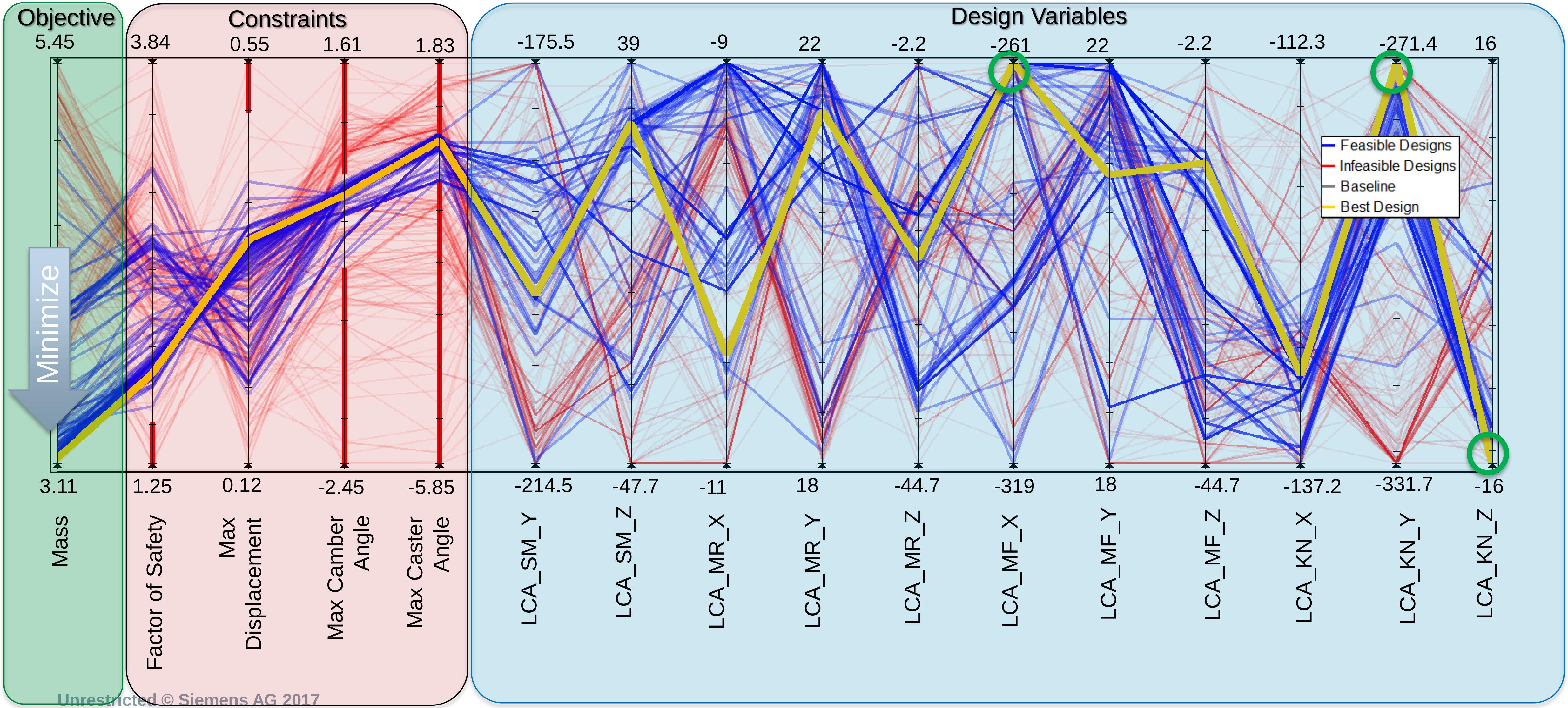

Design Exploration – Baseline & Best Design Comparison

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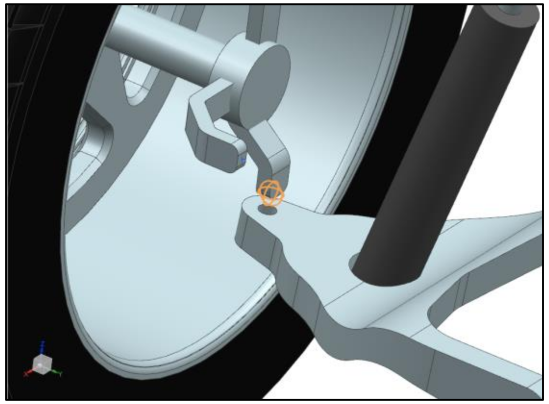
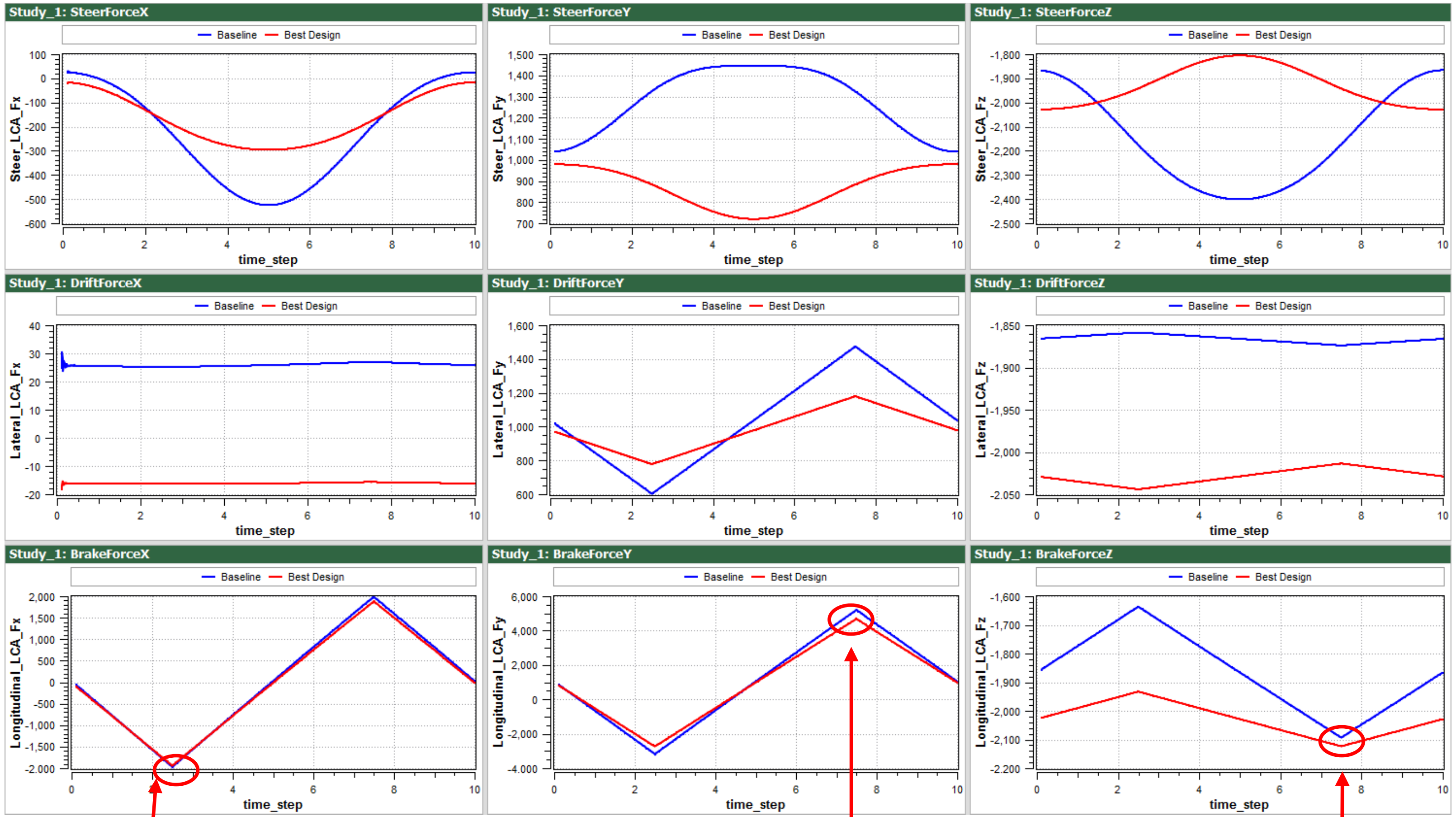
Force profiles comparison at Knuckle-LCA joint



Force in X | Force in Y | Force in Z

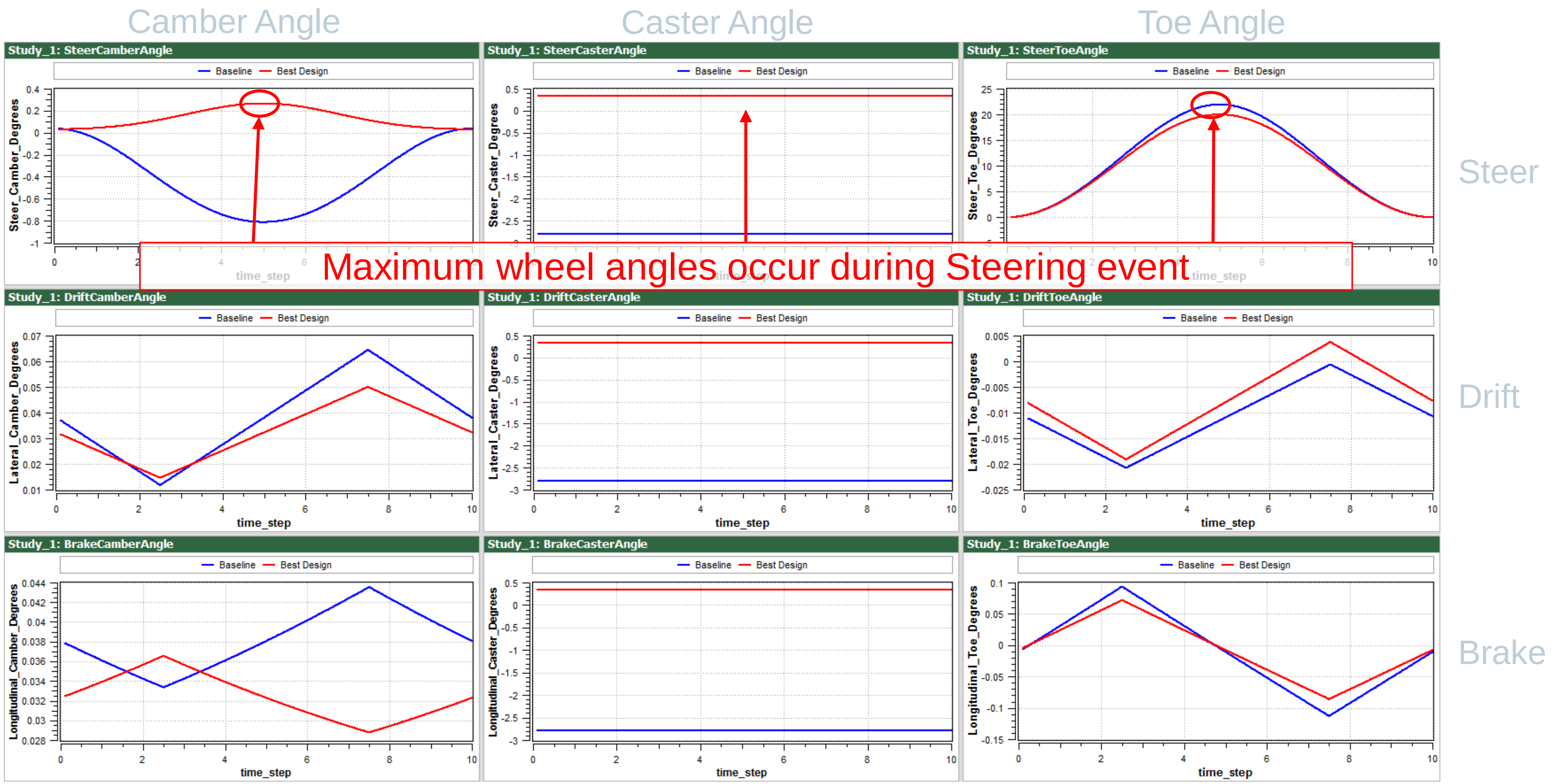
Steer | Drift | Brake



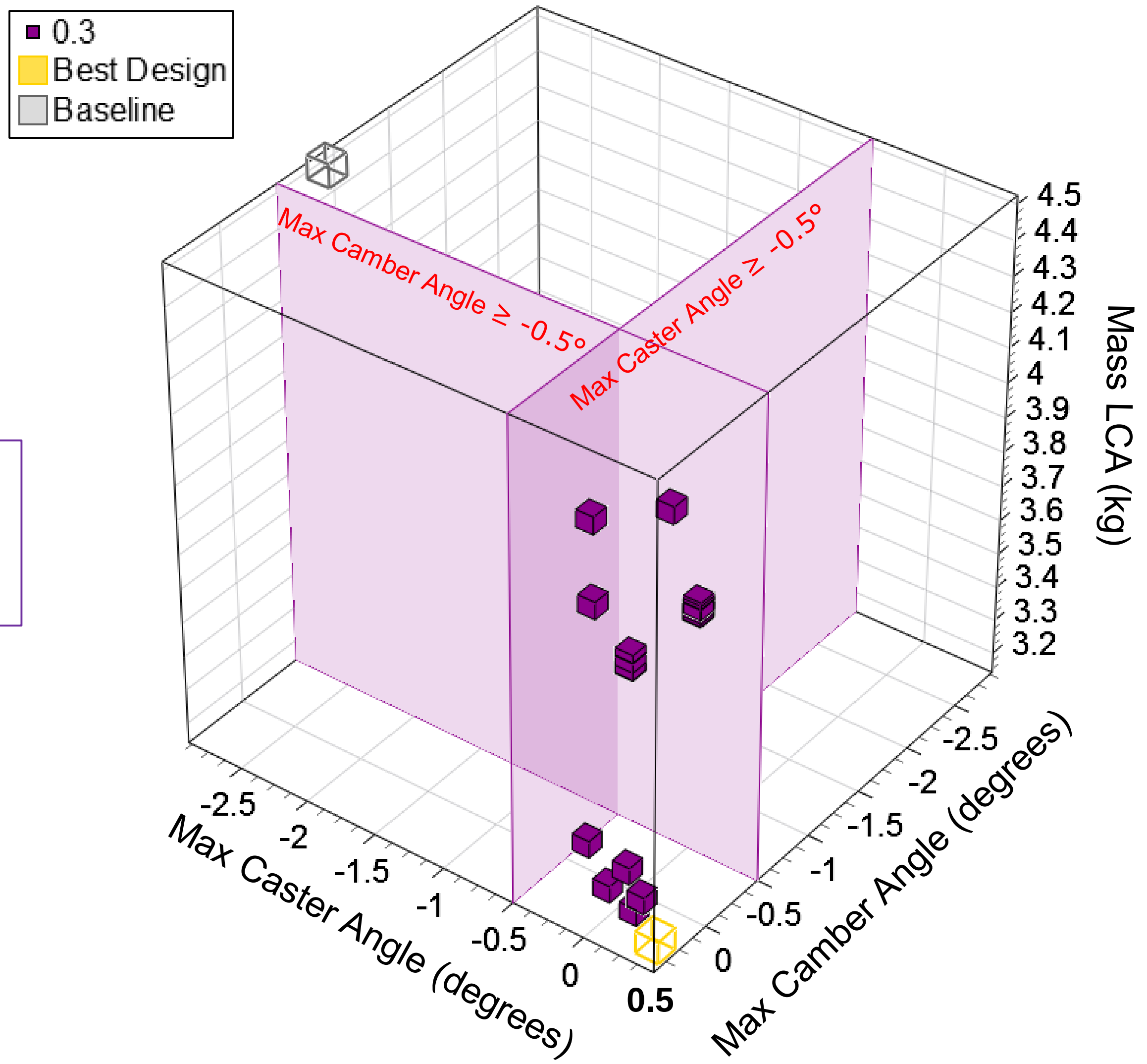
Maximum force magnitudes at Knuckle-LCA joint occur during the Braking event

Design Exploration – Baseline & Best Design Comparison

Wheel angle profiles comparison



Assess Design Trends – 3D Relation Plot: Identifying Design Alternatives



Feasible designs with caster and camber angles within a tolerance of ± 0.3° away from the best design.

Assess Design Trends – 3D Relation Plot: Identifying Design Alternatives

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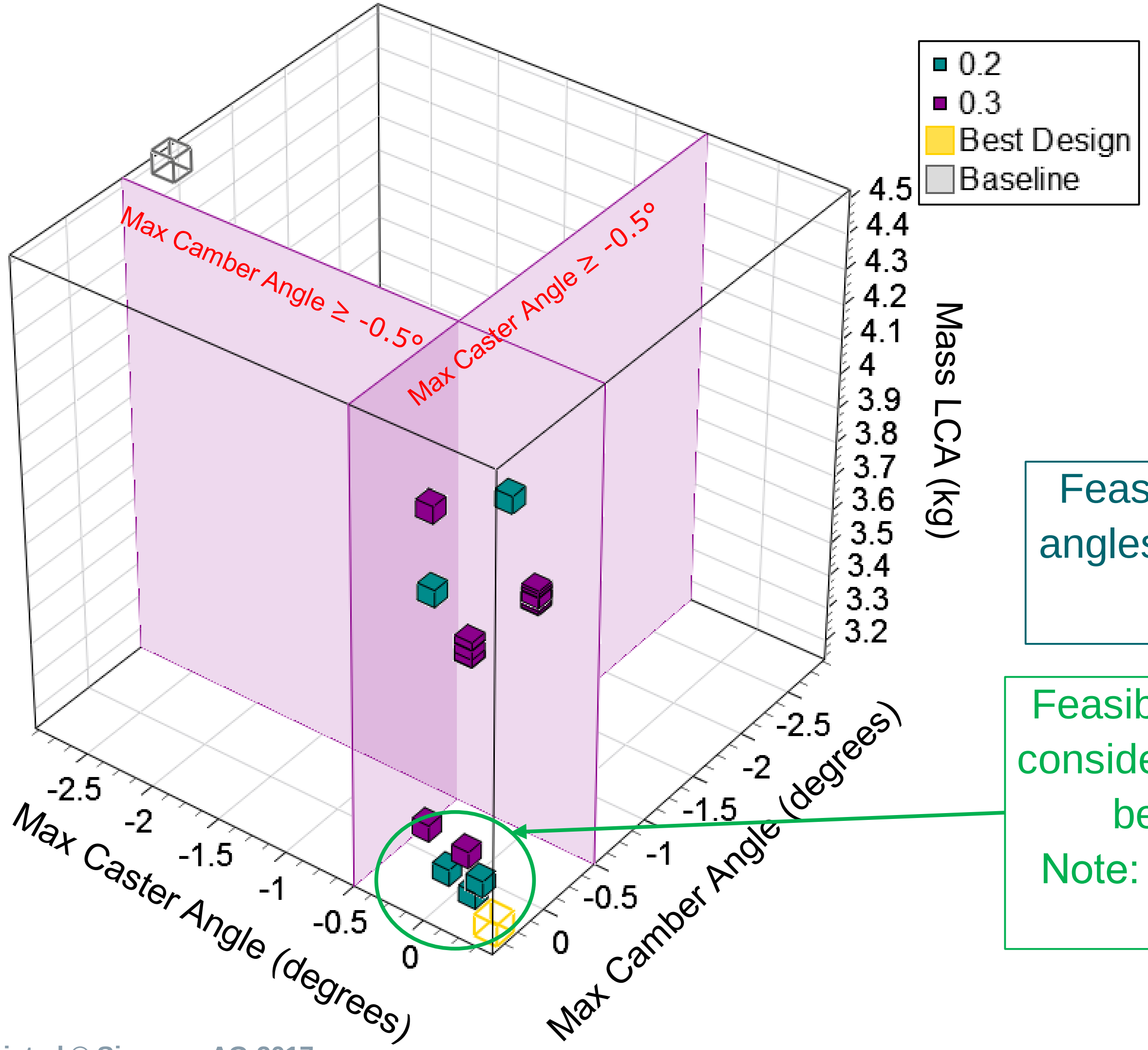
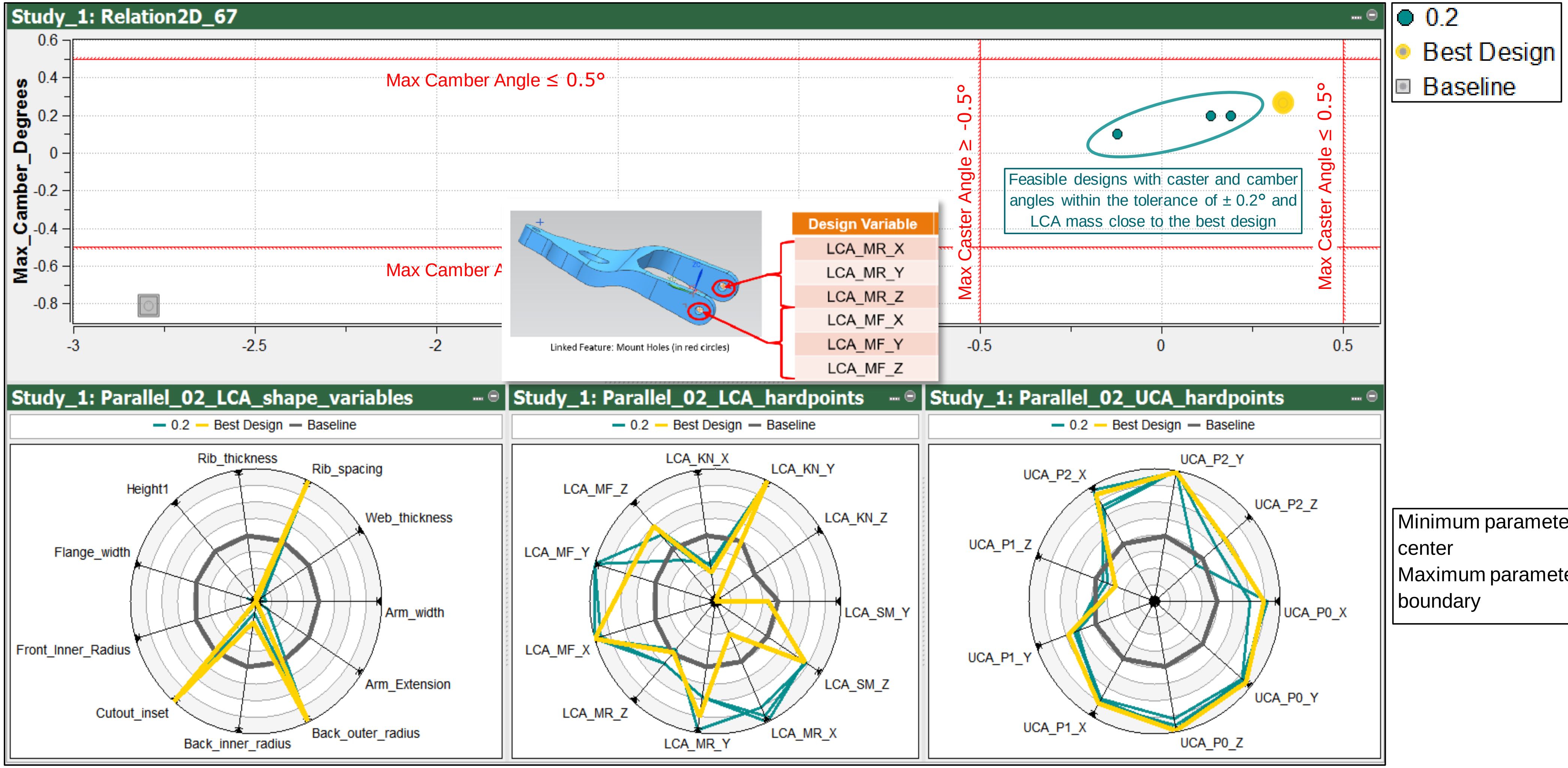


Feasible designs with caster and camber angles within a tolerance of ± 0.2° from the best design.

Feasible designs with tighter tolerance and LCA mass considerably less than the baseline (slightly higher than best design but lower camber/caster angles).
Note: best design had a camber angle of 0.27˚ and a caster angle of 0.33˚

0.5

Assess Design Trends – Plot Views: Identifying Design Alternatives



Minimum parameter value at center
Maximum parameter value at boundary

Very similar control arm shape

Large difference in LCA_MR_X & LCA_MF_Y from best design

Similar UCA hard points

Results Versus Objectives

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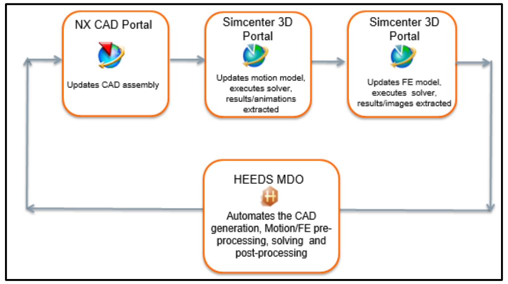
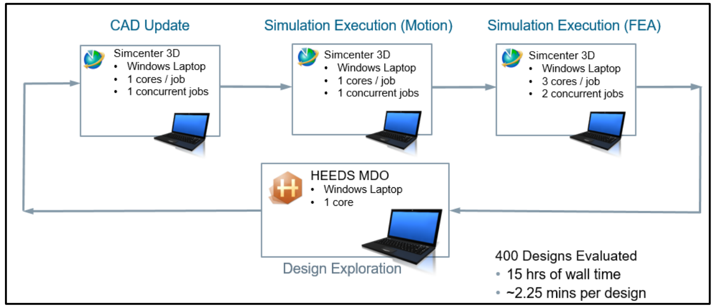
- Demonstrated CAD-embedded automated workflow to simplify virtual prototype construction
  - ✓ CAD: Simcenter 3D (automatically vary 3D geometry)
  - ✓ Motion: Simcenter 3D (prepare model / perform motion simulation)
  - ✓ FEA: Simcenter 3D (prepare model / perform structural analysis)
- Demonstrated that scalable computation hardware and software can be effectively used to accelerate virtual prototype testing
  - ✓ 400 designs successfully evaluated in 15 hours
- Proved that intelligent search can help engineers to discover better designs, *faster*
  - ✓ Discovered a non-intuitive design that reduced the mass of lower control arm power by 30% in under 400 evaluations
  - ✓ Identified critical design variables and relationships between design variables and the various performance requirements

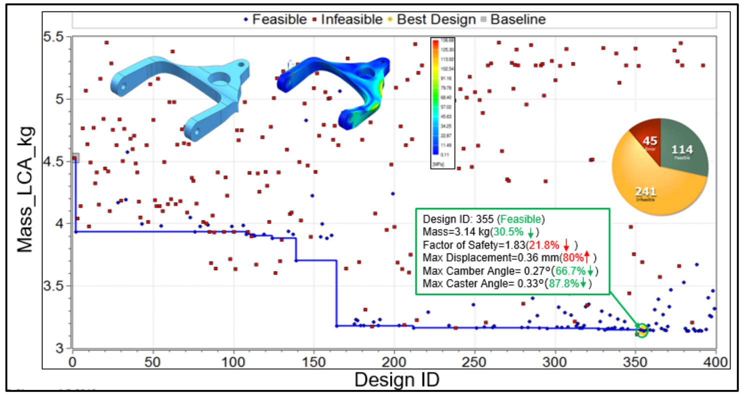
Process Automation



Scalable Computation



Efficient Exploration



Results Versus Objectives

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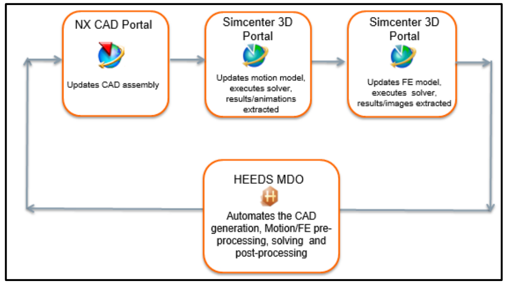
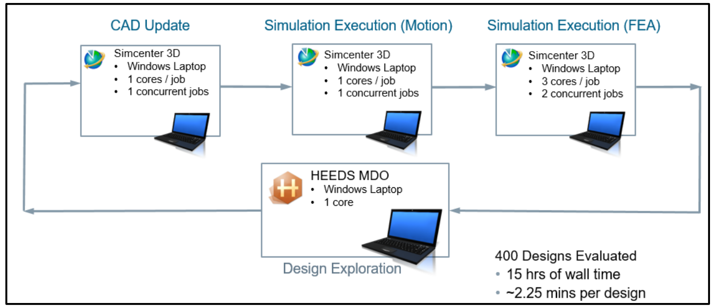
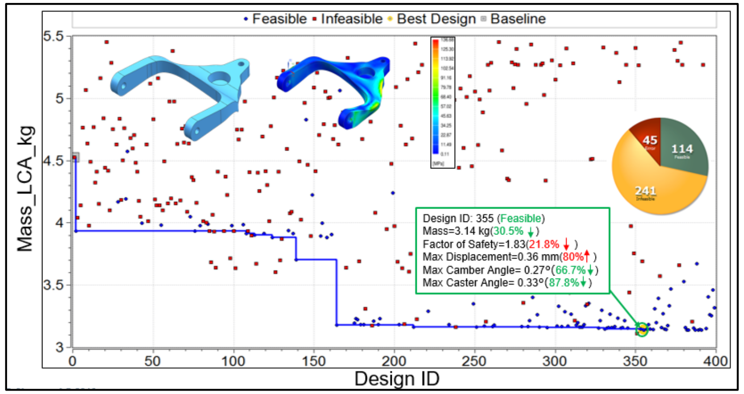
Process Automation



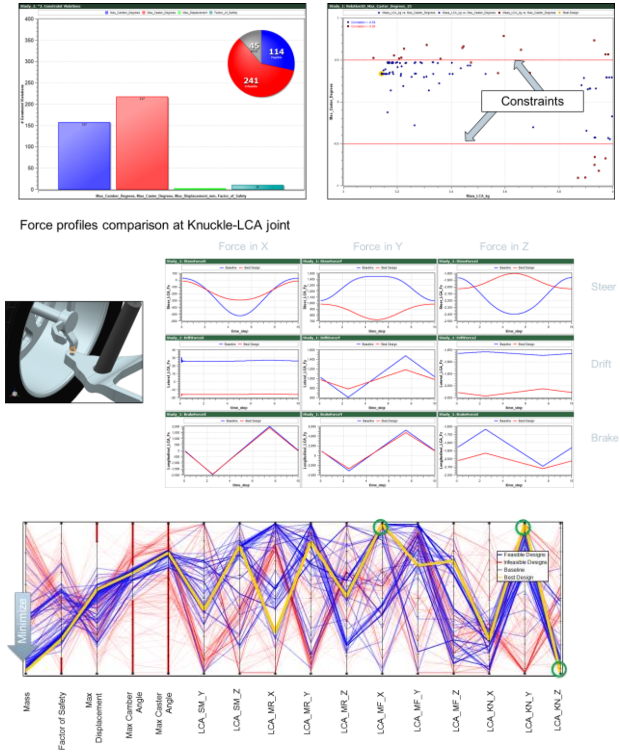
Scalable Computation

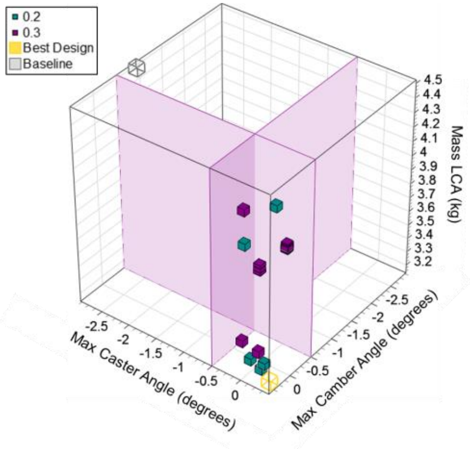


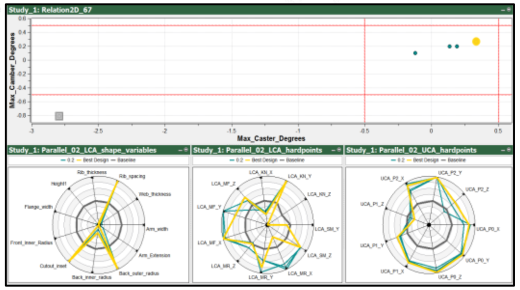
Efficient Exploration



Insight & Discovery







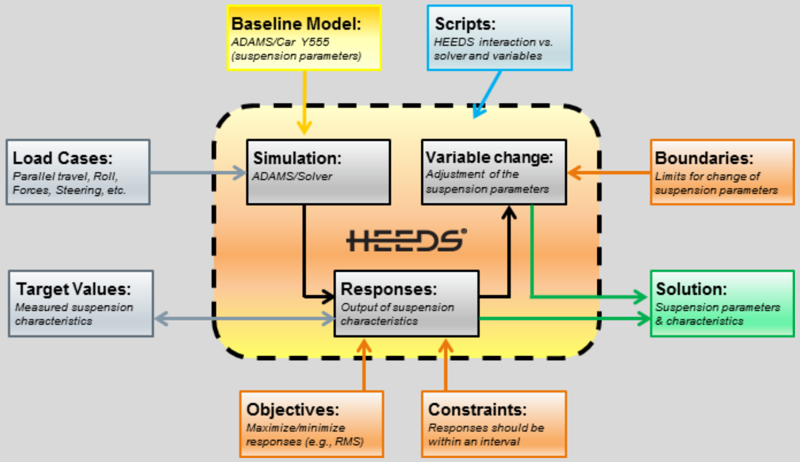
Discover Better Designs, *Faster!*
HEEDS

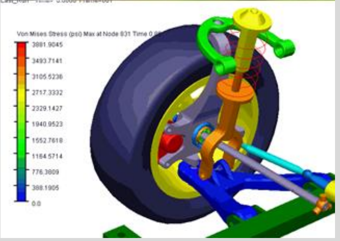
Multidisciplinary Design Exploration Platform

- Accelerate design process with automated workflow
- Explore early & often with a streamlined process
- Increase product knowledge with multi-variant analysis
- Discover better designs faster with automated intelligent search
- Assess design robustness
- In PLM context, configurations are stored, managed and can be reused
- **Easy to use – no need to be an optimization specialist**
- **Easy to deploy across organizations**

HEEDS

Process Automation | Distributed Execution | Efficient Search | Insight & Discovery





Suspension Auto-Correlation reduced time from months to under 1 week
“HEEDS drastically reduces correlation time.” — Erik Wendeberg, Chalmers