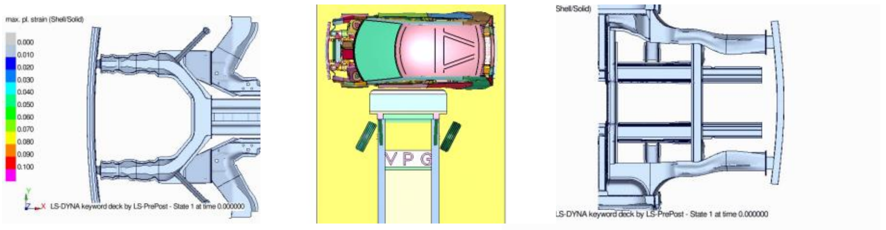
World Auto Steel
Future Steel Vehicle

Challenge:

- Use a new performance-driven, holistic product development process (ACP) based on HEEDS to minimize mass of new Battery Electric Vehicle
- Loading conditions
  - Crash (LS-Dyna), NVH (Nastran), Handling (ADAMS)
- Design variables
  - Geometry, Gauge, Grade (AHSS)

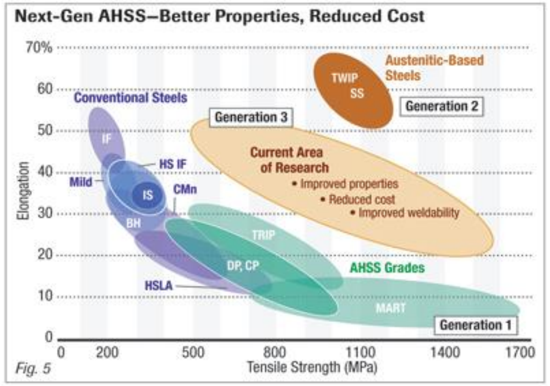
IIHS Impact Crash Tests



Results:

- ✧ 35% Mass Savings
- ✧ 5-Star Crash Safety Rating
- ✧ 70% Emissions Reduction
- ✧ No Cost Penalty

Body Structure	FSV-1 BEV
Benchmark Mass	290 kg
Achieved Mass	187.7 kg



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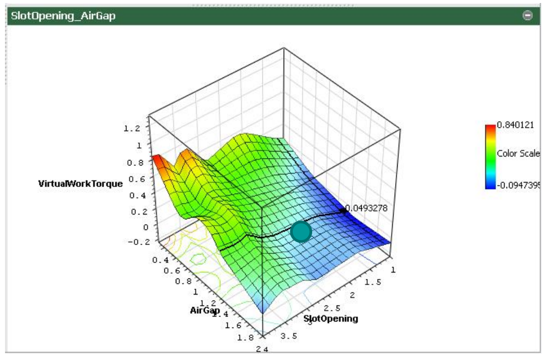
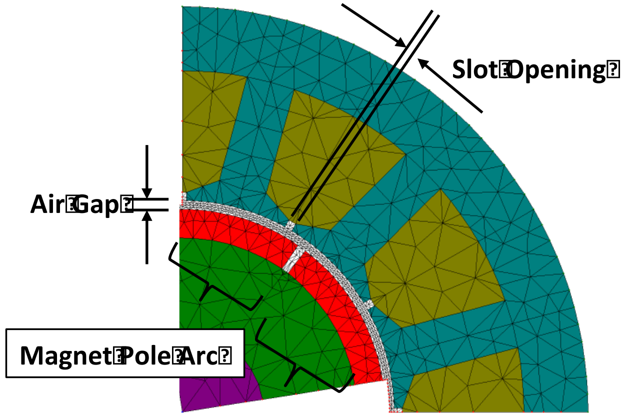
Customer Success: Electric Motor Design Study

Challenge

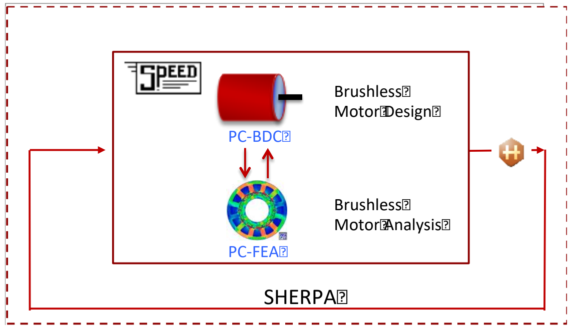
- Minimize cogging torque
- Design variables
  - 100° < Magnet Pole Arc < 180°
  - 1 mm < Slot Opening (SO) < 4 mm
  - 0.3 mm < Air Gap (Gap) < 2 mm





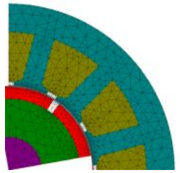
Results

- 99% lower cogging torque



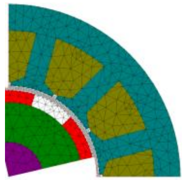
Baseline Design:

- Cogging Torque= 0.7185 Nm
- Magnet Pole Arc = 170°
- Slot Opening (SO) = 3.0 mm
- Air Gap (Gap) = 0.5 mm



Improved Design:

- Cogging Torque= 0.004 Nm
- Magnet Pole Arc = 123°
- Slot Opening (SO) = 1.15 mm
- Air Gap (Gap) = 1.35 mm

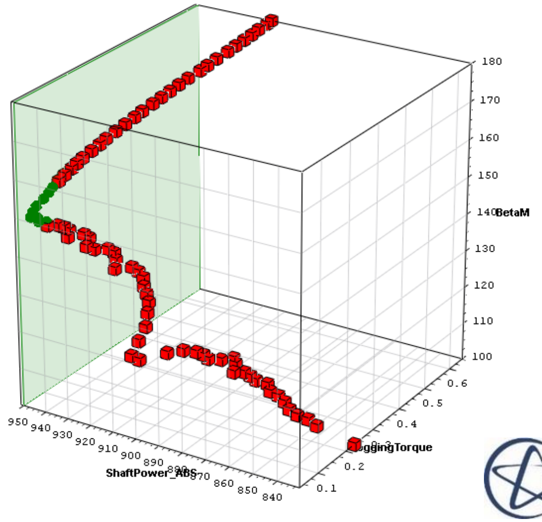


SIEMENS

Customer Success: Electric Motor Design Study

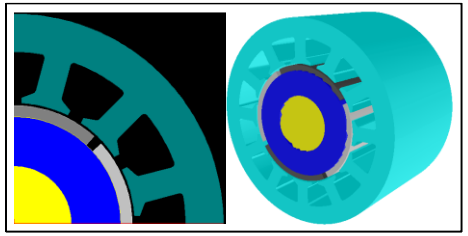
Challenge:

- Minimize cogging torque and magnet volume
- Constraints (8):
  - 950 W < Shaft Power < 1050 W
  - 190 V < Induced Voltage < 200 V
  - Copper Losses < 100 W
  - Iron Losses < 20 W
  - Total Losses < 120 W
  - 1.4 T < Stator Flux Density < 1.6T
  - 1.4 T < Stator Yoke Flux < 1.6T
  - Rotor Yoke Flux Density < 1.6T
- Design variables (10):
  - 100° ≤ Magnet Pole Arc ≤ 180°
  - 1 mm ≤ Slot Opening ≤ 4 mm
  - 0.3 mm ≤ Air Gap ≤ 2 mm
  - 10 mm ≤ Slot Depth ≤ 17 mm
  - 50 ≤ Number of Coils ≤ 150
  - 60 mm ≤ Stack Length ≤ 80 mm
  - 4 A ≤ Current Set Point ≤ 7 A
  - 5 mm ≤ Tooth Width ≤ 10 mm
  - 1 mm ≤ Magnet Thickness ≤ 5 mm
  - 26 mm ≤ Outer Rotor Radius ≤ 36 mm

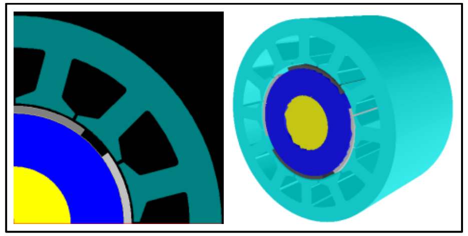


Results:

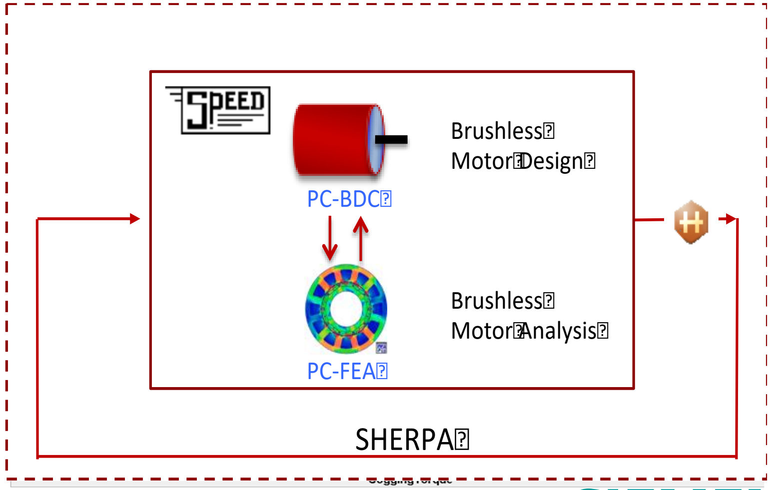
- 94% reduction in cogging torque
- 46% reduction in magnet volume



Baseline



Optimized (46% Reduction in Magnet Volume)



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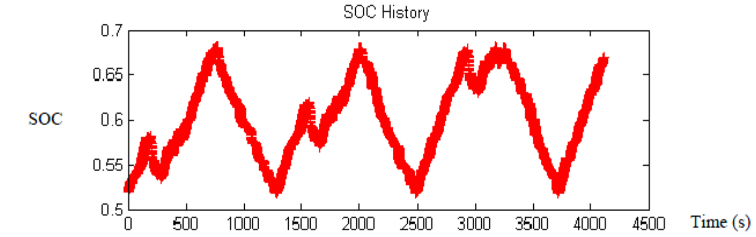
Michigan Economic Development Cooperation
Hybrid Bus Design

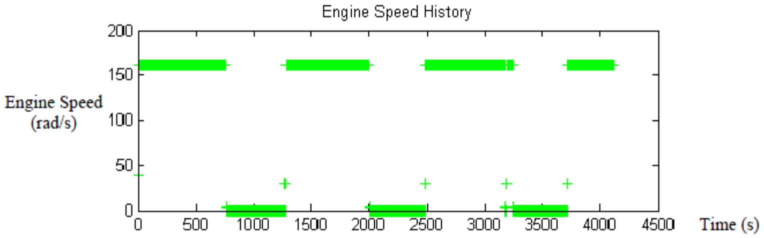
Challenge:

- Maximize fuel economy for a series hybrid electric bus
- Constraints
  - Missed trace less than 5 mph
  - Maintain a battery charge greater than 51.75 %
  - Accelerate from 0-60 mph under 42 seconds
  - Accelerate from 0-30 mph under 10 seconds
- Design variables
  - Engine size, battery pack, electric motor, generator

Results:

- Increased fuel economy by 9%
- Decreased missed trace from 15.7 mph to < 2.5 mph
- Decreased 0–60 acceleration time from 53 s to 25 s
- Decreased 0–30 acceleration time from 21 s to 7 s





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Streamlining the Design Exploration Process

Application Example Excavator Performance Improvement with Electric Swirl Motor

Objective:

- Minimize operation cycle time
- Minimize fuel consumption

Design variables (5):

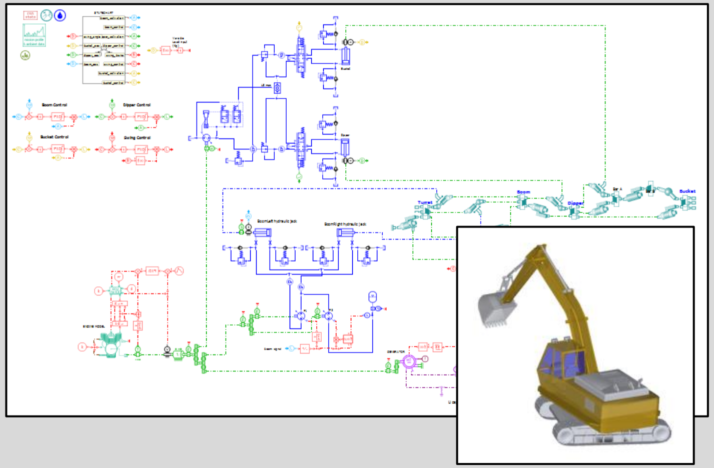
- Electric motor torque
- Gearbox gear ratios
- Ultra capacitor size, and control scheme

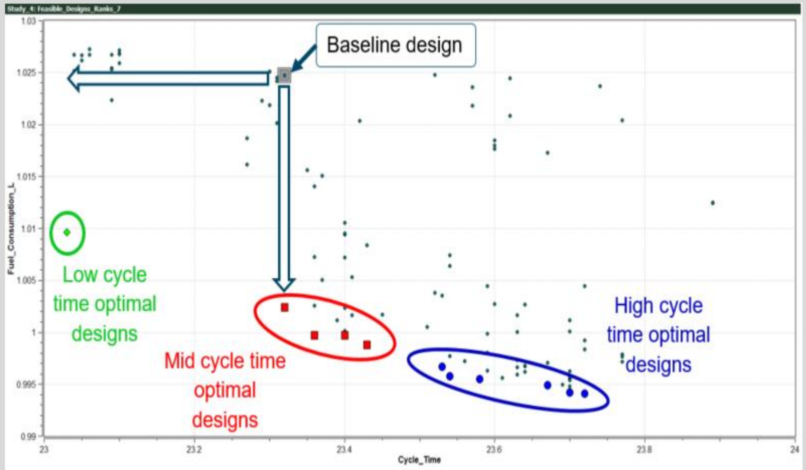
Results:

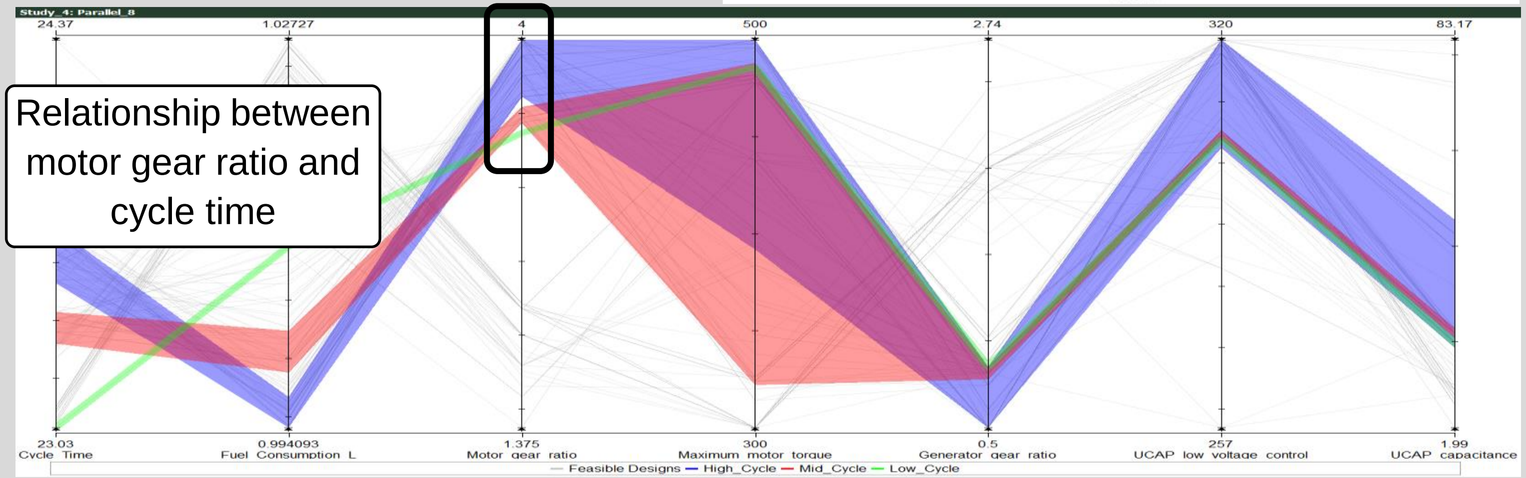
500 design evaluations were performed

Designs were discovered which improved cycle time and fuel consumption compared to the original design

Discovered tradeoff relationship between fuel consumption and cycle time







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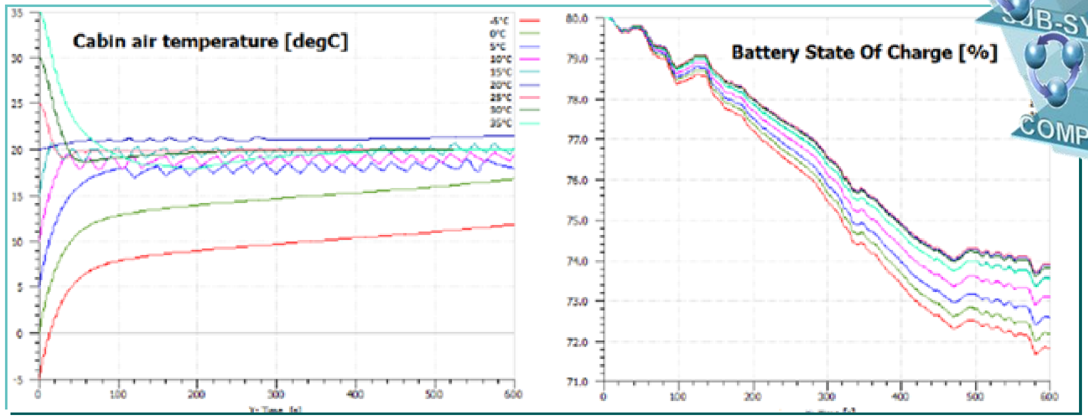
Customer Success: Performance, Range & Comfort

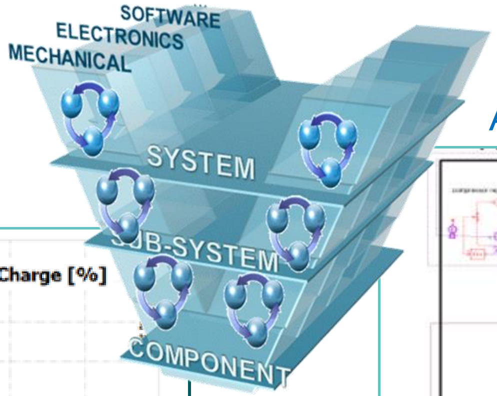
Challenge:

- Balance performance, range, and passenger comfort of an electric vehicle
- AMESim and Matlab/Simulink used to simulate 1D system behavior
- HEEDS adjust bypass orifice to improve system performance

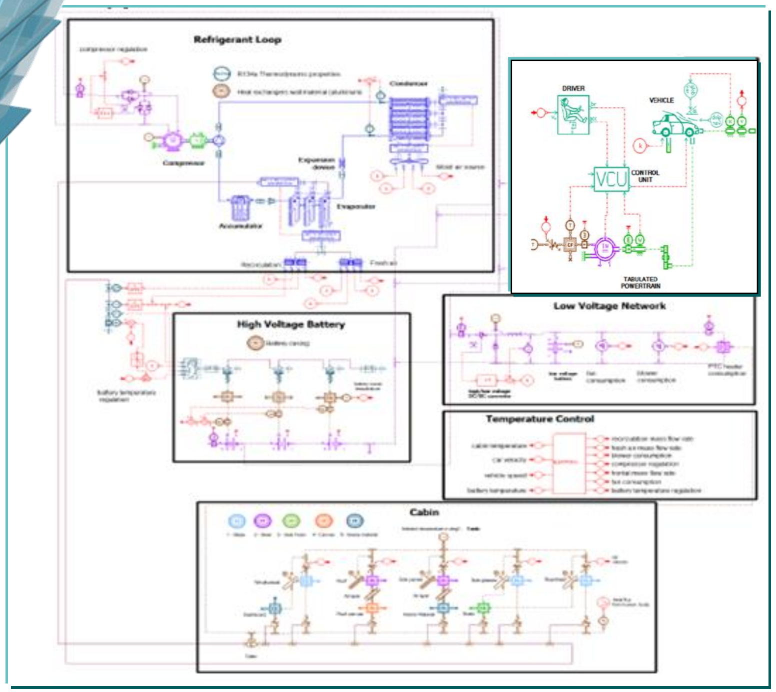
Results:

- Best balance achieved





AMESim 1-D Subsystem Models



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Streamlining the Design Exploration Process

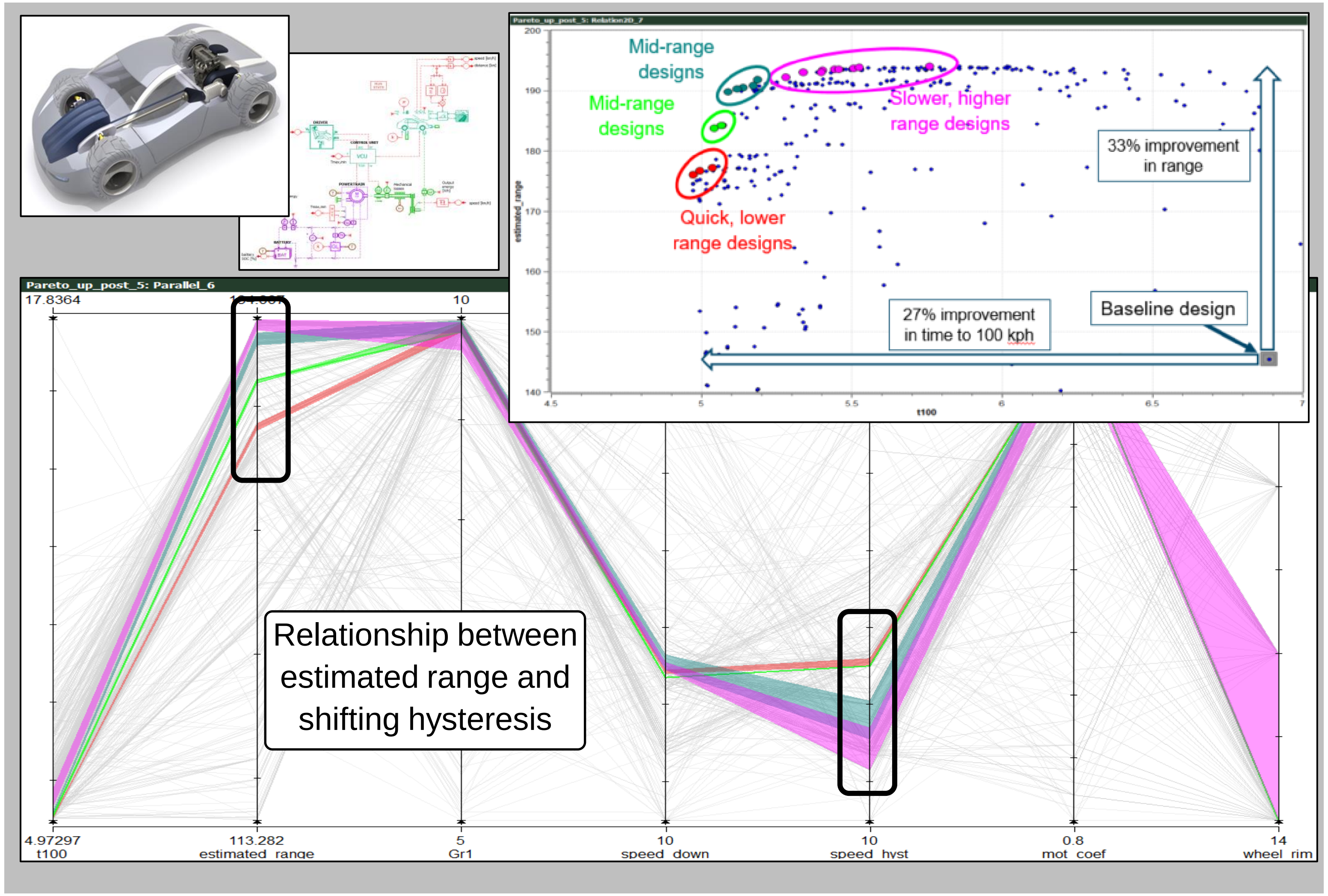
Application Example: Electric Vehicle Sizing

Objective:

- Minimize acceleration time (0 -100 km/h)
- Maximize range

Design variables (5):

- Torque Curve Coefficient
- Gear Ratio
- Downshift Speed
- Shifting Hysteresis
- Rim Diameter



Results:

500 design concepts were evaluated in five hours of simulation clock-time (5 cores used on Windows laptop)

Discovered tradeoff relationship between goals, with improvement over starting design ranging from 27% gain in acceleration to 33% longer range

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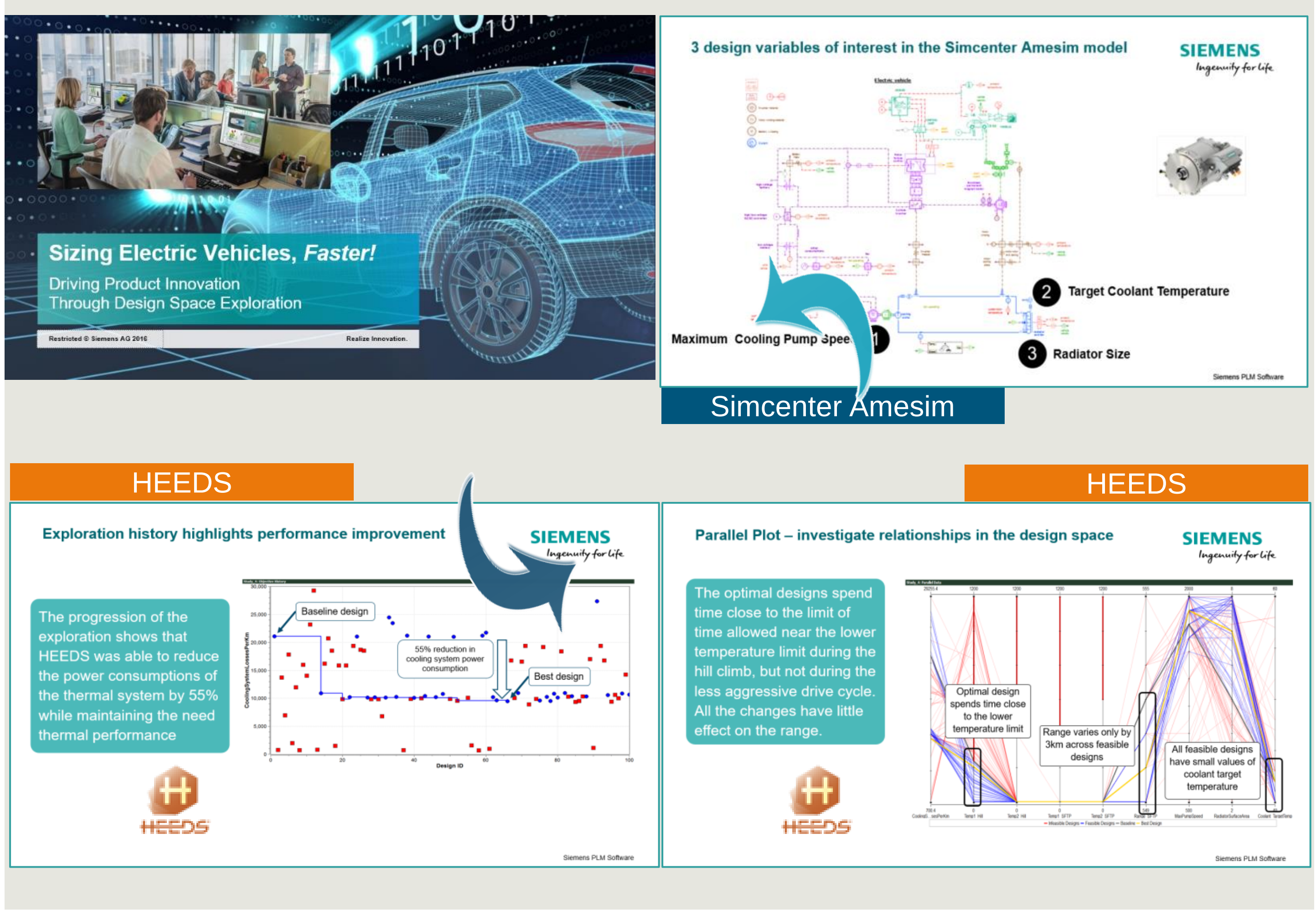
Simcenter™
Sizing an electric vehicle for optimal thermal performance



Challenge

The cooling system design of electric vehicles affects the thermal system performance and range, making it critical to find the best design.

Solution

Simcenter Amesim for electric vehicle thermal sizing coupled with HEEDS to scan the design space, in order to reduce the cooling system power requirements.

Benefit

- Find optimal cooling systems without affecting thermal performance and range
- Shorten product development time
- Validate the cooling control system

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Valeo EEM
Design Optimization of EV Architecture

Final Design

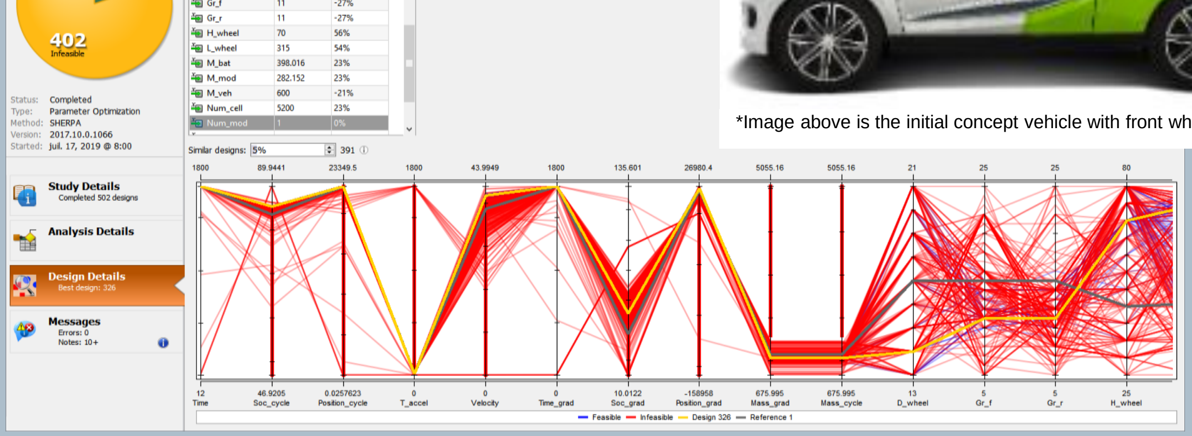

*Image above is the initial concept vehicle with front wheel drive

* The HEEDS simulation study above is for a 4WD design

Results:

- In 500 iterations, HEEDS improved the overall performance of a 4 wheel drive vehicle
- Reduced acceleration time by 14%
- Increased max. speed by 5%
- Increased vehicle range (WLTC Class 3) by 11%
- Reduced mass by 8%

HEEDS improved all 8 objectives in a single study, while satisfying all the constraints!

