Optimization and Design of Rail Vehicle Running Gear Components under Dynamic Loading

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DLR

German Aerospace Center

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- Space Research and Technology
- **Transport**
- Energy
- Defence and Security
- Space Administration
- Project Management Agency

- Approx. 8000 employees across 33 institutes and facilities at 20 sites
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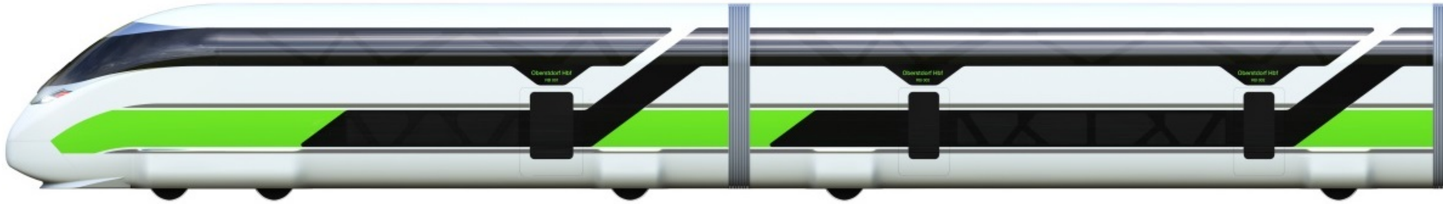
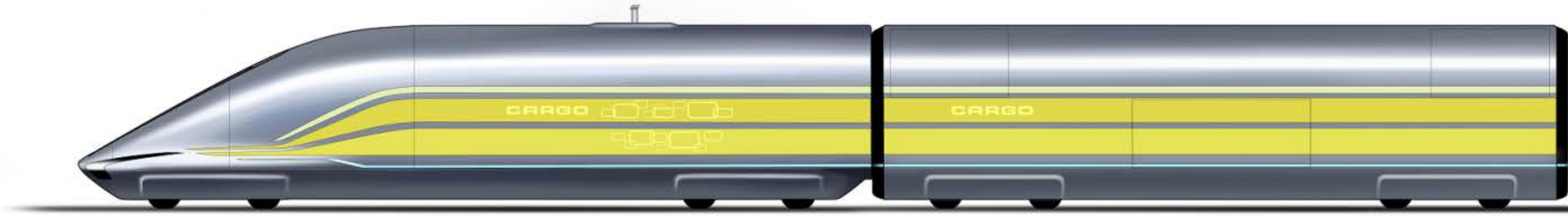
Next Generation Train (NGT)

- NGT HST
  Ultra-high speed EMU passenger train (400 km/h)

- NGT LINK
  High speed EMU passenger train (230 km/h)



- NGT CARGO
  Automated EMU freight train (400 km/h)



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Next Generation Train - High Speed Train

NGT HST

- Operational speed of 400 km/h
  → High dynamic loads

- Halving the specific energy consumption compared to the ICE 3
  → Lightweight design

Approach for Designing Running Gear Considering Dynamic Loading

Classic Approaches

- Pure static approach:
  Static equivalent loads derived from standards (EN13749, EN13103)

- With dynamic loads:
  Iterative process of multi-body simulations and structural optimizations
  - Separate models for multi-body and optimization runs
  - Data transfer between models/software

  → High maintenance and manual labour

New Approach

- Combine multi-body simulations with static structural optimizations in one optimization run

  → Reduce manual labour

  → Apply realistic load patterns

  → Consider kinematics, spring and damper forces

  → Achieve highest possible lightweight potential with as needed dimensions

Structural Optimization using the Equivalent Static Load Method

Static Topology Optimization

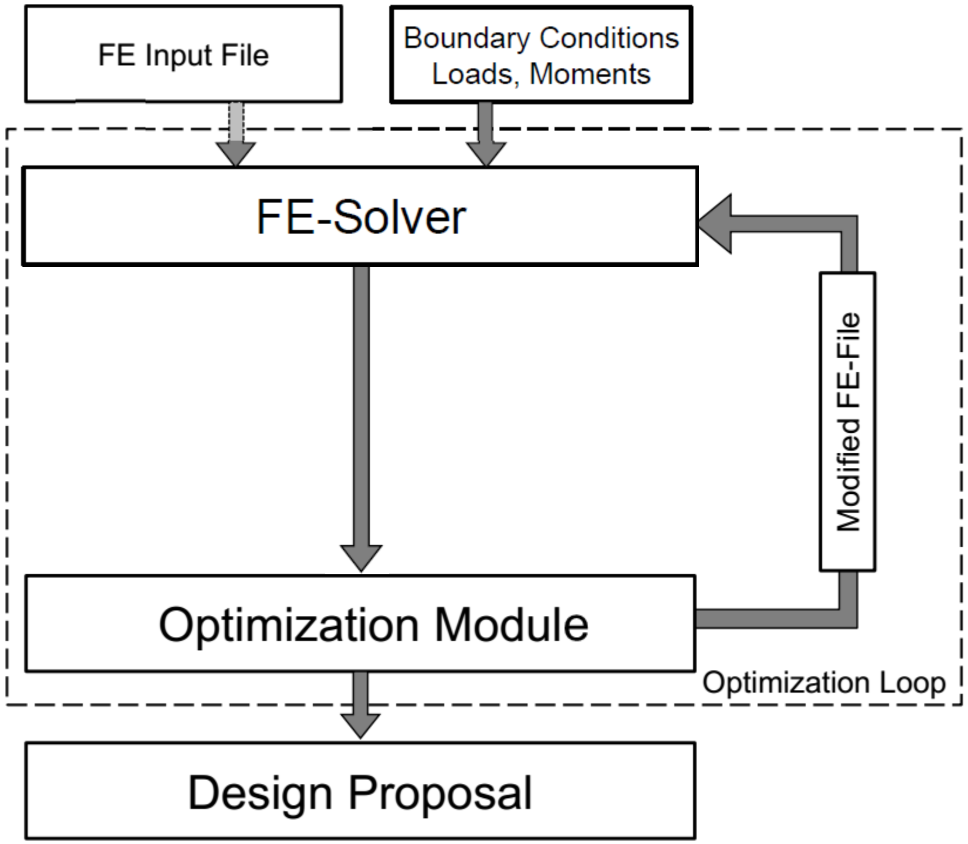


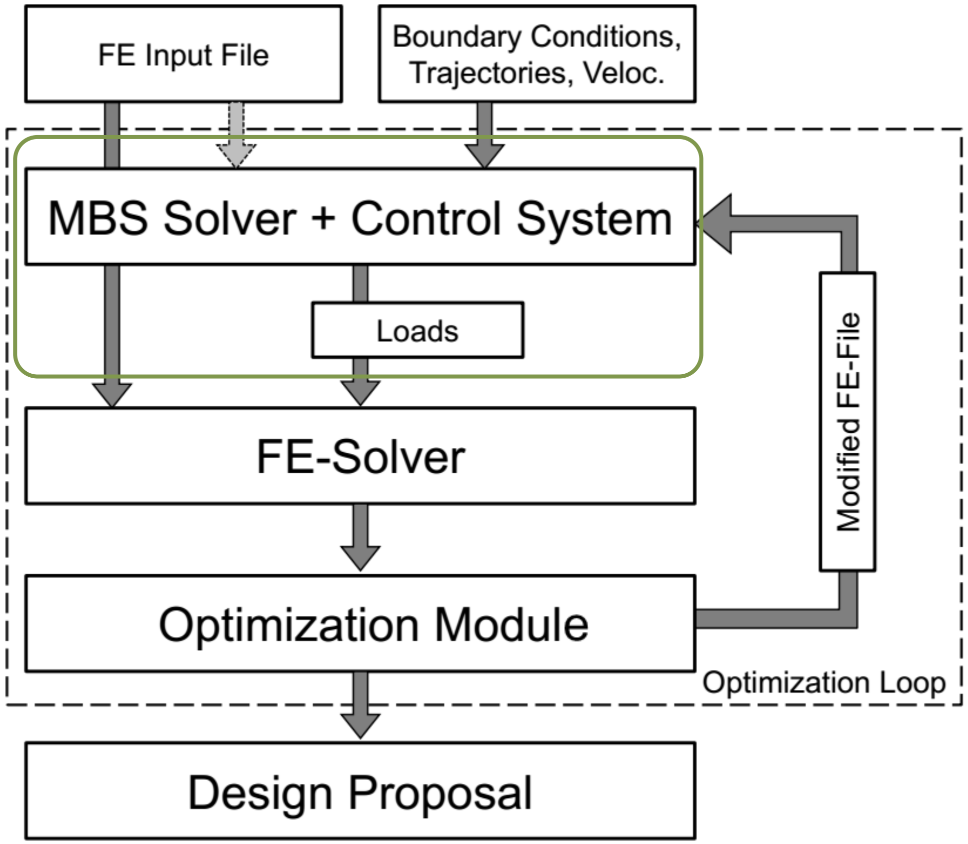
Image: Sander, C.: Extented topology optimization - two factors to decrease energy consumption of structural parts during dynamic movements. url: http://edok01.tib.uni-hannover.de/edoks/e01fn14/781374405.pdf

Structural Optimization using the Equivalent Static Load Method

Multi-Body Simulation

Equivalent Static Load

Static Topology Optimization



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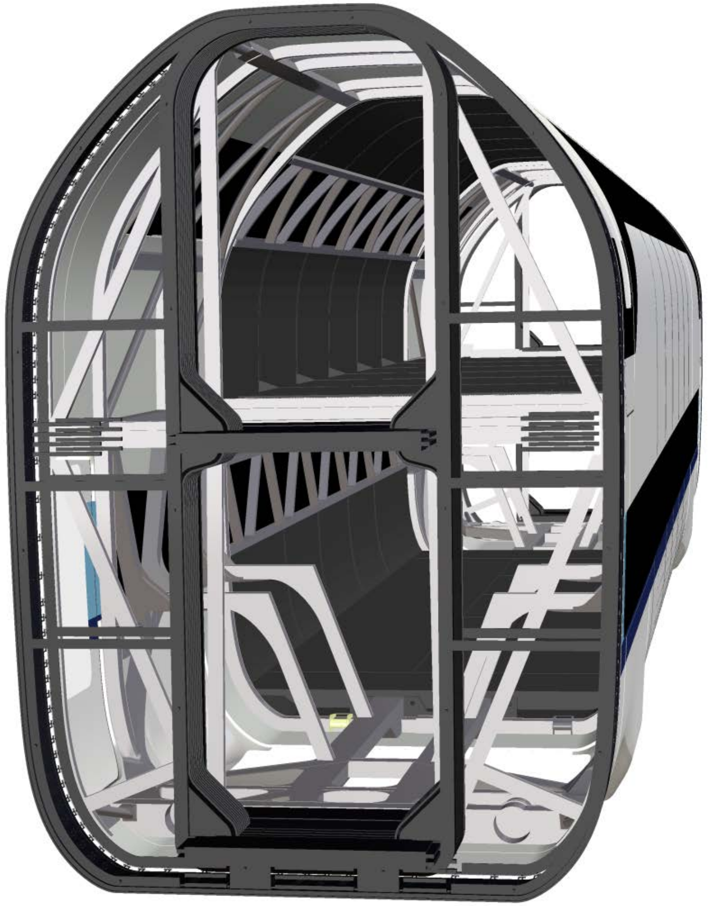
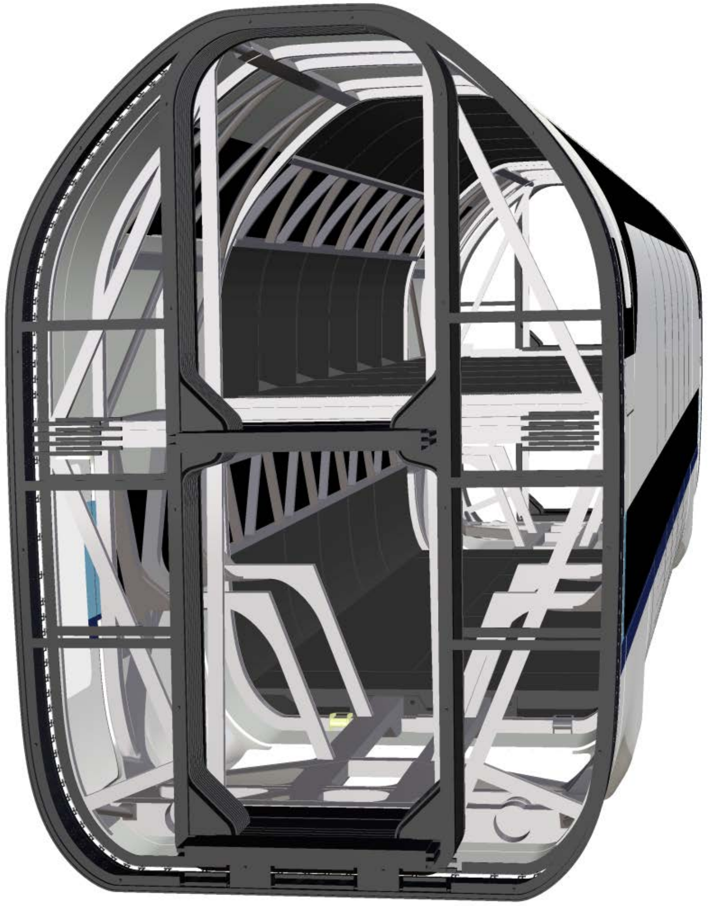
NGT HST Running Gear
Simplified Model

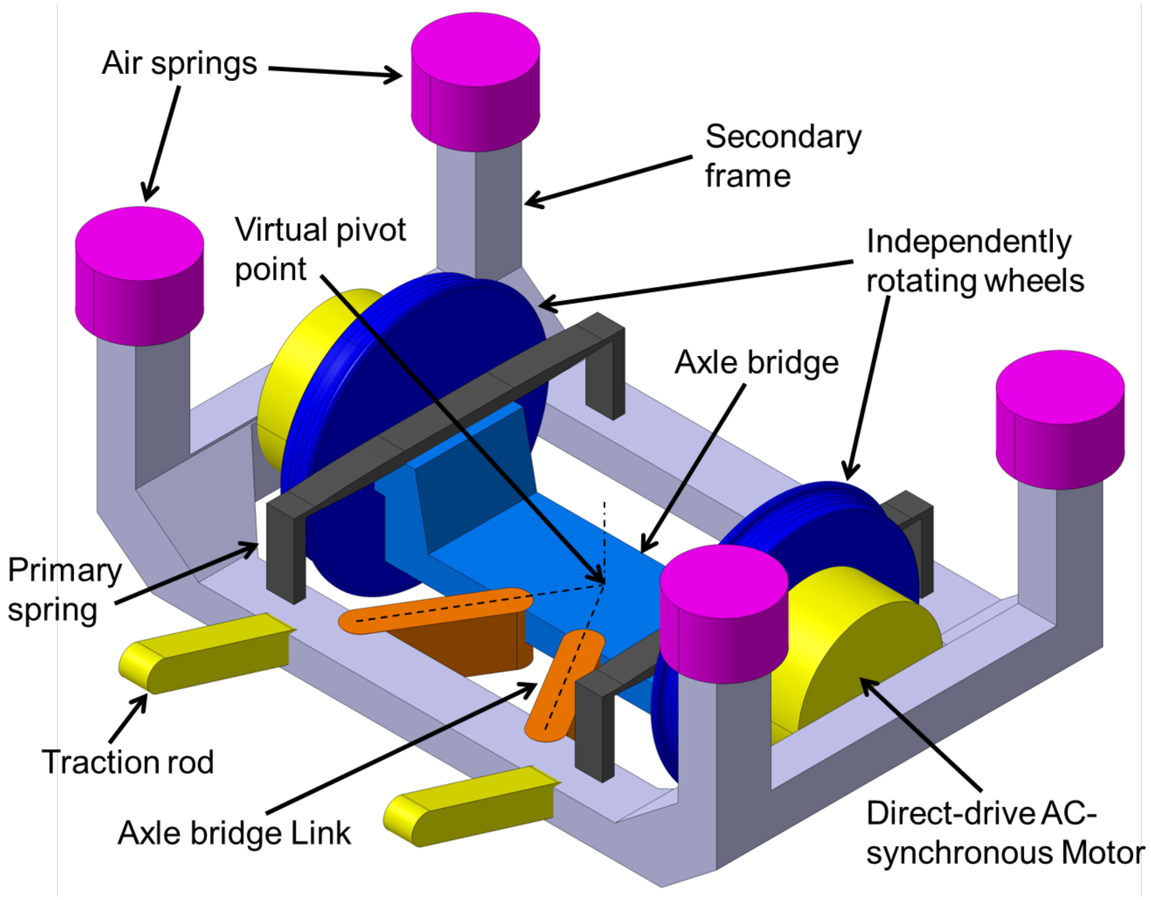


End-to-end double deck cars with level access on both floors over entire train length

→ Low-flor running gear concept
- Independently rotating driven wheels
- Actively steerable
- Single-wheelset bogie

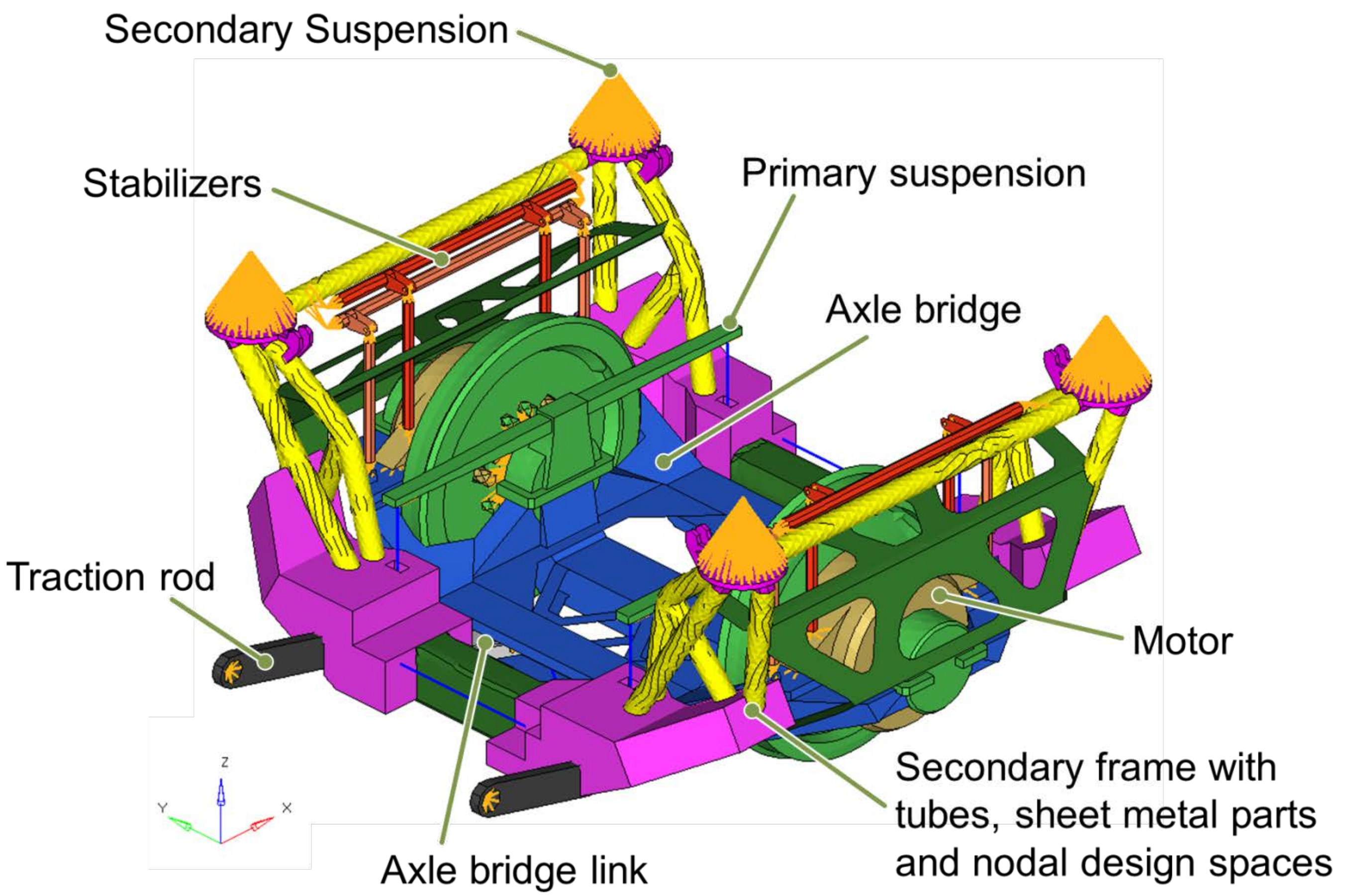
NGT HST Running Gear
Simplified Model





Applying the ESLM to Structural Optimization of the Secondary Frame

Constraints, Loads, Optimization Settings

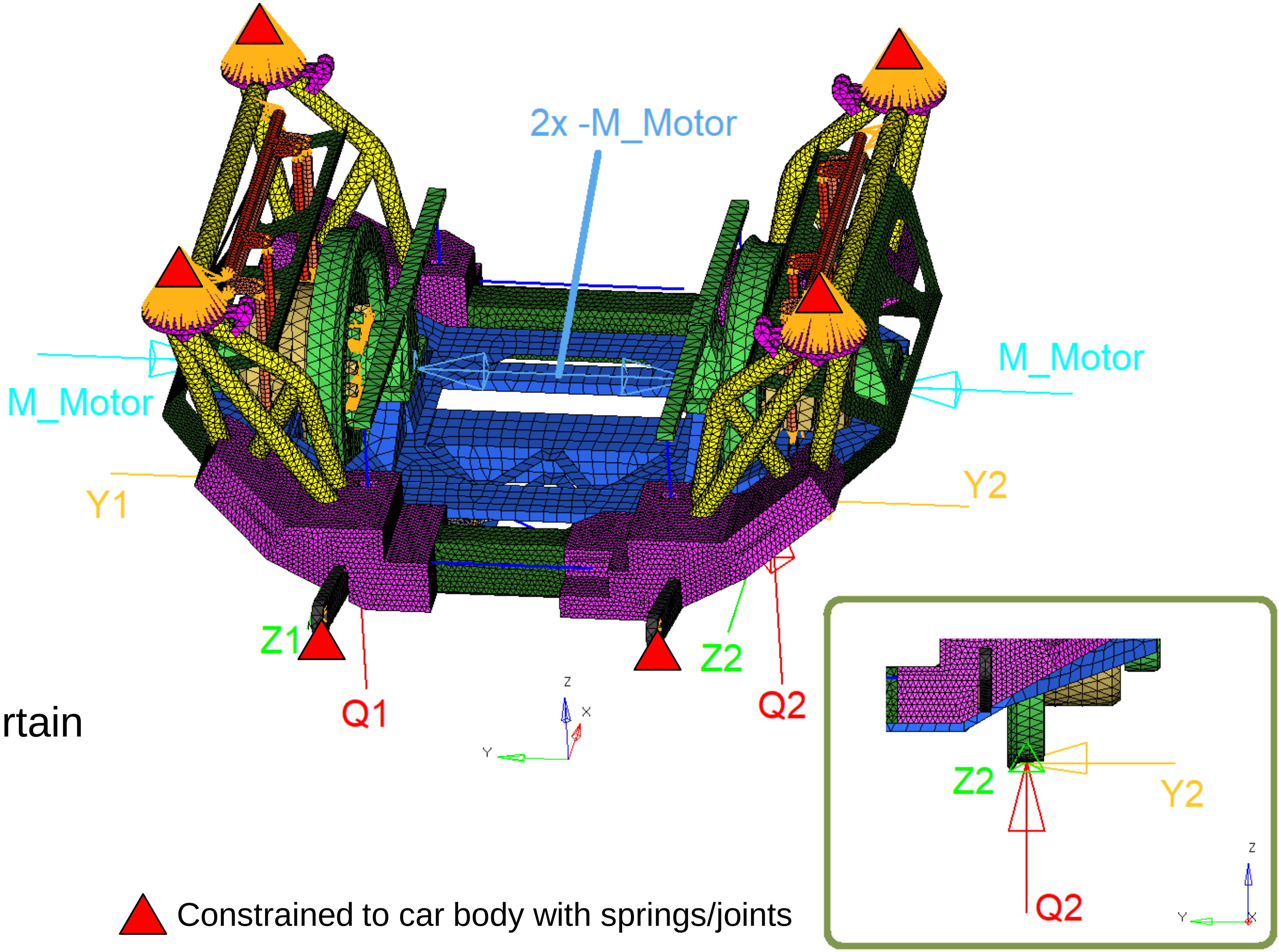


Applying the ESLM to Structural Optimization of the Secondary Frame
Constraints, Loads, Optimization Settings

- Optimization areas:
  - Gauge: tubes and all sheet metal parts
  - Topology: nodal design spaces

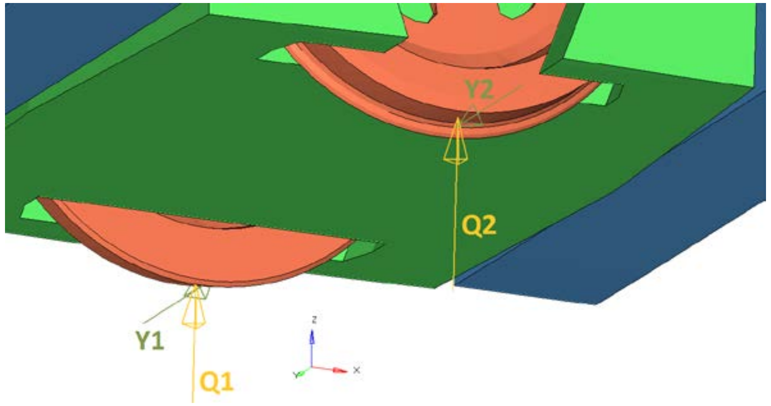
- Optimization objective:
  - Minimize total mass of secondary frame

- Optimization constraints:
  - Keep compliance minimal
  - Respect response limits on stress and certain displacements

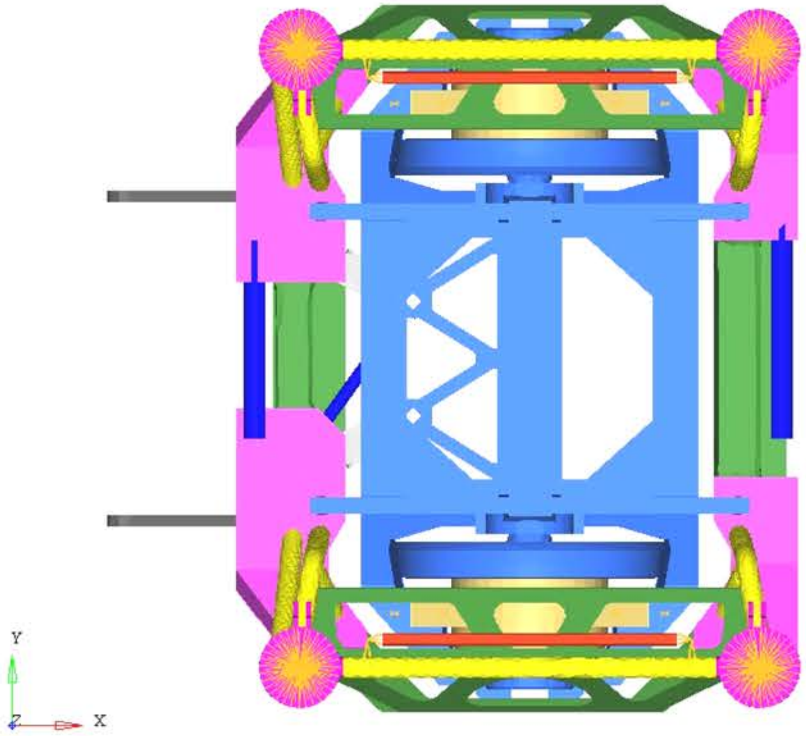


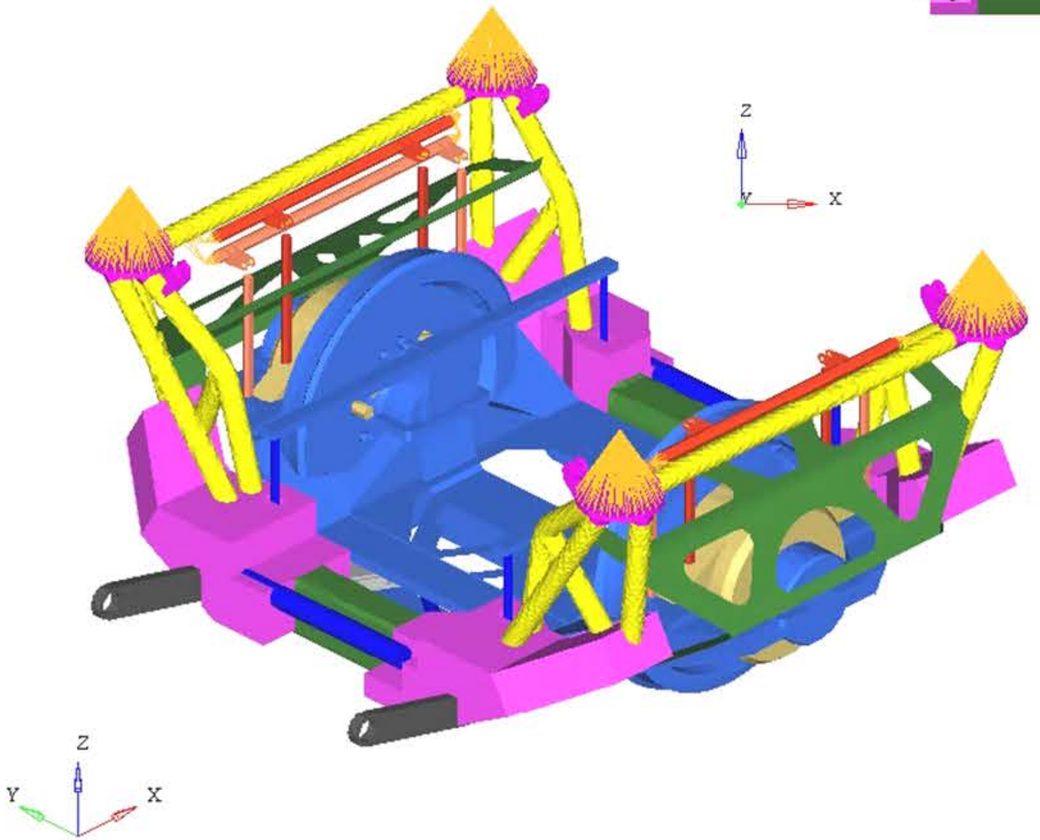
Applying the ESLM to Structural Optimization of the Secondary Frame

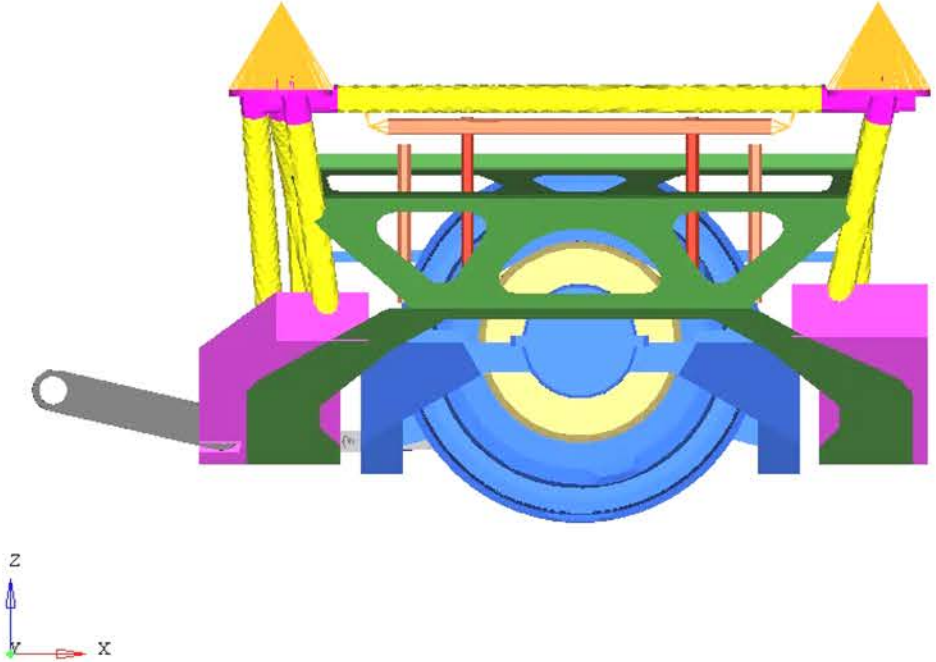
Time-dependent Load Curves



Results of Multi-Body Simulation







Optimization Results of ESLM Runs as Guideline for a New Design

FEM simulation and optimization

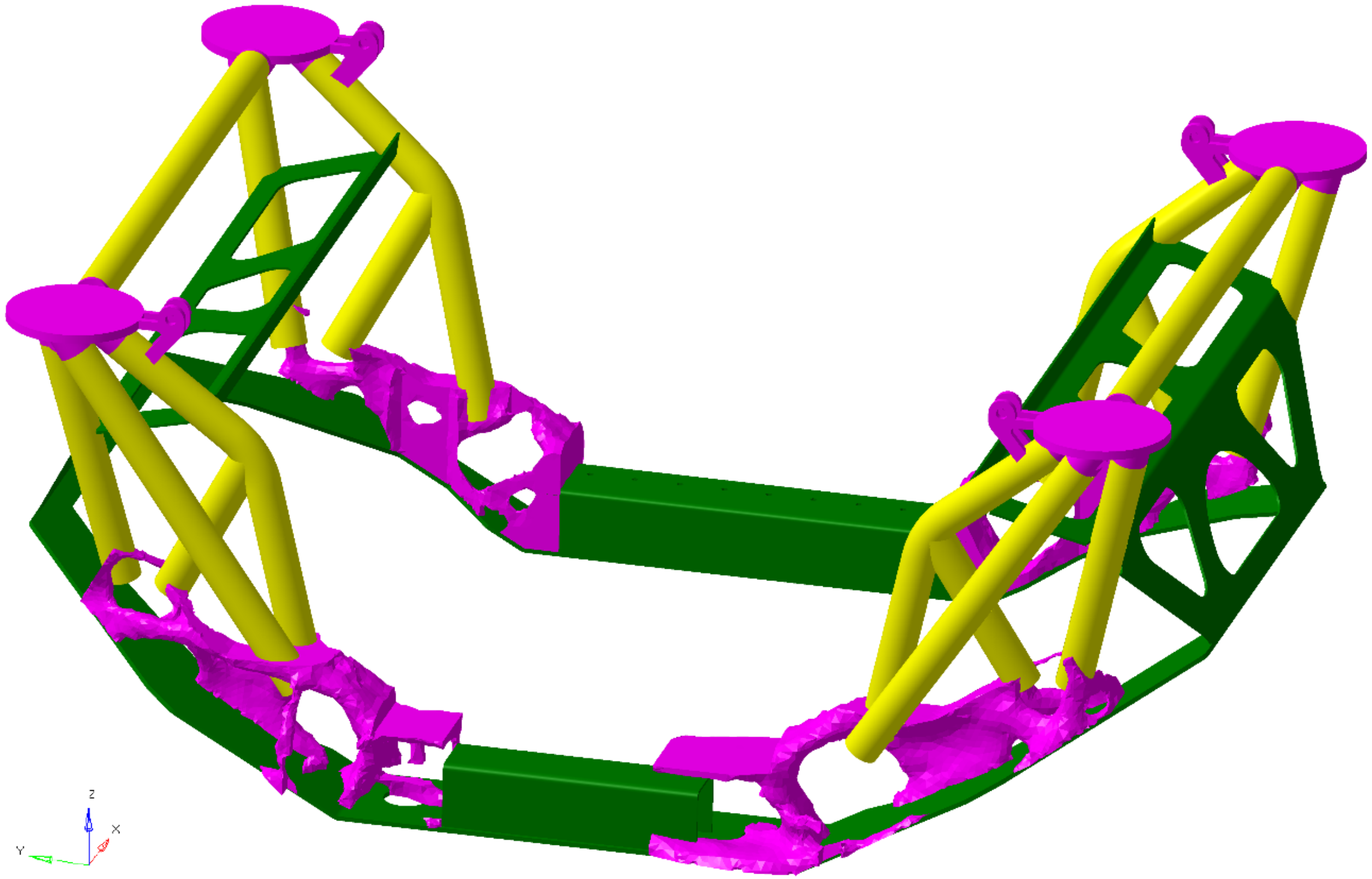
Displacements, stresses, topology and gauge results

Multi-body simulation

Movements, accelerations

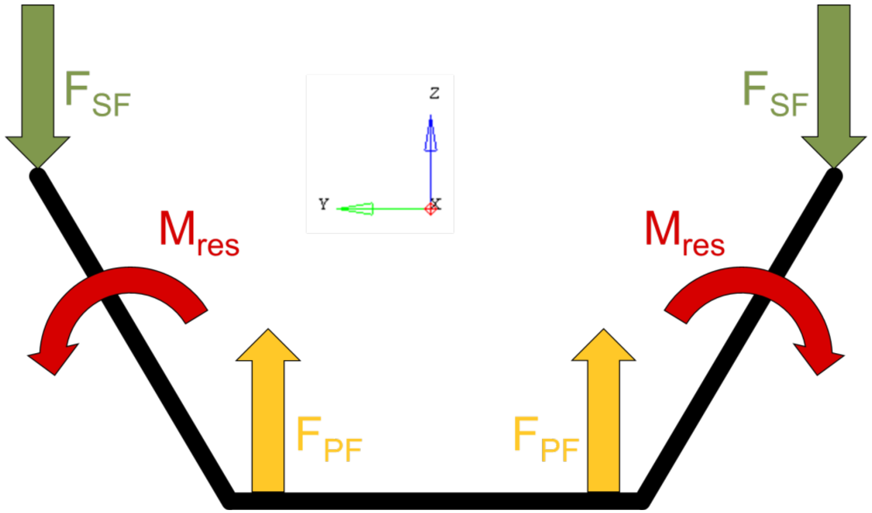
Requirements for structural integrity

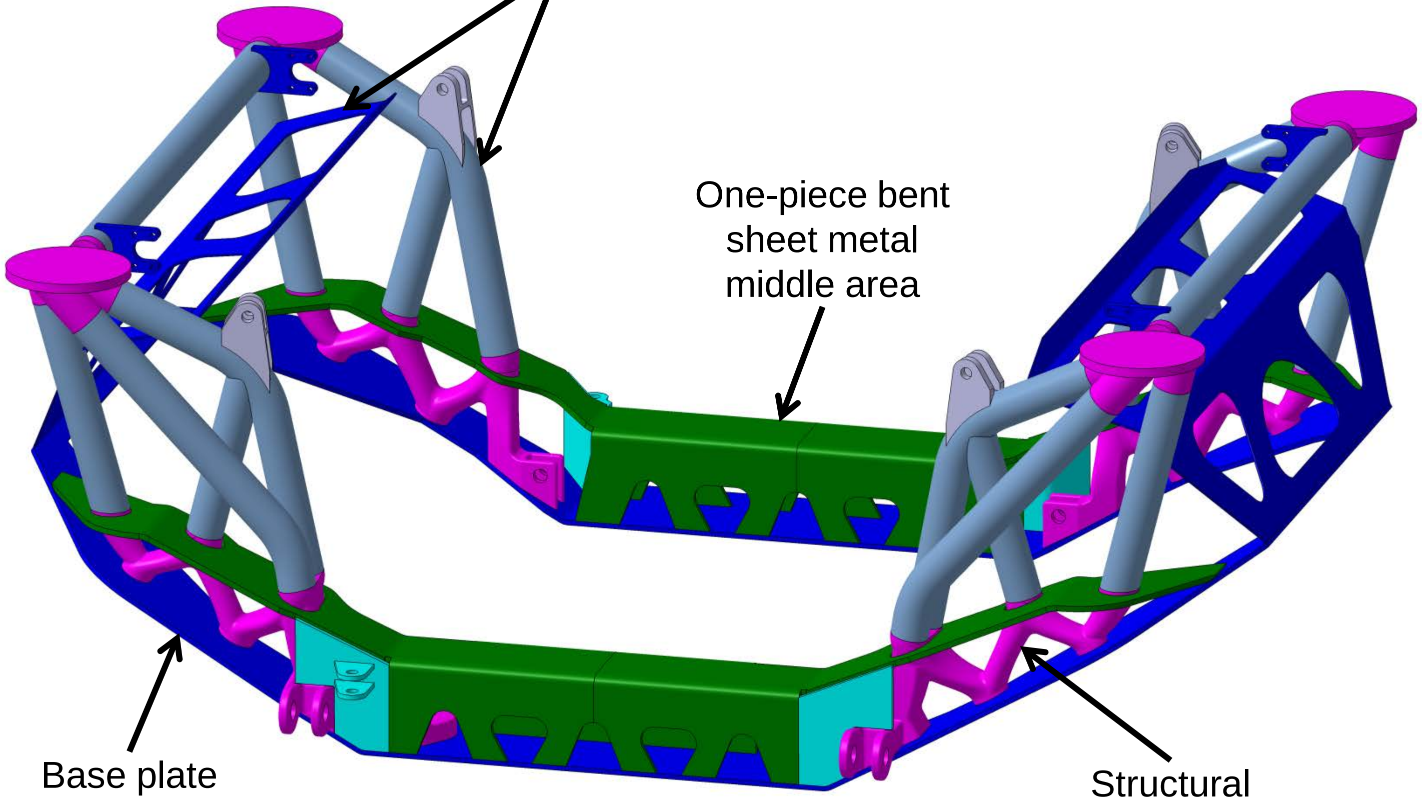
New design for secondary frame



Transfer of the Results to New Design of the Secondary Frame

- Continuous bent sheet metal parts in middle area
  - provide non-interrupted force flow against main load case
  - No welds in highly-stressed load paths in middle section



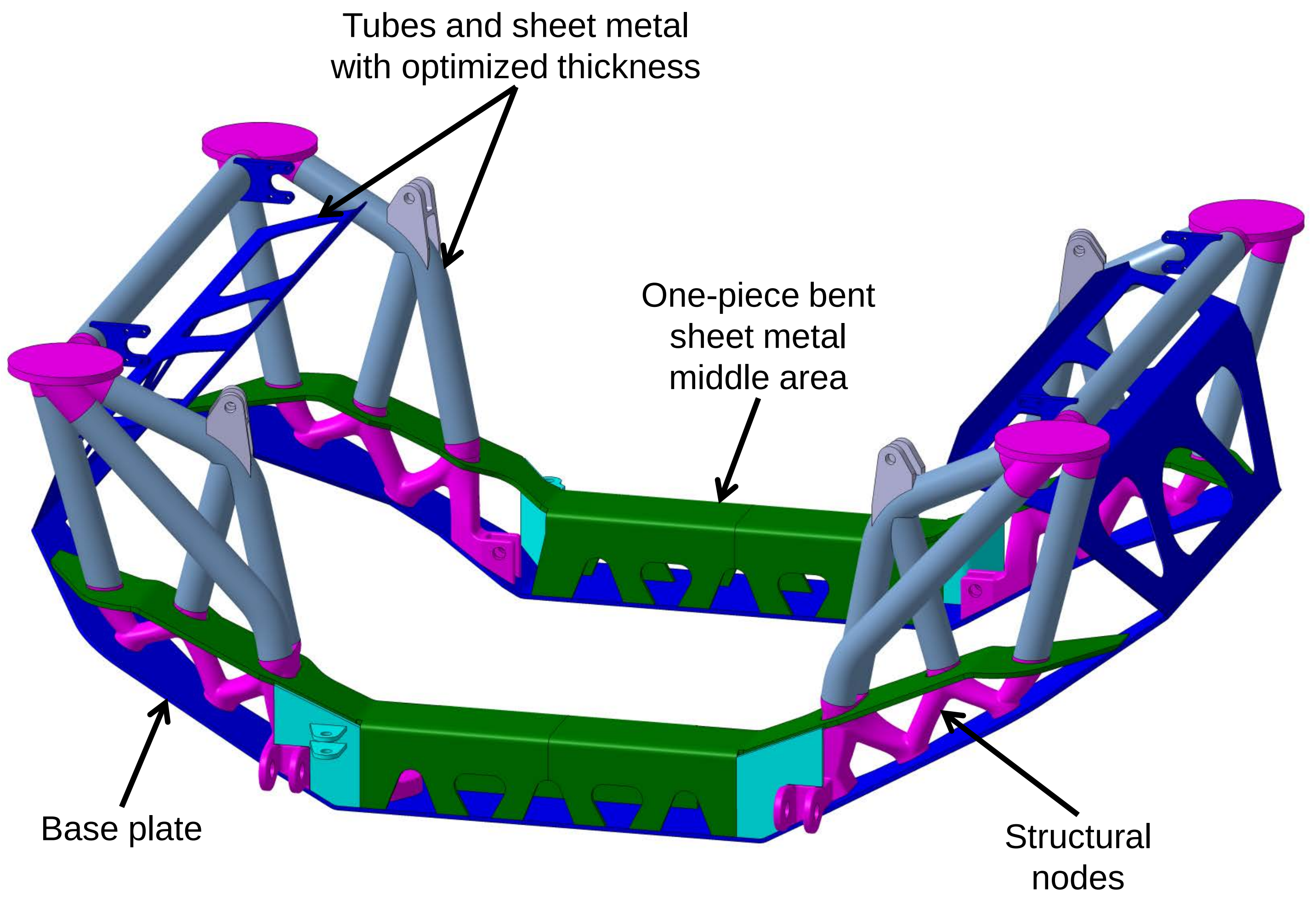


Transfer of the Results to New Design of the Secondary Frame

- Continuous bent sheet metal parts in middle area
  - provide non-interrupted force flow against main load case
  - No welds in highly-stressed load paths in middle section

- Hollow cast structural nodes
  - Connect tubes with base plate
  - Follow the topology optimization
  - Casting planned with 3D-printed sand preforms

→ Redesigned frame is stiffer, cheaper and easier to manufacture



NGT HST Running Gear – Lightweight-Optimised Driving Gear Concept

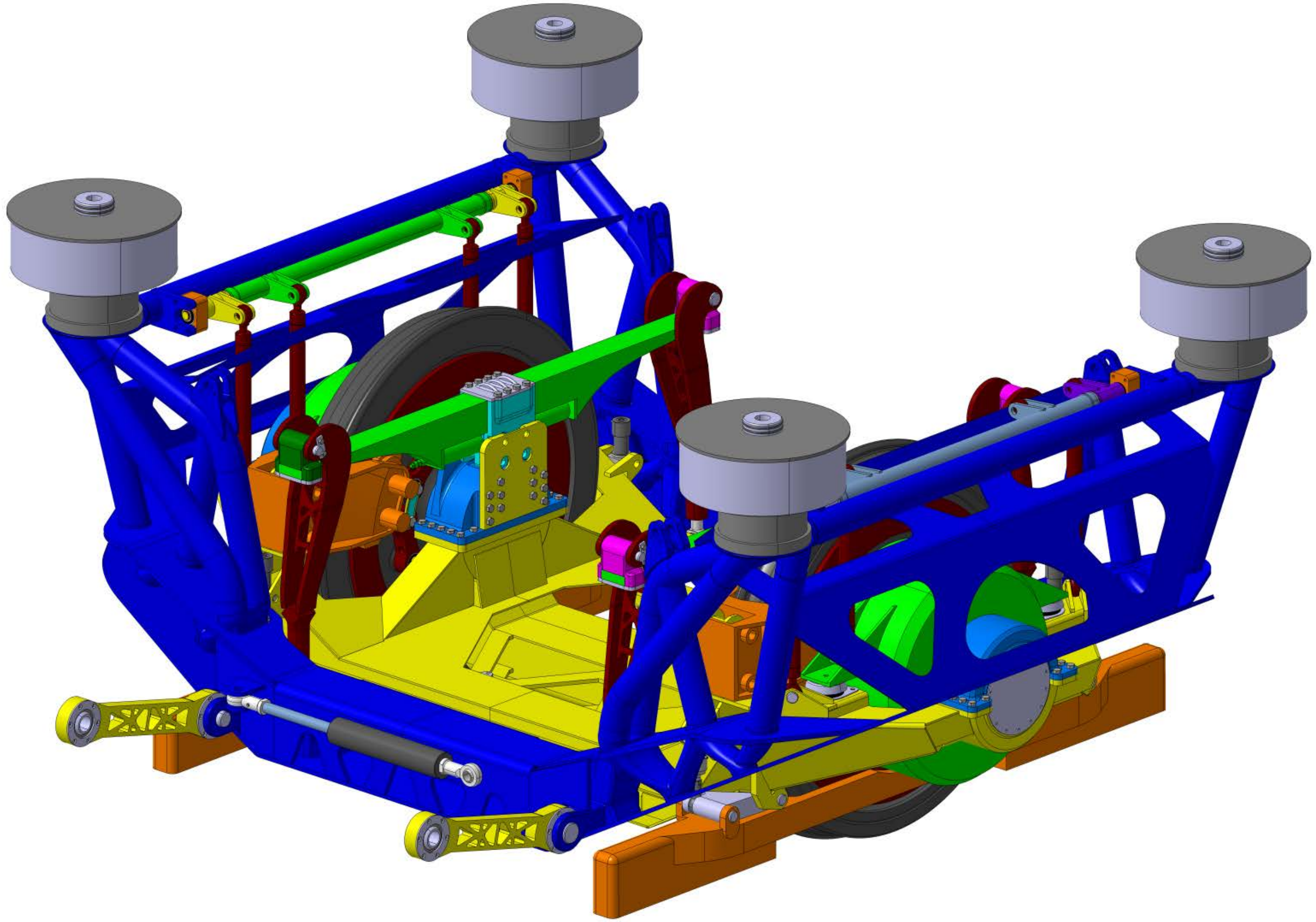
- Single axis running gear with independently rotating wheels

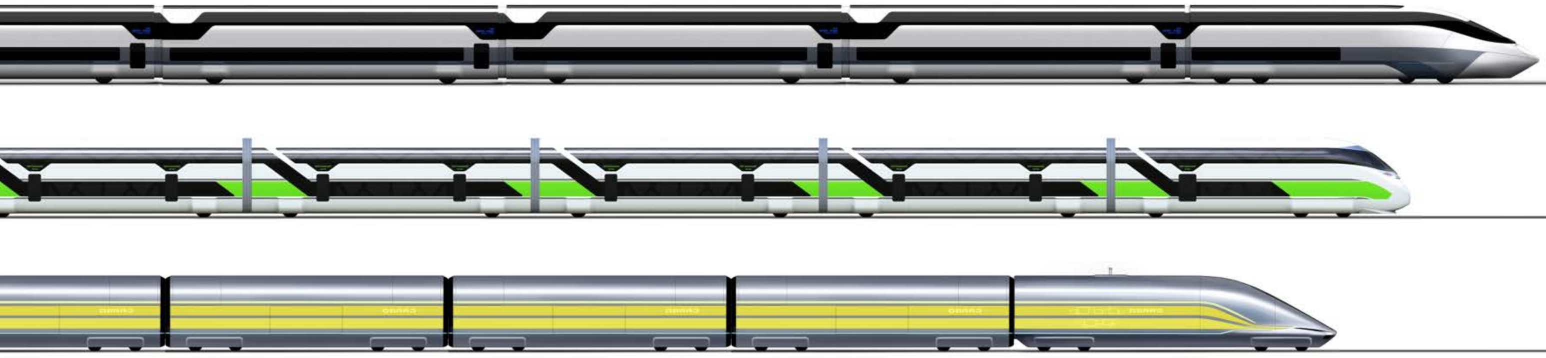
- Implementation as steel hybrid design

- Axle bridge weldment ca. 310 kg
- Secondary frame weldment ca. 500 kg

- Total driving gear mass ca. 2900 kg

- Mass of a comparable set of (non-driven) high speed running gear ca. 3000 kg





Thank You!