FROM DATA QUALITY TO DESIGN AUTOMATION

Physics-based wiring harness design based on standardized KBL/VEC processes

Daniel Dengel
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Bordnetze Digital, Stuttgart, 24.09.2026

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Agenda

1 Insights and purpose
2 The basis for scalable design automation
3 Design automation application cases
4 Outlook & conclusion

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1 **Insights and purpose**

2 The basis for scalable design automation

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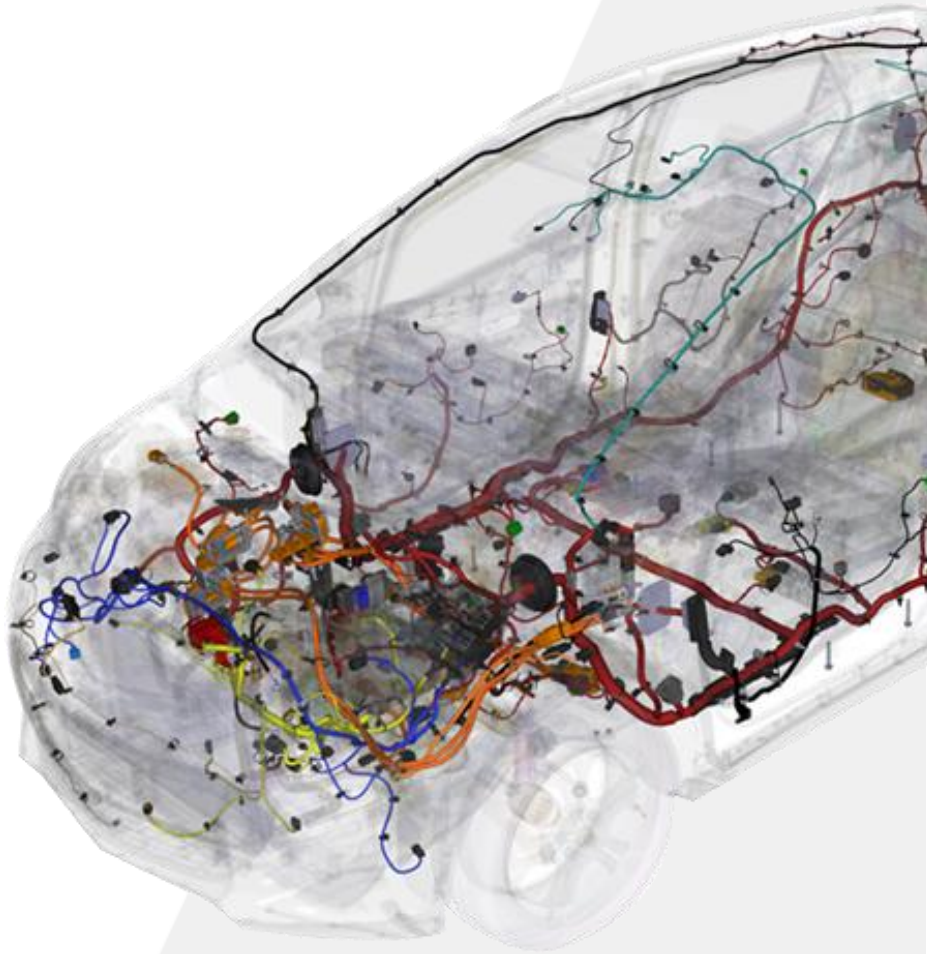
Insights and purpose

About us

- 2012: High-tech spin-off of Fraunhofer ITWM Kaiserslautern **leading real-time technology** for flexible components
- **Realistic, physics-based design and validation** in one step, static and dynamic
- Over 180 customers from various industries, including almost all **automotive OEMs, cable manufacturers and service providers**



Vision

- Bringing revolutionary technology to an innovative 3D electrical system development process “Living digital twin”

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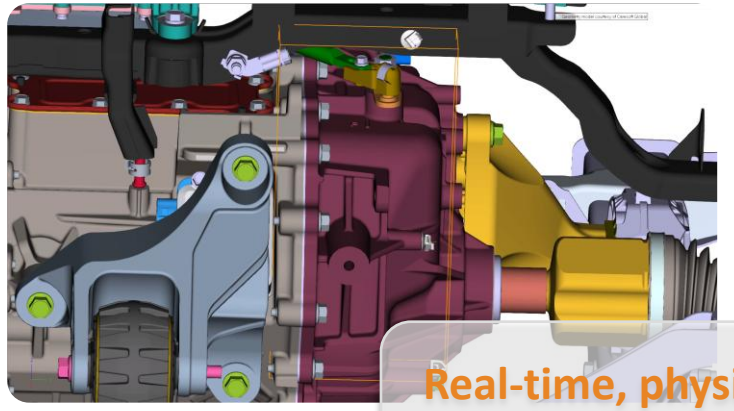
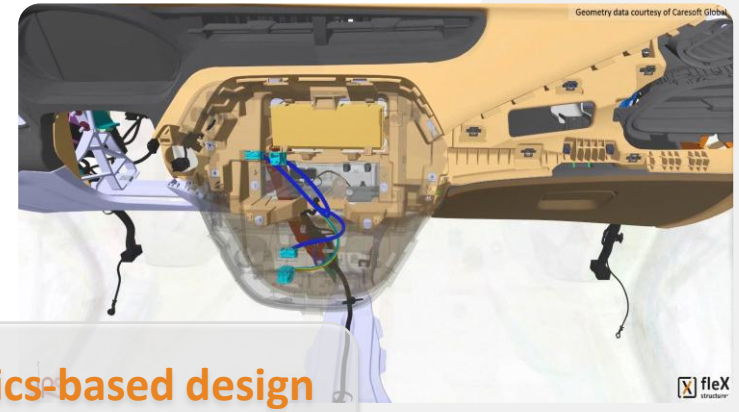
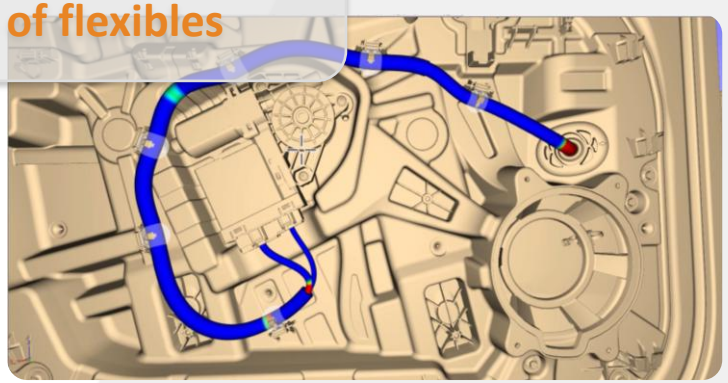
Insights and purpose
IPS Cable Simulation

- Design & validate
- Simulate motion
- Validate behavior
- Optimize automatically





Real-time, physics-based design & validation of flexibles



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Insights and purpose

From structured product data to a physically robust 3D design and release decision

SOLUTION COVERAGE

IPS fleX Hub · data, interoperability & automated workflows

IPS Cable Simulation · Topology

IPS Cable Simulation · Physical behavior, design, validation & optimization

PREPARE DATA

Reuse verified component models from a central source

VALIDATE DESIGN EARLY

Physically assess routing, lengths, clips and package space

VALIDATE

Validate motion, design rules, tolerances and objectives

OPTIMIZE & SCALE

Reuse predecessor knowledge and automate targeted changes

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1 Insights and purpose

2 **The basis for scalable design automation**

3 Design automation application cases

4 Q&A

The basis for scalable design automation

1 Standardized Data

KBL / VEC

What is installed?

2 Physical Data

validated components

How does it behave?

3 IPS Physics

Simulation & Validation

Does it work?

4 Automation

Generate · Evaluate · Optimize

What is the best solution?

STANDARDIZE → PHYSICALIZE → AUTOMATE

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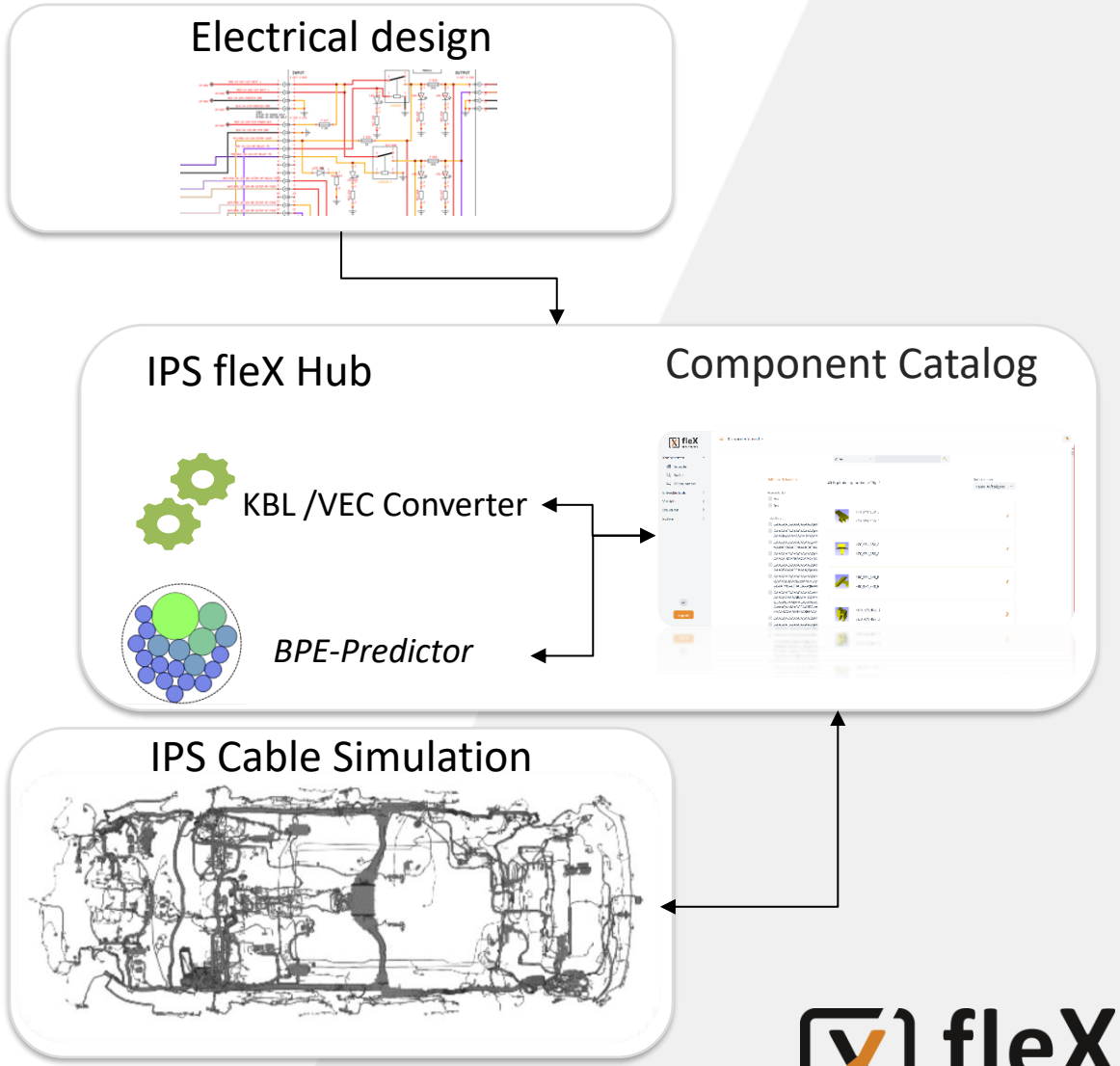
1 Standardized Data

- Automatic, complete and physically correct creation of harnesses in seconds
- Correct positioning and creation of branches
- Automatic linking with connectors, clips and all other components from the catalog
- Automatic determination of the mechanical properties of the harness and cross-sections



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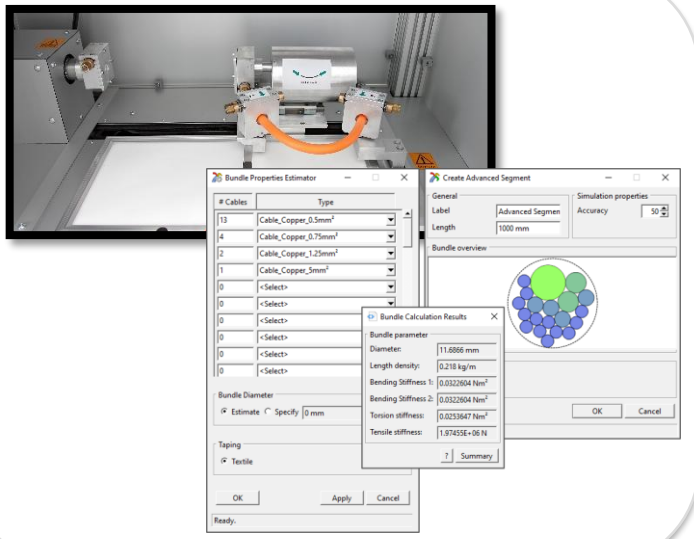
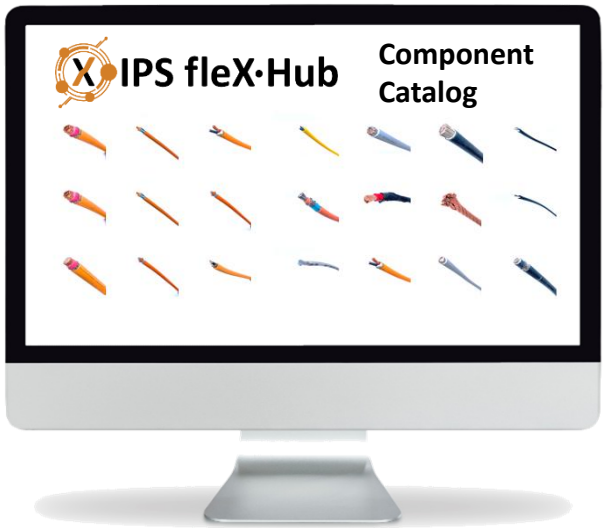
2 Physical Data

MeSOMICS



Standardized measurements & estimations of components

IPS fleX·Hub



Manufacturer number / Cable type / Cable cross-section

IPS

Physics-based design & validation in IPS

Correct result right from the start

Design, Optimization,

Validation

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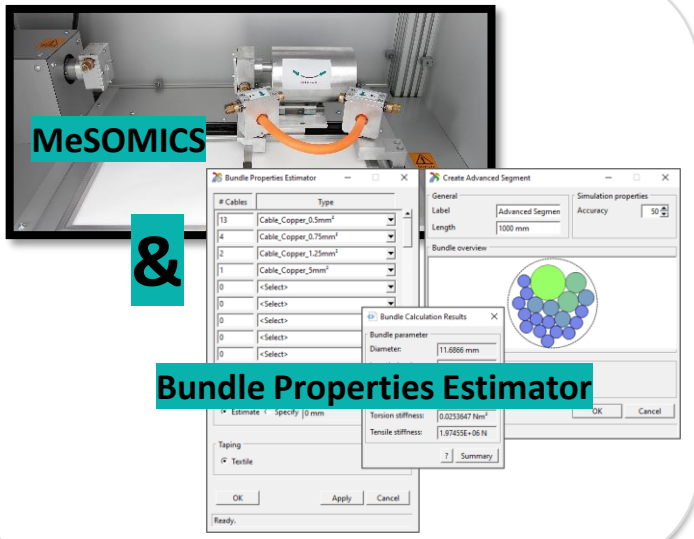
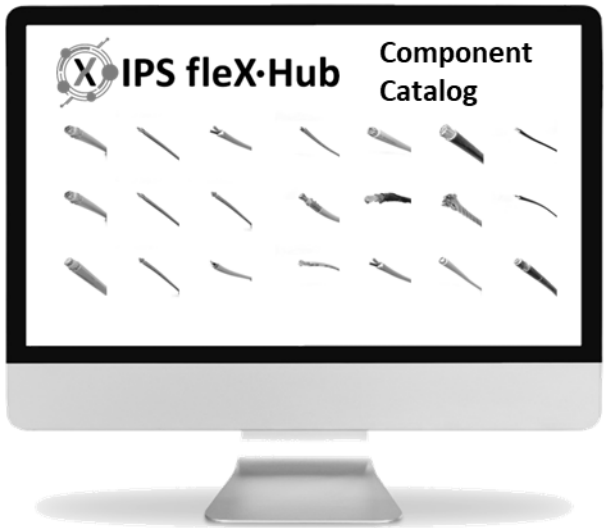
2 Physical Data

MeSOMICS



Standardized measurements & estimations of components

IPS fleX·Hub



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Correct result right from the start

Design, Optimization, Validation

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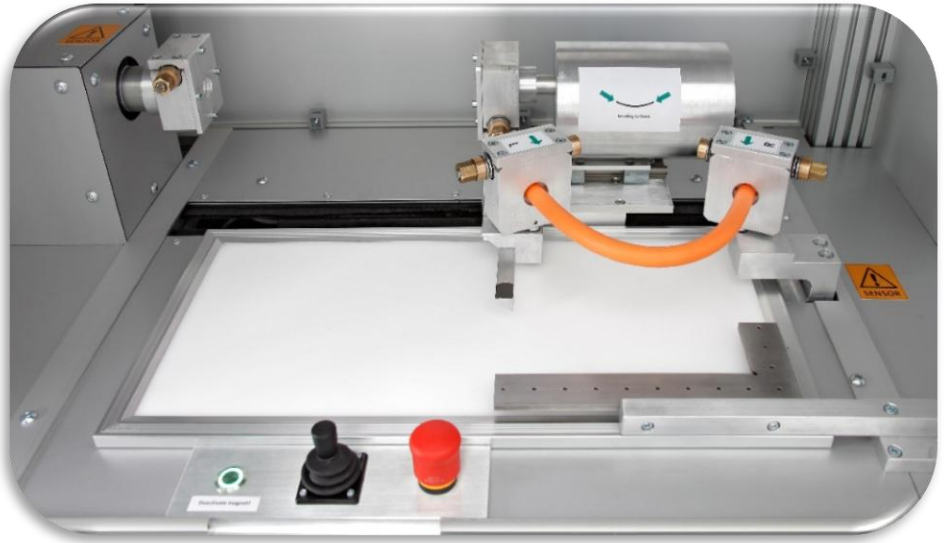
2 Physical Data - MeSOMICS

Measurement System for the Optically Monitored Identification of Cable Stiffnesses

- Identification of effective mechanical cable properties
- Highly automated for fast parameterization
- Innovative bending test



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2 Physical Data – Bundle Properties Estimator (BPE)

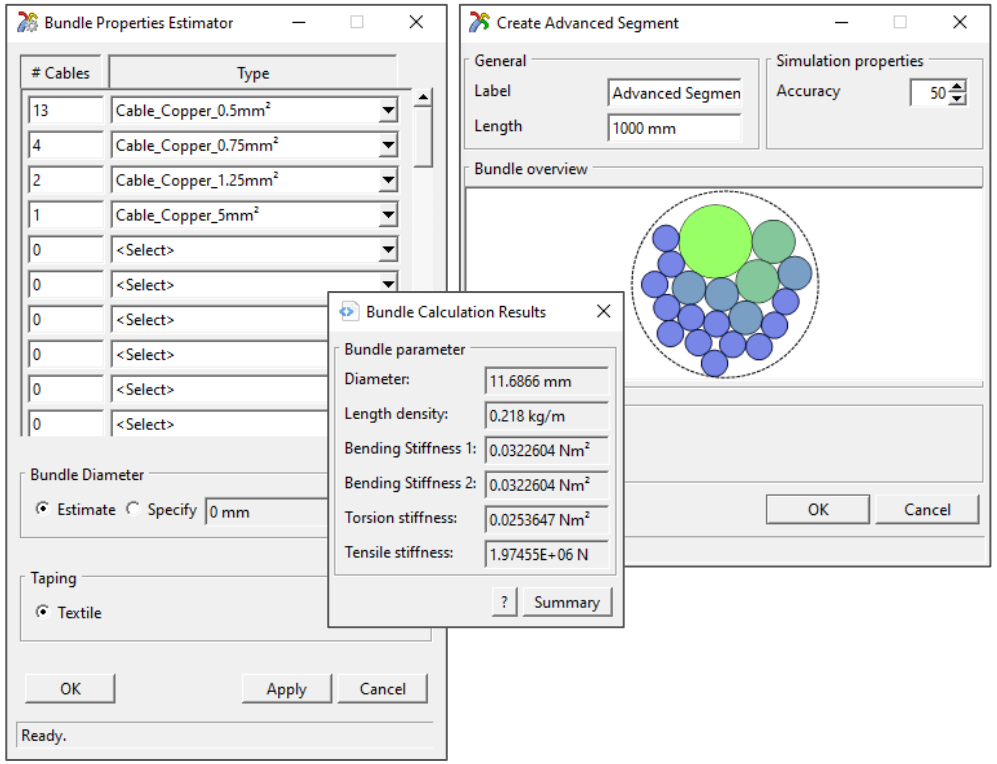
AI-based estimation of effective properties

Motivation

- Measuring all cables is manageable; measuring all cable bundles is not
- In early design phases, bundle specimens are often unavailable

The Bundle Properties Estimator

- Generates complete bundle data set, based on the properties of the single cables



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2 Physical Data

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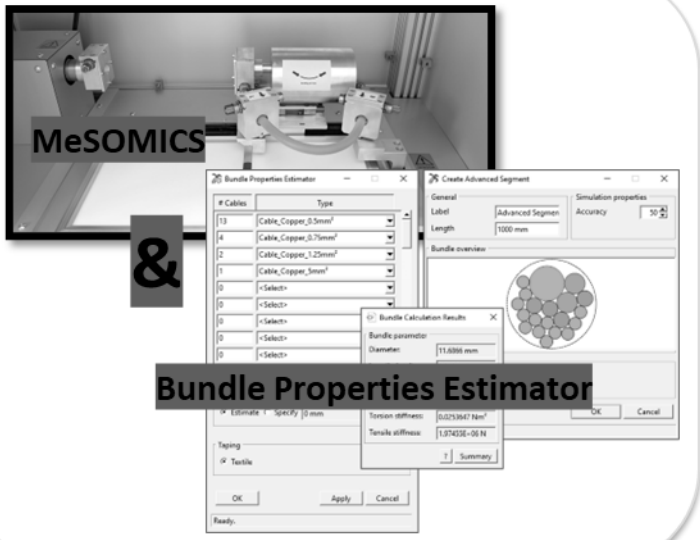

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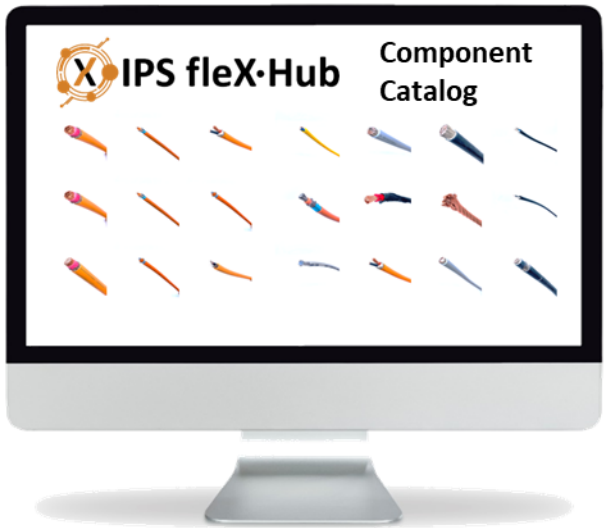
IPS fleX·Hub



Manufacturer number / Cable type / Cable cross-section

IPS

Physics-based design & validation in IPS

Correct result right from the start

Design, Optimization, Validation

fleX structures

STANDARDIZE → PHYSICALIZE → AUTOMATE

Turn engineering data into simulation-ready value

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Result: Physical correct wiring harness

1 Standardized Data

KBL / VEC / PLM

What is installed?

2 Physical Data

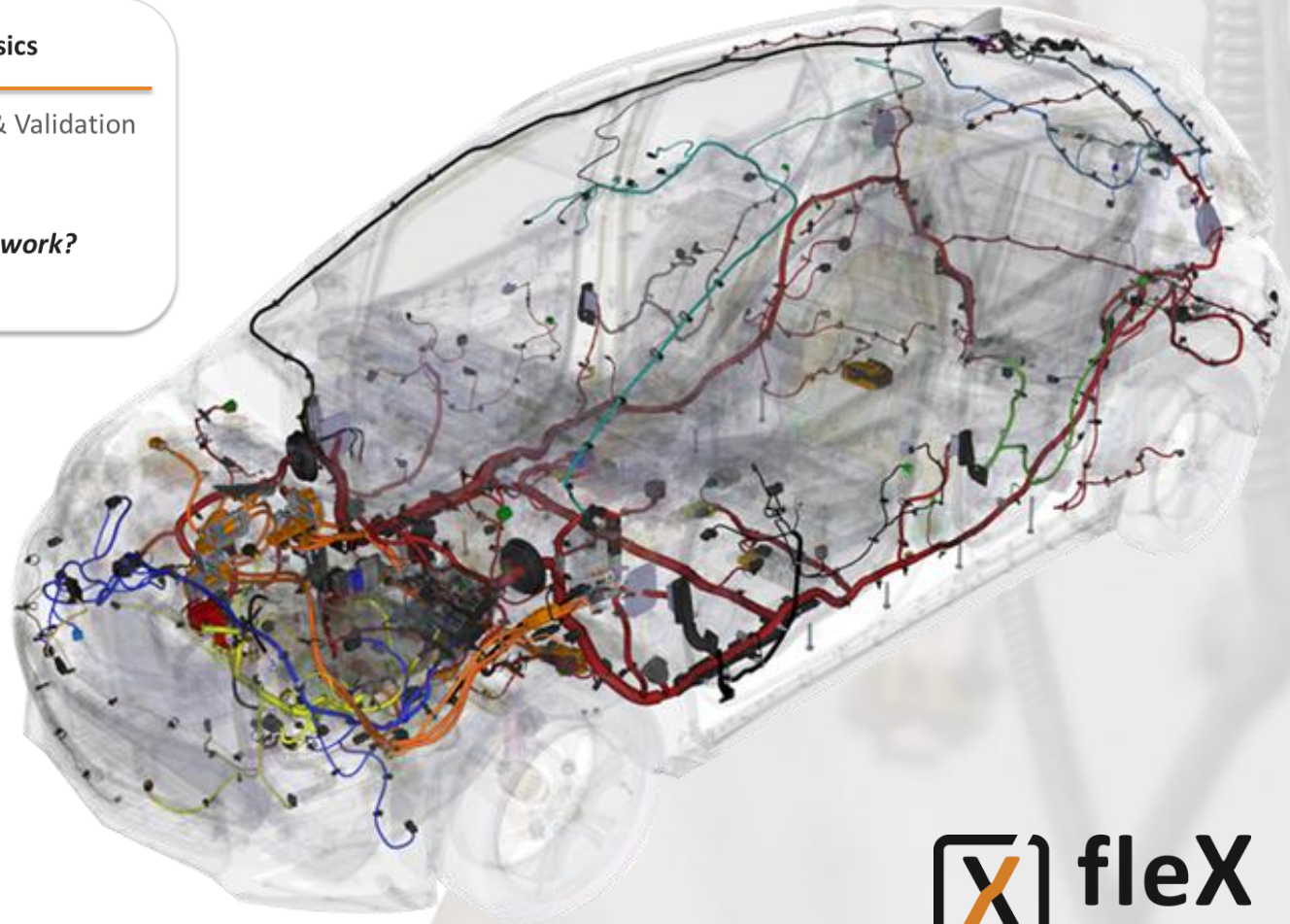
validated components

How does it behave?

3 IPS Physics

Simulation & Validation

Does it work?



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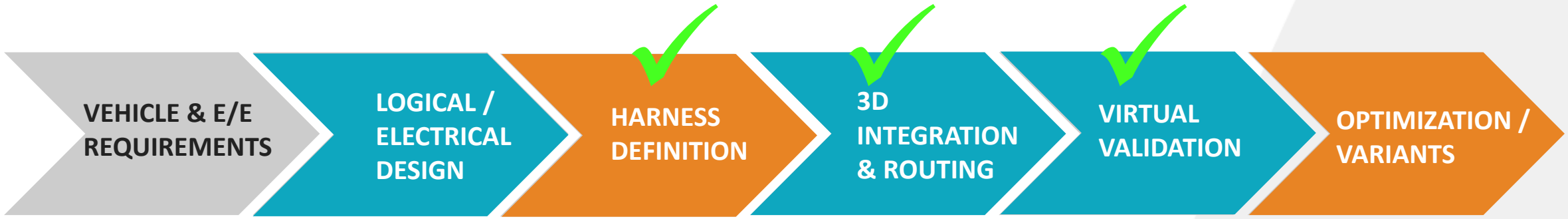
From structured product data to a physically robust 3D design and release decision



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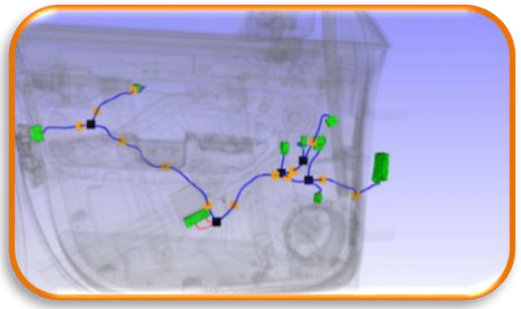
Design automation application cases

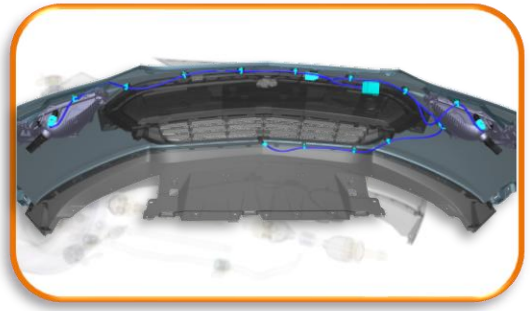
Overview of application cases

1 Architecture phase



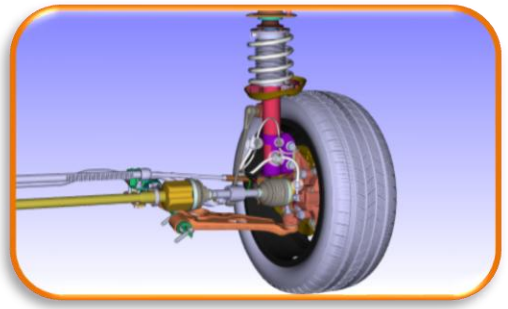
Logic → Topology → Reality

2 Automated design adaptions



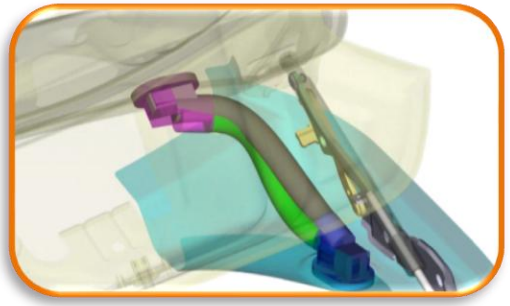
Check → Adapt → Check

3 Global optimization



Define → Calculate → Understand

4 Grommet optimization



Define → Calculate → Understand

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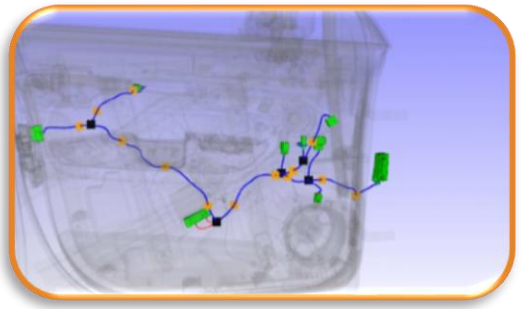
Design automation application cases

Overview of application cases

1 Architecture phase

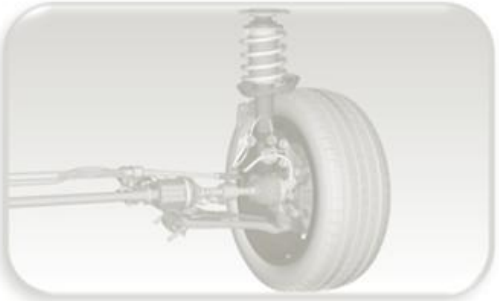


Logic → Topology → Reality

2 Automated design adaptions

Check → Adapt → Check

3 Global optimization



Define → Calculate → Understand

4 Grommet optimization

Define → Calculate → Understand

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1 Architecture phase

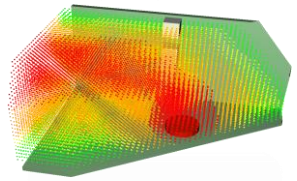
Design proposals based on different objective functions:

- minimal cable length vs. minimal installation effort

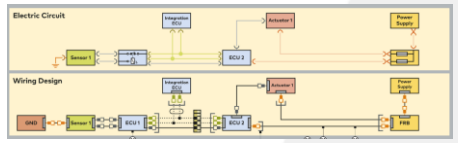
Selection of an optimal compromise

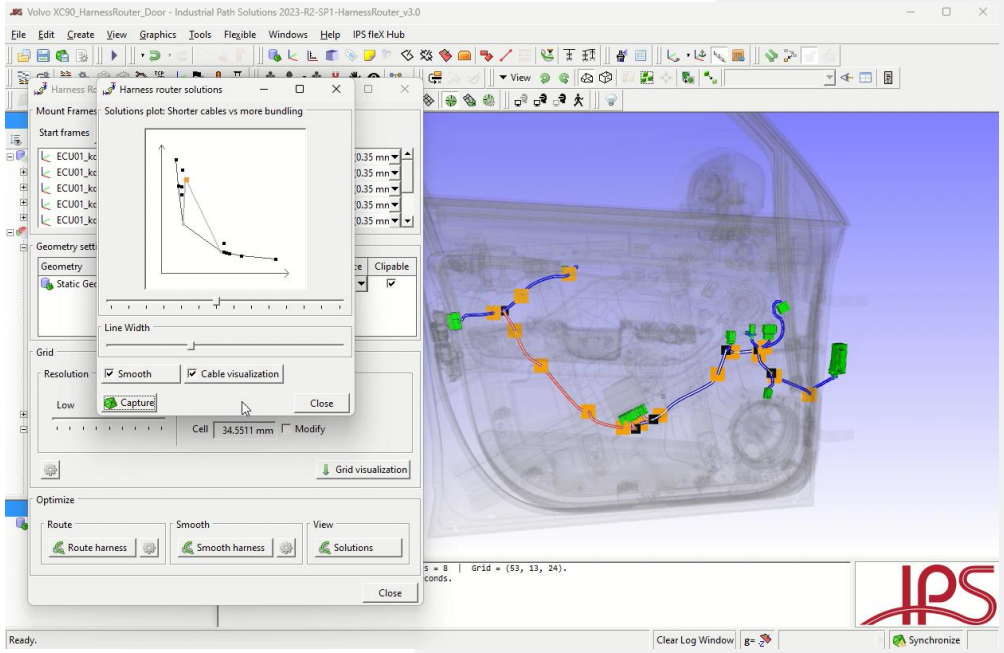
- High maturity level of the wiring harness concept in a short time

Design space



E-Logic





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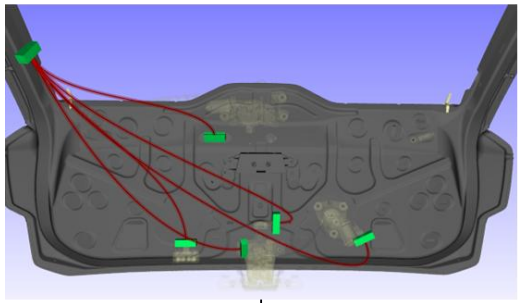
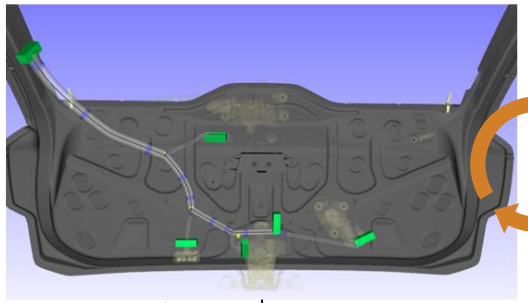
1 Architecture phase

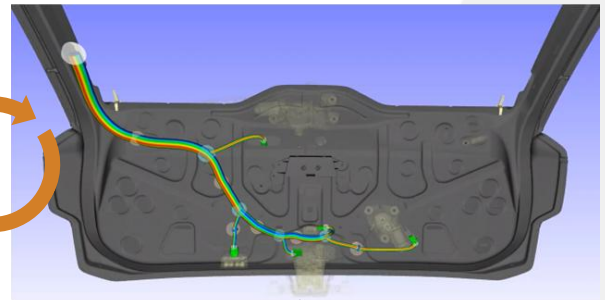
Logic

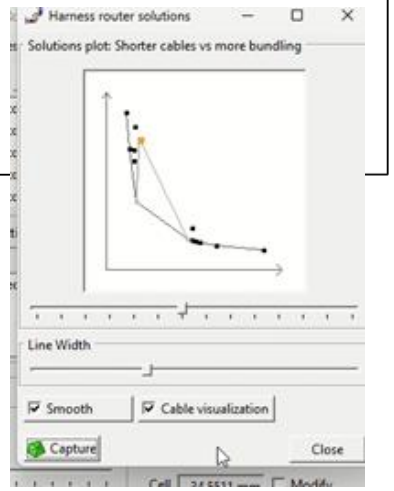
Topology

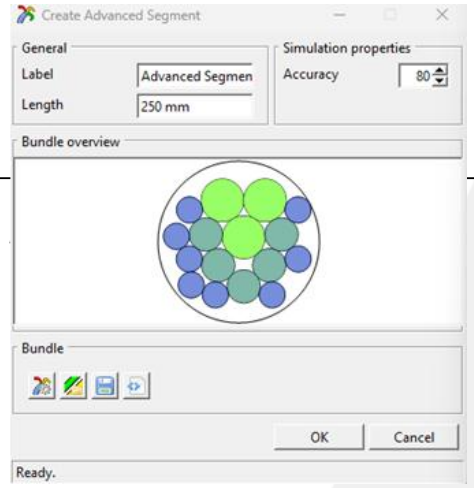
Realistic design suggestions











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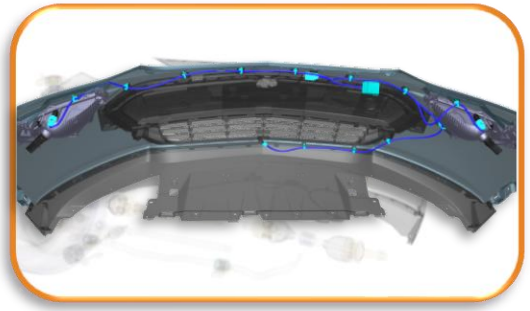
Design automation application cases

Overview of application cases

1 Architecture phase

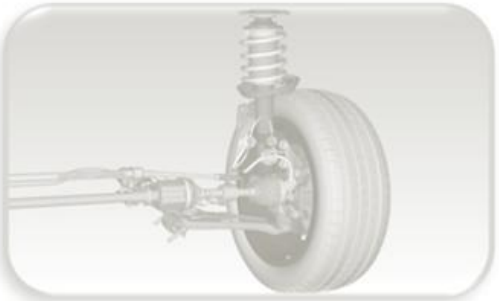
Logic → Topology → Reality

2 Automated design adaptions



Check → Adapt → Check

3 Global optimization



Define → Calculate → Understand

4 Grommet optimization

Define → Calculate → Understand

fleX structures

The Engineer´s role shifts
3D integration → virtual validation

EXAMPLE
Radar position changed

TODAY · MANUAL & ITERATIVE

Trial & Error ↺

The engineer creates and checks individual solutions one after another.

1. **CREATE** → Adjust routing manually
2. **CHECK** → Check simulation / DMU
3. **FIX** → Correct the problem
4. **REPEAT** → Check again & iterate
5. **DECIDE** → Without convidence

NEW · DATA- & PHYSICS-DRIVEN

validated selection

The engineer defines objectives & rules – the system generates and evaluates alternatives.

1. **DEFINE** → Define objectives & design rules
2. **GENERATE** → Generate variants automatically
3. **VALIDATE** → IPS Physics validates
4. **OPTIMIZE** → Prioritize valid solutions
5. **DECIDE** → Engineer selects & releases

Key message: The engineer designs fewer variants manually – instead, they define the solution space and decide between physics-validated alternatives.

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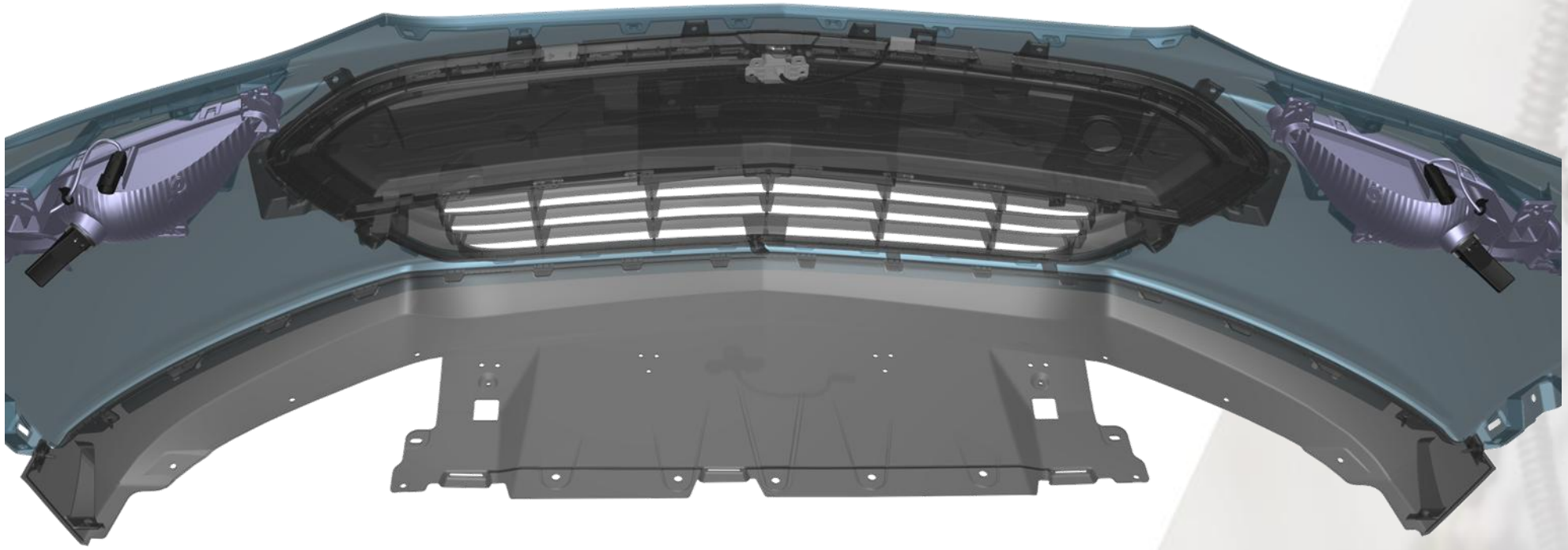
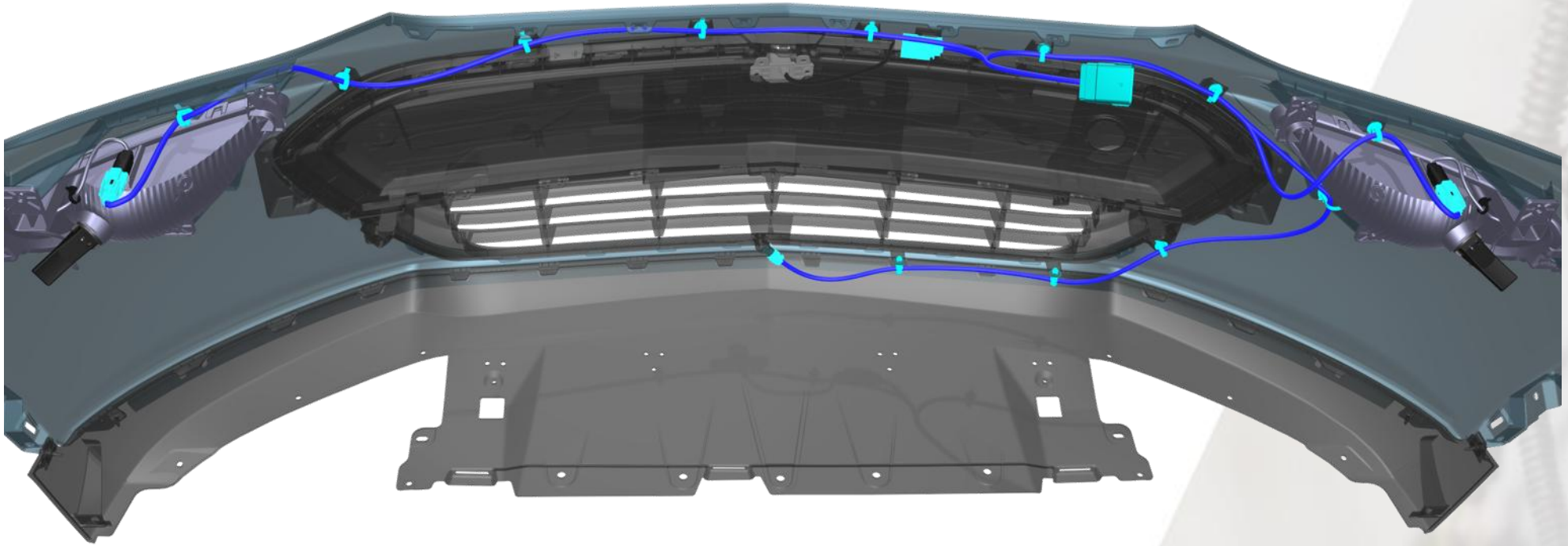
2 Automated design adaptions - Bumper example



Import KBL/VEC → Possible changes → Apply design guides → Automated changes → Final design check

fleX structures

2 Automated design adaptions - Bumper example



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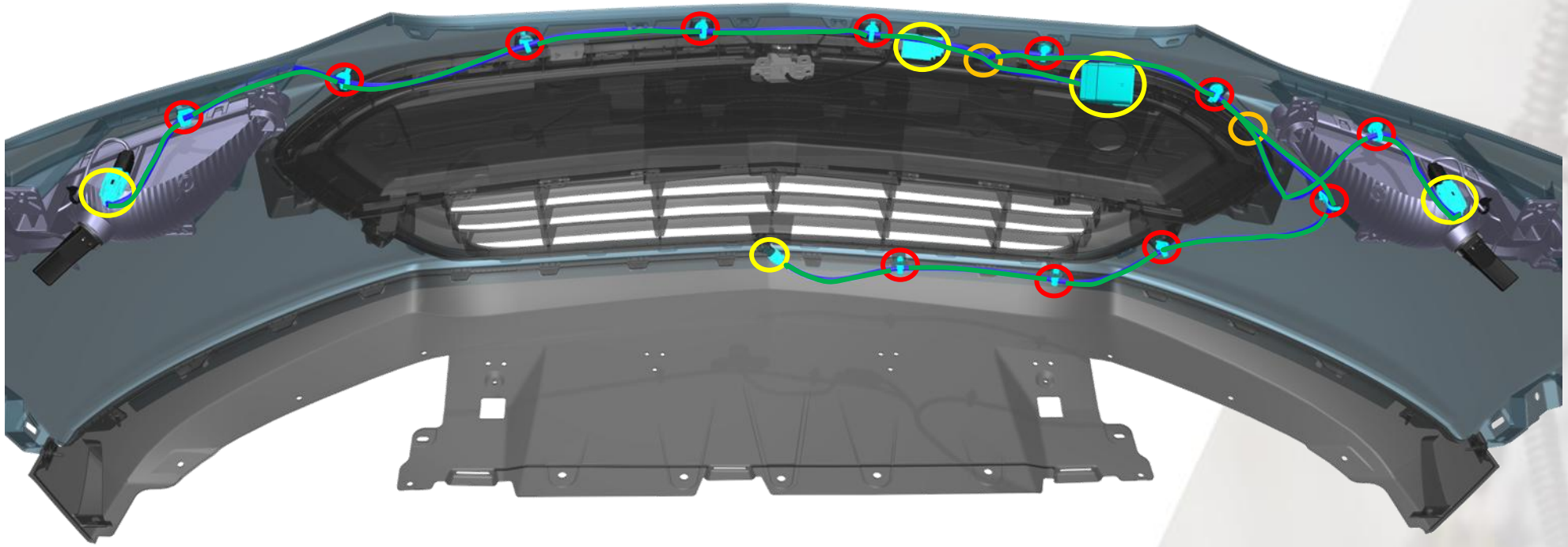
2 Automated design adaptions - Bumper example

Clip position
Clip orientation

Branch position

Connector position
Connector orientation

Harness length



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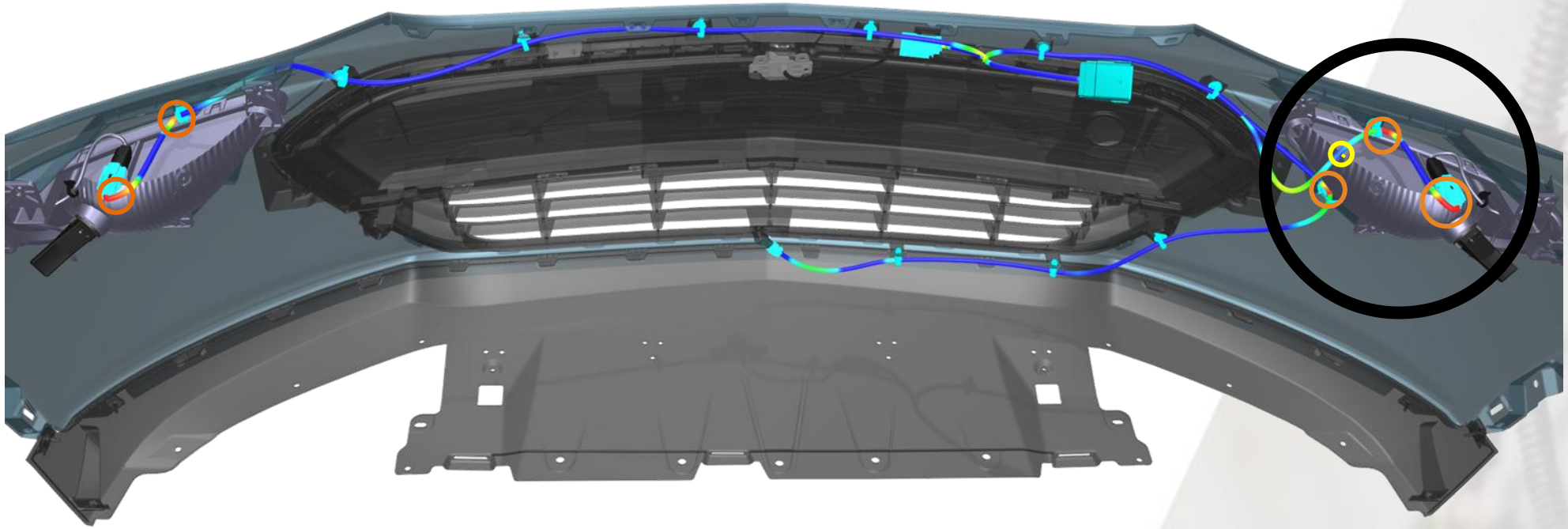
2 Automated design adaptions - Bumper example

Bending radii
Tension forces

Clearance



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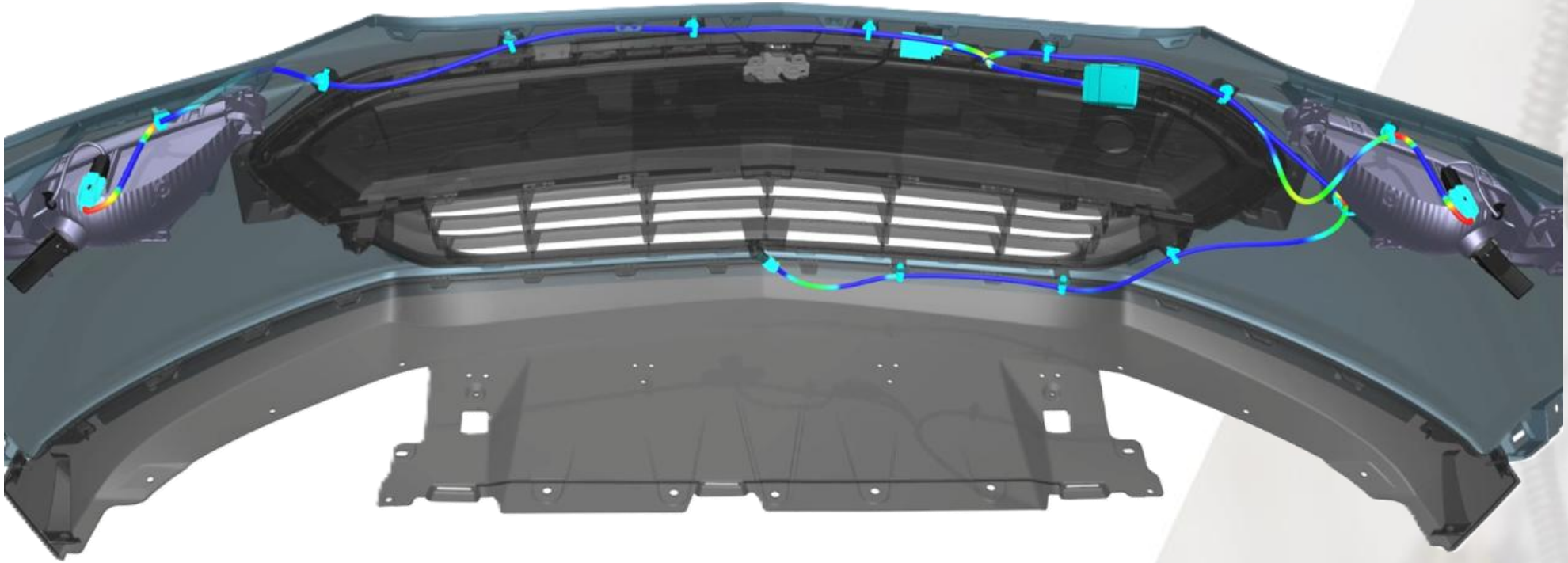

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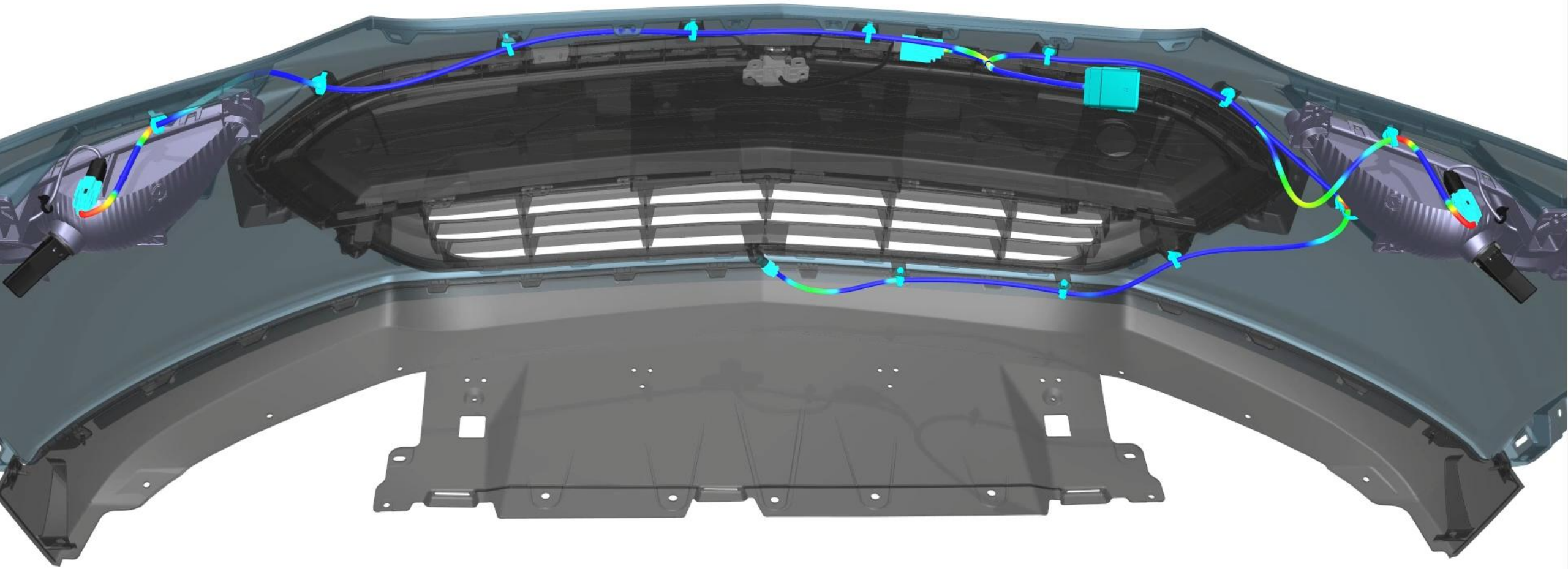

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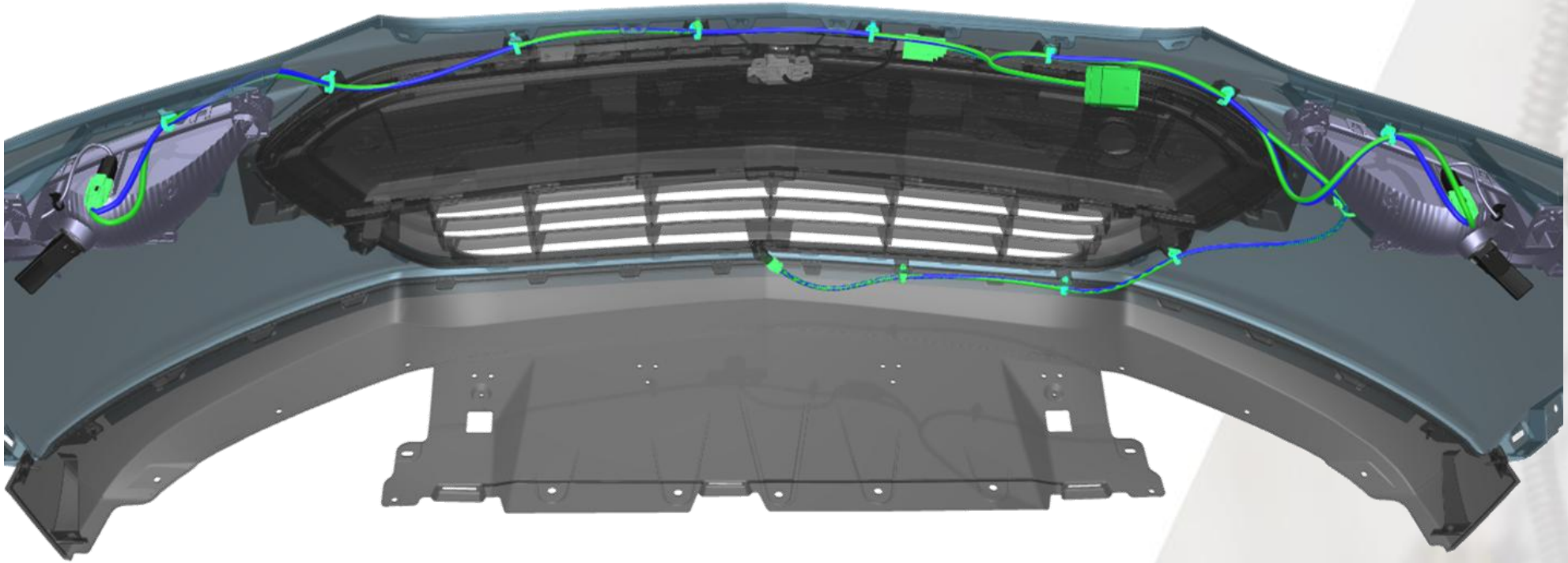

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Design automation application cases

Overview of application cases

1 Architecture phase

Logic → Topology → Reality

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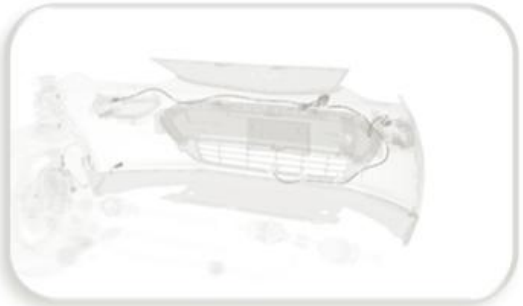

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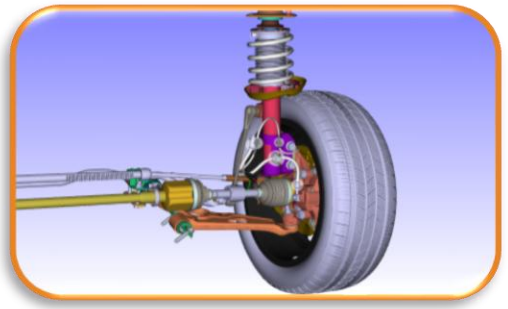

Define → Calculate → Understand

4 Grommet optimization

Define → Calculate → Understand

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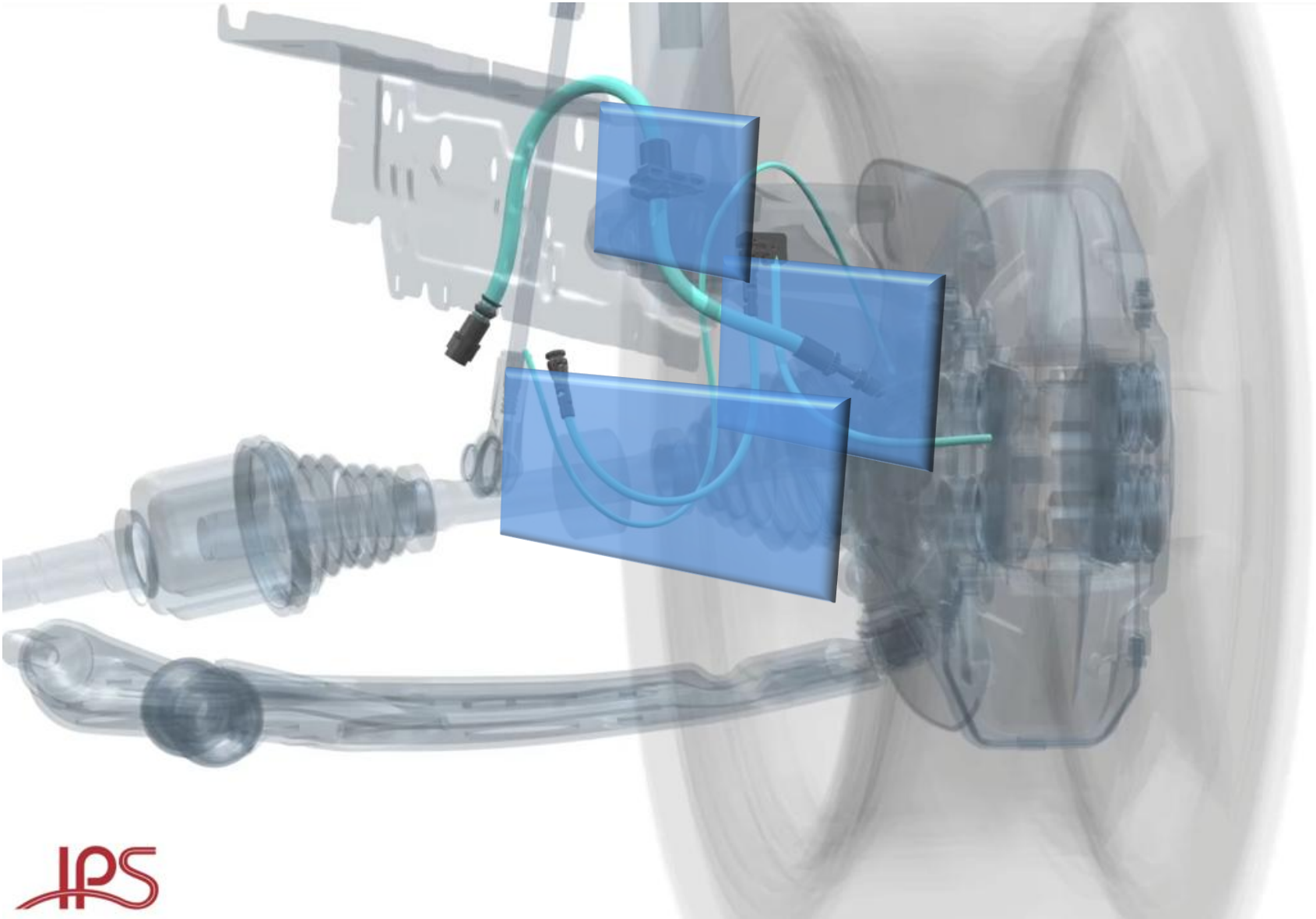
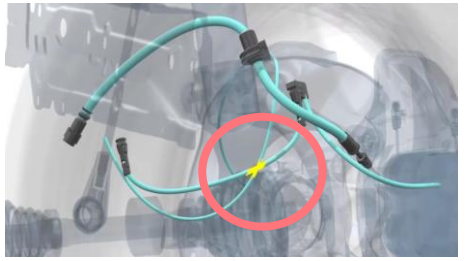
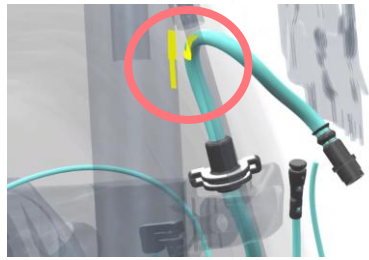
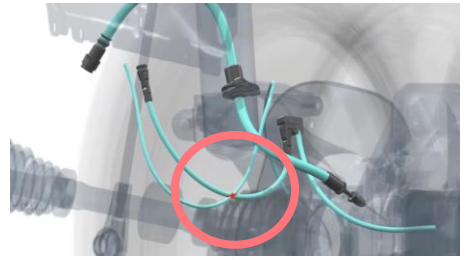
3 Global optimization – Suspension example – Initial situation



Unintended collisions and insufficient clearance!





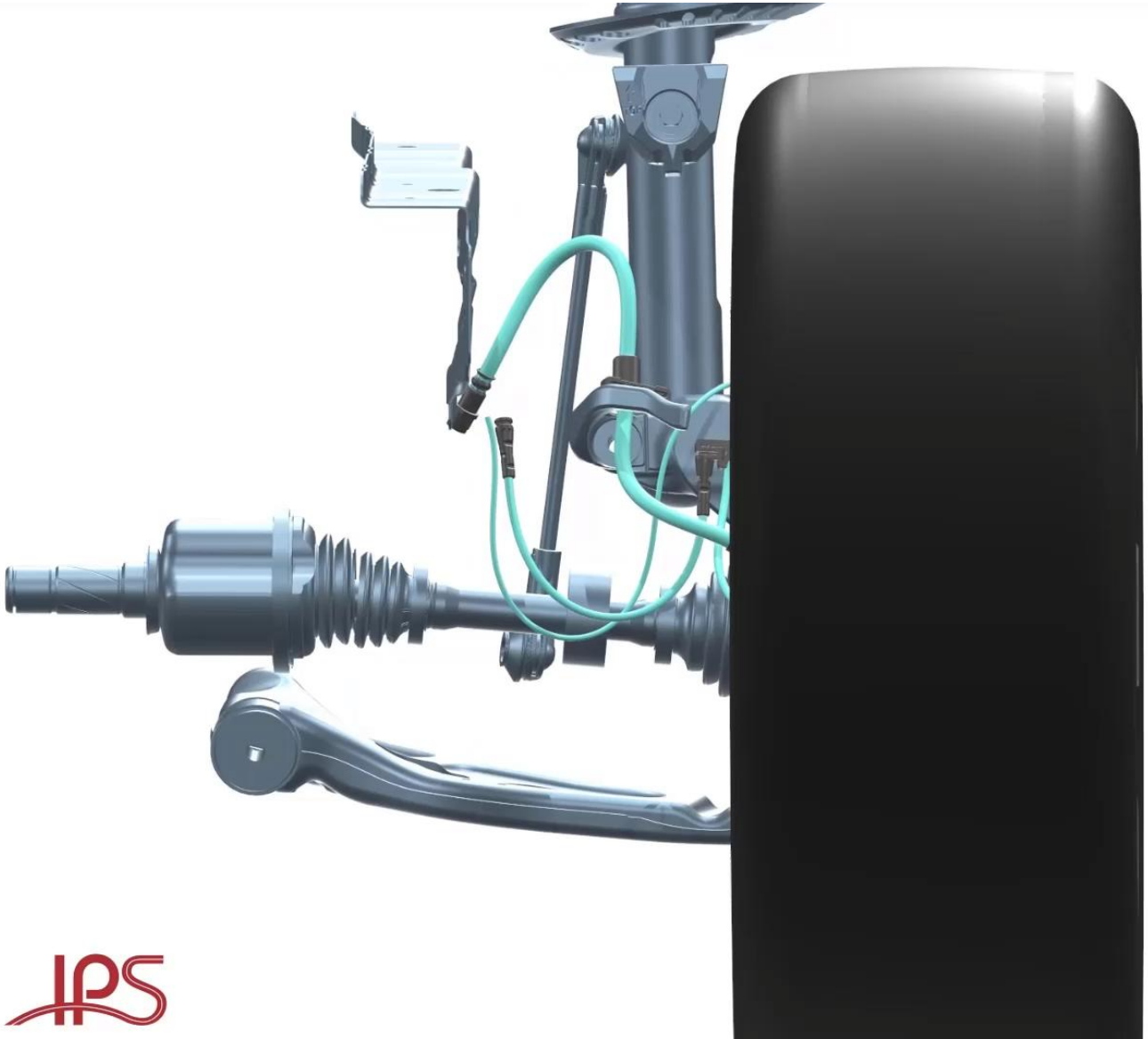


fleX structures

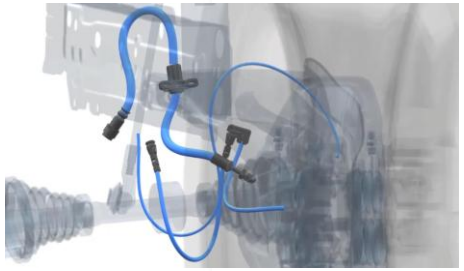
IPS

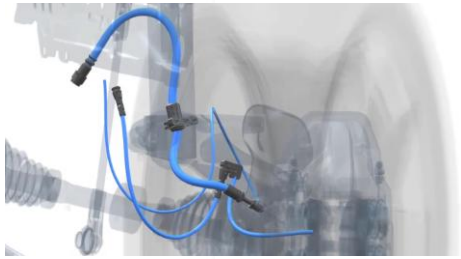
Collision Test 1: No collision
Collision Test 2: No collision

3 Global optimization – Suspension example – Result



No collisions and
adherence to minimum clearances

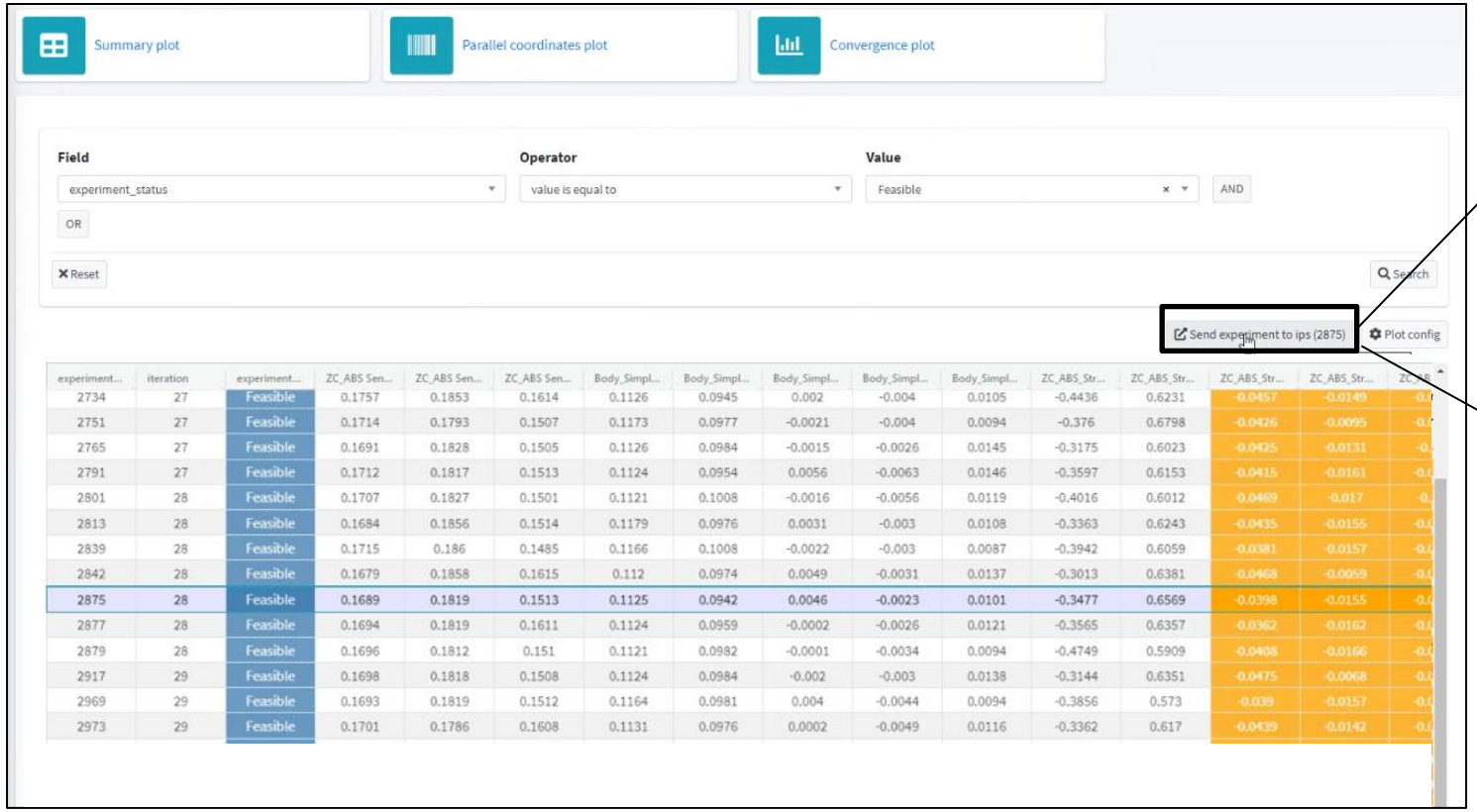




IPS

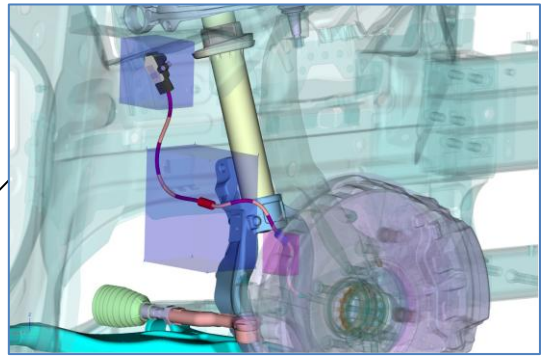
fleX structures

3 Global optimization – Suspension example – Postprocessing



experiment...	iteration	experiment...	ZC_ABS Sen...	ZC_ABS Sen...	ZC_ABS Sen...	Body_Simpl...	Body_Simpl...	Body_Simpl...	Body_Simpl...	Body_Simpl...	ZC_ABS_Str...	ZC_ABS_Str...	ZC_ABS_Str...	ZC_ABS_Str...	ZC_AB
2734	27	Feasible	0.1757	0.1853	0.1614	0.1126	0.0945	0.002	-0.004	0.0105	-0.4436	0.6231	-0.0457	-0.0149	-0.
2751	27	Feasible	0.1714	0.1793	0.1507	0.1173	0.0977	-0.0021	-0.004	0.0094	-0.376	0.6798	-0.0426	-0.0095	-0.
2765	27	Feasible	0.1691	0.1828	0.1505	0.1126	0.0984	-0.0015	-0.0026	0.0145	-0.3175	0.6023	-0.0425	-0.0131	-0.
2791	27	Feasible	0.1712	0.1817	0.1513	0.1124	0.0954	0.0056	-0.0063	0.0146	-0.3597	0.6153	-0.0415	-0.0161	-0.
2801	28	Feasible	0.1707	0.1827	0.1501	0.1121	0.1008	-0.0016	-0.0056	0.0119	-0.4016	0.6012	-0.0469	-0.017	-0.
2813	28	Feasible	0.1684	0.1856	0.1514	0.1179	0.0976	0.0031	-0.003	0.0108	-0.3363	0.6243	-0.0435	-0.0155	-0.
2839	28	Feasible	0.1715	0.186	0.1485	0.1166	0.1008	-0.0022	-0.003	0.0087	-0.3942	0.6059	-0.0381	-0.0157	-0.
2842	28	Feasible	0.1679	0.1858	0.1615	0.112	0.0974	0.0049	-0.0031	0.0137	-0.3013	0.6381	-0.0468	-0.0059	-0.
2875	28	Feasible	0.1689	0.1819	0.1513	0.1125	0.0942	0.0046	-0.0023	0.0101	-0.3477	0.6569	-0.0398	-0.0155	-0.
2877	28	Feasible	0.1694	0.1819	0.1611	0.1124	0.0959	-0.0002	-0.0026	0.0121	-0.3565	0.6357	-0.0362	-0.0162	-0.
2879	28	Feasible	0.1696	0.1812	0.151	0.1121	0.0982	-0.0001	-0.0034	0.0094	-0.4749	0.5909	-0.0408	-0.0166	-0.
2917	29	Feasible	0.1698	0.1818	0.1508	0.1124	0.0984	-0.002	-0.003	0.0138	-0.3144	0.6351	-0.0475	-0.0068	-0.
2969	29	Feasible	0.1693	0.1819	0.1512	0.1164	0.0981	0.004	-0.0044	0.0094	-0.3856	0.573	-0.039	-0.0157	-0.
2973	29	Feasible	0.1701	0.1786	0.1608	0.1131	0.0976	0.0002	-0.0049	0.0116	-0.3362	0.617	-0.0439	-0.0142	-0.

Exp.2791



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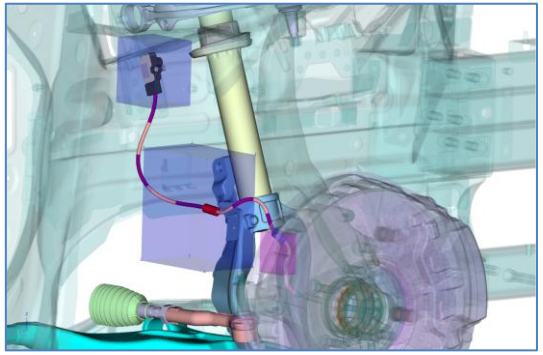

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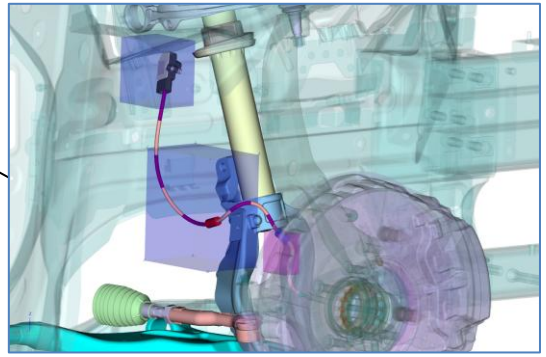


fleX structures

fleXstructures

Agenda

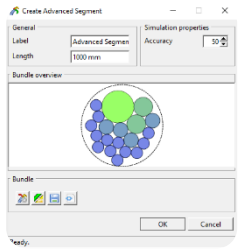
1 Insights and purpose
2 The basis for scalable design automation
3 Design automation application cases
4 **Outlook & conclusion**

fleX structures

Outlook

Usage of AI

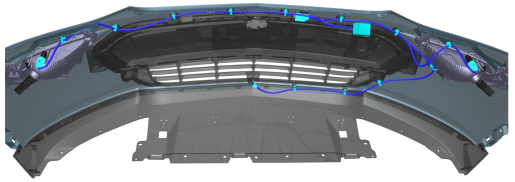
AI-ASSISTED ENGINEERING

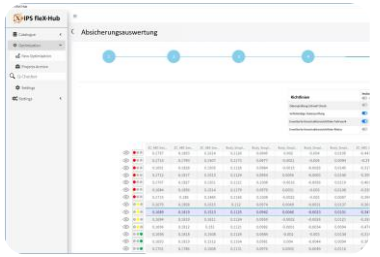


Estimation of associated stiffnesses
Trained Gaussian Process

AI-Assistent

Chat function for component catalog



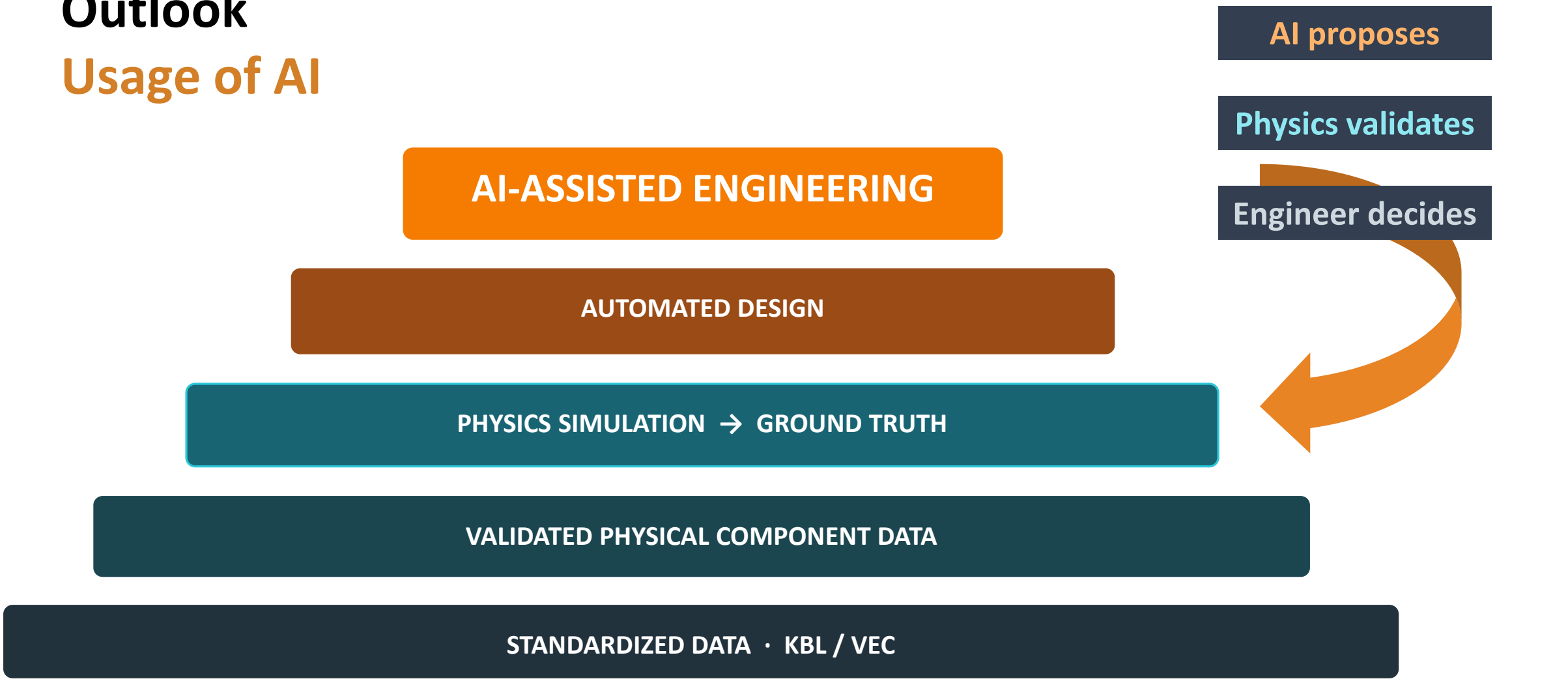


Design adjustments AI-driven suggestions and changes where safety criteria are not met

fleX structures

Outlook

Usage of AI



fleX structures

From data quality to design automation

Conclusion

The physics-based decision layer within the digital wiring-system chain.

Key aspects at a glance

- **10% shorter** total cable length, **zero collisions**, improved clearances
- New system understanding with various valid solutions identified from thousands of experiments.
- Reusable designs accelerate validation of new vehicle derivatives – one-time investment
- Final result within minutes or **a few working days for complex tasks**
- Proven reduction of costly hardware tests through virtual validation! **Up to 80% time saving**

fleX structures

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