Pantograph developments with special regard to the catanery-pantograph contact

Pantograph developments with special regard to the catanery-pantograph contact

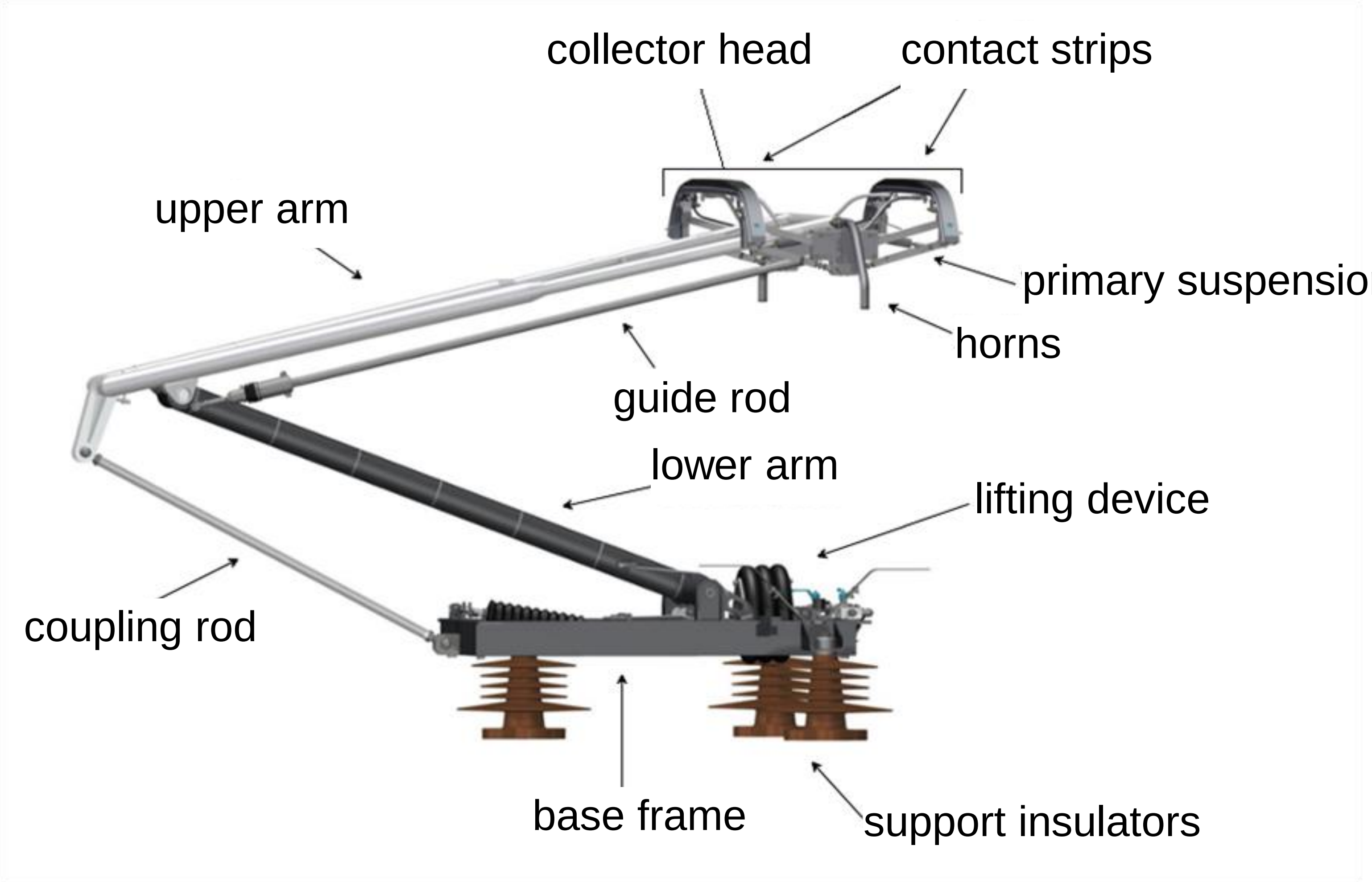
SIEMENS
Ingenuity for life

- Introduction
- Challenges
- Trends to improve the pantograph / OCL interaction
- Monitoring
- Advancements in Simulation and Emulation

Introduction

A short introduction to pantographs and overhead contact lines

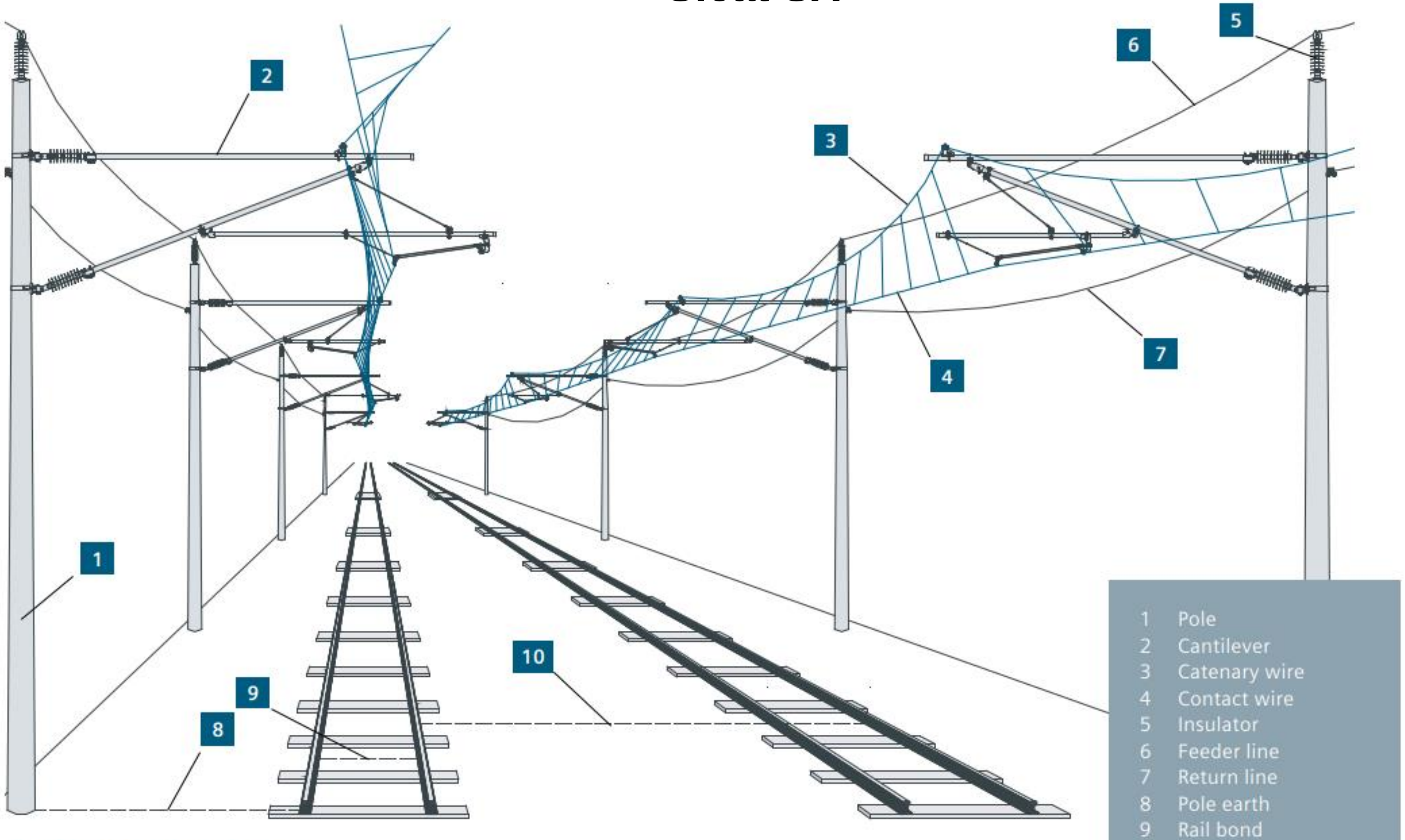
Pantograph main components



Main overhead contact line (OCL) / catenary components

SIEMENS
Ingenuity for life

Sicat SX

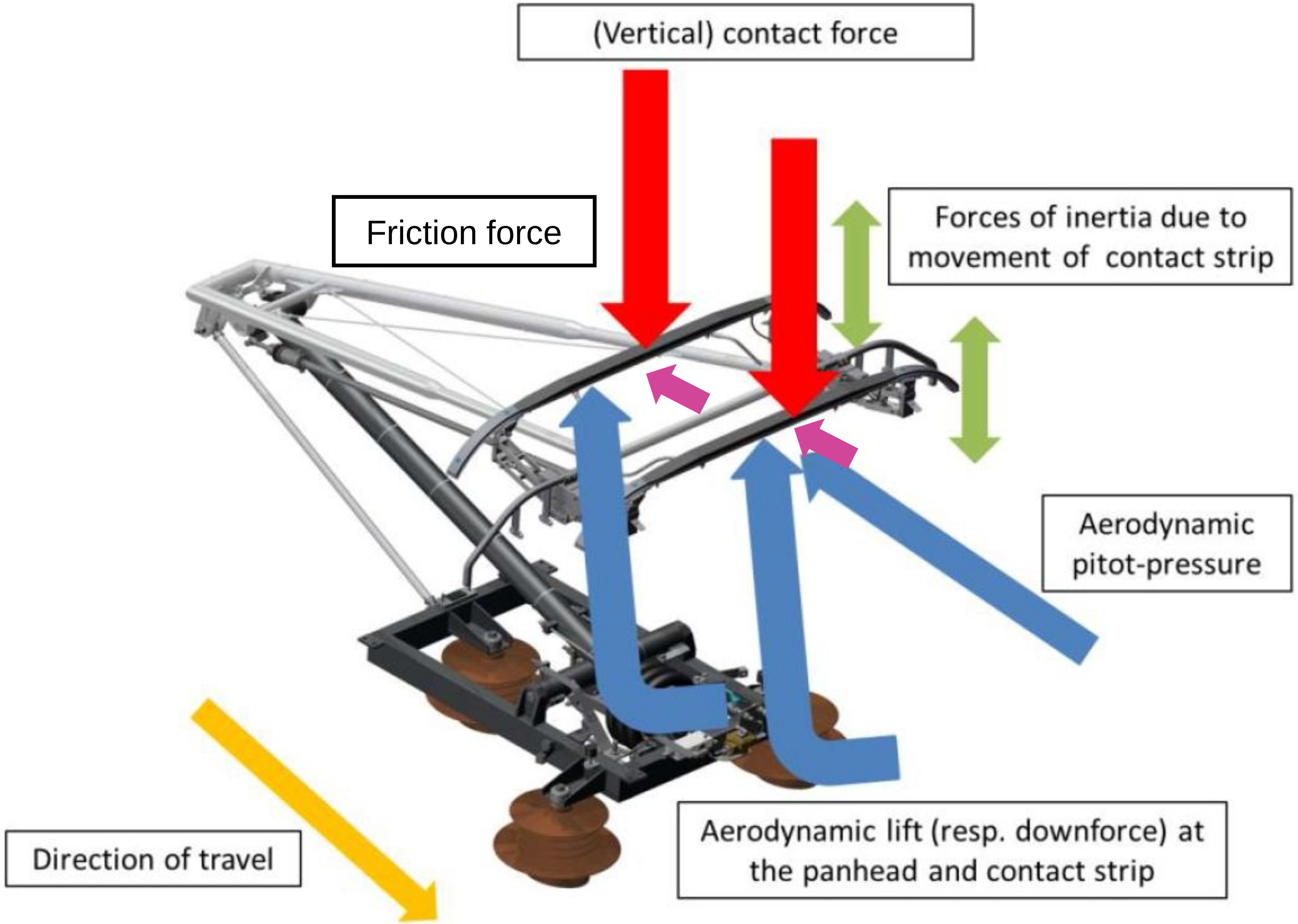


Sicat SX layout (schematic view)

The shown example of a modern OCL system is already in use on the following routes:

- Bajánsenye-Boba, HU, since 2010
- Banedanmark, Denmark, ~1,300 km until 2026

Operating conditions for pantographs



Single arm pantographs

Modern single arm pantographs require less space on vehicle roofs and incorporate better dynamic characteristics

Despite their asymmetric shape they must ensure safe and reliable operation in both running directions

Challenges

Challenges of interoperability in cross boarder operations throughout Europe

European railway networks

a multitude of systems

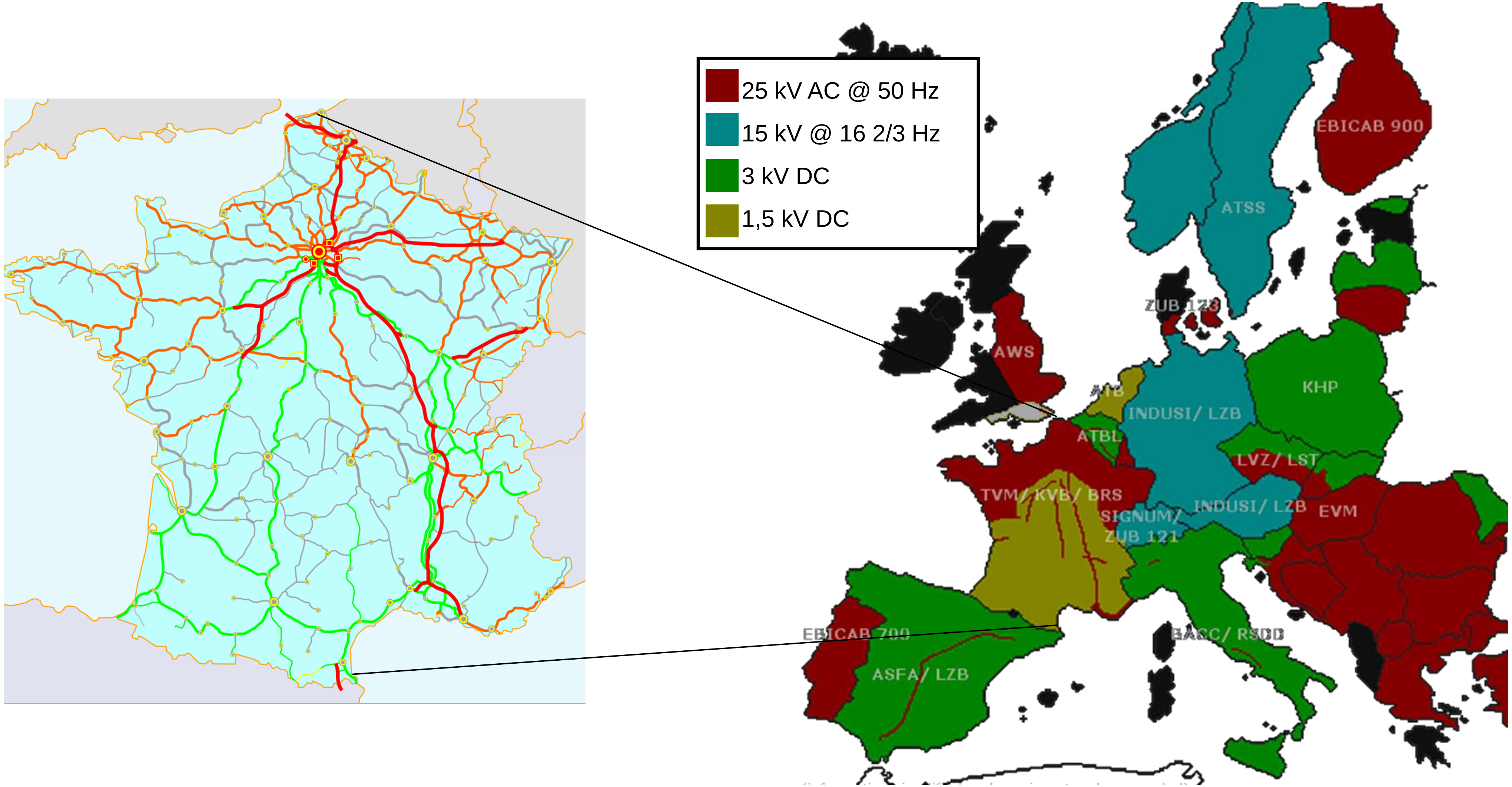
European railway corridors

SIEMENS
Ingenuity for life

Core TEN-T network corridors

Corridor	Route
1.	Baltic-Adriatic: includes the Semmering base tunnel and Koralmbahn.
2.	North Sea-Baltic: the most important element of this corridor is Rail Baltica.
3.	Mediterranean: rail projects include Lyon – Torino and Venezia – Ljubljana.
4.	Orient/East-Med.
5.	Scandinavian-Mediterranean: includes Fehmarn Belt fixed link and Brenner base tunnel.
6.	Rhine-Alpine: includes Swiss base tunnels and access routes in Germany and Italy.
7.	Atlantic: includes high speed and conventional rail.
8.	North Sea-Mediterranean.
9.	Rhine-Danube Corridor

European railway networks – a multitude of systems
Focus: Overhead contact line current



Collector head profiles in accordance to EN 50367 2017

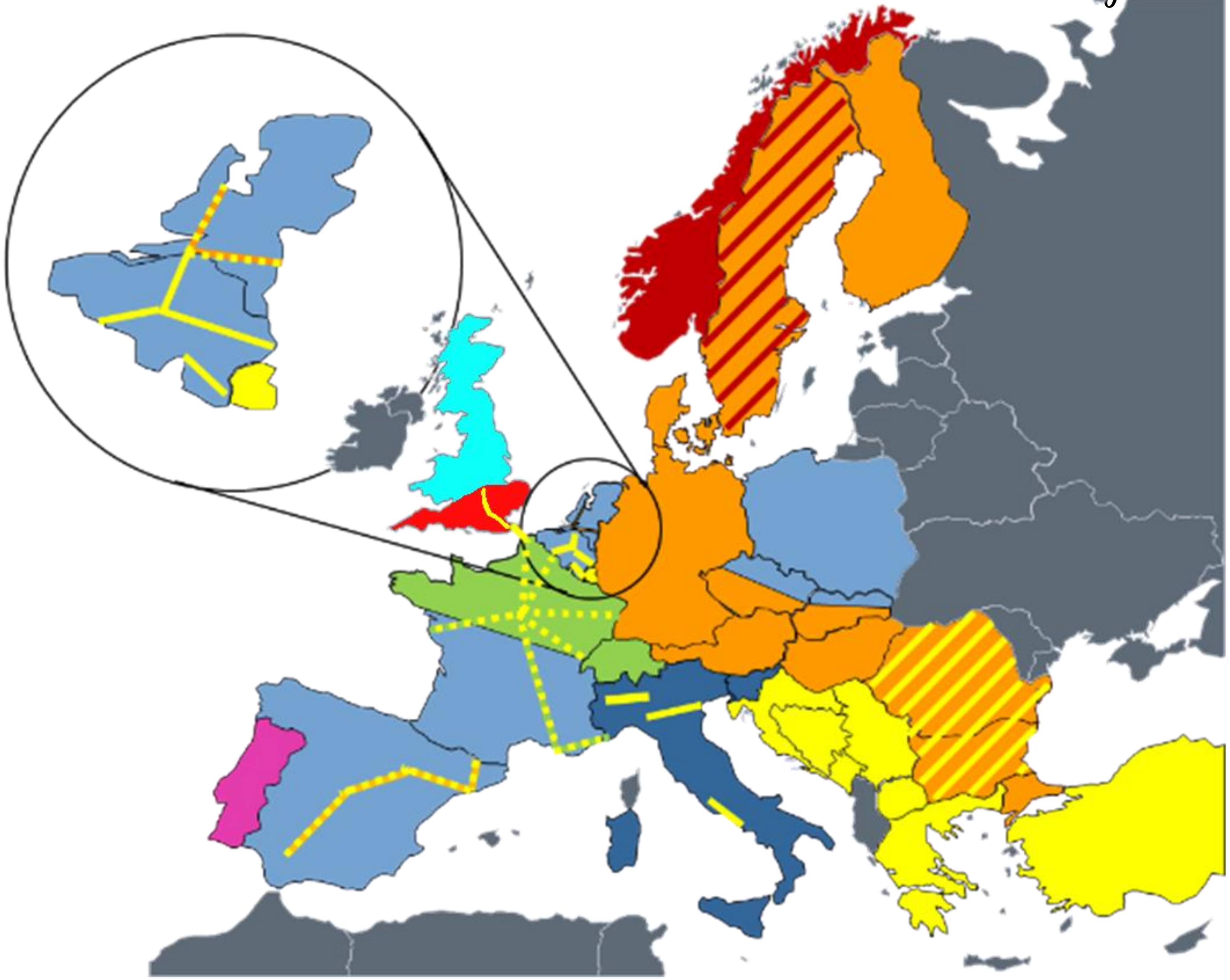
SIEMENS
Ingenuity for life

AC Networks:

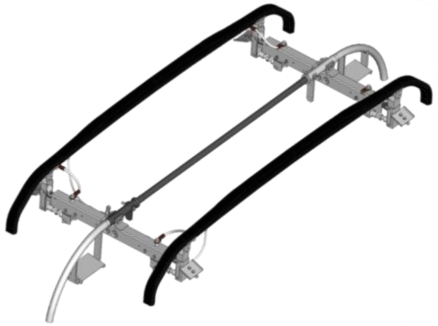
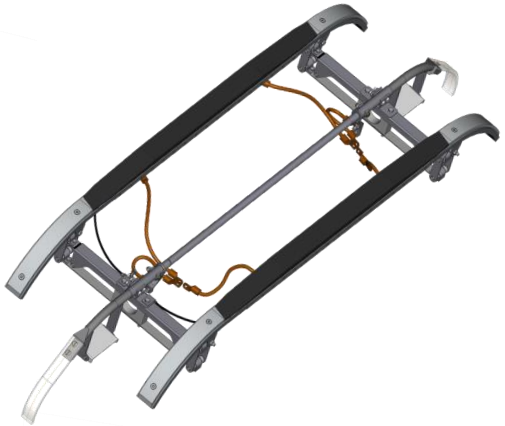
- Profile A.7 – 1950 mm
- Profile B.1 – 1450 mm
- Profile A.6 – 1600 mm
- Profile B.5 – 1800 mm
- Profile X.Y – 1450 mm (PT)
- Profile B.6 – 1600 mm (GB)

DC Networks:

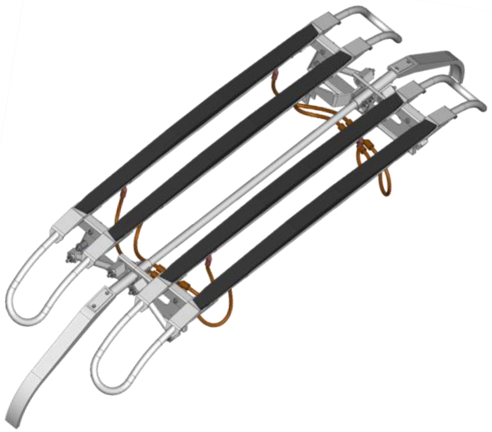
- Profile B.1 – 1450 mm
- Profile A.7 – 1950 mm



Collector heads for operating all across Europe



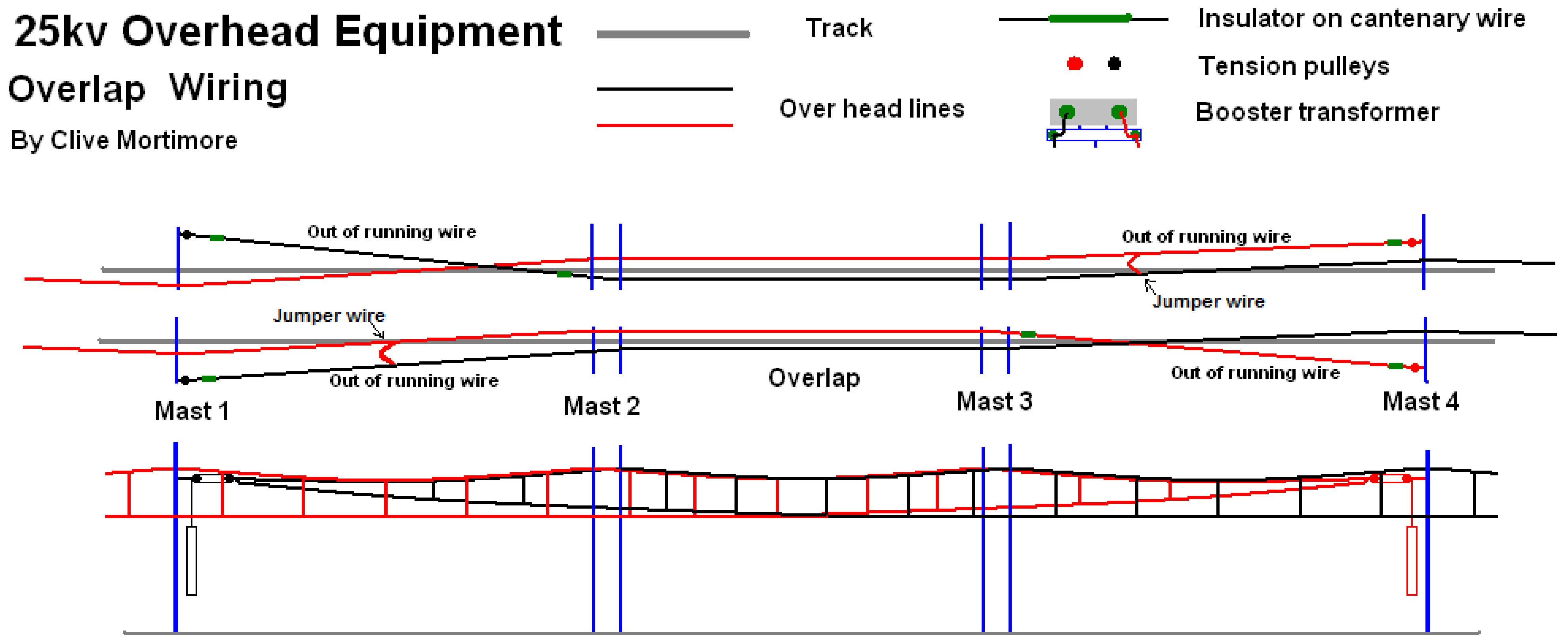


OCL sections

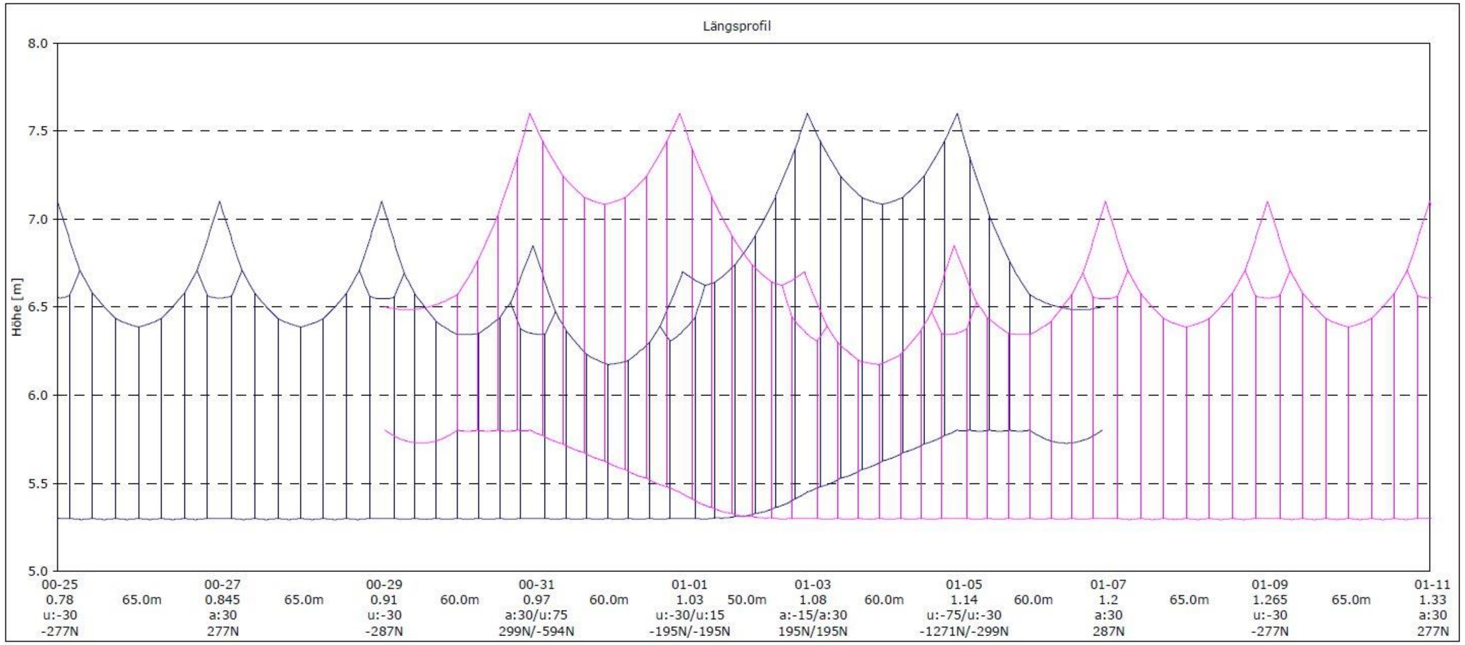
traversing overhead contact line section overlap

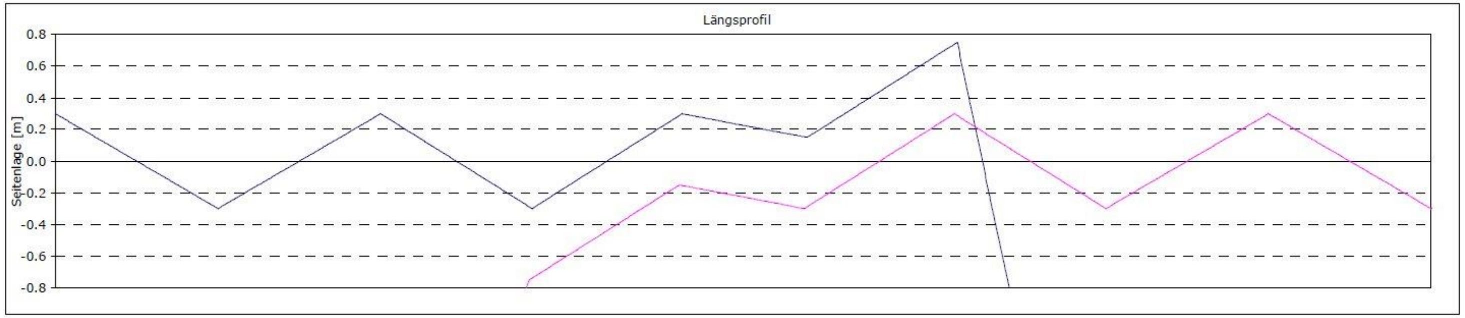
Example of 25 kV overhead contact line overlap section

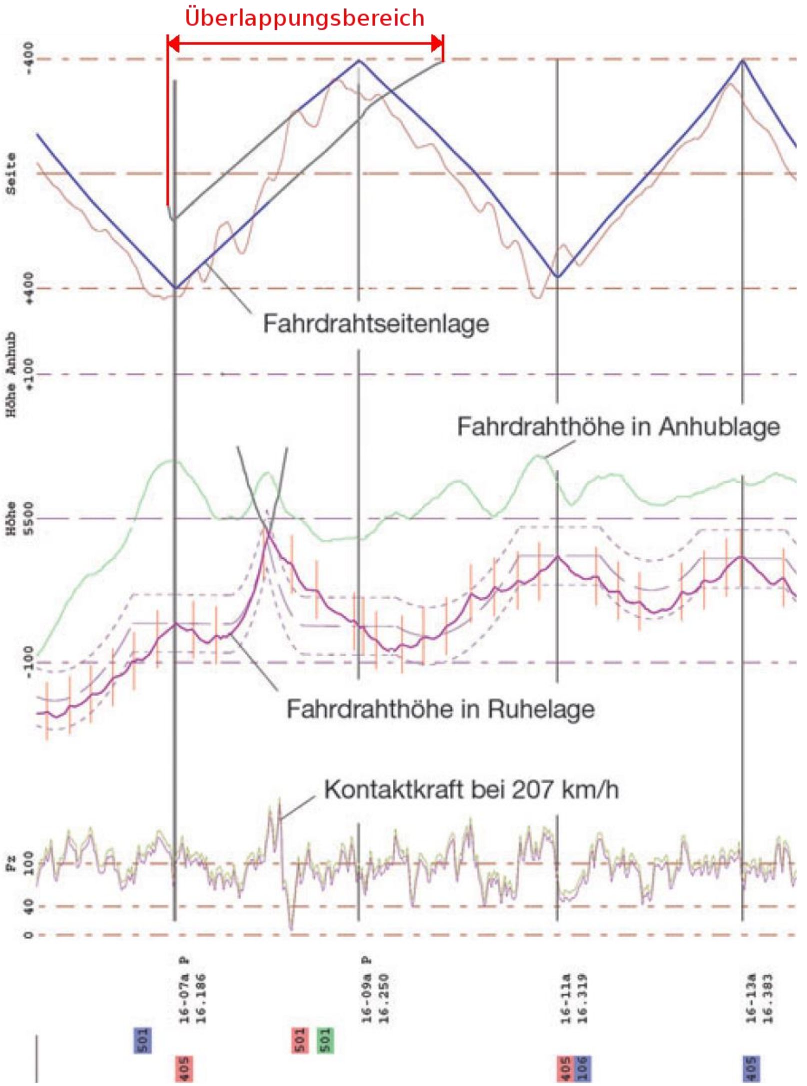
SIEMENS
Ingenuity for life



Challenge of traversing OCL overlap sections







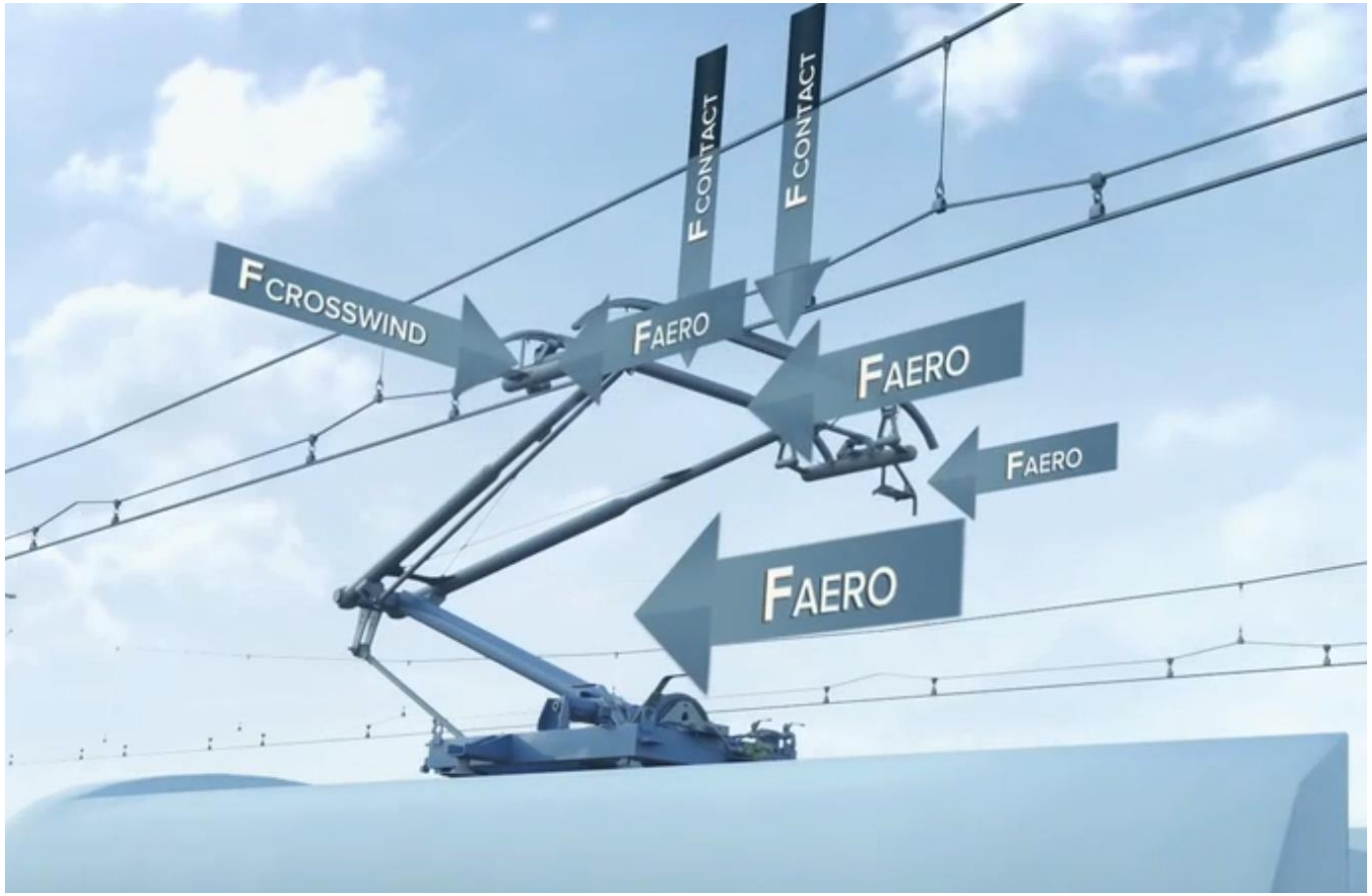
Contact quality and wear

Finding the sweet spot

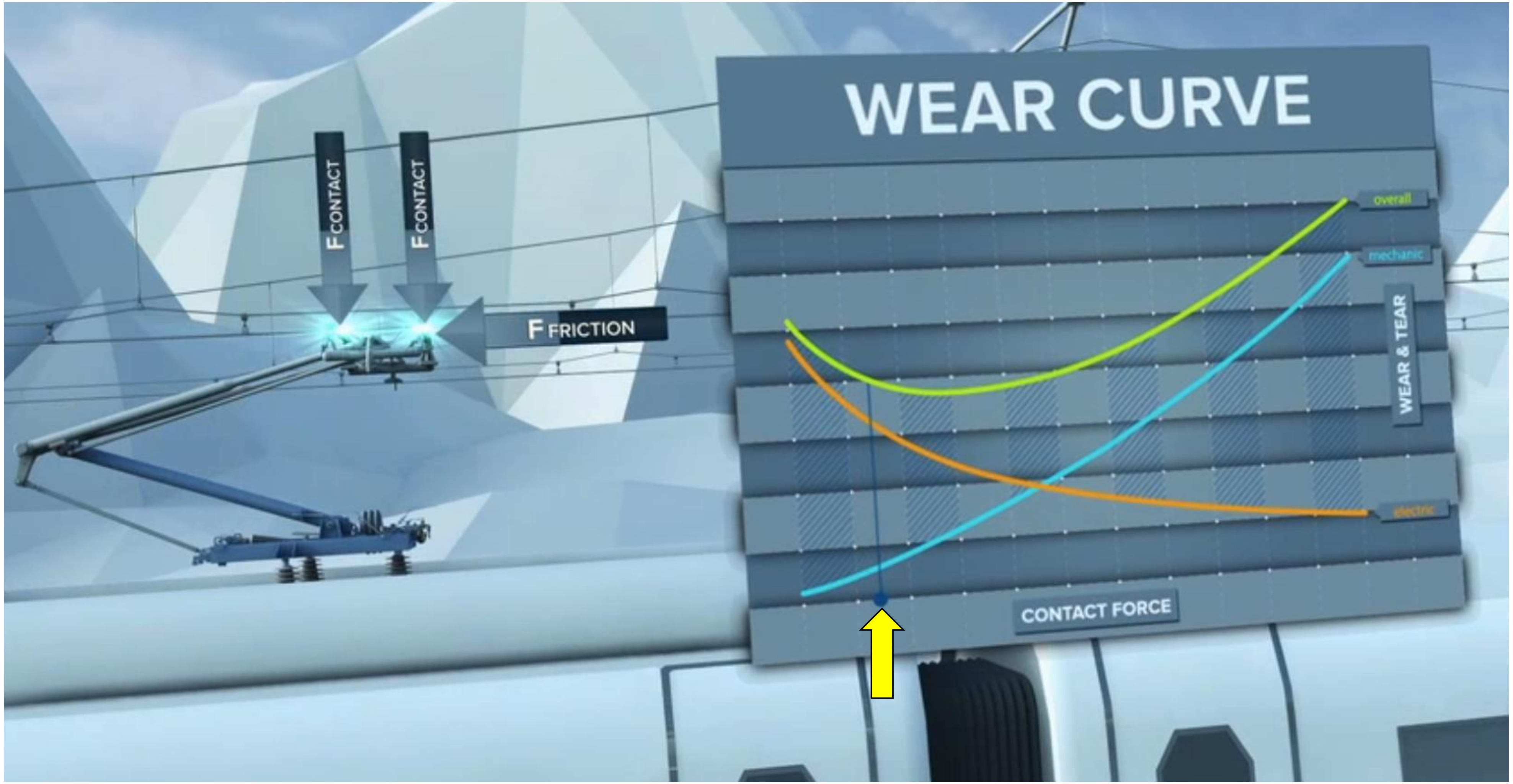
Operating conditions for pantographs

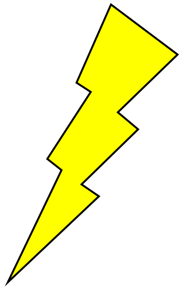
SIEMENS
Ingenuity for life

Video 1: Forces on the pantograph and contact strip wear

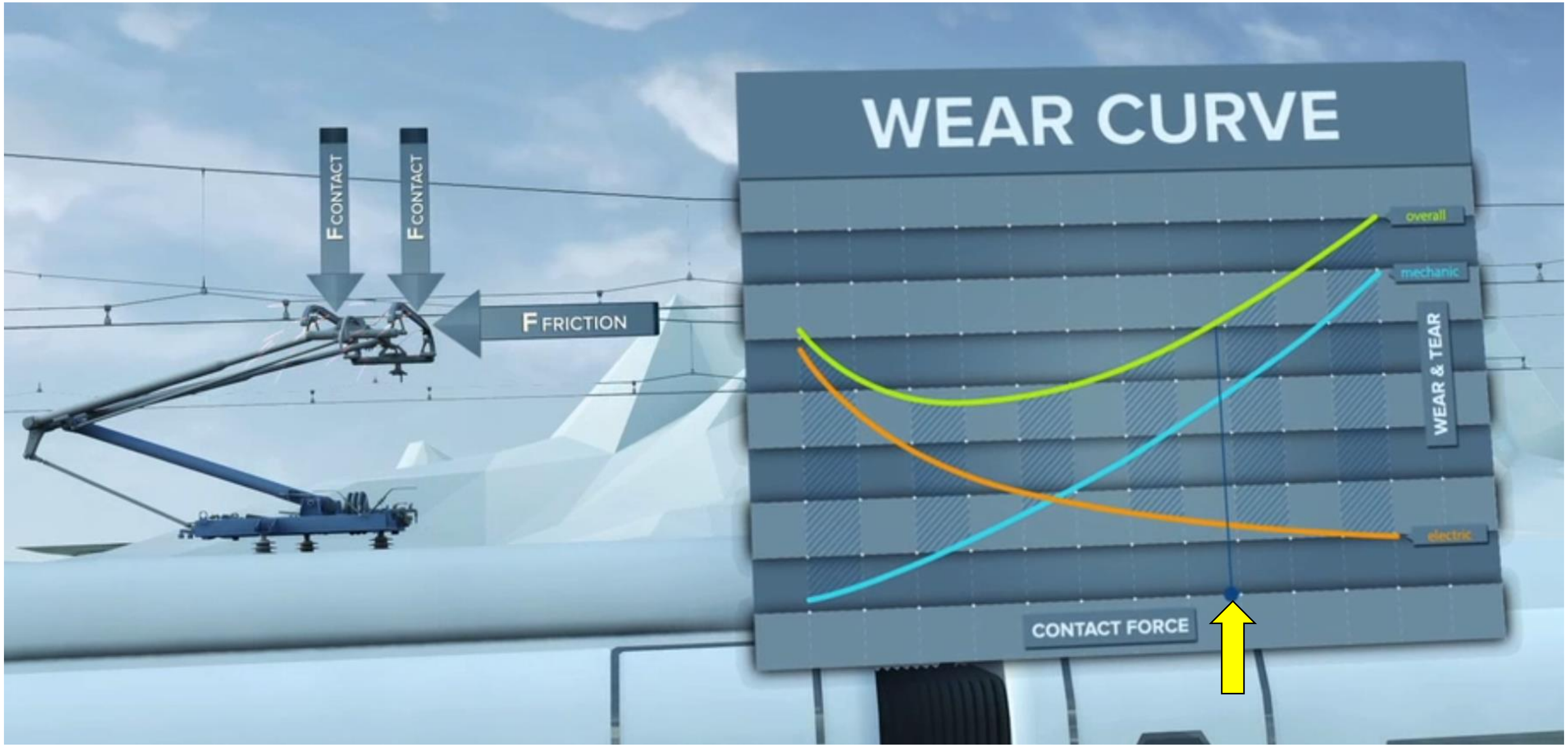


Pantograph contact strip wear



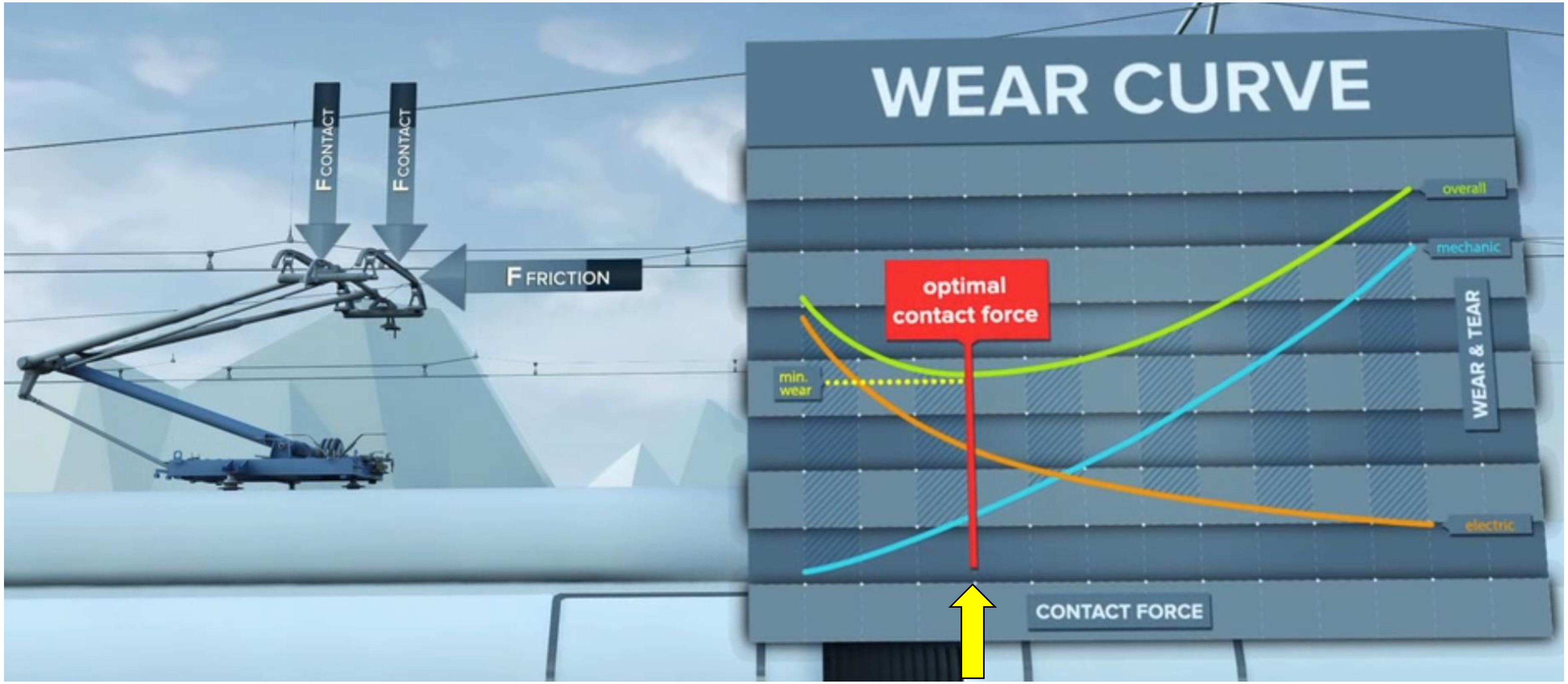


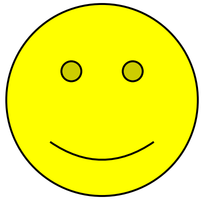
Pantograph contact strip wear



Pantograph contact strip wear

SIEMENS
Ingenuity for life





Multiple traction

operating with multiple pantographs simultaniously

Multiple pantograph operation

SIEMENS
Ingenuity for life

Video 2: Multi traction test runs

Multiple traction

New challenges arise when more than one one pantograph ist interacting with the overhead contact line

Multiple traction can occur if
- Higher currents or higher power demand
- Coupling multiple, individually powered rolling stock units to a single train

Appropriate pantograph spacing is critical

Trends for improvement

of pantograph / overhead contact line interaction

General trends for improving pantograph / OCL interaction

SIEMENS
Ingenuity for life

The following trends can be observed in the railway industry to improve the contact quality and reduce wear regarding the pantograph / catenary interaction

- Lightweight design
- Actively influencing the contact force
- Monitoring pantograph / OCL interaction
- Improvements in simulation and emulation

} Focus for today (Monitoring pantograph / OCL interaction; Improvements in simulation and emulation)

Monitoring

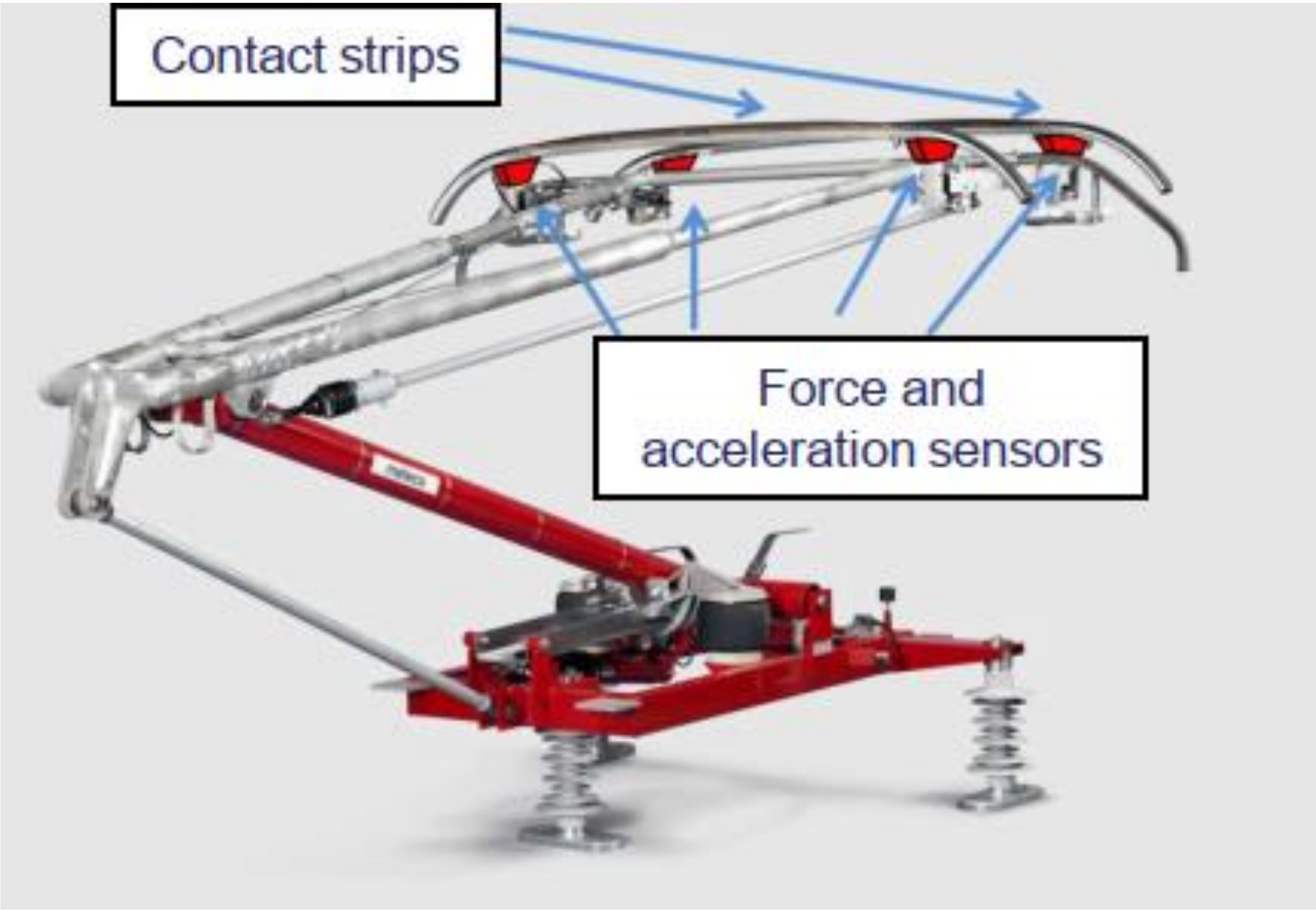
Improving safety and overall operations via methods of pantograph and overhead contact line monitoring

Monitoring pantograph / OCL condition and interaction via specially equipped pantographs

SIEMENS
Ingenuity for life

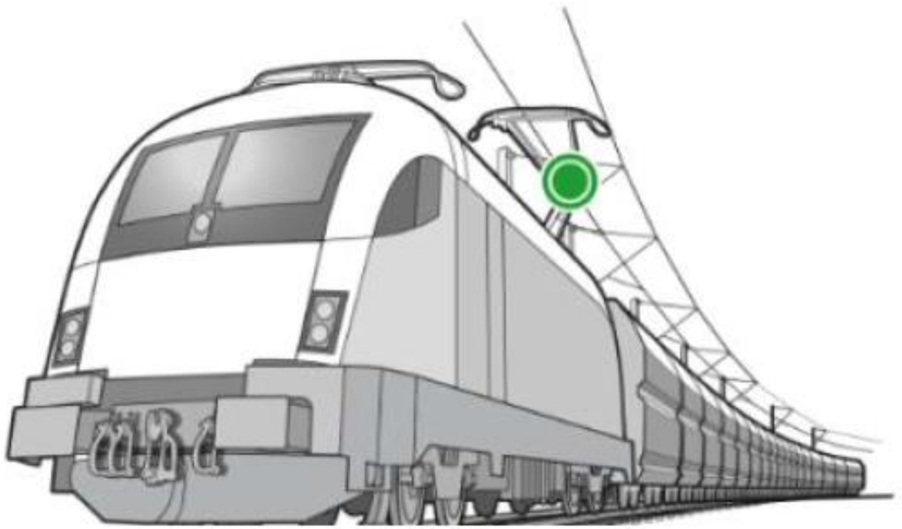
$$F_c = \sum_{i=1}^{k_f} F_{Sensor,i} + \frac{m_{above}}{k_a} \sum_{i=1}^{k_a} a_{Sensor,i} + F_{corr,aero}$$

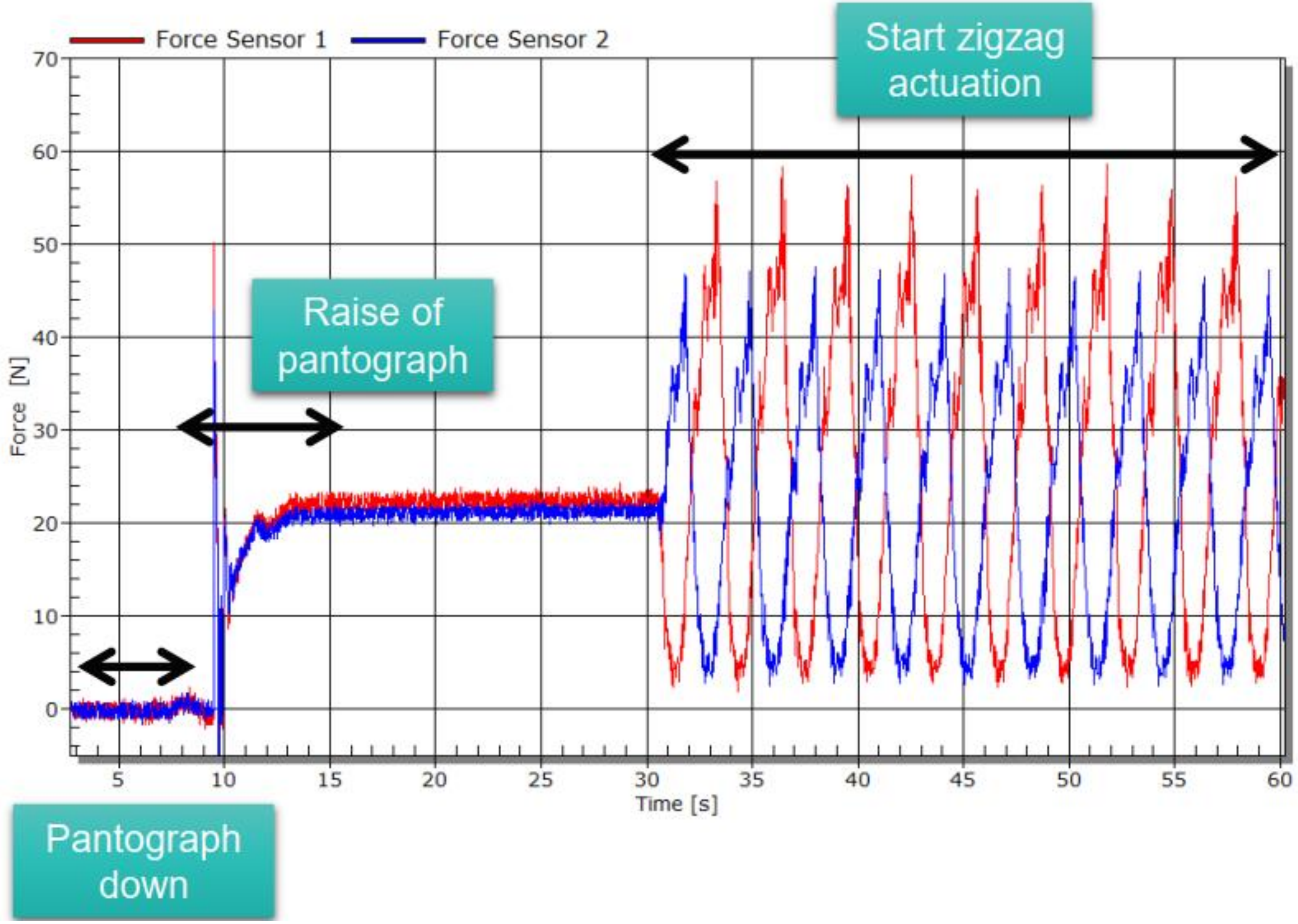
F_c = contact force
$F_{Sensor;i}$ = measured force at sensor i
$a_{Sensor;i}$ = measured acceleration at sensor i
k_f = number of force sensors
k_a = number of acceleration sensors
m_{above} = mass of the panhead located above the force sensors
$F_{corr;aero}$ = aerodynamic correction force
(velocity dependent, retrieved from lookup table)



Monitoring pantograph / OCL condition and interaction via specially equipped pantographs

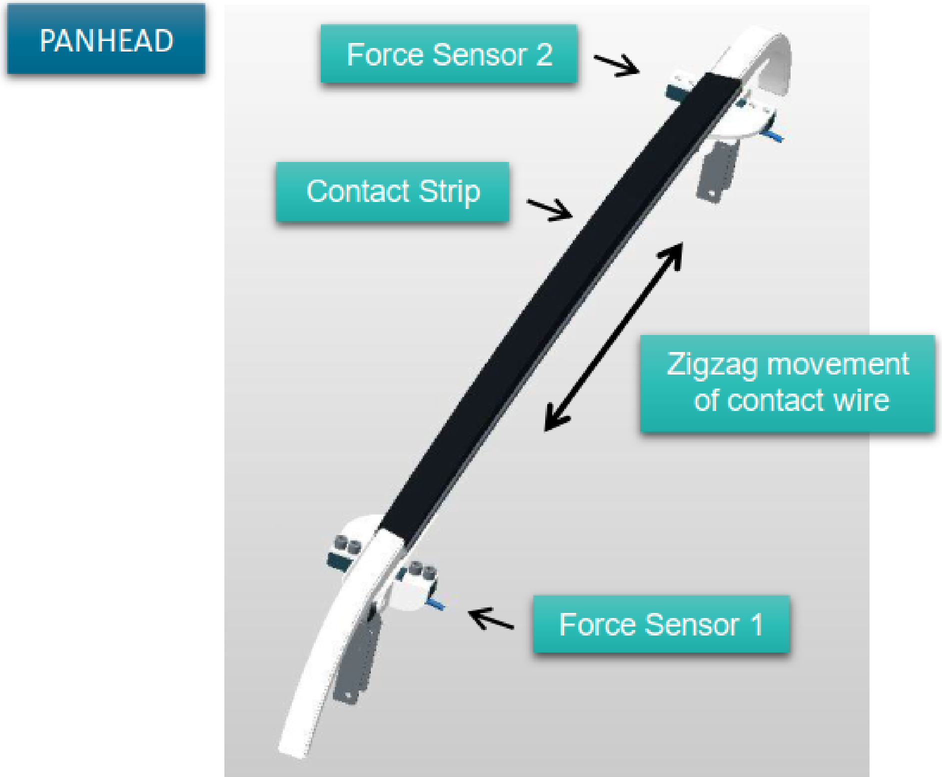
- Force under zigzag actuation scenario





Monitoring pantograph / OCL condition and interaction via specially equipped pantographs

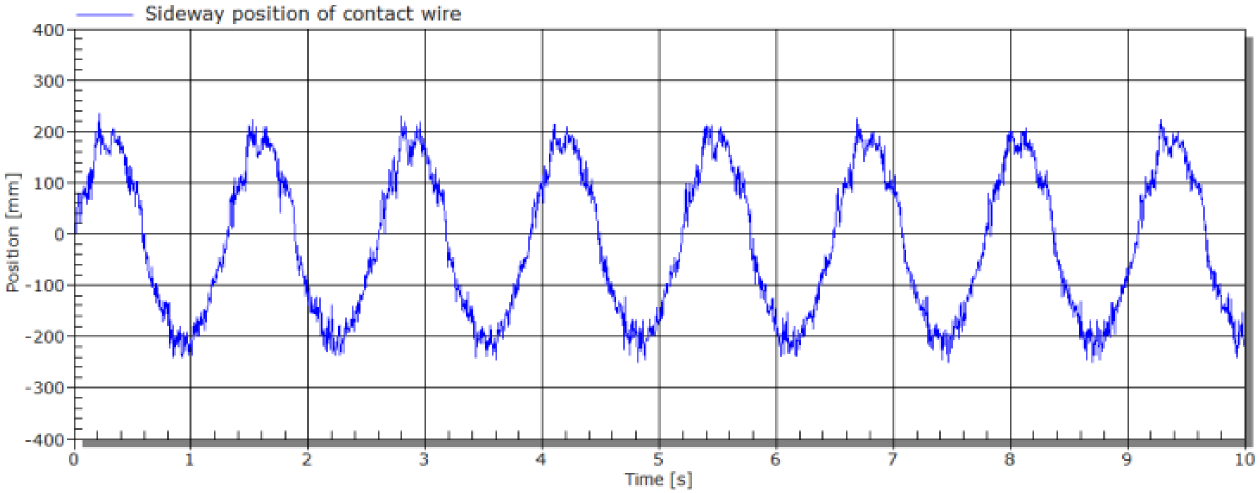
SIEMENS
Ingenuity for life



$$x = \frac{F_2}{F_1 + F_2} L - L/2$$

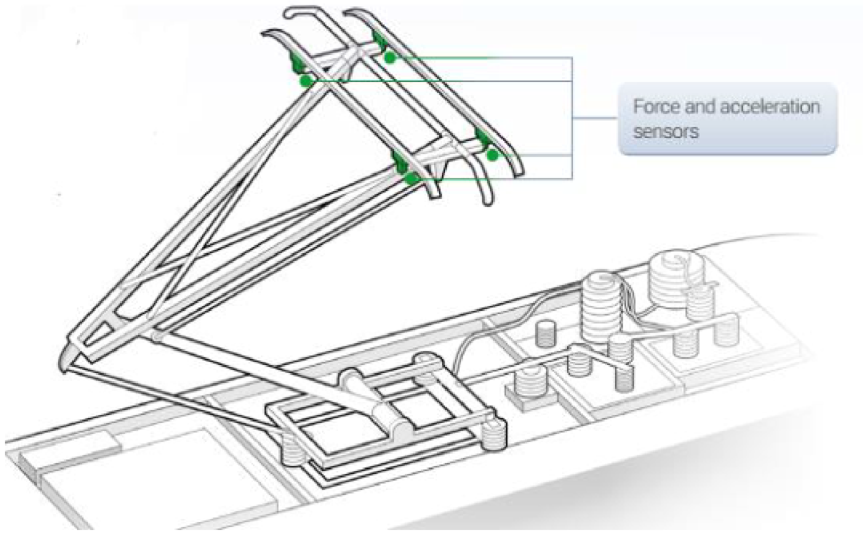
With:

x = 0	middle position
L	distance between force sensors

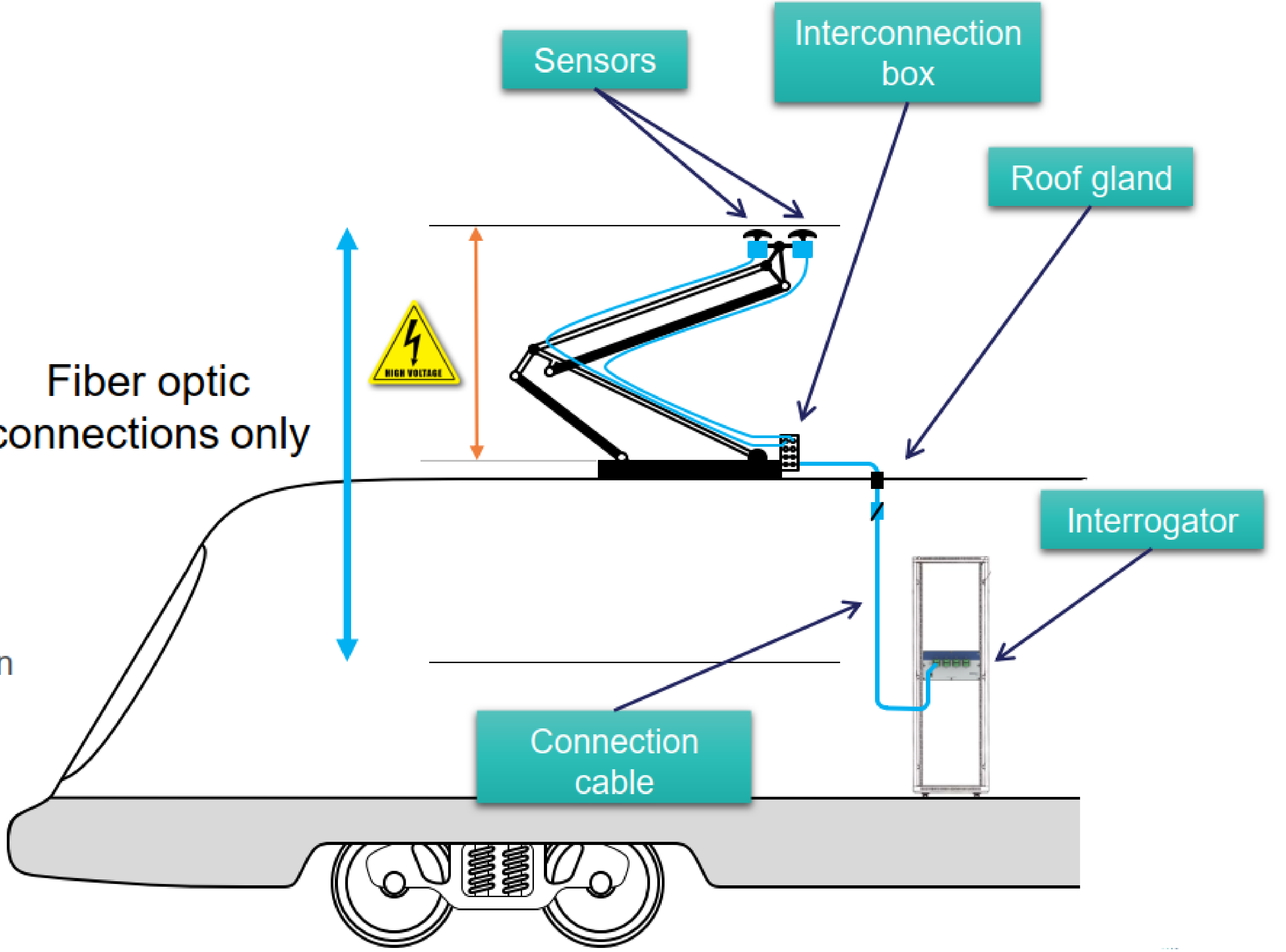


Monitoring pantograph / OCL condition and interaction via specially equipped pantographs

SIEMENS
Ingenuity for life



Fiber optic connections only



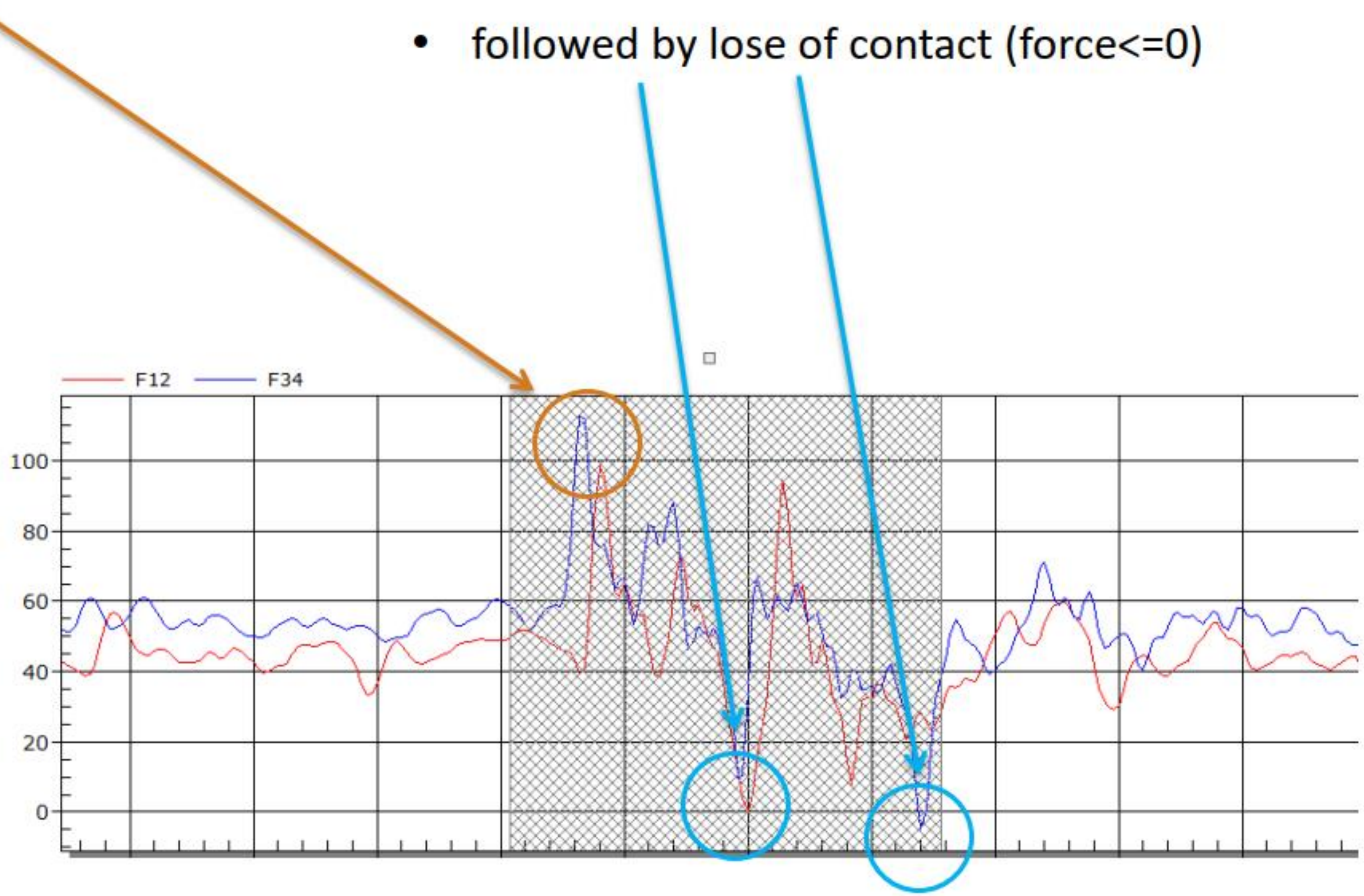
All cables, including on sensors, are rated for railway applications (manufactured by Huber+Suhner)

Monitoring pantograph / OCL condition and interaction via specially equipped pantographs

SIEMENS
Ingenuity for life

- Sum force per contact strip in red and blue
- Bigger impact

- followed by lose of contact (force<=0)

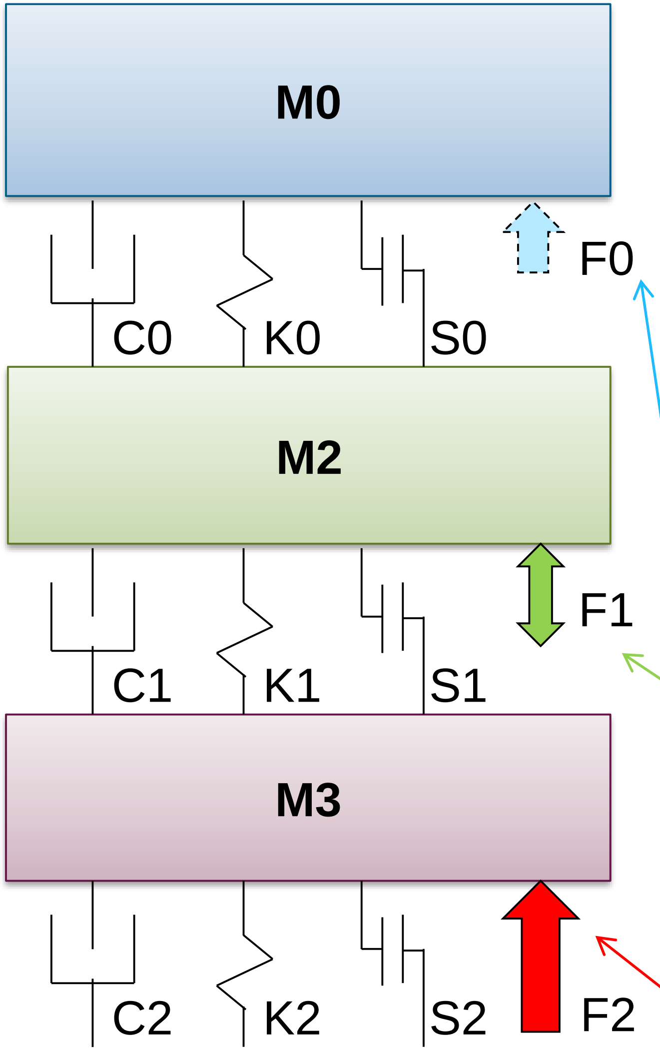


Simulation / Emulation

Improvement in pantograph and overhead contact line interaction via advanced simulation and introduction of emulation

Status quo of simulating pantograph / OCL interaction

SIEMENS
Ingenuity for life



Current theoretical simulations of pantograph / catenary interaction are based on **simplified lumped mass models** of the pantographs in question.
Such detailed simulations take hours or even days to deliver results for a certain combination of overhead contact line and pantograph model, for a limited scope of a certain amount of spans (e.g. 10) including one overlap section.

Lumped mass models generally consist of:

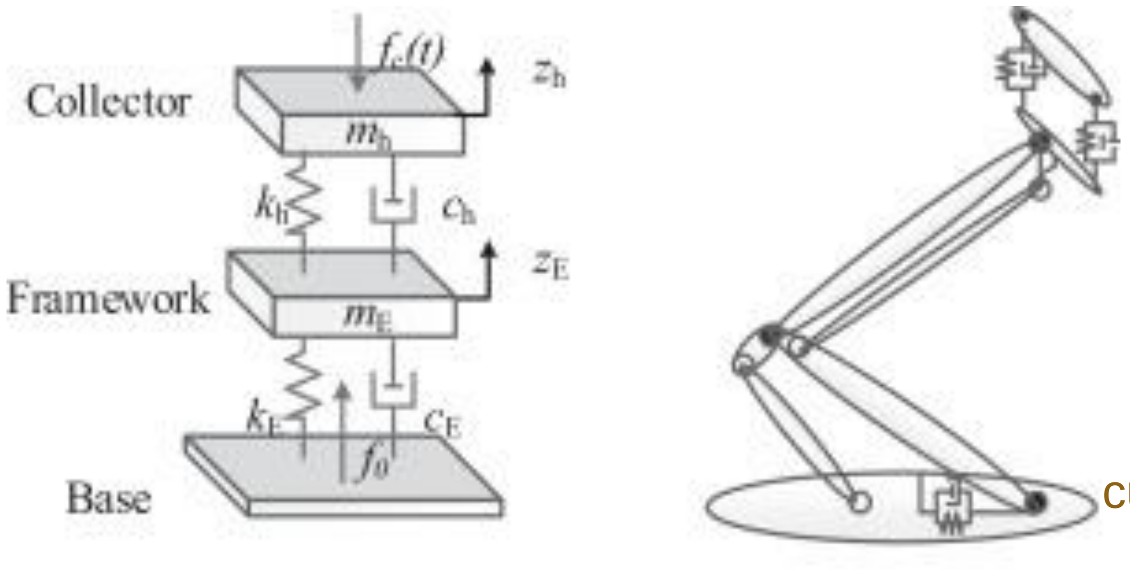
- M … Mass (x3)
- C … Damping (x3)
- K … Spring rate (x3)
- S … Damping (x3)
- F … Force (x3)

External forces
Mainly aerodynamic influences depending on running speed and direction

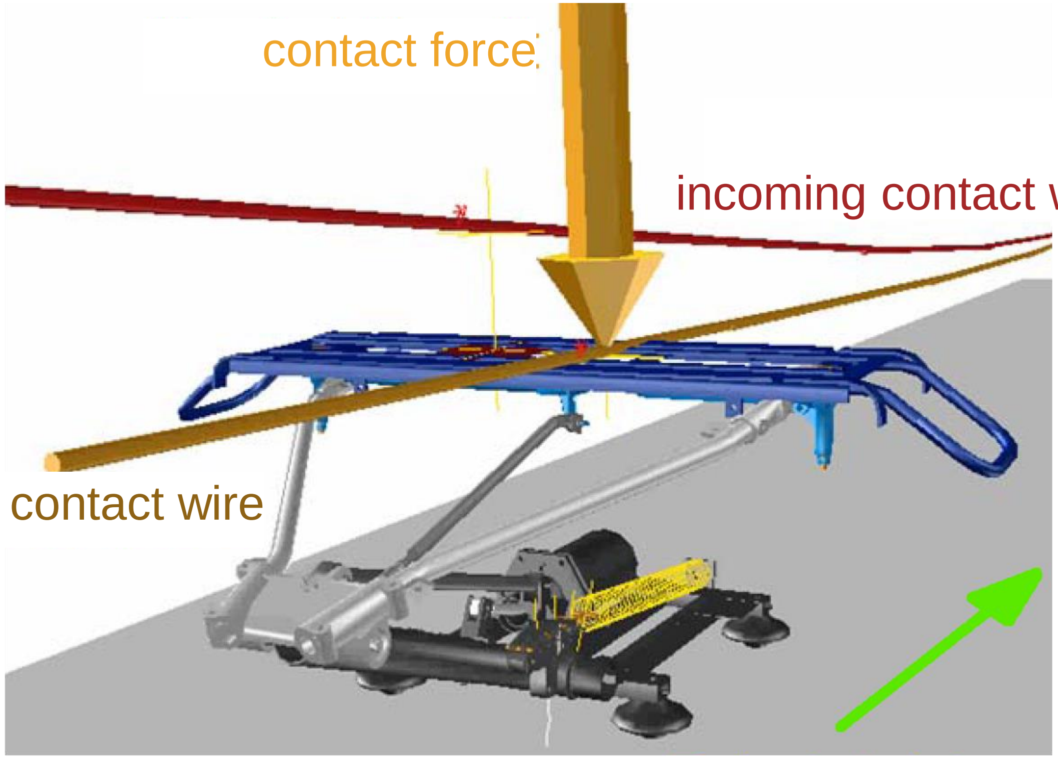
Static contact force
As provided by the actuator

Multiple-body simulation

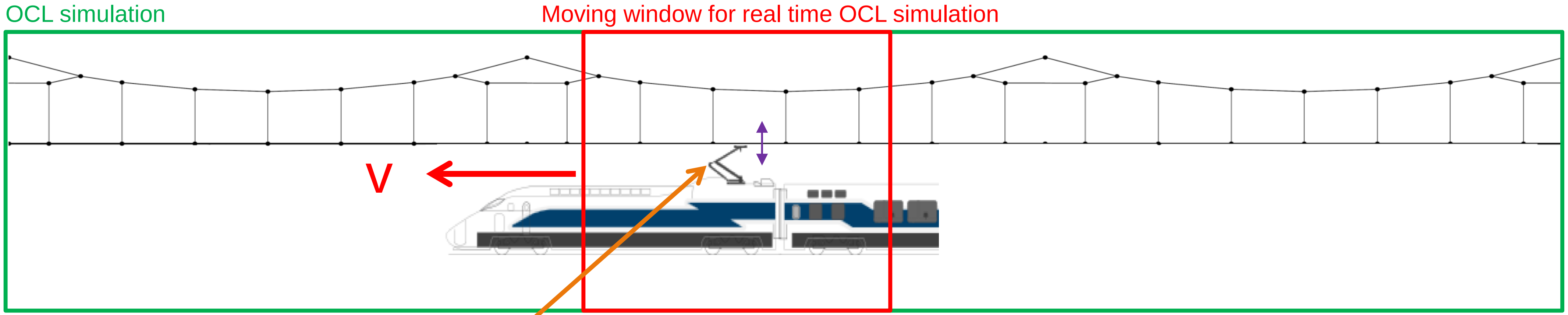
Introducing multi body simulation can greatly improve the predictability of pantograph characteristics and pantograph / OCL behaviour

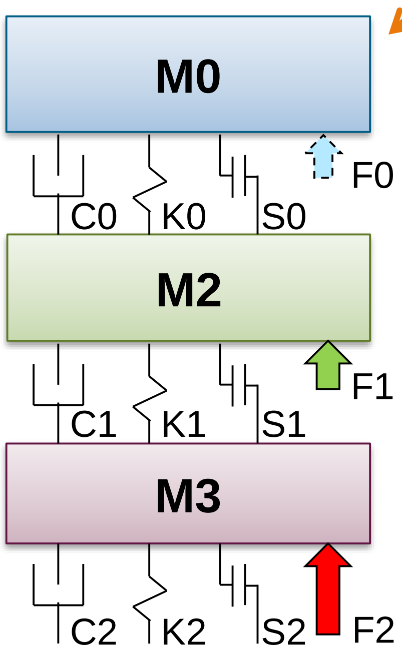


(a) Lumped-mass model (b) Multi-body model



Real time simulation of pantograph / OCL interaction



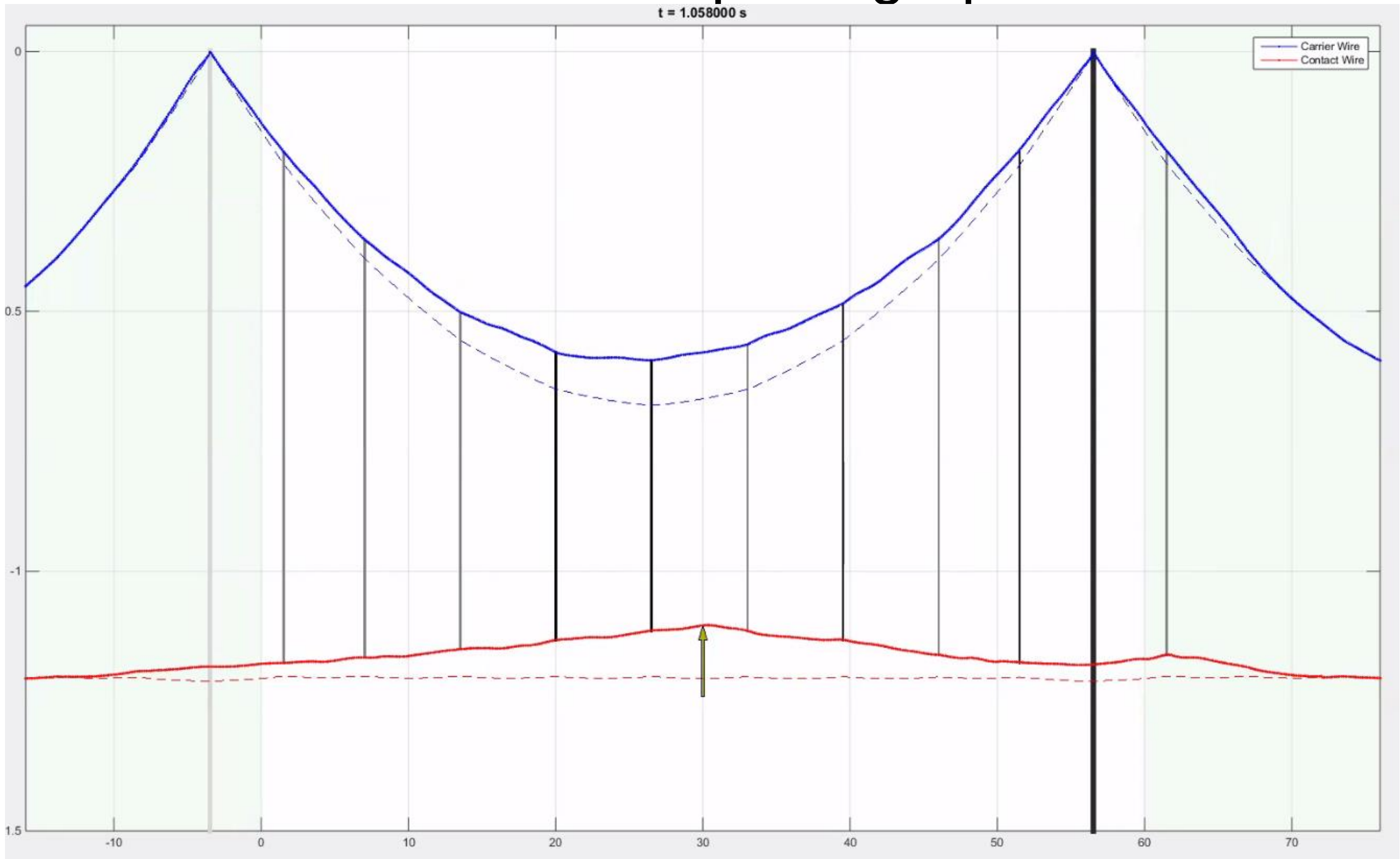


In case of our method of **real time OCL simulation** a window moves along the simulation model of the overhead contact line and solves all necessary equations around the pantograph model in real time

Real time simulation of pantograph/OCL interaction

Introducing real time simulation methods of pantograph/OCL interaction enables new methods for hardware-in-the-loop testing

Video 3: Interaction pantograph/OCL



Emulation

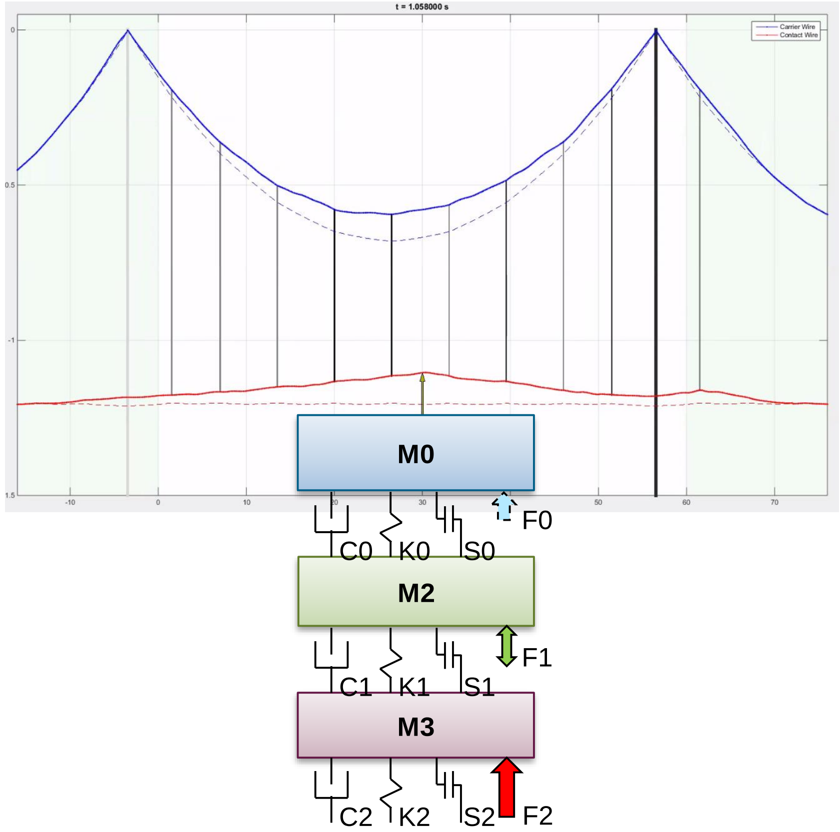
Incorporating hardware-in-the-loop testing to aid the development homologation process

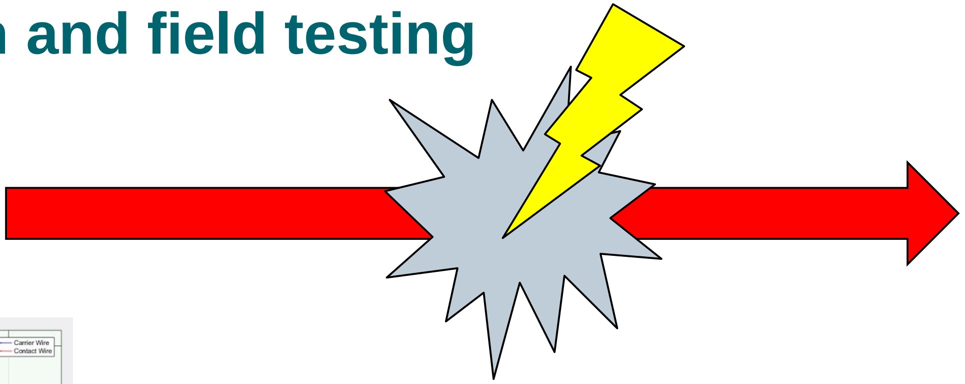
Status quo
Gap between simulation and field testing

SIEMENS
Ingenuity for life

Simulation

- Lumped mass





Field tests

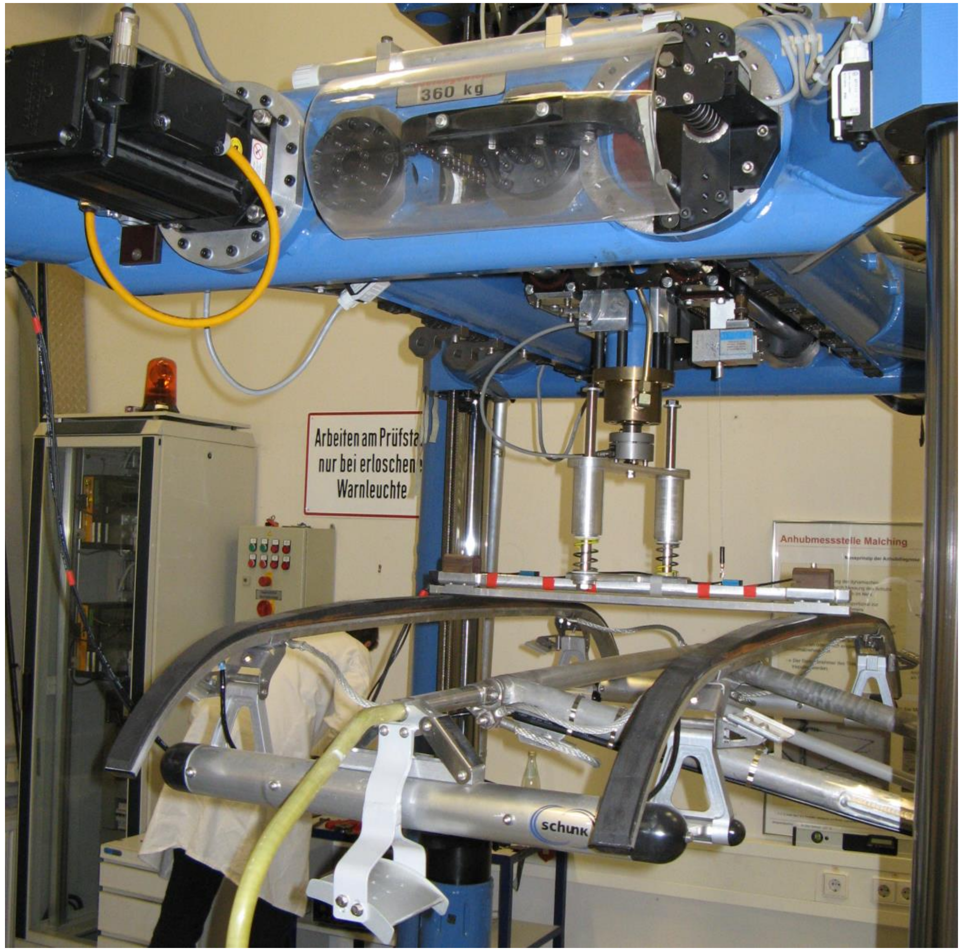
- Vehicle test runs under operating conditions

Transitioning from OCL simulations with simplified pantograph models to field tests can entail the following risks:

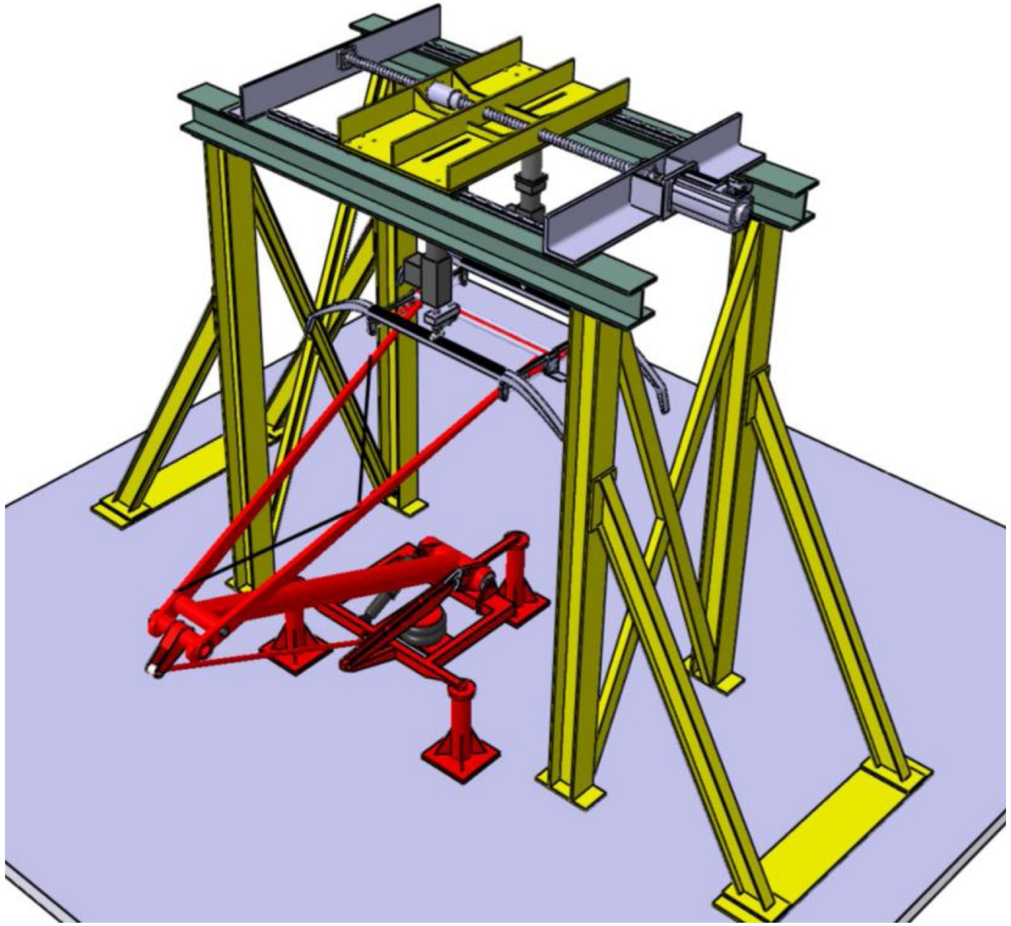
- **Safety risks** (can it be done safely?)
- **Technical risks** (can it be done at all?)
- **Deadline risks** (can it be done in time?)
- **Economical risks** (can it be done on budget?)

Examples of pantograph test rigs for hardware-in-the-loop (HIL) testing

SIEMENS
Ingenuity for life

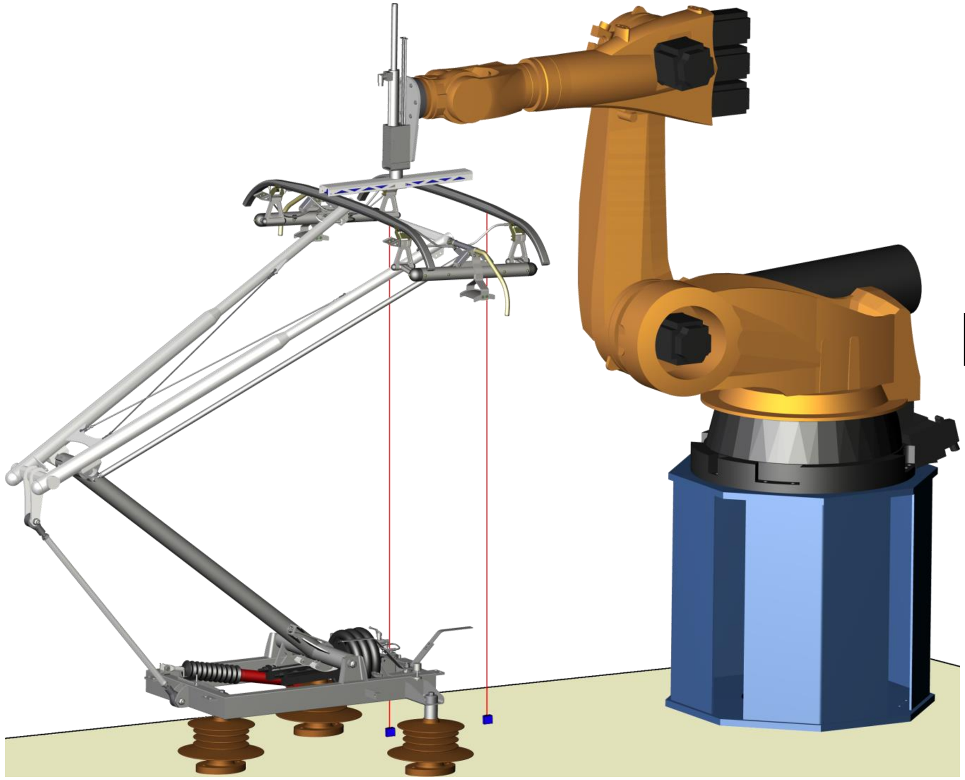


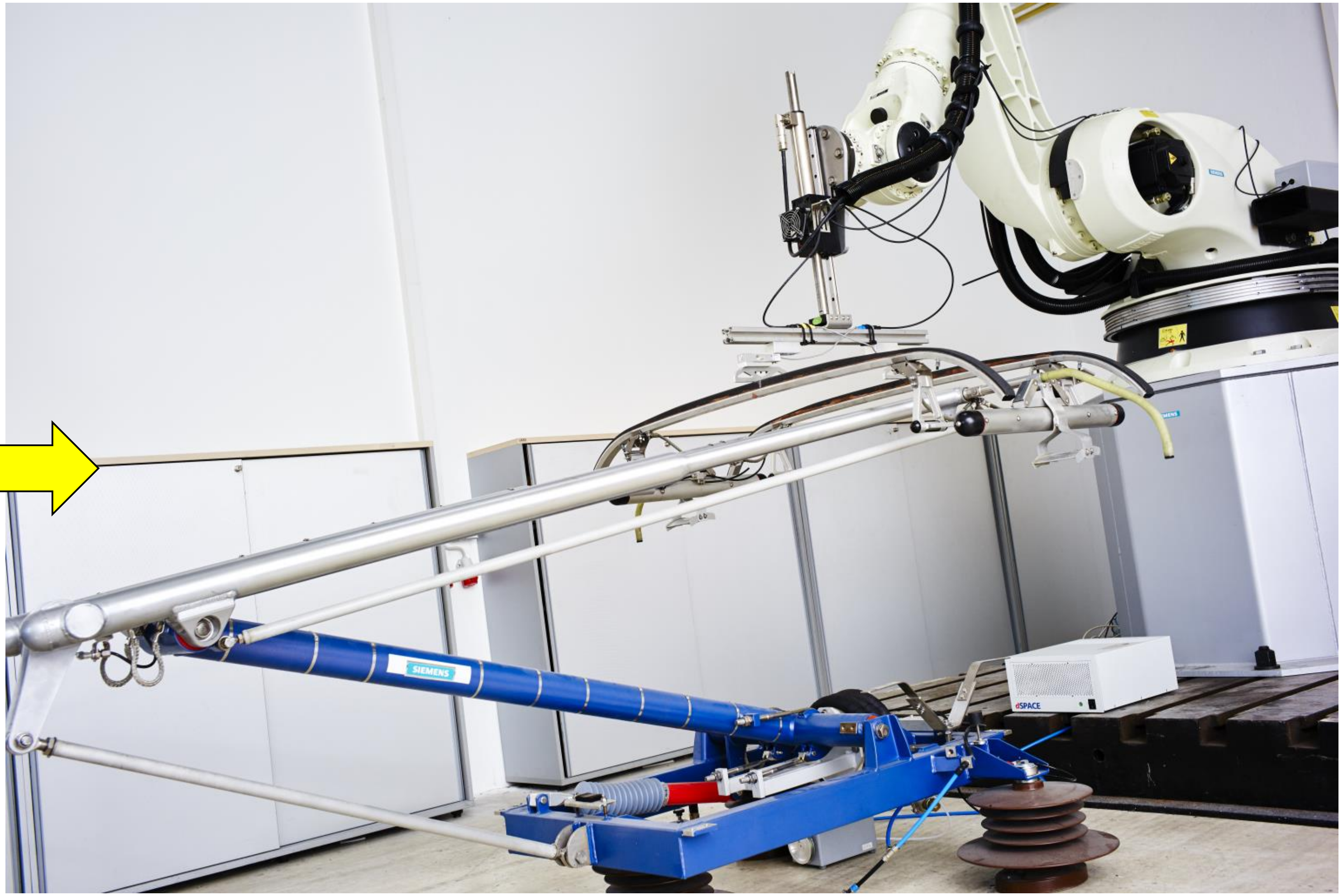
DB Systemtechnik



PoLiMi

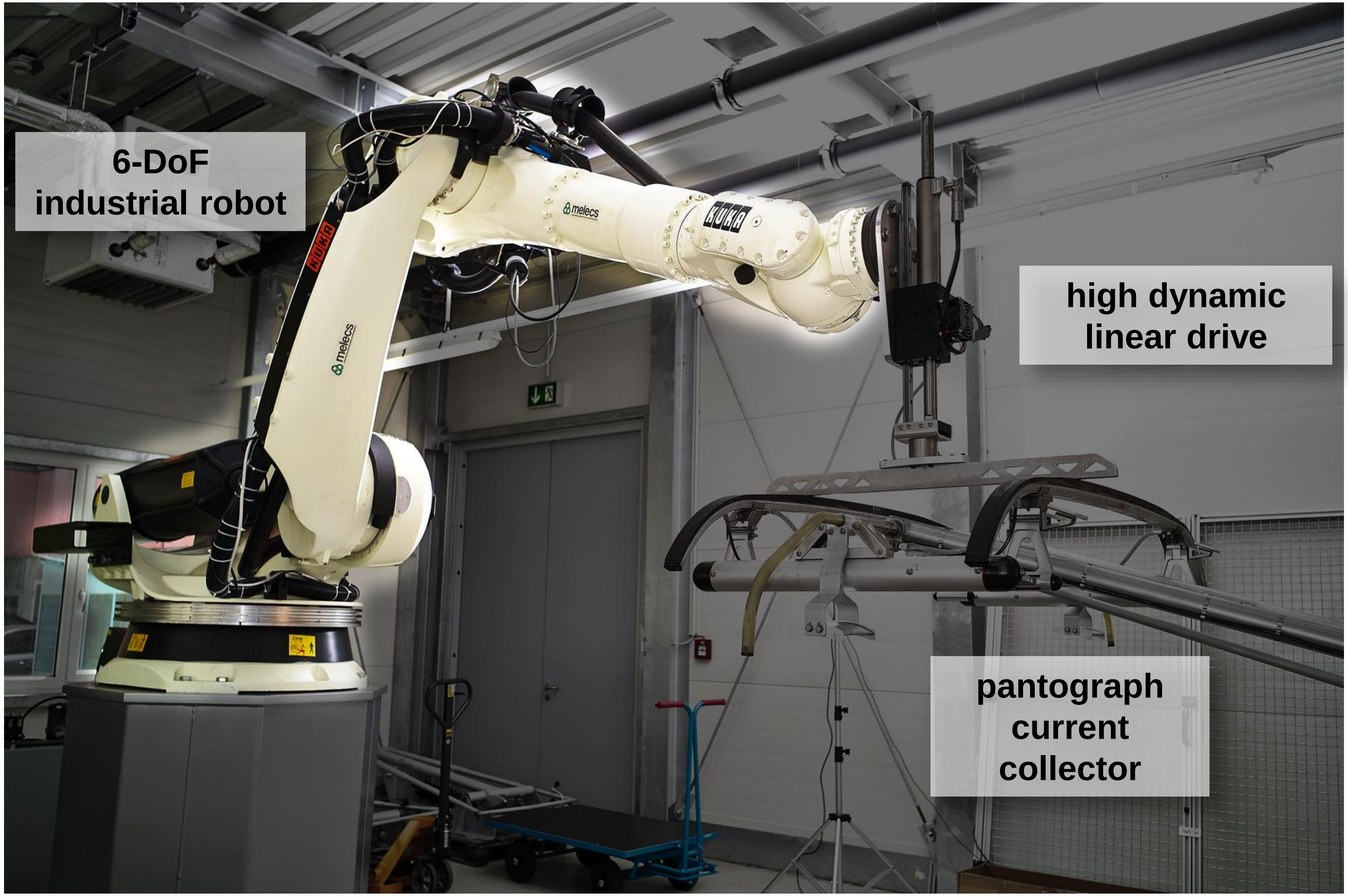
SIEMENS pantograph test rig





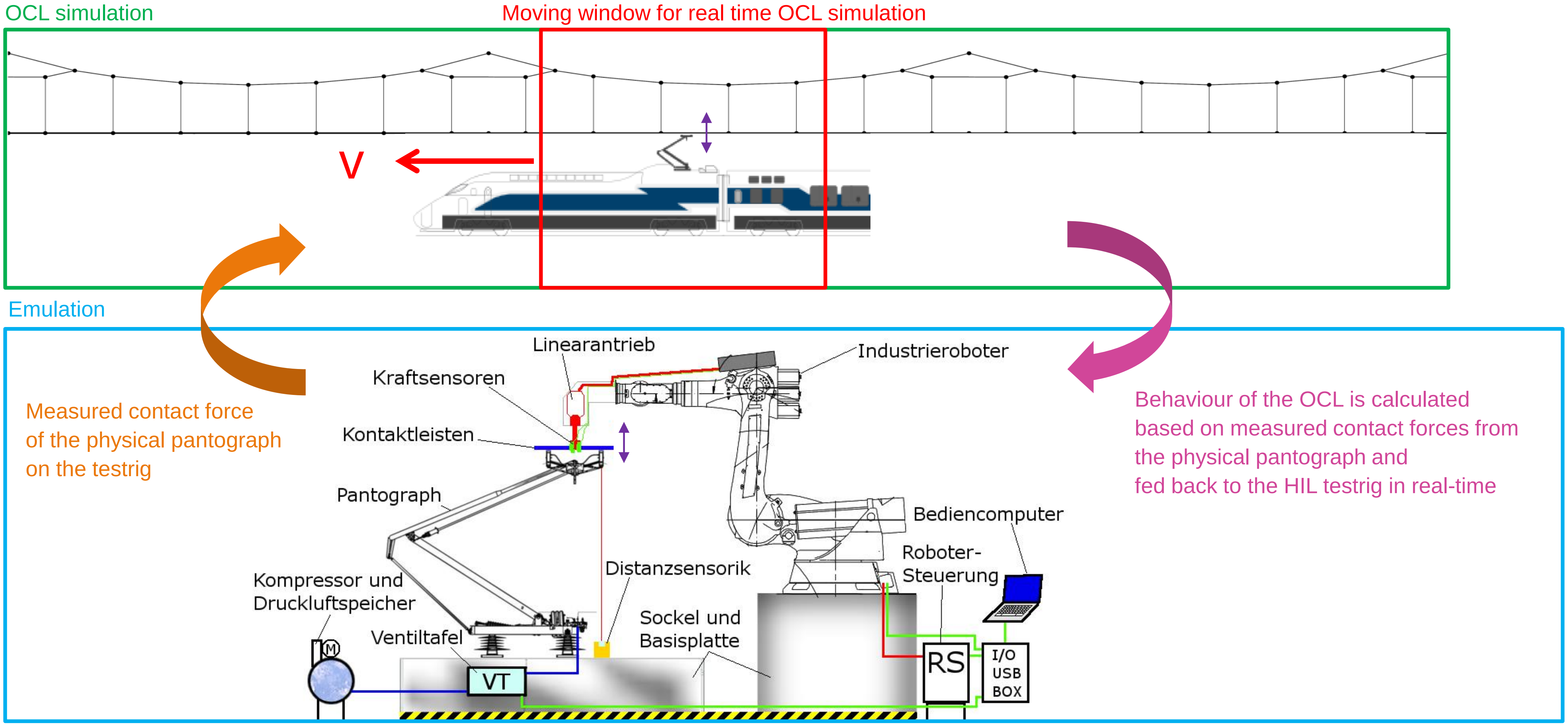
SIEMENS pantograph test rig

SIEMENS
Ingenuity for life

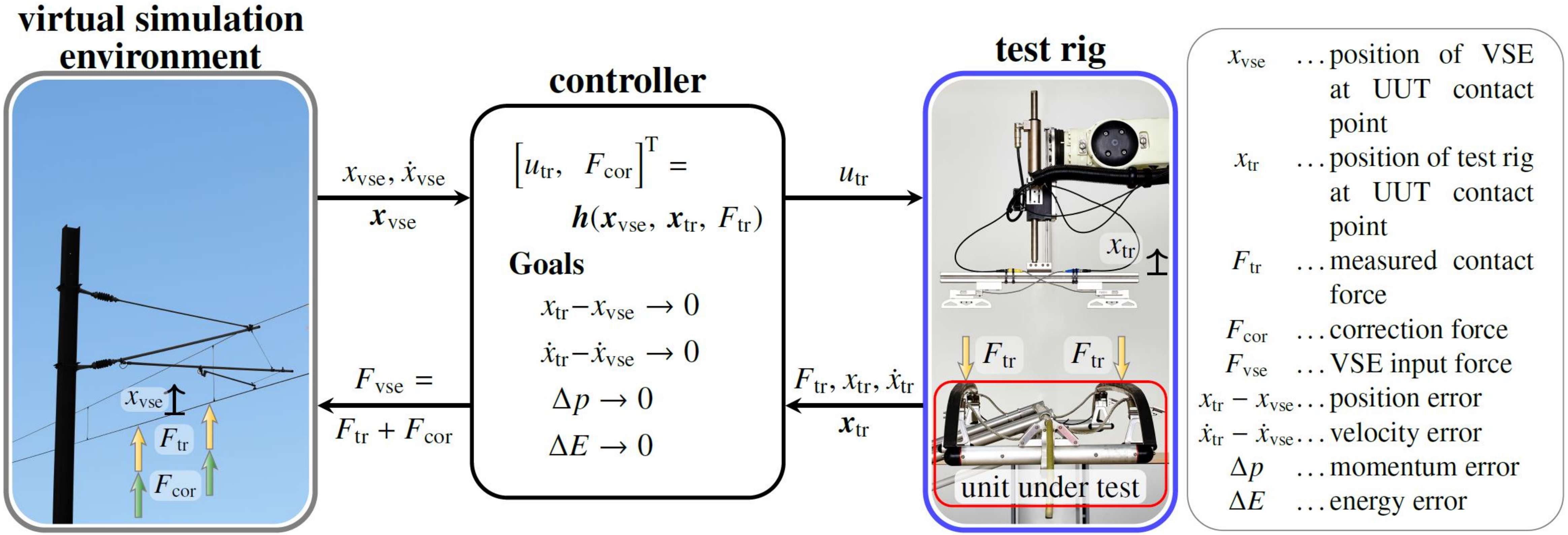


High-end hardware-in-the-loop testing by combining real time simulation with hardware-in-the-loop testrigs

SIEMENS
Ingenuity for life

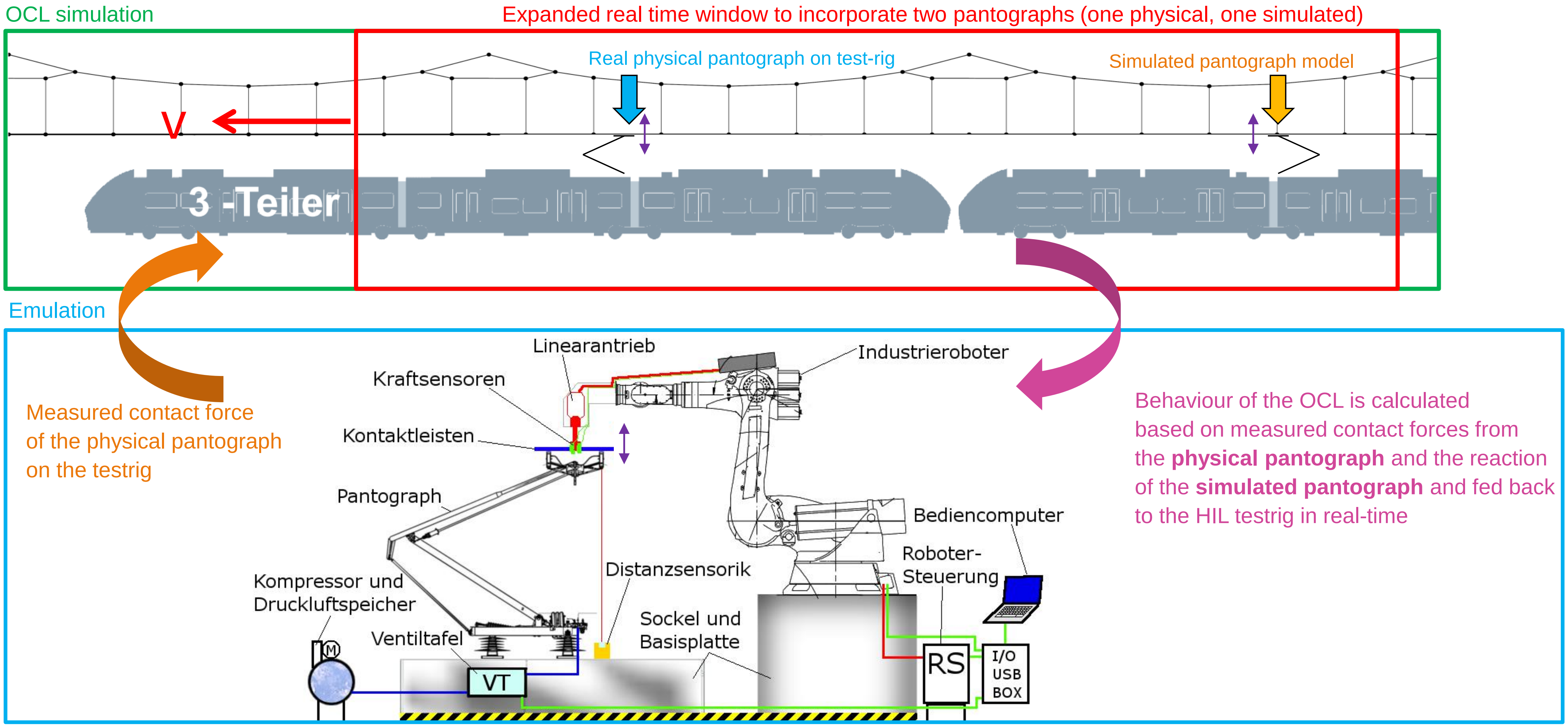


High-end hardware-in-the-loop testing by combining real time simulation with hardware-in-the-loop testrigs



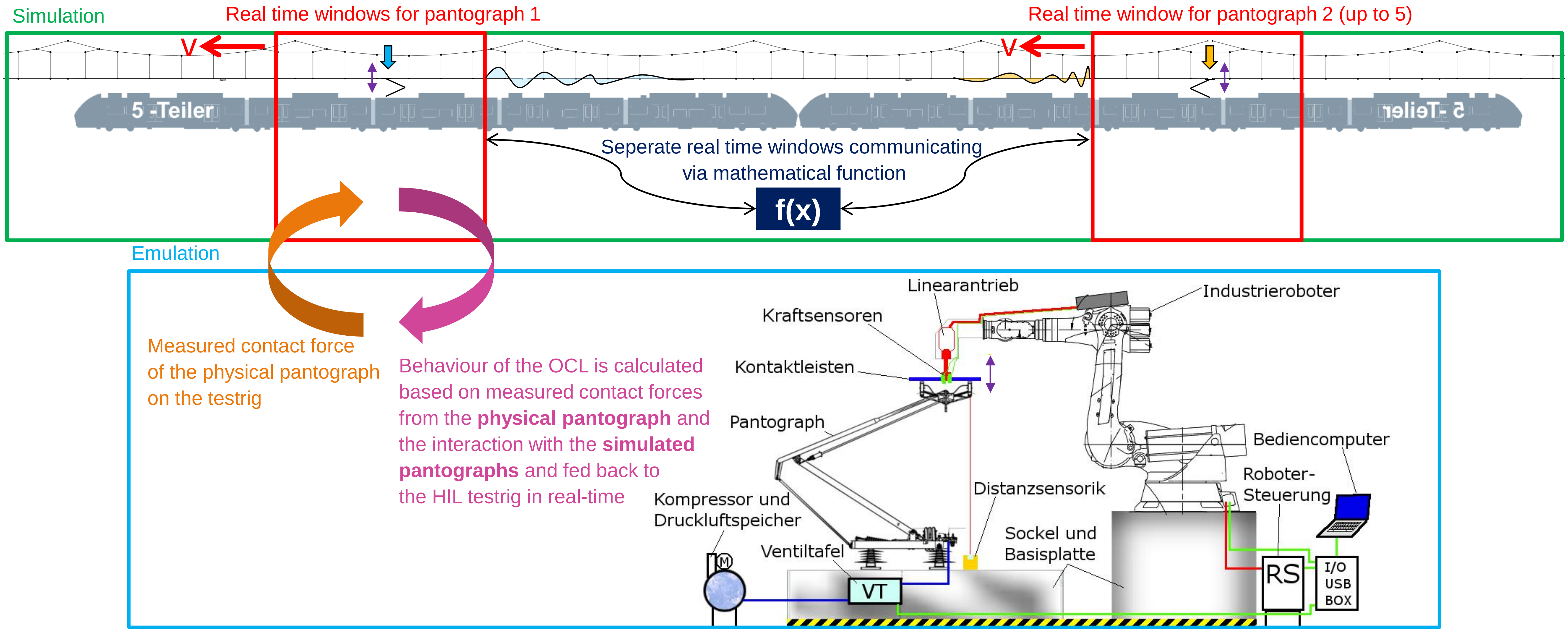
Expanding the scope for multi traction

SIEMENS
Ingenuity for life



Scalable scope expansion via multiple real time windows

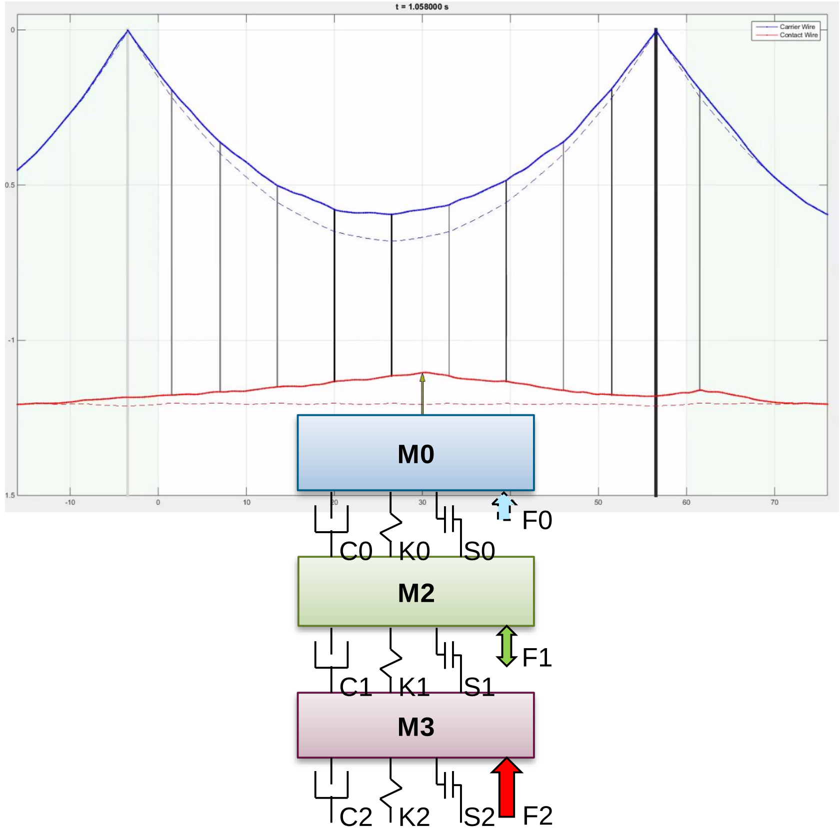
SIEMENS
Ingenuity for life



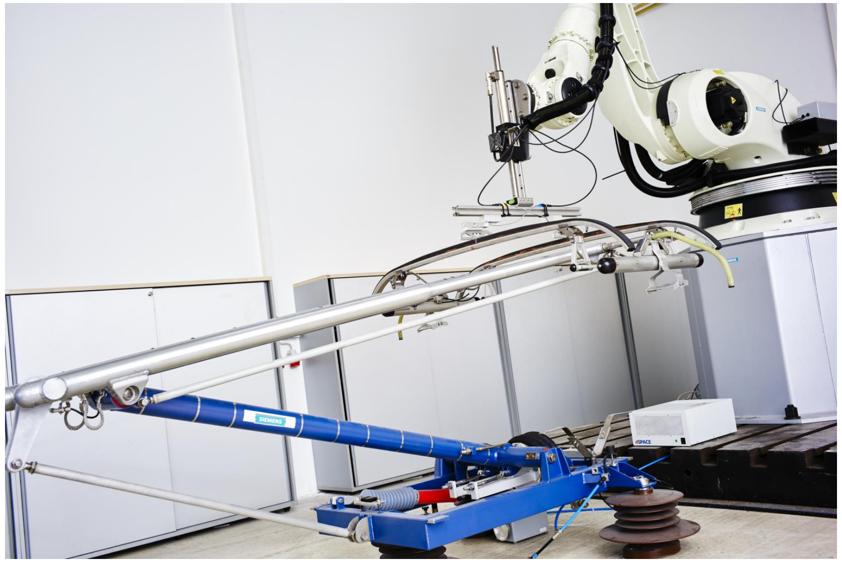
Hardware-in-the-loop-testing
closing the gap between simulation and field testing

SIEMENS
Ingenuity for life

Simulation
- Lumped mass
- Multi body



Emulation
- Hardware-in-the-loop testruns



Field tests
- Vehicle test runs under operating conditions

Introducing **hardware-in-the-loop testing** to bridge the gap between theoretical simulations and field tests

- **Minimizes risks (technical and economical)**
- **Improves safety**

Thank you very much for your attention

Herausgeber: Siemens Mobility GmbH

Christian Saliger
R&D Engineer
MO RS SC BG PN

Siemensstraße 90
1210 Wien

Phone (mobile): +43 664 88 55 32 22

E-Mail:
christian.saliger@siemens.com

siemens.com