VIRTUAL MANUFACTURING
ENABLER FOR LEARNING FACTORIES

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Volvo Car Corporation

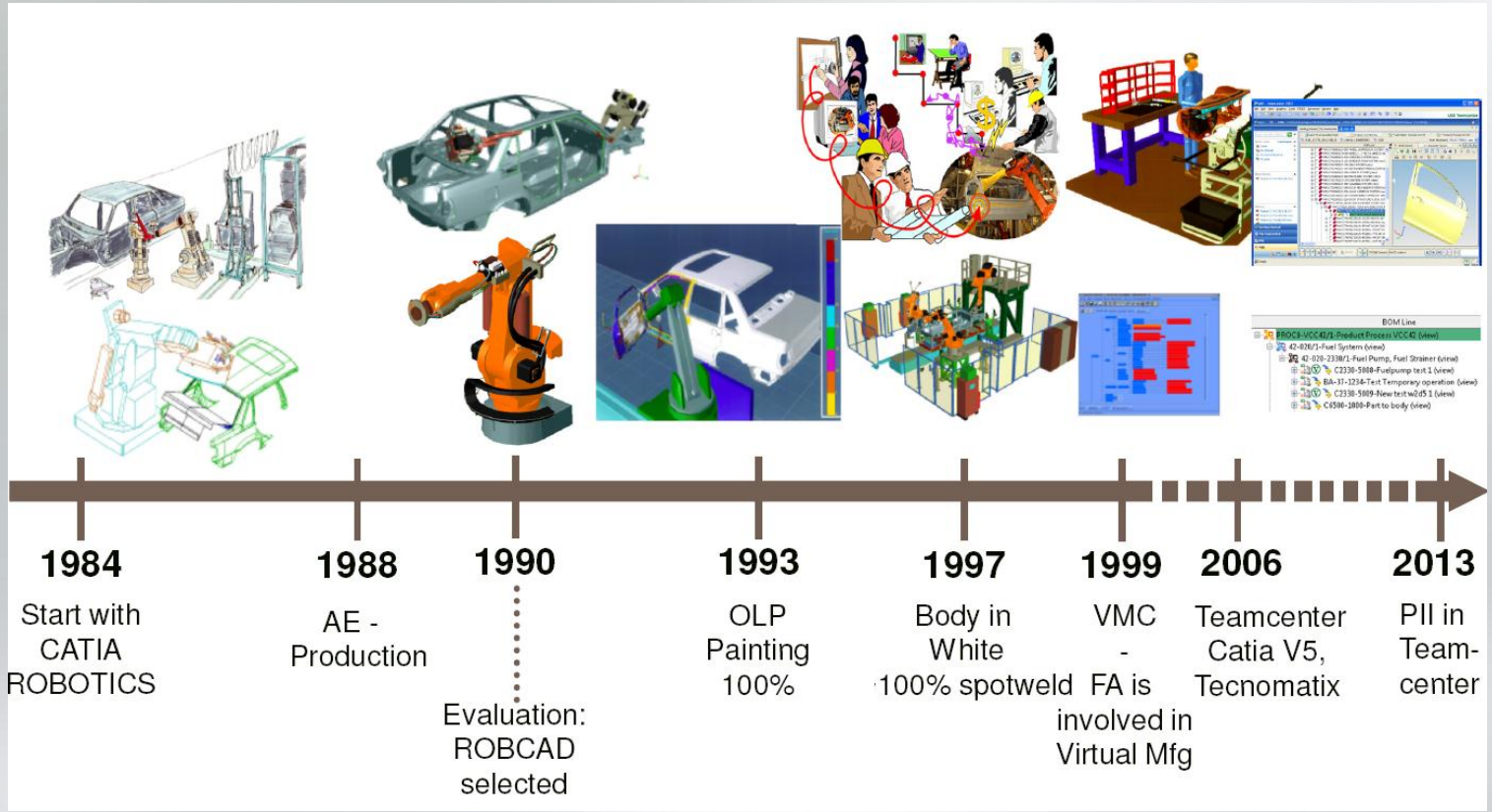
Manufacturing Engineering

Virtual Methods & IT

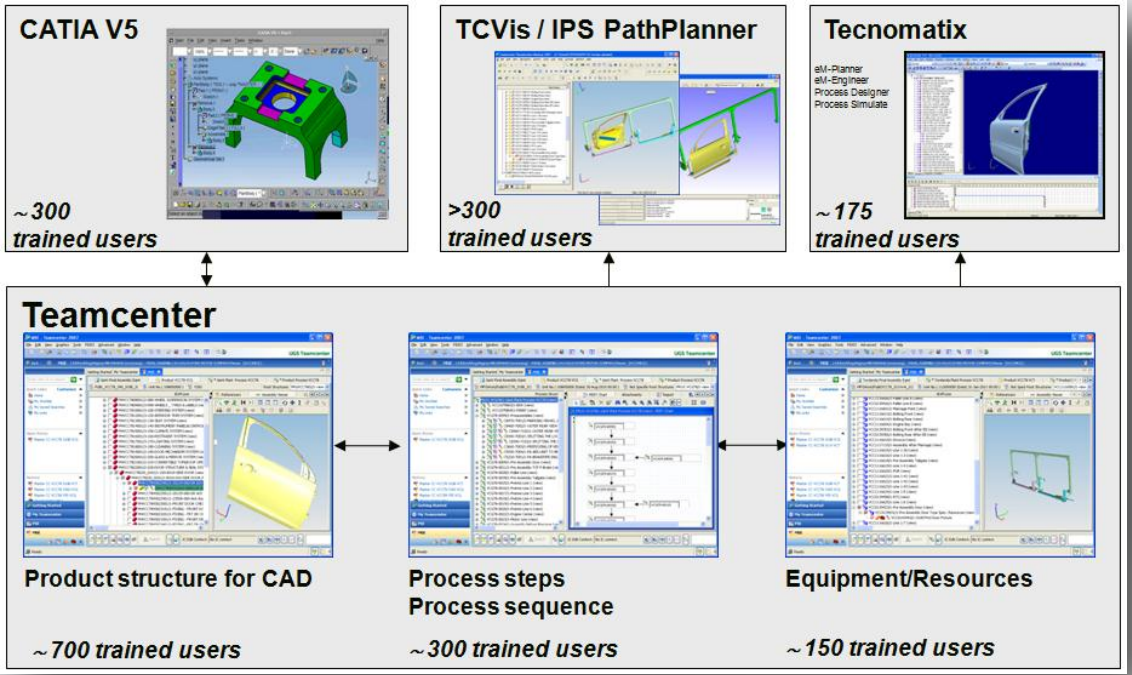
OUTLET

- ✓ Background and changing conditions and future challenges
- ✓ Layout and flowsimulation
- ✓ Plant Hybrid Model – scanning of our plants
- ✓ Virtual verification of manual assembly tasks
- ✓ Virtual training of assembly workers

BACKGROUND
VIRTUAL MANUFACTURING AT VOLVO CARS - HISTORY



TOOL SET FAMILY - MANUFACTURING ENGINEERING



Within the Manufacturing Engineering organization there are Virtual Manufacturing Engineering (VME) groups in all areas:

- VME BiW
- VME Paint and Sealing
- VME Final Assembly

Approx. 35 simulation engineers (FTE)

CHANGING CONDITIONS AND FUTURE CHALLANGES

From

To

2012

- Engineering only in Sweden
- 2 flex. assembly plants
- 1 engine plant
- 1 stamping plant
- Volume ~400k vehicles/year

2016

- Global Engineering (EU, China, Suppliers)
- 30% lead time reduction
- Limited physical builds
- 4 flex. assembly plants
- 2 engine plants
- 3 stamping plants
- ~ 600k vehicles/year

2020

- 3x Engineering Output
- 50% lead time reduction
- > 4 flex. assembly plants
- > 2 engine plants
- > 3 stamping plants
- Volume ~800k vehicles/year

SPA

MORE MODELS!

BUT HOW?

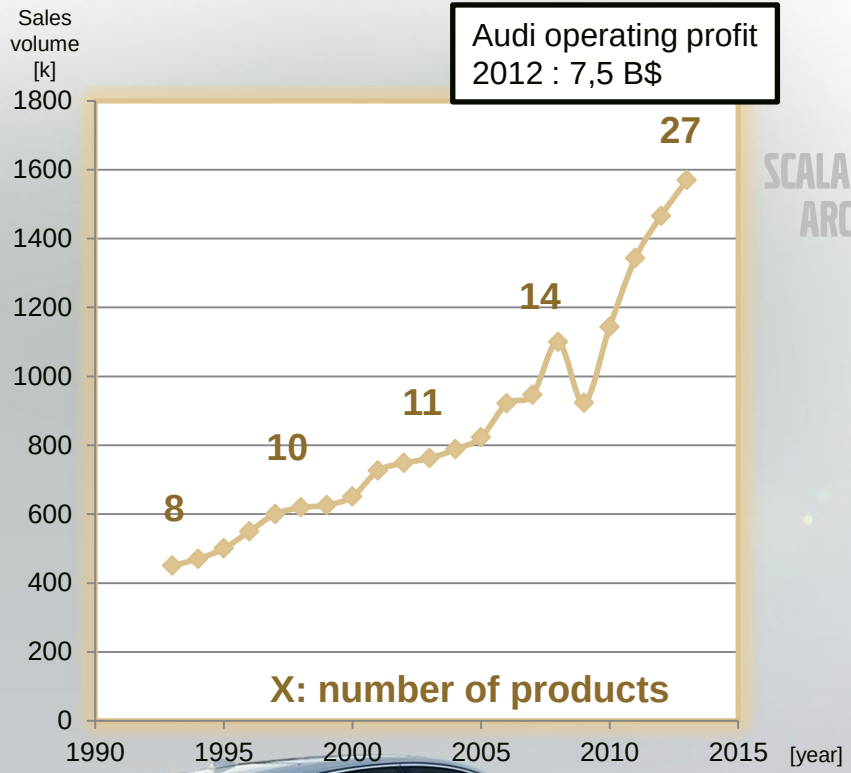
RAPID FOLLOWER!

SHORTER TTM/LEAD TIME

WHEN YOUR ARE SMALL...

FIRST WITHIN SAFETY, ENVIRONMENT AND DESIGN AROUND YOU

Audi operating profit
2012 : 7,5 B$



SPA

SCALABLE PLATFORM ARCHITECHTURE

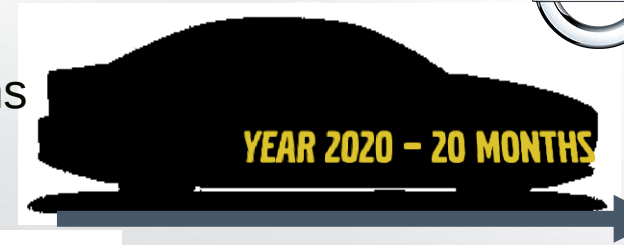
OUR MODEL RANGE 2014

MORE MODELS!

THE FIRST SPA BASED CAR
IS INTRODUCED IN FEBRUARY 2015

SHORTER TTM/LEAD TIME

Vision 2020-20: Leadtime from PS to J1: 20 months



Simulation is seen as one of the major enablers for reaching this vision!

NEW S80 – 40 MONTHS

VOLVO S80 – 50 MONTHS

VOLVO 850 – 60 MONTHS

DESIGNED AROUND YOU IN 2014

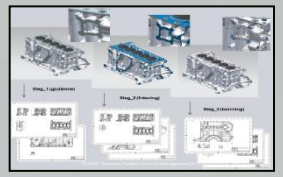
FIRST WITHIN SAFETY, ENVIRONMENT AND DESIGN AROUND YOU

SHORTER TTM/LEAD TIME – FROM 40 TO 20 MTHS

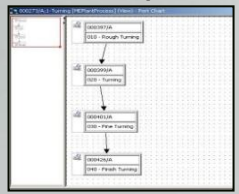
✓ Simulation is seen as one of the major enablers for reaching this vision

TARGET: FULL VIRTUAL SIMULATION & VERIFICATION

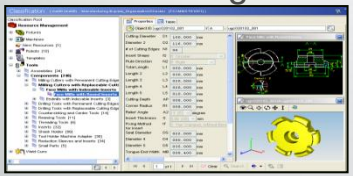
All products in sequence



Process/Operations

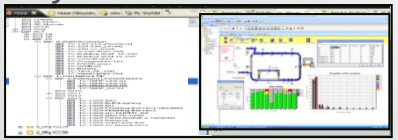


Tooling

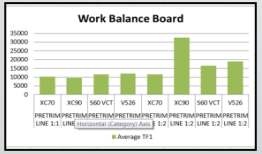


Line design

Layout Flow simulation

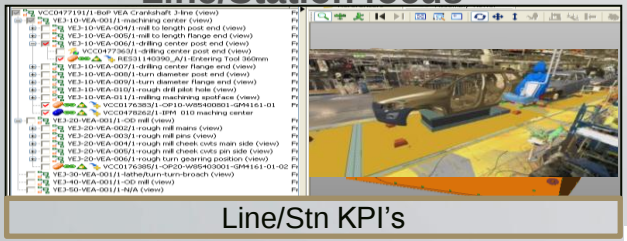


Balancing



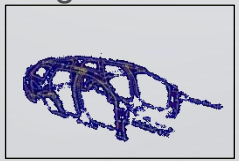
Requirement Verification

Line/Station focus



Line/Stn KPI's

Mfg features

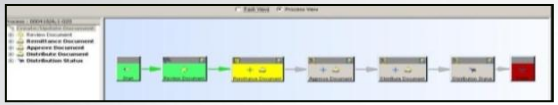


Logistics

Issue visualisation

Atacq
VQDC
MPDC
Etc.

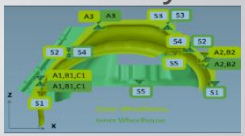
Offline changeover



Operator training PLC Robot

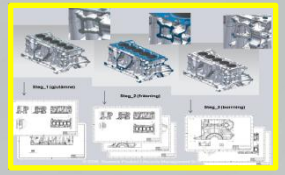
Ergonomics TF1 + TF2

Geometry

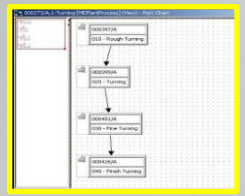


CAPABILITY OF FULL VIRTUAL SIMULATION & VERIFICATION

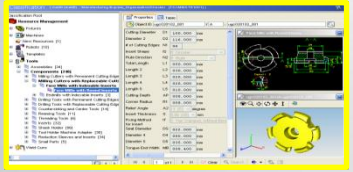
All products in sequence



Process/Operations



Tooling

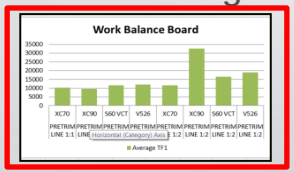


Line design

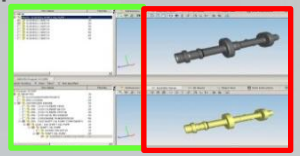
Layout

Flow simulation

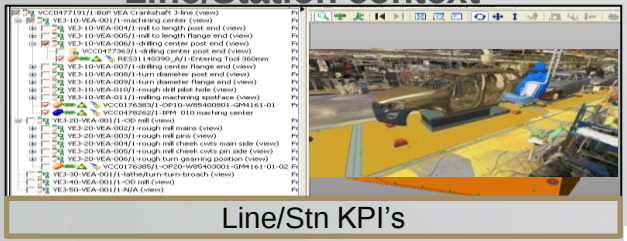
Balancing



Requirement Verification

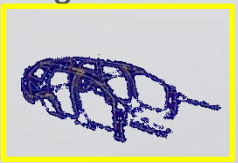


Line/Station context

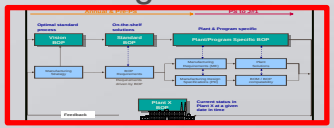


Line/Stn KPI's

Mfg features



Logistics



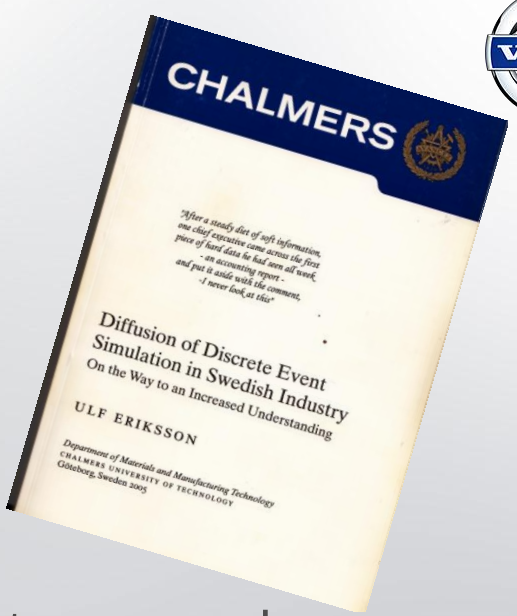
Production Issue

Offline changeover

Ergonomics | TF1 – TF2

Geometry

FLOW SIMULATION



✓ Several studies* show that flow simulation is a relatively small activity within most organizations

✓ The potential using flow simulation is known, both among managers and engineers

✓ Two major reasons for why flow simulation is not as spread as it could be are:
- hard to generate models of the flow and rules of logic
- very hard to find relevant and correct data

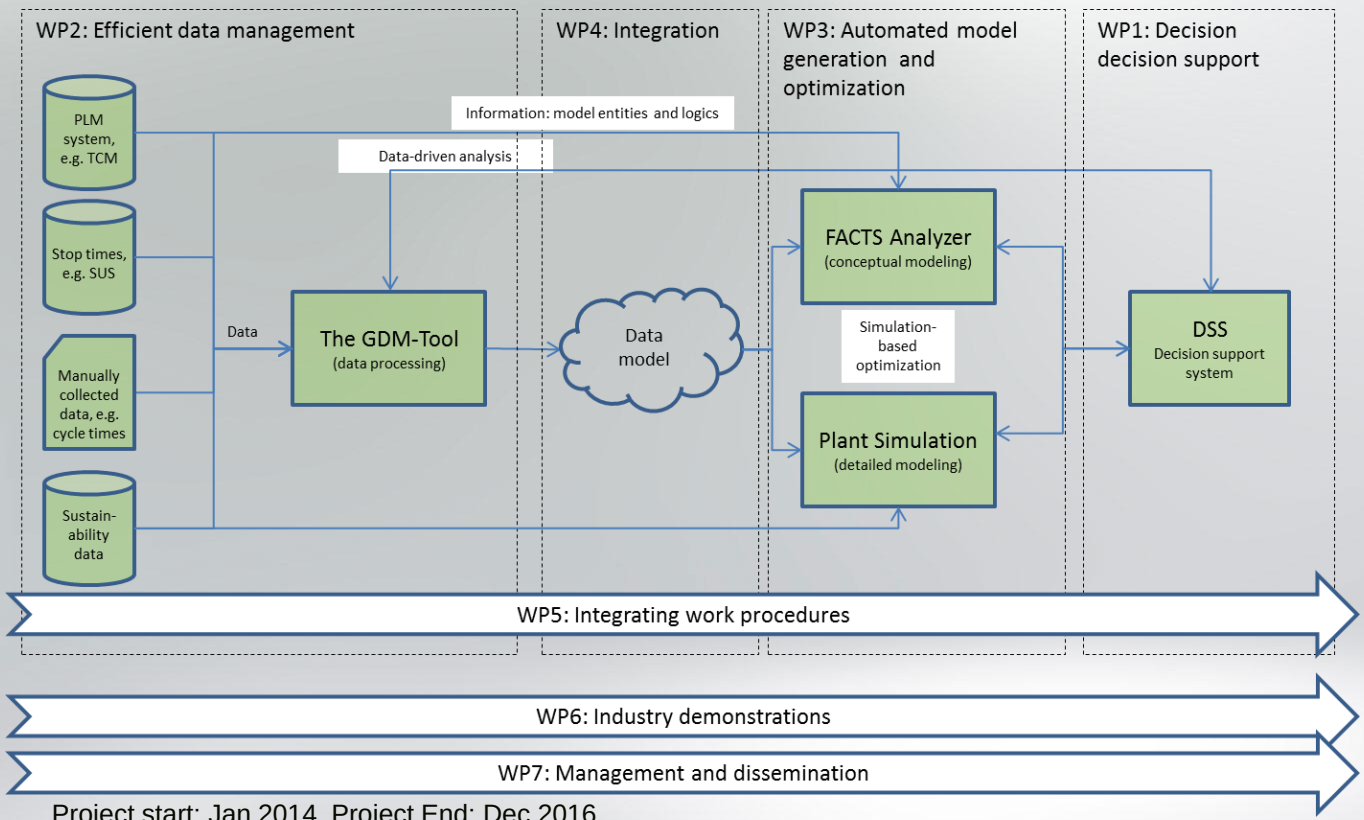
*) Eriksson, U. (2005), Johansson, B. (2006), Skoogh, A. (2011)

FLOW SIMULATION

✓ We have started a research project which aims are:

- ✓ Reduced lead-time for simulation of production flows to <24h response time, including data collection, model building, optimization, and improvement suggestions
- ✓ Proven identification of improvement potential never detected by analytical analysis, resulting in 10% increased throughput at our demo-lines
- ✓ Extended user base and more frequent use of modeling techniques in production systems analysis
- ✓ Increased amount of quality assured data compared to current assumptions and guesses
- ✓ Industry-based demonstration of full integration between automated data collection, automated simulation update, and automated optimization
- ✓ Demonstrations validated by the industrial partners.

FLOW SIMULATION - PROJECT STRUCTURE & DELIVERIES



Project start: Jan 2014, Project End: Dec 2016
Budget: 11,205 MSEK with 5,4 MSEK (48%) public funding

Project deliveries:

PD1. Methodology/work procedure to identify and quality assure available data, and complete unavailable data.

PD2. Tool for finding and visualizing production constraints, finding conceptual solutions, and providing fact-based decision support for taking action.

PD3. Industry demonstrator proving integration between PLM, MES and other data sources through simulation model and optimization engine.

PD4. Methods for advanced data analysis. Both data-driven analyses from production data and data mining on output data from the simulation model.

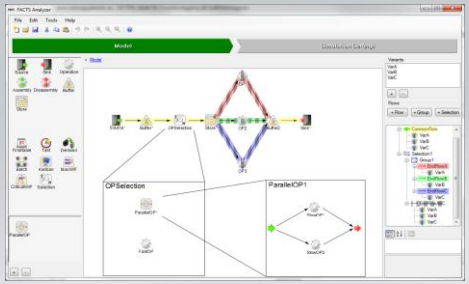
PD5. Novel approaches for connecting simulation models to data sources using IDP.

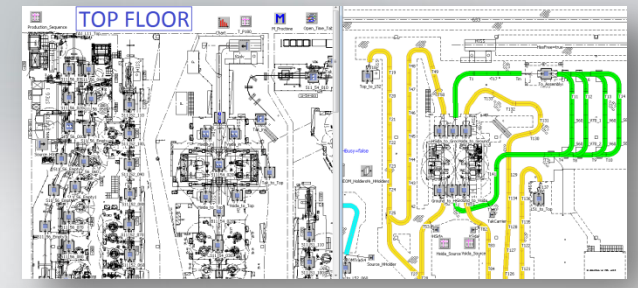
FLOW SIMULATION

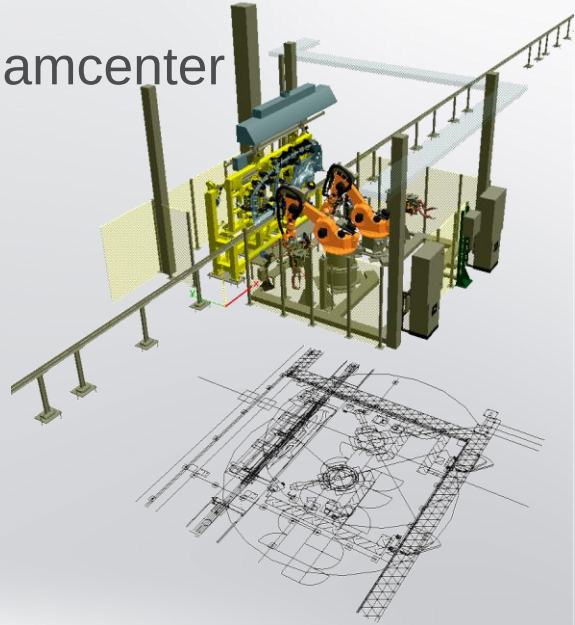
✓Flow simulation in early phases and integrated in Teamcenter

✓ A standard tool box has been formalized for all organizations within VCME:

FACTS and Plant Simulation







LAYOUT

✓ Layout is mostly 2D

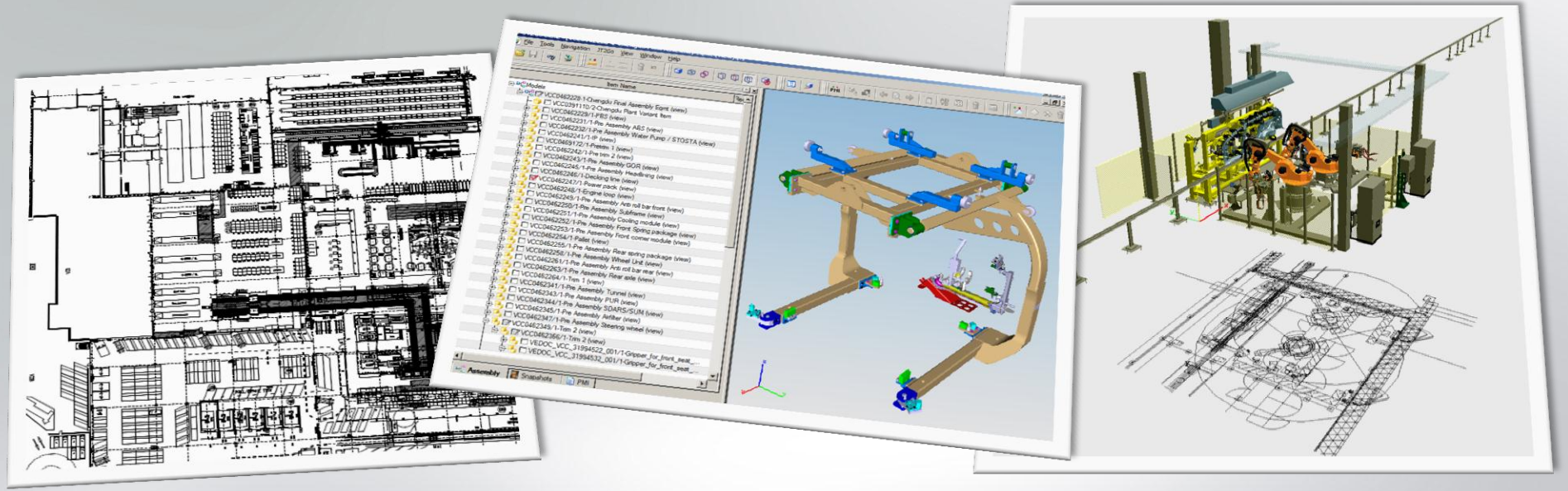
✓ We have problems managing plant layouts over time

✓ Being a small manufacturer, the plant becomes complex since many products are going through the same plant

✓ We need layout in 3D and layout information easily distributed to all stakeholders over time

LAYOUT - WHAT DO WE HAVE TODAY?

✓ We have 2D layout, equipment models, and very good status on robot cells



LAYOUT – WHAT DO WE MISS TODAY?

✓ We miss a plant structure with effectivity (intro weeks)

✓ It should be possible for any manufacturing engineer to get a layout over any plant in any time

✓ It is desirable to have the layout in 3D from start and 2D as a viewer form

✓ Layout is more and more related to Plant scanning

PLANT SCANNING AND LAYOUT

Laser scanned model built up of points and, if necessary, mixed with CAD models (Plant Hybrid Model)

Each point has information of (X, Y, Z, R, G, B)

The point clouds can easily be clustered as a “component” and treated as any CAD model

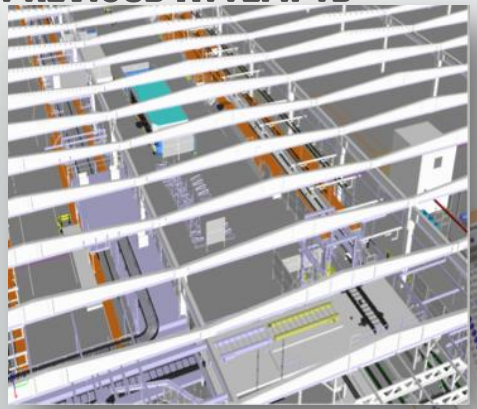
PLANT SCANNING AND LAYOUT - PREVIOUS ATTEMPTS

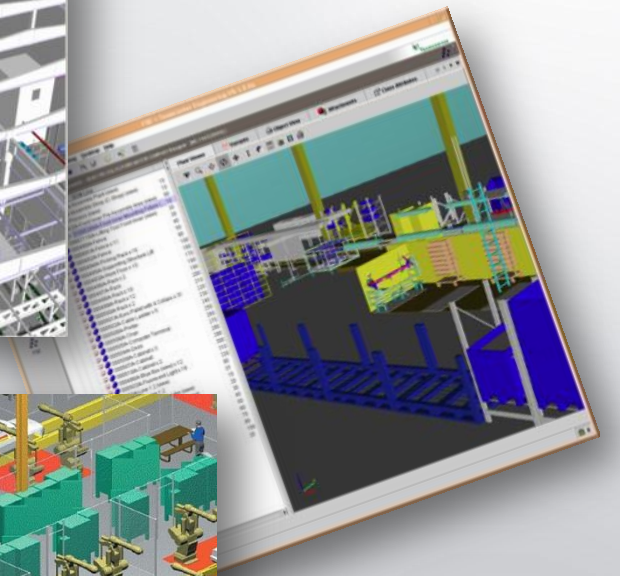
Numerous attempts to make CAD models of the plants

Our experience:

Not working;

- Too time consuming
- The CAD models are not accurate enough
  - Not always 90°
  - Not always parallel
  - Not always perfect plain
  - ... ...
- Who to CAD for?
- What to include?
- Who will pay for the time?





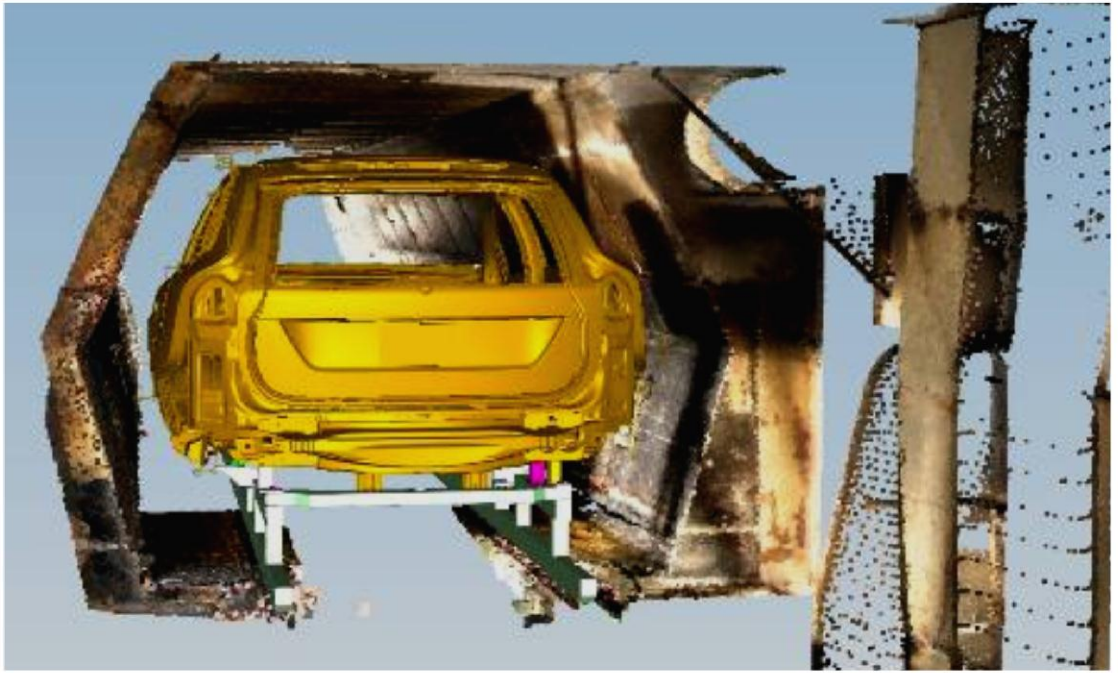
PLANT HYBRID MODEL - USE CASES

Virtual Linewalks

PLANT HYBRID MODEL - USE CASES

Virtual Linewalks

Body window studies

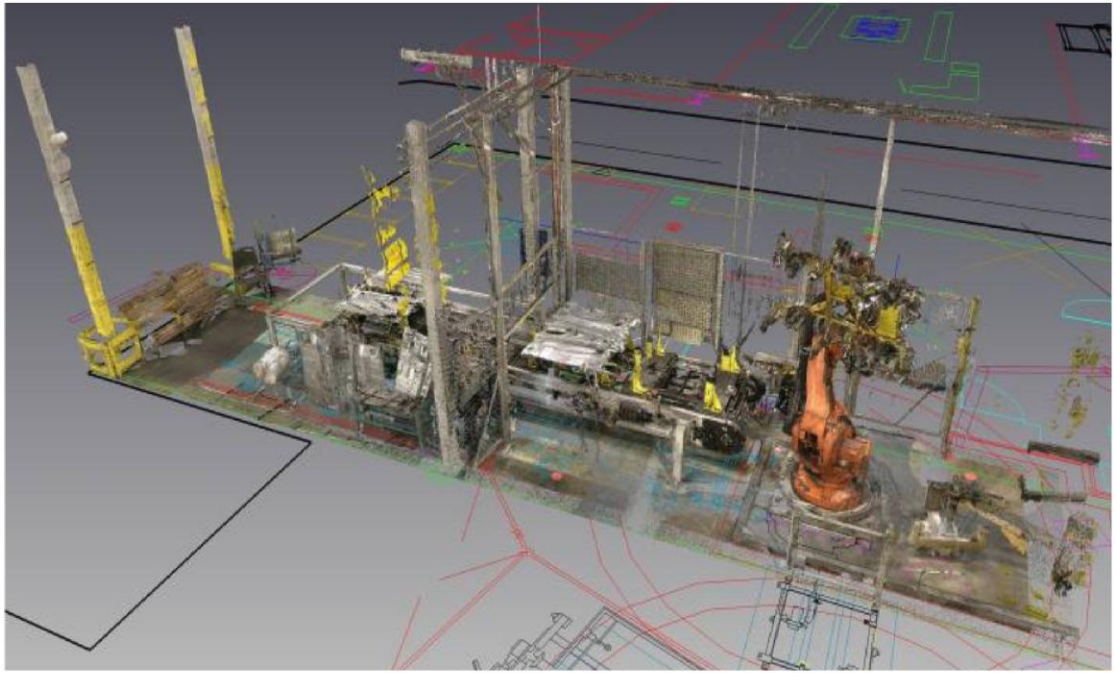


PLANT HYBRID MODEL - USE CASES

Virtual Linewalks

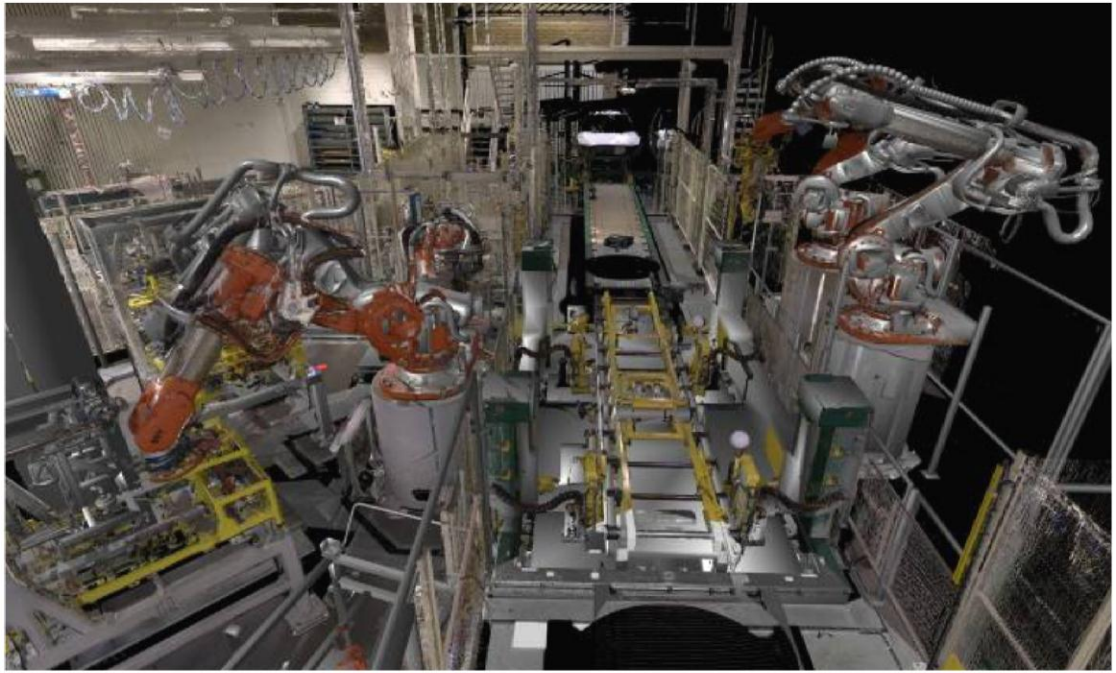
Body window studies

2D layout validation



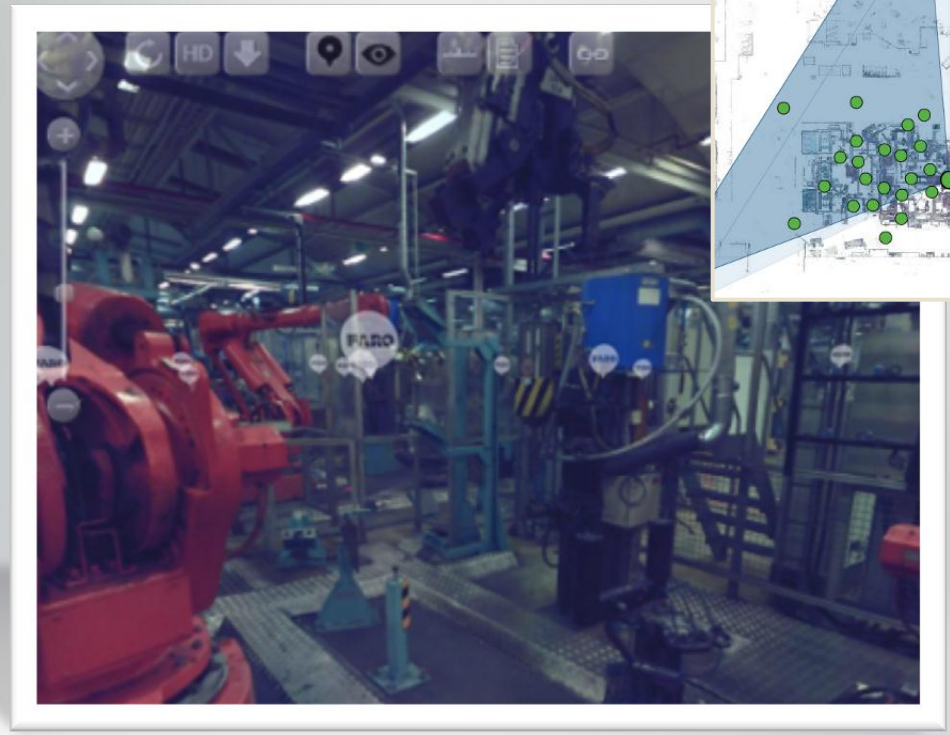
PLANT HYBRID MODEL - USE CASES

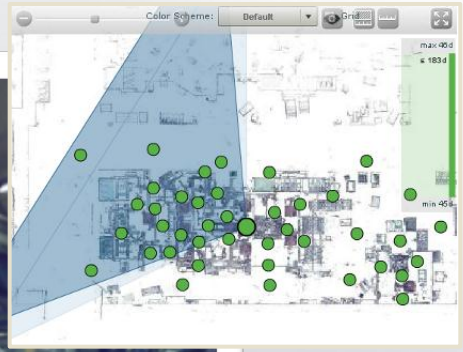
Virtual Linewalks
Body window studies
2D layout validation
Installation verifications



PLANT HYBRID MODEL - USE CASES

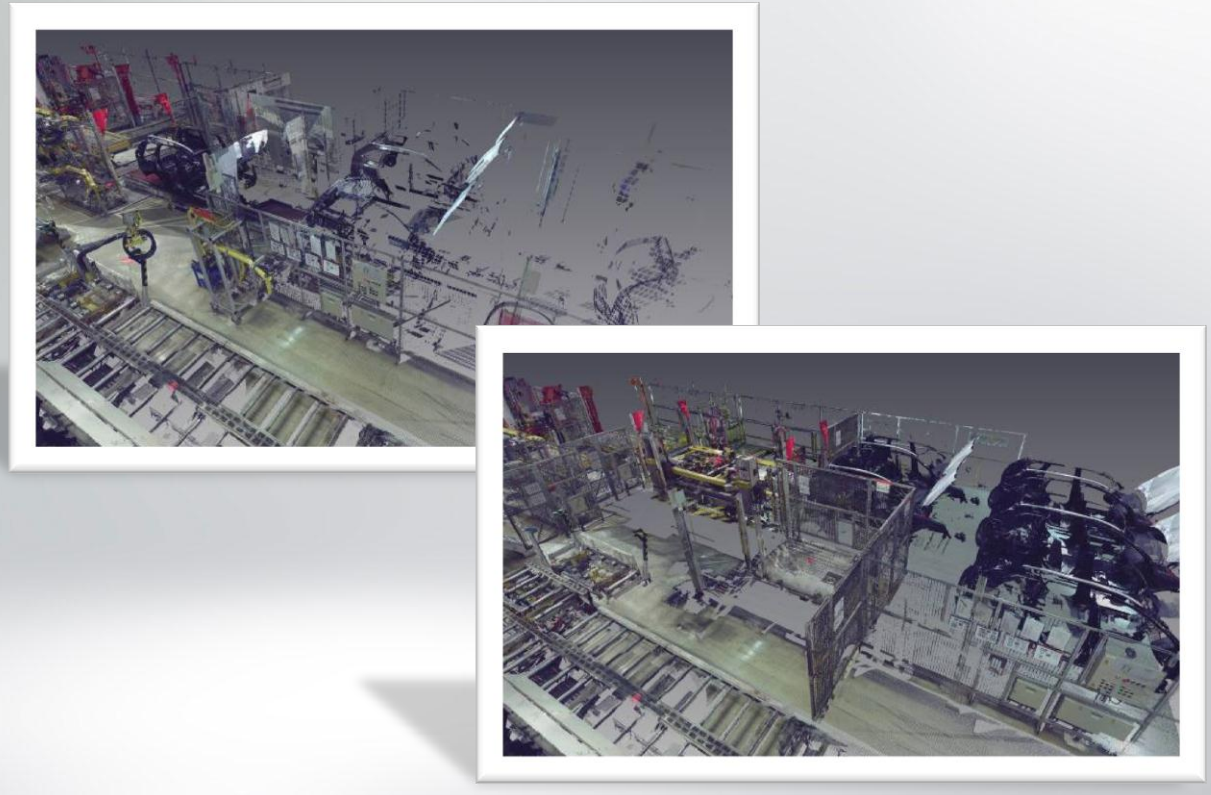
Virtual Linewalks
Body window studies
2d layout validation
Installation verifications
Plant visualization



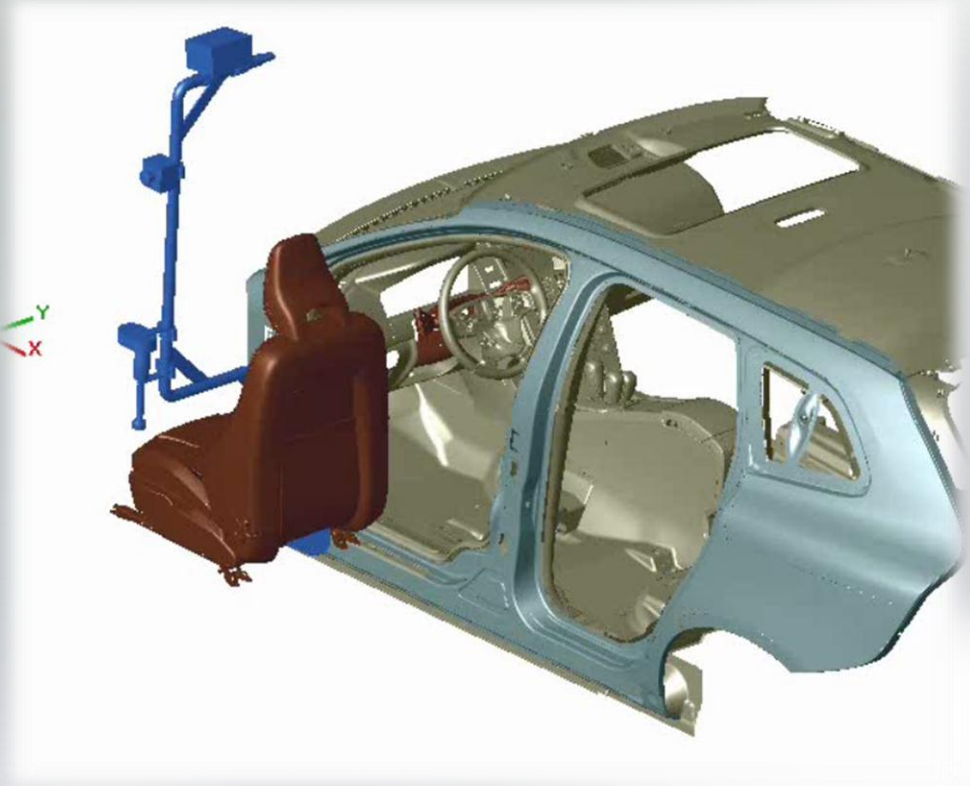


PLANT HYBRID MODEL - USE CASES

Virtual Linewalks
Body window studies
2d layout validation
Installation verifications
Plant visualization
Visualize rebuilds



WHAT DO WE MISS IN OUR SIMULATION TODAY?



- The Plant

Material Façade
Line, working height
Distance between cars on line

- The holistic view

- Product and product close equipments are included

WHAT IF...

THE POINT CLOUD IS OUR DIGITAL PLANT

Scan what we have!
CAD what is new!

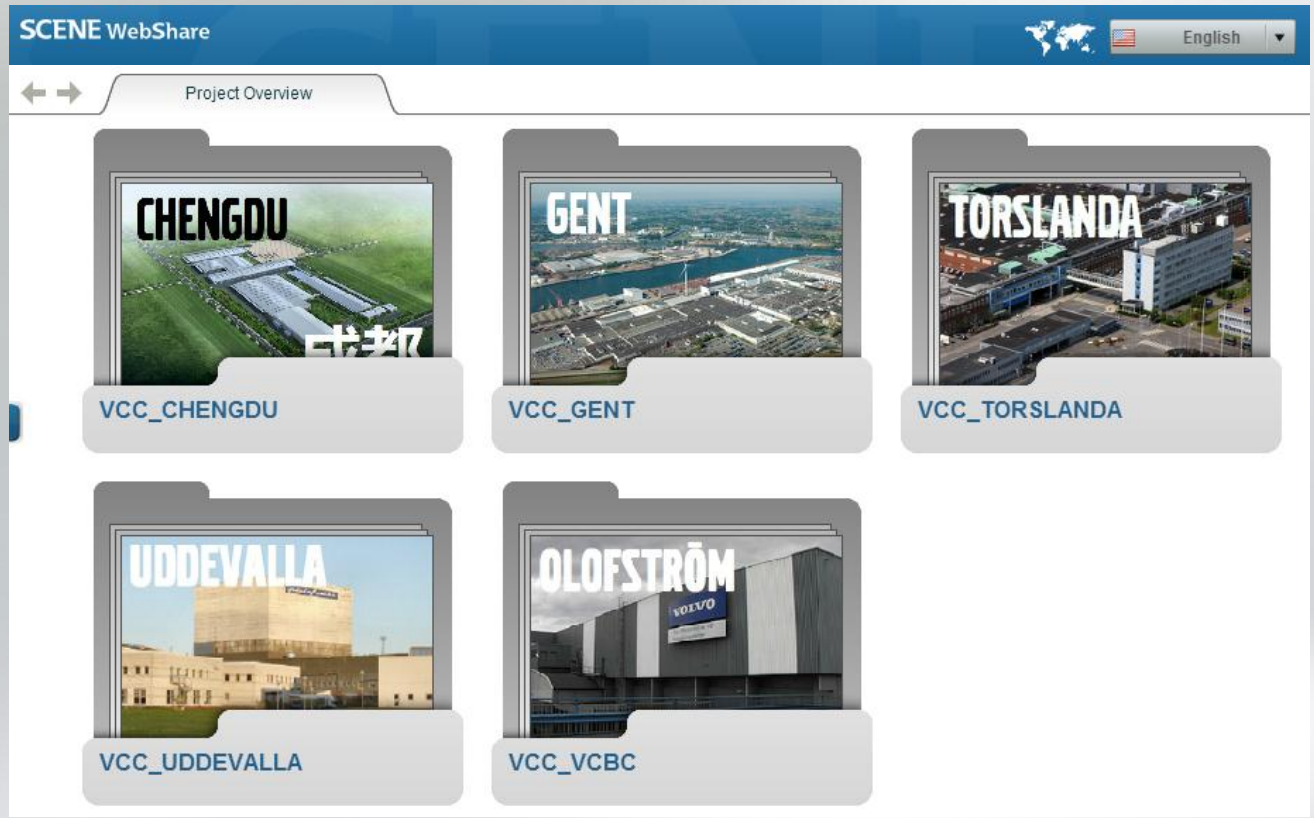
Incremental scanning

No conversion!
Avoid reverse engineering!
No objectification!

<u>Use Point Cloud As Is!</u>

VERIFY ASSEMBLY CASE AND LOGISTICS/LAYOUT

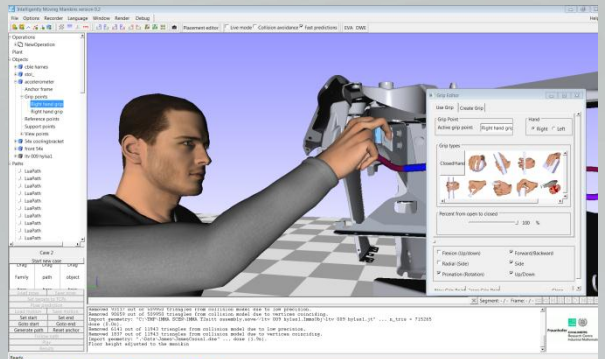
DEMOCRATIZING THE DATA



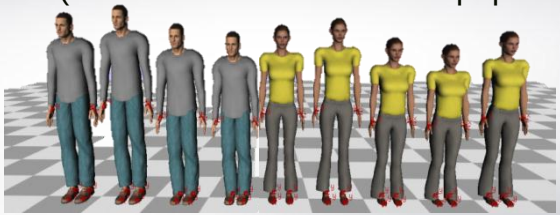
VIRTUAL VERIFICATION OF MANUAL ASSEMBLY TASKS

- ✓ Sofar most ergonomics simulations have been static analyses
- ✓ Most manikin software are closed and hard to integrate with
  - company specific standards or anthropometrics are hard to integrate in the tools
- ✓ Volvo Cars is therefore developing an own manikin in a research project together with Volvo Trucks and Scania and FCC
- ✓ The manikin is dynamic and finds a collision free assembly way if there is any – IMMA project (Intelligently Moving Manikin in Assembly)

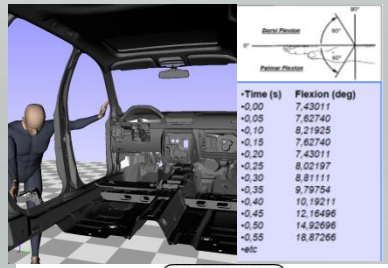
USING OF IMMA FOR VIRTUAL VERIFICATION OF MANUAL ASSEMBLY TASKS



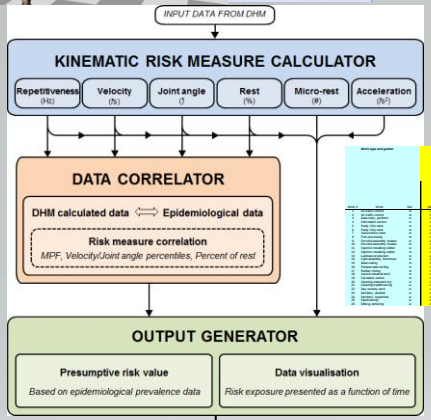
- ✓ Self collision algorithm implemented
- ✓ Field of view included as kinematic constraint
- ✓ Balance function
- ✓ Automatic fitting of a 3D character to the IMMA digital human model
- ✓ Adjustable skin model in size
- ✓ Multivariate methods for defining representative manikin measurement configurations in order to offer advanced functionality to consider anthropometric diversity within a whole workforce has been developed
- ✓ By using this approach only twelve manikins are needed to represent a considerable larger amount of the workforce
  (12 manikins => 98% of the population)

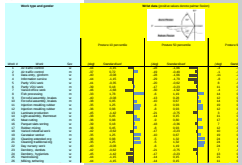


DEVELOPMENT OF OF BIOMECHANICAL ACCEPTANCE RULES



Time (s)	Flexion (deg)
0,00	7,43011
0,05	7,62740
0,10	8,21925
0,15	7,62740
0,20	7,43011
0,25	8,02197
0,30	8,81111
0,35	9,79754
0,40	10,19211
0,45	12,16496
0,50	14,92696
0,55	18,87266
etc	

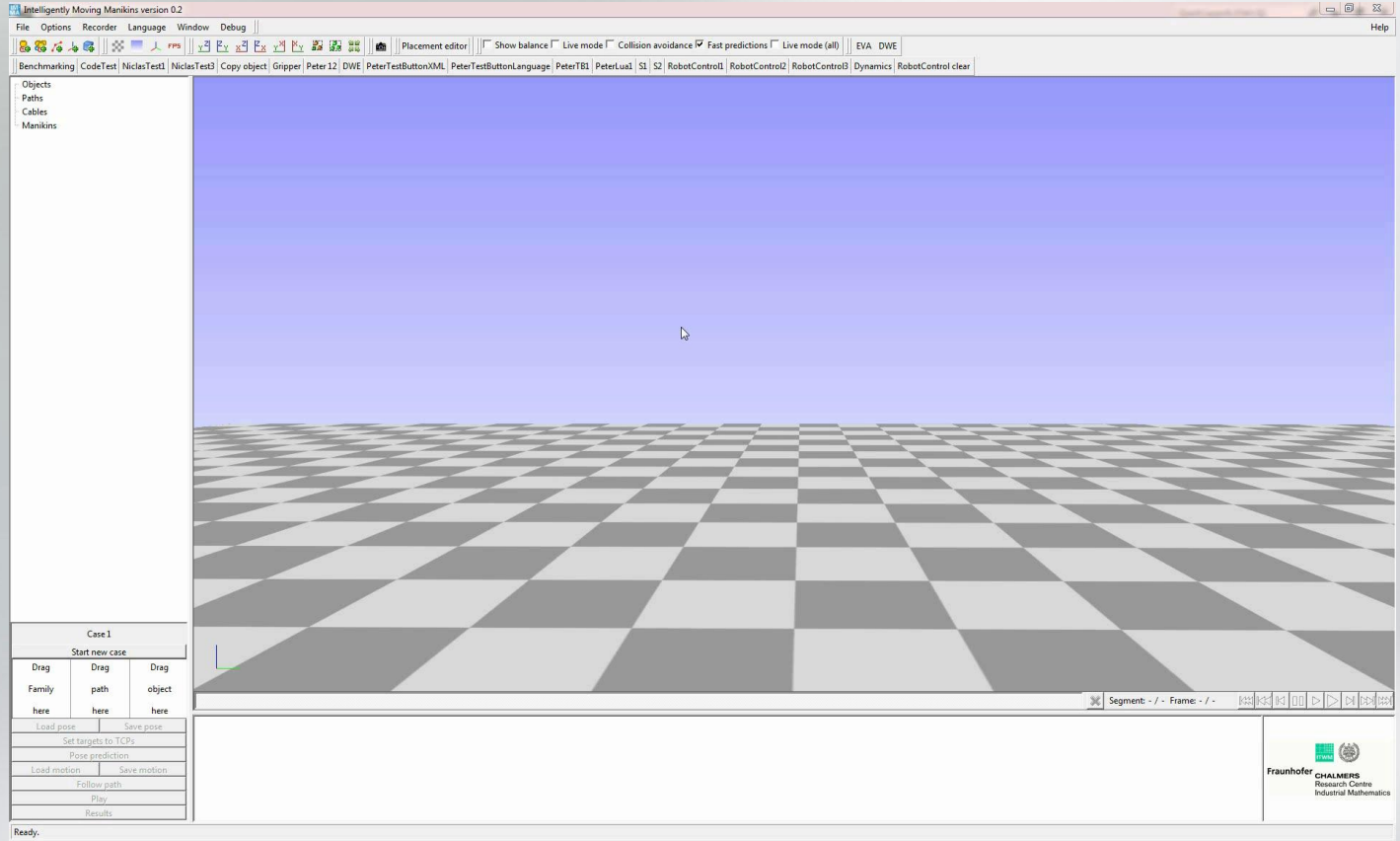




Complaints		Diagnosed disorders				
During past 12 months (%)	*During past 7 days (%)*	*One or more diagnosed disorders (%)*	*Lateral epicondylitis (%)*	*Medial epicondylitis (%)*	*Carpal tunnel syndrome (%)*	*Overused hand syndrome (%)*
66	38	14	0	4	11	2

- ✓ The study to identify appropriate kinematic exposure variables to use as input data for the biomechanical acceptance rules was continued during first half of 2012 leading to a specific set of six exposure variables: *Repetitivity*, *Velocity*, *Acceleration*, *Rest, Micro-rest* and *Posture*
- ✓ The developed ergonomics evaluation concept is implemented in IMMA
- ✓ A reference database model was compiled from existing research. The database describes correlations between exposure data for specific joints and segments and associated prevalence of injury

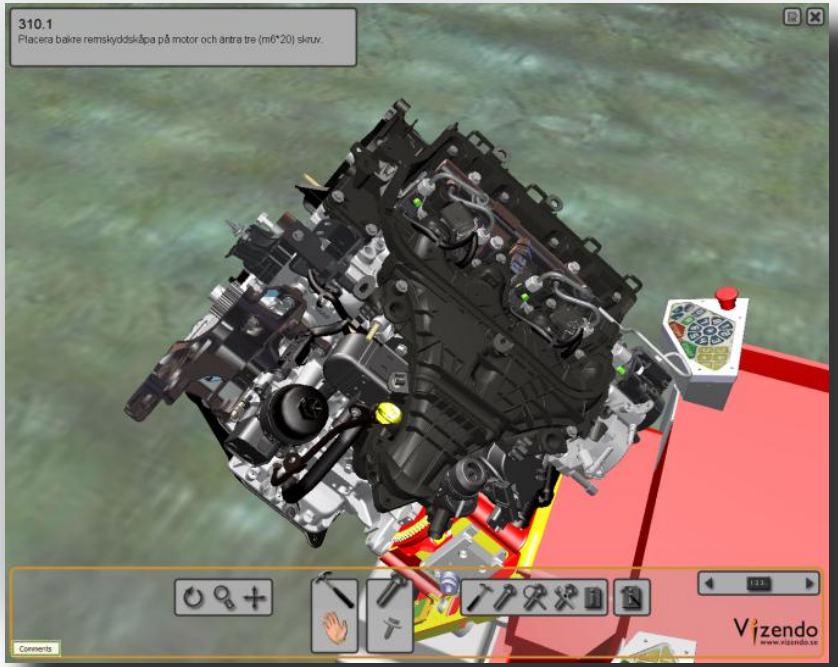
IMMA USER INTERFACE AND WORK METHODOLOGY



VIRTUAL TRAINING OF ASSEMBLY WORKERS (VIRTUAL OPERATOR TRAINING / PCPT)

- PCPT is a virtual training application,

and is a complement to traditional operator training



- In PCPT the operator can train on different work sequences:
  - ✓ which part to assemble?
  - ✓ what tool to use?
  - ✓ where to perform the assembly?
  - ✓ in which order shall the different parts be assembled?

- PCPT also enables the operator to train on different variants, e.g. variants with different engines or specific options.

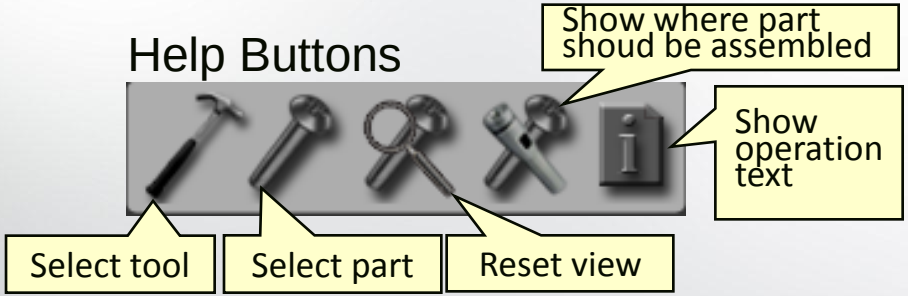
VIRTUAL PROCESS TRAINING

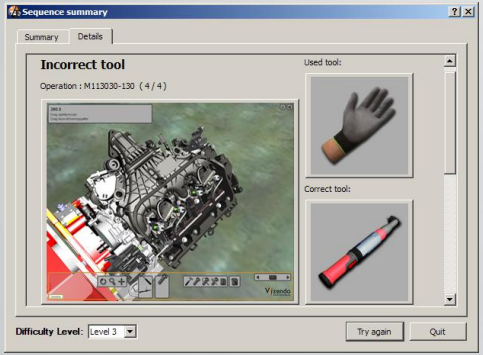
PCPT is an interactive tool with four different levels of difficulty. Level 1 is the easiest and level 4 is the hardest.

	Location highligths	*Pre-selected tools/parts*	*Simple listing of parts/tools*	*Operation text*
Level 1	✓	✓	✓	✓
Level 2	✗	(✓)	✓	✓
Level 3	✗	✗	✗	✓
Level 4	✗	✗	✗	✗

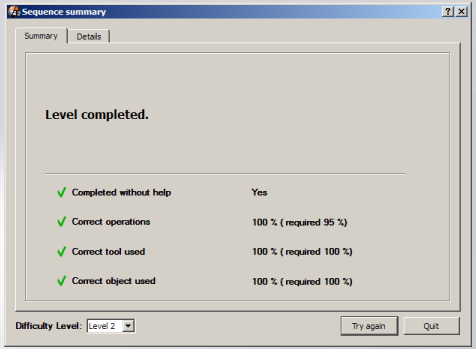
VIRTUAL PROCESS TRAINING

- If an operator makes a mistake in PCPT immediate feedback from the software will be provided. The operator can also ask for help



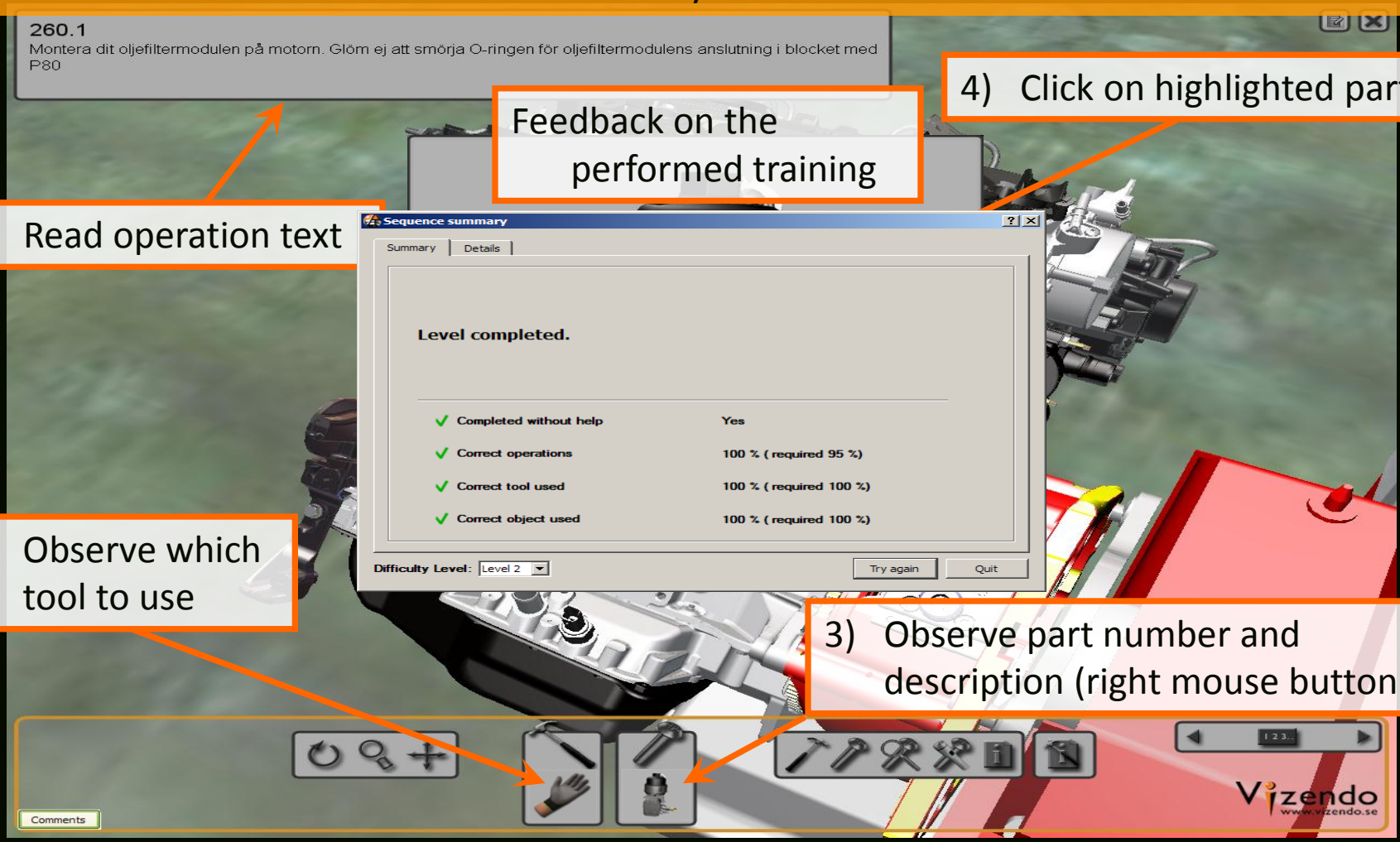


- Any mistakes made are presented in an overview after fulfilled sequence



- To be approved on a level, the operator must complete the whole sequence without mistakes

Difficulty Level 1



1) Read operation text

Feedback on the performed training

4) Click on highlighted part

2) Observe which tool to use

3) Observe part number and description (right mouse button)

VIRTUAL PROCESS TRAINING

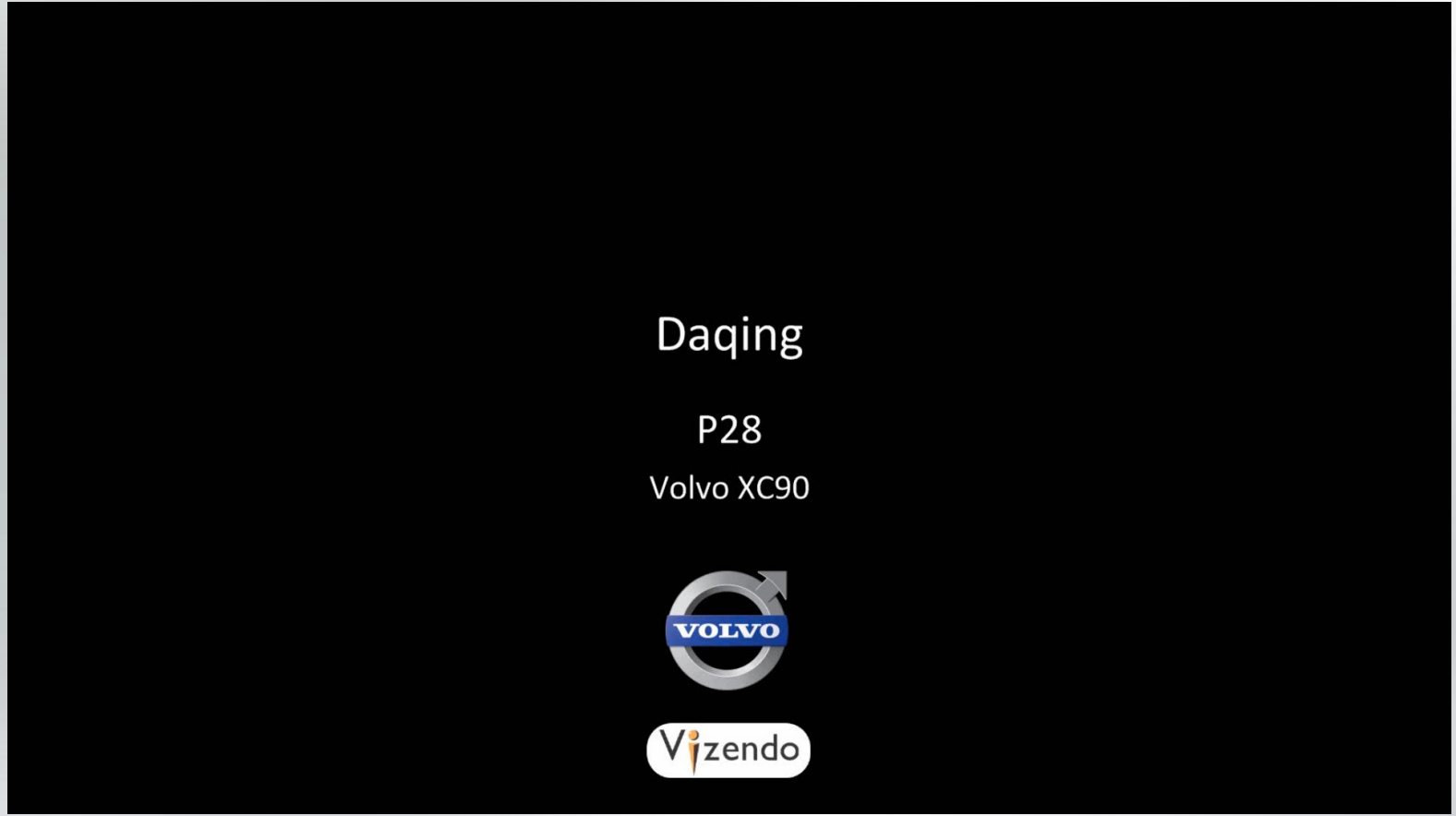
Complement to traditional training

Especially we are training:
- Sequence
- Variants
- Product knowledge

Major benefits:
- We can reduce the number of physical cars
- Training time reduced by 40-60%
- Independent on individual experts
- Rather language neutral (pictures instead of text/speech)

- More than 4000 employees have been trained during 2005-2014

VOLVO XC90 – OPERATOR TRAINING EXAMPLE



THANK YOU FOR YOUR ATTENTION!