Experience Benefit
Driving Simulator for the Linde Safety Pilot
T. Pendzialek and M. Kuhn, Linde Material Handling GmbH, 09/2018
Outline

- Linde Material Handling as part of the KION group
- CarMaker and Xpack4 for SW testing at Linde’s testing department
- Linde Safety Pilot
- Linde Safety Simulator
  - Overview / Setup
  - Environment simulation
  - Interface XPack4 ↔ Hexapod platform
  - Sound Module
- Summary
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Kion Group is the parent company of several brands
Global Production – Locations worldwide

- Linde Material Handling North America Corp. - 1 Factory
- Fenwick-Linde S.A.R.L. - 1 Factory
- Linde Pohony s.r.o. - 2 Factories
- Linde Material Handling - 5 Factories
- Linde-Xiamen Forklift Corporation Ltd. - 1 Factory

- ca. 14,000 Employees
- ca. 3 Billion € Revenue in 2014
Product Portfolio
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**HIL Project History**

**HIL Functionality**

- **Gen. 1 HIL** for model based driver assistance system test of electric trucks ECUs
- **Gen. 2 HIL** for ECU test of IC trucks Fail safe tester unit added
- **Gen. 3 HIL**
  - Full scalability from vehicle based to model based ECU test
  - Integrated CAN gateway
  - Special purpose additional features
- **Driving Simulator Project**
  - Gen. 1 HIL reassembled from left over parts
  - Added missing hardware
  - Build the actual simulator
- **HIL 4,5,6,7** as copies of gen. 3 HIL go to different development sites of KION
  - Start of the global ramp up support project
- **HIL 8** as copy of gen. 3 HIL goes to another development site of KION
  - Ramp up support project ongoing

**Timeline**

- **2011**
  - Develop Gen 3 HIL
- **2012**
  - Prepare global KION project
- **2013**
  - 2014
  - 2015
  - 2016
  - 2017
  - 2018

**Capacity extension 2019**
SW testing at Linde

HIL Project History

1. Logical Failure

2. Electrical Failure

3. Basic Functionality
   - Driving
   - Steering
   - Lifting
   - Tilting

4. Driving Maneuver
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Linde Safety Pilot

Load Force → Pressure Sensor

Lift Height → Wire actuated encoder

Axle Force → DMS Force Sensor

Visual and Audible Feedback → Display
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Linde Safety Simulator
Overview / Setup

- original series ECU and series truck parts
- 2 large 65“ TV screens (for driver and outside viewers)
- sound system in the completely darkened cabin
- camera and communication system in the cabin to instruct unexperienced drivers
Overview / Setup

Linde Safety Simulator

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Linde Safety Simulator

Environment setup

- Closed loop vehicle behaviour was simulated by CarMaker
- All required signals from and to the ECU have been managed with the XPack4 and CM
- Visualization with IPG movie and the standard traffic objects interface

- What the driver can do:
  - Full realistic access to vehicle functions driving, lifting, tilting
  - Full access to the driver assistance systems features
    - Driver selected speed, lift or tilt limitations
  - Drive the vehicle with turn over prevention system (Linde Safety Pilot) and without
  - Turn over the vehicle and get a feel for how helpless you are in such a situation
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**Linde Safety Simulator**

**Interface XPack4 ↔ Hexapod platform**

- Message exchange on 1ms basis
- Communication via UDP protocol
  (UDP library for Xpack provided by IPG)
- Relevant vehicle simulation data:
  - ax, ay, az
  - vx, vy, vz
  - Yaw rate, pitch rate, roll rate
  - actual center of gravity
- 2 days tuning session with Rexroth engineers
  → Tuning of the platform movement is something empiric, not absolute
- Platform state management:
  - TCL control panel → XPack4 → hexapod
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Linde Safety Simulator
Sound Module

- Recorded sound files:
  - Driving
  - Braking
  - Lifting
  - Lowering
  - Steering

- Created separated TCL server instances

- Repeated looping of the sound files in each instance

- Main application as client requests volume adaption corresponding to actual simulated vehicle behaviour
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- It hasn’t been the cheapest solution – but ...
  ... the fastest
  ... the most realistic (ECU with series software!)
  ... the most flexible (only little external help was needed)
  ... the most interesting
  ... the most impressive (turn-over feeling)

- Feedback ranged from „As in the real vehicle!“ to „This is totally different!“ → very subjective

- Things to think about before you do it
  - How will the handling of the simulator for marketing purposes be?
  - Do you want it realistic or just beautiful?

We would definitely do it again!
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Thank you for your attention!