IMR Mining and Metallurgy Machinery

How ROS works together with the mining industry in i2mine project

Prepared for ROSCON 2014

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RWTH AACHEN UNIVERSITY

Outline

- About IMR and RWTH Aachen University
- About i2mine project
- Industrial-grade Sensors
- Mobile Robotic Test Platform
- ROS Integration
- Outlook

Acknowledgements

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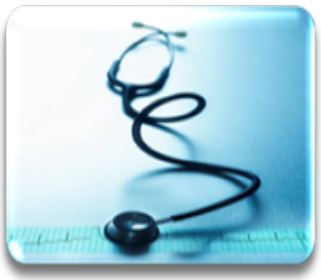
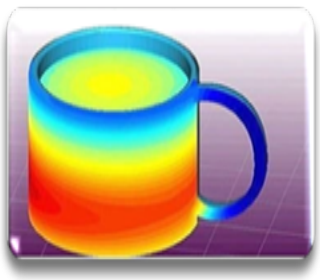
IMR and RWTH Aachen University

- RWTH Aachen University
  - 40 000 students
  - 10 000 staff
- Mining and Metallurgy Machinery
  - Faculty of Georesources and Material Engineering
  - 60 staff
  - Univ.-Prof. Dr.-Ing. Karl Nienhaus, since 1999

The Intelligent Mine of the Future
Introduction

- Changing the Way of Mining
- „Small Invisible Mining“
- Cross Linked Real Time Information Network
- Innovative Mining Methods
- Next Generation Mining Machines
- Autonomous Operation
- Integrated Intelligent Sensor Technologies
- Economical and Safe Exploitation
- Adverse Environmental Impacts

Industrial and academic partners

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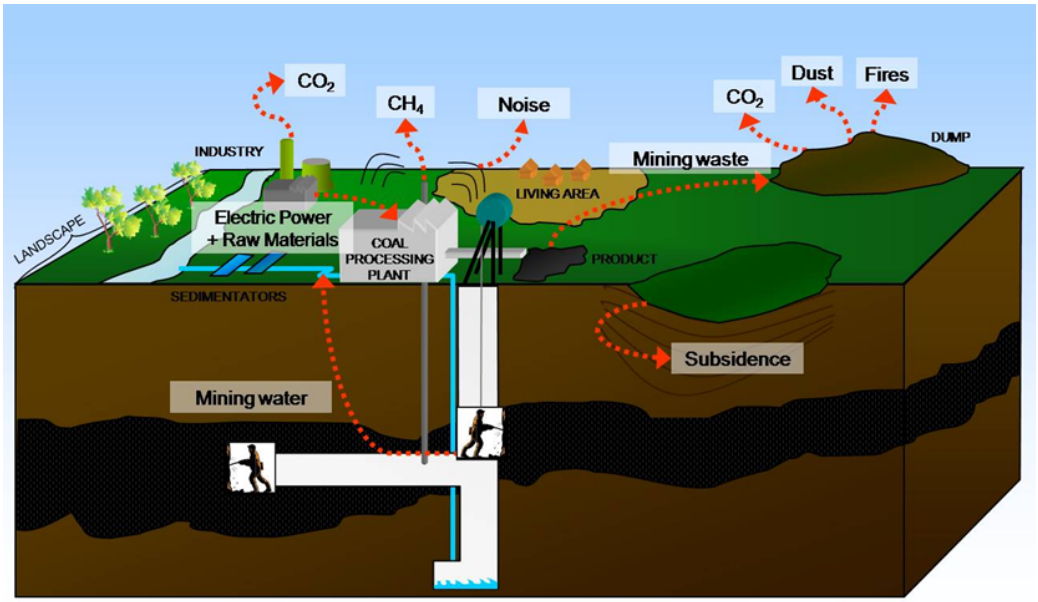
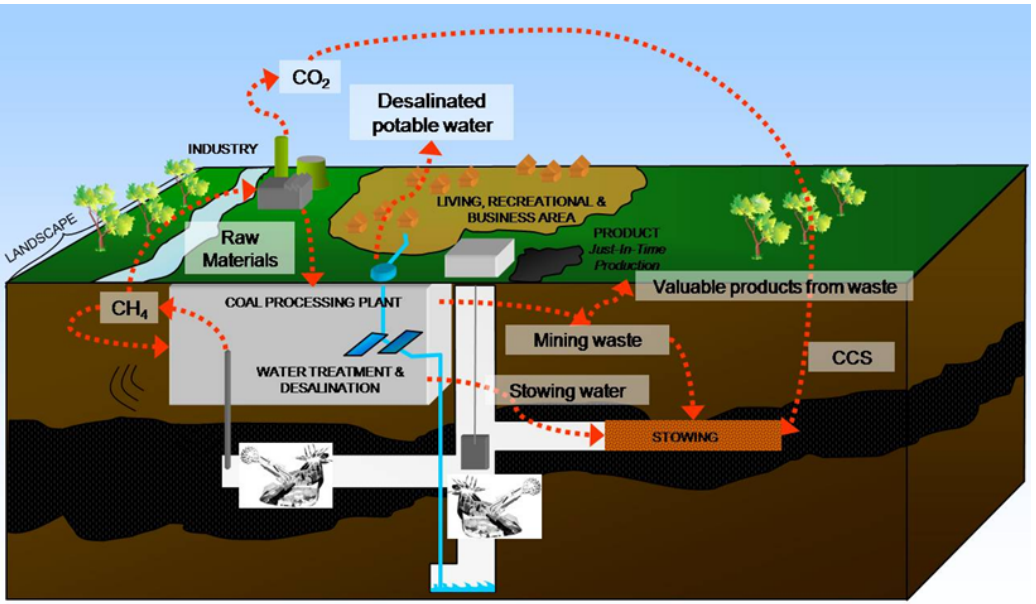
The Intelligent Mine of the Future
Vision

- **Today‘s mining operation**

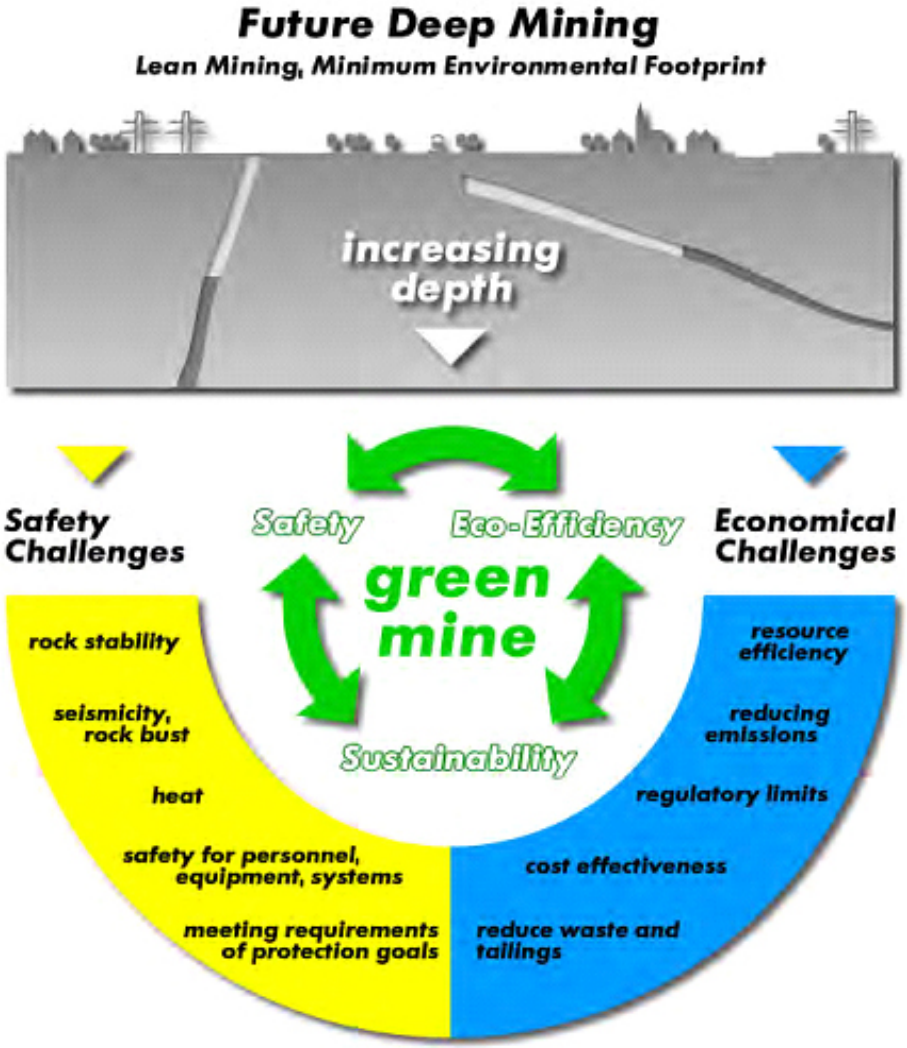


- **i2mine vision**



- Development of methods, technologies and machinery for deep mining
- Autonomous mining operation
- New sensors for highly selective cutting
- **Improve health and safety**

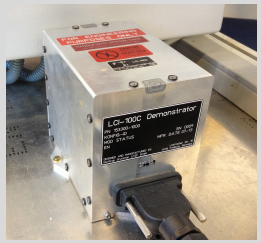
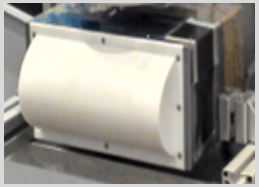
The Intelligent Mine of the Future



- Work Packages
  - Subtask 4.2.1
    Boundary layer and material detection
  - Subtask 4.2.2
    Collision avoidance and local underground navigation at the face
  - Subtask 4.2.3
    Machine guidance for precise positioning and cutting trajectory
  - Subtask 4.2.4
    A highly integrated, modular system for process optimization on autonomous mining machinery

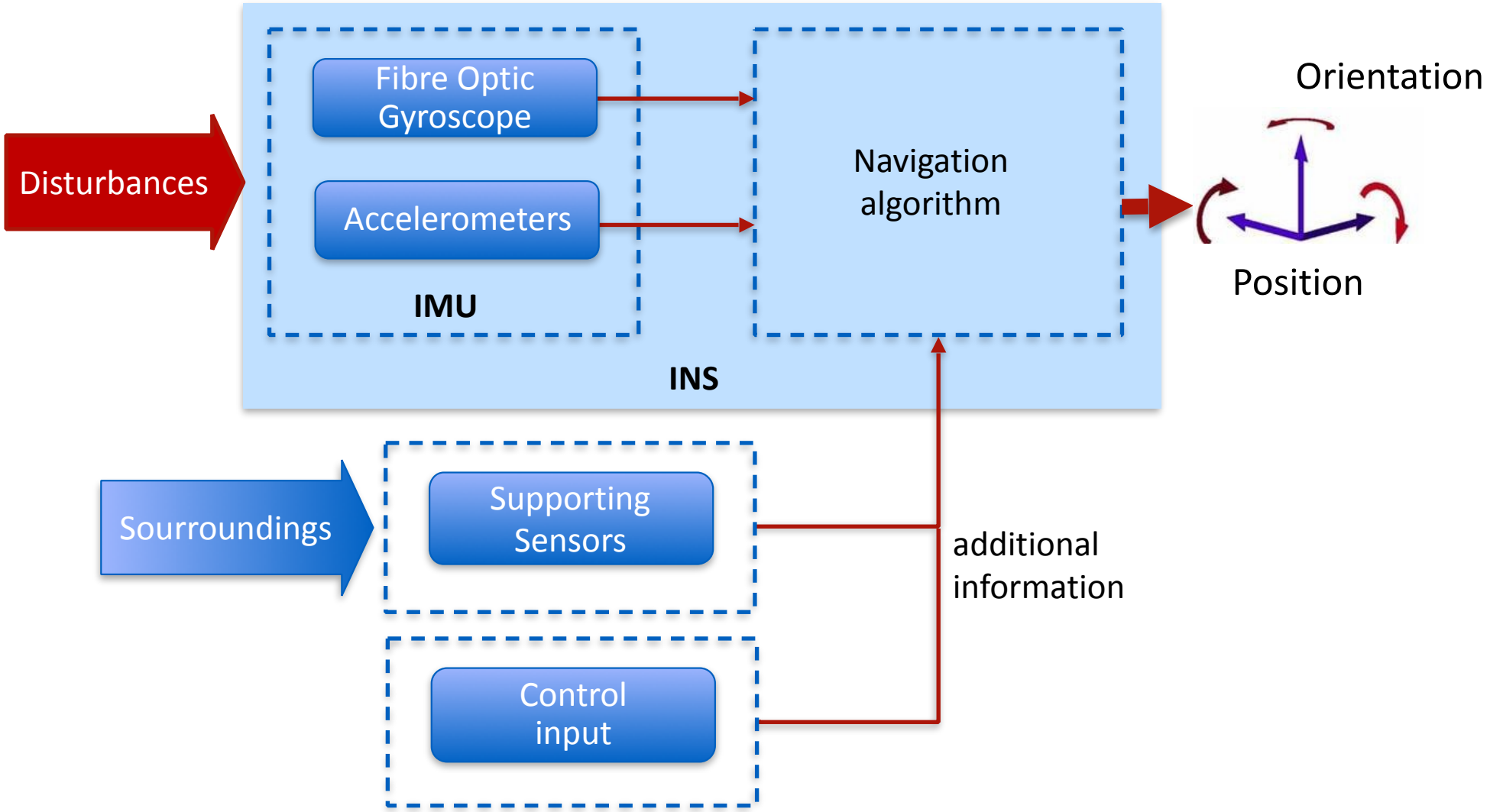
Industrial-grade Sensors

For collision avoidance and navigation

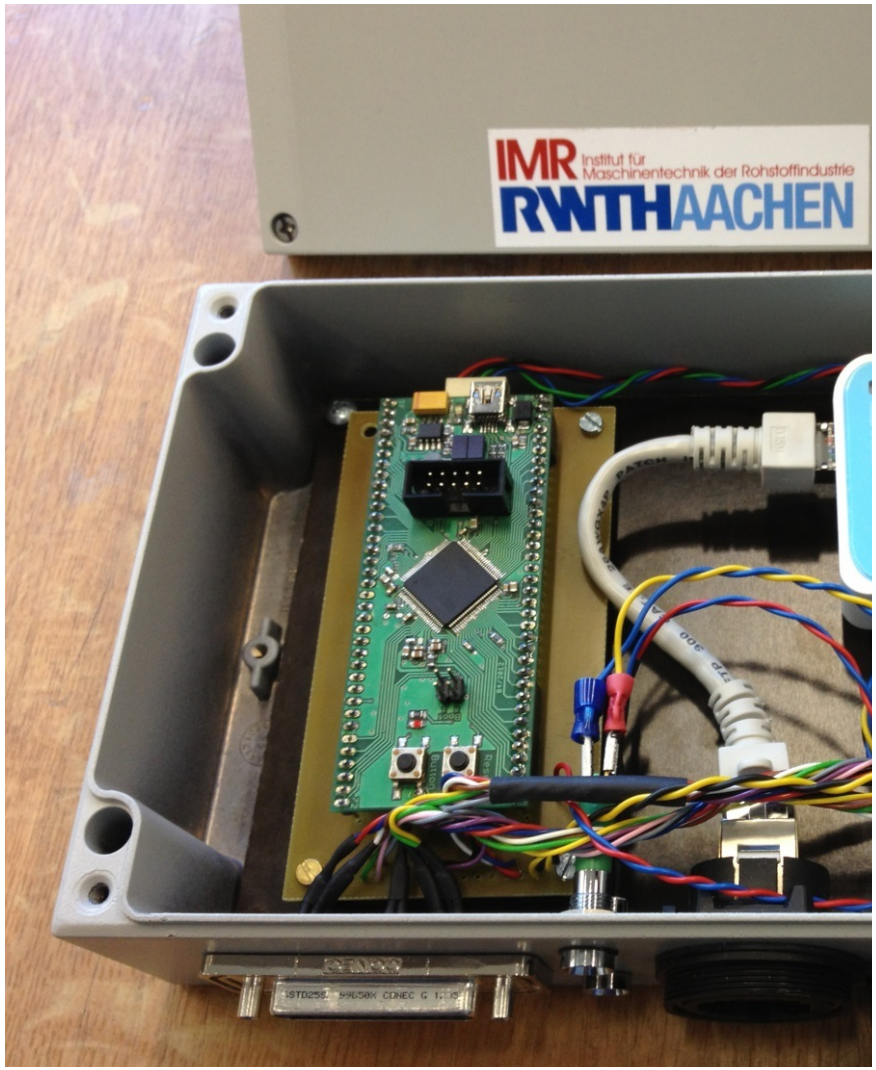
3D	 *IR TOF*	 *UWB*	 *IMU*
2D	 *Laser Scanner*	 *IMR Radar*	 *iDRR* *Dual Range Radar*
1D	 *iLDR* *Linear Dynamic Radar*	 *Encoder*	

Concept

Navigation System

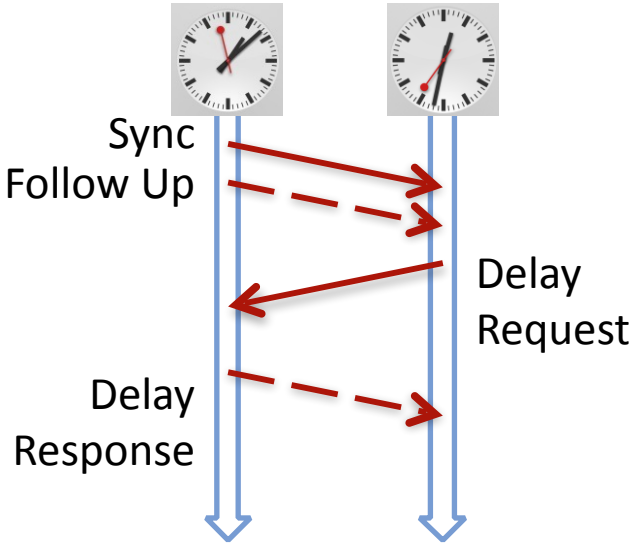


Sensor Interfacing



- Industrial-grade Ethernet
- Unified software interface with TCP/IP
- Sensor data accessible with different user tools, in parallel
- No realtime burden for applications
- Data recording with precise time stamp
- Technology
  - ARM Cortex-M4f (STM32)
  - Embedded Linux for Ethernet

Sensor Synchronization



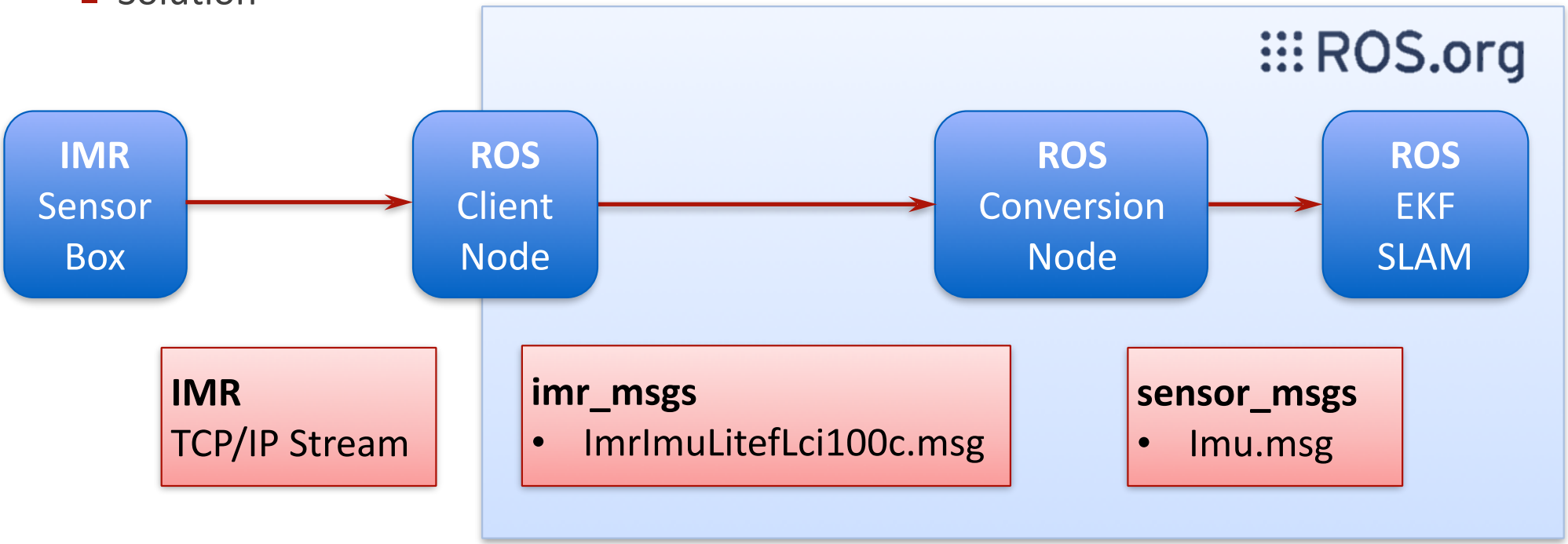
- Problem
  - Heterogeneous mix of time-discrete sensors
  - High data rate (400 Hz, 100 Hz)
  - Proproprietary interfaces and protocols
  - Arbitrarily placed on vehicle
  - Realtime un-capable user software (Windows, Matlab)
- Solution
  - Local clocks
  - Synchronised by Ethernet by micro seconds (PTP)
  - Time stamping of each sensor sample in sensor box

ROS integration

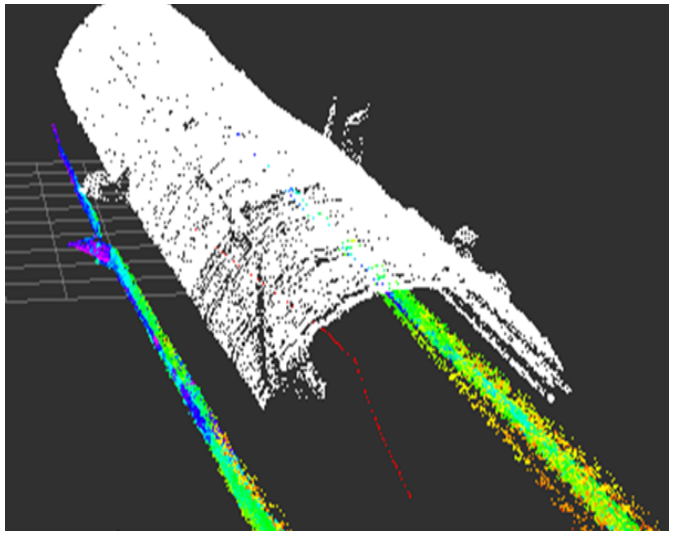
- Without ROS
  - Developing algorithms in Python, Matlab, C++ works well
  - Sensor data available everywhere in research network
    - TCP/IP Server in each sensor box
  - No visualization
  - No data storage, no play back
  - No access to already developed algorithms
- With ROS.org
  - Use rviz
  - ROS bag files
  - Algorithms like navigation stack (SLAM, EKF, ICP from PCL)

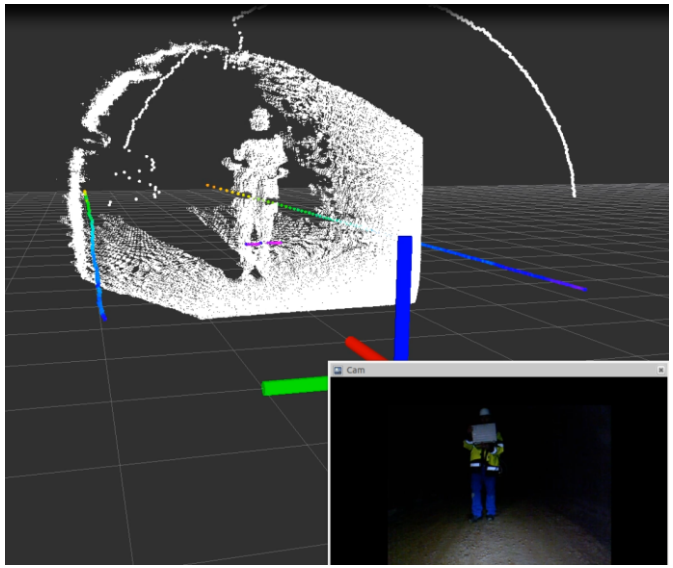
ROS integration

- ROS-ify all sensors and actuators
- Dilemma
  - Our sensors include more data than standard ROS messages
    - e. g. temperature, status flags of IMU
    - Measurements campaigns are expensive and rare
    - Do not discard any data as storage and bandwidth come at no cost
  - Wanted to use standard ROS messages for ROS algorithms
- Solution



Mobile Robotic Test Platform
Results





ROS results

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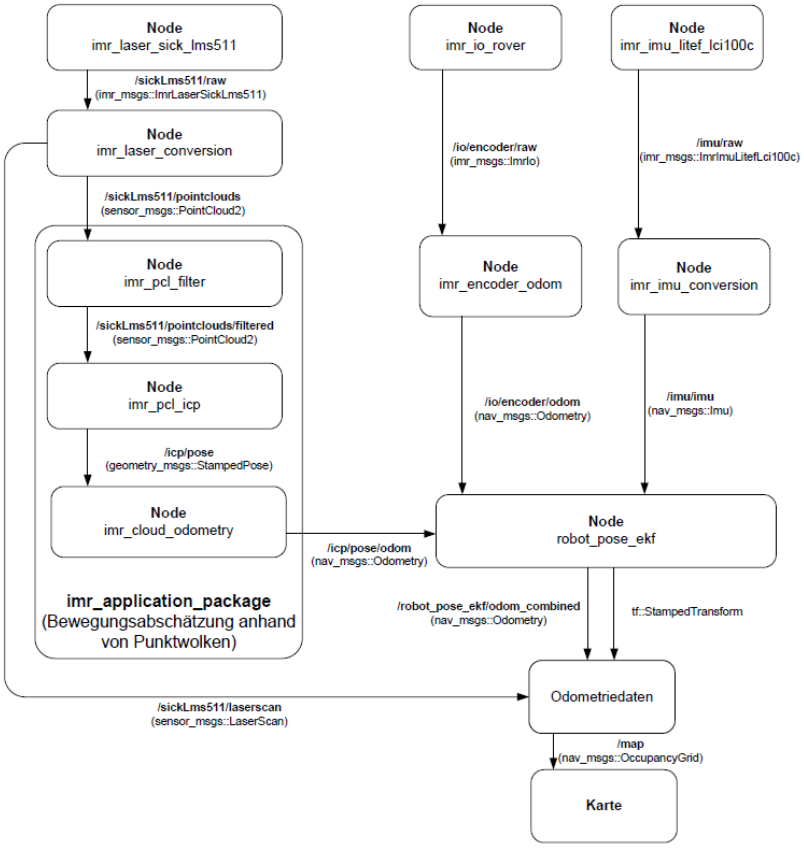
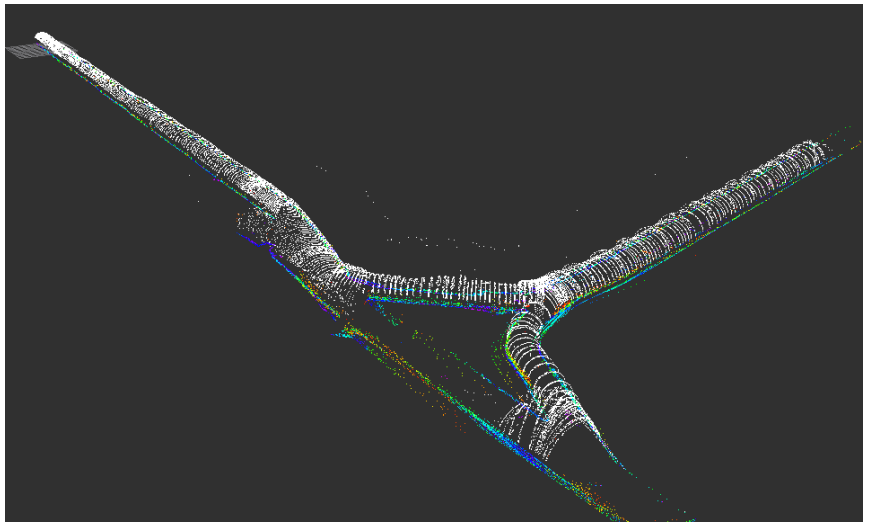
ROS Nodes



SLAM map



ROS Lessons Learned

- Do not change created ROS messages during development
  - This breaks backward compatibility of already recorded data
- Git repository for each node when more than one person is working on the project
  - Use gitslave to provide unified catkin workspace
- Always record visual camera images to interpret data more easily
- Unfortunately not everything always works out of the box
  - Camera
  - Catkin and message generation
  - Need to recompile PCL to support all cameras

Outlook

- Upcoming demonstration phase with industrial partners
  (one year starting next month)
- Project proposals
  - Nationally funded
  - EU-funded (Horizon 2020)
- ROS will play a key role in these projects

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Thank you for your attention!

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