SAP Predictive Maintenance & Service powered by SAP HANA

Selected Co-Innovation Projects

September 2015

Industrial Machinery
& Construction

Predictive Maintenance - Co-Innovation Projects

Defect Pattern Identification

Identification and prioritization of machine failure pattern for product improvement based on business and configuration data

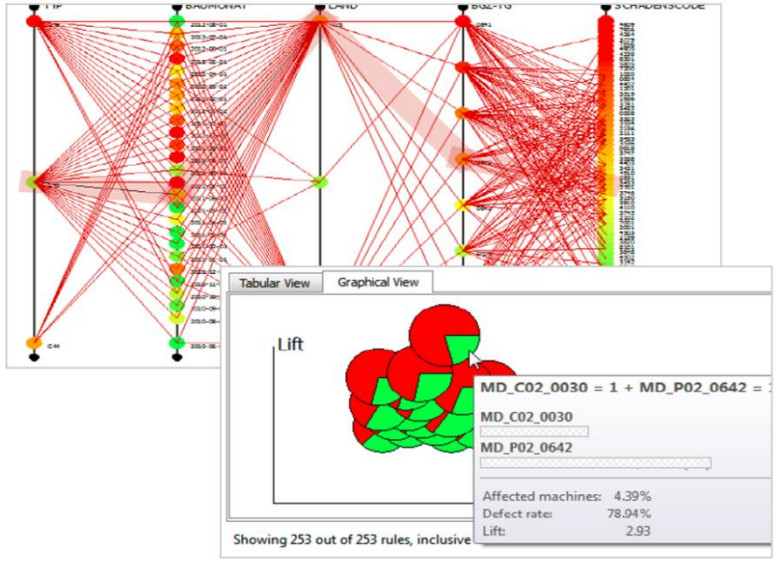
Based on claims / damage reports

Combining

- visualization (parallel coordinates, multi-dimensional scaling) ,
- mapping of expert knowledge into HANA and
- statistical analysis (text clustering, association analysis, decision trees)

  in an iterative approach

Improved product quality at lower costs



- Quick identification of new defect patterns
- Guidance for root cause analysis
- Reduction of manual work in quality management
- Cost reduction & increased customer satisfaction

Aerospace

Predictive Maintenance - Co-Innovation Projects

Systems Trending and Alert Management

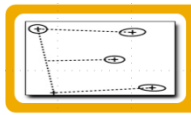
Predicting unscheduled maintenance events based on historical data

With predictive modeling we

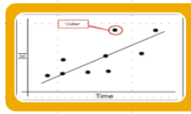
- predict unscheduled maintenance based on engine health data patterns
- detect outliers and anomalies in the data with machine learning, (supervised and unsupervised)
- use text analysis to classify scheduled vs. unscheduled maintenance events

Allows customer support

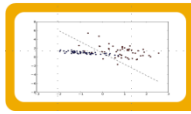
- to propose alternative maintenance schedules which may avoid unplanned downtime,
- to increase aircraft availability and
- to increase service and maintenance revenues



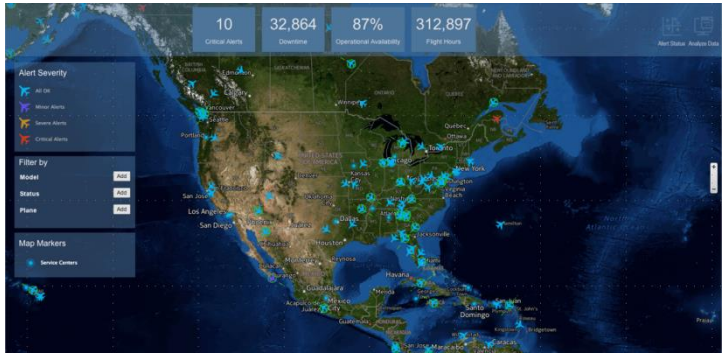
Anomaly Detection
- EHM Data
- Unsupervised Approach



Outlier Detection
- EHM Data
- Supervised Learning Predicting Engine Outputs



Predictive Maintenance
- Both EHM & Maintenance Data
- Supervised Learning Predicting Unscheduled Maintenance Activities



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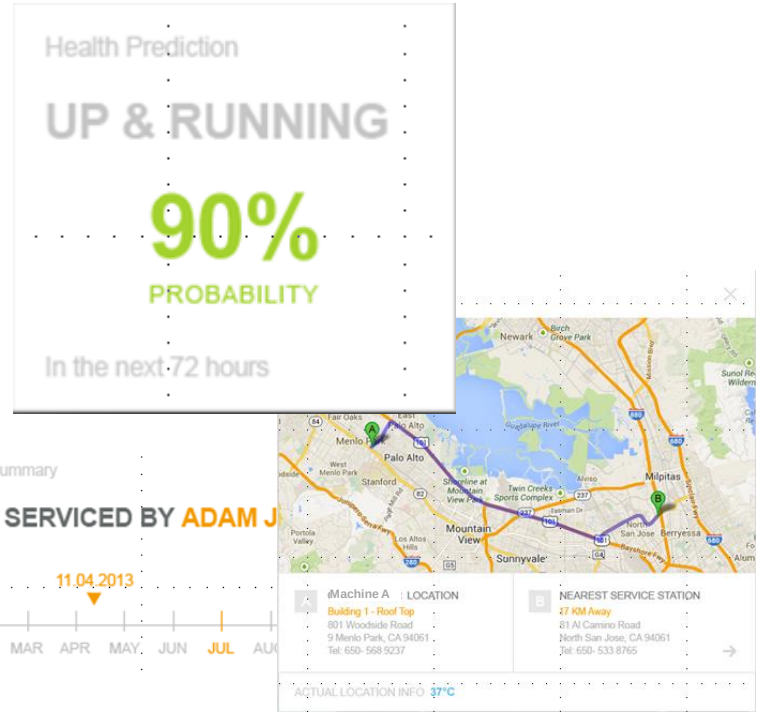
Machine Health Prediction

Enable service, sales and R&D to transform the company to an industrial service provider.

To lower service costs and increase machine up-time

- historic machine data are used to predict breakdowns via **decision trees**
- energy consumption pattern profiles are calculated with **k-means clustering**
- domain expert knowledge was modeled in HANA with **decision tables**
- 360° view on machines was provided with **real-time calculation of KPIs** from ERP and telemetry data



Improved Maintenance by

- better transparency of current condition
- machine health prediction from historic data
- efficient dispatching of field techs, including proactive planning based on predictions

Automotive

Predictive Maintenance - Co-Innovation Projects

Vehicle Health Prediction

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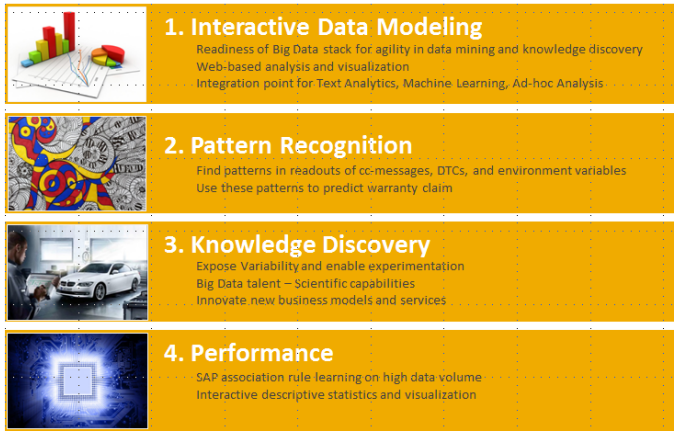
Vehicle health prediction to improve manufacturing quality, service planning and customer satisfaction

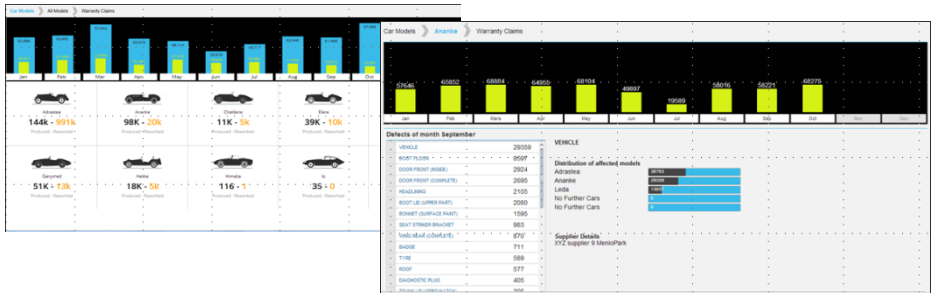
Based on single point of access to all related business and technical information using an in memory database for reporting and predictive analytics

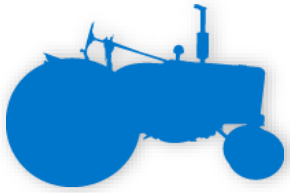
- Integration of SAP HANA and Hadoop
- Used Association rule mining and regression tree learning to correlate production rework and customer satisfaction data
- SAP HANA/R data mining and data visualization capabilities were successfully demonstrated based on surveys and production data sets

Improved prediction of upcoming warranty cases

- with an accuracy of 80% based on vehicle diagnosis and previous warranty claims







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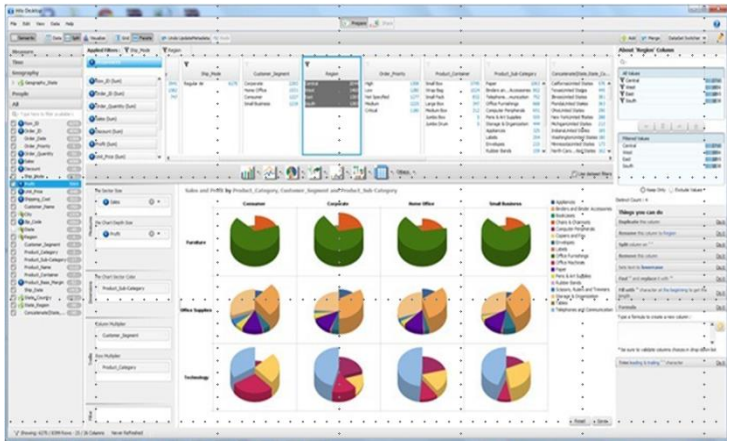
Emerging Issues

Early identification of emerging issues for product improvement and failure prediction to reduce downtime based on business and telemetry data

Based on one single SAP HANA based platform that combines all data that is relevant for emerging issues detection (sensors and warranty)

Analyzing equipment's telematics data, detecting potential issues & relating them to equipment's service and warranty data using text mining, association analysis and HANA database capabilities resulting in shortening the detection-to-correction cycle.



Improvements by emerging issue analysis with root cause analysis

- Quick identification of potentially defective behavior of fleet
- Creation of evidence packages as input to root cause analysis
- Warranty cost reduction & improving the up-time of the equipment

Automotive

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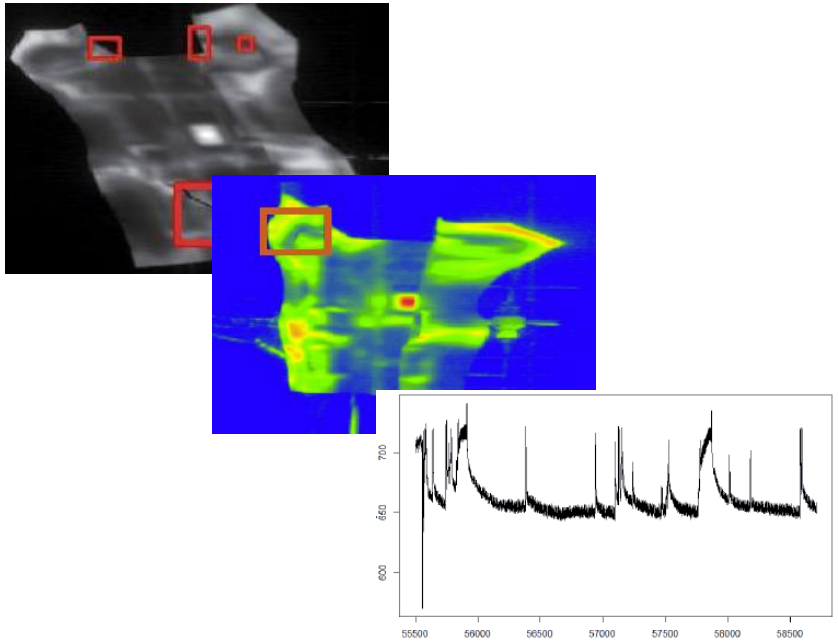
Predictive Quality Assurance

Manufacturing Quality Assurance by automatic failure identification and anticipation based on production machine data

Algorithms for predictive quality assurance in metalworking production processes using image analysis of material via

- visual detection of cracks (image processing techniques)
- heat image comparison of “areas of interest” of sample images of material with issues to current material (euclidean vector distance calculation)



Rapid identification or prediction of production quality issues based on large volumes of sensor data provides a significant business case

- Provided new insights into manufacturing process
- Improved quality control of manufactured parts

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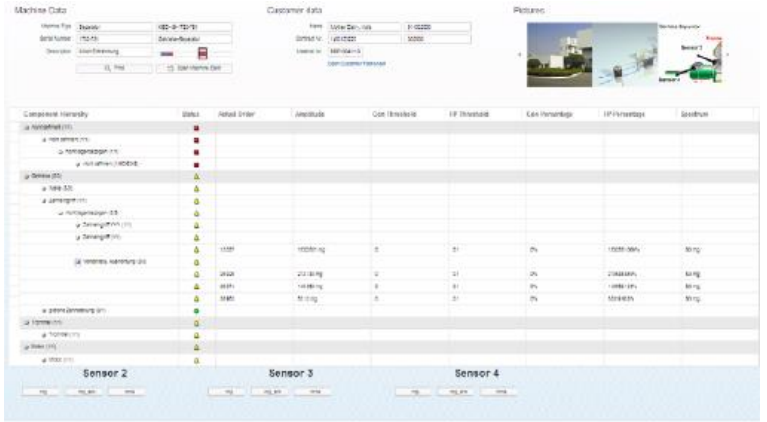
Vibration Analysis

Identification of health finger print based on vibration analysis

Monitoring of machine health using vibration patterns for product improvement based on business and machine data.

- A 360 degree view of a machine by integrating technical machine and business data in a flexible data model in HANA
- Trend analysis on vibration data



Automated vibrations analysis to improve machine utilization and reduction of warranty costs

- Change from manual, reactive vibration analysis process to an automated, proactive process
- 90 % faster vibration analysis as a result of the automated vibration analysis process
- Improvement of machine uptime and reduction of maintenance costs.
- Supporting service technicians by providing information about faulty machine components and defective root causes

Mining

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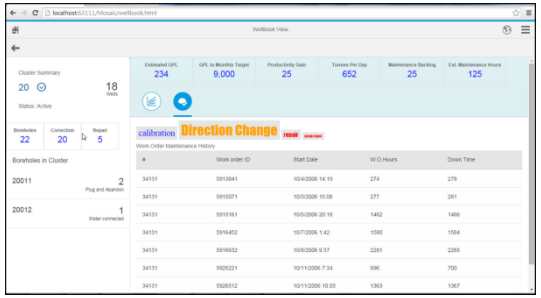
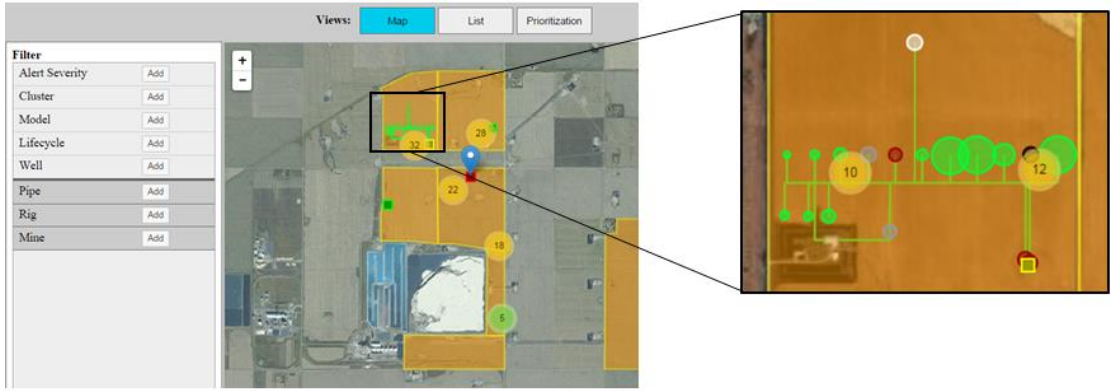
Maintenance Prioritization

Production forecasting, failure prediction and tactical operations analysis



Production forecasting and unscheduled maintenance prediction

- Forecast production and probability of failure calculation at asset level.
- Over 150 assets, 10 years of history and more than 100 potential influencing variables
- Prioritize maintenance activities based on actual and forecasted KPIs



Improved operational planning

- Reducing maintenance rig backlog,
- Increasing average production at plant level,
- Understanding cavity development and operating factors on long term production

Chemicals

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Recurring Failure Pattern

Identification of failure hot spots and recurring failure patterns

The Maintenance Analytics App

Transparency and insights into the hot topics for maintenance, recurring failure pattern and estimation of how much plant availability could potentially be increased by avoiding these issues.

- Transparency is provided by a single point of access to thousands of maintenance notification and billions of machine data readings in an unified repository of IT and OT data. It allows a drill down from the map of the entire manufacturing site down to single parameter readings collected by process control systems.
- Maintenance hot topics are identified by analyzing the failure descriptions provided by service technicians and plant personnel.
- Failure pattern are identified automatically by machine learning for each part of the plant. The key parameters for each pattern are determined and brought to the users attention as a basis of educated decisions. Their potential for to eliminate disturbances and unplanned maintenance actions is calculated.

All content for is machine generated and no manual setup by users is required.

Aerospace

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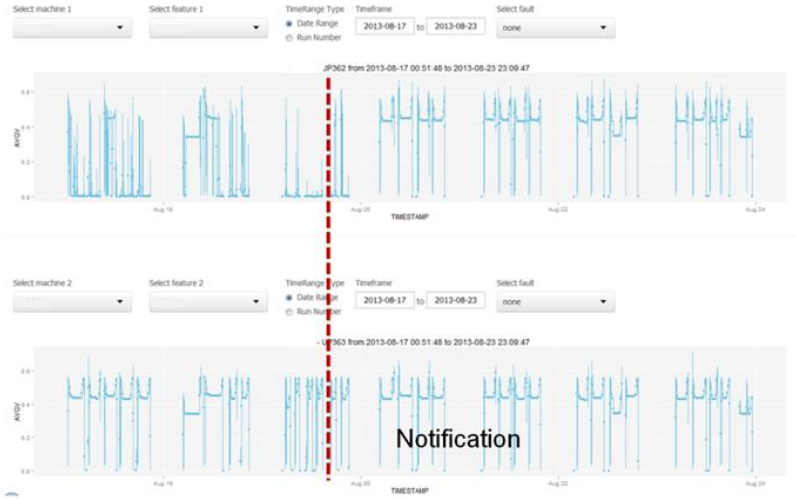
Health Prediction for aircraft components

Reduce cost of maintenance and spare parts stock by failure predictions

Failure predictions via anomaly detection

- 5 aircrafts over 5 years, 400 sensors each aircraft – 44.1 Billion sensor readings
- Correlated with maintenance history (notifications), weather data & geo locations
- Text Analysis to understand maintenance activities
- Use of Statistical Process Control and Symbolic Aggregate Approximation for anomaly detection
- Prediction of maintenance activities with lead time of up-to 7 days



Next-Generation Maintenance Operations

- Reduction of critical aircraft failures (Aircraft-on-ground)
- Minimization of de-central aircraft maintenance
- Optimized spare part sourcing, logistics and stock

Oil & Gas Downstream

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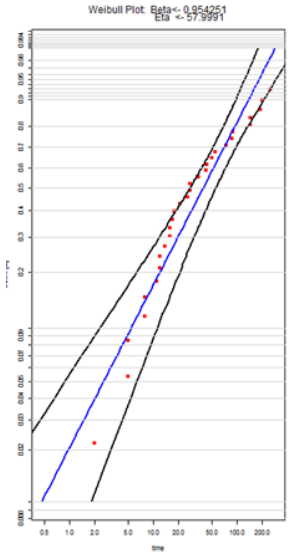
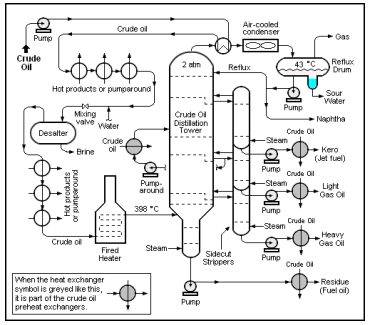
Bad Actor Analytics

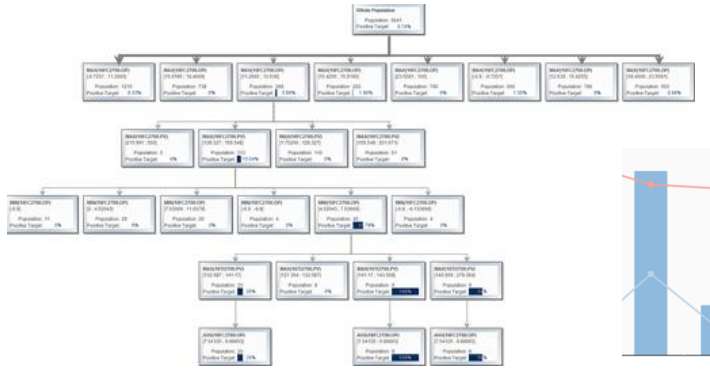
Enhance reliability managers' understanding of what asset failures occur under what conditions, and predict future rotating equipment outages

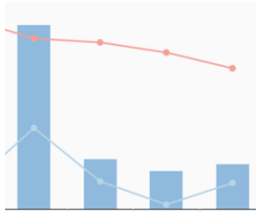


Reliability Manager Reports

- Bad actor pump **reports** based on single set of **interpretation rules**
- **Ranking** pump issues beyond being a bad actor
- Calculate **KPI and cost trends**
- **Weibull** life time analyses
- **Helping maintenance managers** decide which work requests to turn into work orders

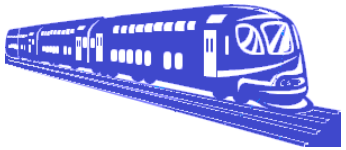






Predict rotating equipment failures

- **Use classification techniques** to identify rotating equipment likely to fail based on past patterns



Railway

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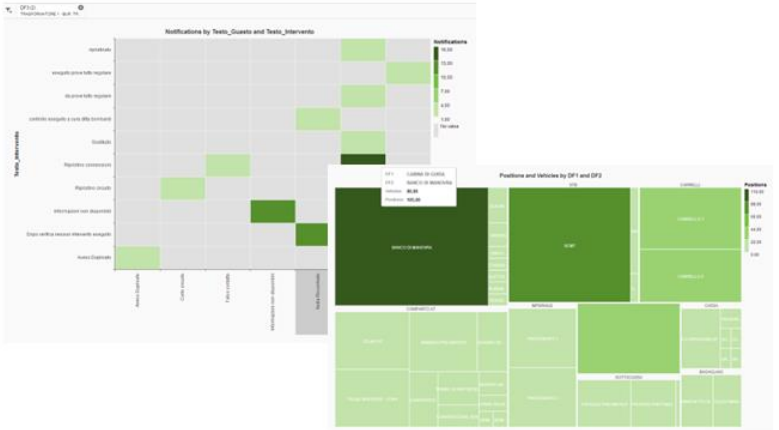
Health Prediction

Health predictions for train components and anomaly detection

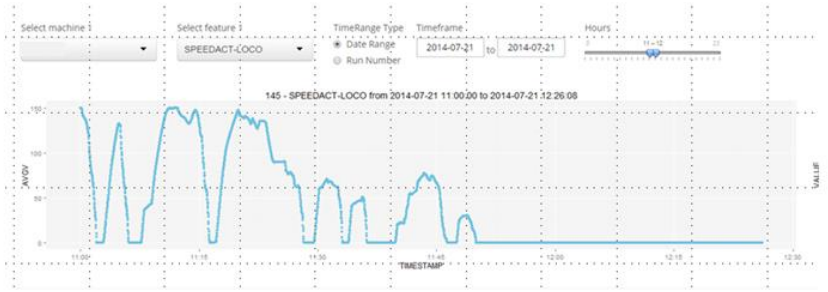
Investigation in signals and patterns

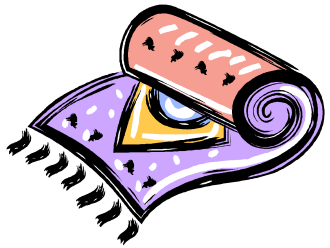
- Identification of anomalies in notifications, events and sensor data
- Focus: Train components with known high risk of failure
- Objective: New prediction based rules to trigger maintenance activities



Health predictions for train components to improve service and spare parts planning

- Reduction of maintenance costs
- Transforming unplanned maintenance to planned maintenance
- Less disruptions in train operations





Flooring manufacturer

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Root Cause Analysis for Quality Issues

Reduce warranty claims by understanding and acting on causal relationships between production machine parameters, production alerts, and claims

Root cause analysis

- Track claims and sold product back to work-in-process product and production settings
- Find causal relationships between claims and production settings from machine readings
- Improve on Statistical Process Control usage
- Learn from cross-data source analytics

Warranty claim impact

- Prevent claim from happening by acting on potentially improvable product during production process

Source: ABC News

Automotive Supplier

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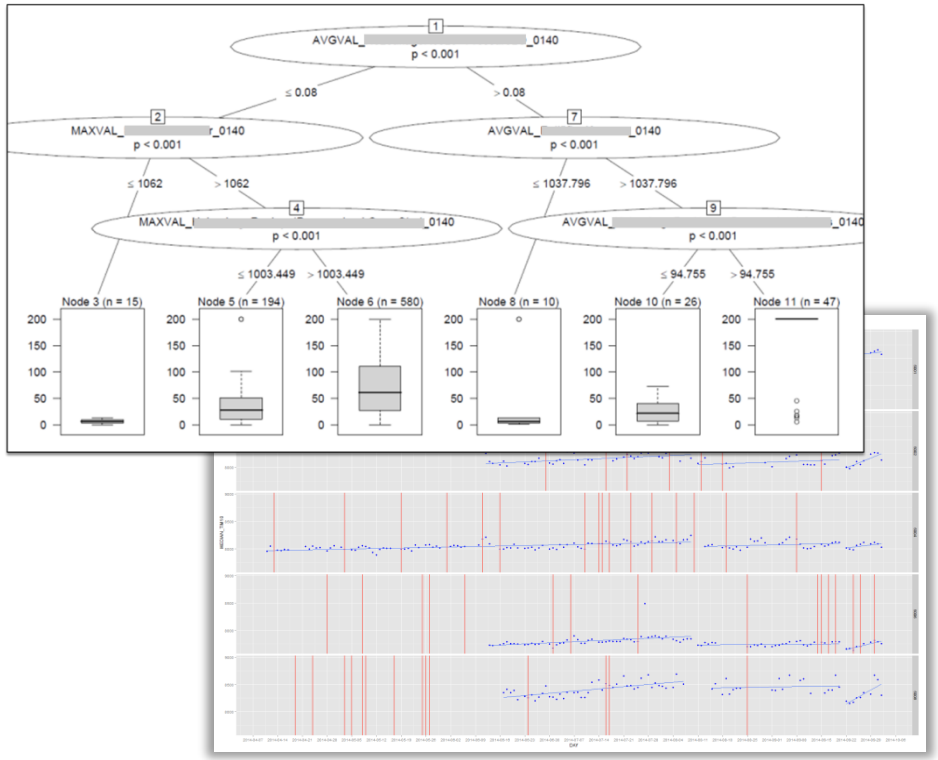
Maximize Machine Efficiency in Production

Increase efficiency of bottleneck production machine to maximize yield at a world leading automotive supplier

Combine supervised machine learning with non-supervised machine learning

- Augmenting (human) expert rules with (machine) rule mining (regression trees)
- Approximating machine state to circumvent "rare event problem" (anomaly detection)
- De-clutter sensor data for root cause analysis (trend analysis)



Transform unplanned downtime into planned maintenance by introducing Predictive Maintenance

- Already high efficiency achieved – *classical* measures exhausted
- Introduction of condition based external maintenance
- Optimize production line maintenance
- Increase value of predictive maintenance by capturing additional data points, e.g. detailed machine state, machine changes

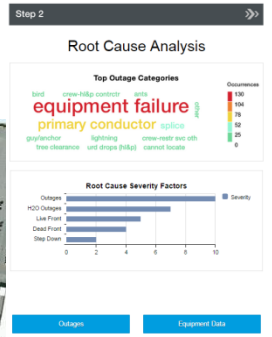
Asset Health Prediction

Utilities

Optimize Operations, Planning and Inventory departments by planned Asset Health maintenance

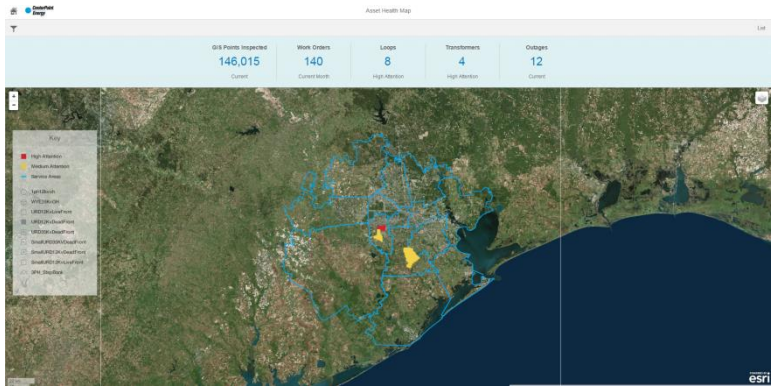
Value Hypothesis

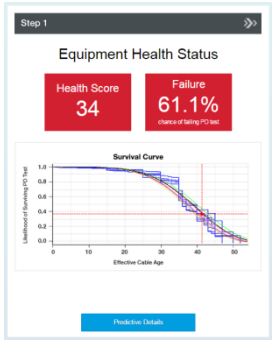
- Optimize testing and crew efficiency based on limited resources
- Optimize capital investment for URD Cables
- Support steady state funding scenarios (“avoid the snowball”)
- Analytics provide relevant factors for asset risk
- Flexible and extendable platform for additional assets classes



Improve Maintenance by

- Better transparency of current condition for proactive and reactive outage management
- Machine health prediction from historic data and outages
- Efficient dispatching of field techs, including proactive planning based on predictions





Industrial Machinery
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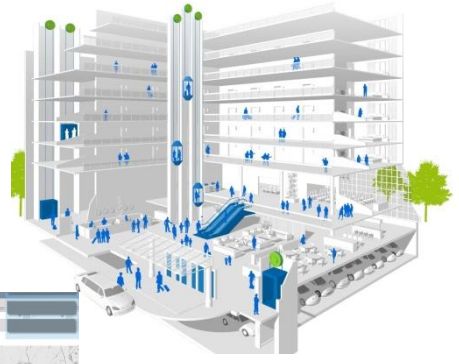
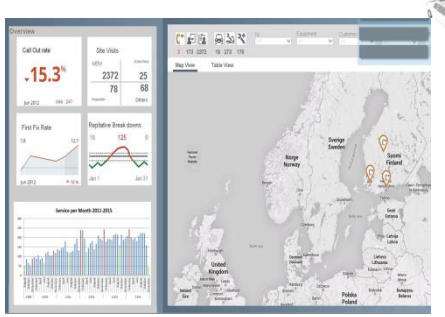
Maintenance planning & Health Prediction

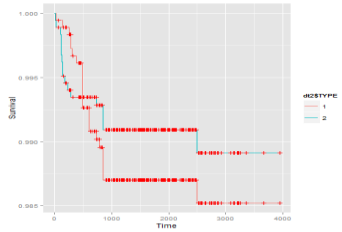
Improve quality and time lines of the maintenance



Prioritization of maintenance service based on part life time analysis & health prediction

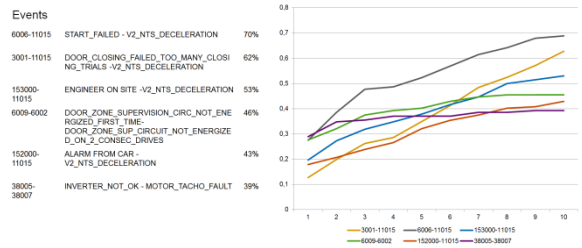
- Fusing several disperse data sources such as Event Data, ERP-Data, call out Information and statistical information to a unified data model
- Part life time and Health Score calculation at asset level
- Prioritize maintenance and service order based on Spare parts and asset Health Score





Improved maintenance planning

- Reduced number of service visits by better transparency of current asset condition
- Optimized and efficient spare part handling & dispatching of field techs including proactive planning based on predictions
- Fulfill the legal requirements of service visit by remote monitoring

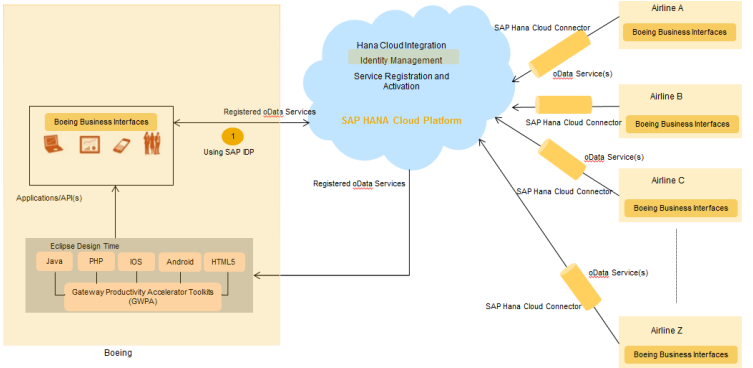


Telematics Data Visualization

Analyze Correlations Between Maintenance Events and Airplane Telematics Data and Connect OEM Business Interfaces with SAP Backend

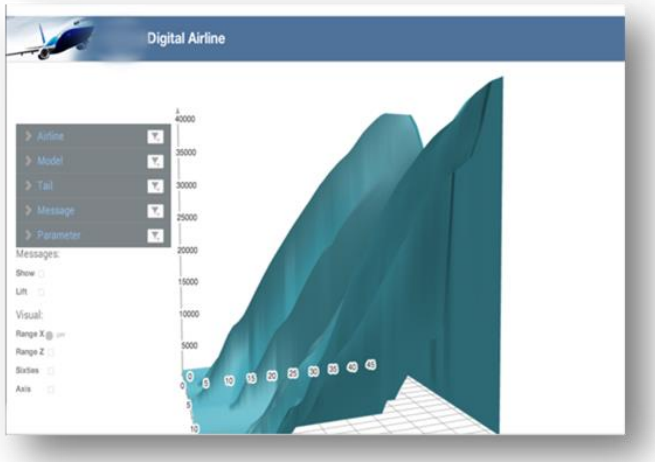
Using State-of-Art 3D Visualization and HANA In-Memory Techniques to Help Engineers and Troubleshooters

- Interactively sift through a large amount of telematics data and visually detect correlations and patterns in historical telematics data
- Integrated OT/IT data ; overlay maintenance data and maintenance events on top of the telematics data and show



Demonstrating end-to-end integration architectureto connect SAP Backend and OEM Maintenance Mobile Applications

- Leveraging HANA Cloud Integration to synchronize business interfaces and SAP MRO Workflows
- Demonstrated performance and scalability required for load-intensive Big Data and mobile applications



Predictive Maintenance and Service

Business Benefits	OEM		Service Provider	Railway		
	R&D	Maintenance Service	Maintenance Services	Maintenance	Procurement	Operation
	"How can I improve my product's reliability?"	*"How can I extend my product offer by additional services?"*	*"How can I provide a competitive service portfolio ?"*	*"How can I provide efficient services ?"*	*"How can I optimize spare parts availability ?"*	*"How can I provide a safe and efficient operation ?*
Increased Asset Utilization				◑		●
Operational Risk Reduction		◑	◑	◑		●
Service Portfolio Optimization		●	●			
Service Cost Reduction		◑	◑	●	◑	
Improved Brand	●	●	●			●

Predictive Maintenance and Service

Key Business Benefits

Owner/Operator Satisfaction
Improved Uptime/On Time
Efficient Machine Usage (asset utilization)
Reduced Cost of Operation
Reduced Energy Consumption
Increase Asset Life
Improved Service
Improved Customer Service Level
Expanded Service Portfolio
Reduced Unplanned Maintenance
Optimized Service Agent Dispatching
Improved Spare Parts Dispatching
Improved Tool Dispatching
Improved Service Information Provisioning

Reduced Service Cost
Reduced Maintenance Costs
Optimize Spare Parts Inventory
Reduced Accrurals
Reduced Warranty Costs
Reduced Operational Risk
Improved Safety
Improve Schedule Adherence
Regulatory Compliance
Improved Brand
Improved Product Image
Improve Product Reliability

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