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<td>0800 - 0830</td>
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<td>Welcome from IHHA / Course Outline</td>
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<td>Course Leader / Manager</td>
<td>Michael Roney</td>
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<td>0830 - 0915</td>
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<td>Subgrade, Drainage, Transitions and Advanced Track Support Analytics</td>
<td>Dr. Hannes Grabe</td>
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<td>Vehicle/Track Interaction and Ballast Maintenance</td>
<td>Rainer Wente</td>
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<td>Key Elements of Track and Bridges for Heavy Haul Operations</td>
<td>Dr. Nigel Peters</td>
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<td>Wheel/Rail Interaction</td>
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<td>1200 - 1245</td>
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<td>Best Practices for Maintaining Rail Integrity</td>
<td>Dr. Richard Stock</td>
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<td>Wheel Maintenance Best Practices</td>
<td>Dr. Robert Frohling</td>
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<td>Wayside Detectors and Rolling Stock Management</td>
<td>Semih Kalay</td>
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<td>Distributed Power, Optimal Long Trains and Control of In-Train Forces</td>
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<td>Driver Assistance to Lower the Stress State and Maintain Schedule and Throughput</td>
<td>Thomas Nordmark</td>
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<td>Service Design and the Integrated Operating Plan</td>
<td>Mark Kirkpatrick</td>
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<td>Health Monitoring of Switches &amp; Crossings</td>
<td>Dr. Rikard Granstrom</td>
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<td>Track Maintenance and Renewal Planning Systems</td>
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<td>Experience of Health Monitoring of Trains</td>
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<td>Road to the World’s First Large Scale Autonomous Freight Operations</td>
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<td>A successful concept for testing of new Technologies – ePilot</td>
<td>Dr. Per-Olof Larsson Kråïk</td>
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<td>Transformative Maintenance Solutions for Railway Assets</td>
<td>Dr. Uday Kumar</td>
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<td>Freight Locomotives 4.0</td>
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<td>Communications Based Train Control</td>
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This lecture concentrates on the function of the subballast layer and the subgrade as part of the entire track structure. Substructure terminology as well as the basic functions of each component will form the basis for the remainder of the presentation. The design of the track substructure layers will be discussed in terms of granular layer thickness design. Subgrade problems and remedial measures will be introduced as well as possible actions for axle load increases. Conventional and more advanced investigation methods and equipment such as Ground Penetrating Radar (GPR) and Continuous Surface Waves (CSW) will be discussed, followed by an introduction to inertial metrology and the use of digital sensors to measure and quantify track performance.

The second part of the lecture focuses on track drainage principles and specific examples of surface and subsurface drains. Geosynthetic products such as geotextiles, geomembranes, geogrids, geocells, geonets and geocomposites will be discussed with specific reference to the contribution that they can make with regard to separation, filtration, drainage and reinforcement. The lecture concludes with the important topic of track transitions and how differential stiffness and settlement are responsible for track component deterioration and vehicle dynamics at transitions. A range of possible solutions from ladder track to ballast reinforcement are proposed, highlighting the benefits of each in terms of differential settlement mitigation.

A brief outline of the lecture is as follows:

- Substructure components & functions
- Substructure investigations
- Substructure failure
- Drainage principles
- Drainage applications
- Track transition examples
- Design challenges
- Design solutions
This lecture concentrates on the function of ballast and its influence on vehicle interaction, track quality, maintenance cycles, sustainability of maintenance and on track cost. The load bearing and load distribution function of the ballast will be explained, also the mechanisms which lead to ballast degradation. Examples of ballast degradation and its influence on track quality will be shown. Next step is how to determine the necessity of ballast rehabilitation. Different methods of ballast rehabilitation will be discussed and how to maintain a good track geometry. Hints will be given how to choose the right machine for certain demands and different track maintenance strategies will be discussed. Finally, life cycle considerations and best practice examples will be presented.

The lecture will cover, sequentially:

- The load transfer function of the track
- Drainage function of ballast
- Degradation of ballast
- Interaction of ballast quality and track quality
- Ballast cleaning/undercutting
- Track geometry
- Sustainability of track maintenance
- Digitalization aspects of track maintenance
- Optimization of track machine application
-
Session 3: Key Elements of track and Bridges for Heavy Haul Operation – Nigel Peters

This presentation will cover matching key components contained within track and bridge structures to the axle load and tonnage demands of heavy haul railway lines. After a brief introduction of the load environment in which heavy haul track and bridges must operate, this presentation will break down the standards for track and structures that have been found to successfully sustain high integrity rail operations in heavy haul railway environments. The presentation will highlight the successful use of the following key components and their standards in line upgrading to match traffic increases and changes in heavy axle loads.

- Bridge components
- Rail selection and metallurgy
- Rail welding
- Ballast and sub ballast type
- Track fastenings
- Sleeper design
- Turnout design

Session 4: Fundamentals of Wheel/Rail Interaction – Kevin Oldknow

Participants will be briefed on the fundamental science that governs the performance of wheel on rail as a system, and its damage mechanisms. The first part will answer the question: What are the Stresses in the Wheel/Rail Interface and What Causes Them?” This will explain how rolling contact fatigue and wear develop on wheels and rails. Examples will be given of how these stresses are calculated and what they mean to yielding and plastic flow of rail and wheel surface layers.

The next part will address “How can we Estimate the Lateral Forces and L/V ratios vehicles are exerting on the Track?” This part will explain how vehicles steer and what impact this has on creepage forces and the damage that is caused. It will then relate how these estimates can be quantified and related to the extent of wear and fatigue and hence wheel and rail life. The presentation concludes with examples of how design and maintenance practices can improve wheel/rail performance.
The lecture will explain the mechanics of rail grinding, how the depth of cut evolves as a function of the contact geometry, applied pressure and the sequence of grinding motor angles. The value of rail grinding will be explained within the context of maintaining rail integrity and extending the life of the rail asset. Best practice will be defined as the practice of preventive rail grinding on tight and prescribed intervals. This practice will be directed to the importance of understanding the root cause of rolling contact fatigue and ensuring that rail grinding addresses the expected crack growth trajectory, while protecting the work hardened zone.

The presentation will review how rail grinding must preserve the transverse conformality of the wheel/rail contact over the life span of the wheel and rail with properly designed “as ground” rail profiles, and covers how this must be adjusted for wide gauge conditions and transposed rails. In the longitudinal plane, it will be explained how grinding reduces dynamic increments to wheel loading from vertical track irregularities such as weld dips and rail corrugations.

Rail metallurgy is another factor that should be considered in a rail grinding strategy. The presentation deals with optimal depth of cuts for different rail metallurgies and track geometries and axle loads and how cyclic metal removal depths relate to the best practice rail grinding cycles. It concludes with an overview of how to plan a productive and effective rail rectification by grinding.

Friction will then be introduced as a factor in both wheel/rail damage and in energy losses. It will be discussed how lubricants provide a protective layer that greatly influences loss of metal at the wheel flange/rail gauge face interface. Then the mechanics of curve negotiation will be reviewed within the context of how lateral forces are affected by friction levels on the top of the rail. Friction management and rail grinding are introduced as complementary maintenance tools that work together to get optimal wheel and rail service lives.

The presentation will outline best practice friction levels that will best balance wheel/rail forces, wear, locomotive traction and train braking. It will then turn to the characteristics that need to be considered in choosing a cost effective rail gauge face lubricant. Given an effective lubricant, the lecture will define best practices for spacing wayside lubricators, what to consider in choosing their track side locations, and what has been determined for best lubricant distribution settings. A parallel approach will be taken to define the characteristics of effective top of rail friction modifiers, and the parameters for 100% effective friction control, such as lubricator spacing and product distribution settings. The lecture will conclude with a review of how maintenance workforces can be organised and equipped to sustain effective friction management.

**Rail Rectification by Grinding and Milling**
- What is rail grinding and milling and how do they work?
- Why it is important to grind rails
- Rail grinding best practice defined
- How rail grinding control of rolling contact fatigue must address the root cause of the cracks
- How to maintain the important work hardened zone of the rail
- The importance of maintaining optimal “as ground” rail profiles
- Controlling vertical track irregularities like rail corrugation or dips at welds
- How grinding must address wide gauge conditions and transposed rail
- Changing rail grinding treatments for premium vs. standard carbon rails
- Recommended preventive grinding metal removal rates
- Optimal cycles for preventive grinding
- Planning an effective grinding program
- The role of rail milling

**Friction Modification**
- Why control friction?
- Lubrication and its role in protecting wheel/rail wear
- The effect of friction on lateral forces
- How grinding and friction control work together to extend rail and wheel life
- Target friction levels
- Characteristics of effective rail gauge face lubricants
- Best practices for rail gauge face lubrication, spacing, location and settings
- Achieving top of rail friction control
- Characteristics of effective top of rail friction modifiers
- Best practices for applying top of rail friction control
- Maintenance organisation to sustain the benefits
- 100% effective friction management
Wheel replacements are a major element of a rolling stock department’s budget. Wheel performance in service, as affected by wheel profiles, wheel impacts, braking and rolling contact fatigue also affects rolling stock and track.

This presentation will start by identifying the mechanisms of wear and fatigue of wheelsets and will then discuss allowable limits that affect wheel performance. It will then cover the aspects of wheel profile design and how design profiles are maintained. Wheel measurement systems will be outlined along with practical best practice examples of how wheel data can be collected and processed to make good decisions on timing of re-truing, replacement, and forecasting of demand on mechanical shop resources.

Finally, the presenter will discuss how wheel truing and replacements cycles can be integrated with the requirements for bearing inspection and replacement, comparing the benefits of time-based vs. condition based maintenance.
The heavy haul railways around the world are increasingly moving toward detector and performance-based rolling stock maintenance to improve efficiency by reducing the cost of maintenance and inspection. Advances in sensors, data collection systems, computer software and communications have enabled the development and deployment of sophisticated, reliable and accurate wagon health monitoring systems capable of automating many train inspection processes; offering opportunities to replace, supplement and enhance the safety and productivity of railway operations. In many instances automated wagon health monitoring systems are capable of examining vehicle performance attributes while in motion, providing additional insight on vehicle behaviour in a dynamic on-track environment.

Currently, the various car health monitoring systems are being used to identify poorly performing cars and bogie components. In the near future, technology will allow for the detector systems to be integrated in order to assess the overall condition of the car and its components and to plan shorter and longer term and proactive maintenance actions. Automated wayside and onboard wagon condition monitoring devices are expected to free wagon inspectors to concentrate on freight wagon repairs to improve productivity of rail operations. As a result, inspection cycles for rolling stock will be extended, and maintenance will be performed when needed.

The detector data management systems store the detector data and provide users with the capability to make predictive, condition-based maintenance decisions rather than having to rely solely on visual inspection. It also makes data available to a wider range of stakeholders than possible before. This means that wagon owners, who did not previously have access to inspection data, can (given railroad permission and a password to access the data) manage their assets remotely. These databases use a variety of automated equipment identification systems located at detector sites to determine vehicle location, direction of operation, and load condition. This information is then utilized to determine optimal maintenance locations.

This presentation will answer the following questions:

- How is the data from vehicle health monitoring systems used to manage rolling stock maintenance? Various real-world examples of how the railroads are using detector data to manage the inspection and maintenance of their rolling stock.
- How do I identify out-of-round wheels and wheel surface defects using wayside detector systems?
- How can I identify overload and imbalanced loading in wagons?
- What type of technology is available to detect poorly performing wagon bogies?
- How can I use wayside temperature detectors to determine brake effectiveness?
- How do automated wheel profile and brake pad measurement systems work?
- How can I identify defective axle bearings defects long before they cause overheating?
- Are there any technologies available to inspect wheel internal and surface defects?
- What are the latest developments in machine vision systems to determine a railcar’s safety?
Session 8: Distributed Power, Optimal Long Trains and Control of In-Train Forces – Michael Roney

This presentation will start with a comparison of train lengths that are used on the heavy haul railways around the world. Participants will be briefed on the benefits and operational challenges of longer trains, differentiating between single and double track situations, and in dedicated and mixed freight environments. The lecture will then illustrate the impact of train length on longitudinal forces, dynamic transients in the train and lateral curving forces, and how these are influenced by the positioning of distributed locomotive power, and driver assist systems.

The third part of the presentation will outline marshalling rules used in making up longer trains that make them more productive and less destructive. Finally, the presenter will review how communications-based train control and autonomous driverless trains may reshape the optimisation function on train length, as tighter headways become possible as alternate means of raising capacity.

Session 9: Driver Assistance to Lower the Stress State and Maintain Schedule and Throughput – Thomas Nordmark

This presentation will trace the evolution of technologies that provide driver-assistance. It will cover the functioning of sensors and systems that can assist train drivers to:

- Maintain trains to the schedule
- Conserve energy consumption
- Reduce in-train forces
- Anticipate and pace trains to meets or service disruptions
- Reduce the risk of broken rails from wheel impacts

The presenter will discuss how each of the above driver assistance systems improves safety and service reliability and how they may play a role in autonomous train operations.
Session 10: Service Design and the Integrated Operating Plan – Mark Kirkpatrick

This presentation will lay the context for how train operations can be scheduled and run with precision, using the central driver of the integrated operating plan. The presenter will address the following questions on an experiential, rather than an academic basis:

- What are the key features of Service Design in developing an integrated operating plan?
- What options does a service design team have to improve the logistics of a working operation?
- What are the typical costs for consideration for a service design team?
- What are key metrics for measuring the success of an integrated operating plan?

The lecture will conclude with a couple of case studies from actual railways that will illustrate their applications, and the metrics that drive their operating plans.

Session 11: Health Monitoring of Switches and Crossings – Arne Nissen

Switches and crossings are both higher maintenance components of railway track, and are also locations of higher risk, and potential service disruptions. This presentation will discuss how switches have traditionally been inspected, noting the key inspection points of their wear and subsequent performance.

In recent times, new technologies have become available that can provide real time monitoring of power switches. Sensors can measure and report on their throw force and information related to the time required to complete a cycle. This information reveals potential issues with the operation of a switch. When the measured current draw starts to move outside of the prescribed envelope, this would prompt an inspection, and possible adjustment of the switch mechanism, throws or switch point support weekly.

The presentation will discuss how technologies can supplement manual inspections of switches, including the use of machine vision systems.
Session 12: Track Maintenance and Renewal Systems – Michael Roney

The presentation will introduce, at a high level, how track quality and service condition can be quantified, trended and projected to guide assessment of its performance vs. service demands, and the timing for maintenance and replacement interventions. For the rail asset, this will cover best practice in tracking rail defect trending and projection of rail wear, and will discuss how limits are set of allowable wear and rail defect levels to determine the optimal time for rail renewal. Rail sleeper condition distributions will be discussed against the context of determining a multi-year plan for sleeper replacement. Track quality indices will be illustrated as key drivers for scheduling tamping and lining operations, and it will be shown how this can be related to assessing ballast cleaning and renewal programs. The lecture concludes with the analysis of track maintenance needs will conclude with notes on how risk assessment can be an overlay to the multi-year maintenance plan, and how the effectiveness of past maintenance actions can be assessed and incorporated into continuous improvement of track maintenance planning.

The lecture will illustrate the following analyses in support of track maintenance management:

- The value of forecasting track component condition and quality
- Projecting rail defect rates
- Projecting rail wear
- Setting limits on rail wear and fatigue
- Determining optimal timing for rail replacement
- Projecting sleeper replacements
- Planning when to do tamping and ballasting
- Accounting for risk in planning track programs
- Evaluating maintenance effectiveness
- Recommended preventive grinding metal removal rates and cycles

Session 13: Experience of Health Monitoring of Trains –LKAB

This lecture will present a holistic view of giving a trainset a clean bill of health through the combined use of manual inspections and both onboard and wayside monitors. The session will provide a practical account on how health monitoring systems integrate with the planned maintenance and availability of trainsets to reach tonnage throughput requirements. This leads to decisions on the optimal timing to schedule programmed maintenance for trainsets and the benefits of taking full trainsets out of service for planned work vs. condition-based wagon maintenance. Examples of maintenance “rules engines” will be presented. Key inspection points and reliability-centred maintenance of this componentry will be covered as best practice guidance.
Session 14: Road to the World’s Large Scale Autonomous Freight Operations Train Operations – Rio Tinto

This presentation will take participants through the pioneering steps that were followed at Rio Tinto in the Australian Pilbara to successfully commence AutoHaul©. Participants will learn how conventional diesel electric locomotives were retrofitted to support autonomous train operations that have involved full integration with communications-based train control and use of LIDAR technology to detect potential hazards. The presentation will trace the benchmarks which led to decisions to launch automated trains, first with drivers overseeing the train operation and then fully autonomous train starts. Participants will be briefed on the important role of advanced communications capabilities to support autonomous trains and the range of new skillsets that have been required of employees.

Finally, the presentation will discuss benefits of autonomous trains for Rio Tinto, including impacts on train cycle times and their variances.

Session 15: A Successful Concept for Testing of New Technologies – ePilot - Per-Olaf Larsson Kraik

New technologies are emerging. The Industry 4.0 concept is transforming heavy haul maintenance and operations. This will influence and change how we do things. Increased digitalization has led to greater information transparency, and the railway industry has taken a more holistic approach when it comes to collaborative information logistics. Hence, there is a need to identify why good 4.0 ideas stop at good ideas and not evolve into good praxis in the railway industry.

In Sweden, the collaboration platform ePilot, has shown that it is possible to evolve 4.0 concepts and aid successful transfer of new technologies in the railway business. The collaboration platform involves different stakeholders, i.e. research and development (Academia), Infrastructure Managers, Railway Operators, Maintenance Contractors, Suppliers and Consultants.

ePilot aims to get all above stakeholders to jointly improve maintenance of the railway system through enabling context-based condition-based maintenance.
In the past, many railway assets were overdesigned and underutilized making the need for effective and optimized maintenance planning non-existent. With passing years, many of these assets (infrastructure and rolling stocks) are getting old and at the same time their utilization has increased. The major challenge is to find the time slot to perform maintenance on the infrastructure and rolling stocks to maintain its functionality and ensure safe train operation. These challenges have led to the search for innovative maintenance solutions and deployment of new and emerging technologies to facilitate the use of predictive maintenance strategy as and when it is economically and technologically viable. So far, railways have been dealing with standard technologies and tools required to run the railway in an effective and efficient way. These technologies can be broadly classified as supporting and optimizing technologies and collectively provide the foundation for the predictive technologies that are used for the estimation of the remaining useful life (RUL) using condition monitoring tools and technologies, RAMS (reliability, and maintainability and safety) modelling, LCC analysis, etc. to arrive at the correct maintenance decision.

The on-going digitalization of railway asset condition (infrastructure and rolling stocks) provides enormous capabilities for the sector to collect vast amount of data and information (i.e. Industrial Big Data), from the railway assets in operation. Gradually, the railway sector is adapting and adopting operation and maintenance practices aligned to big data scenarios.

Railway systems have complex technologies, with a wide range of standard maintenance solutions and organization forms. During the last few years, the focus has been to find transformative maintenance technology and business solutions for these assets which will ensure safe and failure free train operations at the lowest possible maintenance cost. Such solutions should make mature railway assets highly utilized with almost no risks. This real time data driven approach railway operations is expected to transform the way railway assets are operated and maintained, ensuring increased reliability and quality of service, increased capacity and reduced life cycle costs for the asset. To get useful information out of high volumes of data generated by railway assets, advanced tools are developed and implemented so that data can be systematically processed into information and facilitate decision making with more information.

These technologies, such as Virtual Reality (VR), Augmented Reality(AR), Big data analytics (predictive and prescriptive analytics), industrial Internet of Things(IoT), 5G communication technologies that offer near perfect solutions (even in real time) for the maintenance of the aging railway assets, are collectively termed as transformative technologies. Such transformative technologies are expected to facilitate correct decisions and actions at the lowest possible cost using the power of predictive and prescriptive analytics by the railway managers. Such solutions are expected to support railway’s digital transformation journey and operations goals. The presentation will be centered on the capability of enabling technologies that will facilitate development of transformative technologies for the effective maintenance of railway assets using the power of predictive and prescriptive analytics.