WP2: Enhanced Switches & Crossings
WP2 Partners
WP2 Objectives

- TD3.1 ‘Enhanced Switch & Crossing System’
- to improve the operational performance of existing S&C designs through the delivery of new S&C sub-systems with enhanced RAMS, LCC, sensing and monitoring capabilities, self-adjustment, noise and vibration performance, interoperability and modularity
WP2 Focus

- Task 2.1: Identifying and understanding core S&C issues [TRL 6]
- Task 2.2: Enhanced S&C whole system analysis, design and virtual validation [TRL 5]
- Task 2.3: Enhanced monitoring, operation, control and maintenance of S&C [TRL 4]
WP2: Key Areas of Research

- Improved knowledge of key areas
- Whole system modelling approach
- Improved design and manufacturing
- Enhanced operational abilities
Improved Knowledge of Key Areas (D2.1)
Improved Knowledge of Key Areas

SWITCH PANEL
- Distance Blocks
- Heel Blocks
- Supplementary Drive System (May include supplementary detectors)
- Points Operating Equipment (Actuation, Lock & Detection)
- Switch Rail
- Slide Baseplate
- Stretcher Bar
- Stock Rail
- Pads

CLOSURE PANEL
- Heel Plates
- Bearer Joints
- Bearer

CROSSING PANEL
- Crossing (Frog) Unit
- Baseplate
- Check Rail
- Pads
- Clips
- Screws

Ballast / Formation / Sub - Structure
FMEA Scope

SWITCH PANEL CLOSURE PANEL CROSSING PANEL

Points Operating Equipment (Actuation, Lock & Detection)

Bearer

Stretcher Bar Stock Rail Pads

Switch Rail Slide Baseplate

Bearer Joints Heel Plates

Check Rail Pads

Bearer

BASE PLATE PADS

BEAVER JOINTS

BALLAST FORMATION PREPARED SUBGRADE SUBGRADE SUB-STRUCTURE

RAIL FASTENINGS (SCREWS/ CLIPS/ RAIL PADS)

BASE PLATES/ INCLINED WEDGE CHECK RAIL SUPPORT BASE PLATES

CROSSING (FROG) UNIT

CLOSURE RAILS

EXTENDED CHECK RAILS (OPTIONAL)

CHECK RAILS

TOOL RAILS

RAIL JOINTS WELDED/ FISH PLATED/ TEMPORARY

Bearer

Baseplate Pads Clips Screws Check Rail

Check Rail Support Base Plates

BASE PLATE PADS

BEAVER JOINTS

BALLAST FORMATION PREPARED SUBGRADE SUBGRADE

SUB-STRUCTURE

(May include supplementary detectors)
Failure Mode Prioritisation Process

- S&C Functions
- Potential Failure Modes
- Potential Root Causes
- Potential Effects of Failure
- Existing Controls
- Detectability

- Severity (S)
- Criticality (C) (F x S)
- Frequency / Likelihood (F)

- Identified Prioritised Areas for Improvement
- European FMECA

- S&C Failure Mode Catalogue

- (F x S)
Prioritised Areas for Research

SWITCH PANEL
- Points Operating Equipment
- (Actuation, Lock & Detection)
- Supplementary Drive System
  (May include supplementary detectors)
- Bearer Slide Baseplate
- Heel Blocks
- Distance Blocks

CROSSING PANEL
- Crossing (Frog) Unit
- Baseplate Pads Clips Screws
- Check Rail Pads
- Bearer Joints Heel Plates
- Check Rail Support

Ballast / Formation / Sub - Structure
Focus of WP2 Research

• elimination of failures relating to rail deformation, fatigue, wear and Rolling Contact Fatigue, including monitoring and assessment of the switch rail profile
• optimised support stiffness / track elasticity
• monitoring and self-adjusting capability
Whole S&C System Modelling (D2.2)
S&C Whole System Modelling

Integrated **whole track system model** approach for design, optimization and certification / authorization of track concepts and components.
S&C Whole System Modelling

- vehicle properties
  - vehicle types
  - load spectrum
  - velocities

- track properties
  - track geometry
  - rail profile geometry
  - material properties

- vehicle track interaction
  - contact forces
  - contact position

- track structure
  - ballast settlement model
  - sleeper model
  - rail pad model
  - rail fastening model
  - rail damage model
  - rail wear model

- other subsystems
  - point operating equip.

- global/local results:
  - RCF-damage
  - change of...
  - material condition
  - rail profile geometry
  - track geometry
  - track stiffness
Switch Performance

- Scientific assessment of the performance of four switch families
- Identification of switch-stock interface design effects
- Proposal for a design methodology
Crossing Fatigue Evaluation

- 3D numerical protocol to evaluate crossing fatigue performance
- Protocol validated by field measurements

Fatigue calculation results vs cracked crossing
Whole System Modelling Developments

- **Simulation of accumulated plastic rail damage for longer periods of traffic**
- **Greater flexibility in S&C assessment via a script that can generate turnout simulation models for a wide range of configurations and designs**

Whole system modelling scheme

Parameterised flexible turnout structure in MBS code SIMPACK

Parameterised track layout in Matlab

Simulated plastic deformation for a crossing nose section after 150 load sequences corresponding to an accumulated load of 0.8 MGT. The material is R350HT.
S&C Whole System Model Approach Applied to RCF Damage Assessment

• “S&C whole system model” approach for RCF damage in crossing panel, combining MBS and “wedge” model

• Results showing the applicability of the “whole system model” approach and the feasibility of the applied RCF damage assessment with the “wedge” model

RCF damage distribution in crossing panel

Accumulated normalised RCF damage distribution calculated with the “wedge” model at the crossing panel with the views of the wheel position derived from the SIMPACK simulation
S&C Substructure Interaction

- Review of S&C substructure interaction carried out and testing to investigate the performance of different S&C jointed bearer designs
- A numerical tool has been modified and used to simulate bearer/substructure interaction

1. Field measurements from the literature show the asymmetric behaviour of long S&C bearers
2. A testing apparatus has been modified for long bearer testing
3. An existing numerical tool has been used to simulate different bearer properties and their influence on substructure interaction under idealised conditions
S&C Substructure Interaction

Distribution of permanent deflections along bearer length at 1M load cycles

Distribution of resilient deflections along bearer length at 1 M load cycles

General testing arrangement:
(on 300 mm bed of ballast, loads applied as 20 Tonne equivalent axle load evenly distributed onto the rails)
S&C Bearer Modelling Requirements

Wheel/rail loading. Rails and fastenings of known properties and locations

Joint of known properties

Mainline rails

Crossing rails

Mainline rails

Response of Substructure (ballast and subgrade) modelled at least below railseats:

- Load and/or strain dependent accumulation of plastic settlement
- Cycle dependent (taking account of loading history) cyclic plastic settlement increments
- Load dependent resilient (recoverable) response
- Cycle dependent (taking account of loading history) cyclic resilient response

Long bearer of known properties modelled to determine load transfer as function of location along bearer
Example: Wheel Passing Over Turnout Common Crossing
Enhanced Design, Manufacturing and Materials (D2.2)
Enhanced Design, Manufacturing and Materials

Key outcomes

• High-grade rail steels
• Modular Continuous Support for S&C
• Additive manufacturing techniques
Enhanced Design: Steel Grades Used in Turnouts

State-of-the-art steels for turnouts

Testing of enhanced steels for the crossing panel and the switch blade

Specifying optimum material characteristics, negating existing manufacturing constraints

R400HT wing rails with minimal wear and no fatigue damage (31.6MGT)

Existing standard rail steels

R260/R350HT

New, high-performance steels

R400HT  HP335  B360
Modular Continuous Support

Further detailed development of the Modular Continuous Support (MCS) - based on the fastening system L-Track system developed under Capacity 4 Rail - including outline design of complete turnout and enhancements to adjustable track

Hydraulic actuators during the static test
Additive Manufacturing

- Poor bending fatigue performance in foot
- Reasonable wear performance in contact patch

Components:
- Manganese Crossing
- Baseplate
- Bearer
Additive Manufacturing

Tri-metallic weld failures
Additive Manufacturing

- Manganese clad
- New substrate
- As existing / improved wear performance
- Improved fatigue performance
## Additive Manufacturing

### Arc-Welding

- Practical study
- Wheel-transfer area geometry
- Manganese clad

### Laser Powder

- Practical and computational study
- Small-scale twin-disc testing
- Stainless Steel clad
Metal active gas (MAG) welding process with manganese steel filler wire as a feed stock on a high strength carbon steel substrate.

Mechanical testing undertaken according to EN 15689 (Cast AMS crossings)

With the exception of the impact toughness, the overall as deposited weld quality was acceptable to EN 15689 standard. Weld deposit hardness exceeded the minimum values specified by EN 15689
Additive Manufacturing

Additive manufacture using Laser Cladding was investigated for reduction of wear and fatigue damage in S&C surfaces. Laboratory tests showed:

- Wear life was greatly improved.
- Bend testing demonstrated cladding integrity.

Modelling to predict the needs for scale-up to full component demonstration showed:

- The need for thicker coatings.
- The importance of achieving a very high integrity at the cladding to substrate interface to avoid internal defect growth.

Clad (top, white) to substrate (bottom, grain structure) fully bonded interface.

Laser cladding additive manufacture process.

Plastic damage prediction with/without cladding.
Enhanced Monitoring, Operation, Control and Maintenance of S&C (D2.3)
Enhanced Monitoring, Operation, Control and Maintenance of S&C

Key outcomes

• S&C sensor system specification and demonstrator
• EMI method of crack detection
• Self-adjusting S&C
SWITCH PANEL

CLOSURE PANEL

CROSSING PANEL

Stretcher Bar

Points Operating Equipment (Actuation, Lock & Detection)

Stock Rail

Switch Rail

Bear Joints

Distance Blocks

Heel Blocks

Heel Plates

Bearer

Supplementary Drive System (May include supplementary detectors)

Bearer Pads

Clips

Screws

Check Rail

Baseplate

Support

EMI Crack Detection

Self-Adjusting S&C

S&C Sensor System
**SWITCH PANEL**
- Distance Blocks
- Heel Blocks

**CLOSURE PANEL**
- Supplementary Drive System (May include supplementary detectors)
- Heel Plates
- Bearer Joints

**CROSSING PANEL**
- Points Operating Equipment (Actuation, Lock & Detection)
- Bearer

**S&C Sensor System**
- Check Rail
- Check Rail Support
- Baseplate
- Pads
- Clips
- Screws

**Key Components**
- Stretcher Bar
- Stock Rail
- Slide Baseplate
- Switch Rail
- Bearer Plate
- Heel Blocks
- Baseplate Pads
- Clips
- Screws
S&C Sensor System Specification, Design and Demonstrator

Sensor types and metrics ➔ System specification (communications) TRL4 demonstrator ➔ Integrated technology demonstrator
S&C Sensor System Specification, Design and Demonstrator

- **EtherCAT** hub
  - Accurate time sync (<1µs)
  - Each segment can be up to 100m if using ethernet cables
  - EtherCAT ring network has cable redundancy
  - Power can be transmitted over ethernet
  - Data transmitted over ethernet in RailML format

- **LoRa** hub
  - Up to 2km in an urban environment but very slow

- **Bluetooth** hub
  - Bluetooth allows for high data rates over short distances
  - Would require high-power energy harvesting (like solar)

- **Data concentrator**

- **Track-side camera**
  - Future applications may require high-resolution video which consumes high bandwidth

- **Pressure**
  - Current & Voltage

- **Ambient Temperature**

- **Battery power or energy harvesting**

- **Switch toe camera**

- **LoRa** hub
  - Rail Temperature
  - Battery power or energy harvesting

- **Ethernet switch**

- **Ethernet**
  - Up to 2km in an urban environment but very slow

- **EtherCAT**
  - Accurate time sync (<1µs)
  - Each segment can be up to 100m if using ethernet cables
  - EtherCAT ring network has cable redundancy
  - Power can be transmitted over ethernet
  - Data transmitted over ethernet in RailML format
Further definition in IN2TRACK2

S&C Sensor System Specification, Design and Demonstrator

Outputs delivered through all three communications mediums

Difficulties in configuring COTS devices for data collection

railML/SensorML difficult to implement in plug-and-play environment

Further definition in IN2TRACK2
Stretcher Bar
Points Operating Equipment
(Actuation, Lock & Detection)

Stock Rail
Switch Rail

Distance Blocks
Heel Blocks

Supplementary Drive System
(May include supplementary detectors)

Bearer
Baseplate

Pads
Clips
Screws

Check Rail
Support

Crossing (Frog) Unit

Bearer

EMI Crack Detection
Assessment of EMI Used for the Detection of Discontinuities in Work Hardened Mn13 Frog Tips.

- Existing NDT methods unsuitable for manganese steels
- Difficulty in detecting defects in AMS frogs
- Electro-Mechanical Impedance (EMI) technique developed for defect detection in manganese steels
- Physical tests complimented by computational modelling of the technique
Assessment of EMI Used for the Detection of Discontinuities in Work Hardened Mn13 Frog tips.

Simulations: cube baseline vs. cube with slit

- Strong sensitivity to sensor location
- Requirement for pre-defect baseline measurement
- Level of work hindered by significant computational requirements
Self-adjusting S&G

Review of operation and degradation of Actuation, Locking & Detection equipment
Design study of retrofit technology for self-adjusting control and monitoring
Cost Benefit Analysis examining return on investment

Features of the switch rail gap

Logical inputs:
- Position command
- Detection
- Locking state
- Health inputs

Logical outputs:
- Position
- Switch safe
- Switch unsafe
- Health outputs

Schematic of the control and monitoring system design
Prototypes and Enhanced S&C System Demonstrator Specifications (D2.2 and D2.3)
Prototypes and Enhanced S&C System Demonstrator Specifications

Delivered in WP2:

• Whole system modelling approach

• Prototypes:
  ❖ Additively manufactured crossing sample
  ❖ Laser clad S&C rails
  ❖ Optimised rail steel grades, components & transition zones
  ❖ Modular continuous support track
  ❖ Whole S&C sensor system

• Demonstrator specifications:
  ❖ Additively manufactured crossing
  ❖ Modular continuous support turnout
  ❖ Integrated optimised turnout
  ❖ Enhanced monitoring
Additively Manufactured Crossing

Additively manufactured crossing demonstrator specification:

- Process: Cold Metal Transfer (CMT) most promising for this application
- Material selection: substrate with improved fatigue performance and AM material similar to existing AMS used in cast crossings
- Post process work: utilise techniques to improve surface hardness prior to demonstrator installation

Site configuration: location to allow for comparison between the AM crossing and a ‘traditional’ cast-crossing used as a control sample:

- Common location
- Common track bed conditions
- Common traffic and line speed
- Common crossing geometry
Modular Continuous Support

Outline design of complete turnout and enhancements to adjustable track
Optimised Turnout

Turnout demonstrator: planned installation mid 2020 in Austria

Location for installation of two S2T-Demonstrators and two Standard Turnouts BA15 for evaluation of improvement
Enhanced Monitoring Demonstrator

Live rail demonstrator

Laboratory environment demonstrator

- EtherCAT hub
- LoRa hub
- Bluetooth hub
- Ethernet router
- Laptop

Vibration, Temperature, Current Measurements will be shown live on the laptop.

Logic controller

Logical inputs:
- Position command
- Detection
- Locking state
- Health inputs

Logical outputs:
- Position
- Switch safe
- Switch unsafe
- Health outputs
WP2 – Conclusion
WP2 Key Outputs

European FMEA
- FMECA
- Failure mode catalogue

Whole System Modelling
- Integrated modelling approach

Enhanced design
- Switch geometry / rail profile
- Whole system stiffness / support
- Optimised rail grades
- Modular bearer joints
- Self adjustment capability

Specifications / plans for Enhanced S&C Physical Demonstrators:
- Additively manufactured crossing
- Modular continuous support turnout
- Integrated optimised turnout
- Enhanced monitoring

Prototypes
- Additively manufactured crossing
- Laser clad S&C rails
- Optimised rail steel grades, components and transition zones
- Modular Continuous Support
- Whole S&C sensor system

IN2TRACK2
WP1: Enhanced S&C
WP2: Next Generation S&C
Many thanks for your attention!