VII. International Scientific Conference of the Faculty of Transport Engineering
6th – 7th September 2018, Pardubice

# S-CODE: SWITCHES AND CROSSINGS OPTIMAL DESIGN AND EVALUATION

Aleš HÁBA[1], Martin KOHOUT[2], Eva SCHMIDOVÁ[3], Jakub VÁGNER[4], Jaromír ZELENKA[5]

**Abstract**
The S-CODE project is addressed all of the aims and objectives detailed in topic Research into new radical ways of changing trains between tracks – and work towards the developments required to realise Next Generation Switches and Crossings, as detailed in the Shift2Rail Multi-Annual Action Plan. The overall aim of the S-CODE project is to investigate, develop, validate and initially integrate radically new concepts for switches and crossings that have the potential to lead to increases in capacity, reliability and safety while reducing investment and operating costs. The project has identified radically different technology concepts that can be integrated together to achieve significantly improved performance for Switches and Crossings based around new operating concepts. Within this project the research team of University of Pardubice Faculty of Transport Engineering deals with optimisation of wheel-rail interface in Switches and Crossings and using of novel material for Switches and Crossings components. This paper contents particular results of both mentioned fields.

**Keywords**
paragraph, page, heading, footer

## 1 INTRODUCTION

The S-CODE project is running alongside sister projects - the ongoing IN2RAIL lighthouse project and the Shift2Rail joint undertaking Research into enhance track and switch and crossing system “IN2TRACK”. Outputs from these two projects is feeding into the S-CODE project, in order to develop a solution of technology readiness level 4 (TRL4) that can be later developed into Technology Demonstrator – Next Generation Switches and Crossings (S&C).

[1] **Ing. Aleš Hába, Ph.D.**, University of Pardubice, Faculty of Transport Engineering, Department of Mechanics, Materials and Machine Parts, Nádražní 547, 560 02 Česká Třebová, Czech Republic. Phone: +420 466 037 428, E-mail: ales.haba@upce.cz
[2] **Ing. Martin Kohout, Ph.D.**, University of Pardubice, Faculty of Transport Engineering, Department of Transport Means and Diagnostics, Nádražní 547, 560 02 Česká Třebová, Czech Republic. Phone: +420 466 037 427, E-mail: martin.kohout@upce.cz
[3] **prof. Ing. Eva Schmidová, Ph.D.**, University of Pardubice, Faculty of Transport Engineering, Department of Mechanics, Materials and Machine Parts, Studentská 95, 532 10 Pardubice, Czech Republic. Phone: +420 466 038 507, E-mail: eva.schmidova@upce.cz
[4] **Ing. Jakub Vágner, Ph.D.**, University of Pardubice, Faculty of Transport Engineering, Department of Transport Means and Diagnostics, Studentská 95, 532 10 Pardubice, Czech Republic. Phone: +420 466 036 493, E-mail: jakub.vagner@upce.cz
[5] **doc. Ing. Jaromír Zelenka, CSc.**, University of Pardubice, Faculty of Transport Engineering, Department of Transport Means and Diagnostics, Nádražní 547, 560 02 Česká Třebová, Czech Republic. Phone: +420 466 037 429, E-mail: jaromir.zelenka@upce.cz

## 2 OBJECTIVES

In order to develop the project, the consortium decomposed the high level aims documented in the project call and the technical ambition for technology demonstrator detailed in the Multi-Annual Action Plan, to identify the key objectives that helps to provide radically new ways of changing trains between track in order to improve capacity, reliability and safety, while reducing investment costs and life-cycle costs [1]:

- **Objective 1:** Identify existing best practice in switch and crossing innovation and fuse this with technological advances from other sectors to develop new approaches for switch and crossing operations, that draw on new concepts for drives, control, monitoring, logistics and installation that will allow the investment costs associated with S&C to be retained (or reduced) whilst significantly improving performance;
- **Objective 2:** Develop a modular switch and crossing architecture that allows subsystems to be easily changed or upgraded such that the gains in S&C system performance available from the adoption of new concepts can be realised progressively without the need for complete system renewal, thus allowing benefits to be attained more rapidly;
- **Objective 3:** Realise resilience-based design methodologies, maintenance free and degradation free systems and self-adjusting technologies that will allow complete **self-inspection** and **self-correcting and healing** functionality through the development of an S&C immune system, contributing towards a **50% improvement in the reliability and availability of switches**;
- **Objective 4:** Develop concepts that utilise new materials and construction techniques, together with an optimised wheel-rail interface to realise a **new movement principle** which has the potential to contribute to a **reduction in the life cycle cost of switches by up to 30%**;
- **Objective 5:** Significantly increase the allowable running speed of trains while also dramatically decreasing the switching time in order to contribute to a **capacity improvement of up to 100%**;
- **Objective 6:** Ensure that an integrated system, including a **fail-safe locking mechanism** design is arrived at that mitigates all risks associated with technical failure, human error and influencing external factors, that may result in incidents occurring, thus ensuring that the number and magnitude of incidents is reduced and the safety of passengers and the work force is retained at the highest level;
- **Objective 7:** To validate the new concepts developed in the project in a laboratory (TRL4) to allow assessment of the performance of the innovations;
- **Objective 8:** To provide hard evidence (calculations and simulations, experimental results, and economic, risk, reliability and LCC analysis) that supports the performance improvements made against Objectives 1 to 6;
- **Objective 9:** To integrate the identified, developed and validated concepts to produce a solution(s) that can be taken forward to **realise the Technology Demonstrator Next Generation S&C**.

The key outcomes and innovations of the S-CODE project will be [1]:

- The development and prototyping of a modular whole system switch and crossing architecture that allows subsystems to be changed over the life of the S&C. This will enable innovations to be added as they become available. The architecture and subsystems will be modelled to allow rapid development of further capabilities.
- The design and prototyping of Next Generation Design components that can be incorporated into the architecture, using new materials and technologies to create a variety of permanent way subsystems.

- The design and prototyping of a Next Generation Control subsystem that can be incorporated into the architecture, which will include an ‘immune system’ capable of self- adjustment, self-correction, self-repair and self-heal.
- The design and prototyping of Next Generation Kinematic subsystem that can be incorporated into the architecture, that includes new actuation and locking philosophies that make use of concepts such as redundancy and ‘limp-home’ through the use of novel actuators and mechatronic systems.
- Analysis will be undertaken to quantify the value of these innovations from the perspective of reliability, life-cycle cost, and higher speed switches/train throughput.

The S-CODE project aims to address the three specific technical challenges in topic "Research into new radical ways of changing trains between tracks in order to improve the overall performance of switches and crossings". Furthermore, the S-CODE project has been developed and conceptualised taking into account the needs of the Shift2Rail Multi-Annual Action Plan Next Generation S&C demonstrator.

Specifically, the S-CODE project:

- Identifies, develop and validate new concepts for next generation control – including a modular architecture, plug’n’play control, monitoring, sensor and data systems;
- Identifies, develop and validate new concepts for next generation design – including materials, component reduction, switching function, installation and logistics;
- Identifies, develop and validate new concepts for next generation kinematics – including actuation systems, mechatronic solutions, fault tolerance and S&C ‘immune system’;
- Uses the modular architecture to integrate the design concepts to develop alternative holistic solutions suitable for different scenarios that are can be selected and developed in later stages of the Shift2Rail programme (see fig. 1).

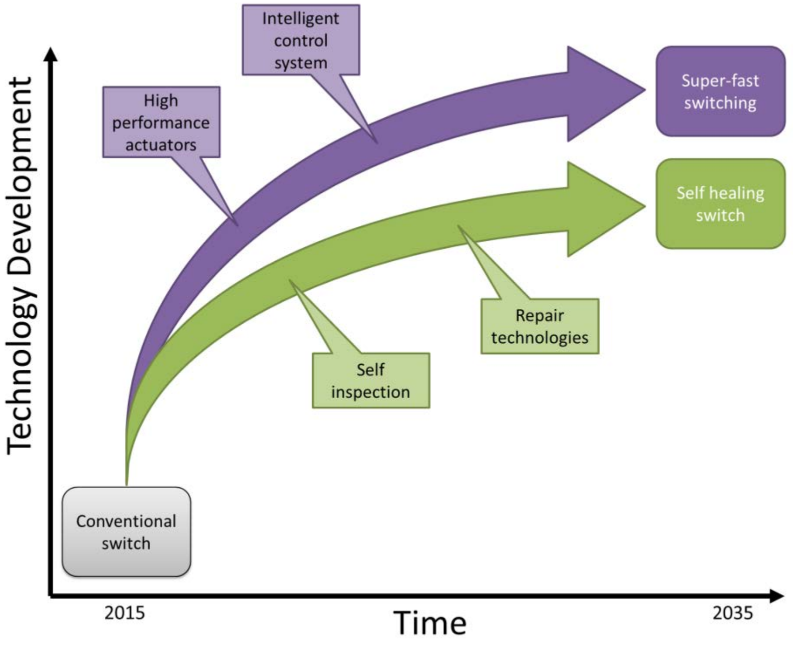


**Fig. 1** The progressive and modular integration of different design concepts to realise Next Generation S&C for use in different scenarios [1]

## 3 METHODOLOGY OF SOLUTION S-CODE PROJECT

The S-CODE project will be divided into three phases [1]:

- Phase 1: Requirements and initial design
- Phase 2: Technical development
- Phase 3: Demonstration and evaluation

### 3.1 Requirements and initial design

This phase of the project mainly addresses **Objectives 1 and 2** by eliciting the key industrial and technical requirements, as well as identifying existing best practice and technologies from other domains that can be exploited to help achieve significant improvements in S&C design. An architecture for modular design is developed that enables different subsystems to be interchanged during the life of an S&C installation. This allows the subsystems to be developed with some level of independence (different manufacturers, different timescale for upgrade/renewal). This phase of the project also considers the design philosophy and develops initial high level conceptual designs for new S&C through the use of horizon scanning techniques, such as back-casting.

- **WP1 – Best practice, elicitation of requirements and horizon scanning**
- **WP2 – Overall system architecture and initial high level design**

### 3.2 Technical development

This phase of the project addresses **Objectives 3 to 6**, and concentrates on the detailed technical design of the three main subsystems (control, design, kinematic actuation). The overall aim of this phase of work is to develop fault tolerant, low-LCC, low-carbon, low-maintenance turnout components and subsystems, through the use of novel materials, processes, electronics, signal processing and mechatronic design concepts as identified in Phase 1. A number of different design concepts is developed for each subsystem, with the most promising designs being taken forward for detailed development.

- **WP3 – Next generation control: monitoring and sensing systems**
- **WP4 – Next generation design: materials and components**
- **WP5 – Next generation kinematic systems: actuators and mechatronics**

### 3.3 Demonstration and evaluation

This phase of the project addresses **Objectives 7 to 9**, and concentrates on the evaluation and validation of the three main subsystems. Initially design concepts are validated separately through laboratory hardware-in-the-loop testing. Later, the design concepts are integrated using the modular architecture to produce a candidate solution for development at higher technology readiness levels through the remainder of the Shift2Rail programme.

- **WP6 – System integration and concept validation**
- **WP7 – Evaluation, impact and future developments**

### 3.4 Work packages interaction

The work packages has been interacting, as shown in fig. 2. In Phase 1, best practice assessment, requirements elicitation, horizon scanning, architecture development and high level design has been undertaken [1]. This produces high level concepts that can be developed into full designs (marked a to d) in Phase 2. In Phase 3, the most promising design concepts from Phase 2 has been taking forward for validation (e.g. WP5 – design a). The validation process enables evaluation and assessment to be undertaken and final solutions to be integrated (e.g. WP3 – design a, with WP4 – design a, and WP5 – design d).

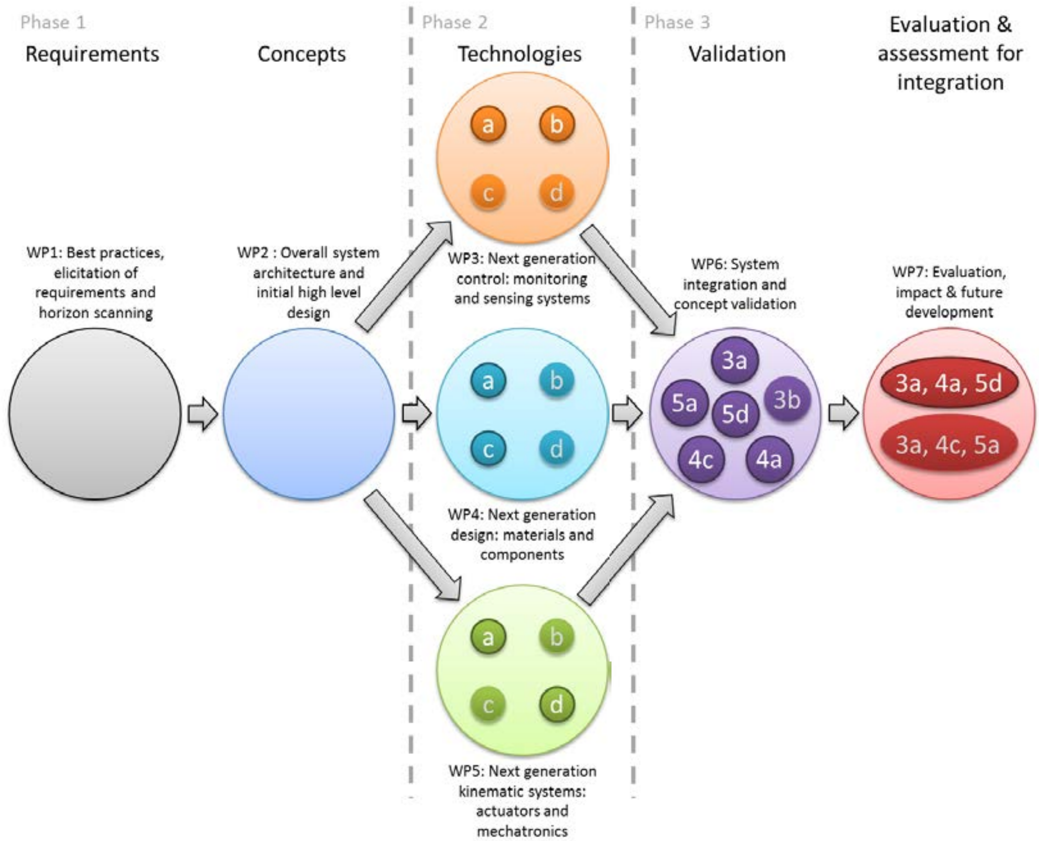


**Fig. 2** S-CODE work package interaction [1]

## 4 AMBITION

The key innovations of the project are the following [1]:

### 4.1 Innovation 1: Modular S&C Architecture

The development of a plug'n'play architecture for S&C allows different components and subsystems to be replaced, renewed and updated over different timeframes. This allows:

- S&C to be configured for different locations, that have particular requirements;
- different manufacturers to develop different subsystems;
- allow future innovations to be made in each of the subsystem areas.

### 4.2 Innovation 2: Next Generation S&C Control

In the area of next generation S&C control, the key innovation lies in the use of embedded electronics and sensors to provide significantly improved control, monitoring, inspection and safety functionalities. This significant improves reliability, and reduce life cycle costs.

### 4.3 Innovation 3: Next Generation S&C Design

Next generation S&C design utilises novel materials that have been designed specifically for application in S&C. This enables the switching and locking function to be radically changed, which improves reliability and reduces switching time (capacity). New materials and optimal design also improves the wheel/rail interaction, which reduces (eliminates with lighter vehicles) degradation of the running rails and support components. Installation and logistics is considered at the design stage, allowing these tasks to be carried out more quickly, and with a reduced need for people to be on the track. BIM is used to integrate the next generation of S&C design, to both help integrate different solutions and to speed-up approvals and standardisation.

### 4.4 Innovation 4: Next Generation S&C Kinematic Systems

Next generation S&C kinematic systems make use of mechatronic systems and fault tolerance – approaches commonly found in other safety critical industries (e.g. aerospace). Such approaches need to be adopted cost effectively, and without increasing the complexity of the S&C mechanism. With improved actuation, many benefits can be realised including improved reliability, improved availability, improved switching time (capacity).

### 4.5 Technology Readiness Level (TRL)

Fig. 3 shows the rise in technology readiness level in each of the mentioned areas through the course of the project [1].

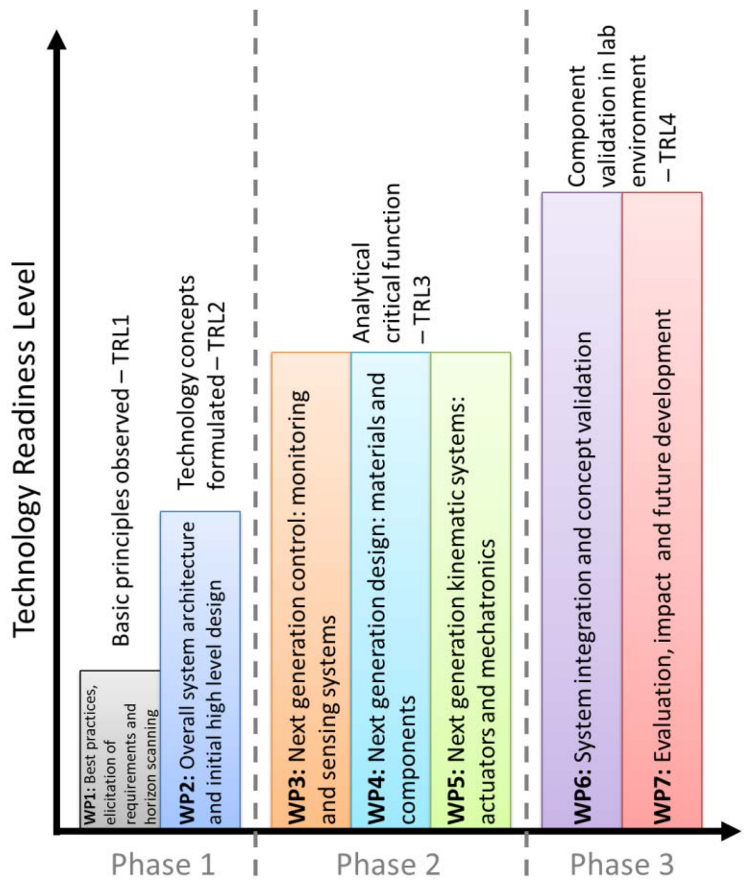


**Fig. 3** Technology Readiness Level improvements through the S-CODE project [1]

## 5 WORK PLAN — WORK PACKAGES, DELIVERABLES

Fig. 4 shows the structure of the work packages that have been developed using a systems engineering process to deliver the S-CODE project [1]. Phase 1 of the project (WP1 - Best practices, elicitation of requirements and horizon scanning, and WP2 - Overall system architecture and initial high level design) is used to decompose the high level objectives, and to develop initial radical design concepts. Phase 2 of the project (WP3 - Next generation control: monitoring and sensing systems, WP4 - Next generation design: materials and components, and WP5 - Next Generation kinematic systems: actuators and mechatronics) focuses on the key detailed technical work, while Phase 3 (WP6 - System integration and concept validation, and WP7 - Evaluation, impact and future development) concentrates on system integration, and preparation for realisation of Next Generation S&C demonstrator.

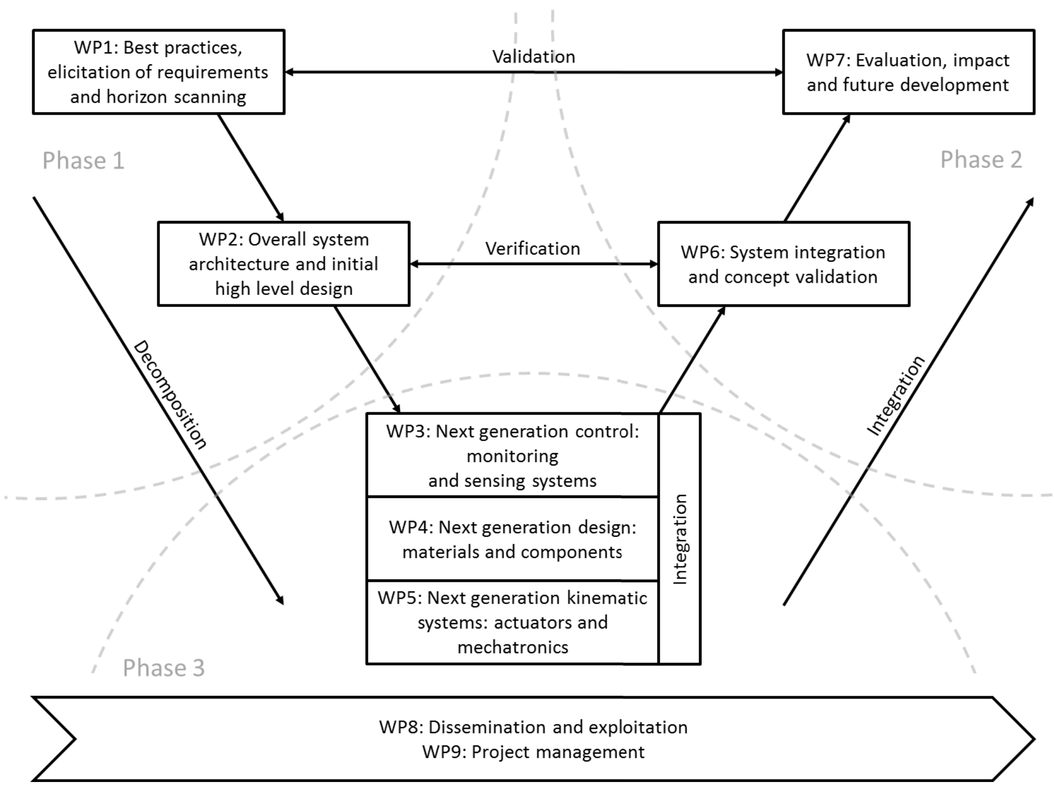


**Fig. 4** S-CODE work package structure [1]

## 6 RESEARCH ACTIVITIES OF UNIVERSITY PARDUBICE, FACULTY OF TRANSPORT ENGINEERING WITHIN S-CODE PROJECT

The research teams of University of Pardubice, Faculty of Transport Engineering deals with 3 activities in WP3 and WP4 of Phase 2 (Technical Development) of the S-CODE project. These activities are described in the following subchapters.

### 6.1 Intelligent self-diagnostic monitoring development

It is one task of WP3 in order to develop approaches for intelligent self-diagnostic monitoring – the first step of developing the S&C immune system. Self-diagnostic monitoring is a precursor to full fault tolerant control. Self-diagnostic monitoring includes functions (and hence algorithms) for self-inspection, fault detection, fault diagnosis and fault prognosis. A variety of algorithmic techniques are implemented for this purpose, including conventional model-based diagnosis, artificial intelligent neural network fault classifiers, quantitative and qualitative reasoning, etc. [1]

For WP3, there are several work streams that is together delivering a unified monitoring and sensing system. The areas of responsibility for sensing are split into:

- Autonomous inspection to inform autonomous repair using lasers, video and other NDT techniques.
- Embedded passive dynamic effect monitoring using accelerometers and other relevant sensors.
- On-train monitoring and correlating the data with the passive dynamic effect monitoring.
- Fault tolerant control of the S&C.
- Embedded monitoring of the actuation system.

These sensor systems must be able to communicate so that the data can be sent wherever it is required. A communications protocol is developing for the In2track project and will be used by all the partners to ensure interoperability and modularity. The data will all then be collected and processed to provide diagnostics and prognostic analytics.

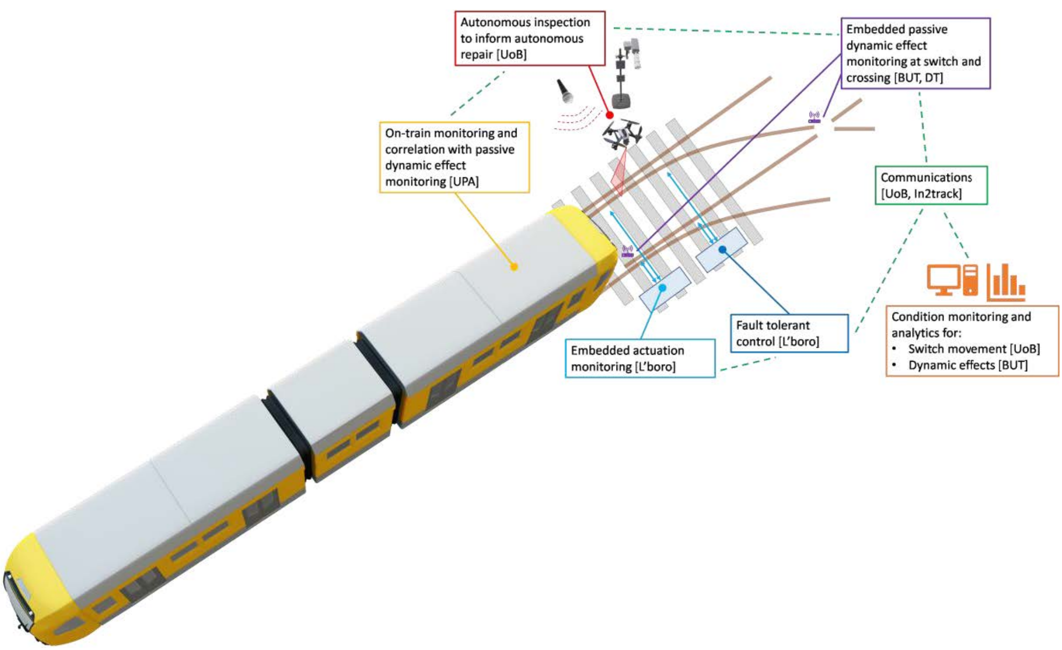


**Fig. 5** S-Code WP3 workstreams [2]

The intelligent self-diagnostic monitoring system is now developing base on experimental experiences of all included project partners. The research activities of University of Pardubice, Faculty of Transport Engineering are concerned to S&C diagnostic system located on the vehicle. The experience also enables to participate in identification of vehicles at the S&C stationary diagnostic system and intelligent evaluation techniques based on neural network.

S&C are problematic points in the track. Dynamic response corresponding maintenance costs are higher than at common track. To prevent the failure or destroying some mechanical parts it is necessary to have the information not only about actual state of specific S&C parts but support effectivity of the preventive maintenance by regular long-term monitoring/measurement of S&C.

Very useful measuring instrument to get the data for following diagnostic evaluation is usage of instrumented rail vehicle.

Measuring technics is normally installed on special measuring cars (DB, OEBB) or whole units (ADIF, SNCF, DB, JAPAN, Network Rail) today, because special measuring technics needs the special handling, professional staff and it is very expensive. The advantage of special vehicle from the point of view of the long term measurement is that the special measuring cars/units have relative same behaviour in time (comparable results for all S&C, negligible influence of vehicle parameter changes) and any deviations in vehicle parameters as well as in measuring technics could be checked and removed (technics recalibration) before each measuring run.

Anyway, there are some tests with monitoring of S&C through common trains equipped with basic measuring technics too. This approach could enable to monitor of chosen track section in relatively short time intervals (in some cases more time a day), but presumes low price, low power consumption, compact autonomous measuring technics (best as wireless) and cooperation with operators/owner of the vehicles. The possibility of wide spreading of such instrumented vehicles on common trains with sending the processed and evaluated qualitative information of S&C state to the vehicle operator (vehicle diagnostics through the vehicle response measured by same sensors as the track and S&C) as well as to the track operator (S&C diagnostics) could be a close future.

Suitable sensor technics for on train monitoring of S&C:

- Optical sensors for measurement of the track geometry in S&C (lateral and vertical rail and track alignment, track gauge, cant), measured and processed according existing standards. Sensor technology as well as data processing is in common use today. Measurement is necessary for knowledge about the deviations of the track geometry (significant influence in dynamic interaction vehicle-S&C) under some load and other conditions like rest of measured quantities.
- Mechanical sensors:
  - Acceleration on axle boxes (lateral for monitoring of the contact geometry wheelset/track – signal filtering till app. 50 Hz, vertical for diagnostics of wing rail and crossing nose wear and ballast and substructure characteristics – signal filtering till app. 1000 Hz). Frequency range depends on track construction and dynamic behaviour of S&C with ballast and subsoil. Sensor technology is in common use today. Future development is in the special software for data evaluation, which will be able to describe separately state of substructure, ballast and rails in S&C through some qualitative markers from measured signal (decomposition of influences of specific construction parts on wheel/rail dynamics). Different methods (statistical, non-statistical) and approaches (analysis in time as well as frequency domain, neural networks) should be used. Precise positioning of signals to S&C parts has to be solved too.
  - Acceleration on bogie frames and carbody (lateral and vertical) describing running safety, running comfort and track loading according common used standards like EN14363 (normalized methodology of the measurement and standard evaluation during vehicle running tests, signal filtering till 20 Hz). Sensor technology is in common use today. Future development is in the special software for data evaluation, which will able to describe separately state of substructure, ballast and rails in S&C through some qualitative markers from measured signal (decomposition of influences of specific construction parts on vehicle/track dynamics). Different normalized and non-normalized methods (statistical, non-statistical) and approaches (analysis in time as well as frequency domain, neural networks) should be used. Precise positioning of signals to S&C parts has to be solved too.

- Optical scanners for rail wear. Technology used for track diagnostics today. In S&C higher sampling frequency to get information about shape of toe/stock rail and wing rail/crossing nose and precise positioning of signals to S&C parts is required.
- Microphones on vehicles. Additional information to previous measurement. Correlation has to be checked.

Sensor technologies (piezo, MEMS, laser and profile scanners) for S&C diagnostics measurement are known and commonly used today. The future development is in low price (but still precise enough), low power consumption, compact sensors (best as wireless) and autonomous DAQ modules with online processing.

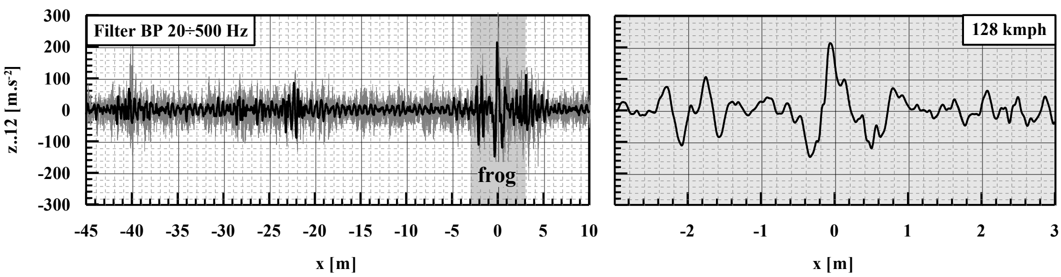


**Fig. 6** Typical acceleration course measured on the axle box in the course of passing over a whole turnout (left); filtered acceleration signal corresponding to passing over the frog area (right) (experimental measurement) [2]

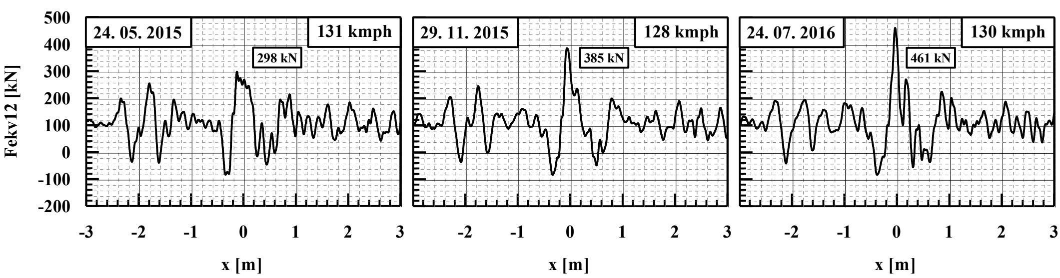


**Fig. 7** Courses of the equivalent loading of the same turnout during its one year operation (experimental measurement) [2]

Software tools are still in development. Methods enabling quality description of the state of specific parts of S&C is the future. Correlation as well as validation of developed software needs to realize a lot of measurement, information about the intervention in S&C during measuring time period (tamping, welding,…) and information about vehicle state. Computational simulations could help with sensitivity analysis between vehicle parameters, S&C state and measured signals. Neural networks as well as controlled preventive maintenance need the information about limit state of each S&C part during the operation or failure behaviour for debugging and "learning" of algorithms.

S&C self-diagnostic system based on dynamic effects measurement consists of

- automatic measuring of vibrations using accelerometers,
- meassured data preproccessing and collecting,
- online evaluation.

All evaluated parameters inputs into the neural network and then faults/degradation at an early staged captured. Identification of the type of fault and fault locations for repairs, trigger autonomous maintenance is necessary.

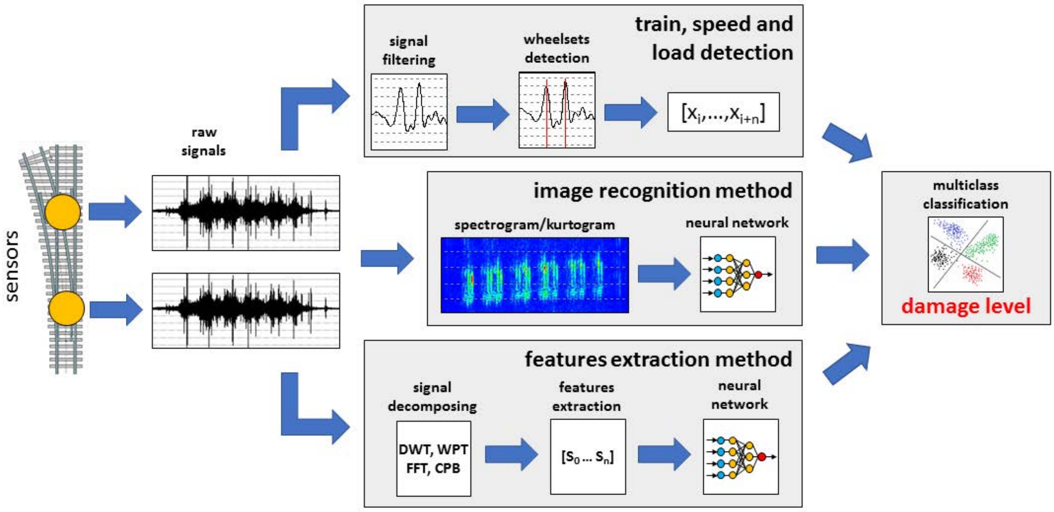


**Fig. 8** Example of S&C self-diagnostic system evaluation [2]

### 6.2 Using novel material and additive manufacturing solutions for reduced complexity and fewer components in the switching mechanism

It is one task of WP4 in order to investigate the technologies for reducing complexity, resulting in fewer components, while also reducing or retaining the same level of carbon emission, noise radiation and cost. Designs are established that make use of novel components to safely enable radically new mechanisms for switching a wheelset from one track to another. The task considers the innovative and constitutive properties of novel materials such as self-healing composites, low-wear low-friction surfaces, durable spring steels, impact- and wear- resistant nose design, geo-polymer and other synthetic materials for the development of new switch and crossing components. The output of this task will be a new design for the switching function that reduces complexity while improving performance. Based on the new design, consideration will also be given to the need for new or improved design guidelines for switch and crossing components, subsystems and systems in terms of safety compliance and reliable implementation across Europe [1].

Within this task of WP4, one part of research team of University of Pardubice, Faculty of Transport Engineering deals with development of contact layer using highly resistible steel. The current research reveals the distinctive restriction of standard pearlitic steels in sense of limited toughness and high temper sensitivity. Also commonly used high alloyed austenitic steel, with superior strength / plasticity ratio, has substantial disadvantages. Despite the intensive twining hardening capacity, this steel requires dynamic pre-hardening in advance the operational loading to suppress intensive wearing in these applications. Hence the multi-phase surface layer, created by diffusion-less phases combined with carbon enriched residual austenite, presents the prospective way to fulfil contradicting requirements for mechanical behaviour of materials in rail-wheel contact, especially for highly dynamic loaded parts of S&C.

The suggested concept is based on usage of the novel steel; diffusionless transformation have been applied to develop steel with microstructure consisting of a mixture of bainitic ferrite, retained austenite, and some martensite. This steel with improved rolling contact resistance and increased wear resistance compared to standard pearlitic steel is considered for the contact layer of the high loaded parts of S&C.

The chemical composition of the steel, mainly the limited carbon content guarantees the enhanced thermal stability. Good weldability is based on the same principle. It means mainly the resistance to unacceptable phase transformation due to slip in rail-wheel contact, followed by intensive heating and fast cooling. The tendency to immediate brittle phase on contact surface, followed by spalling is suppressed as opposed to the standard pearlitic steels.

On the other hand, the surface microcracks creation, caused by depletion of plasticity, is natural response to contact fatigue loading. In this sense, to increase the operational safety in rolling contact means to modify the natural micro-cracks propagation. To avoid the cross-sectional damage, the driving of the cracks propagation will be based on local deformation at a crack tip. Improvement of crack resistance can be achieved by the hardness scattering, i.e. by distribution of hard and soft phases in the microstructure. Thus, the concept is based on intentional structural heterogeneities creation (see fig. 9) creating the obstacles for critical crack propagation. The thinner residual layer and the more intense plane strain stage suppression results in the higher energy consumption during destruction.

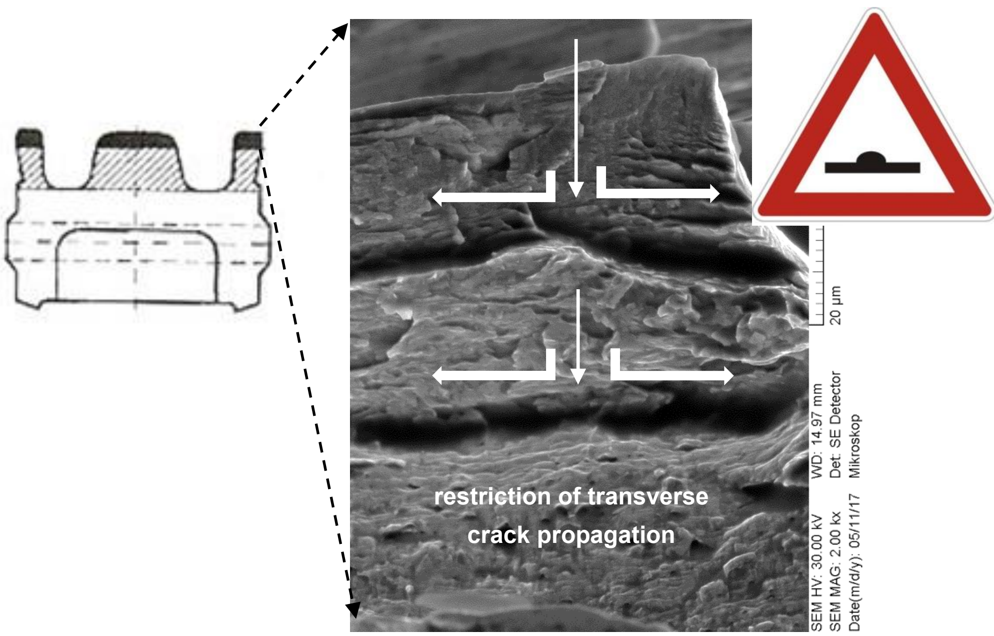


**Fig. 9** Crack propagation obstacles in surface layer [3]

Besides the advantages of primary created microstructure, two subsequent structural transformation of steel is estimated:

- processes due to additional heat and pressure while connecting the surface layer to the rest of crossing profiles,
- diffusionless transformation in surface layer during dynamic loading.

Consequently, the final wear is decreased while fatigue resistance will be substantially enhanced against operational loading.

Contrary to some additive technology, the primary deformation state of cladded surface can be preserved. Required ratio of the hardness and the other mechanical parameters between S&C and wheels should be controlled.

To find out the sensitivity to mentioned processes, the material for surface layer needs to be prepared in different stages of primary deformation state. Based on this concept the comprehensive analyses of novel steel will enable to find the prospective technology solution. To evaluate the response to different heat/pressure ratio, the adjusted flash butt welding technique will be employed to prepare experimental heterogeneous joints.

The experimental testing of rolling-contact response will enable to evaluate the improvement of the operational lifetime and safety. Special test rig (see fig. 10) will be used for simulation of operational loading at defined loading parameters (contact pressure, longitudinal slip, etc.). Precise history of material response, mainly degradation processes need to be recorded and compared to standard pearlitic steel.

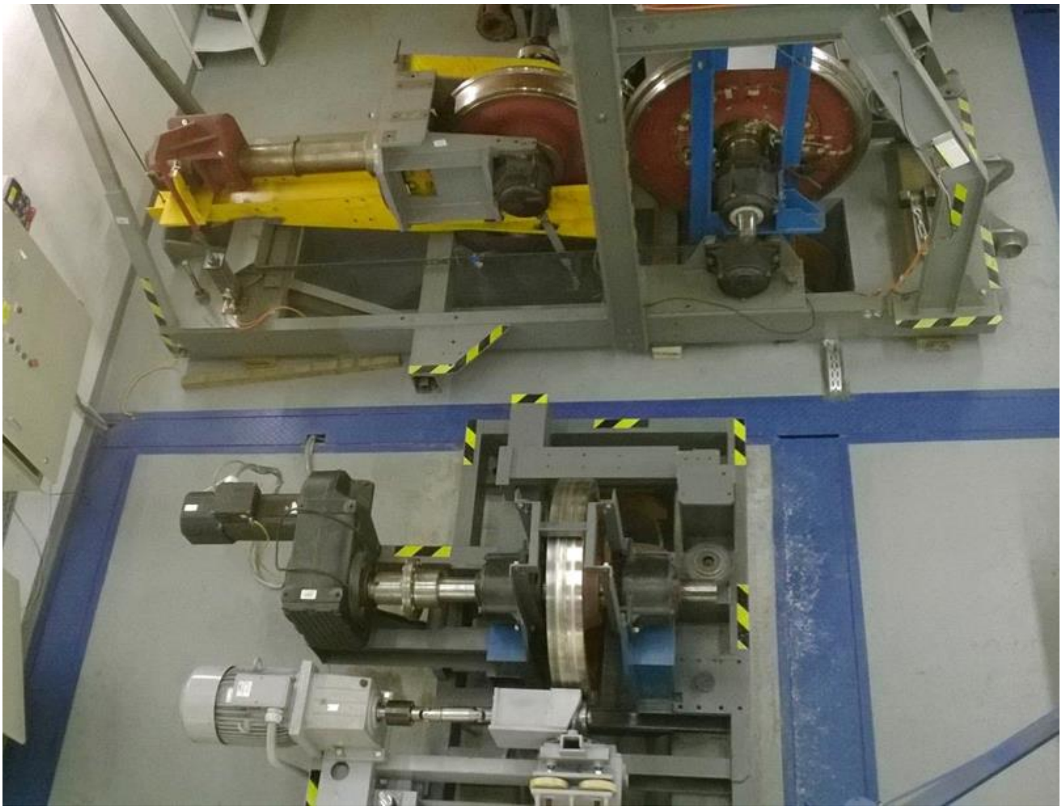

**Fig. 10** Rolling – contact testing rig [3]

### 6.3 Wheel rail interface design and optimisation

It is one task of WP4, which makes use of standard wheel/rail interface models held by the industry partners, as the advanced switch and crossing interaction model that has been developed over a number of years, and used and verified for use on mainline (normal and tilting trains), metros and trams in a number of countries through Europe. This task utilizes previous data collected through measurement campaigns undertaken to assess the dynamic effects of vehicles passing through S&C, and the subsequent analysis of rail and wheel profile evolution, wear, contact geometry and the development of optimised wheel profiles. This task extends this work to simulate and assess rail and wheel profile wear and contact geometry for the new switch and crossing concepts, and then carry out optimisation of both wheel and rail profiles to allow trains to travel at higher speeds through switches and crossing [1]. All parts of this task are covered by research University of Pardubice, Faculty of Transport Engineering.

Actually, the new wheel-rail interface model is developing. The innovation of the current model is based on different rail profiles of one rail during passing of the vehicle over whole switch. The input data consists of 3D model of the turnout which can be obtained from the 3D modelling software (in case of new turnout) or from the 3D scanner (in case of turnout in operational state). In both cases, the 3D geometry of the turnout is obtained which presents the primary data of the turnout geometry. For the wheelset-track contact-geometry assessment, the rail cross sections are necessary to use. Input 3D geometry model can be in both mentioned cases used for creation of cross sections in appropriate longitudinal step (see fig. 11).

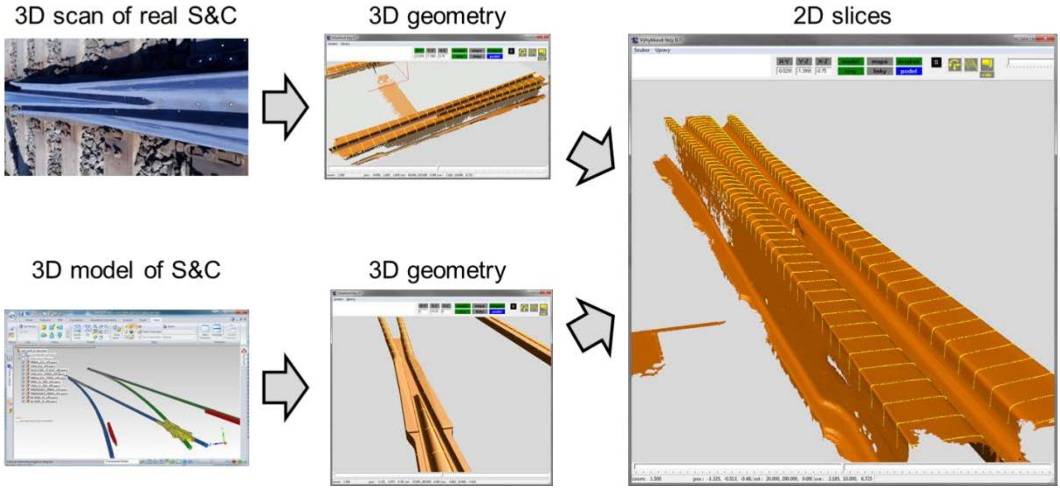


**Fig. 11** Using of 3D geometry obtained from two different systems for rail cross section creation [4]

The new approach to wheelset-track contact geometry assessment is based on analysis of contact points in critical parts of the turnout where wheel changes its contact between two rails (stock rail – tongue in switch area and wing rail – frog nose in frog area). For this analysis, the range of rail cross sections in appropriate step is necessary to evaluate. Therefore, the new wheel-rail interface model includes cross section of both rails with possible contact together (see fig. 12).

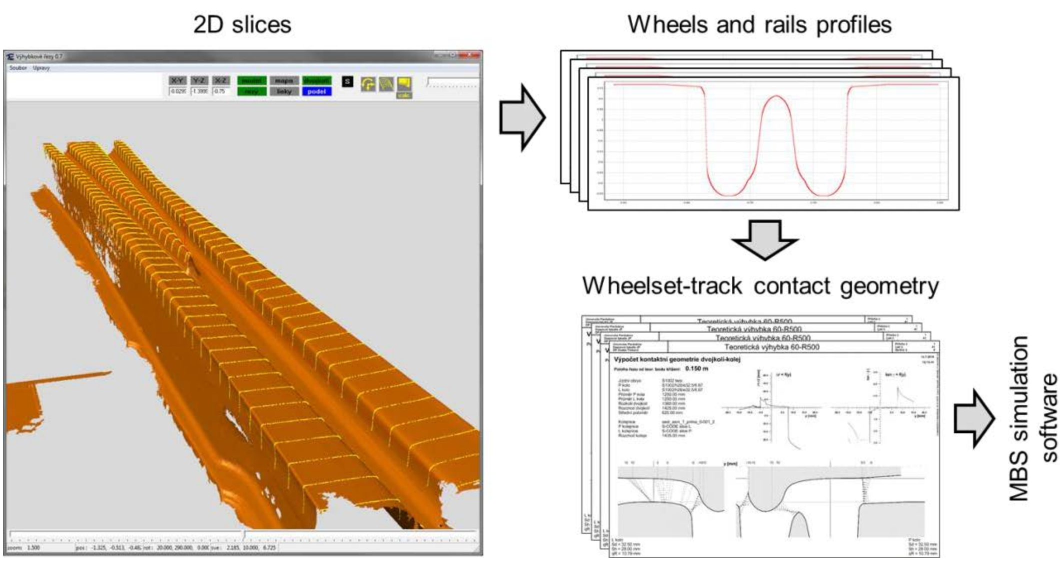


**Fig. 12** Wheelset-track contact geometry assessment [4]

Parameters of wheelset-track contact geometry are one of the important input data to multibody simulation software SJKV (see fig. 13) of vehicle running behaviour evaluation, which presents the result effect of interaction between turnout and vehicle.

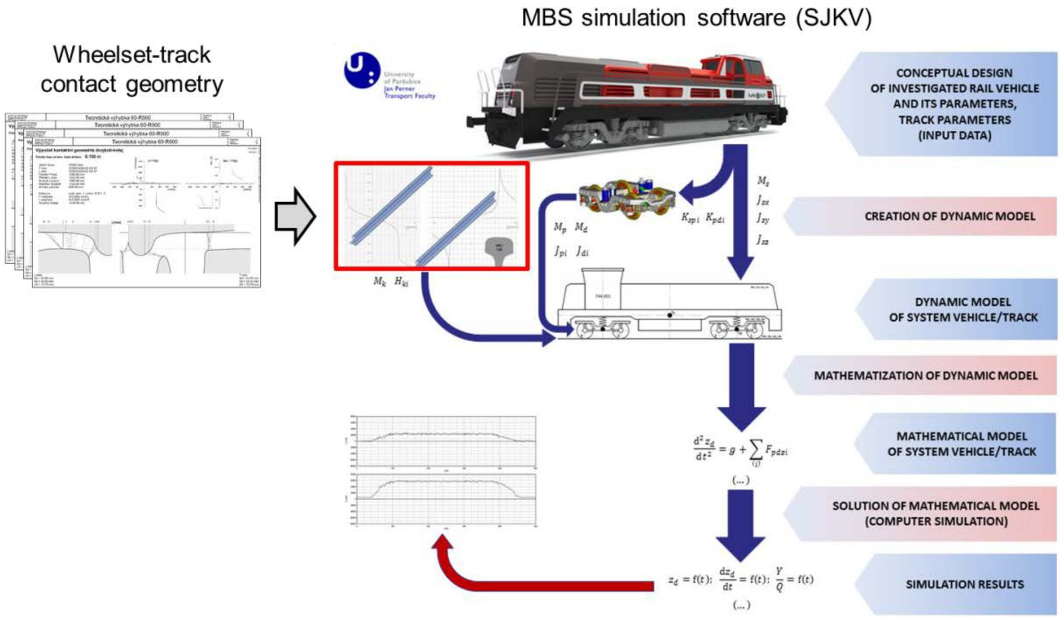


**Fig. 13** System of vehicle running behaviour evaluation with help of multibody simulation [4]

## 7 CONCLUSION

The S-CODE project has determined many challenges in development of S&C design and other resulting consequences. Some ideas, which are developing within this project, have visionary form and it is obvious that they can be applied only for radically new railway system in future. But the project also provides possibilities for developing radical new technologies which can be tested actually only as a laboratory specimen, but these technologies have potential to real application at the current railway in near future. The heterogeneous contact layer described in chapter 6.2 can be included into the range of this type of typical technologies. Development of an intelligent self-diagnostic system is actually common part of important production lines maintenance. The present technical level enables to use these technologies also for S&C maintenance technology and application of these monitoring systems is also possible in near future. Finally, improvement of wheel-rail contact model presents also very important progression in development of S&C wheelset-track contact analysis. A track and a vehicle presents a connected system and we cannot regard their parameters separately. The improved wheel-rail contact model, which has been actually developing, will be able to apply to any radically new S&C structures developed by other partners of S-CODE project.

This research has been supported by the Shift2Rail Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement no 730849 – project S-CODE (S2R-OC-IP3-01-2016).

◆◆

**Bibliography**

[1] S-CODE *Proposal technical Annex*. S2R-OC-IP3-01-2016, 2016.

[2] Requirements and High-level Design for Next Generation Monitoring and Sensing Systems, technical report to milestones M3.1, M3.2, M3.3, project S-CODE, 2018.

[3] Novel materials and additive manufacturing processes, including opportunities to improve logistics and installation, technical report to deliverable D4.1, project S-CODE, 2018.
[4] Integration and optimisation of switch and substructure technologies, technical report to deliverable D4.2, project S-CODE, 2018.