S-CODE: Switch and Crossing Optimal Design and Evaluation

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This project has received funding from the Shift2Rail Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement no 730849.
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S-CODE partners

- University of Birmingham lead
- Total budget 5M€

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Key S-CODE Outcomes

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.
2. 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.
3. 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.
4. 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.
5. Analysis will be undertaken to quantify the value of these innovations from the perspective of: (i) reliability, (ii) life-cycle cost, and (iii) higher speed switches/train throughput.

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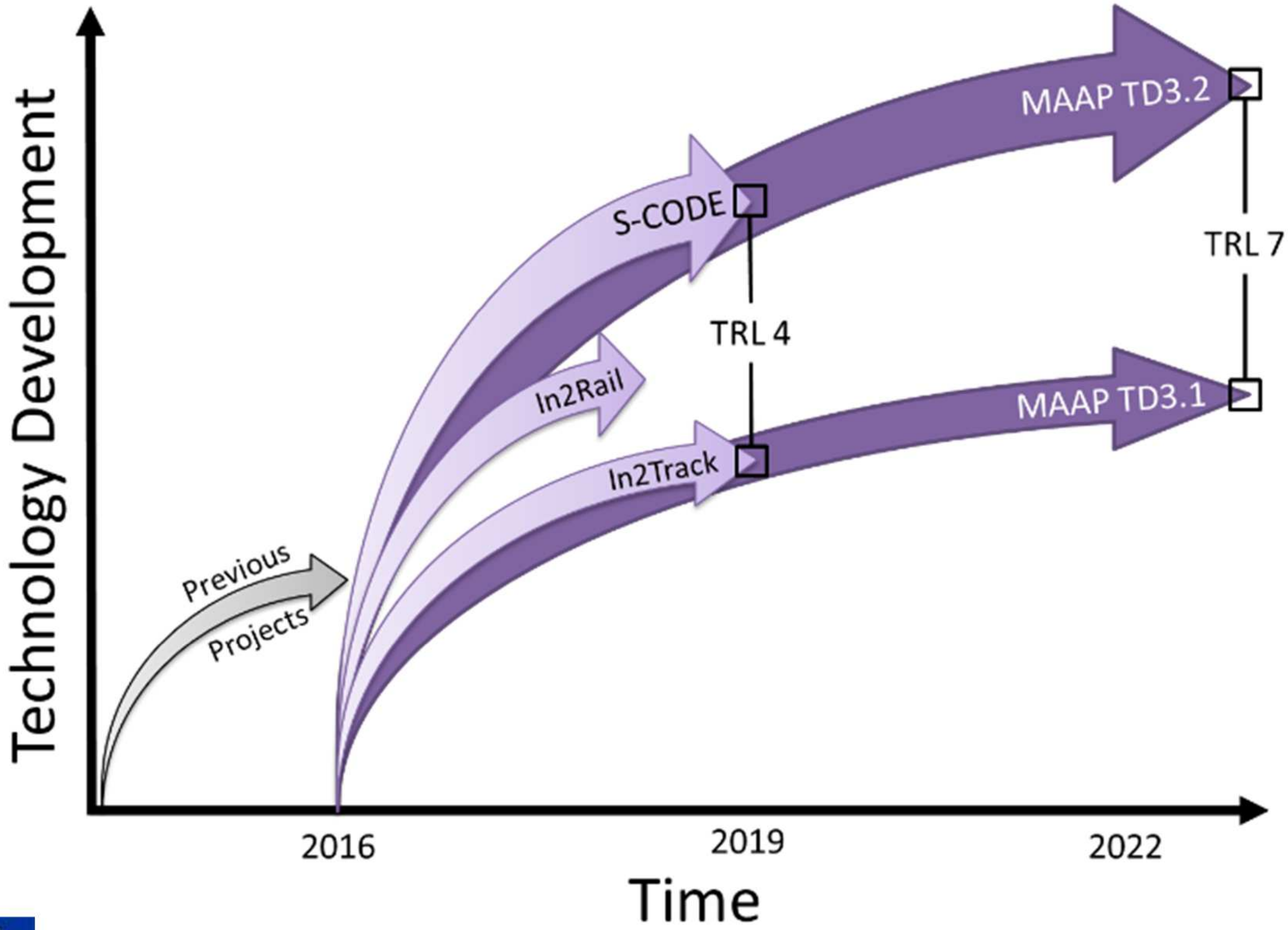
Links between S-CODE, In2Rail and In2Track

- S-CODE works with In2Rail and In2Track
- Draws from previous projects
- Supports delivery of TD3.2
- TRL1-4, but with some higher TRL elements



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Phases of the project

Phase 1 – Start Nov ’16

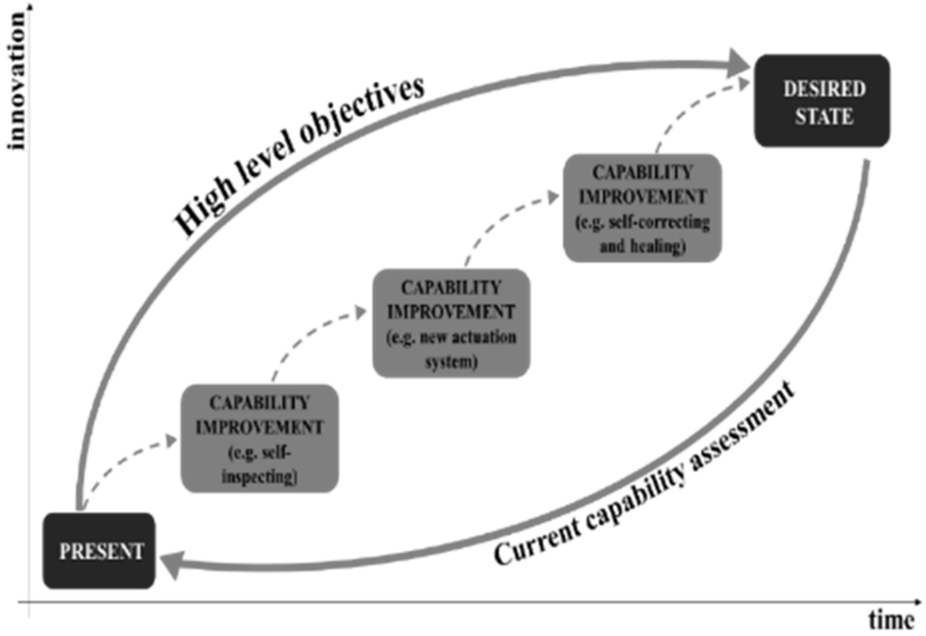
- Requirements and initial design

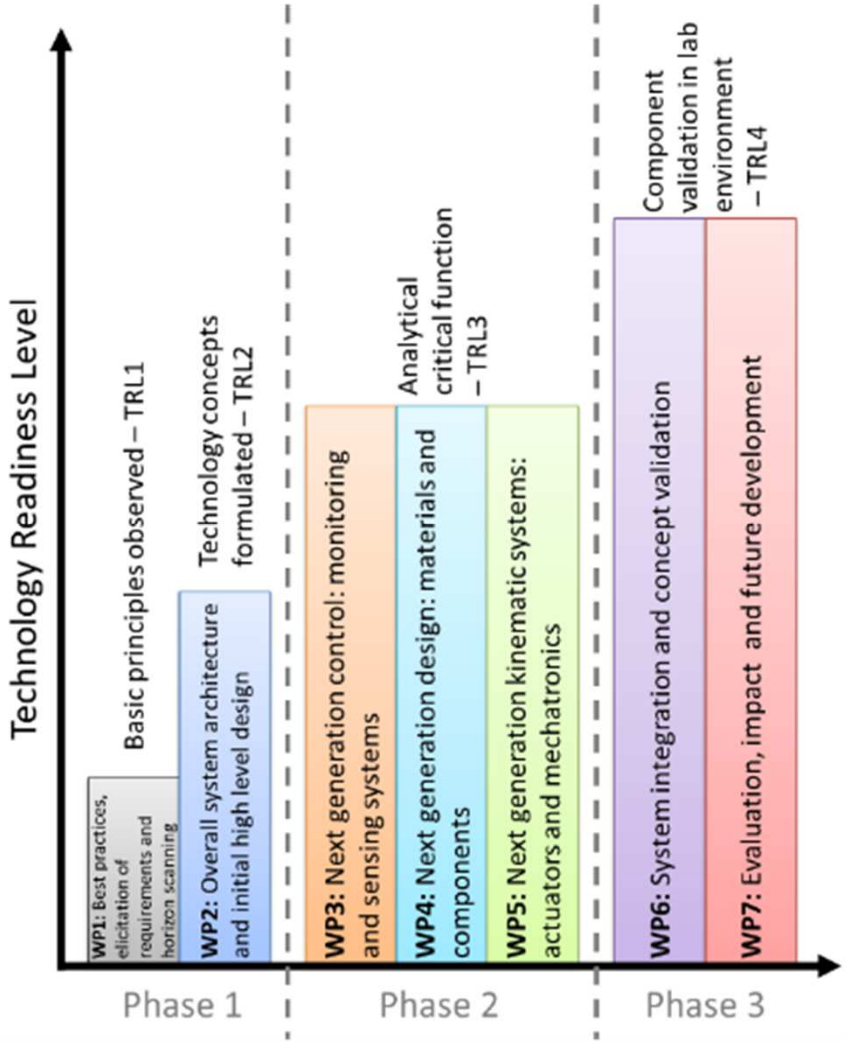
Phase 2 – Start May ’17

- Technical development

Phase 3 – Start Sept ’18

- Demonstration and evaluation





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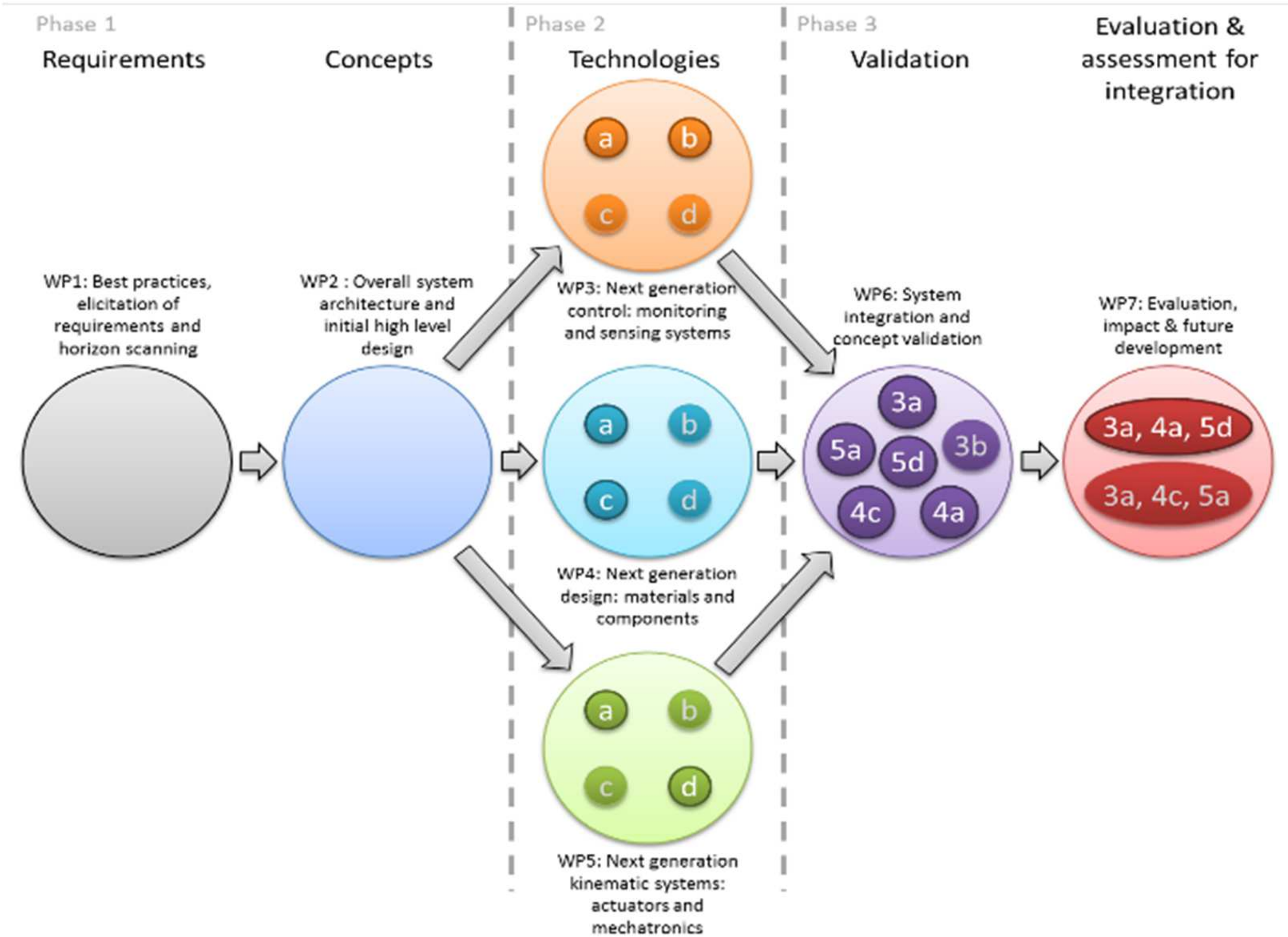
Overall Methodology

- Technologies are identified and prototyped in 3 areas
  - Control, monitoring and sensing
  - Materials and components
  - Kinematic systems, actuators and mechatronics
- Useful technologies are taken forward and further evaluated in combination



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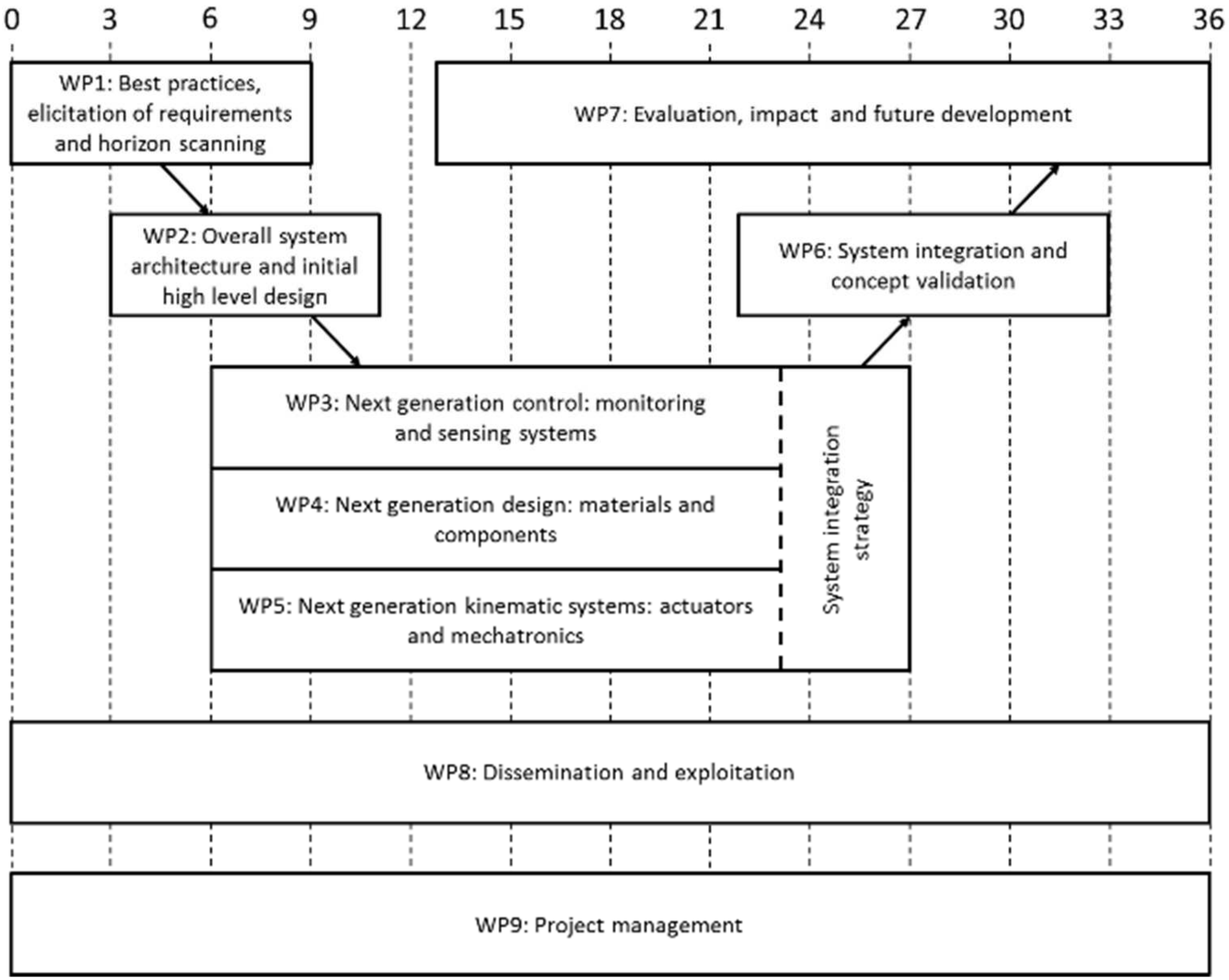
S-CODE Workplan



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Method for Radical Change

CODE

DESIGNING FUTURE SOLUTIONS

A systems approach to backcasting

1	Scope and high level objectives	What is the purpose of the system? What is the context? What do you want it to do, and when?
2	Current Capability Assessment	What is the current status? What are the downsides that you want to avoid/mitigate?
3	Selection of Operational Concept	Identify the future operating concepts. This will identify the gaps between the baseline and future vision
4	Definition of Functional Requirements	Modelling of operational concepts to define the functional requirements
5	Selection of Candidate Technologies	Identify set of technological solutions and market offers that have the potential to meet the functional requirements
6	Optimised Solution Selection	Develop options and test benefits in iterations to reach an optimised solution

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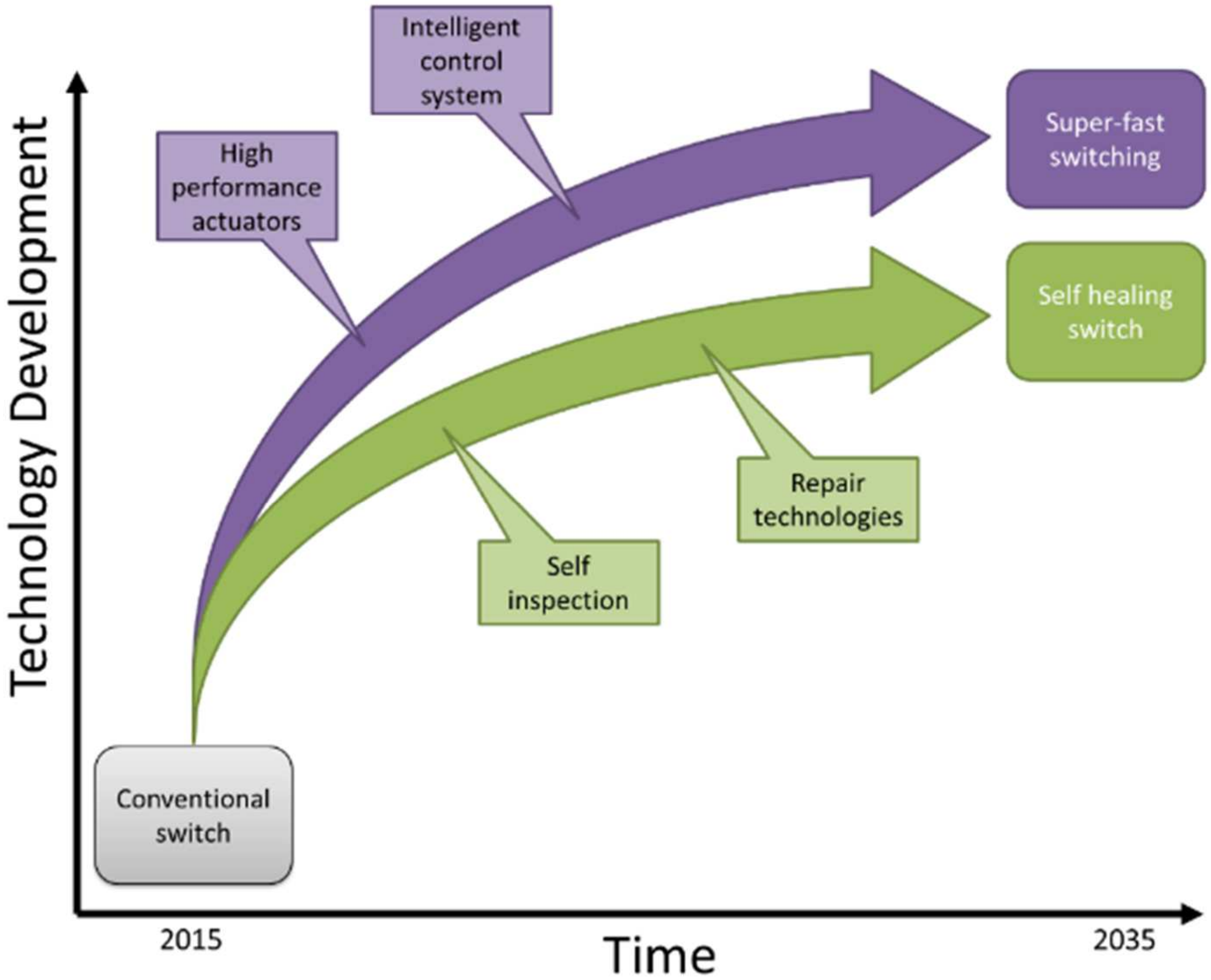
Method for Radical Change

- End-point switch objectives identified
- Key technological developments for each end-point identified
- Research targeted to gaps in key technologies



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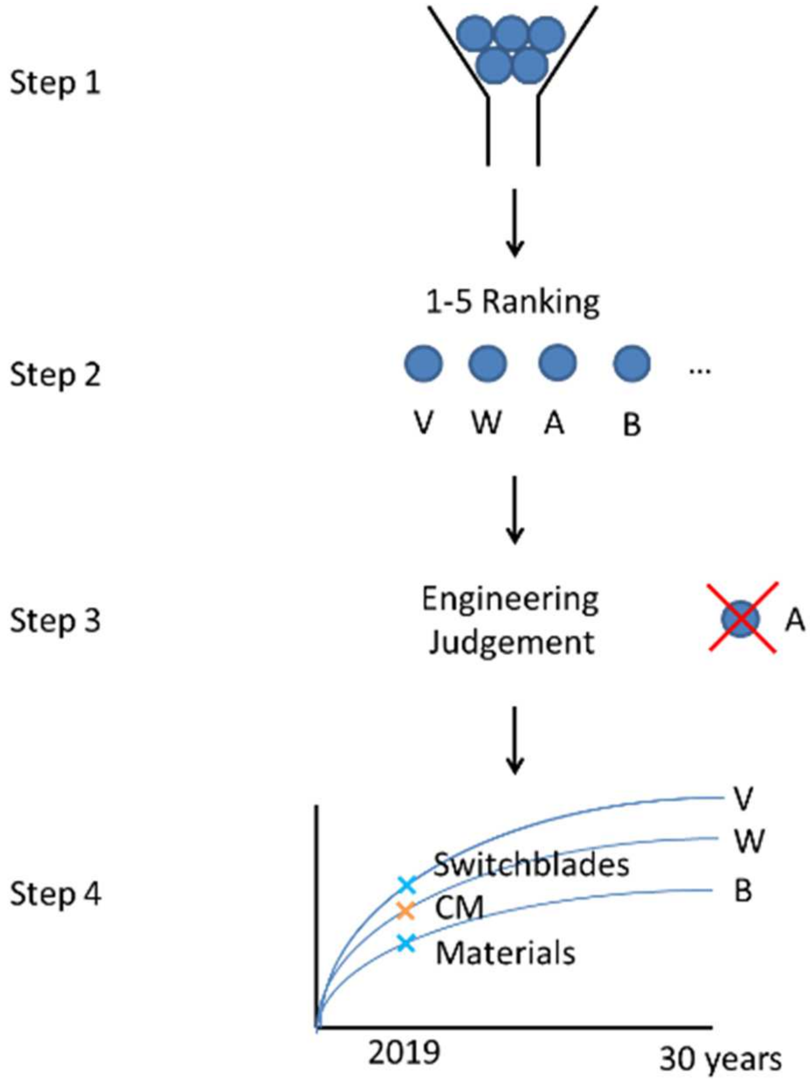
Concept and Technology Identification

- High level concepts identified in literature and through workshops
- Used to drive
  - high level design
  - key technology identification
- Multi-stage process
  - Identification of concepts
  - Selection of concepts or elements of concepts
  - Identification of key technologies required for further development



Innovative approaches in S&C: Switzerland

- **RACK AND PINION SWITCH**

The spring switch is based on the idea of a "cut out" section of track, which acts as a kind of "spring" that is fixed at one point and bends from one end position to the other, along a precisely defined curve.

In the end positions, the system operates like a "closed" track.

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Innovative approaches in S&C: The Netherlands

- **Winterproof Railway Turnout:** This new design turnout is not fitted with horizontal movable tongues, and because of that, snow and ice have no impact on the correct working of the turnout. Therefore, it needs no turnout heating at all.

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Mount Washington Cog Railway

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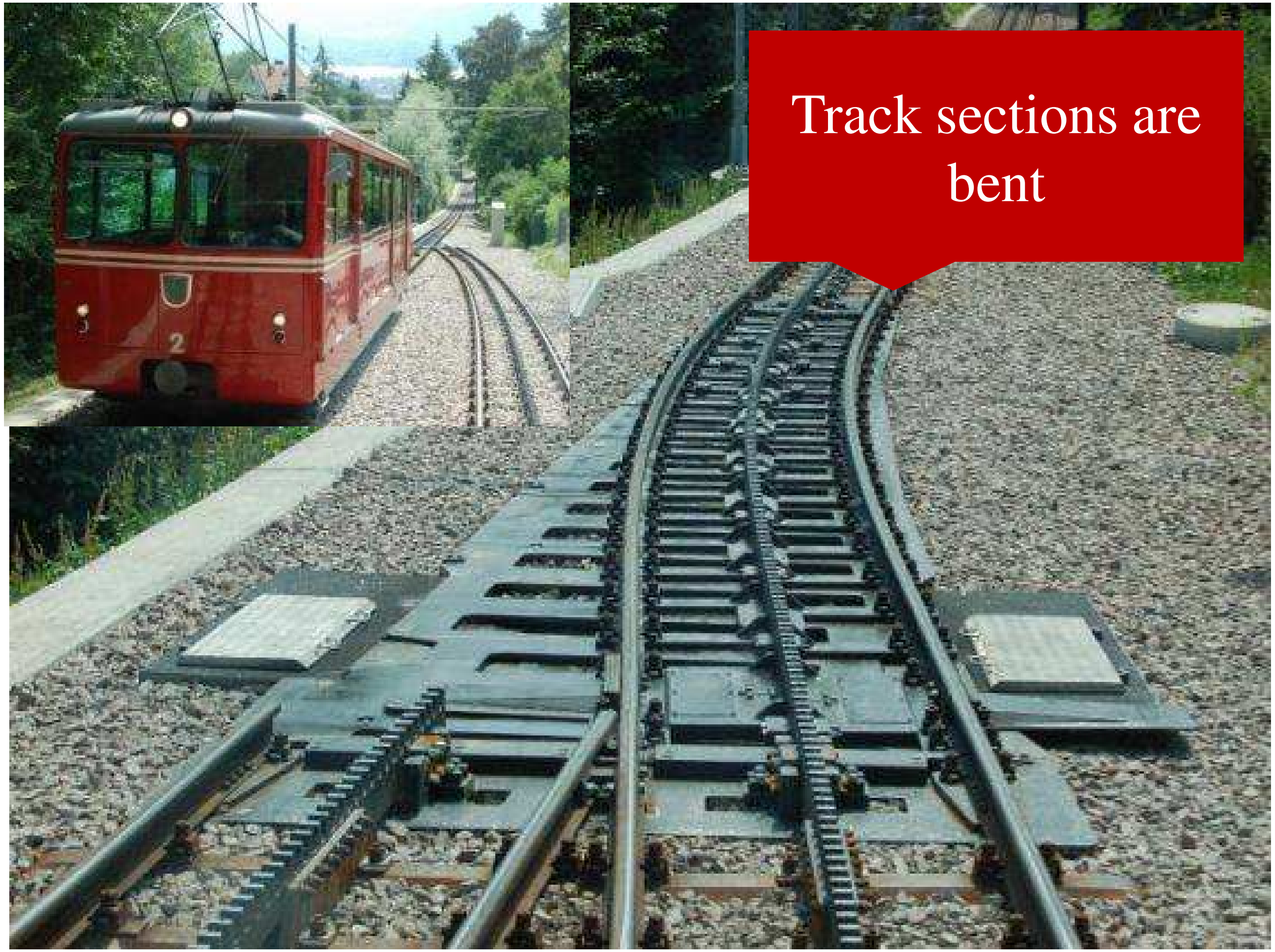
Dolderbahn Bendy Points



Track sections are bent

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Flange Bearing Frogs

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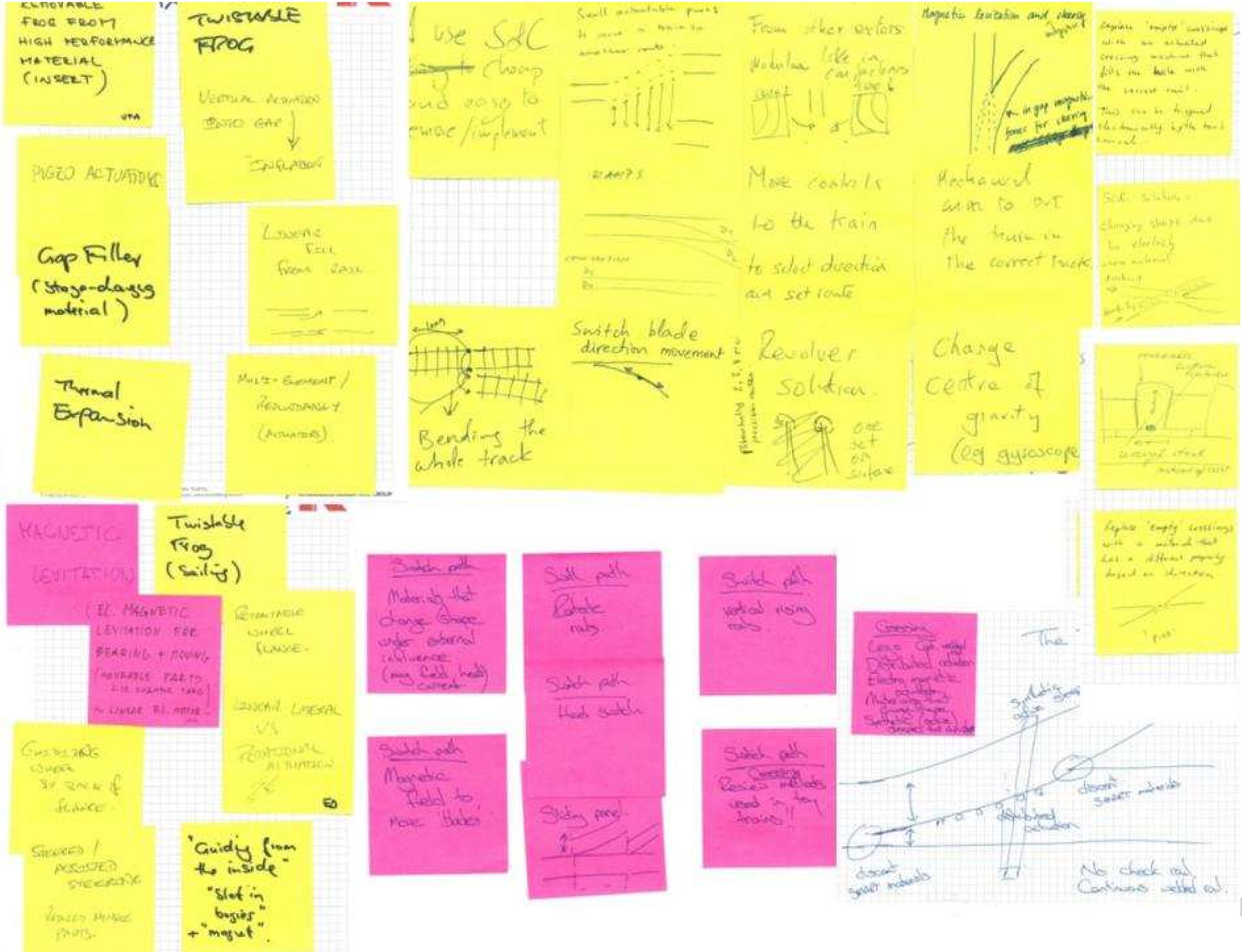
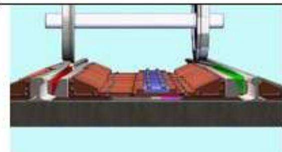
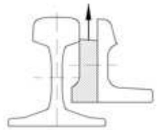

REMOVABLE FROG FROM HIGH PERFORMANCE MATERIAL (INSERT)
TWISTABLE FROG
VERTICAL ACTUATOR
INFLATABLE
PIEZO ACTUATING
Gap Filler (stage-changing material)
Thermal Expansion
MULTI-ELEMENT / REDUNDANCY (ACTUATORS)
use S&C
cheap
easy to
remove/implement
Small actuatable points to move a train to another route
More controls to the train to select direction and set route
Magnetic levitation and steering
Mechanical arm to put the train in the correct track
Switch blade direction movement
Bending the whole track
Revolver solution
one set on surface
Change centre of gravity (eg gyroscope)
MAGNETIC LEVITATION
Twistable Frog (Sailing)
EL. MAGNETIC LEVITATION FOR BEARING + MOVING
LINEAR EL. MOTOR
ROTATABLE WHEEL FLANGE
LINEAR LATERAL VS ROTATIONAL ACTUATION
STEERED / ASSISTED STEERING
'Guiding from the inside' "Slot in bogies" + "magnet"
Switch path
Materials that change shape under external influence
Switch path
Rotate rails
Switch path
Switch path
vertical rising rails
Crossing
Switch path
Magnetic field to move 'blades'
Sliding panel
Switch path
Crossing
Racing methods used in toy trains!
Replace 'empty' crossings with a material that has a different property depend on direction
No check rail
Continuous welded rail

Concepts A-E

- 22 existing concepts identified
- 1-pager summary documents developed identifying key elements of concepts
- Used in conjunction with evaluation matrix to support concept / concept element identficiation

Concept	Title	Illustration
A	Bending of stock rail	 
B	Vertical move-ment of track parts/inserts	 
C	Moving the switch section laterally	 
D	Rotating the switch section	
E	Flange bearing frogs	 

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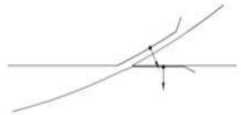
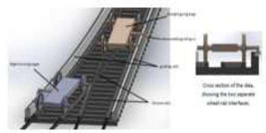
Concepts F-J

- 22 existing concepts identified
- 1-pager summary documents developed identifying key elements of concepts
- Used in conjunction with evaluation matrix to support concept / concept element identficiation

Concept	Title	Illustration
F	Rotation of tongue about the longitudinal axis	
G	Actuated nose for crossings	
H	Moving wing rail	
I	Guiding the trains from the tracks	 
J	Sliding panels for crossings	

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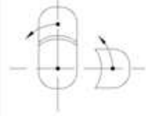
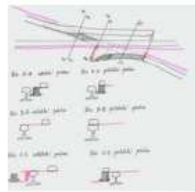
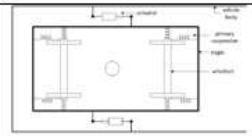
Concepts K-P

- 22 existing concepts identified
- 1-pager summary documents developed identifying key elements of concepts
- Used in conjunction with evaluation matrix to support concept / concept element identficiation

Concept	Title	Illustration
K	Rotation of stock rail or part of it	
L	Pivotable rail for crossings	
M	Overrunning of crossings	 
N	Diverging bridge	 
O	Active steering	
P	Flange-back steering	 

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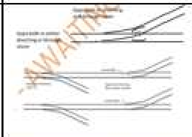
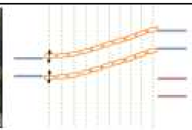
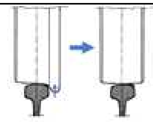
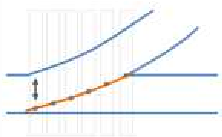
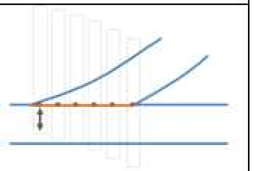
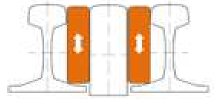
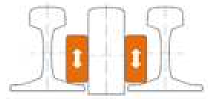
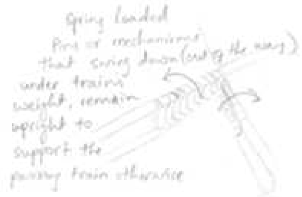
Concepts Q-V

- 22 existing concepts identified
- 1-pager summary documents developed identifying key elements of concepts
- Used in conjunction with evaluation matrix to support concept / concept element identficiation

Concept	Title	Illustration
Q	Single-flange steering	
R	Multiple section switch	 
S	Dynamic flanges	
T	Single switch rail	 
U	Filling the gaps between tracks	 
V	Spring loaded pins	

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Concept Evaluation

- Evaluation criteria identified
  - In conjunction with industrial partners
  - Through stakeholder engagement workshop
- Weighted Pugh matrix
- Evaluation of identified concepts considered
  - By all partners
  - By key groups to support engineering judgement discussion

	Concept Selection Matrix	Weighting	Existing S&C	Concept A	Concept B	Concept C	Concept D	Concept E	Concept F	Concept G	Concept H	Concept I	Concept J	Concept K	Concept L	Concept M	Concept N	Concept O	Concept P	Concept Q	Concept R	Concept S	Concept T	Concept U	Concept V
Design	Radically different	0.105	0	0.19	0.26	0.23	0.19	0.23	0.21	0.22	0.23	0.25	0.19	0.21	0.18	0.19	0.25	0.31	0.15	0.27	0.20	0.32	0.17	0.24	0.24
	Versatile and scalable (can be adapted to various situations)	0.073	5	0.18	0.10	0.14	0.08	0.13	0.12	0.10	0.08	0.17	0.10	0.12	0.12	0.09	0.13	0.16	0.12	0.13	0.15	0.15	0.14	0.09	0.08
	Retrofitting	0.009	10	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.03	0.03	0.02	0.02	0.01
	Modularity	0.076	5	0.13	0.12	0.16	0.14	0.10	0.09	0.11	0.09	0.10	0.08	0.11	0.08	0.07	0.11	0.16	0.09	0.08	0.14	0.15	0.11	0.08	0.10
	Allows track continuity	0.073	5	0.22	0.10	0.24	0.25	0.12	0.11	0.12	0.10	0.12	0.13	0.13	0.16	0.10	0.15	0.16	0.08	0.10	0.22	0.15	0.15	0.10	0.10
Manufacturing	Existing machinery/process can be used?	0.015	10	0.03	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.04	0.03	0.04	0.04	0.04	0.04	0.05	0.03	0.03	0.04	0.04	0.04	0.04	0.04
Maintenance	Easy maintenance	0.07	5	0.11	0.07	0.09	0.08	0.10	0.06	0.05	0.09	0.13	0.09	0.07	0.10	0.08	0.12	0.19	0.07	0.08	0.13	0.13	0.10	0.11	0.12
	Allows maintenance to be done offsite	0.058	5	0.05	0.05	0.08	0.07	0.05	0.03	0.04	0.04	0.07	0.07	0.05	0.07	0.04	0.07	0.08	0.05	0.04	0.08	0.07	0.05	0.06	0.06
Logistics	Deployability	0.073	5	0.10	0.10	0.13	0.10	0.06	0.07	0.08	0.08	0.12	0.10	0.09	0.08	0.07	0.12	0.16	0.08	0.08	0.18	0.17	0.11	0.09	0.09
	Plug and Play?	0.073	5	0.11	0.08	0.13	0.12	0.09	0.06	0.07	0.08	0.17	0.13	0.07	0.09	0.07	0.15	0.14	0.10	0.11	0.16	0.17	0.09	0.09	0.14
Operation	Energy efficiency	0.015	5	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.01	0.02	0.02	0.01	0.02	0.02	0.03	0.04	0.01	0.01	0.01	0.04	0.02	0.02	0.02
	Speed of switching	0.044	5	0.07	0.05	0.07	0.08	0.03	0.03	0.05	0.05	0.11	0.05	0.05	0.05	0.05	0.09	0.15	0.04	0.04	0.08	0.12	0.06	0.06	0.08
	Improvement in loading?	0.056	5	0.08	0.06	0.11	0.06	0.08	0.04	0.10	0.09	0.08	0.06	0.06	0.09	0.07	0.11	0.13	0.06	0.06	0.08	0.09	0.08	0.10	0.10
	Weather resistance	0.067	5	0.12	0.14	0.14	0.12	0.06	0.07	0.09	0.07	0.12	0.06	0.06	0.07	0.06	0.14	0.15	0.07	0.06	0.10	0.17	0.11	0.10	0.07
Safety	Risk of derailment can be reduced	0.082	5	0.13	0.11	0.15	0.14	0.11	0.08	0.13	0.09	0.19	0.14	0.08	0.13	0.17	0.13	0.18	0.07	0.14	0.12	0.16	0.11	0.11	0.11
	Allows safe run-through	0.032	5	0.09	0.07	0.08	0.08	0.02	0.04	0.05	0.04	0.09	0.07	0.06	0.07	0.07	0.08	0.08	0.05	0.06	0.09	0.10	0.08	0.06	0.05
	Reduction of Out Of Correspondence	0.067	5	0.08	0.09	0.13	0.12	0.04	0.06	0.10	0.08	0.16	0.09	0.09	0.09	0.08	0.13	0.21	0.08	0.11	0.17	0.19	0.09	0.05	0.08
Other	Time to market	0.015	10	0.02	0.03	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.03	0.04	0.03	0.03	0.03	0.04	0.03	0.04	0.03
	Cost	0.018	5	0.02	0.02	0.03	0.03	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.03	0.03	0.02	0.03	0.02	0.03	0.03	0.02	0.02
Rank				6	2	20	22	3	17	9	15	14	5	19	12	16	21	7	11	13	18	10	8	1	4

Group	Concept A	Concept B	Concept C	Concept D	Concept E	Concept F	Concept G	Concept H	Concept I	Concept J	Concept K	Concept L	Concept M	Concept N	Concept O	Concept P	Concept Q	Concept R	Concept S	Concept T	Concept U	Concept V
All (U)	6	2	20	22	3	17	9	15	14	5	19	12	16	21	7	11	13	18	10	8	1	4
Track Engineers	7	2	20	22	4	13	9	14	15	5	17	10	12	21	16	6	11	19	18	8	1	3
Control Engineers	6	3	15	22	11	18	12	13	8	9	21	16	20	19	1	17	14	7	2	5	4	10
Mechanical Engineers	3	5	19	22	4	18	14	11	12	9	21	13	15	17	2	16	20	10	1	7	6	8

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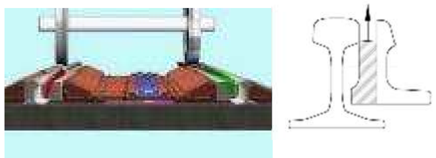
Highest Ranking Concepts

A: Bending stock rail

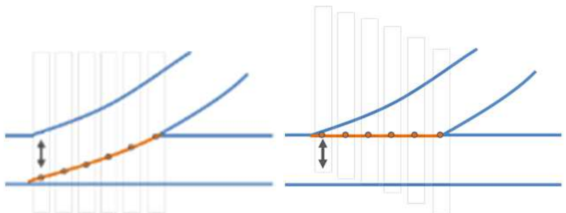


B: Vertical movements

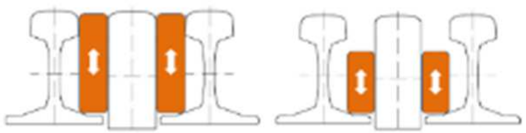
E: Flange bearing

G: Actuated nose

J: Sliding panels for crossing



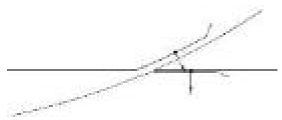
T: Single switch rail



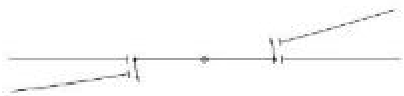
U: Gap filler between rails/tracks

V: Spring loaded pins

	Concept Selection Matrix	Weighting	Existing S&C	Concept A	Concept B	Concept E	Concept G	Concept J	Concept U	Concept V
Design	Radically different	0.105	0	1.80	2.45	2.17	2.05	1.80	2.24	2.28
	Versatile and scaleable (can be adapted to various situations)	0.073	5	2.43	1.33	1.79	1.39	1.38	1.18	1.13
	Retrofitting	0.009	10	2.12	2.27	1.69	2.31	2.28	1.97	3.02
	Modularity	0.076	5	1.75	1.55	1.28	1.50	1.10	1.06	1.31
	Allows track continuity	0.073	5	3.07	1.44	1.70	1.59	1.83	1.35	1.32
Manufacturing	Existing machinery/process can be used?	0.015	10	2.19	2.40	1.95	1.87	2.30	2.79	2.46
Maintenance	Easy maintenance	0.07	5	1.60	1.03	1.43	0.66	1.23	1.53	1.68
	Allows maintenance to be done offsite	0.038	5	1.29	1.37	1.37	0.98	1.88	1.51	1.56
Logistics	Deployability	0.073	5	1.36	1.31	0.83	1.08	1.39	1.27	1.21
	Plug and Play?	0.073	5	1.50	1.15	1.24	0.92	1.74	1.21	1.85
Operation	Energy efficiency	0.015	5	1.36	1.28	1.18	1.28	1.24	1.14	1.25
	Speed of switching	0.044	5	1.68	1.16	0.66	1.18	1.20	1.46	1.76
	Improvement in loading?	0.056	5	1.50	0.99	1.50	1.87	1.15	1.85	1.78
	Weather resistance	0.067	5	1.79	2.01	0.88	1.29	0.88	1.42	1.09
Safety	Risk of derailment can be reduced	0.082	5	1.61	1.31	1.33	1.53	1.65	1.36	1.32
	Allows safe run-through	0.032	5	2.76	2.05	0.59	1.54	2.21	1.78	1.59
	Reduction of Out Of Correspondence	0.067	5	1.15	1.31	0.62	1.42	1.28	0.72	1.17
Other	Time to market	0.015	10	1.60	1.82	2.45	2.16	2.24	2.48	2.31
	Cost	0.018	5	1.37	1.30	1.35	1.35	0.97	1.24	0.93
Rank				6	2	3	9	5	1	4



H: moving wing rails



L: Pivotable rail for crossing

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Technology Application to Concepts

- Technologies identified to support selected concepts
- Weighting based on
  - Significance of technology
  - Further technology development required
- Allows targeting of research activities into specific technologies

gies	Concept A1	Concept A2	Concept B	Concept E	Concept G	Concept J	Concept L	Concept M	Concept T	Concept U	Concept V	Research importance
	7	7	7	7	7	7	7	7	7	7	7	77
	5	5	5	5	5	5	5	5	5	5	5	55
	1	1	1	1	1	1	1	1	1	1	1	11
	5	5	5	5	5	5	5	5	5	5	5	55
	6	6	6	6	6	6	6	6	6	6	6	66
	6	6	6	6	6	6	6	6	6	6	6	66
urces	5	5	5	5	5	5	5	5	5	5	5	55
ns	5	5	5	5	5	5	5	5	5	5	5	55
	7	7	7	0	7	7	7	7	7	7	0	63
:)	7	7	7	0	7	7	7	7	7	7	0	63
	0	0	0	1	2	2	2	2	2	2	2	15
technology	12	12	0	6	0	0	0	0	12	6	6	54
rail, tranfser forces at	7	7	7	7	7	7	7	7	7	7	7	77
e and vibration reduction	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	2	2	2	2	2	2	2	2	2	2	2	22
rials	5	5	5	5	5	5	5	5	5	10	10	65
istance	7	7	14	14	14	14	14	14	7	0	0	105
inding	4	4	0	4	0	4	0	0	4	2	2	24
stening to reduce dynamic	0	0	4	8	8	8	8	8	8	8	8	68
ometric layout	10	10	0	0	10	10	10	10	10	0	0	70
ngs	7	7	7	7	7	7	7	7	7	7	7	77
	2	2	2	2	2	2	2	2	2	2	2	22
	6	6	6	0	6	6	6	6	6	12	0	60
	3	6	3	0	3	0	0	3	6	6	0	30
	6	6	6	0	6	0	6	6	6	12	0	54
	6	6	6	0	6	6	6	6	6	6	0	54
	1	2	2	0	1	1	1	1	1	1	0	11
	10	10	10	0	10	10	10	10	10	5	0	85
	2	2	2	0	2	2	2	2	2	2	0	18
	6	6	6	6	6	6	6	6	6	6	6	66

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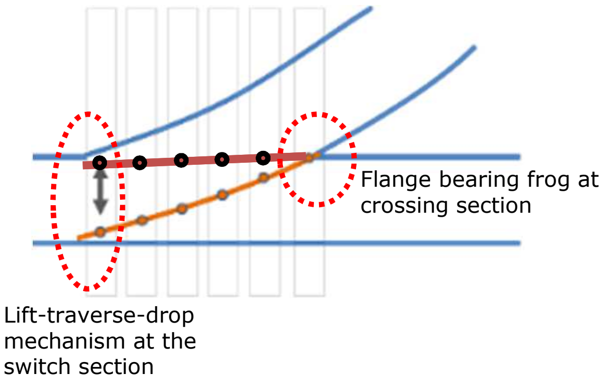
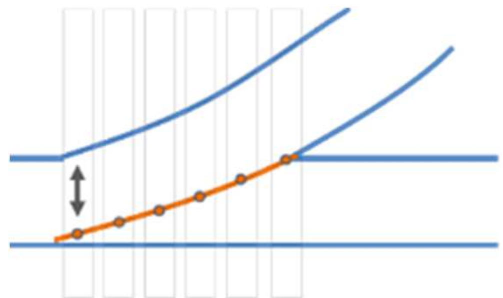
Combined Concepts

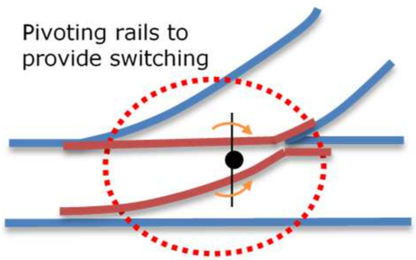
Interesting concepts were combined to make five novel concepts (shown here) that would be modelled as full kinematic systems



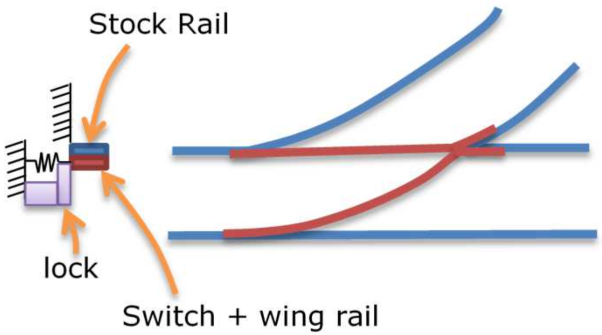
1: **Concept T combined with A1 (at switch section) + E (at nose section)**
Back-to-back bistable switch



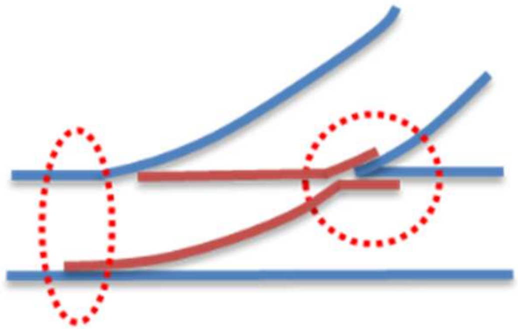
2: **Concept T combined with A2**
Single slender switch



3: **Concept T combined with L**
Pivoting rail switch



4: **Concept T combined with B and V**
Sinking switch



5: **Concept T combined with E**
Vehicle based switching

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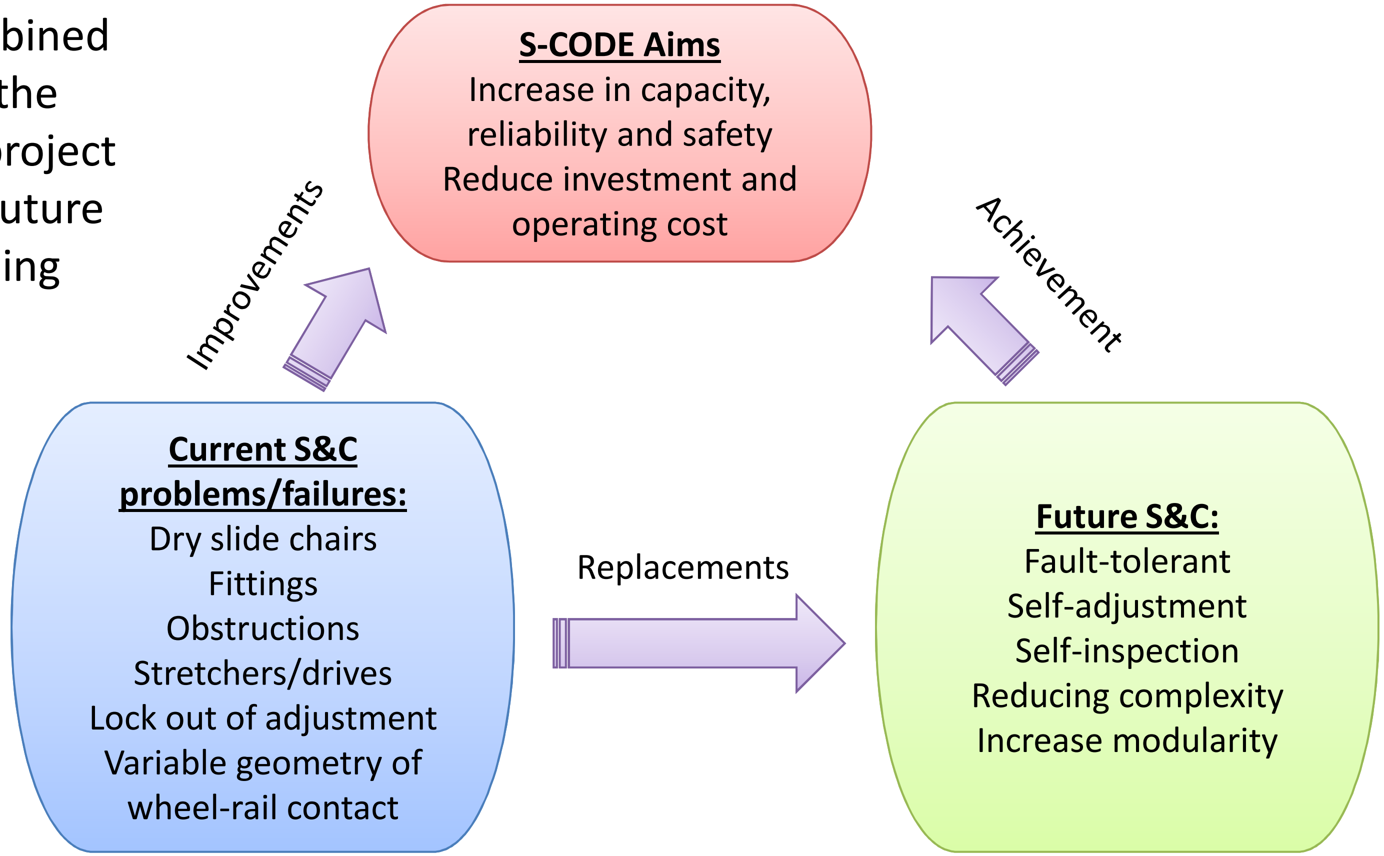
Design Triangle

This iterative design triangle is continuously used to improved the combined concepts to meet the objectives of the project and the needs of future S&C while addressing existing problems



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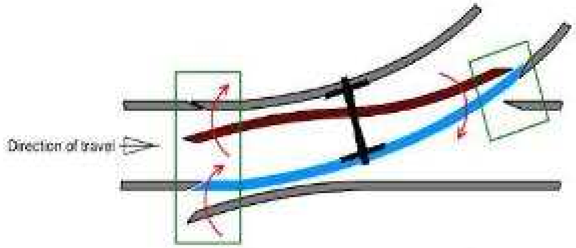
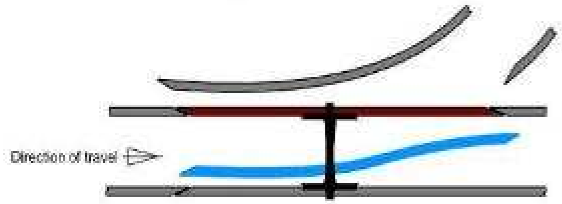
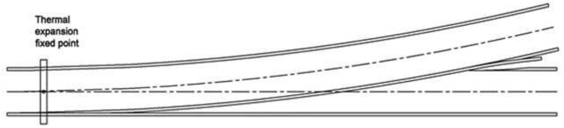
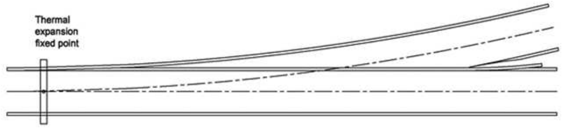
Kinematic Modelling of Concepts

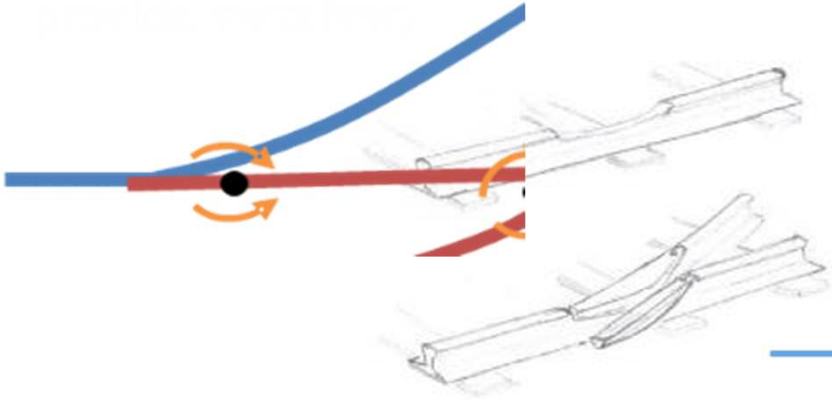
The combined concepts have had their designs iteratively improved and are currently being modelled to determine feasibility

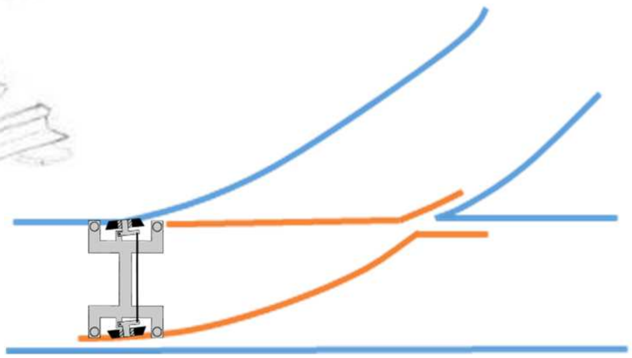


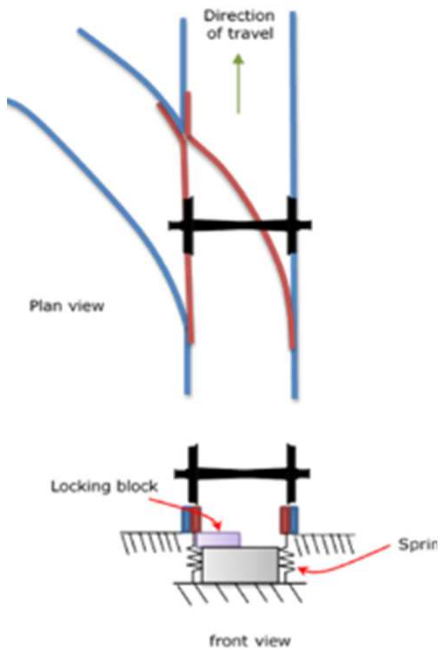












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S-CODE Innovation Development Maps

S-Code innovation development map For WP__	TRL 4-7 **More conventional (could build)**	TRL 3-4 **Modelling and simulation**	TRL 2-3 **Conceptual design**	
Activity	A	D	G	Dependency
Activity	B	E	H	Dependency
Activity	C	F	I	

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S-CODE Innovation Development Maps – WP3

S-Code innovation development map For WP3	TRL 4-7 **More conventional (could build)**	TRL 3-4 **Modelling and simulation**	TRL 2-3 **Conceptual design**	
Actuation monitoring and control	A Power, force, and displacement monitoring of S&C for actuator position control and condition indicators	D Self adjustment of S&C using advanced control system and embedded sensors, condition indicators used to trigger remote inspection and schedule maintenance	G Auto-recalibration of self-adjustment after maintenance. Integration with autonomous inspection to create a detailed assessment of the health of the switch and expected lifetime	**WP5**
Substructure and dynamic impact monitoring	B Accelerometers, microphones and other passive monitoring of S&C for detection of dynamic impacts and substructure degradation	E Embedded accelerometer monitoring of S&C and advanced sensors (e.g. acoustic array or radar). Events used to trigger remote inspection and schedule maintenance	H Combine sensors to isolate fault locations. Integration with autonomous inspection to create a detailed, accurate assessment of the health of the switch and expected lifetime	**WP4**
Autonomous inspection and repair	C Optical cameras, IR cameras, lasers and other NDT inspection techniques to assess the health of the switch	F Drones and/or robots using NDT inspection techniques via remote control to assess the health of the switch and suggest repairs	I Drones and/or robots using NDT inspection techniques autonomously to assess the health of the switch and enact repairs or adjustments	

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S-CODE Innovation Development Maps – WP4

		TRL 4-7 **More conventional**	TRL 3-4 **Modelling and simulation**	TRL 2-3 **Conceptual design**	
Track Stiffness Design	**Composite Bearers**	A FFU Sleepers; Neo Ballast; USP Bearers;	E Composite Sleepers with Harvesting Capacity	I 3D Printing FFU Sleepers; Self Healing Composites	**WP3 WP5**
Track Stiffness Design	**Self Healing Concrete**	B High Damping Concrete Bearers and Slabs	F Self Monitoring Bearers	J Self Healing Concrete; 3D Printing of Concrete Slabs and Bearers	**WP3**
Track Stiffness Design	**Fastening Systems**	C Tunable Stiffness Fasteners (active structure); Adjustable Level Fasteners	G Energy Harvesting Fasteners; Piezo Fasteners	K 3D Printing Fasteners	**WP3**
Rail Steel Improvement	**Bainitic Contact**	D Flashbutt Welding	H Functional Graded Steel Crossing	L 3D Printing Bainitic Steel	**WP5**

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S-CODE Innovation Development Maps – WP5

S-Code innovation development map For WP5	TRL 4-7 **More conventional (could build)**	TRL 3-4 **Modelling, simulation or lab demo**	TRL 2-3 **Conceptual design**	
Actuation	Conventional actuators with new mechanisms (A)	New S&C concept development Multiple actuation (D)	Piezoelectric actuator (scaling up) Electro-active polymer based actuators (G)	**WP4**
Locking	New locking mechanisms, active and passive (B)	Magneto-rheological, Dilatant materials based locking mechanism (E)	Electro-restrictive fluid based locking mechanism (H)	**WP4**
Fault-tolerance	Analytical redundancy Hardware Redundancy (C)	Self-inspection by embedded sensing, self-adjustment by using advance control (F)	Highly redundant elements (I)	**WP3**

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WP3: Next Generation Control: Monitoring and Sensing Systems

Dr Edd Stewart, University of Birmingham

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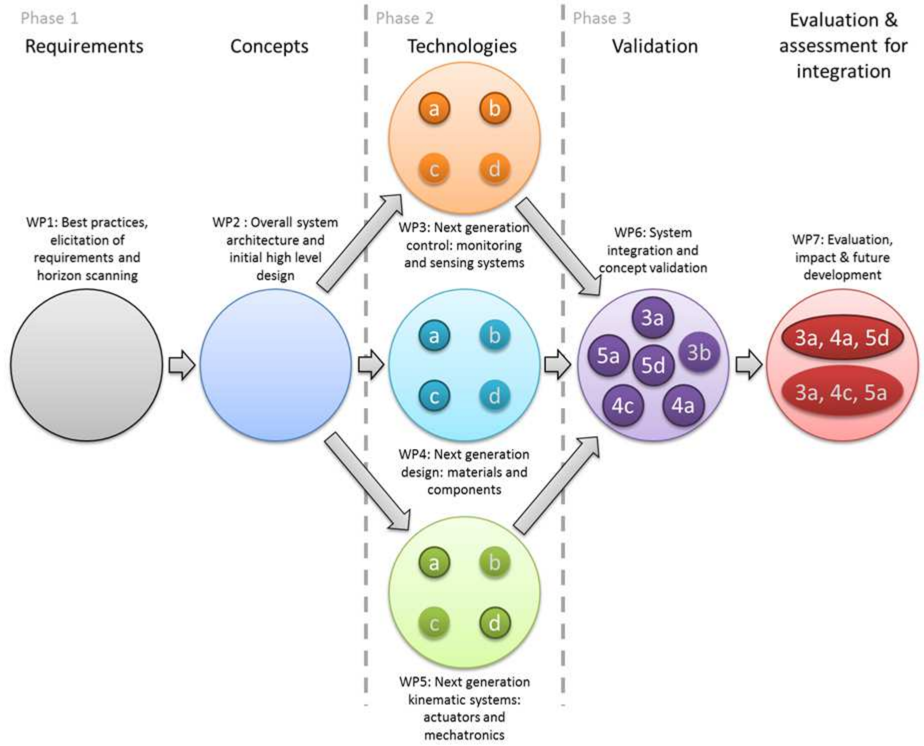
S-Code Phase 2

- Phase 1 – Finished
  - Requirements and initial design
- **Phase 2 – Started May ’17**
  - **Technical development**
- Phase 3 – Starts Sept ’18
  - Demonstration and evaluation



Phase 2

- WP3, WP4 and WP5 to TRL 3

Phase 3

- Further development and integration to TRL4

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S-CODE WP3 Partners

- 8 out of 9 partners
- 4 technology leads

WP3 Objectives

- O3.1 Development and integration of data and **sensor systems** to support the elimination of manual inspection and maintenance interventions

- O3.2 Development and integration of intelligent **self-diagnostic systems** capable of monitoring the current state-of-heath (and future states) which take account of the environment and external factors

- O3.3 Design of **fault-tolerant control systems** that support self- adjustment, self-correction, self-repair and self-heal

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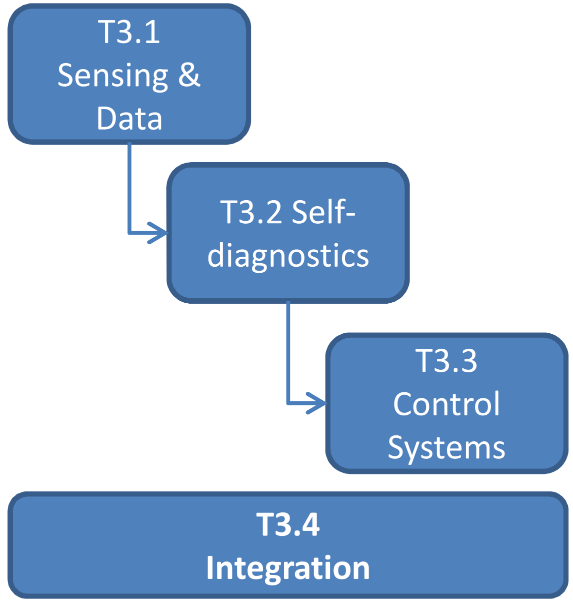
WP3

- T3.1
  - Develop embedded sensing systems
  - Identify key measurements / locations
  - Measurement technologies
  - Data storage / management
- T3.2
  - Self diagnostics and inspection
- T3.3
  - Control systems
- T3.4
  - Integration



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WP3 Targets and Work Streams

- Targets: Identify the best sensing technology to:
  - Ensure correct S&C functionality
  - Provide early warning for common problems with S&C
  - Automate S&C inspection and maintenance activities
- Work Streams:
  - Actuation control

    (local control and feedback to the interlocking)
  - Deterioration of the support or substructure
  - Inspection of the S&C

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WP3 Innovation Development Map

	TRL 4-7 **More conventional (could build)**	TRL 3-4 **Modelling and simulation**	TRL 2-3 **Conceptual design**	
Actuation monitoring and control	**A** Power, force, and displacement monitoring of S&C for actuator position control and condition indicators	**D** Self adjustment of S&C using advanced control system and embedded sensors, condition indicators used to trigger remote inspection and schedule maintenance	**G** Auto-recalibration of self-adjustment after maintenance. Integration with autonomous inspection to create a detailed assessment of the health of the switch and expected lifetime	**WP5**
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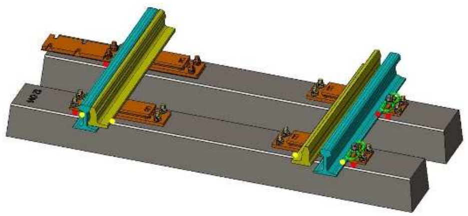
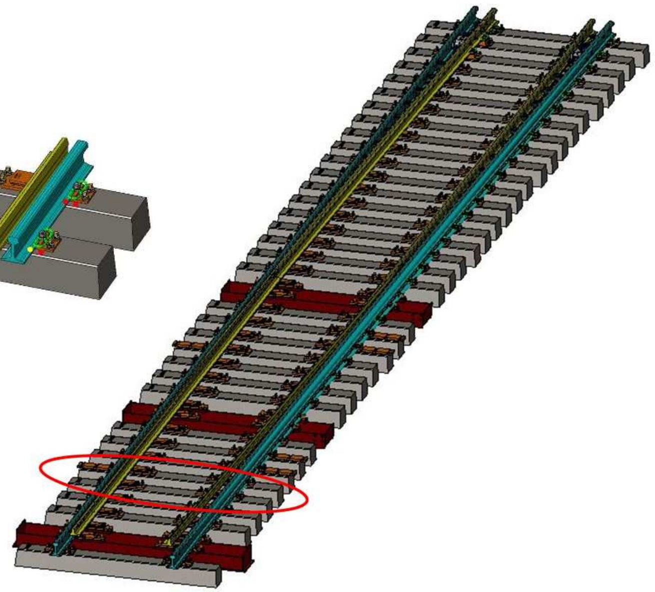
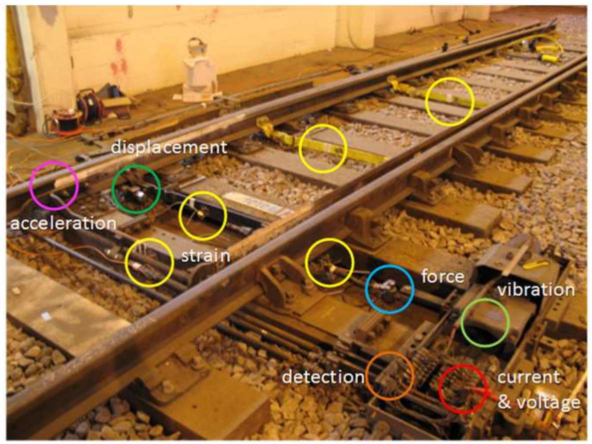
Embedded Sensing for Monitoring and Control

- Sensors embedded in the machine
  - Pressure
  - Displacement
  - Load pins or strain gauges
  - Current and voltage sensors
  - Vibration sensors on the motor
- Sensors embedded in the rails
  - Accelerometers along the S&C
  - Strain gauges in stretcher bars
  - Temperature
  - Smart washers
- Sensors that monitor externally
  - Microphones to listen for defects that generate noise in the machine or the mechanism
  - Cameras to look for obstructions, measure displacement and remote inspection







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Online Monitoring and Data Integration from Online Sources

- Online monitoring
  - Important for experts and maintenance teams
- Data integration from online / disparate sources
  - System can be aware of the railway vehicles that are passing over the S&C
  - Can include datasets from nearby weather stations to take temperature and rainfall into account
- Publishing data
  - Data from the monitoring system is made available online
  - Can be behind a secured framework
  - Other projects can make use of the data

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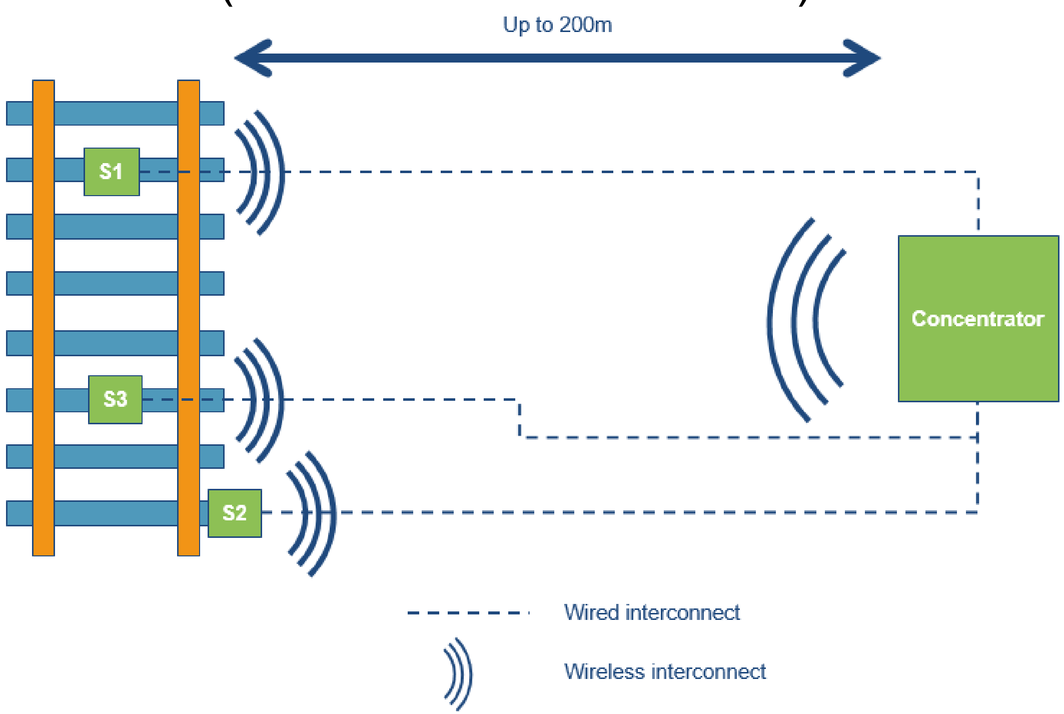
Ad hoc COMs Network and Standard Interface 'Plug & Play'

- Work with In2track (local communications)



- Will allow for multi-drop wired communications and ad-hoc wireless communications
- Will consider data rate and range requirements for the railway
- 3G/4G plug & play

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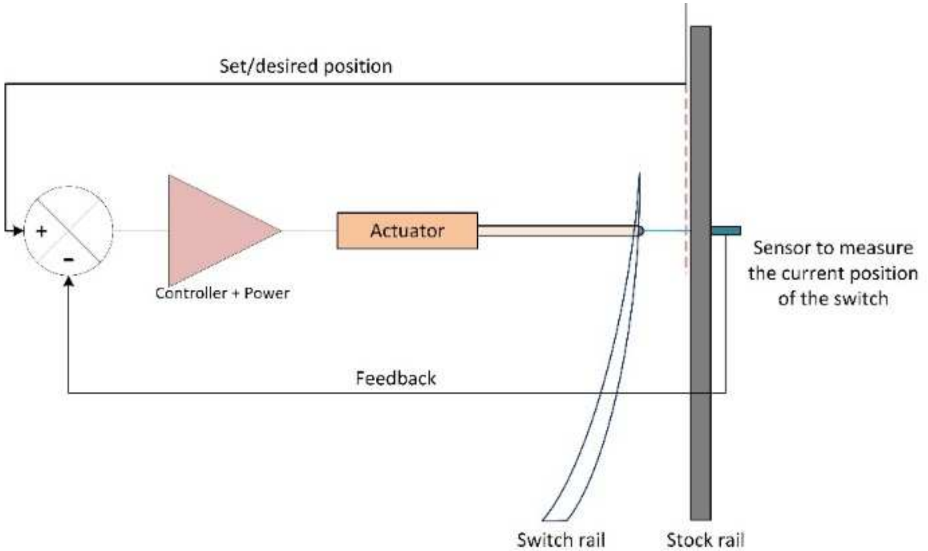
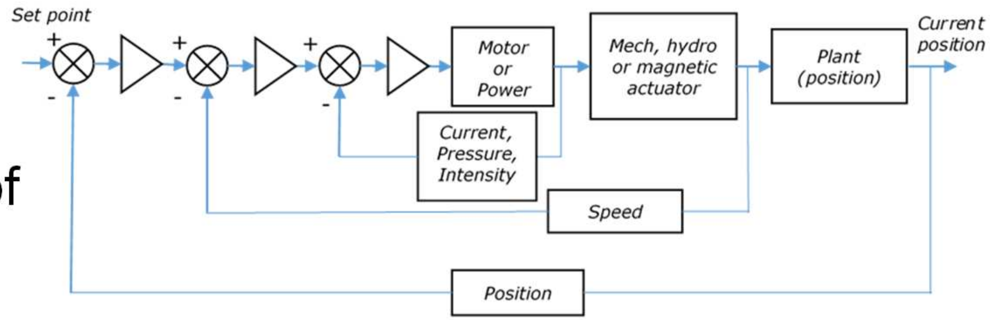
Linear Position Control

- Fault-control strategies will be developed for linear position control
- Three actuator mechanisms are being considered
  - electro-mechanical
  - electro-hydraulic
  - electro-magnetic
- Control will be tailored to selected actuator type
- Linear position control will be achieved through PID control of current
  - Speed and position measurements





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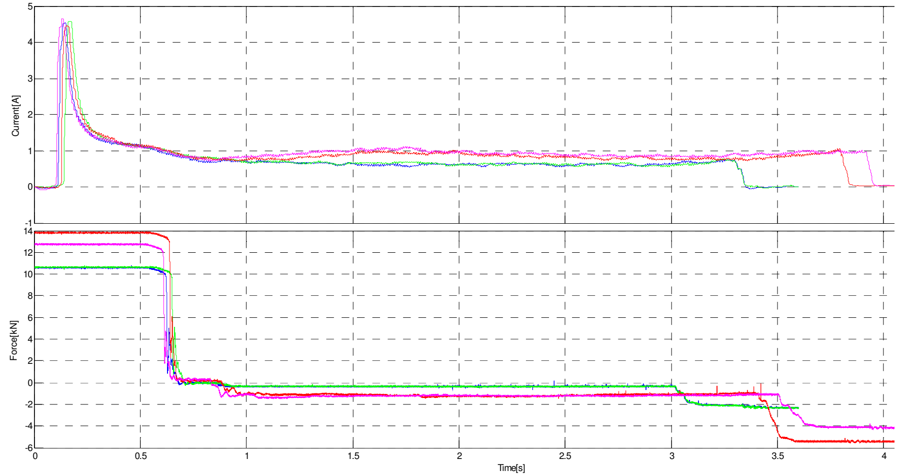
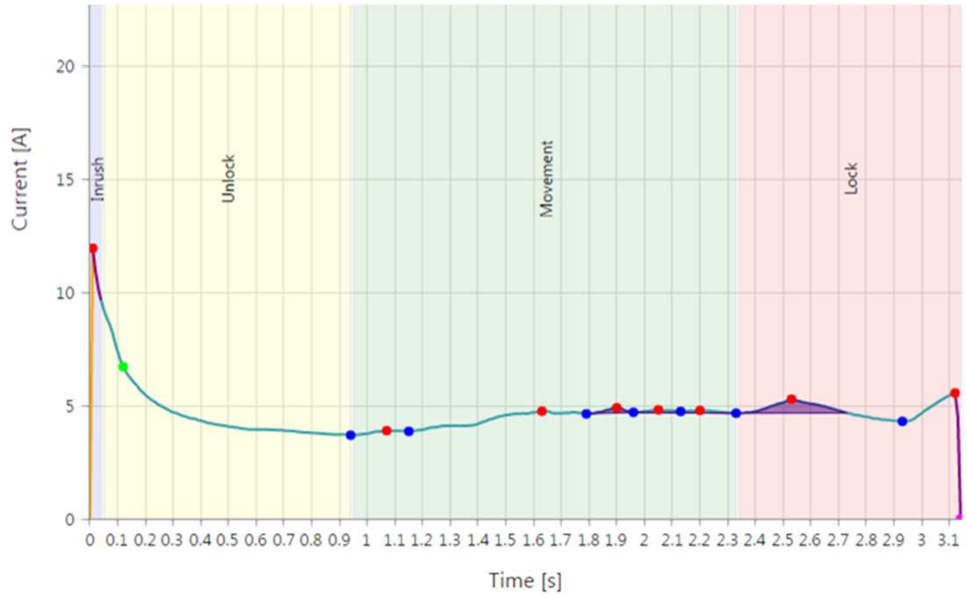
S&C Self-Diagnostic System - Motion

- Identification of faults during switch movement
- Machine and switch faults can be detected
  - Diagnosis is challenging using only current or force
- Algorithms used to classify faults and estimate health
  - Useful for control
- Integration with additional system-wide sensors
  - To identify fault locations
  - To trigger autonomous maintenance





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Self-Diagnostic System for Switch Actuators and Locking Mechanisms

- Sensors selection ongoing
  - Depends on the choice of kinematic system in WP5
  - UoB and L'boro initially prototyping architectures and algorithms for S&C immune system
- Model based monitoring of system parameters / states for the S&C system
- Algorithms used to classify the faults and estimate parameters / states
  - Useful for control
- "Standard" inputs
  - position, current, pressure, etc.
- "Non-standard" inputs
  - acoustic, vision, laser scanning etc.

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S&C Self-Diagnostic System
- Dynamic Effects

- Online monitoring of vibration during vehicle passage
- Accelerometer based sensing
- Evaluation:
  - Time scale (Min, Max, RMS, Crest Factor, etc.)
  - Frequency scale (FFT frequency intervals, position of the maximum peak in FFT spectrum, etc.)
  - Time-frequency scale (images comparison)

↓

Input into the neural network

↓

Capture faults / degradation at an early stage

↓

Identify type of fault and fault locations for repairs and trigger autonomous maintenance

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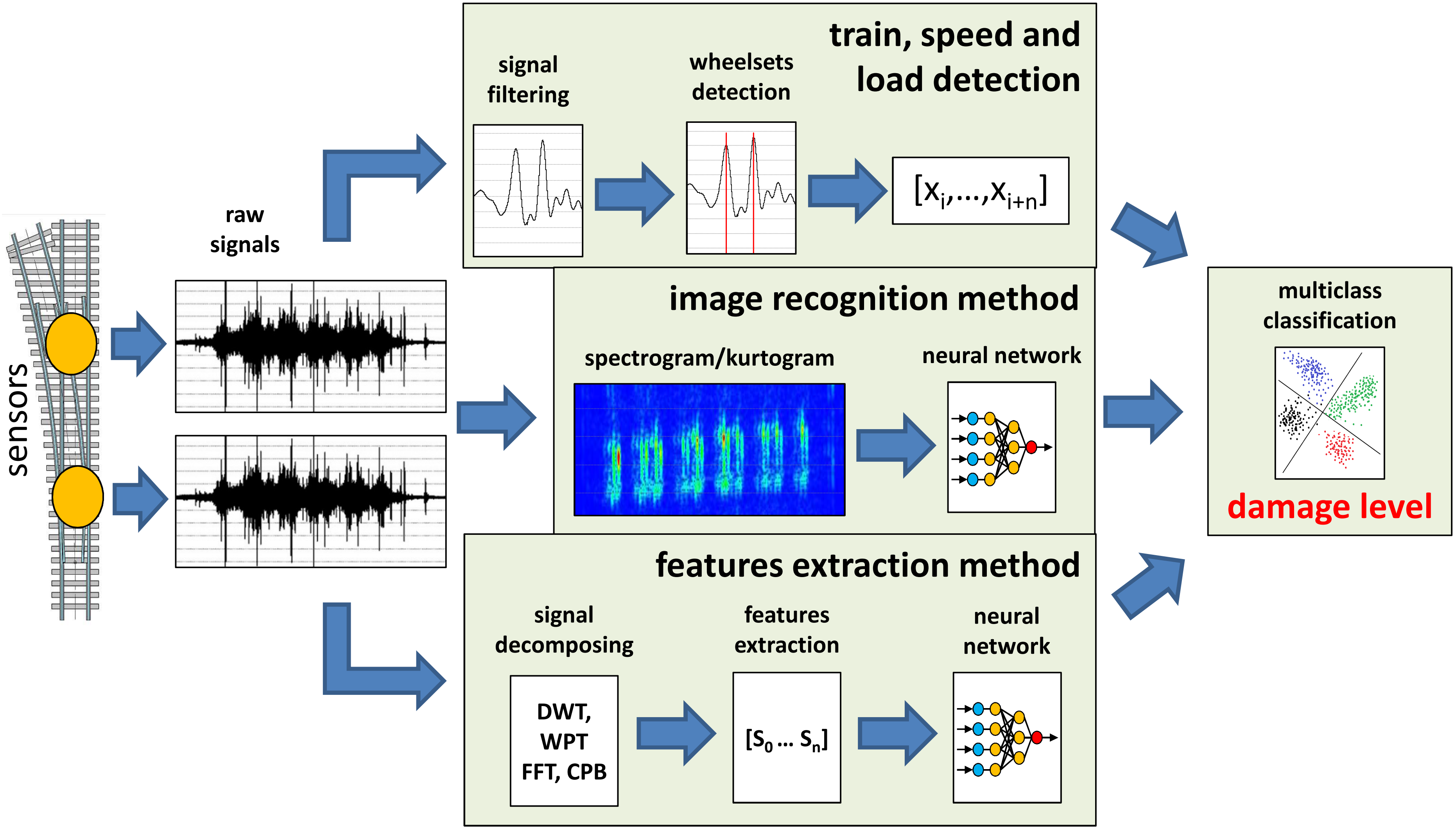
Neural Networks
- Fault Diagnostics and Prognostics



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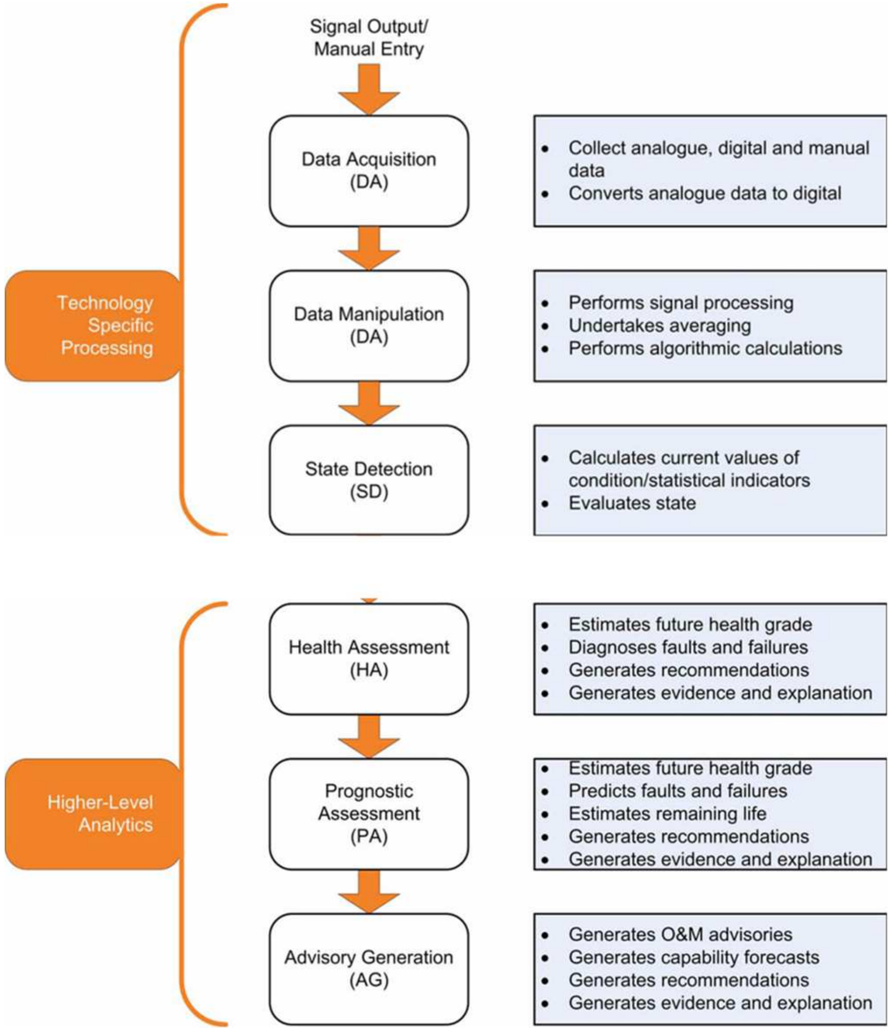
Adaptive and Learning Algorithms: ISO 13374

- Self diagnostic systems
  - Perform abstract health assessments
  - Trigger autonomous inspection systems
- Combined monitoring and inspection systems
  - Generate advisory on the action that must be taken



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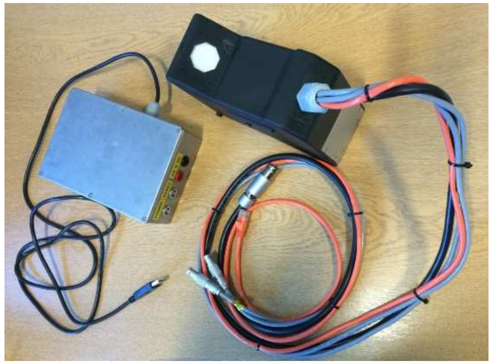
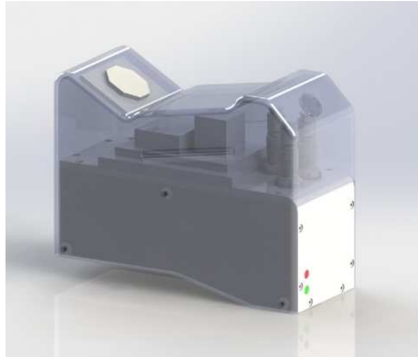
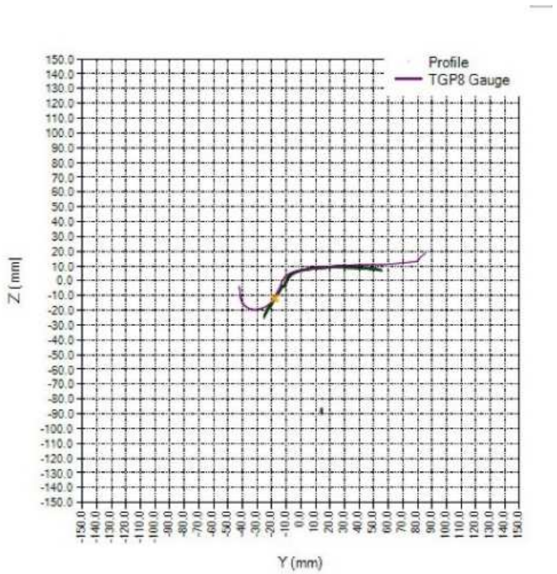
Hand-Held, Drone or Robot Operated Laser and Optical Inspection

- Real-time processing of laser sensor data interpreted alongside corresponding inertial measurements
- Real-time visualisation of rail / switch profile
- Analysis to standard tests
  - TGP8 virtual test on the measured switch / rail profile and visualisation of contact below 60°
  - Exporting measurement data and generating report of the TGP8 test
- Next steps
  - Miniaturising the hardware and adding an actuator so that it can be drone or robot mounted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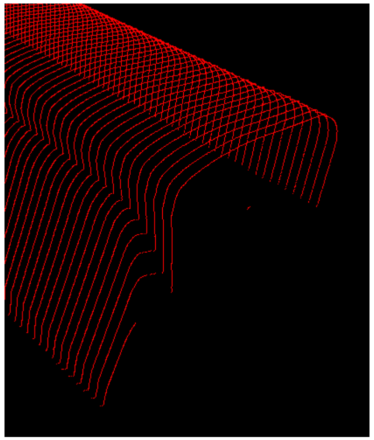
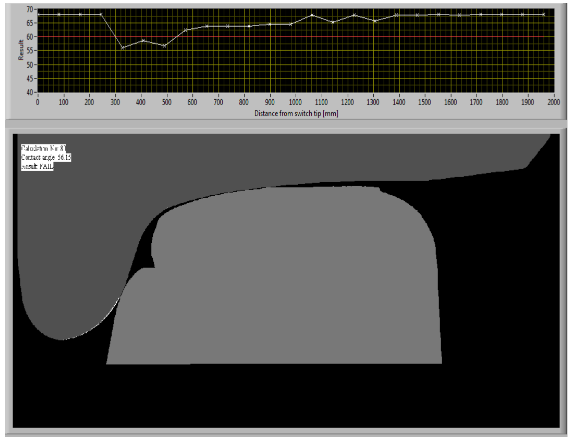
S&C Measurement Trolley / Robot

- Laser based inspection of S&C from trolley platform
- University prototype being developed with a company
- Automated evaluation to NR/L2/TRK/0053 and 0054 standards
- Other NDT sensors can be added to assess the quality of the rails
- Next steps
  - Miniaturising the hardware
  - Design of safe, completely autonomous movement as a rail-mounted robot
  - More sensors to meet more inspection standards





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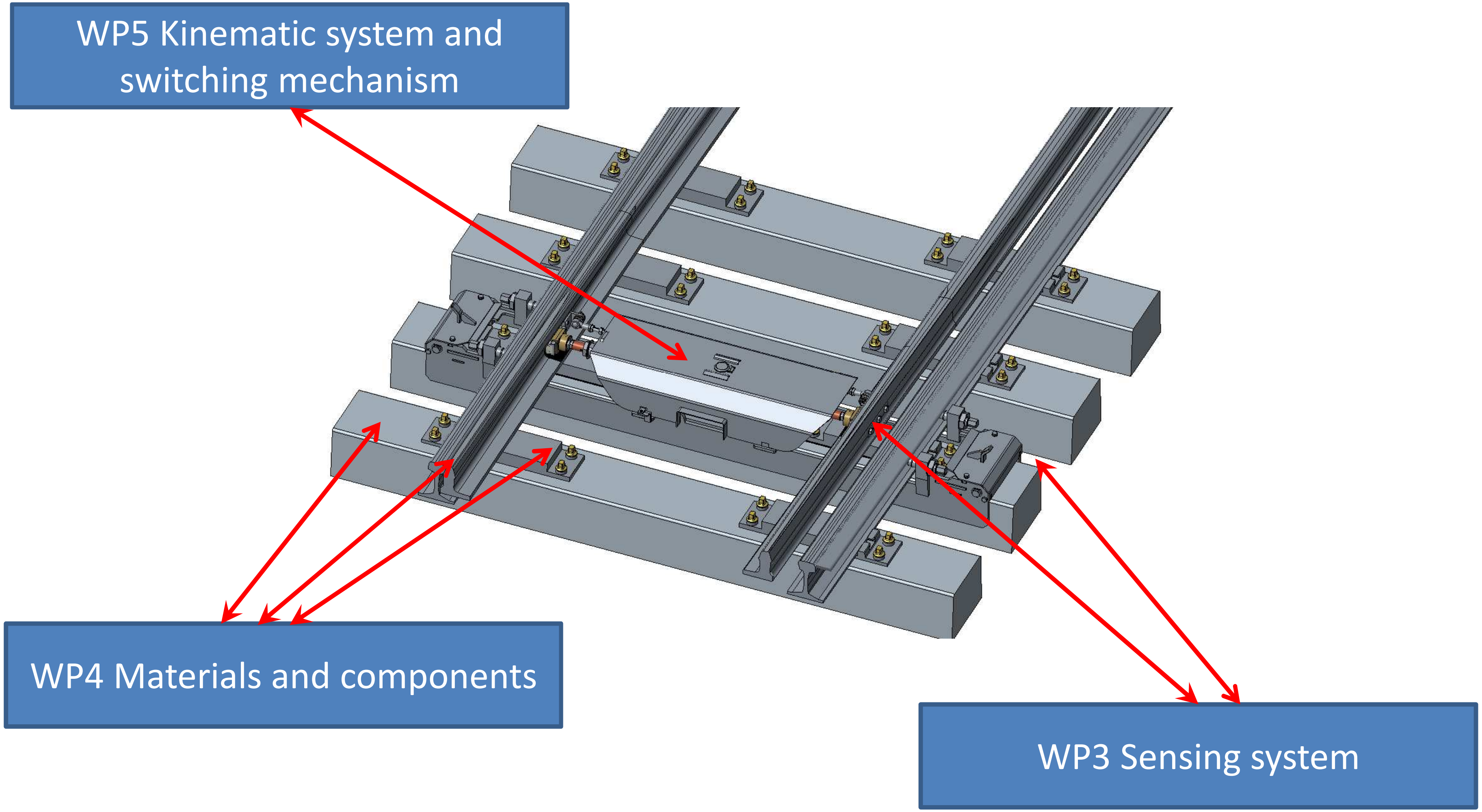
Integration of Work Packages



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Integration Strategy

- Sensors, switching mechanism and components must be compatible to have a final working turnout.
- The final product of integration will be a complex model, which will be used for BIM (building information modelling).
- Usage of suitable sensors will be based on chosen switching mechanism and on whole turnout structure.
- Usage of kinematic system will be based on chosen concepts and used materials and components.

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Next generation design: materials and components

Lukas Raif (DT – Výhybkárna a strojírna, a.s.)

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Innovation development map

		TRL 4-7 **More conventional**	TRL 3-4 **Modelling and simulation**	TRL 2-3 **Conceptual design**	
Track Stiffness Design	**Composite Bearers**	[A] FFU Sleepers; Neo Ballast; USP Bearers;	[E] Composite Sleepers with Harvesting Capacity	[I] 3D Printing FFU Sleepers; Self Healing Composites	**WP3 WP5**
	Self Healing Concrete	[B] High Damping Concrete Bearers and Slabs	[F] Self Monitoring Bearers	[J] Self Healing Concrete; 3D Printing of Concrete Slabs and Bearers	**WP3**
	Fastening Systems	[C] Tunable Stiffness Fasteners (active structure); Adjustable Level Fasteners	[G] Energy Harvesting Fasteners; Piezo Fasteners	[K] 3D Printing Fasteners	**WP3**
Rail Steel Improvement	**Bainitic Contact**	[D] Flashbutt Welding	[H] Functional Graded Steel Crossing	[L] 3D Printing Bainitic Steel	**WP5**

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Working package progress

Setting high level design:
Material and Components (WP2)

SWOT Analysis

Development chosen technologies:
- Composite sleepers and bearers
- Self-healing concrete
- Fastening systems
- Bainitic contact layer
- Additive manufacturing

System optimisation by:
- Wheel-rail interface model
- Substructure model

Integration with WP3 and WP5

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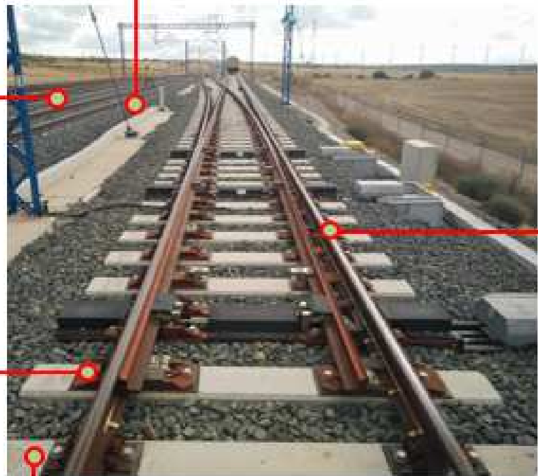
SWOT Analysis

S&C Elements & Materials



Elastomeric pad
- Other types of materials
  - Additive Manufacturing

Ballast
- New types of ballast

Slab
- Concrete + Reinforcement
  - Self-healing concrete
  - Concrete + geo-polymer
  - Concrete + Reinforcement (fibers)
  - Other types of materials: Composites
- Concrete 3D printing

Cast Steel
- New fastening systems

Sleepers
- Concrete + Reinforcement
- Wood
- Self-healing concrete
- Concrete + geo-polymer
- Concrete + Reinforcement (fibers)
- Other types of materials: Composites

Additive Manufacturing
- Concrete 3D printing
- In-situ (repairing)
- Factories (manufacturing)

Laminated Steel
- Carbon-Manganese Steel
- Pearlitic Microalloyed Steel (niobium and vanadium)
- Welding
  - No welding
- Twinning-Induced Plasticity Steel
- Other types of materials: Composites
- Low-wear Low-friction surfaces (for instance Teflon)
- "Self-healing" Steel
  - Capsule-based self-healing materials: DCPD filled microcapsules
  - Self-healing corrosion protection

Additive Manufacturing
- In-situ (repairing)
- Factories (manufacturing)
- Powder-bed systems: Direct Metal Laser Sintering
- Powder-fed systems: Laser Cladding
- Laser Engineered Net Shaping (LENS)

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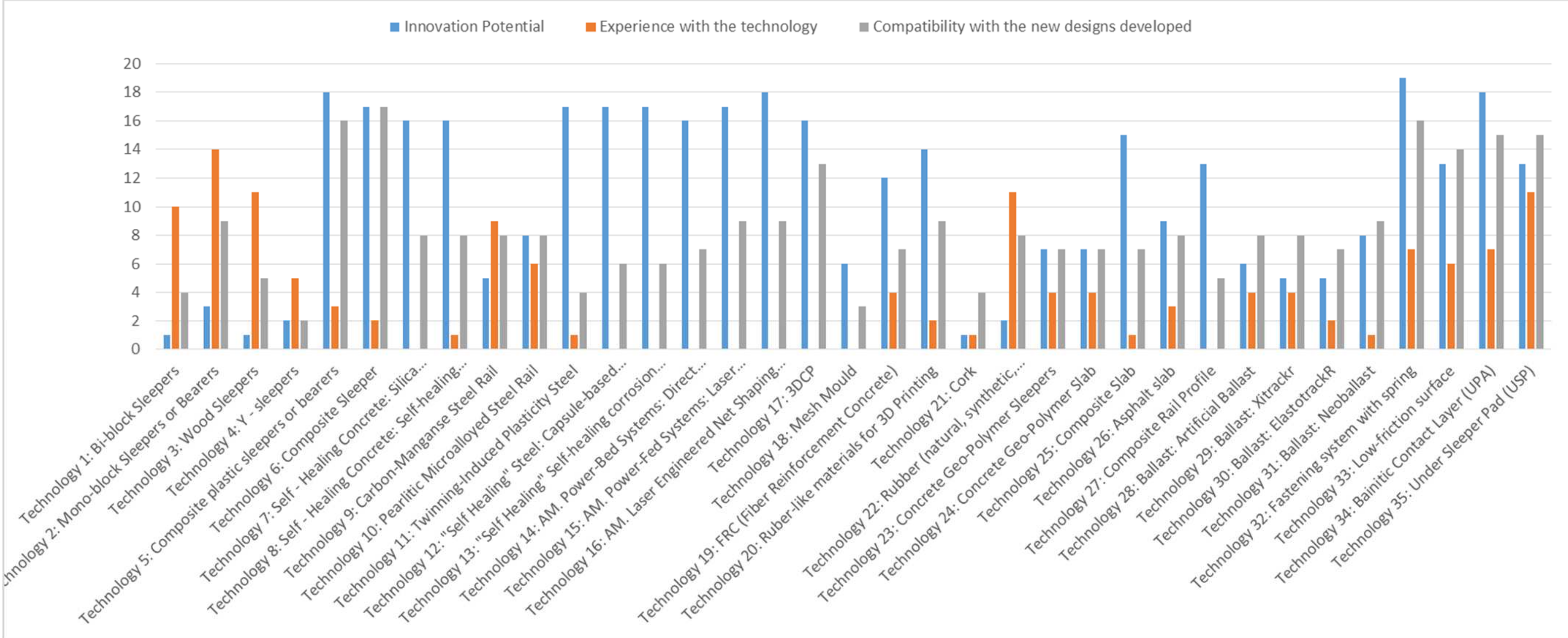
Technologies Prioritization



Selected technologies:

- **Technology 5**: Composite plastic sleepers or bearers
- **Technology 8**: Self-Healing Concrete: Self-healing of Concrete by Bacterial Mineral Precipitation
- **Technology 32**: Fastening system with spring
- **Technology 34**: Bainitic Contact Layer

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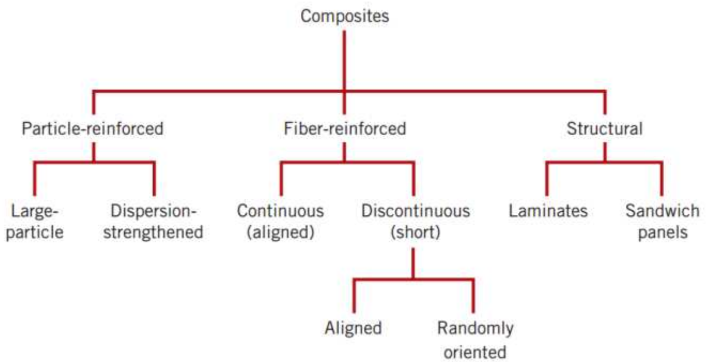
Composite sleepers and bearers

Shape optimisation (regarding switching and locking mechanism, distribution of mass and stiffness)

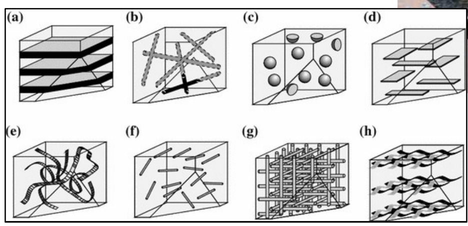
Better mechanical properties

Composite sleepers and bearers



Example of shape optimisation:

- Lankhorst plastic sleeper



Figures source: https://www.researchgate.net/profile/Victor_Eremeyev/publication/278648922/figure/fig11/AS:268010380328990@1440910062383/Figure-1-Classification-of-composites-a-laminate-b-irregular-reinforcement-c.png https://www.lankhorstrail.com/files/9/7/8/3/DSCF6005.JPG?height=458&width=610&mode=fill

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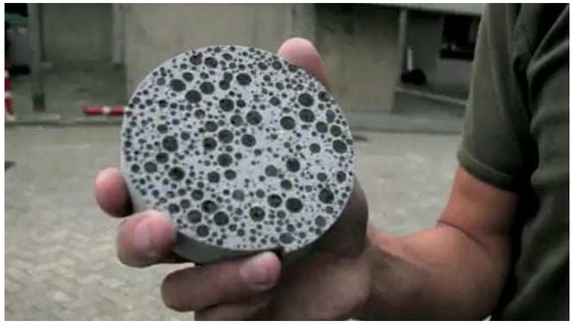
Self-healing concrete

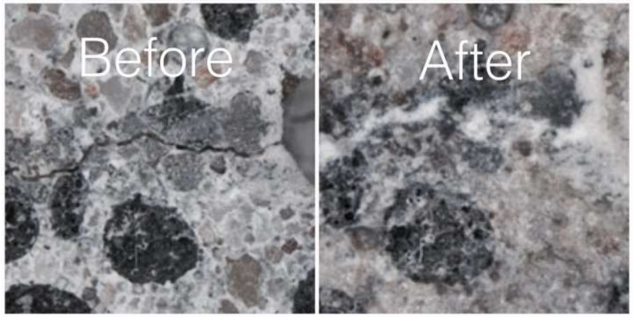
Sleepers and bearers

Slab track

Self-healing concrete

Principle of Bacterial Mineral Precipitation





Figures source: https://theconstructor.org/wp-content/uploads/2016/10/bacterial-concrete-self-healing-concrete.jpg https://happyho.in/wp-content/uploads/2016/05/Bio-Concrete.jpg http://www.zpsv.cz/ohl-group/reference/zs%20pevna%20jizdni%20draha%20rheda.jpg http://www.szdc.cz/obrazky/zeleznice-cr/historie/bezna-kolej/obr.87.jpg

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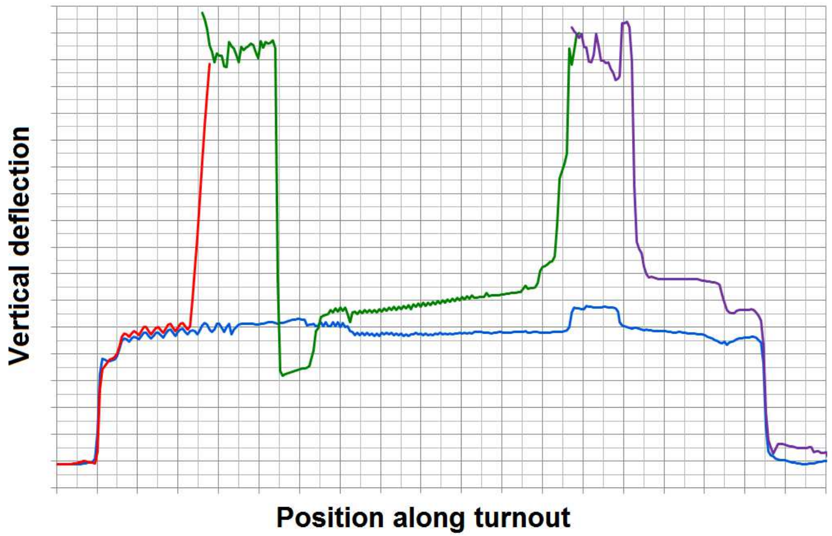
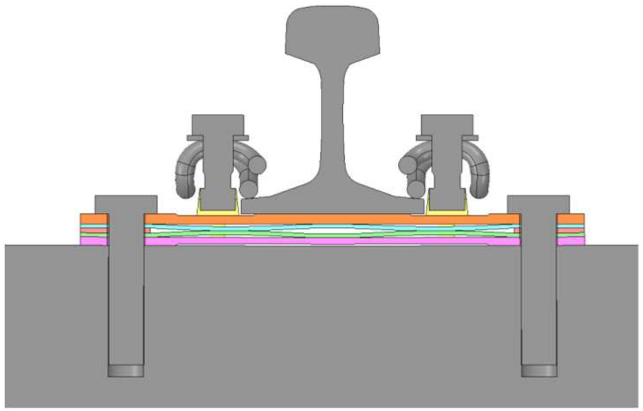
Fastening system

Stiffness irregularities along the turnout:



Optimal rail deflection: 1,5 mm

Fastening systems with tunable stiffness and adjustable level:



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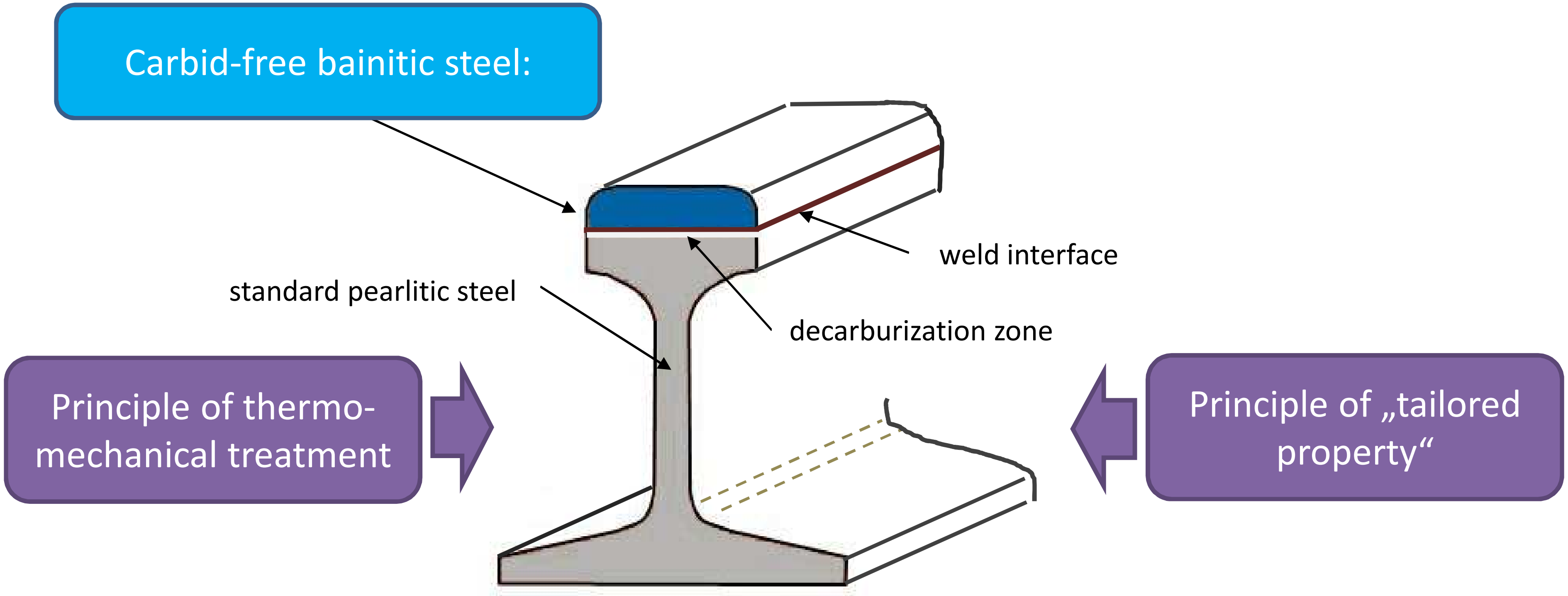
Bainitic contact layer

This concept brings a possibility to combine advantages of two processes:



… both are currently widely used for partial hardened B-pillar for auto-body.

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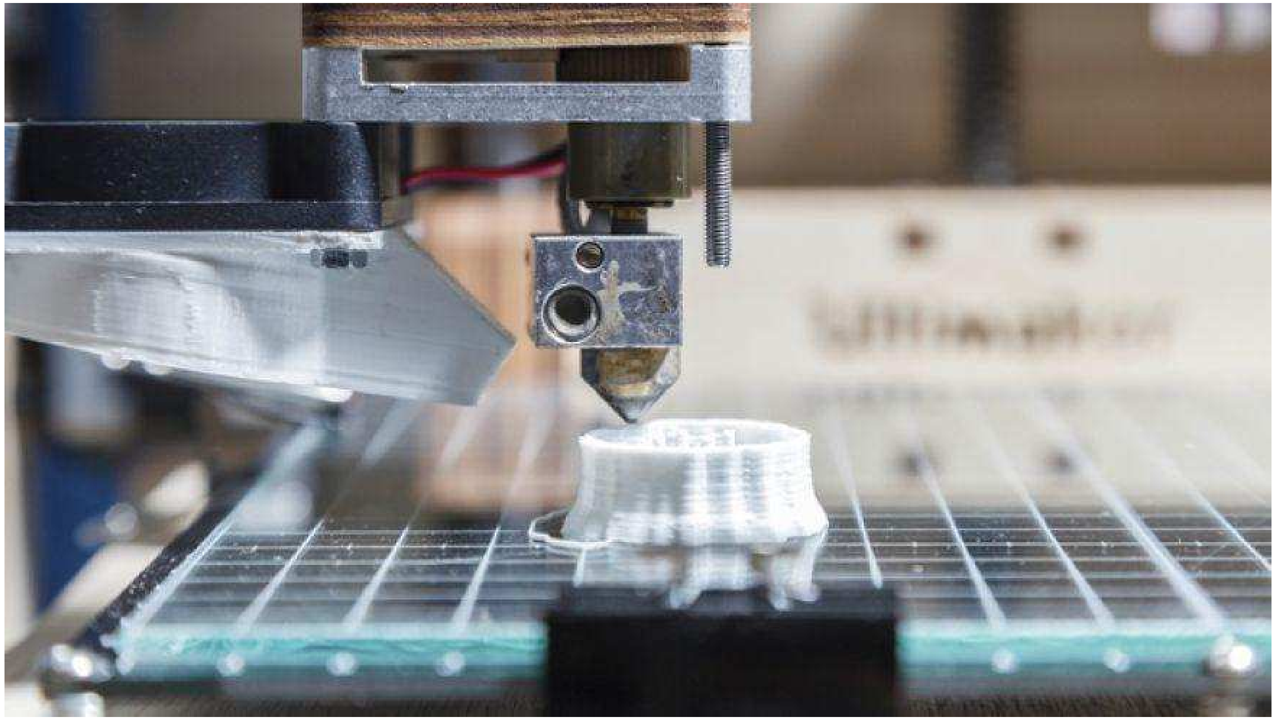
Additive manufacturing

Technology of additive manufacturing = 3D printing



Figures source: https://3dprint.com/wp-content/uploads/2016/05/3dpringtingstock661-2.jpg

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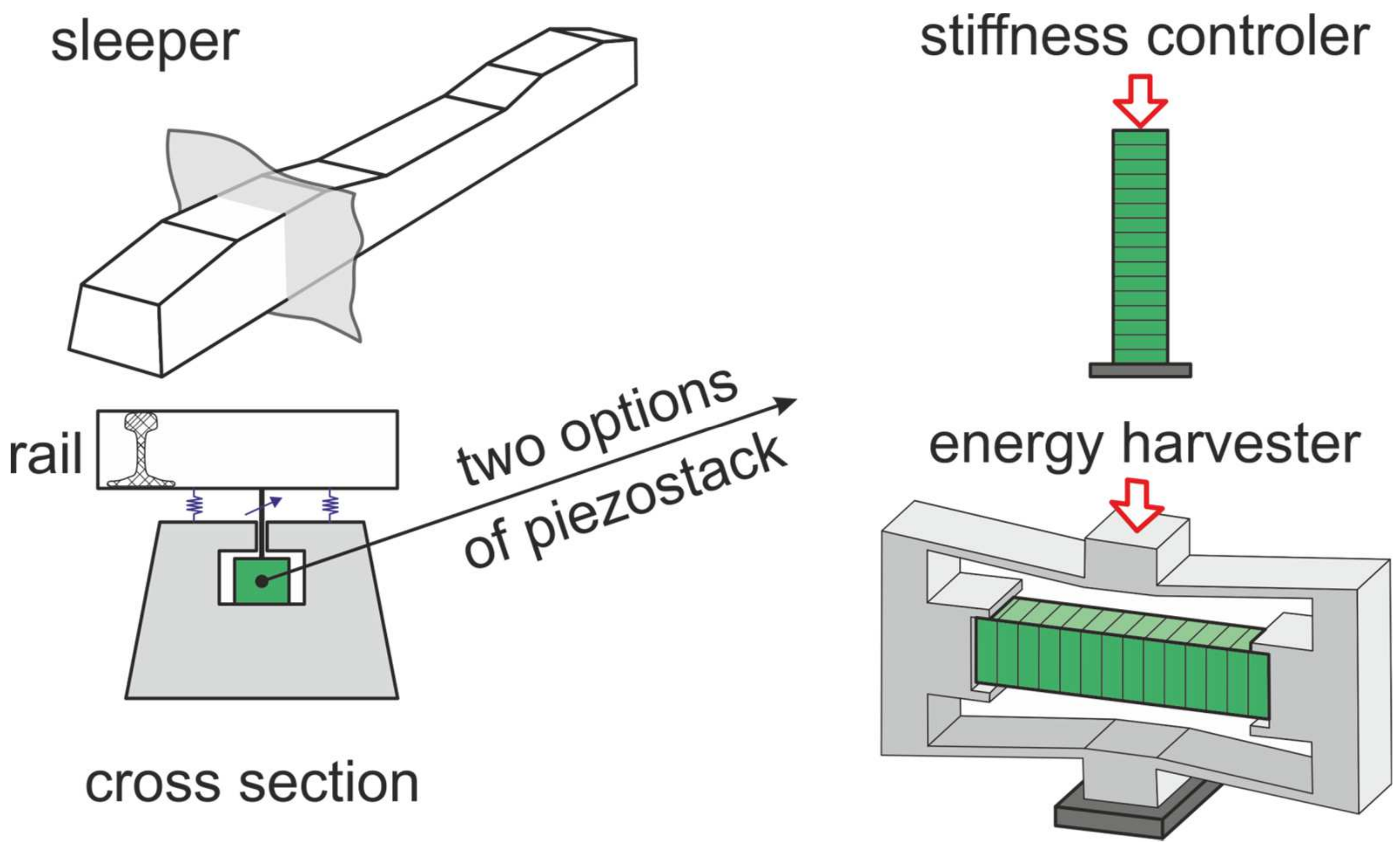
Smart Composite Sleeper

Energy harvesting



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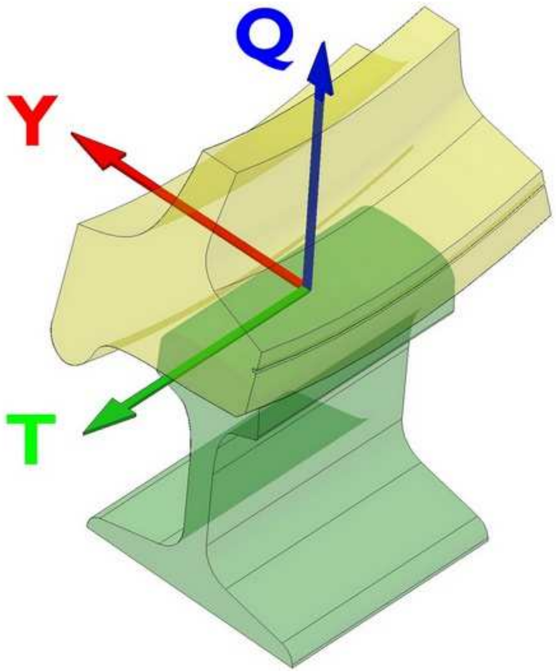
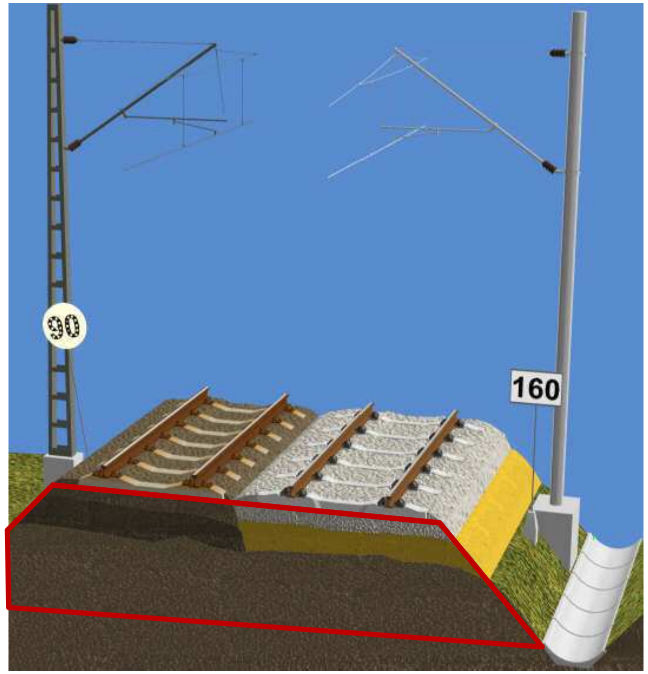
Milestones

Wheel-rail interface model



Substructure model



Figures source: https://www.k-report.net/koridory/images/korid.jpg http://www.zelpage.cz/story/ythomas1/dp-kv/pict_3.jpg

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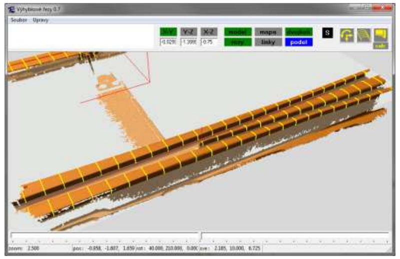
Wheel-rail interface model

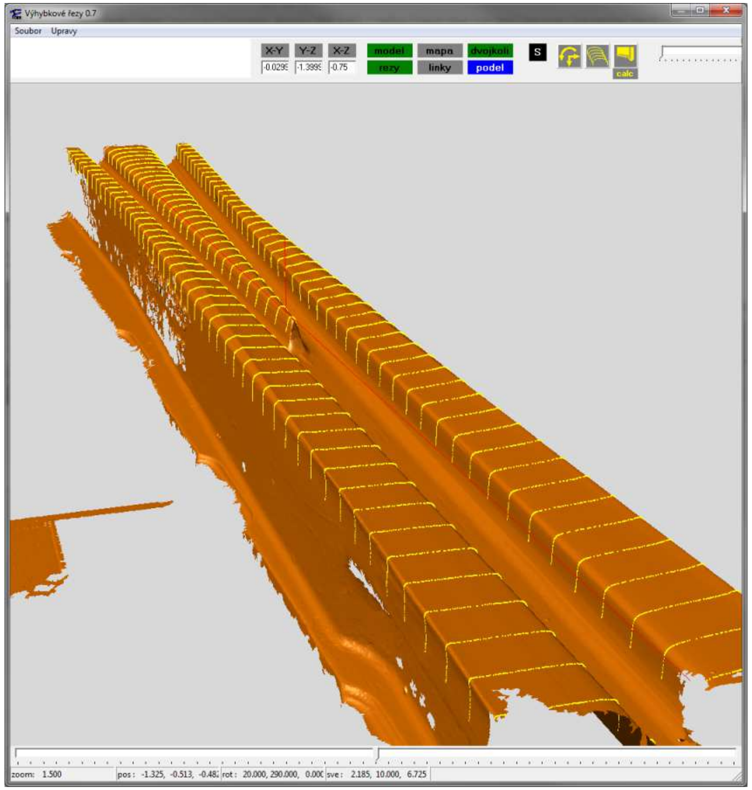
Sources of 3D geometry

3D scan of real S&C

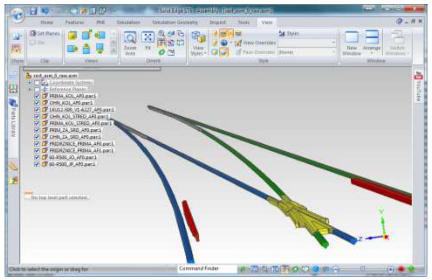
3D geometry



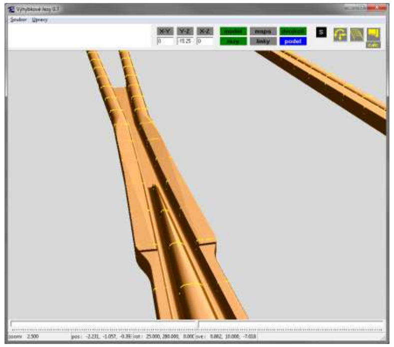
2D slices (cross sections)



3D model of S&C



3D geometry



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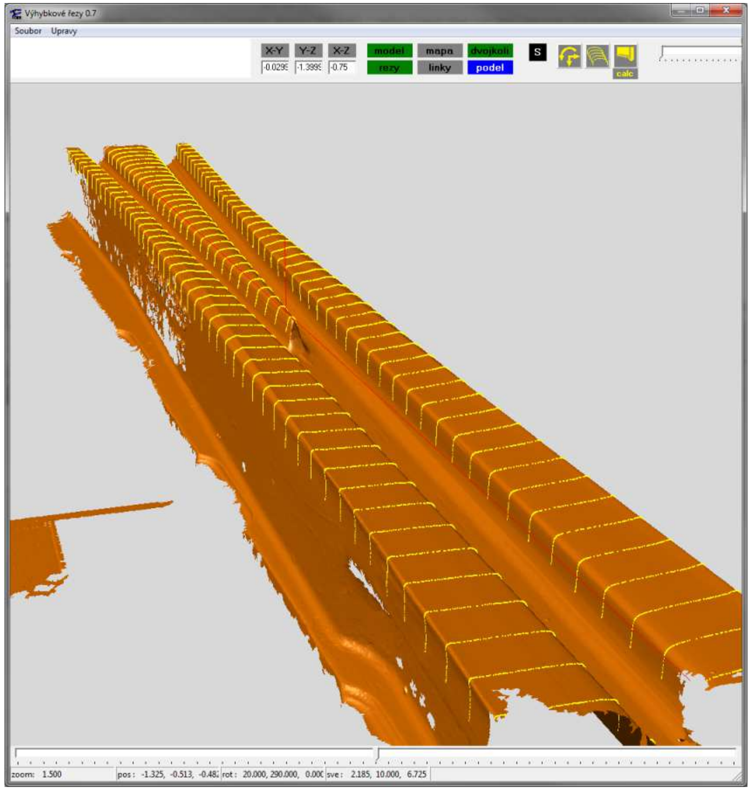
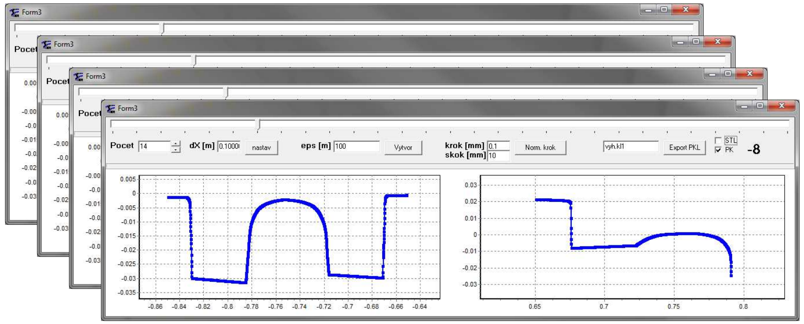
Wheel-rail interface model

Contact characteristics

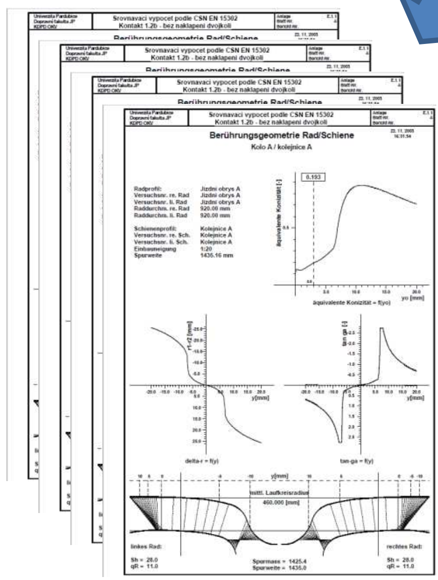
2D slices



rail profiles



contact geometry wheelset-track



MBS simulation software

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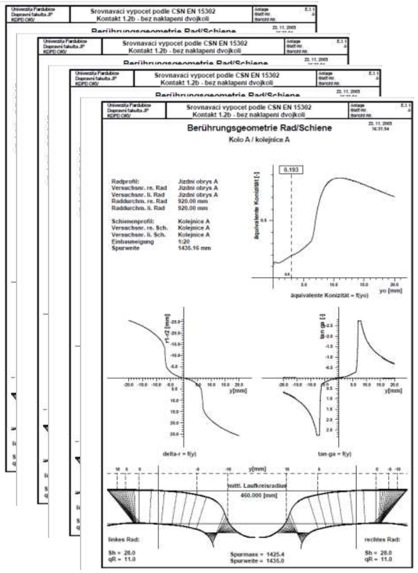
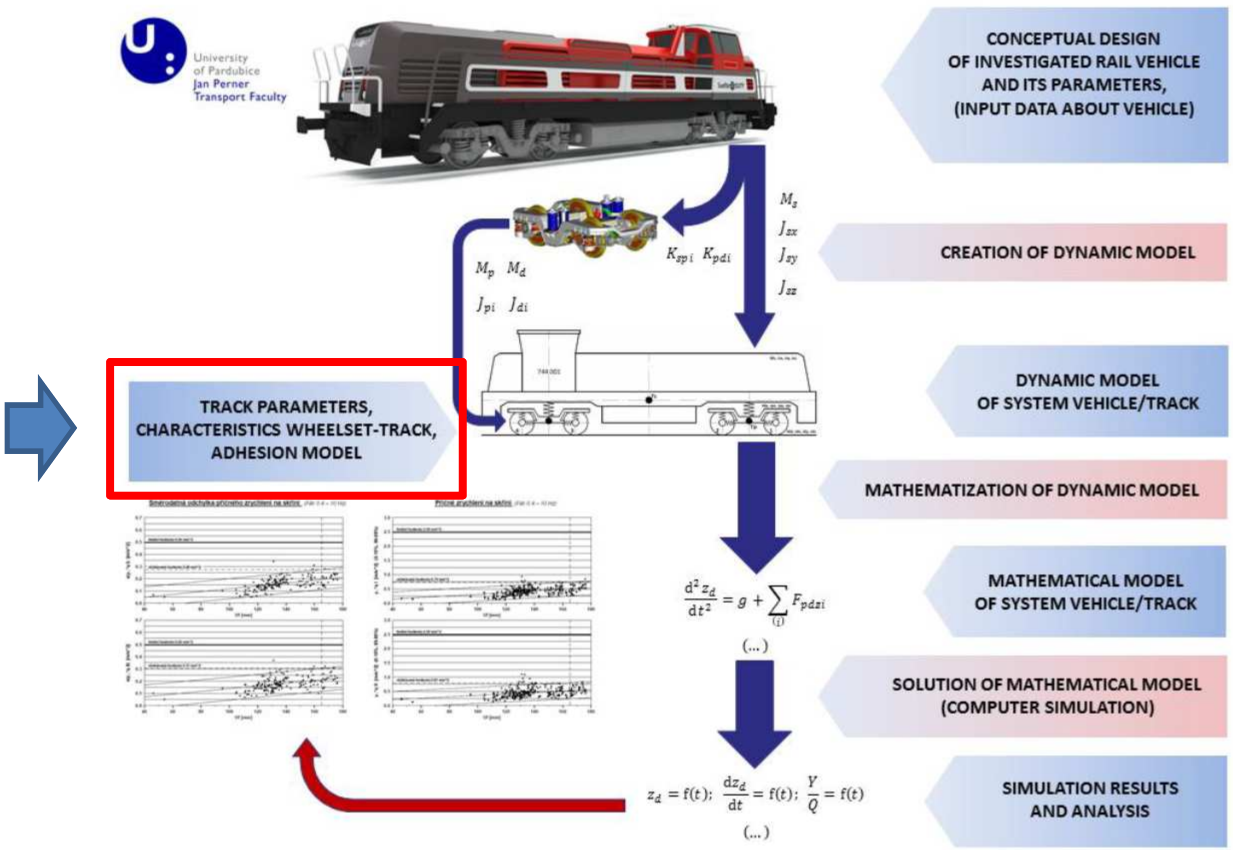
Wheel-rail interface model

Simulation inputs

contact geometry wheelset-track



MBS simulation software (SJKV)



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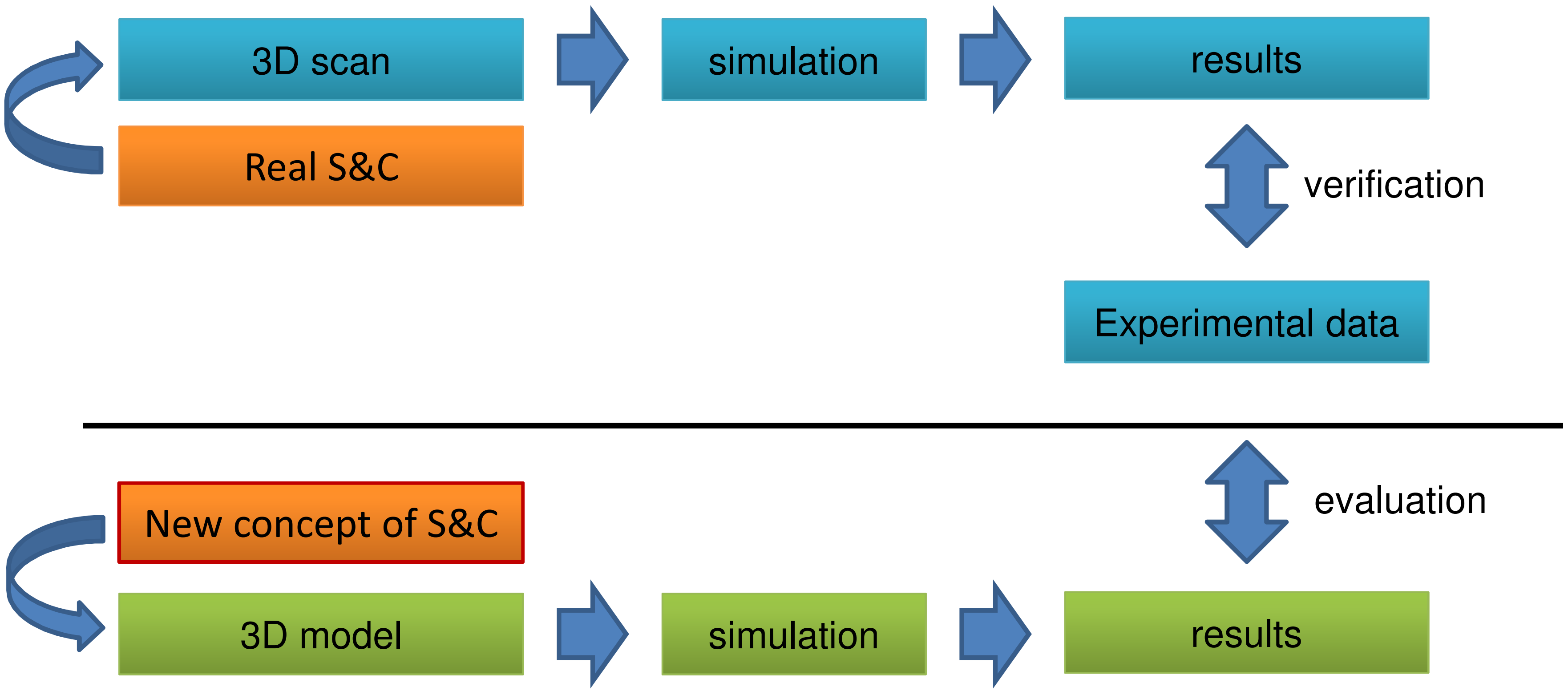
Wheel-rail interface model

Analysis of new concept



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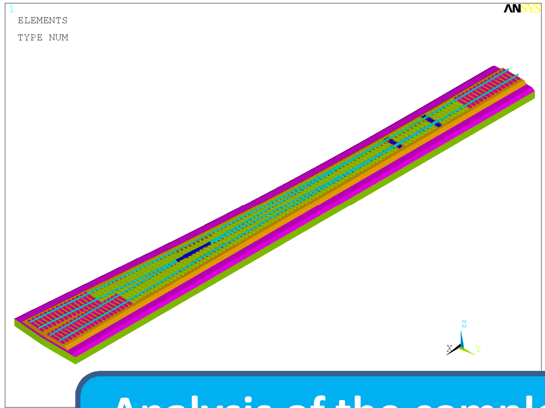
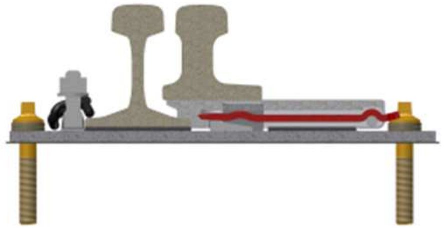
Substructure model

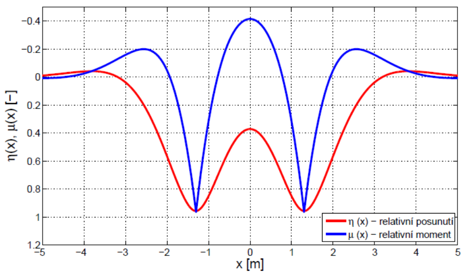


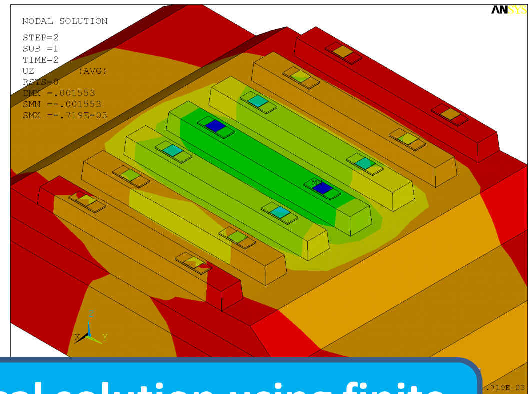
Substructure model



Analysis of the complex switch structure

Analysis of structural elements





Mathematical description using analytical models

Numerical solution using finite element method

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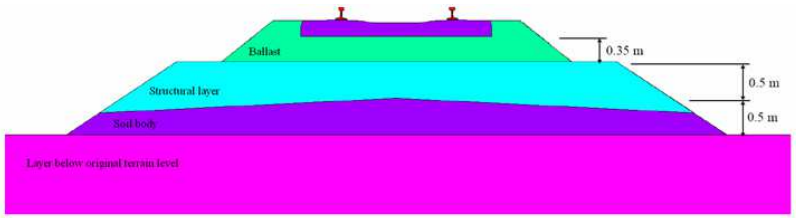
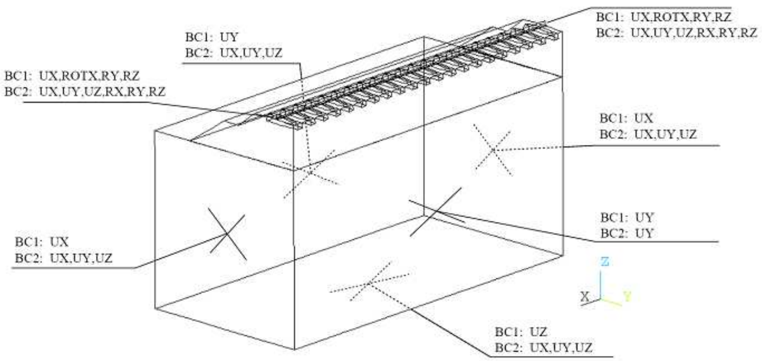
Substructure model

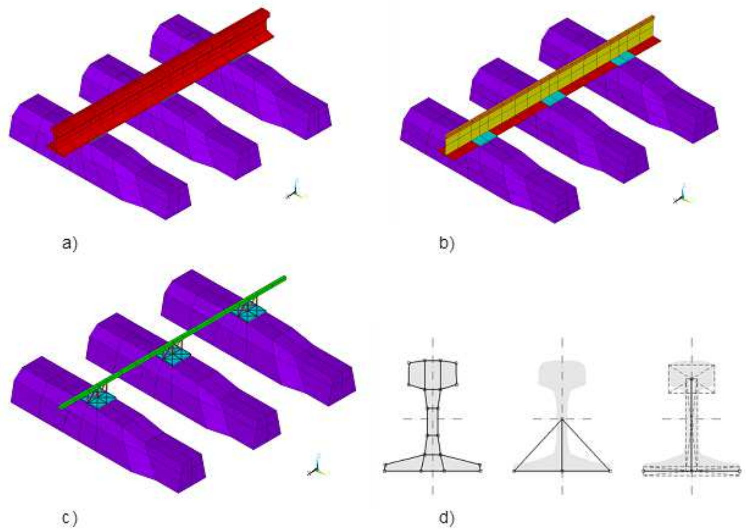
Cross-sectional layout of railway track geometry:



Boundary conditions:



Different alternatives of rail discretization:



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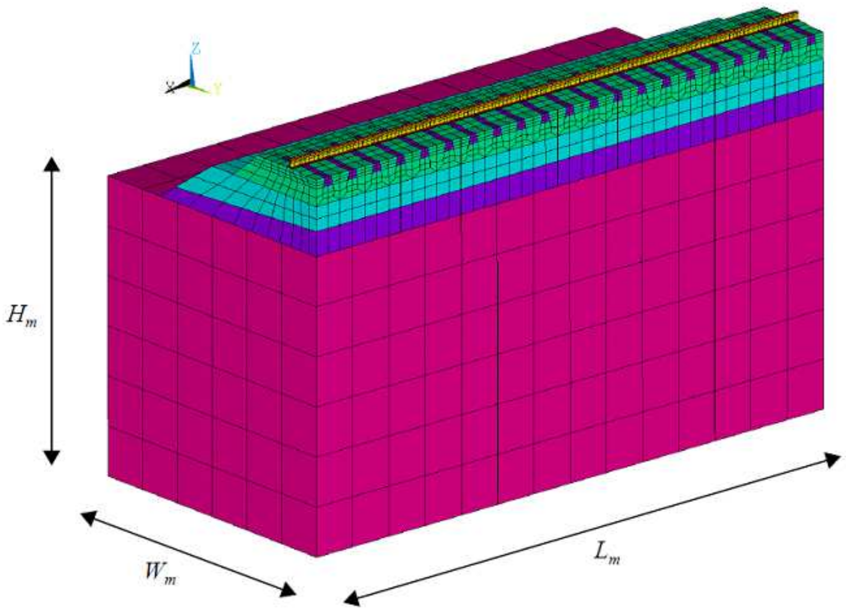
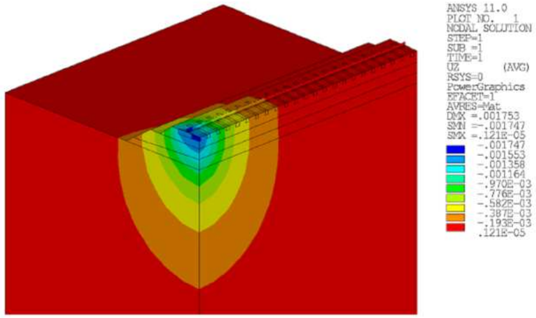
Substructure model

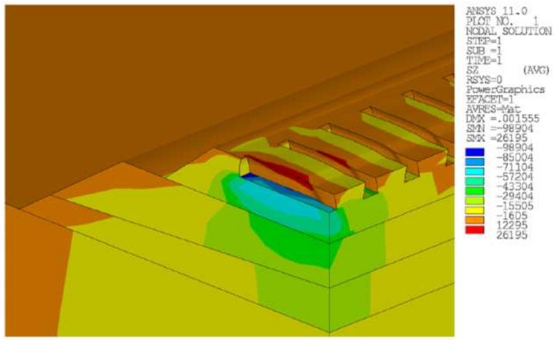
Computational model:



Field of railway track vertical displacements:



Field of sleepers' subsoil vertical stresses:



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Future steps

- Development of chosen technologies:
  - Composite plastic sleepers or bearers
  - Self-Healing Concrete: Self-healing of Concrete by Bacterial Mineral Precipitation
  - Fastening system with spring
  - Bainitic Contact Layer
  - Additive manufacturing
- Achievment of milestones:
  - Wheel-rail interface model
  - Substructure model
- Whole system optimisation
- Installation and logistic consideration
- System integration strategy
  - Interaction with WP3 and WP5

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Partners in WP4:

Thank you for attention!

Lukas Raif

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CODE

Next generation kinematic systems: actuators and mechatronics

Loughborough University

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Progress and future planning

Prof. Roger Dixon, Dr. Hitesh Boghani, Dr. Ramakrishnan Ambur, Dr. Christopher Ward and Prof. Roger Goodall

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Contents

- Overview of WP5
- Concepts for future S&Cs
- Mechatronic Design
  - Actuation
  - Locking
- Conclusion

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Innovation Development Map of WP5

S-Code innovation development map For WP5	TRL 4-7 **More conventional (could build)**	TRL 3-4 **Modelling, simulation or lab demo**	TRL 2-3 **Conceptual design**	
Actuation	A: Conventional actuators with new mechanisms	D: New S&C concept development Multiple actuation	G: Piezoelectric actuator (scaling up) Electro-active polymer based actuators	**WP4**
Locking	B: New locking mechanisms, active and passive	E: Magneto-rheological, Dilatant materials based locking mechanism	H: Electro-restrictive fluid based locking mechanism	**WP4**
Fault-tolerance	C: Analytical redundancy Hardware Redundancy	F: Self-inspection by embedded sensing, self-adjustment by using advance control	I: Highly redundant elements	**WP3**

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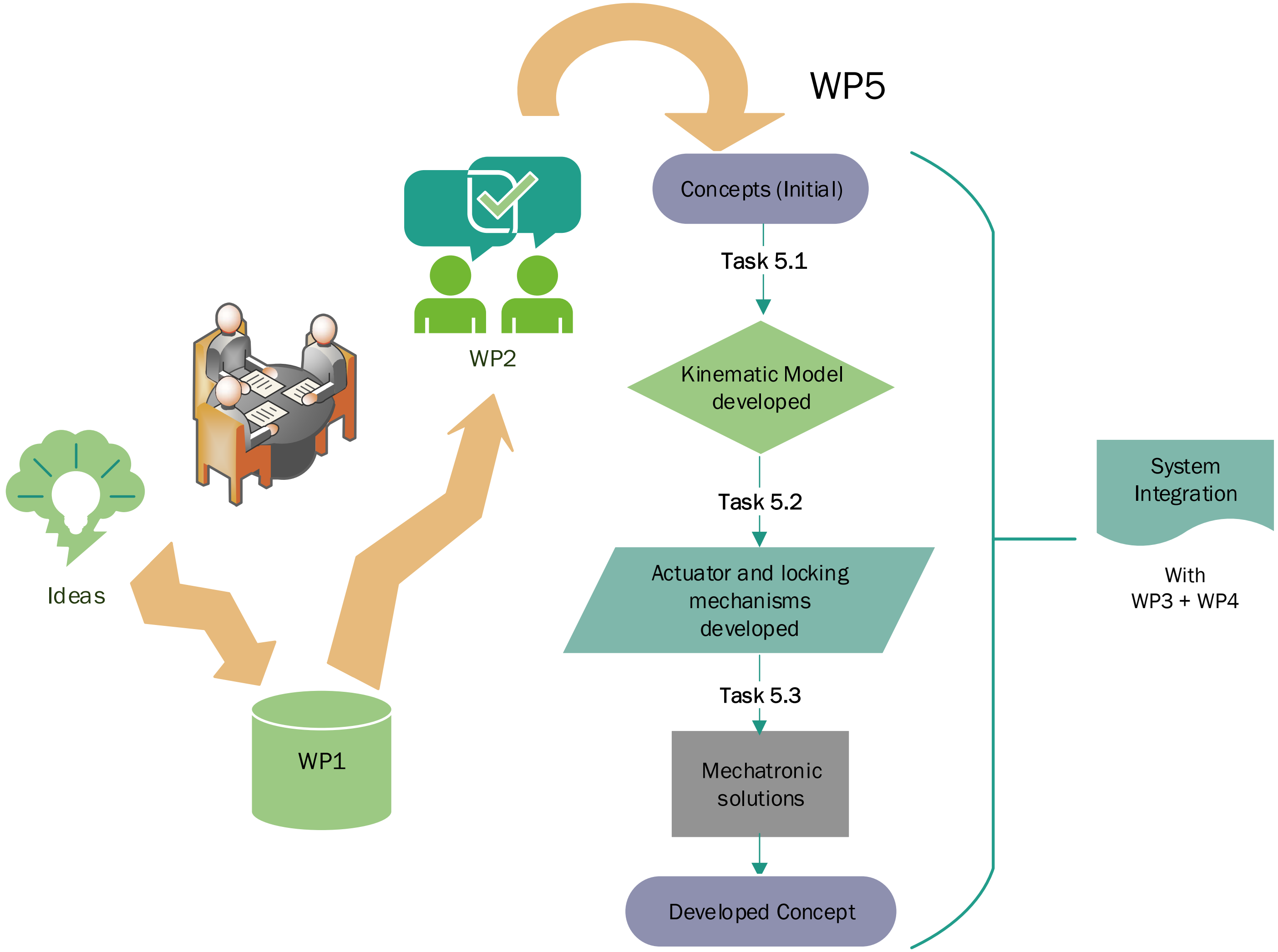
WP5 work flow



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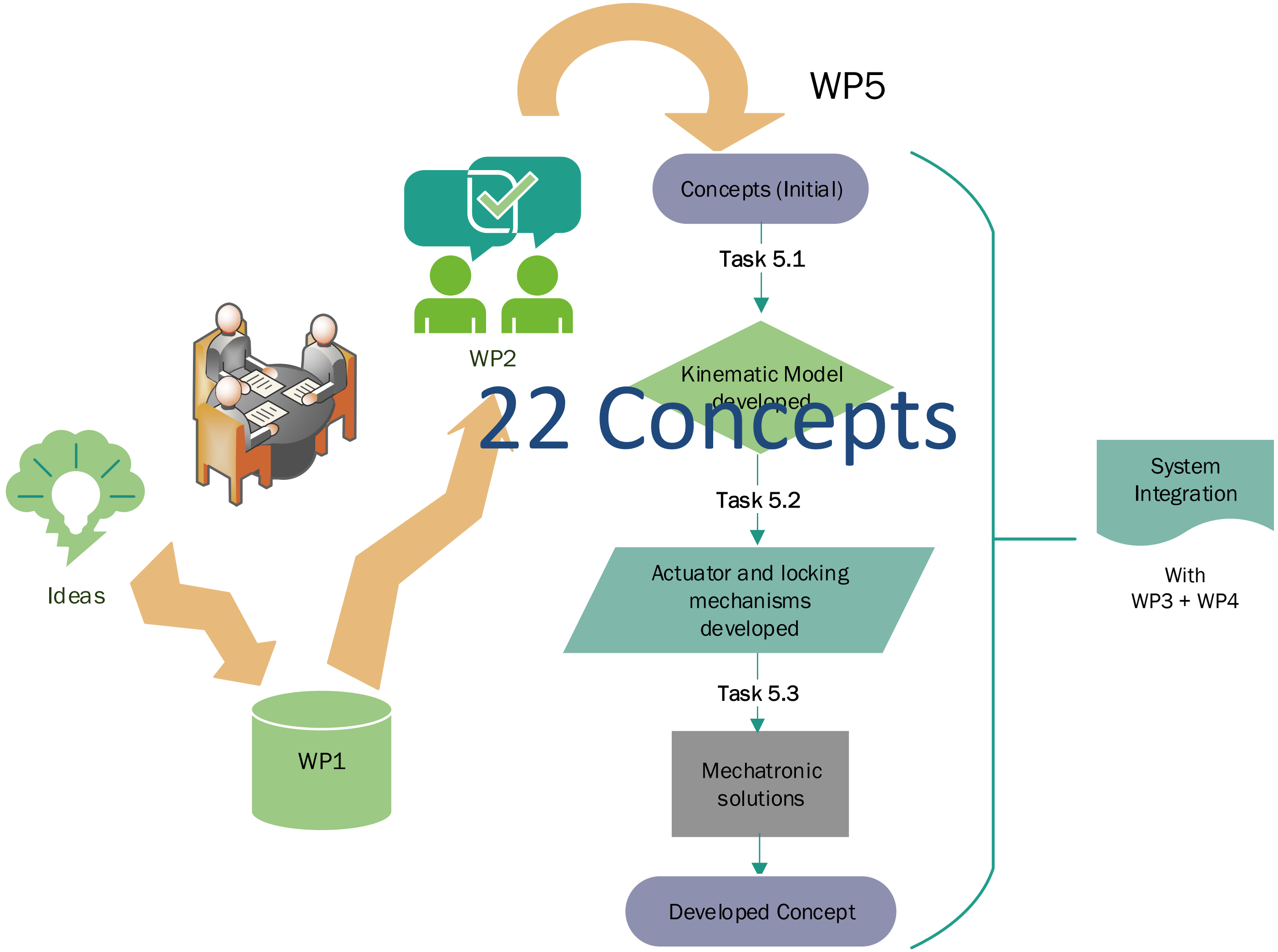
Concept evaluation



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Concept evaluation

S-CODE (WP2 - T2.1)

Concept Evaluation - Pugh Matrix

	Concept Selection Matrix	Weighting	Existing S&C	Concept A	Concept B	Concept C	Concept D	Concept E	Concept F	Concept G	Concept H	Concept I	Concept J	Concept K	Concept L	Concept M	Concept N	Concept O	Concept P	Concept Q	Concept R	Concept S	Concept T	Concept U	Concept V
Design	Radically different	0.105	0	4.75	4.90	4.95	5.70	2.25	4.35	1.90	2.80	5.55	4.75	5.05	4.40	5.00	6.85	6.80	5.10	5.45	7.00	6.50	6.05	5.80	5.85
	scaleable (can be adapted to various situations)	0.073	5	5.30	5.90	4.25	2.85	6.20	4.75	5.65	5.40	4.95	6.30	4.45	5.80	4.55	3.90	6.00	5.75	5.15	5.35	5.80	5.25	6.35	5.70
	Retrofitting	0.009	10	5.80	6.25	4.15	3.50	8.15	5.90	7.50	6.80	3.55	6.35	4.80	6.55	5.25	2.80	4.10	5.95	4.55	4.05	4.20	5.95	6.75	6.20
	Modularity	0.076	5	5.70	4.90	4.20	3.10	6.05	4.75	5.35	5.20	5.20	6.05	4.80	5.80	4.85	4.20	4.80	5.45	5.35	6.85	5.25	5.60	6.80	6.40
	Allows track continuity	0.073	5	5.15	7.20	5.30	4.75	6.20	5.45	6.70	6.55	4.60	6.25	4.85	5.70	6.35	7.15	4.95	4.85	5.30	4.05	5.80	5.80	6.65	6.05
Manufacturing	Existing machinery/process can be used?	0.015	10	7.58	6.90	6.05	5.40	8.65	6.75	8.65	8.15	5.65	7.40	6.05	7.30	7.55	4.05	5.30	7.30	7.70	5.00	4.50	6.75	5.75	6.15
Maintenance	Easy maintenance	0.07	5	5.15	4.30	3.60	2.65	5.60	4.10	4.70	4.30	4.60	4.40	3.75	4.50	4.25	3.20	4.35	4.50	5.05	2.85	3.15	4.90	4.35	4.10
	Allows maintenance to be done offsite	0.038	5	5.75	4.90	3.55	2.70	4.75	4.60	4.70	4.35	5.10	5.55	4.65	5.45	4.45	3.35	6.45	4.95	4.80	5.50	6.60	5.30	5.20	5.30
Logistics	Deployability	0.073	5	5.05	5.15	3.05	2.30	5.50	4.75	5.30	4.90	4.10	4.95	4.40	5.00	4.45	2.70	4.55	4.60	4.55	4.60	4.15	4.60	5.40	5.10
	Plug and Play?	0.073	5	5.35	5.45	4.25	3.75	5.80	4.60	5.00	4.95	4.10	5.25	4.50	4.80	4.30	3.80	4.55	5.05	5.15	4.60	4.75	5.00	5.25	5.05
Operation	Energy efficiency	0.015	5	4.20	5.45	2.60	3.35	5.65	5.75	4.50	3.95	6.45	4.50	4.90	4.30	4.85	3.45	5.35	5.10	5.20	2.75	4.45	4.10	5.15	5.75
	Speed of switching	0.044	5	5.10	5.25	3.05	3.00	5.30	5.35	4.65	4.80	5.55	4.80	4.80	4.40	4.65	3.20	5.55	5.15	5.35	3.60	5.05	4.05	5.35	5.45
	Improvement in loading?	0.056	5	5.85	5.40	5.40	3.65	6.35	4.70	6.70	6.30	4.70	6.55	4.60	5.85	6.10	4.60	5.35	4.75	5.05	4.20	4.85	5.65	5.60	5.70
	Weather resistance	0.067	5	5.05	5.95	4.75	4.20	5.35	4.75	4.75	4.30	5.50	4.60	4.70	4.30	4.45	4.05	6.85	5.25	5.55	4.00	6.05	4.50	4.85	4.00
Safety	Risk of derailment can be reduced	0.082	5	5.80	5.65	5.85	5.25	4.75	5.15	5.85	5.70	4.75	5.75	4.90	5.45	5.15	4.15	3.90	4.90	3.20	5.35	3.60	5.55	5.45	5.20
	Allows safe run-through	0.032	5	2.95	3.90	2.70	2.60	5.15	4.50	4.95	4.60	5.60	3.50	3.65	3.00	3.65	3.50	6.35	3.95	3.80	3.10	5.85	3.90	4.70	5.70
	Reduction of Out Of Correspondence	0.067	5	5.50	5.65	4.65	4.15	5.20	5.20	4.70	4.50	6.25	4.05	4.60	4.30	5.00	4.30	5.05	5.10	4.85	3.90	5.30	4.95	5.25	5.30
Other	Time to market	0.015	10	6.40	6.60	6.15	5.65	7.90	5.55	8.40	7.40	3.85	6.75	4.95	5.60	6.00	3.35	3.10	5.35	5.45	3.85	3.35	4.95	4.65	4.50
	Cost	0.018	5	4.75	5.00	3.35	3.15	5.85	4.60	4.85	4.30	2.50	4.10	3.45	4.70	4.10	2.70	1.85	4.45	4.00	2.65	2.50	4.50	3.80	3.65
Weighted Sum			5	5.27	5.43	4.40	3.83	5.35	4.84	5.09	4.94	4.97	5.28	4.61	5.01	4.90	4.32	5.23	5.04	4.97	4.74	5.05	5.19	5.53	5.34
Rank			19	6	2	21	23	3	17	9	15	14	5	20	12	16	22	7	11	13	18	10	8	1	4

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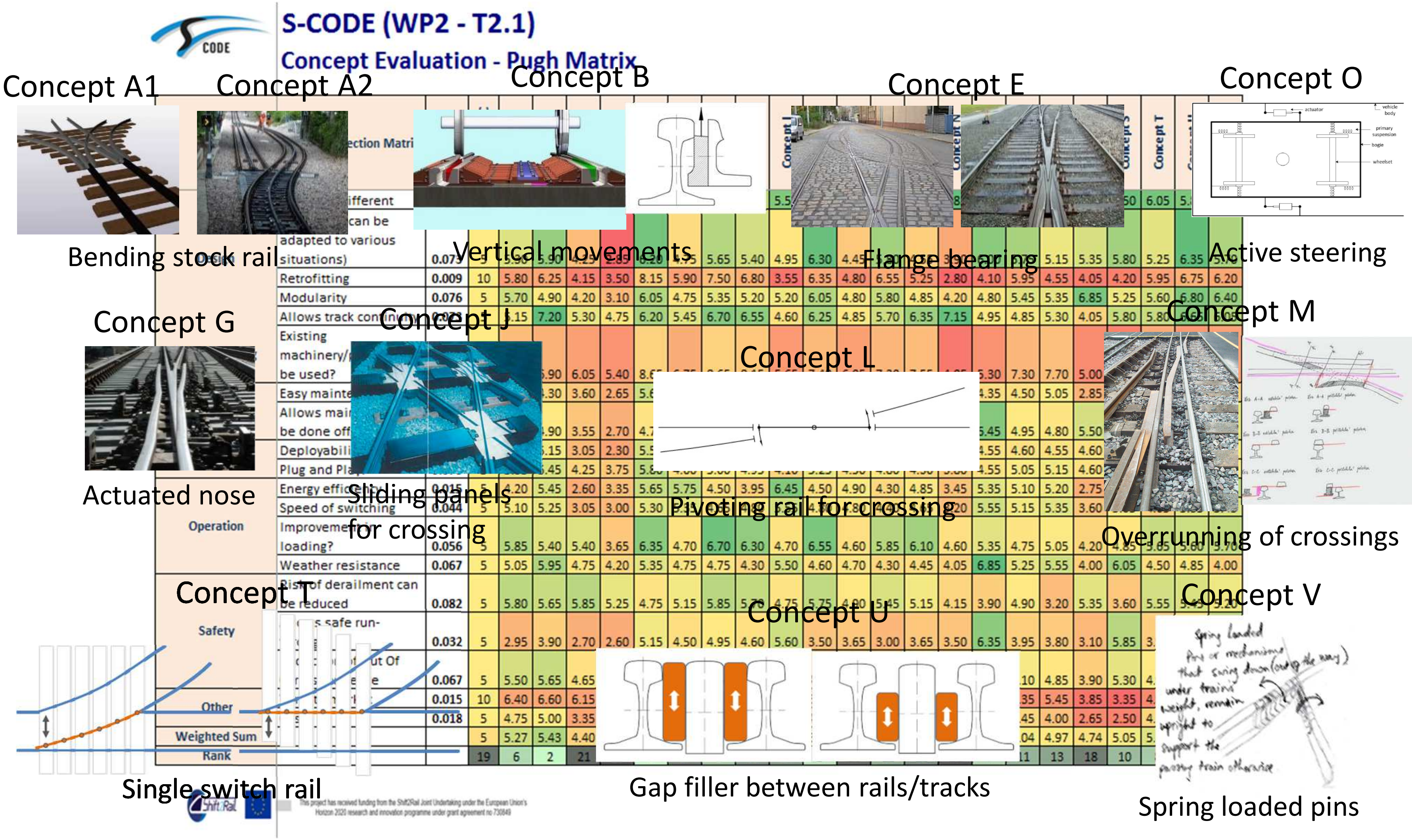
Concept selection



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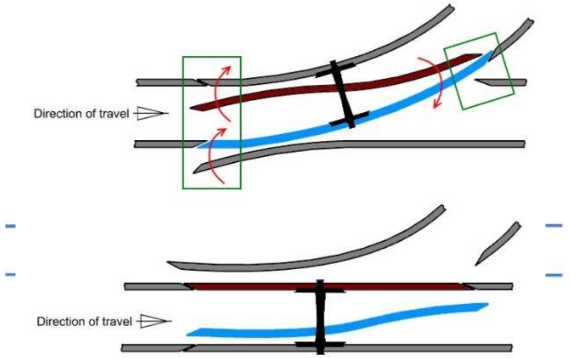
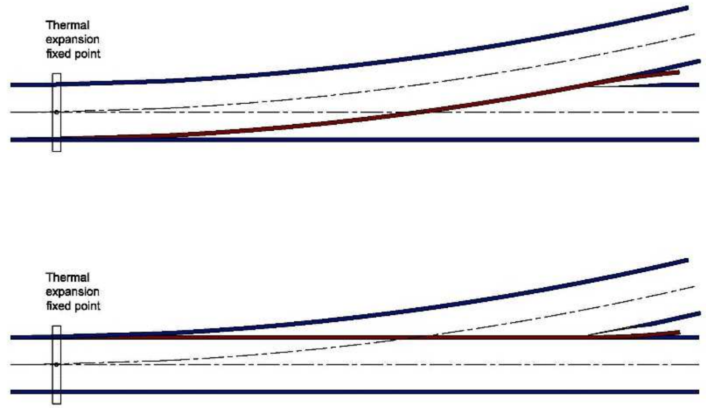
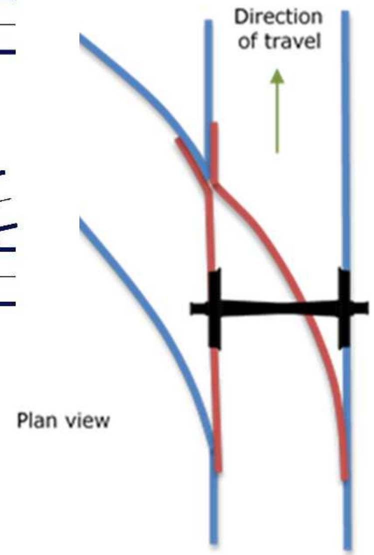
Concepts for track switching

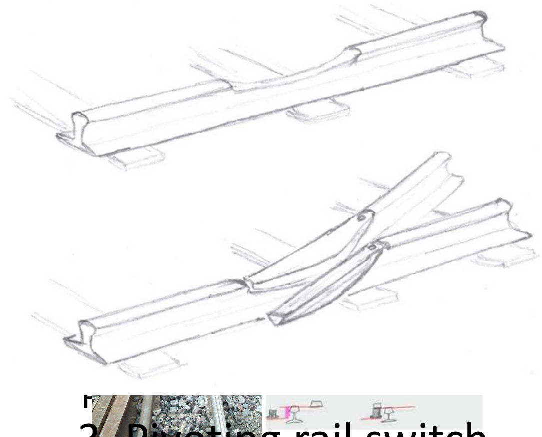


1. Back to back bistable switch

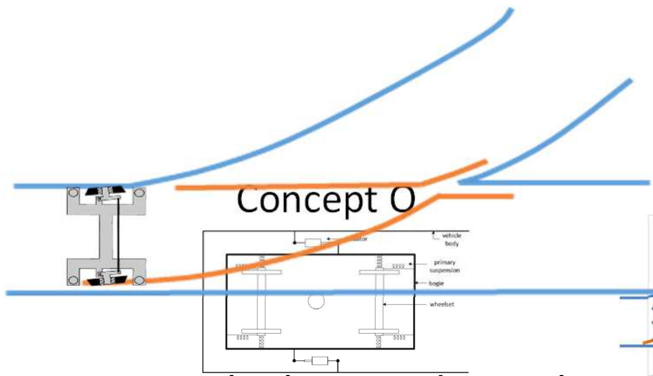


2. Single slender switch

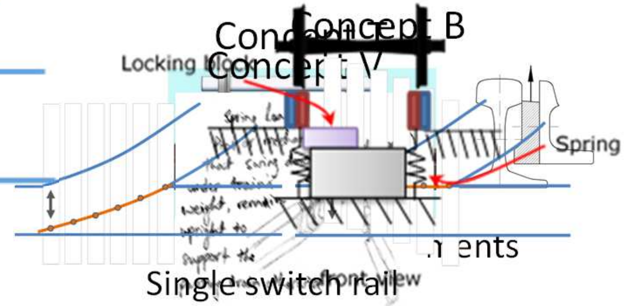




3. Pivoting rail switch
Overrunning of crossings



4. Vehicle Based switch
Active steering



5. Sinking switch

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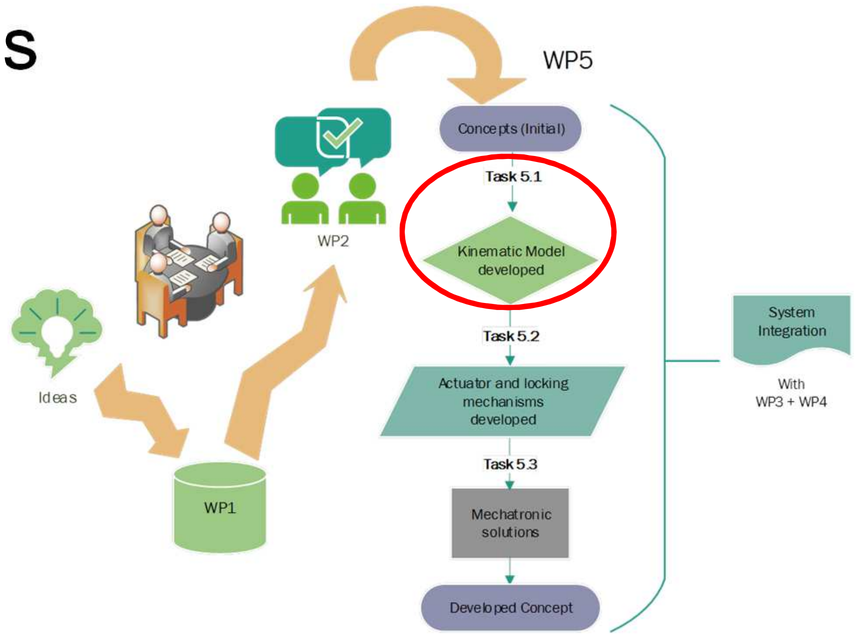

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Preliminary studies

Assessment of required and achievable displacements

1. Back to back bistable switch

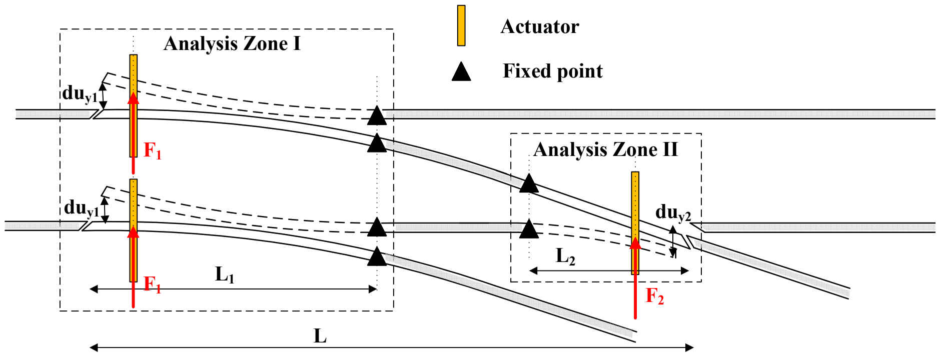


Table 1. Maximum Von Mises stress with different constrained location and applied vertical displacement

Fixed location, m	Lifting displacement at free end, mm									
	50	100	150*	200	250	300	350	400	450	500
0.5	5.6Gpa	11.1Gpa	16.7Gpa	22.3Gpa	27.8Gpa	33.4Gpa	39Gpa	44.5Gpa	50Gpa	55.6Gpa
1	2.3Gpa	4.5Gpa	6.8Gpa	9.1Gpa	11.3Gpa	13.6Gpa	15.8Gpa	18.1Gpa	20Gpa	22.6Gpa
2	0.6Gpa	1.2Gpa	1.8Gpa	2.4Gpa	3Gpa	3.3Gpa	4.2Gpa	4.8Gpa	5.5Gpa	6.1Gpa
4	0.17Gpa	0.33Gpa	0.51Gpa	0.68Gpa	0.85Gpa	1Gpa	1.2Gpa	1.4Gpa	1.5Gpa	1.7Gpa
6	0.078Gpa	0.16Gpa	0.24Gpa	0.31Gpa	0.39Gpa	0.47Gpa	0.55Gpa	0.63Gpa	0.7Gpa	0.79Gpa
8	0.044Gpa	0.09Gpa	0.13Gpa	0.17Gpa	0.22Gpa	0.26Gpa	0.3Gpa	0.35Gpa	0.39Gpa	0.44Gpa

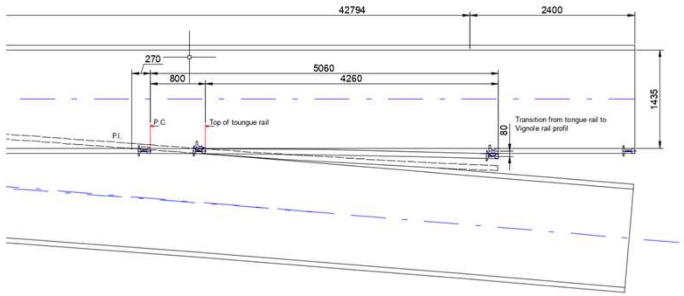
* UIC60 foot length is 150mm * Rad: Maximum Von Mises stress higher than 50% of ultimate tensile strength (UTS)

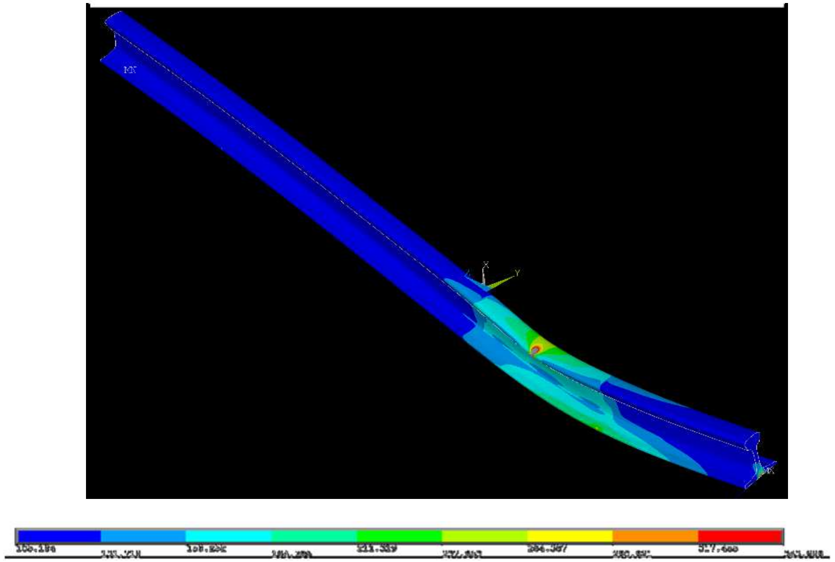
Table 2. Maximum Von Mises stress with different constrained location and applied lateral displacement

Fixed location, m	Applied lateral displacement at free end, mm									
	50	100	150*	200*	250	300	350	400	450	500
0.5	5.7Gpa	11.5Gpa	17.2Gpa	23Gpa	29Gpa	34Gpa	40Gpa	46Gpa	52Gpa	57Gpa
1	1.7Gpa	3.4Gpa	5.1Gpa	6.8Gpa	8.6Gpa	10Gpa	12Gpa	14Gpa	15Gpa	17Gpa
2	0.46Gpa	0.92Gpa	1.4Gpa	1.8Gpa	2.3Gpa	2.7Gpa	3.2Gpa	3.7Gpa	4.2Gpa	4.6Gpa
4	0.12Gpa	0.24Gpa	0.36Gpa	0.48Gpa	0.6Gpa	0.7Gpa	0.8Gpa	0.96Gpa	1Gpa	1.2Gpa
6	0.054Gpa	0.11Gpa	0.16Gpa	0.22Gpa	0.27Gpa	0.32Gpa	0.38Gpa	0.43Gpa	0.48Gpa	0.53Gpa
8	0.038Gpa	0.076Gpa	0.11Gpa	0.15Gpa	0.19Gpa	0.23Gpa	0.26Gpa	0.3Gpa	0.34Gpa	0.38Gpa

*UIC60 Rail height is 172mm

2. Single slender switch





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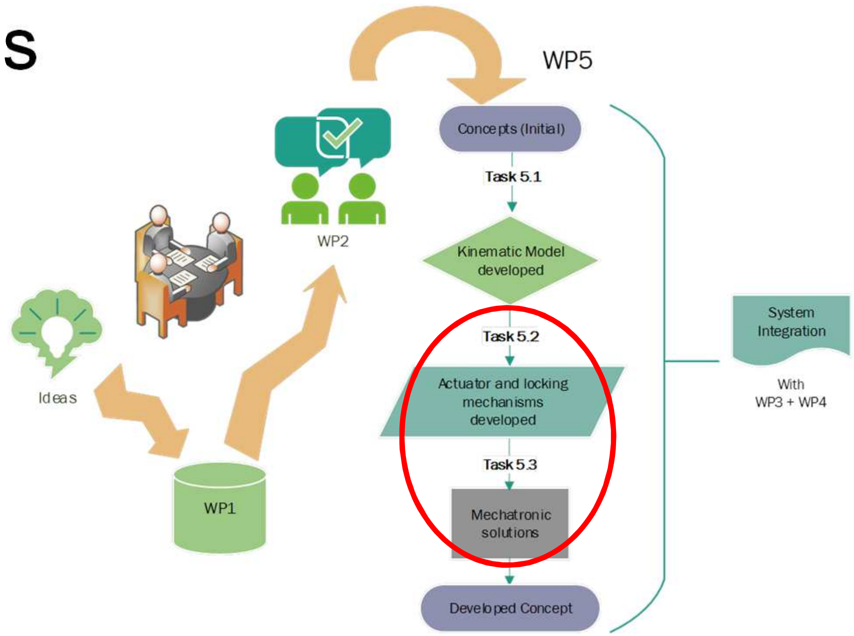

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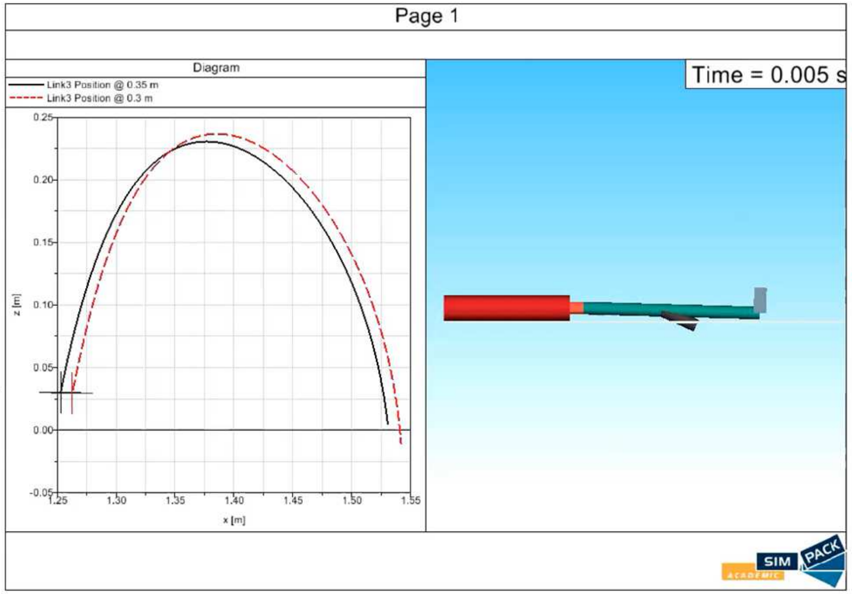
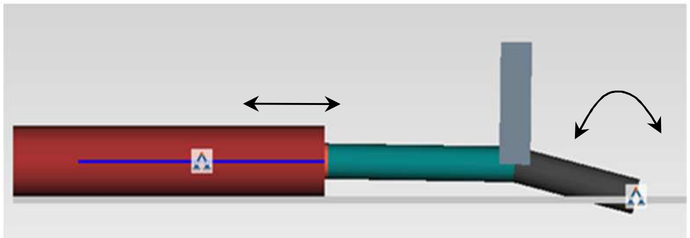
Actuation: Conventional actuators in new configurations

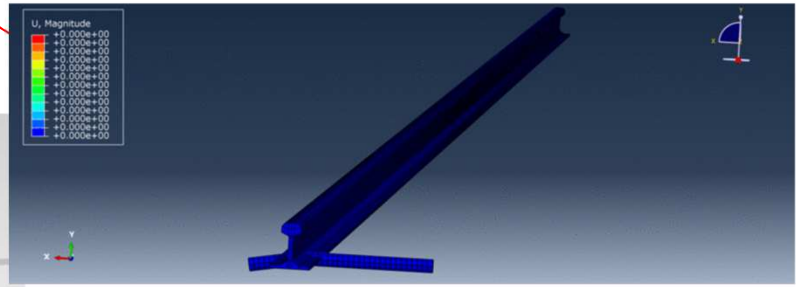
For Concept: Back to back bistable switch

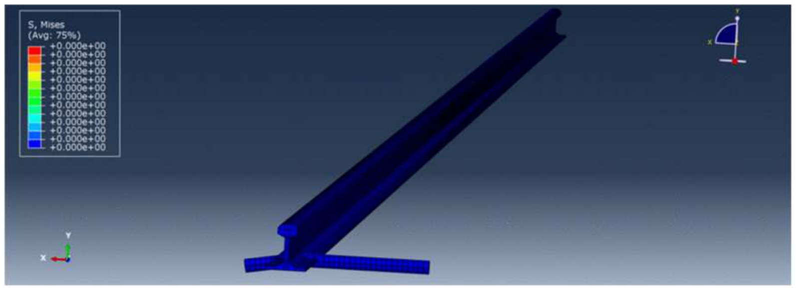
Linkage
rod/levers

Actu









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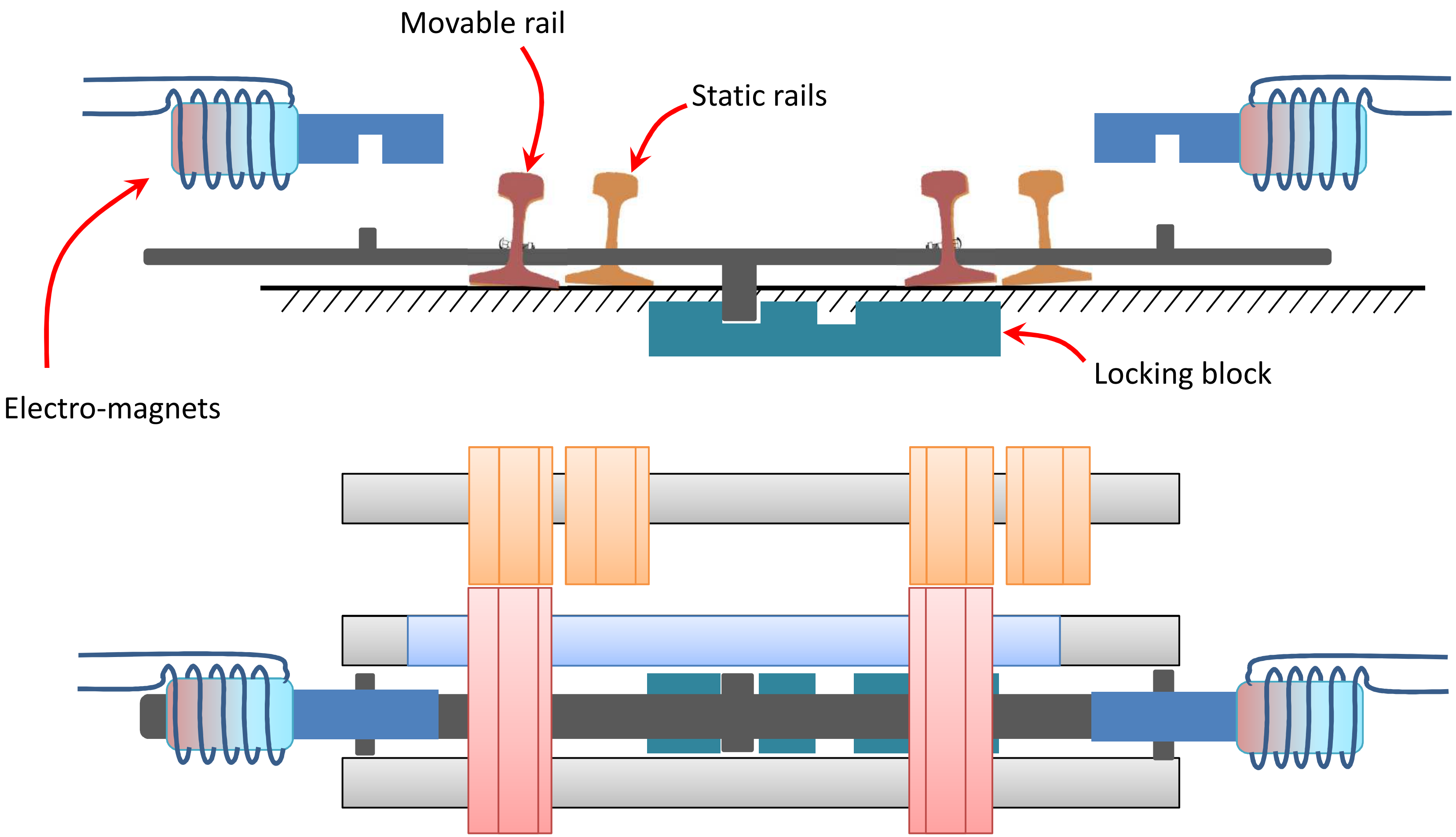
Actuation: electro-magnetic



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Actuation: Piezoelectric

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Actuation: High redundancy actuator

- Small actuation elements in multiple numbers.
- Failure in individual actuation element reduces the actuation power: Graceful degradation.

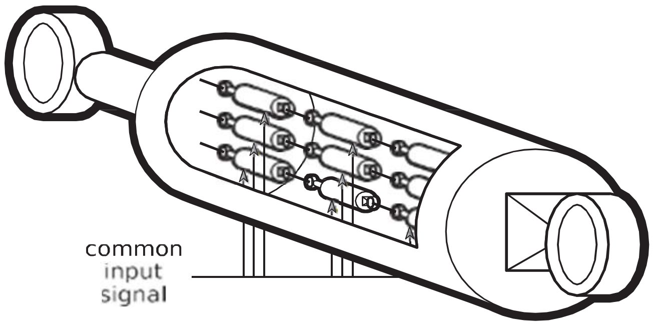

Photo of laboratory prototype

T. Steffen, F. Schiller, M. Blum, and R. Dixon, “Analysing the reliability of actuation elements in series and parallel configurations for high-redundancy actuation,” *Int. J. Syst. Sci.*, vol. 44, no. 8, pp. 1504–1521, Aug. 2013.

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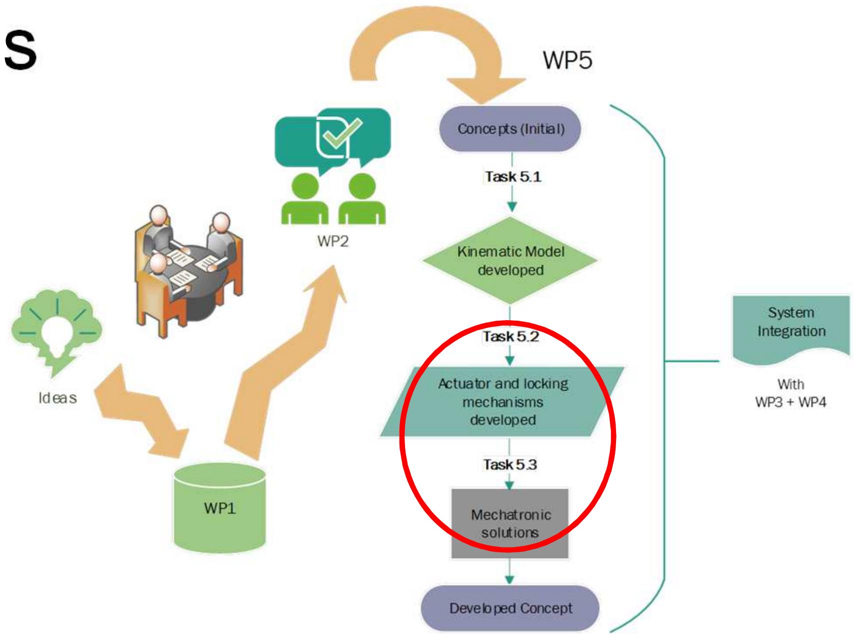

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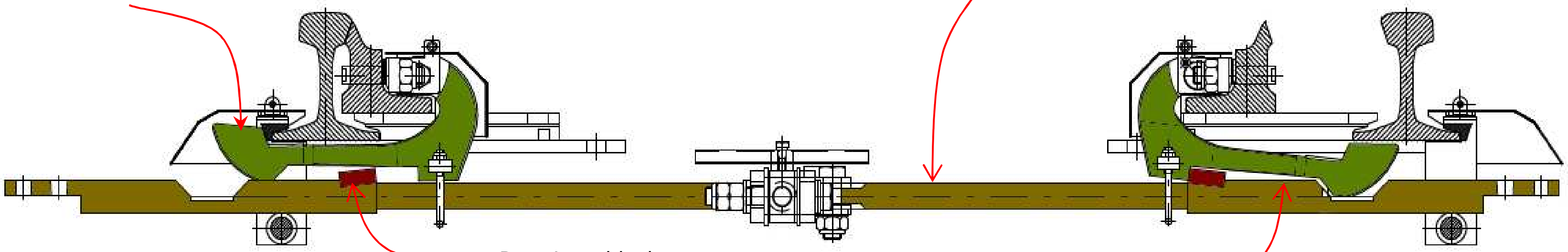
Locking mechanism at present

- Clamp lock



https://www.azd.cz/admin/files/Dokumenty/pdf/Produkty/Kolejove/40-VZ-200-ENG.pdf

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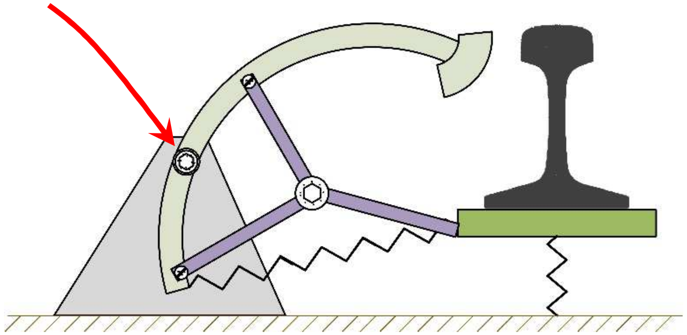
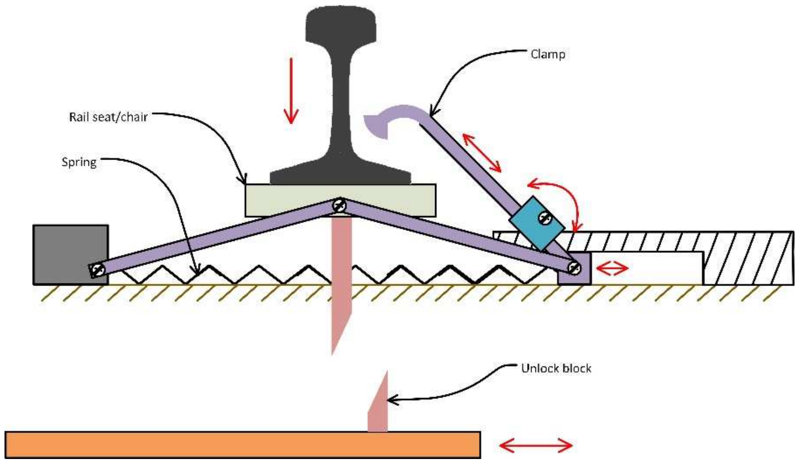
Locking: Linkage based

Self-locking mechanisms

– Active unlocking needed

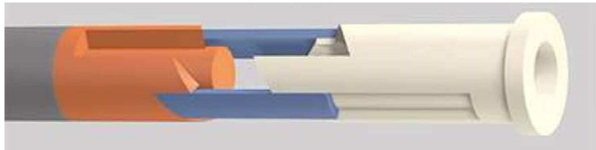
Pivot point





Retractable pen mechanism

Unlocked



Locked

(http://mentalfloss.com/article/77535/how-retractable-ballpoint-pens-work)

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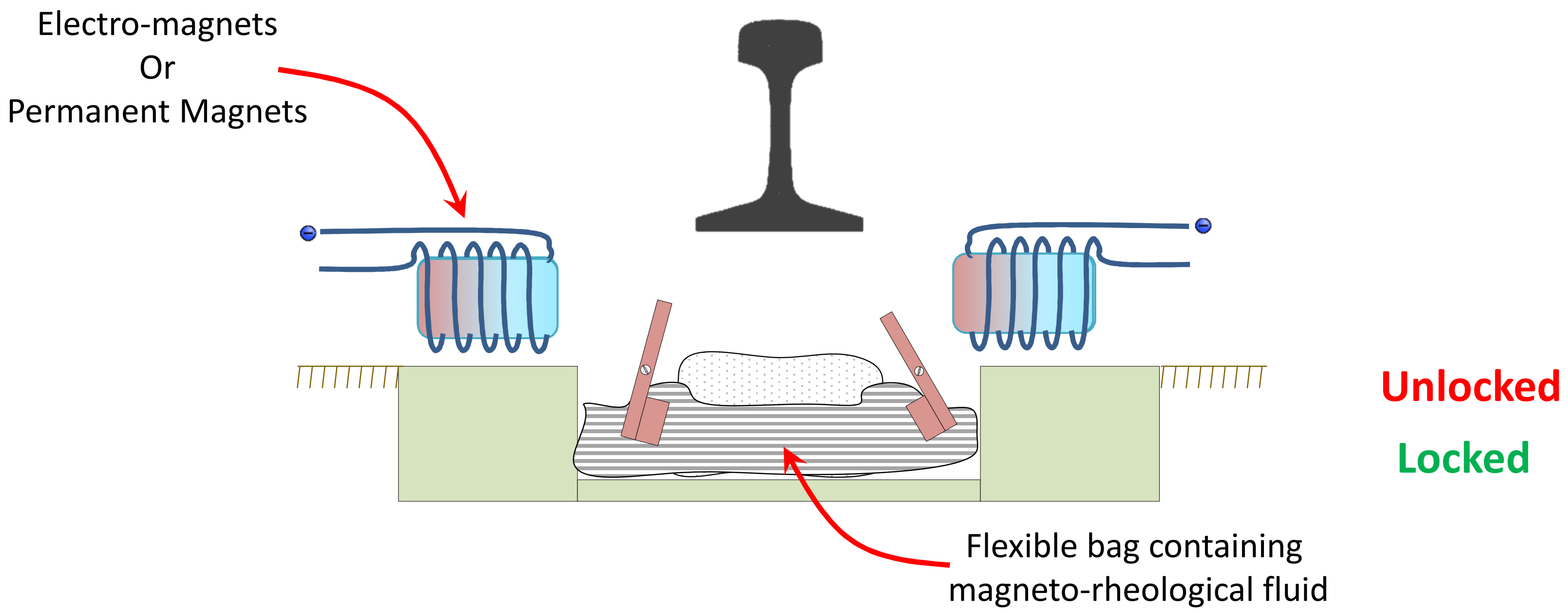
Locking: Magneto-rheological fluid based



- Self-adjustable
- No exact geometry needed as the flexible bag attains the shape of the rail
- Can be maintained easily
- No complex mechanisms

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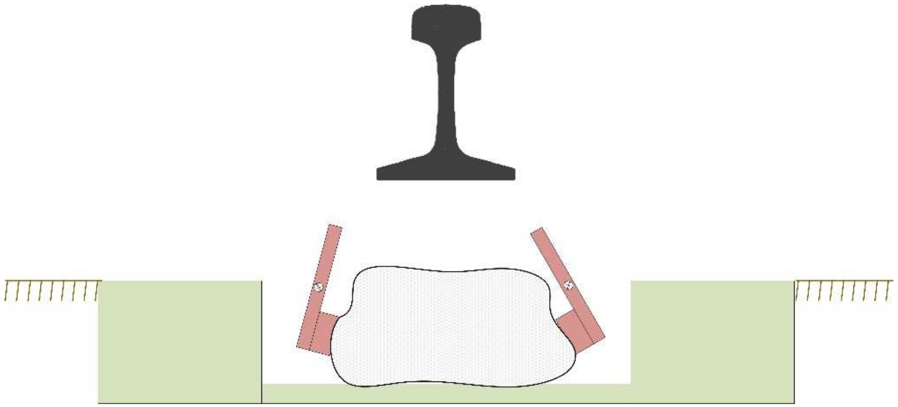
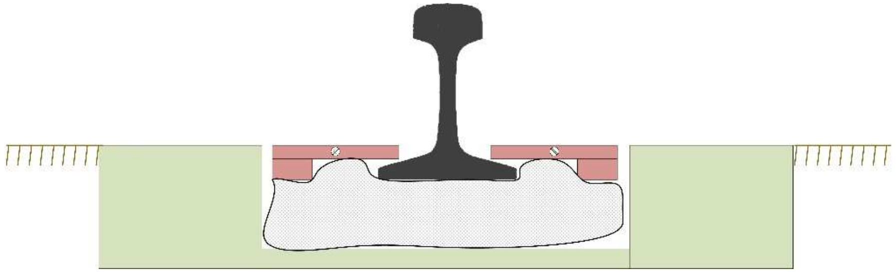
Locking: using dilatant material



Unlocked



Locked

https://www.youtube.com/watch?v=uXlFiuB1txY&t=22s

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Conclusion

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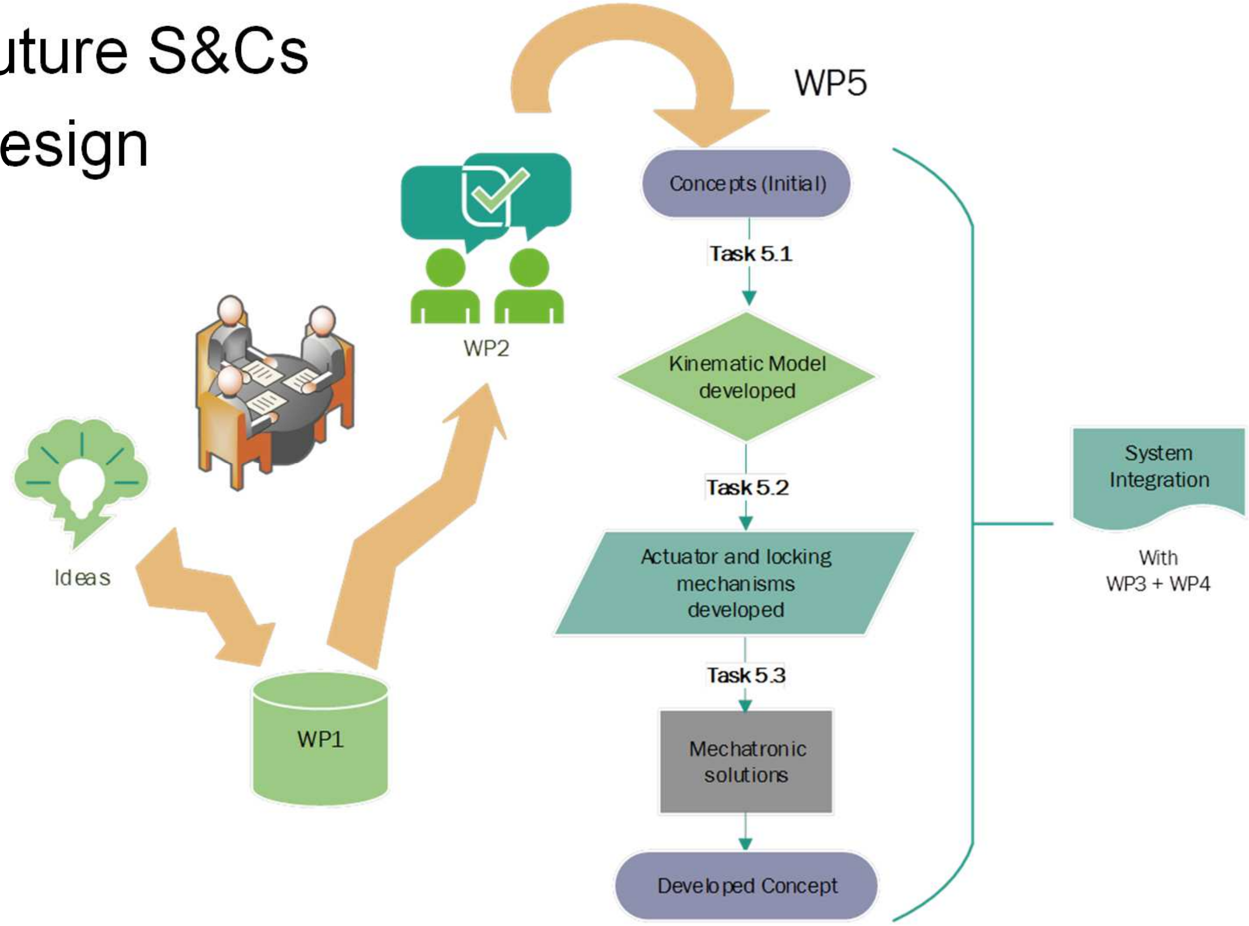

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Acknowledgements

- The work-package 5 group……

- And the wider S-CODE……

Conclusion and Next Steps

Professor Clive Roberts, University of Birmingham

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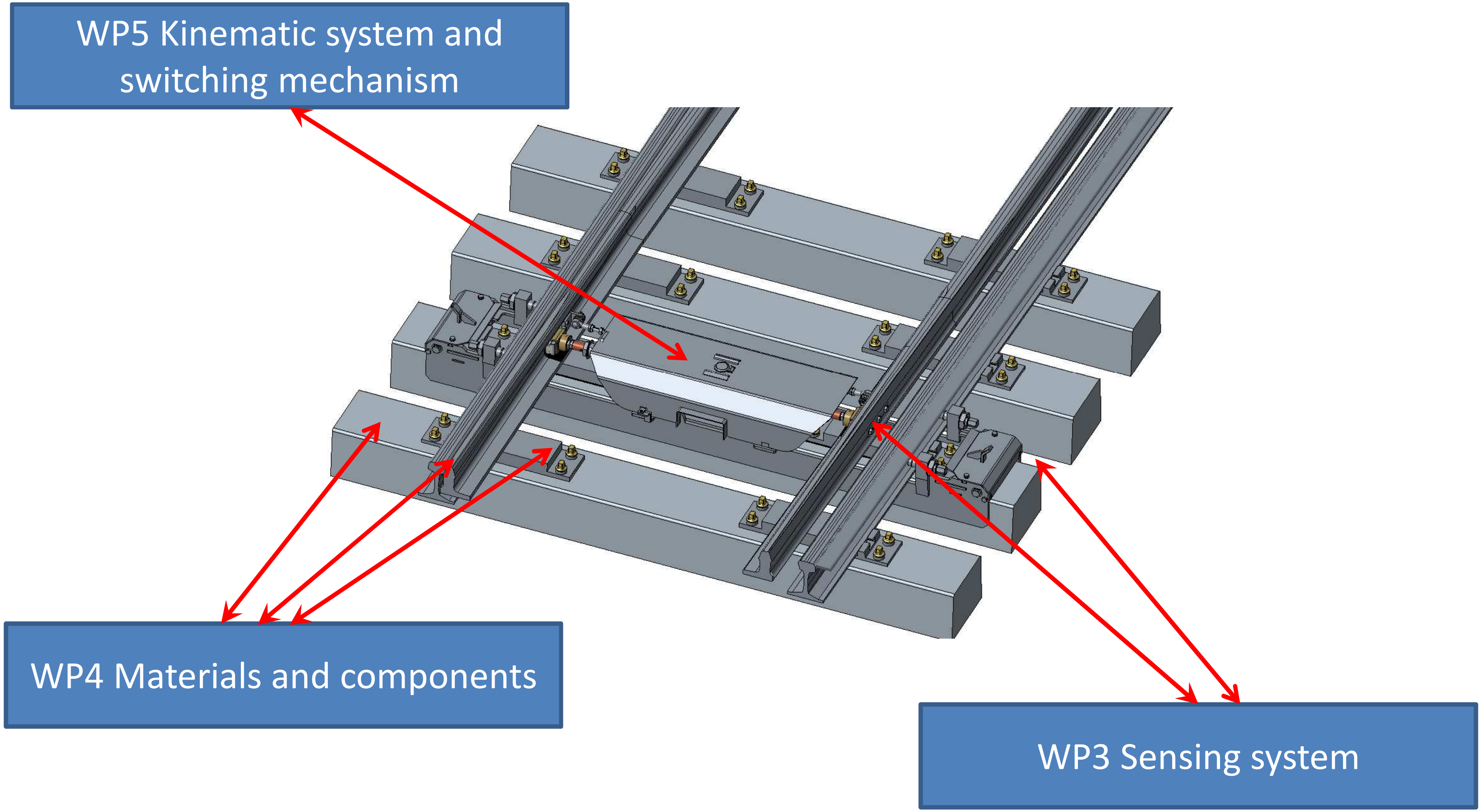
WP6 – Verification and Validation



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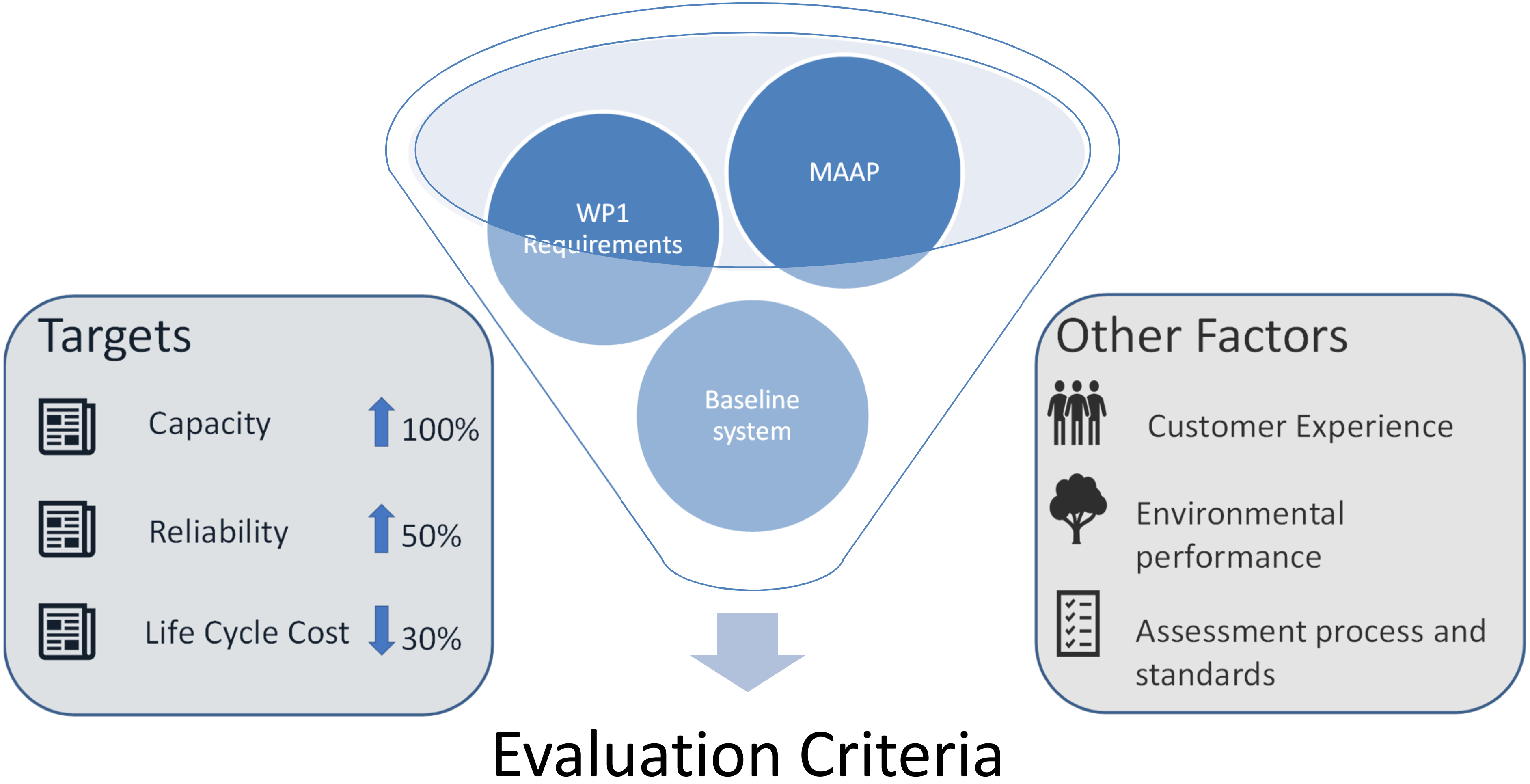
WP7 – Evaluation - Development of evaluation criteria



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WP 7 - Three tiers of evaluation

What the project has developed and to what maturity?	Technologies and concepts	TRL Level
What impact the developments will have against MAAP objectives?	Capacity Reliability LCC	RAMS Tools techniques
What standards and industry process would need to be challenged?	Assessment and Standards	Qualitative Evaluation process

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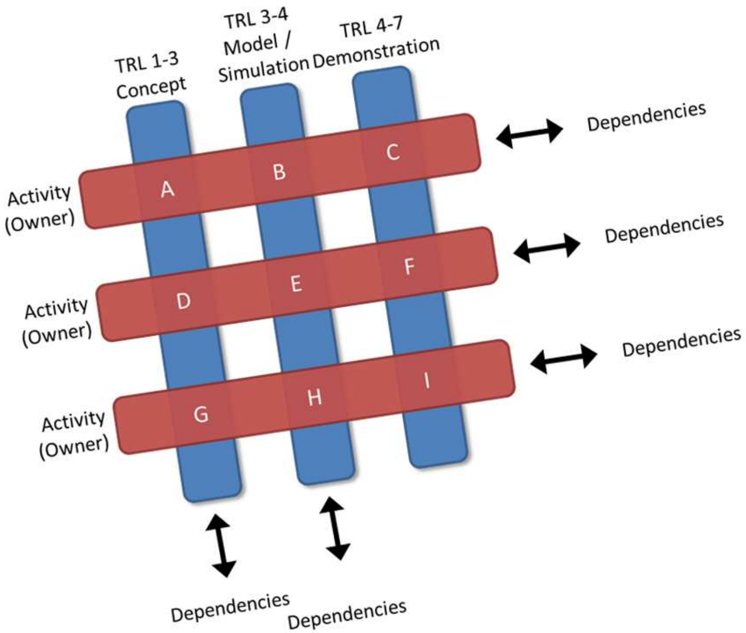
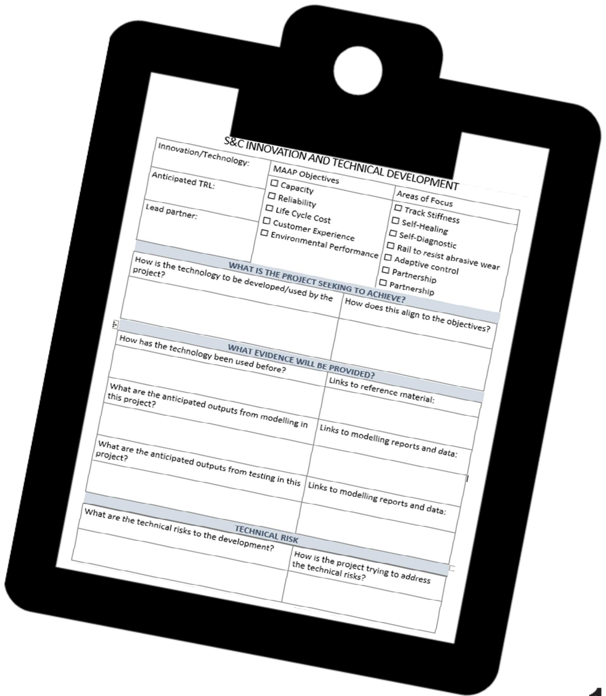
WP 7 – Tier 1 – Developments and TRLs

What the project has developed and to what maturity?

Technologies and concepts

TRL Level





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WP 7 – Tier 2 - Impact

What impact the developments will have against MAAP objectives?

Capacity
Reliability
LCC

RAMS Tools techniques

Objective	Parameter	Baseline Model	Improvement delivered
Capacity	• Time to Throw • Mean time to Repair	....	
Reliability	• MTBSAF • Duty Cycles • Life	....	
LCC	• Maintenance costs • Manufacturing costs • Installation costs	....	
Other	• Noise • Power Consumption	....	

FMECA?

Fault Tree Analysis?

Reliability Block Diagram?

LCC Model?

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WP 7 Tier 3 – Standards and Process

What standards and industry process would need to be challenged?

Assessment and Standards

Qualitative Evaluation process

Technology development:					
Operating Parameter	TSI Requirement	EN Requirement	Compliance assessment	Commentary	Future testing needs/capability

-Complies
-Complies with the intent of requirement
-Requires standard change

WP1

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TD3.2 Next Generation Switch & Crossing System Demonstrator

The MAAP outlines the following objectives for TD3.2:

- New methodologies for track switching (radical)
- Reduction in failure modes (less complexity)
- Inherently weather resistant system
- Scalability and applicability across a range of geometries, tonnage and speeds
- Future proofed for mechatronic steering bogies
- Less energy intensive to manufacture
- Reduction in noise and vibration (3db peak noise reduction)
- Improvements in ride quality
- Reduced possession times for installation and maintenance
- Reduction in maintenance costs
- Reduction in manufacturing costs
- Reduction in installation costs
- Increased life expectancy

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Multi Annual Action Plan

The MAAP also makes specific reference to potential areas of focus:

MAAP Objectives

- Reduction in failure modes (less complexity)
- Inherently weather resistant
- scalability and applicability across a range of geometries, tonnage and speeds
- Future proofed for mechatronic steering bogies
- Less energy intensive to manufacture
- noise and vibration (3db peak noise reduction)
- Ride quality
- Reduced possession times
- Maintenance costs
- Manufacturing costs
- Installation costs
- life expectancy

Areas of focus

- Rail steels to resist abrasive wear (Nano technology for metallurgy)
- Track support condition and transition zones
- Reduction in wheel/rail dynamic forces
- Automated manufacture, installation and maintenance
- Signalling philosophy
- Self adjusting
- Self healing
- Adaptive control
- Self diagnostics (real time)

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Thank You

Questions?

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