Institution of MECHANICAL ENGINEERS

Sustaining Real Innovation in Railway and Trains: The Centrality of Technology

Railway Division Lecture- Presented by Andy Doherty

14 January 2013

European - Joint Technology Initiative (JTI) Shift²Rail – Real Innovation

Andy Doherty

Working title;
Can we reinvent the wheel?

Content

- JTI Perspective
- Innovation Programmes
- It is a System!
- Technology Opportunities & Demonstrators
    - Trains
    - Traffic Management
    - Infrastructure
    - Information
    - Freight
- Conclusion

EC Perspective

- Historically
  - EC has provided significant Framework funding for transport research but rail – only €20m / 30m per annum (projects in TRL1-3)
  - ERRAC has been influential in guiding the call topics to which the UK has achieved significant involvement
  - EC has been frustrated with 'low' take up/implementation from Framework projects
  - EC developed together with the aerospace sector the 'JTI' (joint technology initiative) concept at TRL 4-7 to improve take up
  - EC has provided significant funding to Air and Road, including the existing 'Clean Sky' & 'Green Car' JTIs
  - EC is preparing its next 7 year plan – Horizon 2020, it accepts (to some extent) that it has to balance funding between aerospace, automobile and railways (and water)

EC Perspective

- ERRAC is working to influence Horizon 2020 – currently we believe it will propose to allocate circa €1B to railways
- EC needs guidance on the future role of railways, and how to spend this money and has asked ERRAC to provide this.
- UNIFE and a consortium of Rail Suppliers proposed a rail JTI to EC nearly 2 years ago
- This has now developed into a JTI proposal entitled SHIFT²RAIL
  - Funding target €800-1000M (usual 50% funding arrangement)
  - Full scale demonstrators (TRL4-7)
  - Existing 'framework' project funding process to continue in Horizon 2020!
  - ERRAC to run the JTI Strategic Board - setting strategy and measuring remit compliance
- The EC expects that much of this increased funding will be directed through the Shift2Rail JTI

Rail Route 2050

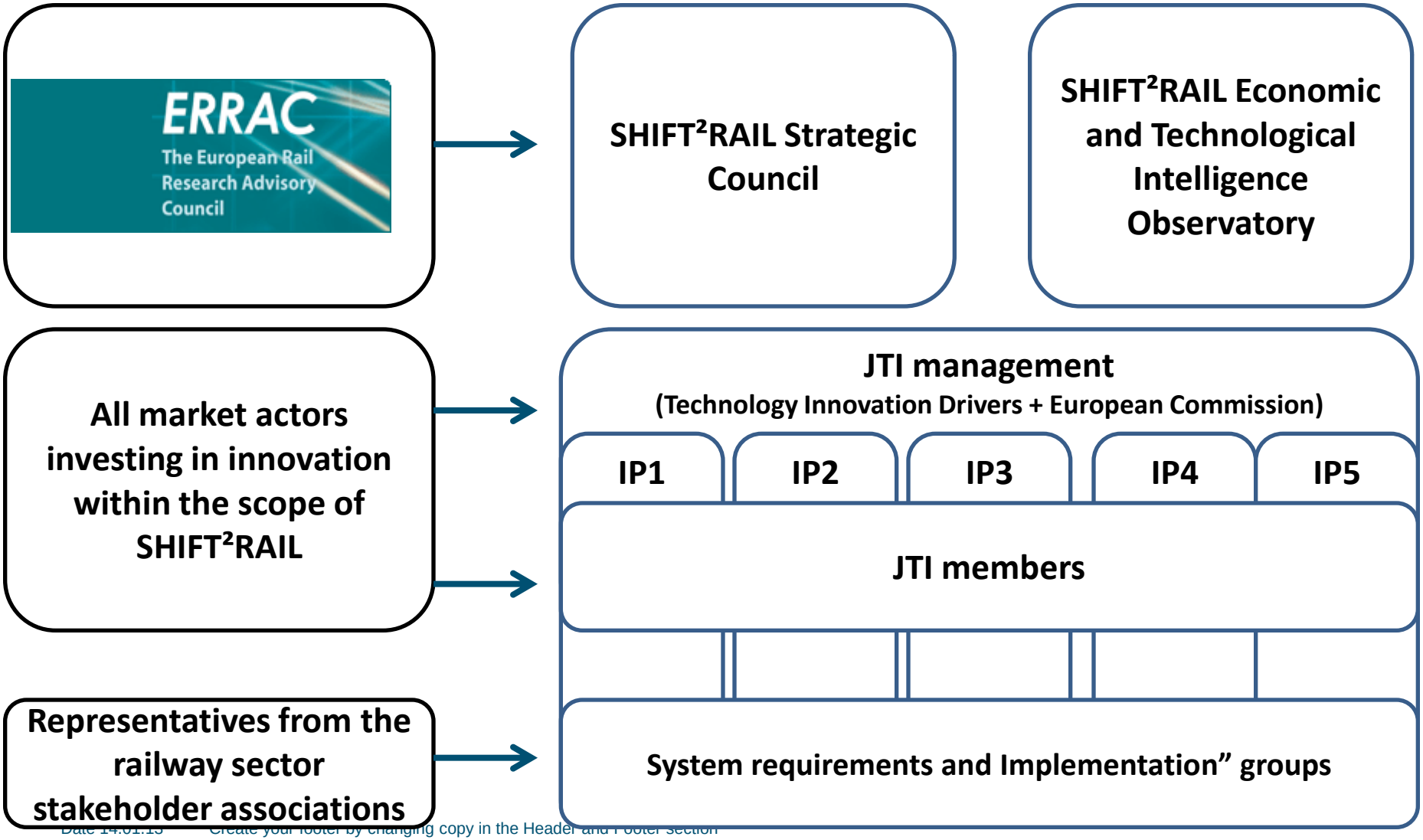
ERRAC has recently launched its Rail Route 2050 vision

- **Route maps for**
  - **Intelligent Mobility**
  - **Energy and Environment**
  - **Security**
  - **Safety and Certification**
  - **Competitiveness and Enabling Technologies**
  - **Strategy and Economics**
  - **Infrastructure**
- **Available from the ERRAC website; www.errac.org**
- **Will provide guidance to the EC on future research calls and the JTI scope**

What is a JTI?

- The current Clean Sky JTI is;
  - A 7 year contract between the EC and special purpose company.
  - A consortium came together and negotiated a scope and cost for the JTI
  - Leadership is by some 20 full time employees on EC international contracts (time limited)
  - The first rank members are the consortium members and are ‘defined recipients’
  - There are other grades of members, and subcontractors
  - The EC provides 50% funding to match the funding provide by the members.
  - There is a JTI Board running the company, and Governance Board of the EC, Suppliers, Operators/Users and advisory Groups

SHIFT²RAIL – ERRAC interface



SHIFT²RAIL five Innovation Programmes

1. Energy & mass efficient technologies for high capacity green trains

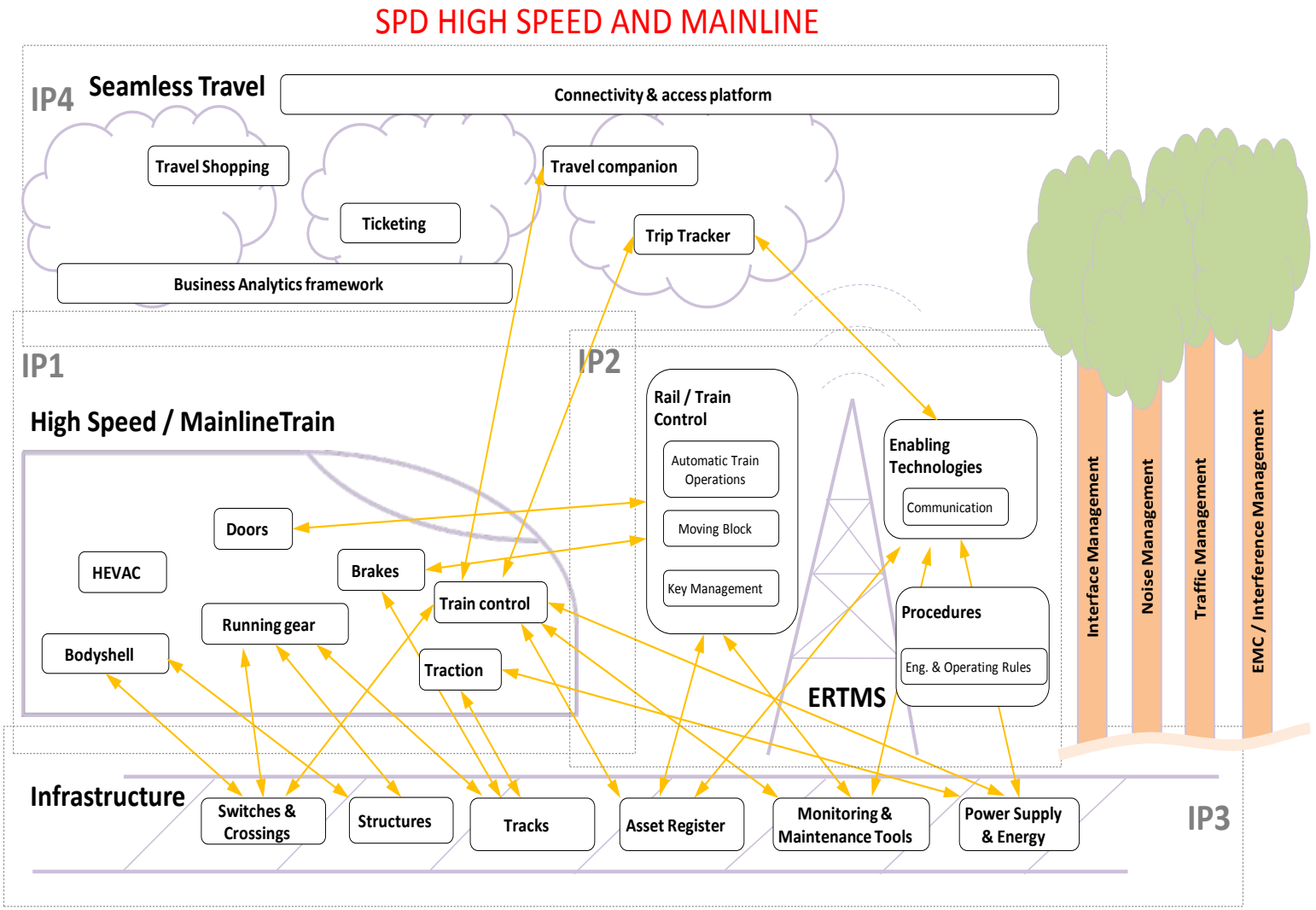
2. Advanced traffic management and control systems for the improvement of main line and urban rail capacity and resilience

3. Long life and low noise tracks for higher infrastructure capacity and reliability

4. Innovative IT solutions for a seamless attractive railway transport system

5. Innovative technologies for sustainable & attractive European freight transport

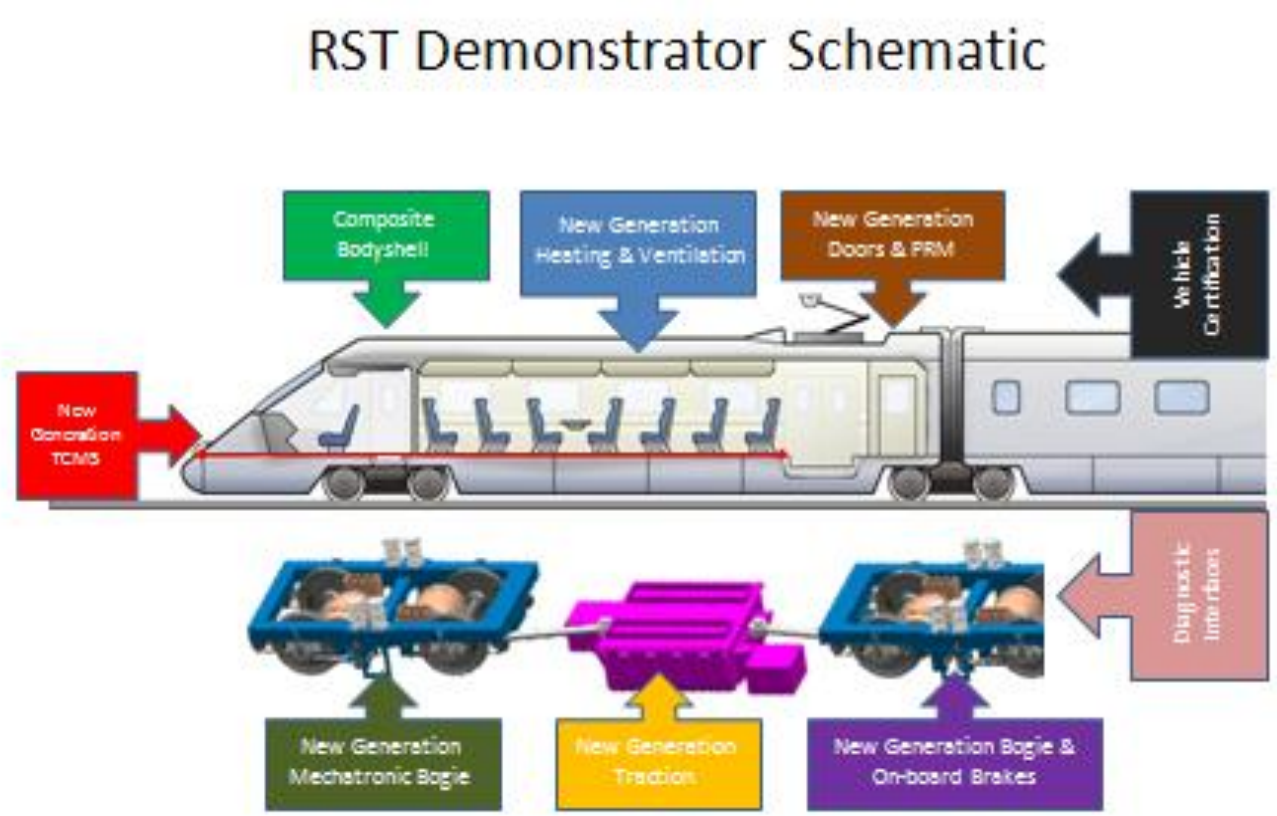
It's a System!


SPD HIGH SPEED AND MAINLINE
IP4
Seamless Travel
Connectivity & access platform
Travel Shopping
Travel companion
Ticketing
Trip Tracker
Business Analytics framework
IP1
IP2
High Speed / MainlineTrain
Rail / Train Control
Automatic Train Operations
Moving Block
Key Management
Enabling Technologies
Communication
Doors
HEVAC
Brakes
Train control
Running gear
Bodyshell
Traction
Procedures
Eng. & Operating Rules
ERTMS
Interface Management
Noise Management
Traffic Management
EMC / Interference Management
Infrastructure
Switches & Crossings
Structures
Tracks
Asset Register
Monitoring & Maintenance Tools
Power Supply & Energy
IP3

The JTI - to be radical!

- The JTI must deliver system solutions that radically improve capacity and performance and reduce costs
- The JTI will seek to set out a radical design philosophy, similar to the way the US develops new fighter aircraft
- A 2 stage process that allows for iterative improvement and radical solutions that out perform anything that the original system can do!
- The EC Framework projects working at TRL 1 to 3 should review the many candidate solutions to particular problems and narrow the options to say 2 to 3 maximum. These projects should not need to be concerned with direct take up by railways or industry but do the conceptual validation of radical solutions.
- The JTI being more focussed on TRL 4 to 7 has significant funding and resources to take the most promising radical options to full and extensive trials.
- The JTI will also tackle standards and validation such that take up by railways and industry can be rapid

IP1 – Trains


RST Demonstrator Schematic
Composite Bodyshell
New Generation Heating & Ventilation
New Generation Doors & PRM
Vehicle Certification
New Generation TCMS
Diagnostic Interfaces
New Generation Mechatronic Bogie
New Generation Traction
New Generation Bogie & On-board Brakes

New Train Summary

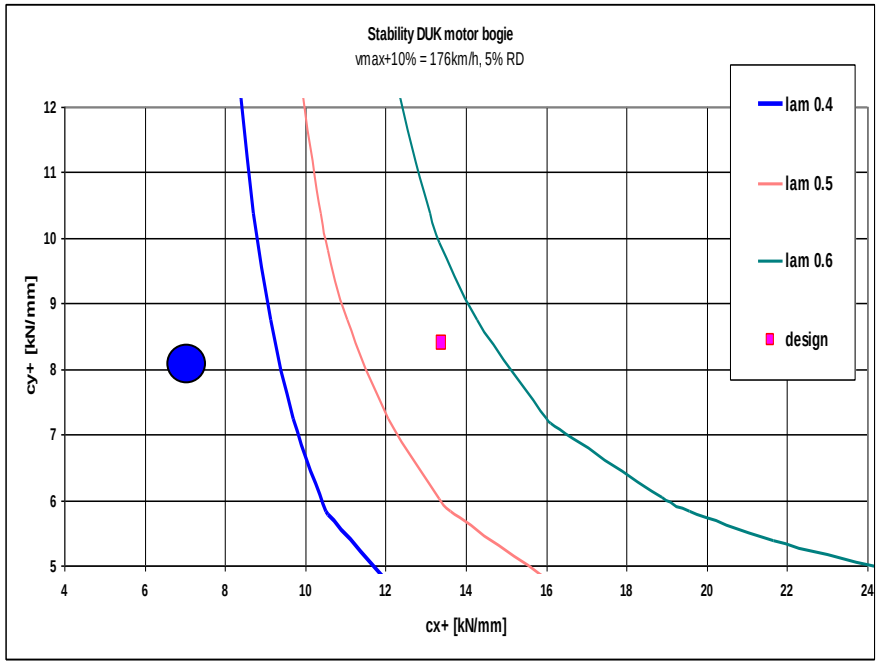
- Composite body shells; lighter, stronger, more flexible, improved environment
- Heat and Ventilation system, more efficient, less energy, heat exchanger?
- New doors; energy, speed, reliability
- Brake systems; improved performance, assured braking,
- Traction system; increased efficiency and weight reduction
- Customer information; step change in concept of information to the seat and individual customer
- Couplers; automatic, wired/wireless
- Bogies; mechatronics?

IP1 – What are the opportunities?

- Trains that are lighter, faster, less energy and track damaging etc – lower whole life cost?
- More efficient traction packages - higher frequency? More harmonics? Different EMC issues to be managed as a system?
- If a mechatronic bogie were to be able to steering through points and crossing there are huge possibilities for a new S & C design philosophy! Railways are no longer dominated by ‘CONICITY’
- A perfectly steering mechatronic bogie probably moves to a fatigue driven railway with little wear of the rails
- New brakes, we can expect higher brake rates (17%? Perhaps – and assured? even in autumn) This would give big capacity gains!
- A lighter train might be more sensitive to wind and aerodynamic issues but does simply move the problem to wind breaks (that are also noise barriers) for 100s of miles! So the ‘right’ weight train!
- Automation means do we need a driver? do we need a driving cab? does it need to be in the front?
- Weather and climate resilient

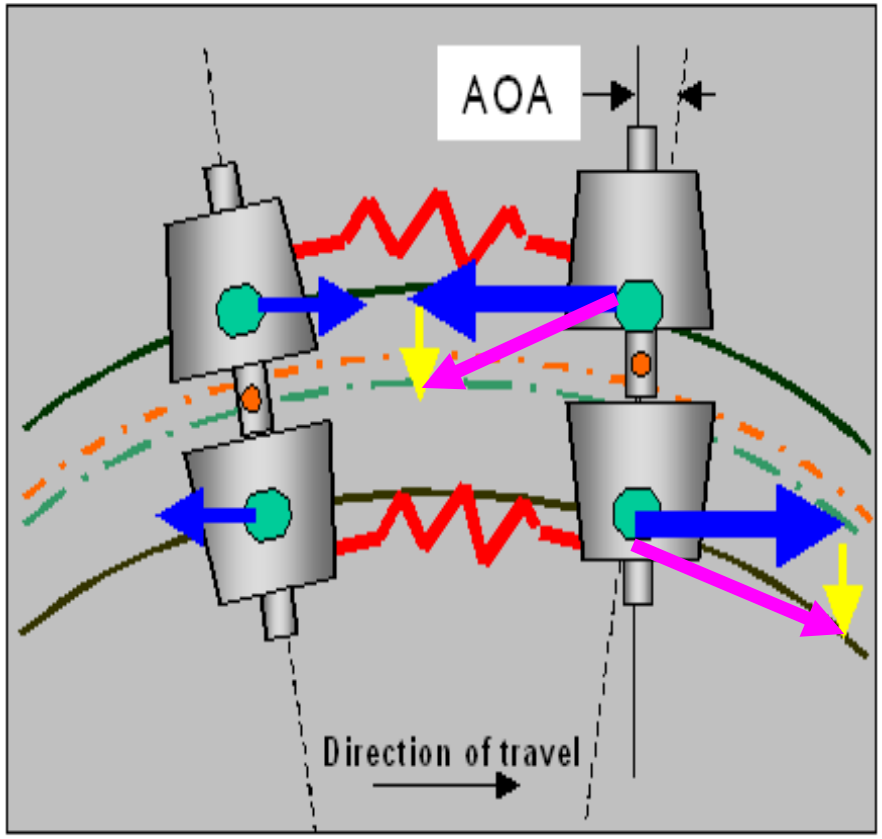
Mechatronics Bogie and Conicity

- Typically a UK train will be designed to have a conicity in the range 0.4 – 0.6 (some railways in Europe much higher)
- Previous VT SIC analysis of a mechatronics bogie considered it as replicating a traditional bogie and characteristics!
- But consider a modern fighter aircraft (indeed the latest airliners) they are designed unstable and then stabilised by computer
- So why in a mechatronics world couldn't conicity be set at zero
- Certainly with a basic get you home level of safety at say 0.2 and stabilised by the mechatronics and control system



Mechatronics Bogie - Opportunity

- So if we have none or very little AOA
- We could have a fast reacting but stable bogie
- We could now tell the train to turn left or right i.e. steer the bogie (as well as tilt etc) through the signalling
- Opportunity; have we opened the envelope?
  - Capacity?
  - Speed, curving rules?
  - Track and bogie degradation?
  - New point design?



Rail oriented Wheel/Rail forces

IP2 – Traffic Management and Train Control

What are the opportunities?

- Merging of ETCS and CBTC technology essential – yes
- New functionality for mechatronic bogies like; steering/direction
- But what is the new system offering?
- ERTMS as opposed to ETCS
  - Predictive traffic management
  - Load sensitive
  - Energy management as well as traffic management by timetable

The whole question of driverless trains? Do they have a role?

- Convoying trains?
  - Auto coupled and decoupled on the move?
  - Running together 100 meters apart (is this still a long train?)
  - Different risk profile, so different design requirements, so different infrastructure and train features (100% derailment containment? Obstacle detection? Wheel-rail lock in?)
  - Real point to point service for passengers
- Should we be talking about autonomous intelligent train control to provide the above and not just railway signalling?

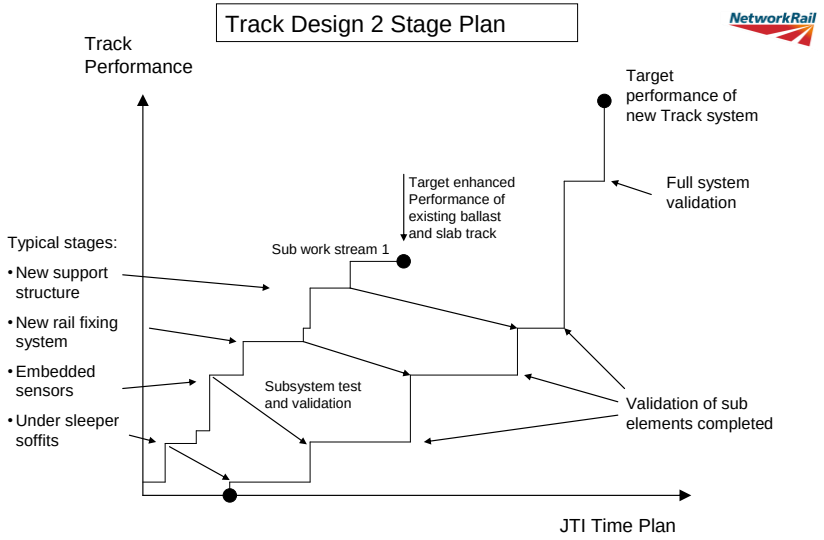
IP3 – Infrastructure
What are the opportunities?

- Based upon the assumptions of train design – right weight, mechatronic bogies, steering, low wear
- Track forms that last 60 years (as long as sleepers), and manage water!!
- Generates solutions for low cost M & R, 24/7 working and safety of track workers (IM M& R SNCF €4B, NR €3.6B PA, Europe Total €20B PA!!!!!!)
- Solutions must be and are validated and tested to extremes (100 Millions of gross tonnes)

Validation

The project will use the 2 stage design and development process with interlinked plans.

- The first stream will seek to develop and validate specific aspects or parts of the new track design. This work will be done by trialling the new concepts in the existing ballast and slab track designs.
- The second work stream the candidate radical new track designs will be evaluated and where possible tested in the existing designs,
- The most promising will be taken forward to a structured work plan of testing and development of the final new track design concept.



Mechatronic S & C Proposal

- To develop a radically different concept of switch and crossing design
- Potentially moving away from the traditional moving switch blade to new concept of train direction changing that does not rely on conicity
- The proposed work plan will involve to interlinked plans.
  - Consider the output from Innotrack and the Forever Open railway project which will identify and validate candidate design options
  - The first stream will seek to develop and validate specific aspects or parts of the candidate designs. This work will be done by trialling the new concepts in the existing S & C systems. This will have the double benefit of bringing forward individual improvements to improve the existing switch and crossing system performance in addition to validating each part of the new design.
  - The second work stream develop the most promising radical new switch and crossing designs, using mechatronic actuators? and then taken forward to a structured work plan of testing and development of the final new concepts.
  - The new designs will be validated and ‘approved’ within the project

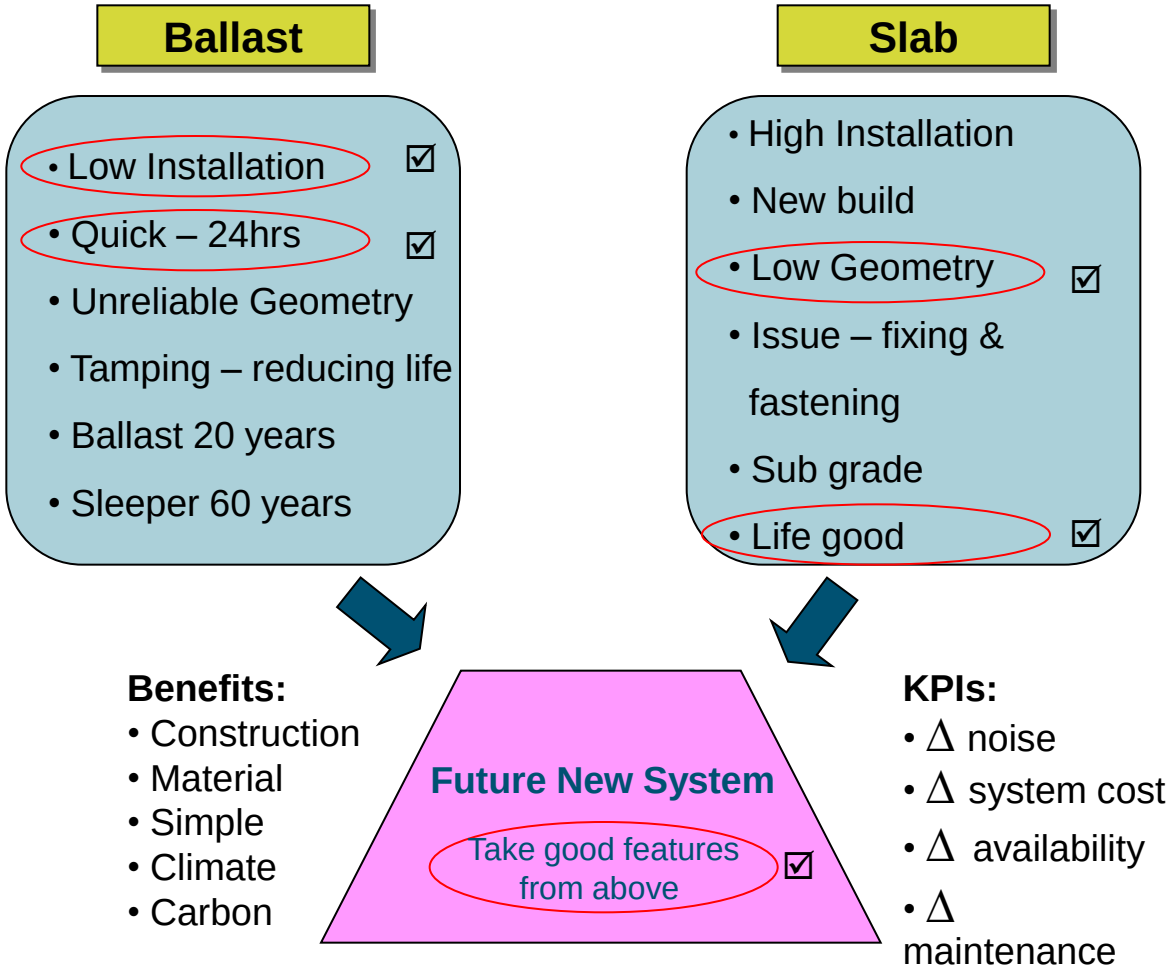
Mechatronic S & C cont

- These new concepts and new locking philosophy's (inherently fail safe) will take technology and machine science already in use in other sectors and transfer this technology and techniques into the railway (e.g. Aerospace and automotive).
- The project will review historical culture of signalling and switch operation and maintenance philosophy, with a clear plan to develop and propose a new philosophy of allowing automatic self adjustment techniques to maintain safety limits. This would significantly reduce the need for very regular testing. Linked with remote monitoring and an effective asset management the railways will reduce cost and improve performance.
- The new switch and crossing system will designed with embedded sensors to enable automatic self adjustment and condition measurement, will be fully readable by railway monitoring systems. The data would feed into the intelligent maintenance work stream and enable 'predict and prevent' maintenance scheduling. This data and information will be open and transferable across the industry.

Mechatronic S & C cont

- The new switch and crossing design will be designed fundamentally to be robust for all climatic conditions and especially reliable and safe operation in ice and snow.
- The work stream will consider from first principles the interaction with the substructure, and consider the sub structure stiffness requirements, given that the switch and crossing area of the area of the railway will get less access for maintenance. The work will seek to produce a business justification for an enhanced substructure for switch and crossings, together with provision of power, lighting and air supplies to enable effective maintenance in all weathers and at all times night and day.
- These potential new solutions will remove a number of the present failure modes and enable significantly higher performance. The final solution(s) will be developed from small scale models through to full scale trials to prove performance and safety.

IP3: Ballast and Substructure



New Rail Design

- Certainly we need to rethink rail design and metallurgy
- Certainly if the rules of conicity have changed we need can rethink rail and wheel profiles
- Do we need inclined rail? Embedded rail?
- New rail steels must reduce and lower the carbon footprint, and take resilience to fatigue to a new level
  - Self healing and lubricating rail steel (nanotechnologies)
  - Multi-use rail surfaces (as per old bull head) to reduce carbon demand

IP3 Demonstrator Principles (S&C and Track)

Testing Infrastructure

- Activity 'A'
- Costs in Infrastructure IP3

- Lab
- Small scale

- Full scale
- 'Pueblo'/Other
- Tonnage

- Validation of Concept

- 100MGT test, including
  - High axle load - Freight
  - Many axle loads – Urban/Suburban/Regional
  - High Speed – Ballast Stability
  - Combinations of above

Mainly Infrastructure Design Development & Testing

Integration

- Activity 'B'
- Shared Costs with Rolling Stock IP1

- System Integration
- Deployment readiness

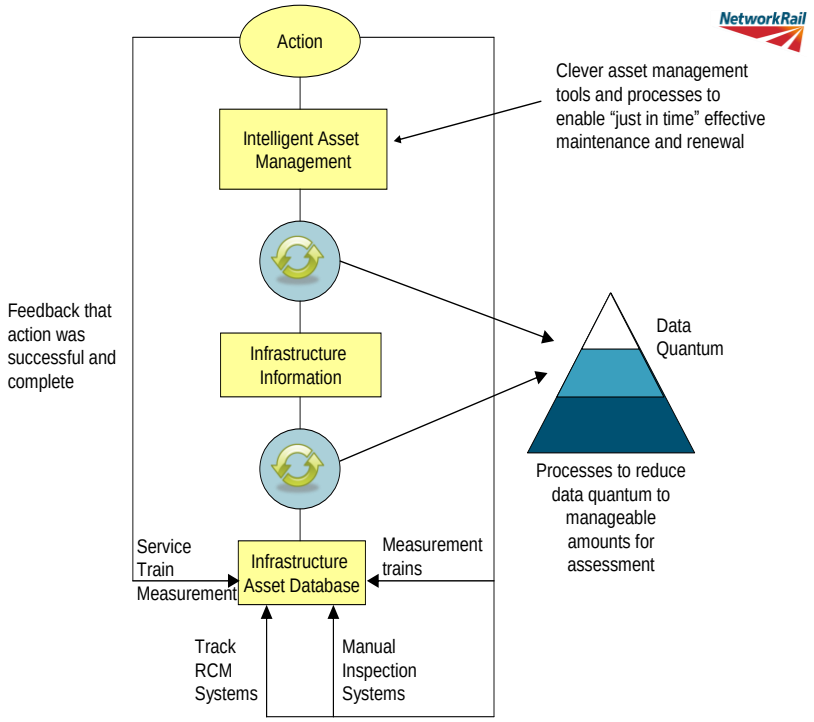
- Passenger, Urban, Suburban, Regional
- Dynamic integration
- Freight
- High Speed?

With Rolling Stock + Energy + Signalling as needed

Asset Management

Intelligent Asset Management

- Intelligent Asset Management; using Autonomous Intelligent systems and predictive asset degradation and condition tools (full suite as per Track Ex)
- Structured and open asset data process/construct (aligned but not the same database as the RINF)
- Asset Management – definition of the plan-do –review process as it applies to railways
- Turning data into information and into intelligence by the development of clever asset prediction and degradation tools

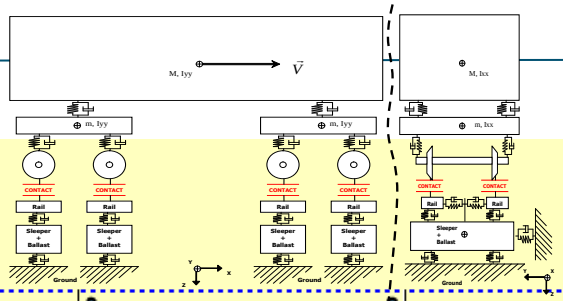


Prediction Asset Management Tools

- The JTI will radically change train and track design
- The interfaces and degradation of these assets will be different
- Therefore we need to develop our understanding such that degradation can be managed and that railways are ready to operate and maintain the new solutions
- With a mechatronic bogie we can expect a fatigue driven degradation of track, so the wheel-rail models will need to be redesigned.
- Indeed all the asset degradation models and understandings will change
- In addition the JTI will develop ‘PREDICTIVE’ asset models for all asset types to enable intelligent asset management

Predictive Modelling tools for Asset Management

Sensors for remote condition monitoring to be embedded into the whole track system



OHL Ex©
Wire/Pan degradation Prediction Model

Track-Ex
Wheel Rail degradation model that predicts maximum track capability with real time output to control system

Wheel

Under-sleeper pad:
Energy recover capability
Increased ballast life

Rail

Fastening

Sleeper

RCF
Fatigue resistant rails that are low carbon but have multi-use surfaces

Buckling
Risk reduced

Sub-ballast

Ballastbed

New ballast specification that requires no tamping to maintain geometry

Ballast Ex©
Degradation Prediction Model

Track Degradation

Subgrade

Improved Stiffness function & climate change resistant

Whole system model

Bridge EX©
Degradation Prediction Model

Energy Efficiency

- ‘Innovative integration of regenerated energy, energy storage devices, renewable energy production systems and the optimisation of the railway energy supply network’
  - Innovative Protection Devices for AC Traction Supplies
  - New Energy Management Systems
  - Energy Regeneration Systems, and lastly
  - Inspection Gates for the Identification of potentially damaging pantographs
- As a system we need to reconsider the supply network design, especially if frequency and voltage is to be increased.
- The new ERTMS control systems will allow dynamic timetabling and will manage power demand, this changes the design requirement
- New modelling tools that anticipate the above and new train traction features will be needed

Noise and Vibration

- All sources of Noise Generation such as Aerodynamic/ Motor/ Wheel-rail contact/ OHL-pantograph contact need to be evaluated in a systematic manner. So do the related types & transmission methods such as: Sound – air/ Vibration – soil/Rayleigh – surface/Pressure – layer/Shear – soil and Retransmission.
- Noise and Vibration mitigation effects such as: Deflection/ Dampers/ Added mass/ Bafflers/ Absorption will need to be measured in a Rail environment for effectiveness. The potential for transition into other energy forms, rotational energy and potential energy will be investigated.
- Trackside IP3: Testing track area, specs & instrumentation; Energy harvesting; Short barriers close by; Damping possibilities/ slab-track/ US pads; Acoustic/ green mats; Baffle structures depending on wave lengths; Acoustic profile grinding track.

IP4 Information Technology

- Develop a service-oriented IM framework based on open architectures to support the operators and provide an intermodal, interoperable pan-European end-to-end transport service to the end users with unprecedented levels of services.
- Facilities; travel shopper, trip tracker, travel companion, smart ticketing including payment and settlement, as well as business analytics tools.
- E-ticketing within a framework of a European multimodal transport information, management and payment system, common vision for air, rail and urban transit. **The concept of ticketing will evolve to become closer to that of travel rights:**
  - Near Field Contact (NFC) introduction.
- Data management – Cloud Computing and Big Data.

IP4 – What are the opportunities?

- Consistant ‘interoperable’ ticketing and information’ systems for the passengers, freight forwarders etc One system approach to IT enables a systematic approach to data management both for Asset Management of Infrastructure and Trains as well being ‘communication’ for all operational and information systems, including telecoms, GSM-R etc aspirations
- TAP, TAF, RINF ERATV etc databases can be developed as ‘second stage’ to live operational systems, enabling faster approvals, and increased cost efficiency of IMs and RUs assets

IP5 – Freight
What are the opportunities?

Opportunity to design the future really interoperable Rail Freight System for Europe

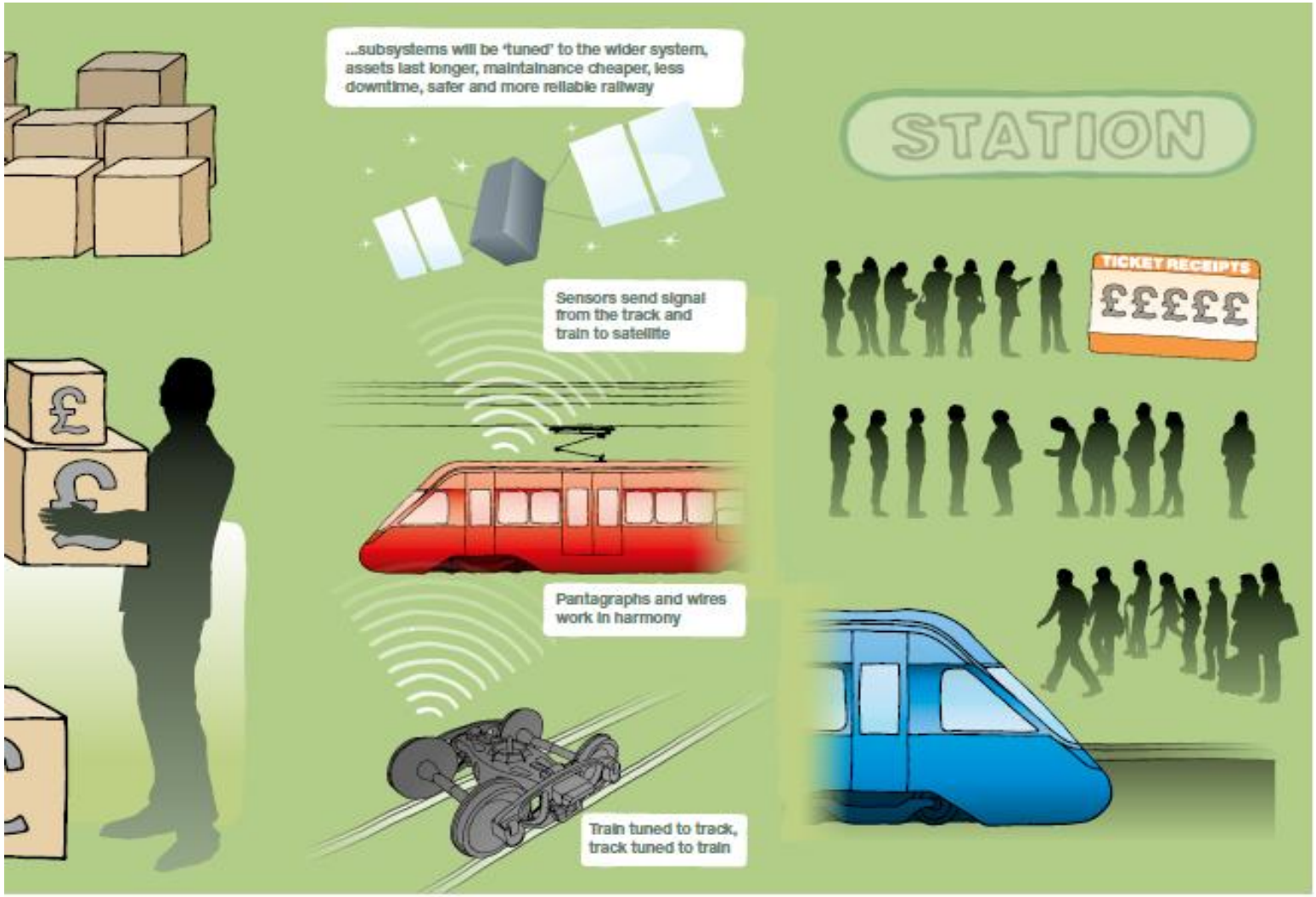
- Combined trains passenger and freight
- Convoying
- Automatic train consist build up in depots and marshalling yards
- Auto coupling and decoupling on the move
- Increased % of payload to gross load
- Faster, logistics freight to run at passenger speeds freeing capacity

Summary

- Passenger
  - New train designs, composites, interior flexibilities, energy efficient traction and hotel systems
  - High capacity infrastructure; autonomous signalling and strong low cost track
  - Convoyed trains
  - Connectivity, continuous information and communication
  - Mechatronics, Steering trains, and the move away from Conicity enables; higher speeds, improved ride comfort, lower costs, less energy usage

  Freight
  - Auto coupling capability
  - Auto consist building
  - Convoyed trains
  - Mixed trains
- Linked all together by an ‘enabling IT system architecture for the all our customers and the railway’s management

Real Innovation - Whole System step change



Benefits

- We need to now develop these paradigm shifts in the railway's offering for; capacity, performance, cost, attractiveness, energy efficiency.
- Make full use of dramatically increased opportunity of European funding
- Alignment of UK railway plans and needs with JTI
  - UK RTS
  - UK R & D initiatives (Catapult, EIT etc)
- Rebuilding of high value UK railway industry
- Note ; Cost of introduction and timescales must be factored in