The Great Western Electrification Programme - Collaborating for Success

Tuesday 10th September
INCOSE – Railway Interest Group

Nassar Majothi – Parsons Brinckerhoff
Joe Silmon – Atkins
Acknowledgements
Overview

• What is the GWEP?
• The Atkins / Parsons Brinkerhoff Team – LDO
• The integration challenges
• SE Tools and techniques
## Programme Goals

<table>
<thead>
<tr>
<th>The Route</th>
<th>London and Bristol, including Newbury and Oxford, by 2016 and to Cardiff by 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>New trains</td>
<td>Enabling the route for the new fleet of Intercity Express Trains</td>
</tr>
<tr>
<td>Capacity</td>
<td>More seats and faster journeys</td>
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<tr>
<td>Environment</td>
<td>Reduction in emissions, carbon and local environmental impact</td>
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<td>Economic growth</td>
<td>Stimulate economic growth across the region by better connecting towns and cities</td>
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<tr>
<td>Reduce costs</td>
<td>Higher overall reliability, lower operations and maintenance costs</td>
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</table>
Programme Scope

1. High Output Plant System – Construction Technology
2. New Product Technology – Series 1, FEDs. IPC, RATS
3. 3 new Grid Supplies
4. Circa 50 Local Auto Transformer/Switchgear Sites
5. 22,000 OLE Support Structures
6. 1000 Km of Wiring
7. 150 Structures to gauge clear (reconstructions, track lowers, jacking; awnings, tunnels, demolitions)
The Delivery Team

1. Network Rail Investment Projects – The Client
2. Network Rail Route & EPDG
3. Amey – The Construction Contractor
5. Other Designers
6. Furrer & Frey – Series 1 Development
7. Windhoff – High Output Train
What is a Lead Design Organisation?

Network Rail

Infrastructure Projects
Electric Trains Programme

Contract Requirements - Technical
Project No
Electric Trains Programme
Title
Lead Design Organisation and
System Integrator

ATKINS PARSONS BRINCKERHOFF
The LDO responsibility for systems integration

The LDO shall... enable the *co-ordination and integration of engineering, designs, construction and commissioning* produced by the LDO and others and to provide on going site design/engineering support *and validation of the works during implementation and commissioning through to Entry into Service (EIS).*
The LDO responsibility matrix

GWML: Lead Design Organisation and System Integrator
Delivery Structure (route sections 1-9)

W&W-Electrification System Integration - LDO
(RSAR; Crossrail; Bristol & Oxford Station Redevelopments)

<table>
<thead>
<tr>
<th>Signalling</th>
<th>Telecoms</th>
<th>Contact Systems</th>
<th>Protection and Control</th>
<th>Power distribution and INO</th>
<th>DNO</th>
<th>Earthing and Bonding</th>
<th>Civilians</th>
<th>Stations</th>
<th>Other associated works (eg: Signage etc.)</th>
<th>Track and Gauging (including EF works)</th>
<th>Structural interventions</th>
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<tbody>
<tr>
<td>GRIP 4</td>
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<td>LDO</td>
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<td>LDO</td>
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<td>GRIP 5</td>
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<td>Distribution Alliance Partner</td>
<td>LDO</td>
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<td>LDO</td>
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<td>GRIP 6</td>
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<td></td>
<td>Distribution Alliance Partner</td>
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<td>Other Works Contractors (To be appointed)</td>
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<td>GRIP 7</td>
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<td>Entry Into Service - LDO</td>
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</table>

** Outline design work for distribution, Protection and Control
Why a JV and the drive for collaboration

1. Market forces
2. Breadth of skills required
3. Size of team
4. Efficiencies
5. Innovation
6. Multi-discipline Approach
Approach to Systems Integration

Systems Integration

Design Integration
Construction Integration
Operational Integration

EDMS / CAD Management System
Document Control
Project, Design & Engineering Processes
PM, Project Controls & Schedule Management
The Challenge of Multiple V’s
A Complex Set of Programme Interfaces
A Complex Set of Programme Interfaces
Engineering Challenges

Earthing and Bonding Schematic
Open Route Section of an Electrified Railway

*Grid Site Earth Potential Rise: Calculations required for all interconnections between the railway and traction return system.
Governance Challenges

Case A: LDO undertakes all design work for the route section

Case B: Design work is shared between the LDO and other organisations. LDO retains integration accountability.

Case C: LDO undertakes no design work, all design is done by other organisations. LDO retains integration accountability.
SYSTEMS ENGINEERING TECHNIQUES
Requirements management – guiding principles

Requirements drive the design

Provide requirements to designers at the start – reduce retrospective verification

GRIP3 design contains numerous requirements

Huge value in Approved in Principle designs

Requirements are not confined to the PRS, they are defined and refined by design

GRIP4 and GRIP5 designers write new requirements that are relevant to the next stage

Requirements relate to the system in different ways

Need to ensure each design package only sees the applicable requirements

Avoidance of unnecessary work

Reject non-value-adding requirements

Rich traceability

Record and justify how requirements were evolved through the life-cycle
Challenge 1: a distributed system

- **Requirement**
  - Minimise environmental impact (type a)
  - W10 structure gauge (type b)
  - No impact piling near Mr X's house (type c)

Each of these links must be independently verified for full technical assurance.

Physical OLE Production Unit GW/00

Physical OLE Structure GW/00/01

Physical OLE Structure GW/00/02

Physical OLE Structure GW/01/01

Physical OLE Production Unit GW/01

- traces to

- traces to

- traces to
Multi-level applicability of requirements

Requirement
Type a) requirement
All elements

Requirement
Type b) requirement
All elements of type

Requirement
Type c) requirement
location specific

Physical
T00 Generic design element

Physical
T03 OLE Structure

Physical
GW/00/01 structure
Inferred applicability of requirements

- Inference: If A → B and B → C then A → C

- If the requirement applies to OLE structures, and GW/00/01 is an OLE structure, then the requirement applies to GW/00/01.
Requirements that apply to each element

• Now three logical conditions are brought together to infer the traceability

• Useful for global requirements and aspirations e.g. environmental impact

• Use sparingly to avoid overloading designers!
Challenge 2: Multiple requirements sources

- 65 requirements source documents from GRIP3
- ~5000 requirements
- Definition of specialist requirements ongoing
# Challenge 3: Evolution of assurance through the life-cycle

<table>
<thead>
<tr>
<th>Activity</th>
<th>Requirements</th>
<th>Progressive assurance</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRIP3 design</td>
<td>Operational and performance requirements</td>
<td>GRIP3 outputs satisfy client &amp; sponsor</td>
</tr>
<tr>
<td>LDO Initial requirement capture and analysis</td>
<td>System requirements (PRS, Strategies &amp; AIPs)</td>
<td>Route requirements satisfy system requirements</td>
</tr>
<tr>
<td>GRIP4 design</td>
<td>Route section requirements specification</td>
<td>GRIP4 design satisfies route requirements</td>
</tr>
<tr>
<td>GRIP5 design</td>
<td>Detailed design requirements in Form A/equivalent</td>
<td>GRIP5 AFC &amp; test spec demonstrates design implementation</td>
</tr>
<tr>
<td>Construction, inspection, test, integration, commissioning</td>
<td>Inspection, test &amp; commission requirements</td>
<td>As-built works meet test specifications</td>
</tr>
<tr>
<td>Entry into service</td>
<td>Inspection, test &amp; commission reports</td>
<td>In-service system meets output requirements</td>
</tr>
<tr>
<td>In-service monitoring</td>
<td>In-service monitoring</td>
<td>In-service system meets system requirements</td>
</tr>
</tbody>
</table>

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[ATKINS] [PARSONS BRICKEERHOFF]
Integrating requirements with design

Traceability by Network Rail requirements manager

Traceability by LDO capture and analysis

Owned and traced by LDO design teams

e.g. Approved in Principle designs, EMC strategy, etc.
e.g. Form 001
Leaf-level requirements

- Requirement Originating requirement 1
- Requirement Originating requirement 2
- Requirement Originating requirement 3
- Requirement Derived requirement 4
- Requirement Derived requirement 5
- Requirement Derived requirement 6

Set of leaf-level requirements

- Traces to Document Project specification
- Supersedes
- Supersedes
- Supersedes
A simple rich traceability metamodel

Direct traceability

Physical [TRAK] a physical

Document [TRAK] a document

Requirement [TRAK] a requirement

Requirement [TRAK] a requirement

Issue (UML) argument of necessity

Change (UML) argument of sufficiency

Satisfaction argument

Audit trail documented by

addresses

satisfies

resolves

[TRAK] traces to

[TRAK] traces to

implies

arises from

traces to
“Pilot’s manual” instruction flowcharts

- Guide to contents of detailed documents
- Indicate involvement of multiple actors
- Easy to test logic
Simplified architecture framework

VP01: Requirement capture
- Document a document
  - Satisfaction Argument: reason for changing/refining requirement
- Requirement a requirement
  - traces to VP02: Requirement tracing, refinement and applicability
  - traces to VP04: Functional model

VP02: Requirement tracing, refinement and applicability
- VP03: Geographical asset hierarchy
  - System Route: System
    - is configured with System Geographical area
      - is configured with System Environment/external system
        - System Railway system/subsystem
          - is configured with System Context
  - Physical Asset [specific]
    - traces to (global req)
    - traces to (area/section req)
    - traces to (localised/site req)
      - interfaces with VP06: Element classification

VP04: Functional model
- System Railway system/subsystem
- System Environment/external system
  - interfaces with
  - interfaces with

VP05: System interfaces
- VP06: Element classification
  - Physical Asset [specific]
    - traces to (discipline/asset type req)
      - traces to (interface req)

VP07: Asset checklist
- Requirement a requirement
  - traces to VP03: Geographical asset hierarchy
  - traces to VP05: System interfaces
Collaborative tools for SE

- NR DOORS environment (via Citrix):
  - Client reporting of V&V
  - Mirroring of developed traceability downstream of PRS
  - Mastering of traceability upstream of PRS (Client & Sponsor requirements)

- LDO Enterprise Architect environment (on the cloud, eventually...)
  - Mastering of traceability downstream of PRS (GRIP3 and GRIP4 output requirements)
  - System architecture / Interface modelling
  - Safety risk assessment (WIP)
Interface Management

Programme Boundary

Programme Interface register

I/F Reqs & ICDs

System Architecture input

Top level technical interface register

Master technical interface registers

Route Section Interface Registers
## Interface Management

<table>
<thead>
<tr>
<th>Interface Reference Number</th>
<th>Interface Description</th>
<th>Responsible Discipline</th>
<th>From</th>
<th>To</th>
<th>Technical Complexity</th>
<th>Internal/External</th>
<th>Schedule</th>
<th>Sum Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>GWEP/TIF/0101</td>
<td>Structural load bearing of OLE for design of OLE support structures.</td>
<td>OLE</td>
<td>Overhead Line Equipment (Catenary)</td>
<td>OLE Supporting Structures</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>GWEP/TIF/0102</td>
<td>Physical clearance between OLE supporting structure and catenary.</td>
<td>OLE</td>
<td>Overhead Line Equipment (Catenary)</td>
<td>OLE Supporting Structures</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
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<tr>
<td>GWEP/TIF/0103</td>
<td>OLE catenary interface between the FEDs and motorised switches.</td>
<td>OLE</td>
<td>Overhead Line Equipment (Catenary)</td>
<td>Distribution-Power Supply</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>GWEP/TIF/0104</td>
<td>Physical location coordination of OLE cables and cable route with respect to telecoms cables and equipment.</td>
<td>OLE</td>
<td>Overhead Line Equipment (Catenary)</td>
<td>Telecoms System</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>GWEP/TIF/0105</td>
<td>Physical location coordination of OLE cables and cable route with respect to telecoms equipment.</td>
<td>OLE</td>
<td>Overhead Line Equipment (Catenary)</td>
<td>Telecoms System</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>GWEP/TIF/0106</td>
<td>Position of signals with respect to OLE (coordination of signalling scheme planning with respect to OLE layouts).</td>
<td>OLE</td>
<td>OLE Layout</td>
<td>Signalling System</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>5</td>
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<tr>
<td>GWEP/TIF/0107</td>
<td>Interface of Traction distribution equipment with SCADA for monitoring.</td>
<td>OLE</td>
<td>Distribution-Power Supply</td>
<td>SCADA</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>6</td>
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<tr>
<td>GWEP/TIF/0108</td>
<td>Compatibility of OLE earthing and bonding with Earthing and Bonding of other disciplines earthing and bonding (inline with overall earthing and bonding strategy).</td>
<td>OLE</td>
<td>Overhead Line Equipment (Catenary)</td>
<td>Earthing &amp; Bonding</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>5</td>
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<tr>
<td>GWEP/TIF/0109</td>
<td>Electromagnetic Compatibility of OLE with respect to other discipline subsystems (Internal).</td>
<td>OLE</td>
<td>Overhead Line Equipment (Catenary)</td>
<td>Electromagnetic Compatibility (EMC)</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>GWEP/TIF/0110</td>
<td>Electromagnetic Compatibility of OLE with respect to other discipline subsystems (Third party)</td>
<td>OLE</td>
<td>Overhead Line Equipment (Catenary)</td>
<td>Electromagnetic Compatibility (EMC)</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>5</td>
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<tr>
<td>GWEP/TIF/0111</td>
<td>Heights and staggers of the OLE Catenary with respect to track structures.</td>
<td>OLE</td>
<td>Overhead Line Equipment (Catenary)</td>
<td>Track Structures (formation and drainage)</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>
A receptive environment to SE

• “You guys are so crucial”
  – LDO Project Director (a civil engineer)
• “If you meet any resistance, let me know straight away”
  – LDO Project Director (a civil engineer)
• “We have a golden window to achieve a requirements-led design”
  – LDO Engineering Director (a mechanical engineer)
• “Oh yeah, we’ve done requirements capture before. No problem”
  – Discipline leads (several)
• “and of course, we’ll be producing a verification report for the design”
  – Route Section design manager (a mechanical engineer)
Work in progress...

1. Reliability, Availability & Maintainability
2. Testing & Commissioning Planning
3. Entry Into Service Planning
4. Safety Assurance & Safety Case Development
5. Operational & Maintenance Development
Conclusions

1. GWEP has set off with a systems engineering – the challenge is to embed it and keep it going

2. Systems Integration / engineering is a core responsibility for the LDO and is facilitating wider collaboration

3. Team approach working jointly with NR and all partners

4. Collaboration is a necessity for good systems engineering on major programmes