Overview

• Integrating SE practices into major procurements
• Convincing of the benefits of an SE approach
• Delegating systems engineering responsibilities down the supply chain
• Using (or not) systems engineering standards
• Ensuring systems assurance is a progressive activity
• Measuring systems integration success
• Commissioning using SE practices
Context & History - ELLP

- East London Line (ELLP) Project concept devised by LU mid 1980’s

- TWA planning powers 1997 & 2001

- Project transferred
  - LUL to SRA in 2001
  - SRA to TfL in November 2004

- Benefits
  - Links north and south London
  - First step towards an orbital system
  - Offers congestion relief to central London
  - Catalyst for significant regeneration
ELL Project Scope

Phase 1 (Orange)
Extend the existing line
- North to Dalston Junction
- South to Crystal Palace and West Croydon

Phase 1a (Red)
- Extend the existing line
  - North to Highbury & Islington from Dalston Junction

Phase 2 (Blue)
- Further extend services west to Clapham Junction
ELR Train Service

• 4 - car trains travelling on national rail infrastructure

• Phase 1 - 12 trains per hour to and from Dalston Junction, one third to New Cross, one third to Crystal Palace and one third to West Croydon

• Phase 1a – 8 trains per hour extended to Highbury & Islington

• Phase 2 - 16 trains per hour through the central section connecting to North London Line and Clapham Junction
Introducing SE into a Major Project

• Avoid jargon and SE speak
• Convince not impose
• Integrate SE practices into overall processes
• Be pragmatic and persistent
• Set out a clear strategy – and then communicate it
ELLLP Engineering Strategy

System Engineering principles applied :-

- System Breakdown Structure ( Levelling )
- Lifecycle Management
- Operational Concept
- Modelling
- System Definition
- Requirement Management
- Interface Definition and Management
- Configuration Management and Baselines
- Progressive Assurance
Planning the Project - Lifecycle

- Based on EN50126 RAMS standard to use V lifecycle

- Other Standards and methodologies considered
  - LU E1008
  - NR GRIP
  - Office of Government Commerce lifecycle
Planning the Project - System Breakdown or Levelling

- World
  - Railway
    - Existing Railway
    - East London Line
      - Changing Railway
    - Not Railway
  - Infrastructure
    - Trains
    - Operations
      - Engineering Rolling Stock
      - Passenger Services
      - Network Operations
      - Infrastructure Managers
      - Rules & Procedures
      - Agreements
      - IDABS
      - Passenger Services Operation
      - Network Operators
      - Infrastructure Managers
      - Rules & Procedures
      - Agreements
      - VBS
      - IDABS
      - VBS

- Level 1 (System)
- Level 2 (Element)
- Level 3 (Package)
- Level 4 (Sub-System)

- Enabling Works
- Main Works
- Network Rail Works
- London Underground Works
- Other Works
- Passenger Rolling Stock
- Engineering Rolling Stock
- Train Control & Protection
- Dynamics, Gauging & Movements
- Performance
- RAMS
- Acoustics
- Climate
- Materials & Environment
- Passenger Functionality
- Structures
- Cab Interior
- Saloon
- Power Supply
- Train Control & Protection
- Dynamics, Gauging & Movements
- Performance
- RAMS
- Acoustics
- Climate
- Materials & Environment
- Passenger Functionality

- Routeside Systems / Disciplines
- Track
- Civils & Structures
- E & M
- Signalling
- Traction Power
- HV Power
- LV Power
- Telecoms

- Locations
- Dalston Jnt
- Shoreditch HS
- Whitechapel
- New Cross Gate
- OBC
- NXG Facility
The Levelled Lifecycle

- Requirements Definition
- Preliminary Product Specification
- Detailed Product Specification
- Product Creation
- Product Test
- Install
- Proving (In-situ) Test
- Acceptance Test
- Transfer into Service
- In Service Support
- Decommission & Disposal

Level 1

Level 2

Level 3

Level 4
ELLIP Engineering Strategy

System Engineering principles applied :-

• System Breakdown Structure (Levelling)
• Lifecycle Management
• Operational Concept
• Modelling
• System Definition
• Requirement Management
• Interface Definition and Management
• Configuration Management and Baselines
• Progressive Assurance
System Definition - 2003

Development Remit

Functional Specification

Project Design Specification

Core Proposition
Business Case

Asset Condition Reports
Hazard Assessment
Technical Studies
Constructability Assessment
Maintenance Strategy & Requirements
Performance Strategy & Requirements
Operations & Control Strategy & Requirements
Safety Requirements Specification
Standards Matrix
Project Consents Register
Environmental Requirements
Interface Information Queries
Interfaces Definition
Rolling Stock Technical Business Specification
Architectural Vision

Baseline No. 2
Asset Condition Report
Risk Register
Project Design Basis Patronage

ROLLING STOCK REQUIREMENTS
Scope, Contract Management, Operational & Performance (inc. RAMS), Interfaces (Infrastructure), Technical (inc. standards), Environmental Assurance Process

OPERATIONS PROCESS REQUIREMENTS
Timetable, Rules of Route, Rules of Plan, Operational Procedures & Processes, Operating Staff, Contingency Plans, Emergency Plans

INFRASTRUCTURE REQUIREMENTS
Scope, Contract Management, Operational & Performance (inc. RAMS), Interfaces (rolling stock, boundary, package, other projects) Technical (inc. standards), Planning & Consents, Environmental Assurance Process

Enabling Works
Main Works
LUL Works
NR Works

Rolling Stock Design
Timetable, Operational Publications
Infrastructure Preliminary Design

Main Works
LUL Works
NR Works
Requirements Management

• Key decisions
  – Procurement Strategy
  – Operational Concept
  – Operational Requirements Capture

• Use of Requirements Management Tool
  – Tried TeamTrace in 2003
  – Migrated DOORS in 2005

• Risk based assessment use of DOORS
  – Product requirements in DOORS
  – Contract requirements specification directly from DOORS
  – Process requirements in other Contract documents
Project Design Specification

The requirements for the development of operational concepts, rules and procedures will be defined and achieved by the London Overground Operations Directorate. ELLP will continue to liaise with the London Overground Operations Directorate to ensure the interfaces between operations, rolling stock and infrastructure can be properly managed within the ELLP.

DOORS structure
East London Railway System Modelling

• System modelling to allocate reliability targets
  – Concept stage – PPM < 92%
  – Preliminary Design stage – PPM 92.9%
  – Detailed Design stage – PPM 93.5%
  – As built stage – PPM (in 2010)

• Infrastructure
  – Uses actual data where possible
  – Infrastructure reliability is area needing most focus
  – Use proven systems to avoid development risk

• Rolling stock
  – Fleet of 20 trains (18 in service)
  – Mean miles to failure event (>2 mins) – circa 38,000
East London Railway System Modelling

Example of Element Type Delay per Annum (minutes)
System Engineering principles applied :-

- System Breakdown Structure (Levelling)
- Lifecycle Management
- Operational Concept
- Modelling
- System Definition
- Requirement Management
- Interface Definition and Management
- Configuration Management and Baselines
- Progressive Assurance
System Architecture
System Architecture (expanded)
DOORS structure

Project Design Specification (a collection of documents) ELM-TEC-240-14-05-0002 Issue 5

Ops Process Requirements
The requirements for the development of operational concepts, rules and procedures will be defined and achieved by the London Overground Operations Directorate. ELLP will continue to liaise with the London Overground Operations Directorate to ensure the interfaces between operations, rolling stock and infrastructure can be properly managed within the ELLP.

Rolling Stock Requirements
(RSR-T)
ELM-COM-109-32-05-0002 Issue 5

Enabling Works Infrastructure Requirements - Technical (EWIR-T)

Enabling Works Infrastructure Requirements - Operational (EWIR-O)
ELM-TEC-210-14-05-0002 Issue 2

Rolling Stock Requirements – Technical (RSR-T)

Infrastructure Requirements

(PDS-GR) (MWIR-T)
ELM-TEC-210-14-05-0001 Issue 2

(PDS-GR) (LUWIR-T)
ELM-MW-515-02-0002 Issue 6.2

(PDS-GR) (LWIR-T)
ELM-MW-515-06-0003 Issue 1

(PDS-GR) (NRTWIR-T)
ELM-TEC-225-04-06-0002 Issue 1

(PDS-GR) (NRONWIR-T)
ELM-TEC-225-04-06-0007 Issue 1

(PDS-GR) (NRONIR-T)
ELM-TEC-225-04-06-0006 Issue Draft A

(TGSWIR-T)
Ticketing and Gateline System Works Infrastructure Requirements – Technical (TGSWIR-T)
ELM-TEC-225-04-07-0004 Issue 2

(EDFEWIR-T)
EDF Energy Works Infrastructure Requirements – Technical (EDFEWIR-T)
ELM-TEC-248-04-06-0002 Issue 2

(NRAWIR-T)
Network Rail Ancillary Works Infrastructure Requirements – Technical (NRAWIR-T)

(EWIR-T)
Enabling Works Infrastructure Requirements – Technical (EWIR-T)
ELM-TEC-210-14-05-0001 Issue 2

(RSRT-T)

(LUWIR-T)

(NRTWIR-T)

(NRSTWIR-T)

(RETIR-T)

(DVR)
Development Remit
ELM-TEC-225-14-05-0001 Issue 2

(FNS)
Functional Specification
ELM-TEC-225-04-05-0001 Issue 5

(OCR)
Operations and Control Strategy
ELM-TEC-215-04-05-0001 Issue 3

Does not currently exist
Dalston – Western Curve Works Infrastructure Requirements – Technical (DWCWIR-T)
Interface Definition
ELLP Engineering Strategy

System Engineering principles applied :-

• System Breakdown Structure (Levelling)
• Lifecycle Management
• Operational Concept
• Modelling
• System Definition
• Requirement Management
• Interface Definition and Management
• Configuration Management and Baselines
• Progressive Assurance
Progressive Assurance using Technical Cases

- Overall Assurance Objective
  - Product Argument
    - Argument that Requirements are Valid
    - Argument that Requirements are Satisfied in Design
    - Argument that Requirements are Satisfied in Preliminary Design
  - Argument that Requirements are Satisfied
  - Requirements Management Argument
  - Configuration Consistency Argument
  - Non-interference Argument
    - Argument that Requirements are Satisfied in Detailed Design
    - Argument that Requirements are Satisfied in Construction/Manufacture
    - Argument that Requirements are Satisfied in Assembly/Integration
    - Argument that Requirements are Satisfied in Acceptance Testing & Entry into Service
    - Argument that Requirements are Satisfied in Operation & Maintenance
  - Argument that Requirements are Satisfied in Construction/Manufacture
Technical Cases and Levelling
Requirements are valid

Requirements are satisfied

Requirements are traceable

Consistent set of arguments and evidence exists

Process argument

The early Level 1 ELLP GSN argument - 2005
The developing Level 1 Product GSN argument - 2006
Technical Cases – Wood for the Trees

The developed ELLP Level 1 Product GSN Argument - 2007

Traffic Lights used to monitor progress
Technical Cases – Wood for the Trees

The Rationalised ELLP Level 1 Product GSN Argument - 2008
Technical Cases - The Evidence

- TfL model TC adopted by supply chain – down through the system breakdown;
- Considerable volume of evidence generated for lower level locations and disciplines;
- Some evidence essential e.g. legislation, certification required by standards e.g. BS7671;
- Evidence needed to be categorised on a risk basis
## The Evidence Table

<table>
<thead>
<tr>
<th>Sn</th>
<th>Reference Number</th>
<th>Description of Solution (i.e., the Product(s) and/or Process(es) that satisfy the Goal)</th>
<th>Responsibility (If not Completed/Living/Ongoing)</th>
<th>Status</th>
<th>Ref. Number(s) of the Goal(s) Satisfied by the Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>034</td>
<td>ELM-TEC-225-04-06-0001</td>
<td>ELL System Interfaces and Issues Register</td>
<td>Not Started</td>
<td>Completed (Ongoing)</td>
<td>G01.01.02.01.01.02.01</td>
</tr>
<tr>
<td></td>
<td>ELM-TEC-239-05-06-0002</td>
<td>ELL System Architecture Diagram</td>
<td>Completed</td>
<td>Completed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ELM-TEC-239-05-05-0002</td>
<td>ELL Systems Context and Interfaces Model</td>
<td>Completed</td>
<td>Completed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ELM-TEC-225-14-04-0001</td>
<td>ELL Interface Definition</td>
<td>Completed</td>
<td>Completed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ELM-TEC-225-14-06-0006</td>
<td>NR &amp; TOC Operational &amp; Business Systems Interfaces</td>
<td>Completed</td>
<td>Completed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ELM-TEC-225-04-06-0004</td>
<td>New Cross Gate Operational Interfaces</td>
<td>Completed</td>
<td>Completed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ELM-TEC-225-04-06-0008</td>
<td>New Cross Gate Interface Definition</td>
<td>Completed</td>
<td>Completed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ELM-TEC-225-04-06-0011</td>
<td>Rolling Stock - Infrastructure Traction Interface</td>
<td>Completed</td>
<td>Completed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ELM-TEC-225-04-07-0002</td>
<td>Bulk Supply Points Interface Definition</td>
<td>Completed</td>
<td>Completed</td>
<td></td>
</tr>
<tr>
<td>035</td>
<td>ELM-TEC-240-14-05-0002</td>
<td>Rolling Stock Requirements within ELM-TEC-240-14-05-0002, ELLP Project Design Specification.</td>
<td>Completed</td>
<td>Completed</td>
<td>G01.01.02.01.01.02.01</td>
</tr>
<tr>
<td></td>
<td>ELM-COM-109-32-05-0002</td>
<td>The Rolling Stock requirements within the PDS are currently broken out into ELM-COM-109-32-05-0002, Rolling Stock Requirements-Technical</td>
<td>Completed</td>
<td>Completed</td>
<td>G01.01.02.01.01.04.01</td>
</tr>
<tr>
<td>036</td>
<td>ELM-TEC-215-04-06-0008</td>
<td>Start of Service Strategy</td>
<td>In Progress</td>
<td>In Progress</td>
<td>G01.01.02.03.03.03.02.01.04</td>
</tr>
<tr>
<td>037</td>
<td>ELLP Level 2 Rolling Stock Technical Case - 2nd Release</td>
<td>System Assurance Manager</td>
<td>Not Started</td>
<td>Not Started</td>
<td>G01.01.02.01.01.04.02</td>
</tr>
<tr>
<td>038</td>
<td>ELLP Level 2 Operations Technical Case - 2nd Release</td>
<td>System Assurance Manager</td>
<td>Not Started</td>
<td>Not Started</td>
<td>G01.01.02.01.01.03.02</td>
</tr>
</tbody>
</table>
SE in Commissioning – TR Readiness

- Assurance Accepted
- TCs & Assurance
- Evidence Packs
- TR Pre-requisites (PCP and OAB)
- Draft RBC
- TR Baseline
- L3 & L2
- Review Reports
- PCP Status
- Reports
- TR Plan
- TRRR

- SATRR
- Report
- RBC TR
- Baseline
- Agreed TR
- Plan
- Prioritised
- Action Plan
- Recommendation
TR Readiness Review Questions

Looking back in time
• What scope of ELL System is to be tested (RBC at TR)?
• Is it integrated, tested and commissioned?
• Does it meet the intention and requirements (V&V)?
• Do we have all the Assurance Evidence (TCs)?
• Is it Safe & Environmentally Compliant?
• Have the correct processes, tools and competences been applied?
• Does it satisfy all the Planning Consents / Orders?

Looking forward
• Is there an approved TR Plan in place?
• Are all SMS’s in place?
• Are all Approvals in place?
• Are all participants prepared for TR (IPT, Contractors, O&M parties)?
• Are other Stakeholders informed / prepared for TR?
# Prerequisites to Test Running

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rolling Stock</td>
<td>4</td>
</tr>
<tr>
<td>Signalling</td>
<td>3</td>
</tr>
<tr>
<td>C &amp; C</td>
<td>4</td>
</tr>
<tr>
<td>Track</td>
<td>2</td>
</tr>
<tr>
<td>Traction Power</td>
<td>2</td>
</tr>
<tr>
<td>Stations</td>
<td>2</td>
</tr>
<tr>
<td>Statutory Certificates</td>
<td>10</td>
</tr>
<tr>
<td>Ops &amp; Procedure</td>
<td>22</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>49</strong></td>
</tr>
</tbody>
</table>

## TEST RUNNING - LIST OF PREREQUISITES

<table>
<thead>
<tr>
<th>Item #</th>
<th>Title</th>
<th>Comments</th>
<th>Stakeholder</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td><strong>Rolling Stock</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1</td>
<td>VSSC for class 375 vehicle for ELLP Operation (NR Acceptance)</td>
<td>Commissioning by BT for free run undertaken</td>
<td>NR</td>
</tr>
<tr>
<td>1.2</td>
<td>VSSC for class 375 vehicle with test instrumentation (if applicable)</td>
<td></td>
<td>ELLP, BBCJV</td>
</tr>
<tr>
<td>1.3</td>
<td>Up to date Maintenance Certificate with associated ‘frag’ list</td>
<td>Required in addition to NR Route Acceptance Certificate</td>
<td>ELLP, BBCJV</td>
</tr>
<tr>
<td>1.4</td>
<td>VSSC for NRAP and EAC Certificates</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.0</td>
<td><strong>Signalling</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1</td>
<td>Signalling Level 4 Technical Case</td>
<td></td>
<td>ROG3, NR, BBCJV</td>
</tr>
<tr>
<td>2.4</td>
<td>Signalling NXG Interface Safety Case (CSC)</td>
<td>Possible interim submission</td>
<td>ROG3, NR, BBCJV</td>
</tr>
<tr>
<td>3.0</td>
<td><strong>Communications and Control Systems</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.1</td>
<td>Data Transmission Network, SPT, Tunnel Telephones - AC</td>
<td></td>
<td>LOROL, ROG3, NR, BBCJV</td>
</tr>
<tr>
<td>3.2</td>
<td>GSM-R valid for use with Test Trains</td>
<td></td>
<td>LOROL, ROG3, NR, BBCJV</td>
</tr>
<tr>
<td>3.4</td>
<td>Pway Level 4 Technical Case (Inclusive Gauge certificate)</td>
<td>RT to precise their needs</td>
<td>BBCJV</td>
</tr>
<tr>
<td>3.5</td>
<td>Tunnel Drainage AC (unless contained in Pway AC)</td>
<td>Part of Pway Level 4 Technical Case</td>
<td>BBCJV</td>
</tr>
</tbody>
</table>
Review of Presentation

• Integrating SE practices into major procurements ✔

• Convincing of the benefits of an SE approach ✔

• Delegating systems engineering responsibilities down the supply chain ✔

• Using (or not) systems engineering standards ✔

• Ensuring systems assurance is a progressive activity ✔

• Measuring systems integration success ?

• Commissioning using SE practices ✔
Concluding Comments

- Plan at the start and be prepared to develop SE
- Lead by example
- Integrate and balance project and engineering management
- Manage the paper mountain
- Build an integrated team
- Plan for inevitable change
- Be practical and pragmatic
Questions?
www.tfl.gov.uk/overground