

Institution of Railway Signal Engineers BODY OF KNOWLEDGE

CONTENTS

1 DE	HOW TO USE THE IRSE BODY OF KNOWLEDGE FOR PROFESSIONAL EVELOPMENT
2	INTRODUCTION
3	PLANNING, IMPLEMENTATION AND MANAGEMENT
4	SPECIFY, DESIGN AND DEVELOP PRODUCTS AND SYSTEMS 4-1
5	PRODUCTION AND MANUFACTURE
6	INSTALLATION
7	SYSTEM VALIDATION, SAFETY ACCEPTANCE AND COMMISSIONING7-1
8	OPERATION, MAINTENANCE, MODIFICATION AND DECOMMISSIONING 8-1
9	QUALITY, SAFETY, RELIABILITY, AVAILABILITY AND MAINTAINABILITY 9-1

Organisation of Information

1. How to Use The IRSE Body of Knowledge

2. Introduction

							Ľ	
3. Planning, Implementation and Management								
4. Specify, Design & Develop Products & Systems		5. Production & Manufacture		6. Installation		7. System Validation Safety Acceptance & Commission -ing		8. Operation, Maintenance , Modification & Decommis - sioning
9. Q uality, Safety, Reliability, Availability and Maintain ability								

It can be seen from the above diagram that Section 3 (Planning, Implementation and Management) is very relevant to all other activities. Rather than repeat similar information in every section it has been decided to emphasise the importance of these disciplines in Section 3, although they apply to all sections of this document. Section 9 (Quality, Safety Reliability, Availability and Maintainability) has been treated in a similar fashion and it is therefore necessary to emphasise the need for these disciplines to be resolutely applied to other tasks in other Sections. The user is strongly advised to read the entire document rather than expecting one Section to provide the total information on a particular subject.

Preface

This Body of Knowledge has been produced as part of the IRSE¢ commitment to promote for the public benefit, the advancement of the science and practice of railway signalling and telecommunications and to maintain high standards of practice and professional care amongst those working within the industry. The term £ignallingqas used throughout this Body of Knowledge therefore includes signalling and railway / operational telecommunications in the context of train control, but has been shortened to £ignallingqto avoid repetition.

Originally commissioned by the former Strategic Rail Authority in the UK, this Body of Knowledge has been provided to act as a reference for those seeking to gain and maintain competence in the profession within the UK context. It is derived from, and combines the earlier work of the IRSE Examination, Licensing, and Training & Development Committees and draws on the experience of the Institutions international membership as appropriate (there are distinct differences between UK practices and those adopted in Europe, USA and elsewhere world-wide).

This is a handbook rather than a textbook, and has been designed to be used by individuals and organisations alike, from initial entry into the profession, right the way through to the most seasoned of practitioners seeking to update and continue their professional development in an increasingly competitive, technology advancing and safety sensitive market place.

It may be used by those providing initial training and education to new entrants to the profession or, as a self-help tool for those wishing to maintain and improve their own professional competence as part of their continuing professional development. It may also be used to refresh or update members who are returning to the industry, or to a particular topic, after a break.

In addition, the IRSE¢ £ignalling Philosophy Reviewqforms the most comprehensive and recent reference document, and is most essential reading for the professional development of the Railway Signalling Engineer.

As methodologies, technologies and their uses change, there will undoubtedly be a need to revisit this work and update it in line with later thinking and best practice. Current developments such as ERTMS (European Rail Traffic Management System) and ETCS (European Train Control System) will inevitably lead to convergence of different practices and approaches to international projects. This work can not therefore be a definitive text, and the IRSE does not accept liability for its use. The reader is advised to seek further guidance if in doubt.

In the meantime, this work represents the most comprehensive tool in the profession for the initial training, and continuing development, of competent professional signalling engineers.

Acknowledgements

IRSE policy is to avoid listing the participants, because this Body of Knowledge is the formal considered view of the Institution as a body. Nonetheless, the IRSE wishes to acknowledge the assistance in the preparation of this Body of Knowledge document that has been provided by the Strategic Railway Authority, Members of the Institution and railway industry companies and staff.

1 How to Use the IRSE Body of Knowledge for Professional Development

The IRSE recognises Professional Development as an integral part of its mission. In keeping with this, the IRSE Council has issued a Continuing Professional Development Policy, which states that all members, regardless of level of Engineering Council Registration, are expected to honour their professional obligation to take all reasonable steps to maintain and develop their professional competence.

This Body of Knowledge has therefore been produced to highlight the topics that the professional signalling engineer needs to be familiar with, to act as a guide to relevant competence standards, and source useful reference materials.

It is suggested that this Body of Knowledge be read, as a whole in the first instance, remembering that Railway Signalling is a specialist area of Railway Systems engineering. It is therefore important to consider the interfaces between topics, and consider the overlapping and adjoining areas, rather than try to deal with each topic in isolation. Many of the topics are closely linked or interdependent, but have been grouped into the stages of the engineering lifecycle for clarity.

1.1 Domain Specific Knowledge

The subject matter has been broken down into chapters covering the general engineering lifecycle stages. Each chapter starts with a general description of the lifecycle stage and the key topic areas. It is then followed up with bullet points of the knowledge that is specific to the signalling domain. The professional signalling engineer should aim to have at least a cursory knowledge of the domain specific knowledge within each of the chapters. A more detailed knowledge can then be more easily be acquired and / or updated as appropriate.

It is this domain specific knowledge that will be of greatest interest to those cross training from other engineering disciplines.

1.2 Indicative References

In addition to the references listed in each of the chapters, the IRSE Text books Introduction to Railway Signallingq Railway Signallingq and Railway Control Systemsq are recommended. The IRSE annual programme of Lectures, Conferences and Seminars will act as interim updates, by providing additional reference material, addressing topics that are most relevant at the time.

A complete catalogue of IRSE Technical Papers (at the time of issue), can be found on the IRSE website <u>www.irse.org</u>.

1.3 Relevant International Standards

There has been a great deal of debate about the use of the various standards, which have been referenced in this Body of Knowledge. Many existing products and systems were constructed and implemented using former British Railways Board specifications or LUL specifications, or other appropriate railway administration documentation. The references to, for example, Network Rail Company Standards and subsequent Railway Group Standards have not been included as they are client and application specific,

nevertheless the readers must make themselves aware of all relevant standards in specific area of activity.

Many administration specific documents and standards direct the user to generic norms such as BS IEC 61508, or railway specific standards such as BS EN 50121, BS EN 50126, BS EN 50128 and BS EN 50129, the latter being legally binding in the UK. Those who prefer the IEC standard do so because it gives better and clearer guidance on some issues, whilst the BS EN standards are tailored to the specific needs of the railway, but they have limitations as follows:

- BS EN 50121 (Railway applications . Electromagnetic Compatibility) states that it does not cover safety issues, thus compliance is based on testing when fully operational and not under subsequent failure modes, also the frequencies employed in testing are higher than those used for signalling safety. The benefit of using this specification is to manage EMC (electromagnetic compatibility) with respect to all system stakeholders on, or near the railway.
- BS EN 50126 (Railway applications The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS)) covers system life-cycle but omits installation and testing of new systems adjacent to an existing working railway where the Safety Case for the Stage Works needs to show that the existing systems need to be kept safe. The specification does not cover issues such as the integration of equipment alongside existing equipment. Consideration must be given to methods of ensuring the overall system performance is not detrimentally affected.
- BS EN 50128 (Railway applications Communications, signalling and processing systems - Software for railway control and protection systems) is written to ensure good and traceable practice is used in developing software. The claims it makes for the integrity of software, developed using these processes, derives from the evidence collected during the process of creating and accepting that software, but it is almost impossible to support claims for the higher safety integrity levels for the software that is already written. The processes in 50128 depend on proving that the software fulfils its specification, and are based on that specification requiring only serial processing. Those who wish to provide safety assurance of signalling by only following the principles of 50128 must not specify any parallel processing requirements.
- BS EN 50129 (Railway applications Safety related electronic systems for signalling) assumes that a whole safety case can be compiled from first principles. This is very useful for a new metro or other isolated line. Consideration must also be given to implementing systems which make use of existing infrastructure, such as grandfather rights and cross-acceptance.

Because of these limitations, compliance with these standards is necessary, but in itself not sufficient, to ensure reliability, availability, maintainability and the safety of the railway system. For further guidance on the use and applicability of BS EN 50126, BS EN 50128, BS EN 50129 and IEC 61508, please refer to appendices F - I.

1.4 Competence Standards – Please note this section is under review

It is important to remember that reading of the reference material in itself does not necessarily increase competence.

Competence is defined as the ability to perform activities to the standards expected in employment, and is the **combination of practical and thinking skills, experience and knowledge** (*Source – HSE - Railway Safety Principles and Guidance Part 3 section A*).

Relevant competence standards have therefore been referenced to include information about the practical and thinking skills required to apply underpinning knowledge, and to provide guidance on the necessary experience that needs to be gained for competent performance.

The most relevant competence standards for those involved in applications engineering, are the IRSE Licensing Scheme standards. These are specific to the profession, and have been cross-referenced to the UK National Occupational Standards, (in particular, the Occupational Standing Council for Engineering (OSCEng) Standards) to help ease the transition and recognition of skills when cross-training from other industries and engineering disciplines.

Relevant OSCEng standards have also been included in their own right as they form the engineering ±oot standardqfor railway specific National Vocational Qualifications. (NVQs), are currently being written / updated for this domain, and combine the domain knowledge of the IRSE Licensing Scheme, with the generic ±key skillsqrequired by the NVQ.

The Engineering Council Standards for Professional Engineering Competence have also been referenced, as these are the root standards used by the IRSE for registration purposes. IRSE evidence guides for these standards are available from the IRSE Membership Manager.

Other competence standards that have been referenced are the Institution of Engineering and Technology / British Computer Society Competency guidelines for Safety Related System practitioners. These competence standards relate directly to BS IEC 61508 Functional safety of electrical/electronic/programmable electronic safety-related systems. They are very appropriate to those involved in the development of products, systems and applications, and are particularly relevant to those working on the European Rail Traffic Management System (ERTMS) and Safety Integrity Levels (SIL).

1.5 Prioritising and Recording

Regardless of whether this Body of Knowledge is used for initial, or continuing professional development purposes, it is suggested that learning and development be recorded in a systematic way. This may be done as part of an annual performance appraisal within the employment or training context, or on a personal, self-directed basis.

The IRSE Professional Development Record & Licensing Scheme Log Book is specifically designed for this purpose and includes a section to help with the production of a development action plan and the recording of learning experiences. Copies are available from the IRSE Licensing Registrar at the IRSE Head Office.

Once the Body of Knowledge has been read as a whole, it is suggested that it be read again for the specific purposes of identifying areas for development. These opportunities can then be prioritised, and goals and dates for achievement should be set.

It is then possible to plan, record and carry out development actions using the most appropriate learning methods and opportunities.

Methods may include:

- Reading the recommended Indicative References
- Attending training courses, lectures, seminars or conferences
- Open, flexible or distance learning materials including printed matter, audio tapes, video tapes, interactive video, interactive CD or via the internet
- Reading professional and specialist magazines and journals
- Discussion with colleagues, a mentor, a supervisor, or contacts in discussion groups or professional networks

What ever method is chosen it is important to plan opportunities to gain experience and develop skills in applying newly acquired knowledge by undertaking new tasks or projects. If such opportunities are not readily available in the workplace, then it may be appropriate to consider using extra curricular activities such as: membership of IRSE committees or working groups, or the IRSE Professional Examinations to develop a range of skills including, mentoring and lecturing skills.

The act of recording learning and development helps to develop competence and commit newly acquired knowledge to memory. The Learning Experience Record available in the CPD section of the IRSE Professional Development Record & Licensing Scheme Logbook places emphasis on what has been learned rather than what has been done. It is suggested that this is used to follow through learning by thinking about what has been learnt and how this may be applied in the future. Any follow-up actions should also be noted. The process of thinking through what has been learned and keeping a record will in itself greatly enhance learning.

Developing and maintaining competence is part of an on-going process. It is necessary to review progress regularly and keep up to date with latest developments in light of changing needs, technologies and working methods. This may also be done as part of an annual appraisal system, or on a personal, self-directed basis.

Information and recording mechanisms to help carry out the review process have been included in the IRSE Professional Development Record & Licensing Scheme Log Book.

1.6 Relevant OSCEng Standards

1.6.1 Engineering Competence Standards

8.01 Develop yourself in the work role

- 1.6.2 Higher Level Standards
 - 8.1.1.1 Maintain and Develop own engineering expertise
 - 8.1.1.2 Apply professional ethics and values

1.7 Relevant Engineering Council (EC (UK)) Standards

1.7.1 EngTech (Engineering Technician)

A Use engineering knowledge and understanding to apply technical and practical skills.

This includes the ability to;

A1 review and select appropriate techniques, procedures and methods to undertake tasks;

A2 use appropriate scientific, technical or engineering principles.

E Make a personal commitment to an appropriate code of professional conduct, recognising obligations to society, the profession and the environment. In order to do this an EngTech must:

E1 comply with the Codes and Rules of Conduct of their Licensed Institution or Professional Affiliate;

E2 manage and apply safe systems of work;

E3 undertake their engineering work making and utilising risk assessments, and observing good practice with regard to the environment.

1.7.2 IEng (Incorporated Engineer)

A Use a combination of general and specialist engineering knowledge and understanding to apply existing and emerging technology.

A1 Maintain and extend a sound theoretical approach to the application of technology in engineering practice.

A2 Use a sound evidence-based approach to problem-solving and contribute to continuous improvement.

1.7.3 CEng (Chartered Engineer)

A Use a combination of general and specialist engineering knowledge and understanding to optimise the application of existing and emerging technology. A1 Maintain and extend a sound theoretical approach in enabling the introduction and exploitation of new and advancing technology and other relevant developments

A2 Engage in the creative and innovative development of engineering technology and continuous improvement systems

1.7.4 IEng (Incorporated Engineer) and CEng (Chartered Engineer)

E Demonstrate a personal commitment to professional standards, recognising obligations to society, the profession and the environment.

E1 Comply with relevant codes of conduct.

E2 Manage and apply safe systems of work.

E3 Undertake engineering activities in a way that contributes to sustainable development.

E4 Carry out continuing professional development necessary to maintain and enhance competence in own area of practice.

2 Introduction

The Railway Signalling profession embraces one of the most diverse sets of technologies and concepts to be found. Despite utilising the latest leading edge, safety-critical, real-time software systems the traditional techniques of mechanical signalling, wires levers and pulleys remain widespread.

There is some common ground with other industry sectors, primarily those providing and operating high integrity and/or high availability systems and products especially in real-time and process control environments. Listed briefly below are generic headings of systems and theory, which the professional engineer must address.

Each of these headings may itself encompass a range of diverse equipments, designs and unique installations. Few individuals will be expert in all or most of these areas but all participants need to appreciate their fundamental purpose and characteristics particularly with respect to their interfaces and role in providing the overall system. It is this extremely challenging arena in which overall competence as well as particular expertise requires building.

The subject continues to expand. It is no longer sufficient to be only a signal engineer; train control and, indeed, many business issues regarding trade-off in capacity, performance and costs have become the responsibility of the signal engineer.

An understanding of the interfaces between the many disciplines that contribute to the overall railway system is essential for the competent signal engineer. Preferably all the expert guidance necessary to plan a successful system should be available from the time that the scheme enters its conceptual stage. The participants could include representatives from-

- The Client
- The Operator who will plan the requirements for train movements that will lead to the anticipated track layout, the time table, the frequency of train movements and resultant headways between trains etc. Bi-directional working may be a requirement. The location of Control Centres and equipment rooms will be influenced by the Operator.
- The Civil Engineer responsible for the track bed, bridges, tunnels, cuttings, embankments, buildings, stations, platforms and other structures etc.
- The Permanent Way Engineer responsible for sleepers, rail, rail mountings, points and crossings etc.
- The Electrical and Mechanical Engineer responsible for the provision of lighting and access to power supplies for other rail systems as well as the electrification of the track by overhead catenary or rail based systems, should electric traction be used.
- The Rolling Stock Engineer responsible for the provision of locomotives, carriages and wagons.
- The Infrastructure Engineer responsible for the implementation and maintenance of the railway systems.
- The Signal Control Engineer responsible for the signalling, telecommunications, safety related public address and passenger information systems etc.
- Local Authorities for any level crossing interfaces etc.
- Planning, Risk Assessment, Health and Safety, Quality Assurance inputs.

It must be clearly understood that a decision by one participant can have a profound affect on some or all of the others. Simple examples of these include-

- The signal engineer has a choice of technologies for train detection. If track circuits are used then the type of traction system will influence the choice of train detection. Normally DC track circuits should be used in AC electrified territory and conversely AC track circuits in DC electrified areas.
- If non-insulated metal sleepers are to be used then conventional track circuits cannot be employed and axle counters, for example, could be utilised.
- Some types of equipment on board trains can interfere with signalling systems if not protected against.
- The gradient of the line and the train characteristics affect the layout of the signalling.
- Clearly equipment provided by anyone must not foul the structure gauge above or below the rail, as this could interfere with train movements and possibly cause derailments and collisions.
- The frequency of trains will influence the choice of signalling control system but could also affect the capacity of an electric traction supply.
- Catenary systems can affect signal sighting and positioning.
- The trend towards train borne signalling control will increase the need for close interfaces with train control systems.

Each project will be unique because of location and layout. In some the signal engineer will be presented with an existing layout and the major decisions already taken before being required to provide a signalling solution.

2.1 Major Types of System

- Train detection
- Point operation
- Signals . types, sighting, sequence
- Interlockings . mechanical, relay, computer and ERTMS Level 2 and 3
- Remote control systems . Frequency Division Multiplex (FDM) / Time Division Multiplex (TDM) / coding for public switched transmission
- Level crossings
- Defect detection systems . hot axle box, wheel impact, wide to gauge
- Data and incident recording
- Automatic Train Operation (ATO) / Automatic Train Protection (ATP) and driver warning / advisory systems
- On board radio signalling
- Safety critical communications telephone / radio / data/ Global System for Mobilecommunications - Railways (GSMR)
- Transmission systems copper / fibre / microwave / satellite
- Passenger information and security systems. Public Address (PA) / clock / display boards / Closed Circuit Television (CCTV)
- Power supplies
- Cables & earthing
- Staff protection & warning systems
- Train brake and traction characteristics
- Special needs . subsurface and underground installations, Tramways
- Control centres / systems, including train describers

2.2 Theory, Principles and Concepts

- Multi-aspect signalling
- Interlocking
- Block controls . absolute & permissive working; single, double and bi-directional requirements
- Train protection and warning systems
- Radio propagation
- Transmission Theory
- Control centres automation and decision support tools
- Safety critical and related system engineering, Safety Integrity Levels (SIL)
- Safety critical and related software (SIL)
- Management of safety including configuration and change control (Quantified Risk Assessment, Safety Cases, etc)
- Asset management including life-extension/safety issues
- Verification & validation theory and practice including signalling testing and formal methods
- Life-cycle and human performance / interface issues
- Materials and environment
- Electromagnetic Compatibility (EMC) and in particular between signalling and electric traction systems
- Rules & safe working of trains /railways (including human failure)
- Scheme Design requirements, Reliability, Availability, Maintainability & Safety (RAMS) and Life Cycle Costs (LCC)
- Signalling the layout
- Incident and accident investigation and preservation of evidence

2.3 Systems Integration & Complementary Disciplines

The railway is a system. As such it is helpful for those working in any specialist area to have some knowledge of related and interfacing areas. In particular, Permanent Way engineers need to have some knowledge of both overhead and $3^{rd}/4^{th}$ rail traction power systems and operators need some knowledge of the normal and degraded protection offered by signalling systems.

The train control and signal engineer, however, needs to be the systems integrator. There must be an understanding of the effects on signalling vital control systems of the consequences of Permanent Way and traction power design and engineering choices (both fixed and traction units). There also needs to be an understanding of the perspective of the industry users, the drivers and signallers. Similarly an appreciation of the choices for commercial benefit of maintenance and renewal options as well as new designs is necessary. Allowing for train design characteristics such as braking performance has always been a requirement, but now there is also a need to get involved in detail in train-borne systems for measuring speed and position and in interfacing with train management systems.

This is a developing expertise and the profession is generally starting to recognise its responsibility for helping to set out frameworks to help other disciplines to collaborate towards known outcomes rather than patch and mend the results of independent developments afterwards.

2.4 Prior Knowledge and Experience

It will be apparent that a range of academic training and work experience can be helpful and appropriate for those wishing to master the art and science of train control and signal engineering. It will be increasingly rare for practitioners to be successful without at least some knowledge of electrical and/or software systems but expertise is relevant and necessary in a wide range of topics.

Academic disciplines would include:

- Mechanical engineering, Fluid & hydraulic systems
- Electrical engineering
- Electronic engineering
- Control systems engineering
- Software engineering
- Materials science
- Mathematics & logic
- Communications engineering
- Safety & Reliability Engineering

Work experience would include:

- Design and Development
- Project engineering,
- Asset management
- Maintenance, Installation, Testing, Fault finding and similar roles

Safety related industry sectors would include:

- automotive
- power transmission / nuclear
- aeronautics . aeroplane and air traffic control
- military engineering
- marine engineering
- gas & petro-chemical engineering

2.5 Complementary Knowledge

The Body of Knowledge is intended to be domain-specific and does not, therefore, deal with related and common matters in any detail. However, it is obviously essential to understand and have the necessary knowledge of Health and Safety and other legislation. On a personal basis it is also essential to understand Personal Track Safety and Personal Protective Equipment and to appreciate the risks which must be managed both for oneself and others in applying domain knowledge and working in the railway environment.

2.6 Characteristics of the Railway Signal and Telecommunications Engineer

The characteristics of a successful train control and signal engineer are not rigid, however, the following characteristics are generally recognised as important: cautious & analytical, open-minded & creative, an ability to explain in lay terms, deal with commercial pressures, possessing a positive and fair attitude and a commitment to the profession. These characteristics are shared with many in the engineering community and particularly where safety related work is involved.

2.7 The Profession & Range of Roles

The purpose of Train Control and Signalling is not just signal engineering. The IRSE was founded for: The advancement for the public benefit of the science and practice of signalling (whicho shall mean the whole of the apparatus, electrical mechanical or otherwise, methods, regulations and principles whereby movement of railway or other traffic is controlled) by the promotion of research, the collection and publication of educational material and the holding of conferences, seminarso +.

The profession offers a career of great intellectual and creative challenge. It can be both absorbing and fulfilling and there is always more to learn. It requires knowledge and understanding of not only engineering but also the human factors and Man Machine Interfaces. There is the usual spread of roles within the profession from design and project engineering through the whole of the project lifecycle to maintenance engineering and fault finding, but there are also a couple of roles which have special significance to the industry, i.e. ±esterq& ±cheme designerq Testing is traditional and becoming different in nature quite quickly, whilst scheme design is unique to this industry.

It is important to recognise the different contexts of Product and Applications for railway train control engineering. On the one hand is the design and development of railway control products and systems, whilst on the other is the application of existing products or systems to a particular section of railway. The knowledge required is not separate but nevertheless people can tend to specialise in either the design and development of products and systems, or their application. (See Appendix J for further reading).



Project Lifecycle Diagram

3 Planning, Implementation and Management

Planning, implementation and Management relate to all stages of the engineering lifecycle. Engineering Managers working in the Railway Signalling field need to have an in-depth knowledge of the structure of the industry in order to take critical decisions. In particular, a knowledge and understanding of the contractual interfaces and legislative framework is essential.

Planning must commence at the earliest stage of a project. However distant these items may appear at the start of the planning process it must address those items such as the safety assurance programme, producing the safety case and the safety acceptance strategy

A key part of planning, implementation and management is the assessment of risk. Care must be taken when establishing the requirements to identify the complete range of foreseeable hazards, including business, managerial and technical risks, and provide a means of preventing or controlling such risks. It is important to consider the hazards that arise from outside the signalling system, as well as those from adjacent railway systems. Where the project does not have an applicable safety case, additional care must be taken in this area.

Where the competence of individuals is to be relied upon to control such risks, it is necessary to use a Competence Management System (CMS) that is both auditable and proportionate to the risks, which it seeks to control. The CMS must be operated at an engineering management level to ensure that individuals are not allocated work that they are not competent to perform, unless another adequate control measure can be put in place. Engineering Managers must also consider their own competence to operate the CMS effectively. Where contractors or sub-contractors are used, care must be taken to ensure that the systems employed to control risk are extended to the contractor, is also clearly identified and controlled.

Changes to technology and working practices will all have an impact on the risks identified and it is important to reconsider the implications and hazards when such change takes place. Change management, management of information and communication are therefore key competence areas for the train control & signal engineer.

3.1 Domain Specific Knowledge

- Industry structure and organisation
- Knowledge of signalling or operational communication engineering principles, systems and working practices relevant to the industry
- Working knowledge of other railway engineering disciplines and their impact on interfaces with S&T Engineering
- Legislation relevant to S&T activities
- Risk Management techniques
- Safety, quality and environmental standards
- Procurement Policies and Practices
- Professional Codes of Conduct
- Incident and emergency procedures

- Abilities and competence of staff
- The demands of each job
- Changes in technology, materials and legislation
- Safety approval methodology for new or modified equipment, systems and practices

3.2 Indicative References

IRSE Conference Proceedings Łeep it Safe, Keep it LegalqDec 1999

IRSE Conference Proceedings £ompetence Assurance in the S&T Businessq May 2000.

IRSE Conference Proceedings The Pitfalls of Commercial Contracting in the S&T BusinessqJan 2000.

Patel SD, Procurement Strategy for Train Control and Signalling . The West Rail Paradigm, IRSE Aspect £9 Proceedings p191.

Bell PD, Alliance Projects, IRSE Aspect £9 Proceedings p204

Williams R and Corrie JD, Simplifying the Safety Case for New Signalling, IRSE Aspect £9 Proceedings p339.

HSE Railway Safety Principles and Guidance Part 3 Section A Developing and maintaining staff competence ISBN 0-7176-1732-7

Railway (Safety Case Regulations) 2000 including 2001 amendments Guidance on Regulations ISBN 0-7176-2127-B

Railway Safety Critical Work Regulations Approved Code of Practice & Guidance 1994, ISBN 0-7176-1260-0

Engineering Safety Management - Yellow Book Volume 1 <u>www.yellowbook-rail.org.uk</u> Engineering Council - Guidelines on Risk Issues, ISBN 0-9516611-7-5 Hazards Forum-Safety-Related Systems: Guidance for Engineers ISBN 0-9525103-0-8

See Appendix J for further reading.

3.3 Relevant International Standards

BS 6079 Project Management

BS ISO 10005 Quality Management . Guidelines for Quality Plans

BS EN 12973 Value Management

BSI OHSAS 18001 Occupational Health and Safety Management Systems

BS EN ISO 14001 Environmental Management Systems

BS EN ISO Series 9000, 10000 and 11000 on Quality Assurance

BS EN 10007 Guidelines for Configuration Management

BS IEC 61508 Functional safety of electrical/electronic/programmable electronic safetyrelated systems

BS EN 50126 Railway applications - The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS)

BS EN 50128 Railway applications - Communications, signalling and processing systems - Software for railway control and protection systems

BS EN 50129 Electronic Systems Railway applications - Safety related electronic systems for signalling

3.4 IRSE Licensing Standards (including Management Charter Initiative standards)

1.2.230 / 2.2.230 Project Engineer

6.8.105 / 6.8.110 Engineering Manager

6.8.131, 6.1.132, 6.8.133 Senior Engineering Manager

3.5 IET Competency Guidelines for Safety-Related System Practitioners Please note this section is under review

- CMF Corporate Functional Safety Management
- HRA Safety Hazard and Risk Analysis
- PSM Project Safety Assurance Management
- SRP Safety-Related System or Services Procurement
- SRS Safety Requirements Specification

3.6 OSCEng Standards

- 3.6.1 Engineering Competence Standards 1.xx Series, in particular:
 - 1.01 Establish engineering objectives
 - 1.18 Plan engineering activities
 - 1.26 Control allocated resources to achieve requirements
- 3.6.2 Higher Level Standards 7.x.x Series, in particular:
 - 7.1.2 Plan the delivery of projects
 - 7.2.1 Establish project management systems
 - 7.2.2 Manage the implementation of projects

3.7 Relevant Engineering Council (EC (UK)) Standards

EngTech (Engineering Technician) A1 . E4 Series IEng (Incorporated Engineer) A1 . E4 Series CEng (Chartered Engineer) A1 . E4 Series

4 Specify, Design and Develop Products and Systems

The user is reminded of the fact that Planning, Implementation and Management are very relevant to all the other activities. Rather than repeat similar information in every section it has been decided to emphasise the importance of these disciplines in Section 3, although they apply to all sections of this document.

Specification, design and development may be separated out into two distinct categories:

a) Development of generic systems, generic products and generic applications, which could include domain specifics such as new signalling / safety philosophies, practices and operating rules etc, but could be the domain of the generic electrical/electronics engineer or software designer.

Here, the designer must know and understand how to completely specify a system or equipment so as to achieve the intended functionality and performance (including preventing unwanted behaviours). Design may be considered the creation of a known good original.

The output may be specifications, tender documents, hardware or software, or a tool to facilitate the design process etc. Hardware can range from a component through subassemblies to complete equipments. Software may be program or data, including rules for parameterisation or use.

It is important to develop a level of understanding at the concept stage, to a sufficient level, to enable safety lifecycle activities to be satisfactorily carried out. Such activities include the establishment of the scope and purpose, definition of the project concept, financial analysis and feasibility studies.

The design process must take place in a controlled environment and employ systematic methodologies, including formal methods as required according to the required characteristics of the product. for example high reliability or safety critical applications. It is important to select and apply consistently the appropriate standards, tools and procedures . and to document these as necessary (Verification and validation processes may rely on this evidence.).

For product design, railway domain knowledge requirements vary from low (e.g. design of a defined electrical printed circuit board) to high (defining failure protection and degraded modes of a point machine / controller). A range of the skills and knowledge will be common to other industries especially safety related process control and/or high integrity or redundant hardware.

b) The application of generic products and applications in a specific application, performed to specifications and rules that have been predefined in a) above.

System definition for specific applications encompasses the most domain specific area of railway control and signalling system design, and is referred to as Scheme Design.

Scheme Design is the generation of a fully specified design for a signalling system to serve a specific location, which, if faithfully executed, will achieve the intended performance and functionality in service use. It requires interaction with railway operating and commercial management as well as the infrastructure disciplines, especially Permanent Way, Maintenance and Electrification, to clarify and codify the existing infrastructure constraints and the agreed intentions in unambiguous language and drawings (e.g. control tables, scheme plans, bonding plans etc).

The signalling designer must have the knowledge and understanding to identify, compare and contrast options and explain the consequences to other parties in useful (possibly lay) terms. It is necessary to know and understand the relative characteristics, features and benefits of the system or equipment available, and requires domain knowledge in depth.

It is by this process that the hazards and risks for all reasonably foreseeable circumstances, including fault conditions and misuse (i.e. signals passed at danger) can be determined, and the safety requirements and integrity levels specified to achieve the required functional safety. Specific safety measures may then be allocated which may include other safety-related systems i.e. Hot Axle Box Detectors, or other external risk reduction measures. It is also the responsibility of the signalling designer to define acceptance criteria in order to establish a validation plan.

4.1 Domain Specific Knowledge

- Operating requirements . normal conditions, failures and environmental conditions
- Requirements Management
- Production, Installation, Testing and Maintenance requirements
- Human factor issues . human reliability in design, ergonomics
- Independent Safety Assessment and Safety Management Systems
- Architectures for availability, and Quality, Safety and Reliability, Availability and Maintainability
- Legal requirements and Codes of Practice
- Environmental factors . Electromagnetic Compatibility (EMC), temperature and humidity, Hazardous Materials etc
- Architectures for safety, Safe failure modes, ALARP (As Low As Reasonably Practicable)
- Track protection . integration of the system
- Specification . equipment, rules for preparing applications software
- Materials . Fire properties, ageing, mechanical strength
- Design and QA standards, and Design Principles
- Signalling and Interlocking principles
- Train Detection and Train Protection
- Scheme Application and Development
- Control tables, Track plans, Aspect/Code sequence charts, Site surveys and Bonding plans
- Safety Distances and Movements authorities, Headway design
- Visual signals
- Level Crossings
- Control Centre Techniques
- Signalling power requirements

- Secure Communications, Global Satellite Mobile-communications . Railway (GSMR), Terrestrial European Trunked Radio (TETRA)
- Passenger Information and Train Describers
- Safety acceptance and cross acceptance
- Verification, Validation, Configuration and Change management

4.2 Indicative References

General - product design and characteristics for railway signalling use:

Perkins B; Engineering quality into signal equipment; IRSE Proceedings 1993/94 *Use of microprocessors:*

Wobig KH; Micro processors in failsafe systems; IRSE Proceedings 1986/87 Barnard REB; Electronic interlockings: a survey of approaches to safety critical signalling systems, IEE 8th Residential Course on Railway Signalling and Control Systems April 2000.

Pilkington S, System assurance and safety assessments, IEE 8th Residential Course on Railway Signalling & Control Systems April 2000

Engineering Safety Management - Yellow Book <u>www.yellowbook-rail.org.uk</u>

Train detection technology:

Wood RA; Train detection by track circuit - the effect of the wheel / rail interface; IRSE Aspect 99 Proceedings, p 151

Brown CR; A review of jointless track circuits; IRSE Proceedings 1984/85 Corrie JD; Principles of train detection; IEE 8th Residential Course on Railway Signalling and Control Systems April 2000

Interference by traction systems

Mellitt B; The impact of electrification systems and traction control on signalling and communications; IEE 8th Residential Course on Railway Signalling and Control Systems April 2000 (excluding section 3 which should be treated as background material) *ERTMS / ATP*

Booth PD; Development of an ERTMS moving block interlocking for Railtrack's WCML; IRSE Aspect £99 proceedings p 269

Uebel H; Mainline ATP / ATC intermittent and continuous systems; IEE 8th Residential Course on Railway Signalling and Control Systems April 2000.

Software

Application Guidance Note Software and 50128+. Engineering Safety Management - Yellow Book 3 <u>www.yellowbook-rail.org.uk</u>

Railway Safety Principles and Guidance, part 1 1996 HSE Books ISBN 0-7176-0712-7 Railway Safety Principles and Guidance, part 2 HSG153/2-8 1996 HSE Books www.rail-reg.gov.uk/server/show/nav.1096

See Appendix J for further reading.

4.3 Relevant International Standards

BS 376 . 1 Railway Signalling Symbols. Schematic symbols

BS 376 . 2 Railway Signalling Symbols. Wiring symbols and written symbols BS 442 Specification for terminals for electrical apparatus for railway signalling purposes

BS 469 Specification for railway signalling lamps

BS 714 Specification. Cartridge fuse-links for use in railway signalling circuits

BS 3347 Specification for capacitors for railway signalling track circuits

PD R009-001 Railway applications. Communications, signalling & processing systems. Hazardous failure rates & safety integrity levels (SIL)

PD R009-003 Guide to the specification of a guided transport system

PD R009-004 Railway Specifications. Systematic allocation of safety integrity levels BS EN 50121 series 1-5 Railway applications - Electromagnetic compatibility

BS EN 50125-3 Railway applications - Environmental conditions for equipment part 3 - Equipment for signalling and telecommunications

BS EN 50126 Railway applications - The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS)

BS EN 50128 Railway applications - Communications, signalling and processing systems - Software for railway control and protection systems

BS EN 50129 Railway applications - Safety related electronic systems for signalling BS EN 50159 series 1. 2 Railway applications. Communications, signalling & process systems. Software for railway control & protection systems

BS EN 50261 Railway applications - Mounting of electronic equipment.

BS IEC 61508 series 1-7 Functional safety of electrical/electronic/programmable electronic safety-related systems

BS EN 61000 series Electromagnetic compatibility (EMC)

BS IEC 60050-821 International electro technical vocabulary

HB 10187 Reliability, maintainability & risk 6th edition

BS EN ISO 9001 Quality systems. Model for quality assurance in design, development, production, installation and servicing

Technical Standards for Interoperability (TSIcs)

4.4 Relevant IRSE Licence Categories

- 1.1.100 / 2.1.110 Assistant Designer
- 1.1.150 Signalling Designer
- 1.1.160 Signalling Design Verifier
- 2.1.110 Designer (T)
- 2.1.215 Telecoms Electronic Systems Designer
- 1.1.145 / 2.1.140 Design Manager
- 1.2.230 / 2.2.230 Project Engineer
- 6.8.105 / 6.8.110 Engineering Manager

4.5 Relevant IET Competency Guidelines for Safety-Related System Practitioners

- PSM Project Safety Assurance Management
- HRA Safety Hazard and Risk Analysis
- SRS Safety Requirements Specification
- SV Safety Validation
- SAD Safety-Related System Architectural Design
- SHR Safety-Related System Hardware Realisation
- SSR Safety-Related System Software Realisation
- HF Human Factors Safety Engineering

4.6 Relevant OSCEng Standards

- 4.6.1 Engineering Competence Standards 1.xx Series, in particular:
 - 1.02 Complete designs for engineering products
 - 1.03 Read and extract information from engineering drawings and specifications

4.6.2 Higher Level Standards 1.x.x and 6.x.x Series, in particular:

- 6.1.1 Analyse the risks arising from engineering products or processes
- 6.1.2 Specify methods and procedures to reduce risks
- 1.1.2 Produce specifications for engineering products or processes
- 1.4.3 Create designs for engineering products or processes

4.7 Relevant Engineering Council (EC (UK)) Standards

EngTech (Engineering Technician) A1 . E4 Series IEng (Incorporated Engineer) A1 . E4 Series CEng (Chartered Engineer) A1 . E4 Series

5 Production and Manufacture

The Production and Manufacturing Engineer must know and understand how to ensure that a finished product conforms to the authorised specification with the required degree of confidence. The dividing line between scheme design and production can vary from organisation to organisation, production being the creation of accurate copies (even single) for service use, and specification may include one off parameterisation or configuration for an intended specific use and/or site.

Although helpful context, little domain specific knowledge is required as long as the processes involved in accurate replication and configuration are secure. The product may be hardware, firmware, or copies of software (creating software is considered a design activity). The quantity of replication is immaterial, varying from a single copy upwards. These skills and knowledge are common to other industries.

Manufacturing always requires a controlled environment and is often a team activity with QA, supervision and checks constantly available. Production and manufacturing may well take place away from the project offices and projects site. This does not lessen the need for rigorous processes to ensure that faults that could affect safety are not introduced.

5.1 Domain Specific Knowledge

Safety procedures and requirements Equipment, component and cable identification Interpretation of drawings and schedules Use of hand and power tools Methods of wire and cable termination Equipment and component handling Electrical installation knowledge and practices Installation standards and codes of practice Installation documentation procedures Legislative requirements Content and scope of testing What constitutes a defect and a discrepancy Documentation / Test procedures Configuration Management, hardware and software Copying and verification of specific application data

5.2 Indicative References

No specific references.

See Appendix J for further reading.

5.3 Relevant International Standards

BS 376 . 1 Railway Signalling Symbols. Schematic symbols

BS 376 . 2 Railway Signalling Symbols. Wiring symbols and written symbols

BS 442 Specification for terminals for electrical apparatus for railway signalling purposes

BS 469 Specification for railway signalling lamps

BS 714 Specification. Cartridge fuse-links for use in railway signalling circuits

BS EN 50121 series 1-5 Railway applications - Electromagnetic compatibility BS EN 50125-3 Railway applications - Environmental conditions for equipment part three-Equipment for signalling and telecommunications BS EN 50126 Railway applications - The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS) BS EN 50261 Railway applications. Mounting of electronic equipment.

BS EN 61000 series Electromagnetic compatibility (EMC)

HB 10187 Reliability, maintainability & risk 6th edition

BS EN ISO 9001 Quality systems. Model for quality assurance in design, development, production, installation and servicing

5.4 Relevant IRSE Licence Categories

6.2.115	Factory Installer
1.3.155 / 2.3.155	Signalling Verification / Telecoms Tester
6.8.105 / 6.8.110	Engineering Manager

5.5 Relevant IET Competency Guidelines for Safety-Related System Practitioners

SRS Safety-Related System Procurement

5.6 Relevant OSCEng Standards

- 5.6.1 Engineering Competence Standards 2.xx Series, especially
 - 2.13 Prepare work areas and materials for engineering activities
 - 2.14 Prepare equipment for engineering activities
 - 2.15 Reinstate the work area after engineering activities
- 5.6.2 Higher Level Standards Series 2.x.x and Series 6.x.x, especially:

2.1.1 Determine the production requirements of engineering products or processes

2.1.2 Specify production methods and procedures to achieve production requirements

6.1.1 Analyse the risks arising from engineering products or processes

6.1.2 Specify methods and procedures to reduce risks

5.7 Relevant Engineering Council (EC (UK)) Standards

EngTech (Engineering Technician) A1 . E4 Series IEng (Incorporated Engineer) A1 . E4 Series CEng (Chartered Engineer) A1 . E4 Series

6 Installation

The Installation engineer must have domain knowledge both for personal safety and effectiveness and also with respect to railway systems and operations, including other disciplines and interfaces. It is important that the Installation Engineer works within the limits of authority and knowledge, in particular, liaising with external parties and communicating clearly with a distributed team.

Installation is often carried out on site (including line side) with intermittent contact with others. Whilst the equipment installed is usually standard, the railway itself is far from standard, each site having its own characteristics of gradients, stations, curves crossings etc. Every installation is therefore unique, almost a prototype, and relies heavily on the skill and judgement of the installation engineer. Some installation work may be carried out in the factory environment.

In the past not a great deal of technical information on installation has been available in one place. It has tended to be mainly in individual company or product installation instructions. Installation requirements in British, European and International Standards tend to be mainly for product designers and technical authors but contain little direct information for "on the tools" installation staff.

Poor installation can lead to an overall short life of a signalling project, so it is important that installation standards and techniques are kept under constant review as new systems and equipment are constantly being developed. Worse still poor installation can adversely affect the safety of the system so it is critical that the installation phase of the life cycle is addressed adequately in the system assurance plan and safety case.

6.1 Domain Specific Knowledge

- Appreciation and application of Signalling or Telecoms Principles
- Identification and resolution of contradictory, ambiguous, or inadequate information
- Procedures for working on operational equipment
- Railway Specific Installation methods
- Organisational structures, responsibilities, and sources of information
- Installation Specifications, Procedures and Standards
- Protection, possession and safe working procedures and practices
- Understanding and interpretation of installation drawings and schedules
- Reliability, Maintainability, Availability and Safety (RAMS)
- Conditions that must be fulfilled prior to the hand-over of the allocated tasks
- User Training
- Verification

6.2 Indicative References

IRSE Green Booklet No 10 Mechanical Signalling

Hidden A, Accident Report Clapham Junction 12.12.88. HMSO 1989 ISBN 0-10 108202-9

Corrie J D, Human Reliability For Railway Signalling Trackside Installation Work, IBC Conference Task analysis for industry 06/12/94

Whitehouse W H, On Track Signalling Problems relative to Modern P-Way Practice. IRSE Proceedings 1971/72 Wittamore D, Installation, & Testing of the Signalling System, IEE 6th Vacation School on Railway Signalling and Control Systems July 1996 Railway Signalling, ed O.S. Nock, pub IRSE, ISBN 0-902390-15-5

Fault Free Infrastructure IMechE Professional Engineering Publishing ISBN 1 86058

233 8

IRSE Technical Briefing . Testing & Commissioning 1995

See Appendix J for further reading.

6.3 Relevant International Standards

BS 376 . 1 Railway Signalling Symbols. Schematic symbols

BS 376 . 2 Railway Signalling Symbols. Wiring symbols and written symbols BS 442 Specification for terminals for electrical apparatus for railway signalling purposes

BS 469 Specification for railway signalling lamps

BS 714 Specification. Cartridge fuse-links for use in railway signalling circuits

BS 3347 Specification for capacitors for railway signalling track circuits

BS EN 50121 series 1-5 Railway applications - Electromagnetic compatibility

BS EN 50125-3 Railway applications - Environmental conditions for equipment part three-Equipment for signalling and telecommunications

BS EN 50261 Railway applications. Mounting of electronic equipment.

BS EN 50126 Railway applications - The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS)

BS EN 50128 Railway applications - Communications, signalling and processing systems - Software for railway control and protection systems

BS EN 50129 Electronic Systems Railway applications - Safety related electronic systems for signalling

BS EN 61000 series Electromagnetic compatibility (EMC)

BS IEC 60050-821 International electro technical vocabulary

HB 10187 Reliability, maintainability & risk 6th edition

BS EN ISO 9001 Quality systems. Model for quality assurance in design, development, production, installation and servicing

BS EN 50122-1 Railway Applications . Fixed Installations. Protective provisions relating to electrical safety & earthing.

BS 7671 Requirements for electrical installations (IEE wiring regulations)

BS 6701 Code of Practice for installation of equipment for connections to telecomms equipment.

BS IEC 61508 Functional Safety of Electrical / Electronic / Programmable Electronic Safety . Related Systems Parts 1 . 7.13 and 7.14

6.4 Relevant IRSE Licence Categories

- 1.2.100 Assistant Signalling Installer
- 1.2.110 / 2.2.110 Installer
- 1.2.105 Point Fitter
- 1.2.115 Locking Fitter
- 1.8.100 Signalling Team Leader
- 1.2.140 Installation Manager
- 1.2.230 / 2.2.230 Project Engineer
- 6.8.105 / 6.8.110 Engineering Manager

6.5 Relevant IET Competency Guidelines for Safety-Related System Practitioners

- PSM Project Safety Assurance Management
- HRA Safety Hazard and Risk Analysis
- SV Safety Validation

6.6 Relevant OSCEng Standards

- 6.6.1 Engineering Competence Standards Series 4.x.x, and in particular
 - 1.12 Interpret detailed information
 - 1.21 Determine Requirements for safe access to work locations
 - 2.15 Reinstate the work area after engineering activities
 - 4.02 Install engineering products or assets
 - 6.01 Establish compliance with specifications
- 6.6.2 Higher Level Standards Series 3.x.x, in particular
 - 3.2.2 Solve installation problems with engineering solutions
 - 3.3.1 Monitor the installation process
 - 3.3.2 Evaluate the installation process

6.7 Relevant Engineering Council (EC (UK)) Standards

EngTech (Engineering Technician) A1 . E4 Series IEng (Incorporated Engineer) A1 . E4 Series CEng (Chartered Engineer) A1 . E4 Series

7 System Validation, Safety Acceptance and Commissioning

System Validation is a technique used to check and confirm that a delivered project meets its defined requirements. These techniques may include reviews, testing and analysis. Safety Acceptance of a system or project will be linked to a Safety Case, which should provide a clear, complete and valid line of reasoning that a system is acceptably safe to operate in a specific context, this is usually a documented process. The degree of documentation will vary, but must always address that the system Safety Requirements have been met and are adequate for the application.

Within standard protocols testing is a sub-set of verification and validation that relates to activities performed on both products and their application. In the railway environment verification testing almost exclusively refers to the physical confirmation of the correct disposition, configuration and operation of products and systems. Functional testing is undertaken to confirm that the sub-system or product complies with the design specification and meets the application requirements and is fit for entry into service.

Railway infrastructure has the characteristic of site uniqueness; the principles having to be correctly interpreted on a location-by-location basis. Thus, there is a need to validate the application of the Safety Authority and Railway Administration each time an Interlocking is created or amended. This activity is commonly referred to as Principles Testing.

The testing activity is commonly considered to be a sub-project within a programme of Works. The sub-project is controlled and co-ordinated by a person in overall charge, this person often being referred to as the Tester-in-Charge.

Within the life-cycle of a signalling scheme there is a demand also for testing during maintenance activities; these activities contribute to the continuing assurance of system safety.

7.1 Domain Specific Knowledge

- Operational understanding of signalling equipment and systems
- Document requirements, management and completion procedures
- Independent test methods, options, and procedures
- Safety and protection requirements and procedures (personal and system)
- Content and Scope of testing in relation to level, type and amount
- Correct tools, instrument and equipment identification, condition and calibration
- Provision of temporary labelling
- Defects and discrepancies
- Acceptable test results and checks
- Unacceptable test results and checks, or equipment condition
- Relevant legislation; company rules, regulations, procedures and instructions
- Signalling principles
- Interlocking principles
- Installation practices and procedures
- Interpretation of diagrams, charts and testing and commissioning plans

- Verification of completion of testing, incomplete testing or tests not carried out in accordance with procedures
- Returning the system and equipment to operational use
- Limits of own authority, responsibility and competence
- Lines and methods of effective communication

7.2 Indicative References

IRSE Technical Report - Testing and Commissioning 1995

Accident Report Clapham Junction 12.12.88. Hidden A HMSO 1989 ISBN 0-10-108202-9

Henley C, Tillin J, Testing and Commissioning the Class 92 Cab Signalling, The Channel tunnel experience: lessons for the future, Lille, France, 20-21 March 1997, IEE CONF 433 p 61-70.

Marriot D, Installation and Testing of the Signalling System, IEE 7th Vacation School on Railway Signalling and Control Systems Mar 1998

Marshall N, Testing Methods as applied to Power Signalling, IRSE Proceedings 1950/51

Cartwright WL, Testing of Mechanical Interlocking, IRSE Proceedings 1954/55 Howker AC, Testing and Commissioning of Computer Based Signalling Systems, IRSE Proceedings 1984/5

Corrie JD, Testing and Commissioning, IRSE Proceedings1991/92

Tillin J, Developing Systems and People for Signalling Testing, IRSE Proceedings 1997/98

Neave N, An investigation into Post installation Testing Methods used on LUL Signalling Systems, The Skill of the Tester; Past, Present and Future, IRSE Seminar Nov 1998 Fowler J, & Rogers J, Exploring the Boundaries between the Installation and Testing Disciplines, The Skill of the Tester; Past, Present and Future, IRSE Seminar Nov 1998 Fabbian F, The MTR Experience, The Skill of the Tester; Past, Present and Future, IRSE Seminar Nov 1998 IRSE Seminar Nov 1998

Brookes M, Tester in Charge . Engineer, Manager or Clerk? The Skill of the Tester; Past, Present and Future, IRSE Seminar Nov 1998

Mills D, Focused testing following alleged wrong side failures . using fault trees to devise an appropriate test plan, The Skill of the Tester; Past, Present and Future, IRSE Seminar Nov 1998

Woodbridge P, Have we learnt the lessons of Clapham, and are we teaching it right? The Skill of the Tester; Past, Present and Future, IRSE Seminar Nov 1998

 $\label{eq:solution} \mbox{Engineering Safety Management - Yellow Book } \underline{www.yellowbook\mbox{-rail.org.uk}}$

A guide to the approval of railway works, plant and equipment, HSE 1994, ISBN 0-7176-0741-0

See Appendix J for further reading.

7.3 Relevant International Standards

BS EN 50121 series 1-5 Railway applications - Electromagnetic compatibility BS EN 50125-3 Railway applications - Environmental conditions for equipment part three-Equipment for signalling and telecommunications

BS EN 50126 Railway applications - The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS)

BS EN 50261 Railway applications. Mounting of electronic equipment.

BS EN 50128 Railway applications - Communications, signalling and processing systems - Software for railway control and protection systems

BS EN 50129 Railway applications - Safety related electronic systems for signalling BS IEC 61508 series 1-7 Functional safety of electrical/electronic/programmable electronic safety-related systems

BS EN ISO 9001 Quality systems. Model for quality assurance in design, development, production, installation and servicing

7.4 Relevant IRSE Licence Categories

- 1.3.150 Test Assistant
- 1.3.155 / 2.3.155 Signalling Verification Tester / Telecoms Tester
- 1.4.160 Maintenance Tester
- 1.3.170 Signalling Functional Tester
- 1.3.180Signalling Principles Tester
- 1.3.190 Tester in Charge
- 1.2.230 / 2.2.230 Project Engineer
- 1.3.260 / 2.3.265 Signalling Electronic Systems Tester / Telecoms Systems Tester
- 2.3.295 Telecoms Team Manager
- 6.8.105 / 6.8.110 Engineering Manager

7.5 Relevant IET Competency Guidelines for Safety-Related System Practitioners

- PSM Project Safety Assurance Management
- HRA Safety Hazard and Risk Analysis
- SRS Safety Requirements Specification
- SV Safety Validation
- SAD Safety-Related System Architectural Design

7.6 Relevant OSCEng Standards

- 7.6.1 Engineering Competence Standards Series 6.xx, and especially
 - 1.19 Plan engineering activities
 - 6.01 Establish compliance with specifications
 - 6.02 Conduct specified testing of engineering products or assets
 - 6.03 Analyse and interpret the results of engineering tests

7.6.2 Higher Level Standards

3.4.1 Commission engineering products or processes

7.7 Relevant Engineering Council (EC (UK)) Standards

EngTech (Engineering Technician) A1 . E4 Series IEng (Incorporated Engineer) A1 . E4 Series CEng (Chartered Engineer) A1 . E4 Series

8 Operation, Maintenance, Modification and Decommissioning

It is essential that the above items are included in the ongoing safety management of the project, in accordance with the requirements that should have been documented in the system assurance plan and the safety case.

The Maintainer is accountable for a signalling system or installation throughout most of the time and needs to appreciate all the other phases of its life. In particular the Maintainer must know when to call on the specific skills of others, e.g. Designers or Testers. The Maintainer must take the responsibility of signing the system into and out of service whenever there is doubt about the functionality or performance of the signalling . with due regard for the introduction of risk to train movements by withdrawing whatever protection remains.

It is rare that wholesale decommissioning takes place of a signalling system. More usually stage-works take place where parts of it are modified and the old system is gradually withdrawn as part of maintenance or new works activities.

The maintenance task encompasses the balancing of many priorities. The Maintainer must have the knowledge and confidence to make decisions to take the system out of service for technical work, or not do it, (and be able to justify these decisions) sometimes against the opposition of users or engineering colleagues.

The Maintainer should understand, and be able to explain in lay terms, what are the options for enhancing the performance or reliability of the system or why and when it must be replaced. These issues become particularly difficult and subtle towards life-expiry of systems and the Maintainer must be willing and able to take accountability for related decisions and consequences.

As more of the signalling system is train-borne, the Maintainer must be able to take an overview and liaise with and manage the related engineering activities to optimise service to users. This is particularly important for intermittent or niggling systems problems.

The Maintainer is also responsible for investigating allegations of abnormal behaviours and must understand his responsibilities for preserving evidence and bringing the investigation to a satisfactory conclusion. often amongst the stress of non-technical officialdom and incident investigations.

8.1 Domain Specific Knowledge

Documentation requirements, management and completion procedures Organisational structures & responsibilities Infrastructure controllers requirements, regulations and procedures Maintenance plan acceptance procedures, asset population and characteristics Operating requirements Signalling and interlocking principles and equipment Application of signalling principles relevant to maintenance Maintenance and testing requirements, methods, procedures and standards Limits of own authority, responsibility and competence Protection, possession and safety procedures Identification of outstanding tasks Resource availability capability & limitation What constitutes a significant defect Procedures for the preservation of evidence Quality assurance, fault and change control procedures Acceptance hand over Verification Failure investigation and replacement procedures Change Management

Requirements for the disposal of materials

8.2 Indicative References

Penney R, Maintaining the Signalling Infrastructure, IEE 7th Vacation School on Railway Signalling and Control Systems, Mar 1998

Railway Signalling, ed O.S. Nock, Pub IRSE, ISBN 0-902390-15-5

Railway Technology International 1993, Allan, G Freeman, Stirling publications Ltd London Pbk

Railway Signalling and Communications: installation and maintenance, Lascelles, TS, St Margarett Technical Press: London

Fault Free Infrastructure, IMechE, Professional Eng Publish, ISBN 1-86058-233-8 Brown AR, Signalling Equipment and Systems: Performance and Reliability in Service, IRSE Proceedings 1972/3

Rayner PG, Get it right and keep it running, IRSE International Conference - Railway Safety, Control and Automation 1984

Genner R, Faulting and Maintenance of signalling Equipment . A Scottish experience, IRSE News No 13 May 1988

Short RC, The Life, Death and Retirement of Electronic Equipment, IRSE Proceedings 1988/89

Wittamore D, Installation, Testing and Maintenance of the Signalling System, IEE Power Division Second Vacation School on Railway Signalling and Train Control Systems Wijnands M, Maintenance Policy and Expert Systems, IRSE Aspect @1

Pore J, Towards a More Reliable Railway . Integrated Maintenance on RATP, IRSE Proceedings 1993/94

Dermenghem JP, Towards a more Reliable Railway . Maintenance Support Systems used in Signalling, IRSE Proceedings 1993/94

Harrison A, Managing Obsolescence, Improvements in the delivery of Signalling Projects and Products, IRSE Seminar March 1998

Venter K & West MR, Asset Information Management Strategies for the Railways, IRSE Aspect **@**9

Webb AK & Hamlyn MJ, Signalling Asset Whole Life Modelling, IRSE Aspect @9 Boddy WG, A Modern Approach to Infrastructure Maintenance, IRSE Aspect @9 Errington, S, The Long-Term Support and Maintenance of Computer Based Railways Control Systems, IRSE Aspect @9

Gutteridge KJ, Developing Performance Based Control Train Control System Maintenance Contracts: Can they be made to Work? IRSE Aspect @9

Knowlton & Godber AM, Commissioning and Maintenance of an Integrated System, IRSE Aspect \$99\$

The Future of accident investigation in the railway industry, Railtrack PLC Consultation Document, Keep it Safe, Keep it Legal, IRSE Technical Conference Dec 1999

See Appendix J for further reading.

8.3 Relevant International Standards

BS 442 Specification for terminals for electrical apparatus for railway signalling purposes

BS 469 Specification for railway signalling lamps

BS 714 Specification. Cartridge fuse-links for use in railway signalling circuits

BS 3347 Specification for capacitors for railway signalling track circuits

BS EN 50121 series 1-5 Railway applications - Electromagnetic compatibility

BS EN 50125-3 Railway applications - Environmental conditions for equipment part three-Equipment for signalling and telecommunications

BS EN 50126 Railway applications - The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS)

BS EN 50261 Railway applications. Mounting of electronic equipment.

BS EN 50128 Railway applications - Communications, signalling and processing systems - Software for railway control and protection systems

BS EN 50129 Railway applications - Safety related electronic systems for signalling BS EN 50159 series 1. 2: Railway applications. Communications, signalling & process systems. Software for railway control & protection systems

BS IEC 61508 series 1-7 Functional safety of electrical/electronic/programmable electronic safety-related systems

BS EN 61000 series Electromagnetic compatibility (EMC)

BS IEC 60050-821 International electro technical vocabulary

HB 10187 Reliability, maintainability & risk 6th edition

BS EN ISO 9001 Quality systems. Model for quality assurance in design, development, production, installation and servicing

Relevant IRSE Licence Categories

1.4.100	Assistant Signalling Maintainer
1.4.110	Signalling Maintainer
2.4.105 / 2.4.106	Basic Telecoms Maintainer
2.4.115	Telecoms Maintainer and Fault Finder
1.4.160 / 2.4.160	Maintenance Tester
1.4.120	Signalling Fault Finder
1.4.125	Incident Investigator
1.8.100	Signalling Team Leader
2.4.220	Telecoms Network Management Engineer
1.4.140 / 2.4.145	Maintenance Manager
6.4.230	Technical Investigator
6.4.235	Lead Technical Investigator
6.8.105 / 6.8.110	Engineering Manager

8.4 IET Competency Guidelines for Safety-Related System Practitioners

- HRA Safety Hazard and Risk Analysis
- SRS Safety Requirements Specification
- SV Safety Validation
- HF Human Factors Safety Engineering

8.5 Relevant OSCEng Standards

- 8.5.1 Engineering Competence Standards Series 5.xx, and especially:
 - 1.12 Interpret detailed information
 - 1.21 Determine requirements for safe access to work locations

- 2.15 Reinstate the work area after engineering activities
- 5.01 Carry out planned maintenance procedures
- 5.02 Adjust engineering asset to meet operating requirements
- 5.03 Remove components from assemblies or sub-assemblies
- 5.04 Replace assembly or sub-assembly components
- 6.04 Monitor the performance and condition of engineering assets
- 7.03 Hand-over engineering products or asset to the control of others
- 8.5.2 Higher Level Standards Series 5.x.x, and especially

5.1.1 Determine the maintenance requirements of engineering products or processes

5.1.2 Specify maintenance methods and procedures to achieve maintenance requirements

5.1.3 Schedule maintenance activities to implement the maintenance methods and procedures

5.2.2 Solve maintenance problems with engineering solutions

5.3.1 Monitor maintenance processes

- 5.3.2 Evaluate maintenance processes
- 6.1.3 Investigate incidents relating to engineering products or processes

8.6 Relevant Engineering Council (EC (UK)) Standards

EngTech (Engineering Technician) A1 . E4 Series IEng (Incorporated Engineer) A1 . E4 Series CEng (Chartered Engineer) A1 . E4 Series

9 Quality, Safety, Reliability, Availability and Maintainability

Railways achieve a very high standard of safety. Much of this in the past has been due to established practice that has been passed down from generation to generation, and evolved further as a result of accidents and technology. With todays privatised and globalised railways it has become necessary to evolve even further to cope with cross acceptance of safety systems. European norms . aimed at encouraging standardisation of supply are being mandated, but with each railway having its own inherited rules and practices it is not always easy to be sure that the application of these norms will not compromise the safety of the system. Practices from other safety related industries and high hazard sectors are now often employed to ensure the safety of the system.

The system assurance plan must be established adequately at the front end of the project and applied throughout all stages of the total lifecycle.

Today Railway Signal Engineer needs to have a basic knowledge of each of the following areas and how they may be applied to the Railway control system Life cycle:

- **Quality** Standards, procedures, work instructions and method statements. Configuration management and Change Control
- **Safety Plan** . Policy, legal and functional requirements and targets, Hazard and Risk Analysis and Assessment, architectures and change management. System Assurance and Safety case.
- Reliability, Availability and Maintainability (RAM) Programme policy, requirements, acceptance criteria, programme and management, Failure Reporting and Corrective Action Systems (FRACAS), availability architectures and reliability centred maintenance.

9.1 Domain Specific Knowledge

Design and QA standards Verification of Design Legal requirements and Codes of Practice Safety Plan Safety Assurance Safety Management Systems Safety Acceptance Arrangements **Cross Acceptance** Notified bodies Independent Safety Assessment Change Management Procedures for the preservation of evidence Health and Safety requirements Fault and Change Control Procedures **Configuration Control Procedures** Production of evidence for safety cases Architectures for safety Architectures for availability Safe failure modes ALARP

9.2 Indicative References

Report by the IRSE Technical Committee . Cross Acceptance of Vital Signalling Systems 1992

Stanley PW, Operational Availability of Railway Control Systems, IRSE Proceedings 1993/94

Lamb D and Davis R , Are Microprocessors and Signal Engineers Incompatible? IRSE Proceedings 1994/95

Pore J, European Standards, IRSE Proceedings 1996/97

Allan J and Williams J, The Fundamentals of System Engineering in Major Railway Projects, IRSE Proceedings1995/96

Corrie JD and Gilmartin BP, Managing Safety in Railways . Theory and Reality, in Safety and Reliability Volume 21, No 3 Autumn 2001 ISSN 0961 7353

Williams R and Corrie JD, Simplifying the Safety Case for New Signalling, IRSE Aspect £9 Proceedings p339.

Engineering Safety Management - Yellow Book 3 Volumes 1 & 2 Fundamentals and Guidance <u>www.yellowbook-rail.org.uk</u>

Reducing Risk, Protecting People, 1999, HSE discussion document, DDE11 Regulating Higher Hazards: Exploring the issues, 2000, HSE Discussion Document Railway Safety Case Regulations 2000/2 (& Guidance)

Pilkington S, System Assurance and Safety Assessment, IEE 8th Vacation School on Railway Signalling and Control Systems, April 2000.

See Appendix J for further reading.

9.3 Relevant International Standards

PD R008-001 Railway applications. Communications, signalling & processing systems. Hazardous failure rates & safety integrity levels (SIL)

PD R009-004 Railway Specifications. Systematic allocation of safety integrity levels BS EN 50121 series 1-5 Railway applications - Electromagnetic compatibility

pr EN 50125-3 Railway applications - Environmental conditions for equipment part three-Equipment for signalling and telecommunications

BS EN 50126 Railway applications - The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS)

BS EN 50261 Railway applications. Mounting of electronic equipment.

BS EN 50128 Railway applications - Communications, signalling and processing systems - Software for railway control and protection systems

BS EN 50129 Railway applications - Safety related electronic systems for signalling BS EN 50159 series 1. 2 Railway applications. Communications, signalling & process systems. Software for railway control & protection systems

BS IEC 61508 series 1-7 Functional safety of electrical/electronic/programmable electronic safety-related systems

BS EN 61000 series Electromagnetic compatibility (EMC)

BS IEC 60050-821 International electro technical vocabulary

HB 10187 Reliability, maintainability & risk 6th edition

BS EN ISO 9001 Quality systems. Model for quality assurance in design, development, production, installation and servicing

Relevant IRSE Licence Categories

6.8.105 / 6.8.110 Engineering Manager

9.4 Relevant IET Competency Guidelines for Safety-Related System Practitioners

- CMF Corporate Functional Safety Management
- HF Human Factors Safety Engineering
- HRA Safety Hazard and Risk Analysis
- ISA Independent Safety Assessment
- PSM Project Safety Assurance Management
- SAD Safety-Related System Architectural Design
- SHR Safety-Related System Hardware Realisation
- SRM Safety-Related System Maintenance and Modification
- SRP Safety-Related System or Services Procurement
- SRS Safety Requirements Specification
- SSR Safety-Related System Software Realisation
- SV Safety Validation

9.5 Relevant OSCEng Standards

- 9.5.1 Engineering Competence Standards Series 6.xx
- 9.5.2 Higher Level Standards Series 6.x.x

9.6 Relevant Engineering Council (EC (UK)) Standards

EngTech (Engineering Technician) A1 . E4 Series IEng (Incorporated Engineer) A1 . E4 Series CEng (Chartered Engineer) A1 . E4 Series Follow the below hyperlinks for further comprehensive information: *Please note this section is under review*

- IRSE Career Route Map
- Relationship of IRSE Licences to other competent assessment systems
- IRSE Licence category scope statements
- IET Competency scope statements
- Lifecycle relationship with BS EN 50126
- Lifecycle relationship with BS EN 50128
- Lifecycle relationship with BS EN 50129
- Relationship with BS IEC 61508