Nuclear Commissioning Excellence Manual

Prepared by the members of the Nuclear Commissioning Excellence Forum, an expert forum within the United Kingdom's Nuclear Institute.

Revision 1 - January 2020

Edited by Sam Billington

NCEF

Notes from the Editor

Author: Sam Billington

1. Target audience

The target audience of this manual is the UK Nuclear license holders (licensees) who will benefit by benchmarking against this collection of best practice. For existing licensees this manual will also provide a useful resource when considering moving away from business as usual, for example, the initiation of a significant capital project. For companies which are considering applying to become a Nuclear Licence Holder this manual will provide a road map to inform the development of their commissioning project within their wider programme.

The second target group are the tier 1 contractors who provide support to the licensees and this manual aims to provide a knowledge resource around the requirements placed on the licensees and therefore the expectations that flow down to the tier 1 contractors.

2. Production team

This manual has been developed from the participants of the United Kingdom's Nuclear Commissioning Excellence Forum (NCEF) which was initiated in 2018 as an Expert Forum within the Nuclear Institute.

The Editor would like to express his gratitude for the support of the following nuclear professionals and their respective employers in the development of this manual:

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Andy Waring – EDF Energy Ltd

The authorship of a particular section is noted within that section.

3. Interpretation of the text

The glossary towards the back of this manual has been developed using a list of specific definitions from licensees. In some cases, these definitions have diverged from each other and therefore the Editor has generalised them to be close to licensees' definitions or those of other sources, for example the International Atomic Energy Authority (IAEA).

When writing this manual there has been a constant challenge of applying this to the wide range of projects and commissioning organisations in the UK nuclear industry from new nuclear power stations, through significant new nuclear process and production facilities to small upgrade projects. This means that the commissioning organisation could face a range of challenges from being part of a start up company aiming to become a nuclear licence holder, to a business as usual commissioning organisation which has a constant portfolio of diverse projects and a steady head count to a business as usual commissioning organisation engaging in a significant new nuclear build project. The reader should therefore consider application of this manual to their relevant project and organisational context.

4. Where does this manual fit in to other commissioning guidance?

This manual is not designed to replace existing international documents from the International Atomic Energy Agency (IAEA) or UK commissioning documents from the Office for Nuclear Regulation (ONR) or any other document source as there is little benefit in recycling the same text. Instead it is targeted at a more practical and detailed level for use by UK nuclear commissioning managers.

The challenge in developing such a manual to cover a range of new nuclear builds from a new power station to replacing a small component in an existing facility has been considerable. The aim is to provide best practice where possible but where different project or organisational structures have been chosen by the licensee it will prompt the commissioning manager with a series of questions. In all cases the commissioning manager should be able to address these questions but it is recognised that the answer may be 'not in commissioning scope'.

The benefit is that this manual will challenge the commissioning manager to answer the questions or at least to identify the known unknowns.

5. Benchmarking

This first revision of the manual is initially for wider supply chain comment, review and feedback. Should a licensee wish to use this as a peer review or self-assessment then the key points can be extracted from the text. It is intended that revision 2 of this manual will include a benchmarking or self-assessment guide.

6. Photograph credits

The photographs in this manual have been kindly provided by EDF Energy and Fennovoima.

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Part 1 - Introduction to Commissioning

Part 1 - Introduction to Commissioning

1. Introduction

Author: Andy Waring

a. Reason for Publication

All projects transition through stages, often shortened to EPCC

E = Engineering: the design of the future asset

P = Procurement: the procurement and manufacturing of the components

C = Construction: the building of the asset on site

C = Commissioning: the activities to check, test and start up the asset

Commissioning is a very important part of any project and this is especially true for nuclear projects. It is the stage of a project where assets that have been manufactured and constructed are systematically checked, tested and brought to life. It is where any shortfalls in earlier stages are identified and resolved before an asset can be put into operation.

There are many sources of information and guidance on the early stages of the EPCC cycle, but there is not much that has been published to help practitioners of commissioning understand what to do, and more importantly, how to deliver commissioning.

This manual has been developed with contributions from all of the UK nuclear licence holders who currently perform commissioning of nuclear assets in the UK. It is intended to be a practical guide on how to deliver commissioning of a nuclear asset in the UK and should be used by anyone commissioning nuclear assets and facilities.

It is hoped that this manual will satisfy several requirements:

- A best practice guide to inform commissioning teams
- A self-assessment template for teams to use to check their own readiness
- A peer review and benchmarking guide helping the UK community of nuclear commissioning professionals form a network that helps share good ideas across all parts of the UK nuclear industry.

The UK nuclear industry, from nuclear new build to decommissioning has to be able to deliver the highest possible levels of safety – well beyond what is normal in most industries, whilst at the same time responding to increasing challenges to be as efficient and cost effective as possible.

This practical guide will help nuclear commissioning professionals meet these two objectives applying commissioning methods that are both rigorous and efficient. It has to cover a wide range of assets - from assets that have a high nuclear safety significance to normal industrial assets that are built on nuclear licenced sites.

b. Links to UK and international documentation

The following are key references for guidance on commissioning in the UK. Readers are advised to familiarise themselves with these reference documents. UK licensees are required to comply with 36 licence conditions (LCs) the primary LC that applies to commissioning is LC 21 (commissioning). Several other LCs are important to commissioning so the reader is advised to become familiar with all 36 LCs. The Office for Nuclear Regulation (ONR) provides an easy to read handbook[1] of the LCs, a link for which is provided below.

LC 21 is about one page long and therefore cannot give much specific detail about what is expected. As a result the ONR also publish a guidance document, Technical Inspection Guide 21 (TIG21)[2]. This is about 10 pages long and gives more specific guidance on what is expected for UK nuclear commissioning.

The UK approach in TIG21 follows closely the international guidance from International Atomic Energy Agency (IAEA) which is published in their safety standard SSG28[3] (about 100 pages) and the associated guidance note NP-T-2.10[4] (about 100 pages). These two documents give a comprehensive coverage of international nuclear commissioning requirements.

At the time of writing this guidance manual there are several international industry bodies capturing commissioning best practice and these documents will be published in due course. Some is particularly pertinent to commissioning. The Electric Power Research Institute (EPRI) has published best practice on how to turnover plant information and this is particularly important as a commissioning team will receive information from construction and contractors and pass information to the operations team. This plant information turnover guide[5] was developed with significant input from US new nuclear build power station units 3 and 4 at Vogtle.

The links to these documents are:

Reference 1: http://www.onr.org.uk/documents/licence-condition-handbook.pdf

Reference 2: http://www.onr.org.uk/operational/tech_insp_guides/ns-insp-gd-021.pdf

Reference 3: https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1595_web-30214867.pdf

Reference 4: https://www-pub.iaea.org/MTCD/Publications/PDF/P1742_web.pdf

Reference 5: https://www.epri.com/#/pages/product/000000003002007425/?lang=en-US

Reference 6: http://www.onr.org.uk/saps/

2. What is commissioning and why do it?

Author: Sam Billington

The best explanation of commissioning and also the benefits of performing commissioning are provided by the ONR in their Safety Assessment Principles document[6] (SAP number 196). These are:

> *'The commissioning tests should:*
>
> > *(a) demonstrate that, as built, the design intent claimed (in the safety case) has been achieved;*
> >
> > *(b) collect baseline data for equipment and systems for future reference;*

(c) validate those operating instructions (etc) for which the commissioning tests provide representative activities and/or conditions; and

(d) familiarise the operators with the operation of the facility or process.'

The overriding consideration of all licensees is to maintain nuclear, environmental and industrial safety and security of their plant. When making modifications or building a new plant the licensee needs to be satisfied that the plant remains safe throughout construction, commissioning, operation and ultimately decommissioning. The plant is required to perform certain functions which are necessary to maintain nuclear, environmental and industrial safety as well as security. To achieve this, performance criteria are established during the design phase and it is commissioning's responsibility to demonstrate through testing that these performance criteria have been met. Successful commissioning of a plant will therefore satisfy the licensee that the plant will operate as designed and is therefore safe and regulatory compliant.

Many nuclear plants are designed to operate for in excess of 50 years. Since the functional requirements do not change over the life of the plant, assuming all else remains constant, it is vital for the licensee to know if the performance of the plant is degrading to the point at which the functional requirements and performance criteria will not be met. It is recognised the best functional performance will be during commissioning and therefore the performance data obtained and recorded during commissioning should be retained as a benchmark. This commissioning data is particularly useful to licensees as it is the minimum standard they need to obtain as a result of the capital upgrades to the plant during it operational life.

During the commissioning stage the plant operating instructions will have been developed and reviewed. These procedures include such topics as initial valve line up, system start up, typical isolations for maintenance, maintenance procedures and both normal and emergency operation. The benefit of using these operating instructions during commissioning is that they can be validated on the plant and therefore ensure that the modified or new plant corresponds to the plant operating instructions. The commissioning phase is likely to be the first time that the actual as built plant, the design documentation e.g. piping and instrumentation diagrams (P&IDs), single line diagrams and logic diagrams etc. and the plant operating instructions are brought together. This will provide the first check that the design, the plant and the documentation all align and provides the project an early opportunity to update documentation to the as-built configuration.

The testing performed during the commissioning phase of the project can often be significant, particularly when this is a new plant. Some of the evolutions performed, particularly when commissioning nuclear power stations, will be very infrequent and therefore will provide the operators an invaluable opportunity outside of the simulator to experience and respond to these events. At a more basic level the commissioning tests will be the first time that systems have been aligned and brought into operation, set up, calibrated and any faults rectified. There is a significant learning opportunity of placing the future operators, maintainers and knowledgeable experts (designers, equipment OEMs, system operators from other similar plants) together around the systems and components at this time. The opportunity for operators, maintainers and engineers to access buildings, rooms and areas is invaluable for their future knowledge of operations and maintenance activities.

Taking a wider definition of the term 'operators' to mean all plant personnel, commissioning provides the opportunity for all facility personnel to become familiar with not only plant operation but also the maintenance , supporting the operation of the plant and emergency responses.

The commissioning tests and transients present the operators with an opportunity to optimise the performance of the plant to maximise output and reduce operating costs and inefficiencies. The various tests and activities also allow improvement of plant operating instructions and operating behaviours either by making them more efficient or by the removal of human error traps.

During the commissioning phase plant personnel and particularly the operators and maintainers are building their experience which can be used to demonstrate their overall competence for their future roles. Operator and maintainer competence is particularly important to have in place prior to starting active testing.

3. Phased approach to commissioning

Author: Anthony Macey

a. Development of Commissioning.

The first step is to develop the commissioning strategy document which will describe how commissioning will be delivered. This may cover a large major project or a plan for testing of simple safety systems in an existing plant. The development of the commissioning strategy should be started as soon as possible once the project or work scope has been initiated.

Consideration should be given to;

- Project performance requirements, functional requirements, benefits realisation and end states.
- Regulatory interfaces and permissions.
- Legal and Statutory requirements.
- Major decision and hold points.
- Constraints (project, facility, resource).
- Risks.
- Test scope.
- Interfaces.
- A graded approach to progressive challenge of the systems and plant at the appropriate time.
- Management systems and governance processes.
- Validation of procedures and training of people.
- Maintenance of the asset during commissioning.
- Handover and Acceptance.
- Sources of learning from experience (LFE) and how these will be embedded.

The strategy should detail the appropriate stages of commissioning to be undertaken and the objectives and acceptance criteria that will be achieved at the end of each stage. This may include Factory Acceptance Testing (FAT), Site Acceptance Testing (SAT) and component testing, system testing, integrated testing and active testing. It should define what management systems will be applied and the governance process for assessment of commissioning results.

When developing the strategy consideration must be given to the following key points within LC 21:

- LC 21(4) which requires the licensee where appropriate to divide the commissioning into stages and where specified by the regulator seek permission before proceeding from one stage to the next. LC 21(7) which requires that no plant or process that may affect safety is operated except for the purposes of commissioning until the following are in place;

a) The appropriate stage of commissioning has been completed and a report including any results and assessments considered in line with the licensee arrangements.

b) A safety case(s) must be in place and the safety implications of any design, construction or commissioning changes undertaken since commencement of construction on the safety case(s) must have been considered in line with the licensee arrangements.

Test scope and logic should be developed, giving consideration to the application of systemisation and modularisation in order to effectively test components, systems and facilities.

In planning for delivery of the commissioning scope, consideration should be given to the contracting strategy of the project and whether the contract scope should be extended to include part of commissioning, whether commissioning should be contracted out separately or if the licensee shall self-perform. In the UK it is considered best practice for the licensee to perform active testing. The result of these decisions will allow a commissioning team to be developed and the resource requirements estimated. Working closely with design, construction and operations teams will allow detailed schedules of commissioning work to be developed and a cost estimate to be produced. Risks associated with commissioning should be identified to allow appropriate mitigation to be implemented.

Protocols for interfacing with the design, construction and operations teams should be considered;

- With engineering team to ensure support is available to satisfy the following;
  - Clearly communicated design requirements which need to be demonstrated by testing.
  - Provision of necessary support during the commissioning phase to allow for effective testing and acceptance of the test results.
  - Ensure any modifications undertaken during this phase do not compromise the design intent.
- With the construction team to ensure;
  - Completions align with the programme to facilitate efficient delivery of commissioning.
  - Where contracted, the performance and recording of early testing.
  - Knowledge transfer for maintenance activities during commissioning.
  - Support for area, component and system handover to commissioning.
- With the operations team to ensure that operators are available to be seconded into or support commissioning activities to facilitate knowledge transfer to the end users.

Consideration should be given in the plan, to the principle of early testing and involvement of the operators as soon as possible in the construction and commissioning phases. This will aid in final handover and if testing identifies any differences in performance from that expected by the client.

A strategy or plan should be developed for all commissioning activities although the depth and breadth of what is documented will be commensurate and proportionate to the task being undertaken.

b. Preparation for Commissioning.

The preparation for commissioning can be broken down into the following work areas:

i. Establishing a commissioning organisation and management system.

- In establishing the commissioning organisation both the nature of the project being delivered and the business of the organisation delivering the work should be considered. The organisation may take the form of a commissioning team for the delivery of one project which is then disbanded. Equally it may be more appropriate to build an organisation that has numerous delivery organisations with a central commissioning function in the Project Office or Engineering. In this case consideration should be given to roles which manage the capability in terms of resource, management systems and training.
- In all cases delivery of commissioning should be undertaken by an organisation led by a commissioning manager (or commissioning director for large scale projects). The size, complexity and roles within the organisation will depend on the nature and scope of commissioning work. It may be made up of internally or externally sourced resource.
- A management system for the delivery of commissioning must be developed. The management system should meet the regulatory and statutory requirements e.g. licence conditions, Management of Health and Safety at Work regulations and be aligned to the quality management systems set out in ISO 9001 and other ISO accreditations held by the licensee.

ii. Establishing documentation requirements.

The management system will identify the required level of documentation and information in order to control, document and review commissioning. It will detail the governance and approvals process for the documentation. Documentation will typically consist of schedules/plans, test documents and reports. In addition the management system must also identify how faults and deficiencies highlighted during the commissioning phase will be documented and managed through to an agreed resolution.

iii. Scheduling.

The commissioning deliverables should be identified along with the scope of work required in order to complete all aspects of commissioning. A schedule should then be produced in order to effectively plan and deliver the work.

The schedules should not be produced in isolation but integrated with other functions within the project, wider business or client organisation. Key interfaces relate to the:

- delivery of the design documentation,
- inputs for safety cases,
- handover of plant to and from commissioning
- construction completion,
- availability of plant operating instructions,
- training development and courses,
- availability of licensee's personnel to support commissioning,
- interactions with company and regulatory hold points.

iv. Interface Requirements.

Commissioning interfaces with many different aspects of the project, supplier, business and client organisations along with other interested stakeholders such as the ONR and Environmental Regulators. Commissioning also must take into account physical interfaces and demands.

In order to meet expectations and requirements interface management must be considered when building the plan or strategy. It may be necessary to build or input into:

- Stakeholder management plans,
- Boundaries and Interface Agreements,
- Service Level Agreements.

v. *Evaluating Readiness*

The plan or strategy should consider the need for evaluating readiness and at what stage or stages this should be done. It may be necessary to do it several times during delivery of the project or commissioning scope of work such as at the end of FAT's or Inactive Testing or Active Testing.

The method of evaluating readiness should consider the requirements and success criteria for each stage and measure if these have been adequately met.

c. Factory Acceptance Tests

Plant and equipment should be set to work and tested as comprehensively as possible whilst in the factory in order to reduce the amount of testing carried out on site in subsequent commissioning phases. Factory based testing may also identify and mitigate risks earlier on in the project lifecycle, possibly allowing them to be retired prior to delivery to site and thus minimising risk to the project carried forward. Opportunities should also be taken to collect plant and equipment from different OEMs at a single site to perform integrated testing on interfacing equipment e.g. process plant and equipment can be integrated with plant control systems. This facility can also be used to deliver aspects of the operational and maintenance requirements, such as validation of working level instructions and delivery of training to plant personnel before the equipment is delivered to site.

d. Site Acceptance and Component Testing

Upon completion of construction activities on site the plant and equipment should be brought into service in a safe and systematic manner.

This stage of the work includes:

- Electrical and mechanical energisation of equipment,
- Input/output checks,
- Testing components as single items,
- Instrument loop acceptance tests,
- Statutory tests and inspections on lifting equipment and pressure systems.
- Integration of plant components to confirm correct operation in the plant working environment.

These tests will be undertaken by the most appropriate person and may make use of licensee employees or specialist OEMs and contractors.

The above and subsequent stages of testing will result in the plant being progressively energised and challenged to confirm that it meets its design performance and any functional safety requirements. Safety commissioning tests associated with the structures systems and components will be carried out at the most appropriate point during the testing lifecycle. These tests will be derived from the plant safety case and designed where possible to be end-to-end.

e. System Testing (Inactive Testing)

This stage of testing confirms that each system operates as per the design intent defined in the project functional specification. These tests may be delivered by licensee employees or contractors delivering the project on behalf of the licensee organisation. This is achieved by performing system cycle demonstration tests to confirm that each system meets the requirements specified for:

- System throughput,
- Output quality,
- System reliability,
- Operability, maintainability and recovery.

f. Integrated testing (Inactive Testing)

Once the functionality of individual systems has been proven, integrated testing of systems is carried out using an incremental systematic approach. Multiple systems should be integrated together in clusters or process lines to demonstrate the performance of plant areas before proceeding to carry out complete Plant Performance Demonstration test. This test demonstrates full interfacing of the control and safety systems and full functional and performance testing of the entire plant. This stage should also be used to deliver aspects of the operational and maintenance requirements, such as final validation of plant operating instructions, delivery of training to plant personnel and practising the response to the plant emergency arrangements. This work scope may be performed by licensee employees or contractors delivering the project on behalf of the licensee organisation.

On reactor sites integrated testing is performed to demonstrate the full functionality of the power station. This testing is carried using a staged approach.

- Non active station testing (including nuclear clean, cold functional tests and hot functional tests).
- Full emergency core cooling (ECC) tests to prove the correct operation of all the ECC systems.

g. Active Testing

Active testing includes those commissioning tests that cannot be carried out during inactive testing as they can only be conducted with nuclear fuel or other nuclear process material present and all other tests and activities required to:

- Prove aspects of plant design that have been assumed under inactive conditions e.g. shielding.
- Demonstrate plant performance under active conditions (i.e. not using simulated process materials).
- Validate operational and maintenance processes and procedures.
- Verify operator confidence.

On reactor sites additional requirements for active testing include the following;

- Active testing with nuclear fuel (including first criticality, power raising, grid synchronisation and performance tests).

In the UK the licensee is responsible for delivery of the active testing scope. In this stage typically the operations team will operate the plant with commissioning performing the testing and contract support from the designer, OEM and construction is available.

h. Close Out

Close out is defined as the point at which all functional requirements have been met by the project.

- Final handovers of systems and areas to operations are completed.
- Documentation identified to support ongoing operation and maintenance is handed over.
- Commissioning documents, information and records are archived.
- Any issues that remain unresolved are formally recorded and ongoing ownership agreed.
- The commissioning team members in conjunction with the wider delivery organisation will carry out Learning from Experience (LFE).
- Commissioning team disbanded or redeployed.

4. Management Systems for Commissioning

Author: Sam Billington

a. Licensee Management Systems

Whilst this manual is focused on commissioning it may be useful to describe a typical licensee's management system and where commissioning fits into this prior to taking a deeper look at the commissioning arrangements.

The requirement to develop and maintain a management system for a licensee is derived from, amongst other sources, LC 17 (management systems). This management system will cover all aspects of the licensee's activities of which commissioning will be a part. The management system will typically have the following typical hierarchy of documents:

1. Licensee's Corporate Manual & Policies
2. Directorate Manuals (e.g.: Engineering, People, Operations, Corporate etc.)
3. Departmental Manuals (e.g.: Design Authority, Training, Commissioning, Maintenance etc.)
4. Departmental Processes (e.g.: document production)
5. Departmental Procedure (e.g.: document preparation, document review, document approval etc.)
6. Templates and Guides
7. Records

The ONR might request that they approve the initial and any subsequent changes to the licensee's management system, this typically involves many of the documents within levels 1 to 3 above. They may also request to approve levels 4 and 5 if they see fit. The Environmental Regulator will ensure that the management system of the licensee is compliant with the various environmental permits issued to the licensee. A licensee will usually divide the LCs and environmental permit conditions between their directorates and departments and thereby ensure that these requirements are adequately addressed in the management system. This formal structure usually using a RACI (responsible, accountable, consulted and informed) matrix ensures responsibility and accountability for these requirements are communicated and understood by the various directors and departmental managers.

b. Management Systems Development for a New Licensee

Companies seeking a nuclear site licence will submit an application to the ONR and then the ONR will conduct its assessment. On satisfactory completion of this assessment the ONR will issue a nuclear site license. For companies developing large projects such as a new nuclear power station may wish to consider a phased approach to licensing. In applying this phased approach, the licensee may

agree with the ONR that the parts of the management arrangements covering the following topics are delayed, typically until before the Start of Nuclear Construction hold point is released:

- Commissioning,
- Operations,
- Outages & Maintenance,
- Disposal of radioactive material,
- Decommissioning,

In this instance it is likely that the ONR will require that a strategy document or other submission to detail the broad principles and intended timeline to develop these later management arrangements is submitted as part of the application for a nuclear site licence.

Whilst the commissioning arrangements will not yet have been prepared or approved it should be noted that commissioning will have to comply with a range of other approved procedures as part of this initial phase of licencing.

As part of the initial licensing the ONR would want to see that the commissioning team are on the right track and intend to the meet the requirements of regulator. The recommended best practice is to develop a set of strategy documents which describe what the commissioning arrangements will do and how they will be structured. These strategy documents can also be used as evidence in early submissions of the project safety case. For smaller projects a single commissioning strategy document or plan which includes a description of the proposed commissioning arrangements may suffice.

The remaining parts for the management system typically are approved prior to the start of commissioning and enacted from a defined and agreed project hold point.

c. Commissioning Arrangements

As part of the licensee's management system there will be commissioning management system that govern the conduct of commissioning activities. These arrangements will follow the typical hierarchy of documentation triangle as described below:

1. Commissioning Manual,
2. Processes,
3. Procedures,
4. Guides and templates.

The Regulators will typically review the commissioning manual and possibly the processes as part of licencing. The manual, processes and procedures will typically have a high level of approval often involving the licensee's Design Authority or the Nuclear Safety Committee or equivalent approval routes for environmental and security documents. However, the guides and templates often have a very light review and approval.

Best practice suggests that regulatory approval of the commissioning arrangements should be held at a high a level as possible. The aim for the licensee should be to ensure that the commissioning manual contains adequate information to provide the regulators with sufficient confidence without the need to specify their review and approval of the lower tiers of the commissioning management system.

i. Commissioning Manual

The commissioning manual will typically describe the activities of the commissioning team and provide linkages to other departments and processes to be used. These linked processes could relate to engagement of contractors, people management, security, finance, project management, safety, regulatory interaction etc. The commissioning manual may require that a document is prepared which describes the commissioning usage of these linked procedures, for example, a regulatory interface plan or stakeholder communication plan.

ii. Commissioning Processes

The commissioning manual will have identified and referred out to several similar high level activities for which commissioning is responsible. Each high level activity should be described in a process document which forms part of the licensee's management system. A non-exhaustive list of commissioning processes are as follows:

- Conduct of commissioning tests,
- Conduct of handovers,
- Development of commissioning documentation,
- Oversight of commissioning tests,
- Management of commissioning hold points,
- Management of commissioning non-conformances,
- Training, development and appointment of commissioning personnel.

The above list of processes will need to interface with other non-commissioning processes, for example the management of high level hold points or the recruitment, security clearance and appointment of personnel. In these situations, it is recommended that the commissioning processes simply refer out to other licensee processes and procedures to avoid duplication of effort. Should commissioning decide to use similar or adapted processes then consideration should be given to how commissioning will know when the rules and regulations change and therefore be able to update their processes in a timely manner.

iii. Commissioning Procedures

These high level processes are then broken down into several subordinate procedures which describe in a step by step manner how the activities should be performed. A procedure as part of the management system and will have the following aspects:

- Identify the owner of the procedure.
- Identify the applicable start date and the end or review date.
- Be uniquely identifiable as a procedure.
- A description of the validity and applicability of the process to ensure that it is only applied to the correct activities.
- Clearly and unambiguously identify the steps required.
- Identify the persons who may conduct the steps by post, title, grade, role, appointment or qualification.
- Use the associated templates and forms to generate records of the activities performed.
- Clearly state the transmission of information to other parties as appropriate (unless stated on the templates and forms).
- Identify the location and duration of records retention or link to where this information is stated elsewhere.

For the process structure described in the previous section the following procedures would be typical:

- Conduct of commissioning tests. There will typically be one procedure for each category of testing, for example, site acceptance, system, integrated and active testing. In addition to the recommendations above these procedures should consider the mandating of walk downs, pre-job briefings, provide links to the licensee's permit for work process. There should also be a process for mandating the suspension of a test and all of testing. Also there should be linkages to the non-conformance processes when testing identifies anomalies or performance criteria that have not been met.
- Conduct of handover and turnover. The handover of plant can be structured in many ways and is dependent on the contracting strategy. For example, areas (i.e. the structures such as buildings, rooms and parts of rooms) could be handed over first followed by a separate handover for the systems and components in that room. This is particularly important if a project contracts civil works separately to the supply of components, for example a concrete platform may need to be handed over prior to a large external transformer being installed upon the platform. Also the handover of plant from construction to commissioning and then commissioning to operations could be considered as two separate procedures. The contracting strategy will also drive the requirement for separate handovers to various activities such as maintenance and operation particularly if these activities are not performed by commissioning. There should also be a procedural mechanism to hand back plant to construction should there be significant remedial work necessary on part of the plant.
- Development of commissioning documentation. A range of commissioning documentation will need to be prepared, reviewed, approved and verified so consideration on how best to structure the commissioning arrangements for these activities needs to be undertaken. There will also need to be different procedures for accepting documentation from contractors. Other types of documentation prepared by commissioning which may require separate procedures will include:
- Management systems documents (although this process is not usually owned by commissioning).
- Test specification and justification documents (although these documents are usually prepared by the engineering team or their contractors.)
- Test reports.
- Commissioning strategy & plan documents.
- Commissioning documents in support of project arrangements e.g. project execution plans / commissioning stage plans, quality plans, stakeholder & regulator interaction plans etc. Commissioning should aim to group documentation activities together into as few procedures as possible but every document developed or used by commissioning should be covered by a procedure.
- Oversight of commissioning tests. The majority of projects which involve commissioning will outsource many activities. These may be the development of commissioning documents or the manufacture and testing of components to the assembly of components into sub-systems and the subsequent testing. The contracting strategy may also outsource the construction, installation and site acceptance of plant. In each of these cases the commissioning oversight arrangements should consider not only the acceptance of documents issued to and plant handed over to commissioning but also auditing and witnessing ongoing activities at these earlier stages. Procedures should address, using a graded approach, when audits will take place and when witnessing of testing is required.
- Management of commissioning hold points will be closely linked to and mirror the licensee's project and company hold point process. The commissioning hold points may directly feed

into company or project level hold points and may also require regulatory approval to release. A procedural mechanism for the inclusion of regulatory approval or other intervention in commissioning related hold points has to be addressed as these are mandated in LC 21. For commissioning hold points the commissioning manager (or director for larger projects) is typically the release authority and this may be on the recommendation of a test & commissioning panel. For each of these hold points a management expectations document should be prepared stating what the requirements are for the release of the hold points.

At a lower level a *commissioning hold points procedure* should also address testing hold and witness points within test procedures, in particular those that commissioning personnel expect to attend and also those commissioning tests which Plant Operations or others stakeholders (including the regulators) may wish to attend. At this level the procedure should state who the release authority for that witness or hold point so that this can be replicated in the test procedure.

- Management of commissioning non-conformances. The smooth flow of non-conformances out from commissioning to the interested teams as well as their speedy and accurate resolution is critical to project success in the commissioning stage. For large scale projects the number of non-conformances raised, not just from commissioning, but also during construction and the handover process should not be underestimated. There should be a clear route for commissioning and handover non-conformances to be recorded in the licensee's corrective action programme, sentenced (possibly by commissioning or others) addressed, remedial action undertaken and then the handover or commissioning test repeated. Commissioning should be careful not to duplicate tracking of non-conformances which may be managed centrally by either the licensee or the project. Commissioning should however ensure that it has sight of and rapidly addresses actions received from this central team.
- Training, development and appointment of commissioning personnel. The licensee should already have processes for the recruitment, on-boarding, performance monitoring, promotion and resignation of employees and contractors. The requirement for commissioning to have alternative procedures is unlikely, however particular consideration should be given to commissioning specific on-boarding activities, training and development. One of the key challenges is getting new joiners up to speed and able to work efficiently as soon as possible. Commissioning should focus on training based around its own arrangements and requirements. Specific training and examination of a person's skills may also be considered as part of their on-boarding or development process. One specific area is the recommendation, assessment and appointment of suitable qualified commissioning personnel in accordance with LC 21(5) although this is similar in nature to LC 12 (duly authorised and other suitably qualified and experienced persons) and could therefore be combined.

iv. Commissioning Templates, Forms & Guides

A suite of templates and forms should be produced to standardise the output of the procedures. A series of guides are often developed to provide a more detailed explanation of how to complete the procedure.

d. Project Arrangements

There is an added complexity when considering the application of project management arrangements on commissioning. Whilst licensees who only have one large project, for example, a

new nuclear power station then the commissioning arrangements and project arrangements are very similar. In this case the management arrangements will include project documentation such as a project execution plan.

Where licensees have a large number of projects within the commissioning department, project arrangements become more significant as they define the scope and activities to be performed. These activities are conducted in accordance with but also bounded by the Commissioning arrangements.

Further discussion on a commissioning project can be found in later sections of this manual.

e. Documenting the Management System

The Management System should be available to all persons working on the licensee's site and where appropriate tier 1 contractors and their suppliers. A common failure of projects is a lack of communication and or understanding of the commissioning arrangements in the contractor organisations. The licensee should take time and effort ensure that at both a contractual and working level the contractors understand the requirements placed upon them as well as the constraints under which the licensee is expected to operate. These requirements should be clearly detailed in the contract requirements of the invitation to tender and they should also be explained in the task kick off meeting post contract award.

Commissioning often requires a rapid ramp-up of personnel and the challenge is to ensure that they are quickly able to perform the activities required of them. Whilst the licensee's corporate induction training courses are adequate for how to use the management system, they will not dive down into the commissioning arrangements. The commissioning team should therefore consider a more specific induction targeted at those parts of the management system more applicable to commissioning.

f. Intelligent Customer capability

The Intelligent Customer is a term developed by the ONR which it relates to the capability of a licensee to have a clear understanding and knowledge of what the licensee is procuring. The ONR's definition is:

> *'The capability of an organisation to understand where and when work is needed; specify what needs to be done; understand and set suitable standards; supervise and control the work; and review, evaluate and accept the work carried out on its behalf.'*

There is a recognition that the licensee cannot self-perform all activities, nor can it retain all necessary skills to perform all of its activities. This leads to the licensee contracting out services and therefore an Intelligent Customer is required to be able to correctly and knowledgably to:

- Understand if the works is of nuclear safety significance.
- Specify the works required.
- Specify the standards, requirements and procedures to be applied.
- Assess that the contractor has the management system, capability and capacity to deliver.
- Accept the design, manufacture and testing of the product.
- Inspect and oversight the works performed by the contractor.
- Ensure no counterfeit, fraudulent and suspect items are used.
- Receive appropriate records for the works conducted.

- Capture learning and LFE and correctly apply this to future activities.

The ONR requires that the licensee shall retain adequate capability and capacity to be an Intelligent Customer.

A licensee will typically fulfil this requirement by identify individual employees or embedded contractors as Intelligent Customers after they have been through a formal assessment of their knowledge, and experience. This will be conducted and recorded in accordance with the licensee's competency processes as part of LC 36 (organisational capability).

Part 2 - Commissioning Organisation and Project

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1. Where does commissioning sit in a Licensee organisation?

Author: Tom Chang & Sam Billington

The IAEA states that 'organisational arrangements should be put into place to achieve the safety objectives of commissioning in accordance with the commissioning programme.' The requirement to have these arrangements is clear but where in the organisation or project structure should they be placed?

Where the commissioning organisation is placed within the licensee organisation is open to debate. The aim of commissioning as taken from ONR SAPs is to:

> *(a) demonstrate that, as built, the design intent claimed (in the safety case) has been achieved;*
>
> *(b) collect baseline data for equipment and systems for future reference;*
>
> *(c) validate those operating instructions (etc.) for which the commissioning tests provide representative activities and/or conditions; and*
>
> *(d) familiarise the operators with the operation of the facility or process.*

From the first bullet commissioning is required to check and verify the design and construction. This is achieved by commissioning taking the functional requirements from engineering and then testing to demonstrate that the plant's design and construction meet the functional requirements. Errors in engineering design and or construction will be evident during commissioning and therefore there needs to be adequate separation between the commissioning and both the engineering and construction organisations. Therefore, a degree of separation between commissioning and both the engineering and construction teams is necessary.

Bullets c) and d) show a clear linkage between commissioning and the operations organisations, including maintenance. From a best-practice point of view, both operations and maintenance personnel should be support or be seconded into the commissioning organisation to gain a better understanding of the plant they will operate and maintain in the future. The early engagement not only will assist with building and demonstration operator and maintainer competence but also will allow early validation of plant operating instructions. The support clearly required by commissioning from both operations and maintenance shows that the commissioning organisation leans closer towards operations than engineering or construction. The counter to this is that operations may be a business as usual organisation whereas commissioning is typically part of the project delivery organisation and will be susceptible to normal project pressures (e.g., reducing costs, minimising durations, minimising resources). These pressures do not typically align with those of a business as usual operations team.

As with all aspects of work on nuclear projects there will be a requirement for the licensee to ensure appropriate governance to the commissioning activities. The licensee should ensure that the commissioning organisation is separate to the assurance organisation. For the commissioning of large capital projects of those with a large portfolio of projects in commissioning the commissioning

manager may also have an internal governance team reporting directly to the commissioning manager.

a. Should commissioning own handovers?

When considering handovers of plant from construction to commissioning and then from commissioning to operations there needs to be ownership of that process and activities. Ownership of the handover and therefore the driving force should be the organisation that has most to benefit from the successful completion of the handover.

For the construction to commissioning handover the challenge is that construction will plan to construct in a room by room basis whereas commissioning will require complete systems to start their system testing. The challenge is that a system may span several rooms and floors of a building or even several buildings. If commissioning accept a handover then the project expectation will be to start system testing as soon as possible. Therefore, for an efficient construction to commissioning transition for a project commissioning team should be imposing their requirements to achieve system completion on the construction organisation, this approach will be supported by the project as it protects the overall project timescales. Construction will be willing to perform handovers as they will see this as a series of steps towards completion and a ramp down in construction costs and ultimately close out of the construction project budget. With this in mind the commissioning team should own the construction to commissioning handover. The process and expectations of the handover from construction to commissioning should be agreed early in the project between the construction and commissioning teams.

The commissioning to operations handover may also be a challenge to own. From a project point of view commissioning hold a finite budget and will therefore aim to ramp down their resources and costs as soon as possible. Operations on the other hand are typically not structured in a project way and are run in a business as usual manner so from a budget perspective there is little drive to receive handover from a project. With a poor linkage between commissioning and operations the training and competence assessment of the operators will not have been completed and therefore the plant will remain in commissioning's control until operations are ready to take the handover. As this handover is the last check that everything is correct with the new plant meeting the necessary standard for operations to accept handover can be challenging. The possibility that legacy issues either outstanding or not identified during the construction to commissioning handover are identified will also be a natural barrier to successful handover. However, best practice would suggest that operations are part of the handover from construction to commissioning and accept the construction and maintenance at this point. With this in mind the commissioning organisation is best placed to manage the handover to operations.

Having placed the scope of both handovers with the commissioning organisation it seems that there are more benefits of commissioning being closer aligned to operations than to engineering or construction. Being part of a wider operations organisation and drawing on operations personnel in support will also strengthen commissioning's acceptance standards for their handover from construction. This provides the licensee and the project will earlier identification of issues and time to resolve them prior to the plant being brought into operation.

b. Business as Usual model

Where a licensee has a standing commissioning team and continuous pipeline of separate small projects undergoing commissioning there are several considerations of where to place the

commissioning team within the licensee's organisation. In this model licensees tend to adopt a more matrix style organisation with the typical skills sets of design engineering, construction, commissioning, operations and maintenance arranged vertically. The project organisation is arranged on the horizontal with each project depicted as a separate row.

In this model the commissioning manager is to set the standards and expectations for commissioning and then ensure that competent commissioning personnel are allocated to the projects in a timely manner. The commissioning manager will appoint / nominate a lead commissioning engineer for each project. This lead commissioning engineer therefore has 2 reporting lines, the first is back to the commissioning manager for the correct performance of commissioning against the required commissioning standards and procedures with the second to the project manager for the project management aspects (e.g. costs and schedule). Safety, security and quality aspects for the commissioning work on a particular project could either be the responsibility of the commissioning manager or the project manager or both.

When comparing the respective head counts and budgets of commissioning with other organisations the commissioning team is pretty small and therefore is often placed at a lower level in the licensee's organisation when compared to engineering, construction and operations. This leaves the question of in which of these 3 organisations should commissioning be placed.

The licensee's engineering organisation is typically structured in a project manner and this aligns closely to the commissioning organisation. With commissioning's aim to demonstrate that the plant has been built as designed and that the plant can achieve the required performance criteria it seems that commissioning as part of engineering is an option. Tension between engineering and commissioning tends to arise if tests fail to meet the required criteria and concessions are requested by the project teams. Assuming that the test was correct and was conducted correctly then engineering has the final say in approving a concession or requesting an alternative resolution.

Placing the commissioning organisation within construction would result in a loss of checks and balances in the as built plant and is therefore not considered best practice as the quality of construction would likely be decreased due to pressures to handover to commissioning as soon as possible.

Having the commissioning organisation as part of a larger operations organisation provides the best synergy from the support required by commissioning and positive influence of operations expectations for plant at the point of handover. The one is a lack of synergy between the business as usual nature of the operations organisation in contrast with the project nature of the commissioning team. However, if this can be overcome then having commissioning within the operations organisation is a preferred option.

c. Significant project model

The difference between a business as usual model and a significant project model is that there is a distinct life span to the engineering, construction and commissioning organisations. By definition a project will have a critical path of activities which will move through engineering then construction and into commissioning before ending at final handover and acceptance by operations and project close out and therefore the project's focus will move between the 3 organisations. Each organisation will ramp down towards the end of the project and ultimately disband.

During the initial stages of the project, when headcount is small commissioning may best sit within the engineering team as the main driver will be safety case submissions which will be the

responsibility of the engineering organisation. As the project moves through the development phase towards detailed design the construction organisation will be formed and will start to ramp up. At this time the commissioning organisation and operations team should increase in headcount to start detailed planning for their respective phases. At this time it would be prudent to separate the engineering and construction organisations and depending on their respective sizes put the commissioning and operations organisations in to a third group. Between the Final Investment Decision and the start of nuclear construction the commissioning and operations organisations should be separated to create 4 organisations on the same organisational level i.e. engineering, construction, commissioning and operations.

2. The Commissioning Project

Author: Sam Billington

a. Governance

There will be a requirement in the licensee and commissioning management arrangements that certain oversight will be performed on commissioning activities. This oversight should be applied in a graded manner with the most significant nuclear activities (and those arrangements managing those activities) being subjected to a higher level of scrutiny. There are usually two sets of documents subjected to this governance process, the first is the safety, environmental and security cases for the work being performed and the second the management arrangements. The various cases will include at various times the following information:

- Commissioning Management Arrangements
- Commissioning strategy document and later a commissioning plan
- Other documents which describe how commissioning will be performed
- Commissioning test documentation (usually referred to or a list of references).
- Test results

The highest level of scrutiny is Regulatory Oversight as performed by the ONR will review the Commissioning Manual and possibly several key arrangements under the manual. For highly nuclear significant projects the ONR normally call for these arrangements to be submitted to them prior to the ONR granting approval for construction to commence on the project.

The licensee shall have in place External Oversight in the form of a nuclear safety committee as required by LC 13 (nuclear safety committee) and this will be composed of both highly experienced licensee employees and external persons. This committee will scrutinise all documentation intended for submission to the ONR and in addition the less nuclear significant arrangements. Similar committees may be established by the licensee focussing on the environment and security aspects.

For technical issues of a minor significance the Licensee will normally use Internal Oversight using a Site Committee chaired by the Site Director to approve these arrangements whilst those of no significance will be managed by the Commissioning Manager.

For the witnessing of higher classified tests either engineering or operations typically a Duly Authorised Person may be required alongside that of commissioning engineers.

b. Project Hold Points

The commissioning stage will be part of a wider project delivering a new capability and or increased capacity to the licensee. When planning commissioning the Commissioning Manager shall develop

the schedule around the commissioning stages described earlier in this manual. When establishing the schedule hold points are used to separate the project stages and therefore the stages of commissioning. This section looks at the typical hold points applied during a project and the possible activities required to be completed by the Commissioning team for each of these hold points.

i. Start of Nuclear Construction

There are many terms for this hold point and each of these relate specifically to a part of construction. The term nuclear construction relates to the construction of buildings of nuclear significance as denoted by their safety category. Broadly speaking the building(s) chosen will have a nuclear safety function or safety systems contained within them. The following are examples of terms and the activity subject to the hold point:

- First Nuclear Construction – The first placement of steel rebar into the foundation area of a nuclear significant building.
- First Nuclear Concrete – The pouring of concrete onto the steel rebar in the foundation space of a nuclear significant building.
- For smaller projects this could be linked the first modification to a system or structure with a nuclear safety function or the installation of a new component which has a nuclear safety function. For example, the first time a pipe is cut, a cable connected or disconnected or a component fixed to a structure.

This hold point is one of the major hold points on any project. The licensee will have to have submitted a safety case called a pre-Construction Safety Report (PCSR) and this will have to have been approved by the ONR for more significant projects or for lesser significant projects the licensee's nuclear safety committee or site safety committee for minor nuclear significant projects.

ii. First Energisation

For large projects this is a major hold point as it signifies the first time that power is brought on to the plant to be commissioned and so it constitutes a major step change in the industrial or conventional safety of the project.

The definition will typically identify a switchboard or transformer being energised as the subject of the hold point. Normally this would be one of the main switchboards powering the new plant. For smaller mechanical projects then this could be the first time a fluid is admitted into the systems and therefore a pressure could be applied to the pipework and components.

Since there is no change in the nuclear safety risk the ONR does not approve release of this hold point and therefore it typically remains with the licensee to release the hold point. However, for large projects the time between the ONR's approval of the Start of Nuclear Construction and First Receipt of Nuclear Material may be several years. In these cases the ONR and licensee would agree for the ONR to use its secondary powers to release this hold point. Simplistically this means that the licensee will not release the hold point until amongst other criteria the ONR are satisfied.

iii. First Receipt of Nuclear Material

There will be several different terms for this hold point depending on the type of project being undertaken and the activity being constrained by the hold point. The basis of the definition and the title given to the hold point will remain the same and relates to the first point that nuclear material

is introduced into the new plant as this represents the step change in nuclear risk. Some sample definitions are stated below:

- First Nuclear Fuel Receipt: this would be for a new nuclear power station's permission to bring the first nuclear fuel assembly on to site.
- First Nuclear Fuel Load: this would be for the first nuclear fuel assembly to be lowered into the reactor pressure vessel. By implication this means that nuclear fuel can be received and stored on site but not placed into a geometry which would allow a sustained fission chain reaction.
- First Nuclear Material Admitted: for projects of a more process nature this would be the opening of a valve allowing nuclear process effluent into the new plant.
- First Cask / Box Receipt: For those projects of a nuclear waste management nature this would be the receipt into the new facility of the first transport container or box or cask carrying nuclear material.

The project manager should note that the following items on the project site may require a specific handling licence or certificate which is not aligned to this hold point. The project may require their delivery at an earlier time than the project hold point is planned to be released. The licensee should therefore proactively manage these requirements. Typical examples of components which should be considered are:

- Radioactive sources for non-destructive testing or welds etc.
- Specialised detectors which contain nuclear material for example fission chambers which are used in determining reactor power.
- Radioactive sources for calibration of detectors or those to start up the first reactor core.

For significant nuclear projects the release of this hold point by the licensee will require ONR consent. To release this hold point the licensee will prepare the pre-Commissioning Safety Report (PCmSR) which for the most nuclear significant projects will require ONR approval or those of a lesser nature the licensee's nuclear safety committee or a minor nuclear significance the Site Safety Committee.

iv. Commercial Operations Date

The definition of this will vary from project to project and licensee to licensee. Broadly it can be defined as the new plant is capable of operating to the capacity required in the project business case. For power stations this can be the first time that 100% power is reached or when the operators are free to accept power instructions from the National Grid.

For a process facility this may be the time at which full capacity operations are conducted after a period of reduced capacity operations. Or a waste management plant has processed a pre-defined number of packages where each of these packages is subjected to an increase level of inspection and scrutiny.

Release of this hold point will typically be with the licensee.

v. End of Commissioning

This is the hold point at which the commissioning team will be stood down. It should be preceded by an audit of records and compliance to satisfy the Commissioning Manager and the licensee that commissioning has been conducted appropriately and completed. It may also be linked with a hold point for the end of the project.

Typically the inputs to this will be:

- All tests have been completed correctly and reports (including results) accepted.
- All handovers / turnovers have been completed from commissioning to 'business as usual' departments i.e. operations and maintenance.
- Any deviations, non-conformances have been sentenced correctly.
- Any remedial actions have been documented and handed over to operations.
- Commissioning close out report approved.
- Lesson learned captured and documented.
- Commissioning documentation has been stored correctly in the documentation records system.
- Personnel have had the associated project authorisations and appointments cancelled.
- Personnel's experience in Commissioning has been recorded for use in future SQEP and competency assessments.
- Commissioning contracts have been closed out and feedback recorded.
- For large new build projects the commissioning specific management arrangements have been removed or revised into a 'business as usual' standard from the licensee's arrangements.

vi. Start of Normal Operations

This hold point may well be included with some of the previous hold points. This hold point is closely linked with the safety case for the new plant. The pre-Commissioning Safety Report should also not only allow for commissioning activities but also a period of 'commissioned operational service'. This allows the new plant to operate at 100% capacity until the Start of Normal Operations. This means that there may be a significant time delay between the end of the last commissioning test and the Start of Normal Operations. The reason why this hold point may be some time after the last commissioning test has been completed is to allow for the final test results to be documented, assessed and accepted.

The licensee should also consider if there is a requirement to demonstrate that the plant operating instructions are correct and personnel have appropriate experience it may be necessary for the new plant to demonstrate their conduct of a shut down and maintenance period prior to the Start of Normal Operations. There may also be some inspections and activities associated with non-conformances or test deviations which can only be completed in a maintenance period and also need to be completed before the Start of Normal Operations.

The release of this hold point for nuclear significant projects by the licensee will require ONR consent and for less significant project by the licensee's Nuclear Safety Committee or for minor projects the Site Safety Committee. For this hold point the licensee will prepare the Pre-Operational Safety Report (POSR) which will include all the test results from commissioning (amongst other information).

c. Design Reviews

Commissioning should be involved in the performance of 2 types of design reviews, the first is constructability and the second is commissionability. Whilst these design reviews occur early in the project is vital for project success that they are conducted and that commissioning is resourced to meet the demand which will often be on a tight timeline.

i. Constructability Reviews

These reviews should be led by the designer and involve both construction and commissioning teams. The practice of holding these reviews is becoming common place and this should welcomed. They are normally held towards the end of the design phase.

ii. Commissionability Reviews

These reviews are also led by the designer and should involve commissioning. The practice of holding commissionablity reviews is not yet widely held best practice but licensees should consider this within their design process. Several major projects have suffered from a design not being commissionable leading to late design changes and in the worst cases changes to the new plant during construction. This leads to increased design costs, construction rework and delays to commissioning.

The purpose of these reviews is to:

- A check that the commissioning is being performed in the most logical and efficient manner.
- A check that the equipment and systems can be commissioned and there are no operability issues identified at this stage.
- Identify commissioning test points and the necessary access for maintenance.
- Identify temporary equipment and support and its connection points.

Confidence that the commissioning activity is capable of generating the required verification evidence to demonstrate compliance against the project requirements.

Ideally these reviews should be in the form of a checklist so that a consistent approach to these reviews can be maintained. Sample questions are identified in Appendix 2.

It is the common perception of commissioning teams that engineering teams do not understand how to design to commission a new plant. Therefore, to improve communication between the commissioning and engineering teams the commissioning teams should document the standard requirements and considerations of commissioning systems. This document should be communicated to the engineering team as part of the design requirements during the tender process.

d. Scope

Throughout this manual there is an overriding theme to clearly define the scope of the commissioning activities and who is going to deliver them. At a very high level the commissioning manager should agree the ownership of the following scope:

- Provision of test documentation
- Provision of life time records
- Performance of FATs, SATs, system testing and active testing
- Engineering support during commissioning (either on site or via call off)
- Review of test results by a designer and or OEM
- Performance of maintenance

Where there is a risk of losing scope or simply not identifying the scope gap are at major changes in the project or licensee. Some of these are as follows:

- Re-organising the licensee's departments and their roles and responsibilities.
- Changing project strategy such as moving from an EPCC model to a self-perform model.

- Changing the contract strategy.
- Contract negotiations where a contractor negotiates out commissioning scope and this is not fed back to commissioning by the project and or commercial teams.

In each of the above instances the commissioning manager should review the scope of work identified for commissioning and ensure that there is a clear demarcation of scope attributed to commissioning and it interfaces exactly with another party. This ensures that there is no overlap but also more importantly no scope gaps. The commissioning manager should then perform the appropriate change control to align scope, cost and schedule.

e. Work & Cost Breakdown Structures

The basics of sound project and financial management require the monitoring of progress of the commissioning activities against cost and schedule. Ensuring that cost accounts and contracts are correctly aligned ensures that accurate and efficient reporting can take place. For efficiency the delegated authority to sanction contracts or task orders and approve invoices should be at the lowest level. The following guidance should be considered:

- Financial delegated authority to those managing or supervising the commissioning. Those that can see the work being done (or not) should hold financial delegations.
- Responsibility for the conduct of commissioning should align with financial responsibility.
- Each commissioning project should have its own work and cost structure.
- Each team working on a project should have its own part of the work and cost breakdown under the project.
- Each line of a work structure should represent a tangible deliverable or activity such as:
    - A document (set) delivered.
    - A document (set) approved.
    - Handover / turnover completed – certificate issued.
    - Test complete – permit for work surrendered or test procedure completed.
    - Pre-qualification questionnaire or invitation to tender issued.
    - Purchase Order issued.
    - Authorisation received – minutes of a Board meeting, Nuclear Safety Committee, Site Committee or Test & Commissioning Panel etc.
- Each line should therefore have a clearly defined owner responsible for the activity.
- A cost account (line on the cost breakdown structure) should directly align with one or more work breakdown lines which relate to the deliverables.

f. Risk

The use of risk is often over looked and this at the tail end of a project often leads to challenge from the project management or stakeholders as best practice suggests that there should be ‘no surprises’. Risk workshops should be run to identify the risks on each project and these should be captured appropriately. Broadly speaking the risks work in the following areas:

- Political:
    - Trade restrictions changing the availability or cost of equipment or the ability of a supplier to support the project.
    - A change of UK (or international) government to change the funding of a project.
    - Regulation or design codes change during a project which impact design and therefore testing requirements.
- Project:

  - Scope change from one of many trigger events (project review, shareholder review etc.) which either increase or decrease the scope of a project and therefore what needs to be commissioned.
  - Delays to starting commissioning or delays during commissioning.
  - Design changes during commissioning.
  - Scope transfer from construction or OEM to commissioning i.e. reduction in FATs performed or construction tests not conducted.
  - Change in project categorisation increases the governance and oversight of the project.
  - Handover from construction to commissioning logic is flawed leading to an inefficient start to commissioning.
- Plant:
  - Access to components and systems requires scaffolding etc.
  - Access to plant is restricted due to overlapping activities in construction e.g. radiography
  - Equipment fails a commissioning test and needs to be returned to a supplier.
  - Construction sequence restricts or prevent the supply of water, fuel, waste treatment, gases etc. from existing site infrastructure resulting in commissioning requiring to procure a temporary solution.
  - Inadequate configuration management and underpinning or justification of design functions and requirements.
  - Installation defects not spotted until commissioning or at worst after handover from construction.
  - I&C design not mature enough at the start of commissioning leading to re-testing.
  - Plant is not designed for efficient commissioning.
- Management Arrangements:
  - Changes to management arrangements increase the effort necessary to perform commissioning activities.
- Supplier:
  - A supplier ceases to trade with the licensee either due to bankruptcy, take over or other issue.
  - Licensee or project becomes less attractive to a supplier therefore reducing their support and effort to help the licensee deliver.
  - Relationship between the licensee and or the project with the supplier reduces such that the back office support from the supplier to deliver the project.
  - New lead team with a supplier are unfamiliar with licensee's requirements.
- People:
  - Adequate suitably qualified and experienced personnel are available to commission the project.
  - Loss of a person(s) either an employee or embedded contractor with key knowledge of systems or holds vital qualifications and appointments
  - Licensee's priorities are directed away from the project, in particular engineering or operations personnel.
- Resources:
  - Lack of spare parts – the spare parts are not adequate either due to a higher failure rate or the specific component not being ordered results in a delay.
  - Lack of commissioning parts – these are the temporary components and systems not provided as part of the design and need to be specified by commissioning. Not having these will delay the project.
  - Use of consumables and or utilities exceeds expectations resulting in a higher cost.
  - Lack of communication system means a temporary system is required.

- IT Platform:
  - IT software does not support efficient tracking of completions.
  - IT software is delayed.
  - Hardware cannot be operated in the plant due to connectability or security issues.
  - IT platform cannot be accredited to the appropriate security level.

The commissioning manager should have a clear understanding of which risks are held at project level and which risks are held at commissioning level. For example, the day on day delay to a project and the associated standing cost of a project delay is more likely to be held at the project level.

Risks should be reviewed on at least a 3 monthly basis. Where the risk is intolerable then the route for approving mitigation activities should be clearly understood.

g. Opportunities

The often forgotten aspect of risk is the positive flip side which is the opportunities. These come in many forms but some examples are as follows:

- Challenging the safety categorisation of equipment. Sometimes the safety categorisation is not quite so clear and therefore open to challenge. A reduction in categorisation will result in less governance and a less onerous commissioning test.
- Reduction in consumables and utilities or changing to a less costly version. By planning commissioning carefully and early engagement with the construction sequence a reduction in consumables can be made. A newer and cheaper alternative may be available.
- Reducing the time of flushing. This could include changing the flushing routes, purchase of extra hoses or an extra or higher specification flushing rig to shorten the duration of flushing.
- Reducing electrical energisation time by using construction power applied to low power switchboards to test low power equipment.
- Increasing the qualifications and appointment of personnel to reduce reliance on other in demand departments therefore reducing the standing time during testing.
- Increasing testing in the factory to give certainty to testing which is on the critical path.
- Witnessing of FATs to take credit for testing therefore preventing the need to repeat the testing on site.
- Use of temporary supplies feeding the new plant to test components before the permanent supplies are connected and energised.
- A move to automate and or digitise repetitive activities in the office.

h. Project Change Management

Whilst project change management may seem like a burden to many it is a key communication tool for the commissioning manager to report the impact of an event on the commissioning team. It can be used to draw down risks which have materialised are now going to impact the project.

Keeping the project change management up to date is necessary to ensure that reporting is accurate. Any changes to scope, cost and schedule when approved will then roll up to the project reports and provide stakeholders with a more accurate picture of progress.

i. Key Performance Indicators

For long running projects or a portfolio of projects it may be suitable to highlight milestones within a financial year. These may be the commissioning department's high level targets for the year. These should range across each project and may include several milestones for each project in a year. The

milestones should be carefully selected to ensure that they are relevant and on the critical path through the project or commissioning activities. The commissioning manager should consider the behavioural response of the team to drive to meet the milestones at the possible neglect of other work critical to a project. These milestones could be:

- Submission of a key commissioning document for the safety case.
- Commissioning Plan approved.
- First or last handover for a project.
- Release of a project hold point or one of the milestone stated previously.
- Agreement of a contract.

There are many key performance indicators which can be used to measure the progress of a commissioning department such as:

People:

- The headcount of the commissioning department against the business plan.
- Nuclear Baseline gaps against requirement.
- Post holder not being fully competent.
- Action plans in place and on track.

Quality:

- Audits of suppliers and projects against business plan.
- Number of projects overdue an audit.
- Action plans in place and on track.
- Commissioning documentation not meeting conformance standards.

When considering individual projects within a portfolio the following are best suited to an ‘s’ curve or work down curve type reporting:

- Test documentation prepared against plan.
- Test document approved against plan.
- Handover completed to commissioning.
- Tests completed.
- Handovers completed to operations.

j. Resources

In planning the commissioning activities of a project the commissioning manager should consider the resources required. This manual has talked extensively about the people required but there are other considerations such as:

- Temporary equipment for connections, component bypasses.
- Temporary plant e.g. flushing rigs,
- Test equipment,
- Communication equipment,
- Digital platforms to improve commissioning,
- Consumables and utilities,
- Spare parts.

The commissioning manager should ensure that the above points are considered early in the project lifecycle so that where appropriate design, manufacture, procurement and calibration etc. can be planned and costed.

3. Human Resources and Commissioning Organisational Models

Author: Anthony Macey

The primary objective is to develop an effective and efficient commissioning capability to enable the safe and secure delivery of the project to time, cost and quality.

Consideration must be given early in the project development to the commissioning model deployed and the resources required to support it. The delivery strategy, logic and programme will be used as a basis for any decisions made regarding the commissioning model adopted and the required resources.

a. Commissioning Organisation Approaches

The organisation model chosen will depend on the size, complexity and priority of the project(s).

Large capital build projects will typically have a dedicated commissioning manager reporting to the project manager and a team beneath them that is formed for the sole purpose of delivery of the project and is disbanded on completion.

Where a number of smaller ongoing projects are being delivered within existing facilities an ongoing commissioning organisation may be put in place. This organisation will have a commissioning manager and a core team of commissioners whose numbers will flex each year based on the agreed work scope. The team may be supplemented with skills from the existing plant(s) on a part time or full time basis as required to deliver work.

Where small scale commissioning works with nuclear safety significance are undertaken by teams other than commissioning, an appropriate level of oversight must be put in place to ensure compliance with nuclear site license conditions.

Whichever model is chosen, there should also be appropriate governance within the organisation to ensure work is delivered to the appropriate standard, learning from experience shared and best practice deployed throughout.

b. Test & Commissioning Panel

The Test and Commissioning Panel (T&CP) is made up of a quorate body of members and deputies appointed by the chair. The chair is responsible for ensuring that the combined membership of the panel provides the breadth and depth of experience necessary for the declared business of the panel. Each meeting will have an agenda and a set of minutes to record the discussions that took place and track any allocated actions. The T&CP has a twofold purpose:

- To provide assurance that the commissioning documentation and commissioning activities used for confirming design intent of new or modified structures, systems or components is achieved. This is accomplished through the review of key commissioning test documentation (safety commissioning schedules, commissioning strategies).
- To establish any necessary regulatory or internal hold points associated with a significant change in risk and to review the readiness of the plant and equipment when transitioning through these hold points. An example being prior to introducing nuclear material when

proceeding from inactive to active testing. This is achieved through the review of results, summary reports that detail how the safety function and design performance requirements have been met either through engineered systems or operational preventative measures.

c. Structure of a Commissioning Organisation

The structure of a licensee's commissioning organisation will depend on the scope attributed to the commissioning organisation by the licensee's arrangements. Typically, the commissioning organisations will have the following elements:

- Project Management Organisation,
- People / Training / Competence Team,
- Oversight Team,
- Arrangements and Standards Team,
- Testing Team,
- Handover Team.

Some licensees may group the above teams together but regardless of the actual organisation structure the function provided by the above teams is required to be performed.

i. Project Management Organisation

There will be a requirement for the commissioning organisation to report progress on its activities to the project. This will include development of the schedule and cost estimates and reporting progress against the plan. They may be a need to have risk / opportunity management capability within the PMO team.

Further capability may need in the following areas:

- Document Management,
- Business planning / reporting,
- Estimator,
- Quantity Surveyor,
- Finance ,
- Learning from Experience (LfE), Operating Experience (OPEX) and Lessons Learned.

ii. People / Training / Competence Team

As previously stated the key to commissioning is the people and this remains true regardless of if the licensee has a steady portfolio of commissioning projects or is building a large nuclear power station. The size and organisation of the team(s) within the Commissioning Department will depend on their scope and the nature of the licensee's commissioning activities. The activities required to manage the people are as follows:

- Defining and administering changes to the organisation.
- Establishing and updating post and role profiles with the line manager.
- Determining if a post is nuclear baseline - link with LC 36 (organisational capability).
- Provision of reports against the nuclear baseline.
- Establishing and maintaining the training requirement for each post.
- Monitoring and reporting on the gaps in competence and ensuring that progress is being made to close the gaps.
- Liaison with the Training Department to ensure that adequate courses are available to meet commissioning's needs.

- Down selecting candidates for interview.
- Coordinating interviews.
- Managing, coordinating and expediting the successful candidates through security clearance, HR and IT set up ready for their start date.
- Establishing the week 1, month 1 and quarter 1 activities and training of a new starter.
- Developing and maintaining a succession plan for critical posts and ensuring that the replacements have training booked and development activities planned.

iii. Oversight Team

This team is the Commissioning Manager's conscience or assurance ensuring that the testing teams are doing the right thing. The oversight team may conduct the following activities to ensure that commissioning is conducted in an appropriate and compliant manner.

- Witness FATs and contractor conducted commissioning tests.
- Develop and update the commissioning management arrangements.
- Ensure that commissioning management arrangements are compliant against LC 21 and other requirements.
- Audit the commissioning organisation against the commissioning management arrangements.
- Audit the contractors against their arrangements.
- Review and approve contractor's arrangements against the licensee's requirements.

iv. Arrangements and Standards Team

The Arrangement and Standards Team are responsible for the development and update of the commissioning management arrangements and their linkages with other licensee management arrangements. They will also develop any commissioning standards drawing upon LfE from both the licensee and external organisations. This team would then also review any management arrangements submitted by a contractor to ensure that they are compliant and link appropriately with the licensee's arrangements. Note that this team is the standard setters but it is the Oversight team's responsibility to check compliance of activities against the standards.

v. Testing Team

The testing team may be sub-divided into different knowledge bases, for example, there may be a team which focuses on non-nuclear significant testing and another which focuses on the more nuclear significant testing. Depending on the portfolio of commissioning tests conducted by a licensee there may be other specialist test teams. Typically, a testing team will conduct the following activities:

- Draft and approve test documentation (procedures, instructions and reports).
- Raise non-conformances of test queries as a result of testing.
- Conduct commissionability reviews of designs.
- Review the contractor test documentation.
- Witness and or participate in FATs and contractor led testing to gain an understanding of the systems and components.
- Ensure that the evidence required to be produced from commissioning to support the safety case etc. is completed including testing conducted by the contractor(s).

vi. Handover Team

The licensee's choice to have a separate handover / turnover team and how it views ownership of the systems and areas which move into commissioning will vary significantly between licensee's. If the licensee wishes to adopt a through commissioning life ownership of systems then handover will be performed by the testing team. If the licensee adopts a more functional approach, then a separate handover team could be used.

Whichever structure is adopted the persons responsible will need to:

- Develop and update handover arrangements.
- Understand, document and communicate to the contractor the requirements for the handover to commissioning such as:
    - Coordinate the handover with the contractor and other licensee departments.
    - Understand, document and communicate to the test teams and other the requirements of the handover to operations.
- Coordinate the handover to operations and other licensee departments.

d. Structure and Sizing of Testing Teams

The structure and size of the testing team is not fixed throughout the project lifecycle and needs to flex/adapt in response to the project phase, the programme of work and the specialisms required. The structure adopted will also be influenced by the commissioning strategy and how much commissioning is identified to be done in house or contracted out to specialist contractors and OEMs. At any point in the project lifecycle the structure adopted needs to have people in post with clear roles and accountabilities to allow for effective delegation/substitution in the event that a key role holder is unavailable for a period of time. For teams organised to perform smaller ongoing projects that are part of what can be considered business as usual there will most likely be a structure with a mixture of electrical, control and instrumentation, mechanical, process, building services skills and levels of seniority and occupational category (managers, leads, engineers, technicians, craft)

For large capital build projects a brief overview of the phases and influences that may affect the structure(s) are given below. A pictorial representation of the structure associated with each of the phases is shown below along with a brief explanation.

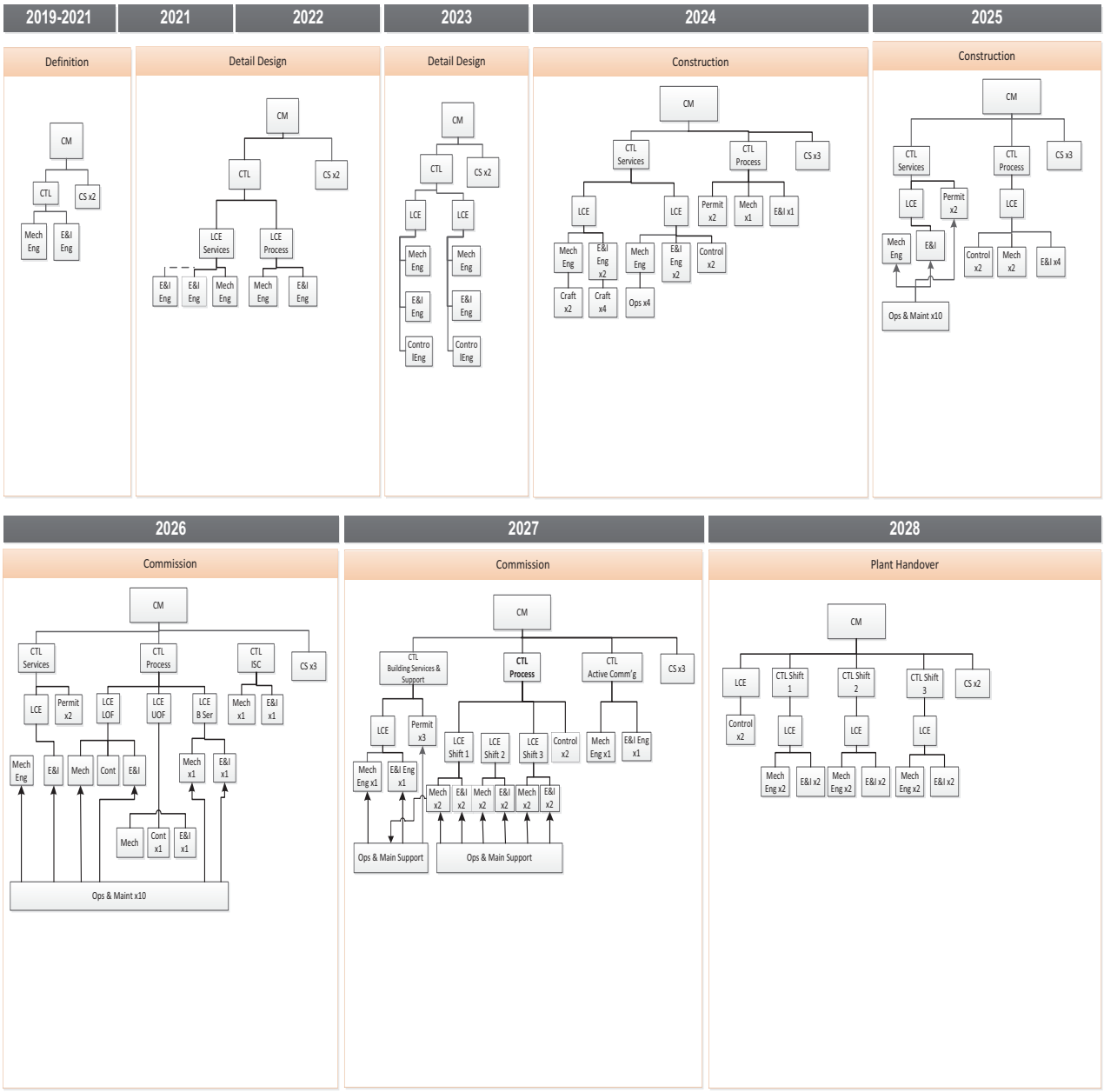

Figure 1: Commissioning Team Structure by Project Phase

- Definition phase. The structure put in place needs to support the development of the commissioning strategy, logic, estimates and schedules. The structure also needs to provide commissioning knowledge and experience that can input and influence proposed designs. This is likely to be a small core team consisting of the commissioning manager and a limited number of experienced commissioners. A commissioning support role(s) to allow early planning and implementation of effective management systems for the commissioning processes and documentation should also be considered.
- Detail Design Phase. As the detail design progresses the structure will need to change with the emphasis being on the development of a plant test schedule and the necessary tests that demonstrate the functional and design performance requirements. Depending on the size of the project the structure may comprise a number of sub teams with particular area(s) of focus and accountabilities e.g. services, process. These teams will be populated with the

necessary specialisms to perform the tasks required with leads assigned to coordinate the activities.

- Construction Phase. During the construction phase the team composition/focus will change from one that is focussing primarily on the development of tests to the delivery of testing at works and making use of opportunities to start testing early through the phased handover of systems from construction. The structure of the team will need to change to fulfil these tasks and be supplemented with additional CE&I, Mech engineering, craft resource to carry out or oversee the testing. Structures to oversee the safe hand over and energisation of equipment will also need to be put in place (permit office).
- Plant Commissioning Phase. At this point in the project lifecycle the commissioning team size will peak. The structure will need to ensure that it can cope with a number of different work faces with additional sub teams and reporting structures put in place. Consideration should be given to how the project will transition into an operational facility by embedding operators and maintainers into the team structure. This may require the use of shifts and an appropriately structured team to support
- Plant Handover. During the handover phase, the plant items will be progressively handed over to the facilities operation and maintenance teams. The commissioning team size will decline and the structure will change to focus on plant support during the agreed handover/confidence period. This may require the use of shifts and an appropriately structured team to support.

e. Resource planning

Resource planning is important for a number of reasons and allows a better understanding of the following;

- Identifies impacts on the critical path.
- Clashes in the availability of work faces during the construction/plant commissioning phase.
- Identifies peaks and troughs in resource demand allowing resource smoothing to be applied.
- Determines the resources required to deliver a specific piece of work.
- Enables the project to plan for the availability of specialist equipment/personnel and facilities.
- Allows the commissioning team to plan their resource requirements in order to hit agreed milestones and regulatory hold points.
- Results in a more robust estimate that can be used to underpin the business case and the amount of funding requested. Increased stakeholder confidence, fewer cost overruns.

Project resource planning is an iterative process that matures in line with the development of the design and refinements to the schedule as key information becomes available with regards manufacture and construction time scales.

For business as usual commissioning team's setup for the ongoing delivery of smaller projects, the resource requirements will be determined by the sanctioned project list for each financial year, the windows of opportunity/outages made available to commission new equipment and the availability of additional resource to supplement the team. Each of these mini projects should have a standard re-usable commissioning sequence and then adapted in collaboration with the project manager to show commissioning resource requirements and timescales. The cumulative total of these will show the resource requirements throughout the year. For out years an assessment should be carried out to determine what work is likely to be sanctioned to determine if the general trend is up or down.

For major projects it is necessary to resource plan for the whole of the project lifecycle which can last a number of years. The ability of the organisation to deliver the commissioning will be the first

determining factor. If the organisation doesn't have the capacity/capability to deliver the commissioning in house they may decide to use a contractor to deliver some or all of the defined scope. A typical resource plan and the factors influencing development are shown below.

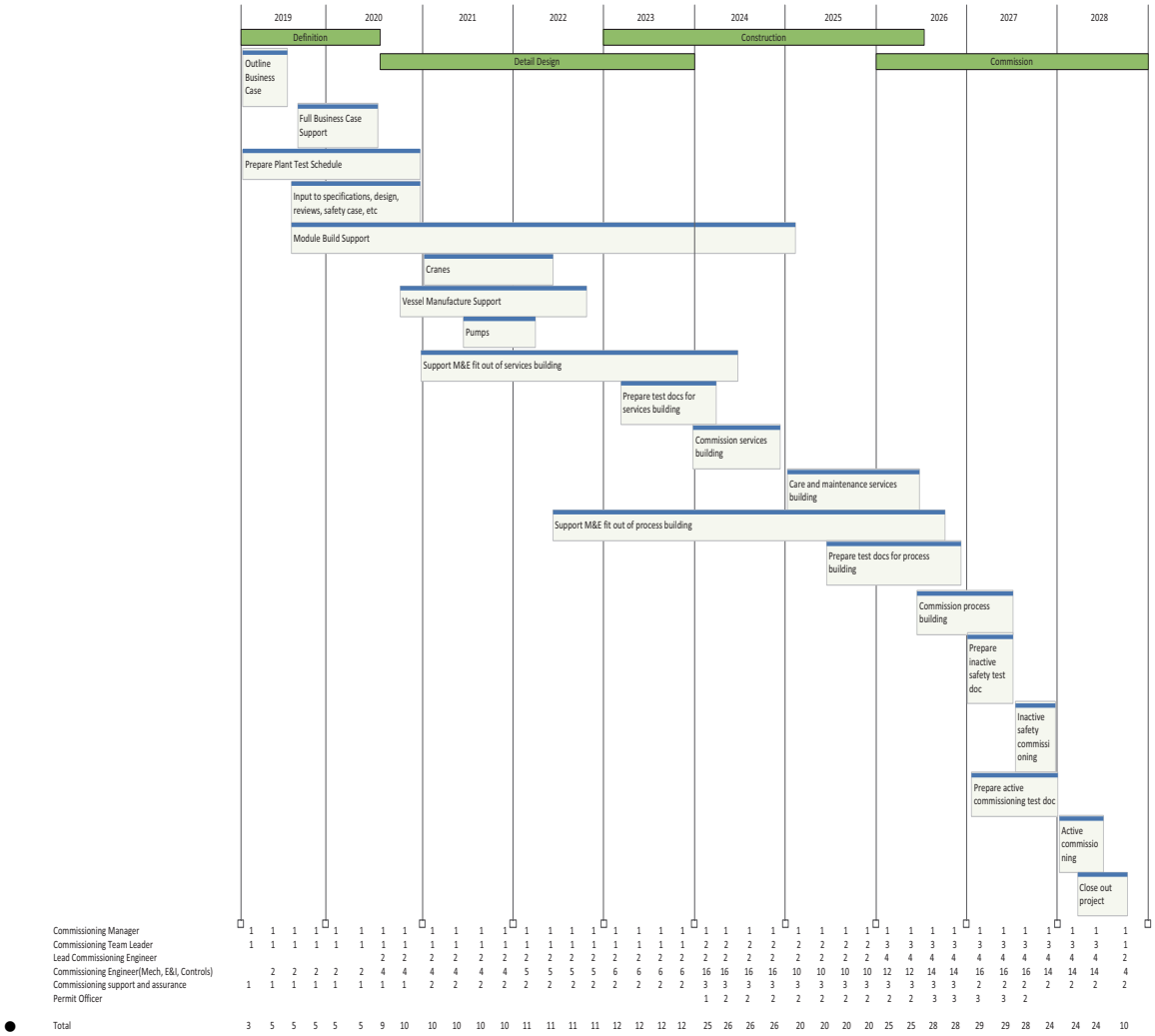

Figure 2: A typical Commissioning Resource Plan

i. Definition Phase.

The starting point generally for resource planning in the early project definition phase will be a top down approach based on engineering judgement, experience and comparative estimating techniques where historical data from similar projects will be used as a baseline and adjusted to reflect differences in scale/complexity. This information will be used to produce a basis of schedule and estimate that will be refined further as the design matures and the schedule develops.

ii. Concept Design.

At this stage it is likely that an understanding of the number of commissionable systems and areas will start to emerge. The basic construction and commissioning logic will be developed sufficiently to allow development of a schedule. Using historical norms and engineering judgement for each of the commissionable systems and areas an initial resource profile for the duration of the project can be developed.

iii. Detail Design

As the project progresses through the design stages, the increased maturity of design allows the production of a detailed bottom up estimate. The detailed design and commissionable systems list can be used to develop a comprehensive plant test schedule. Each of the identified tests will be assessed to determine the extent of testing required and by whom. Commissioning norms should be used to underpin each of the activities. Once this information is fed into the schedule it will be possible to understand where the pinch points are for resource on any time constrained activities. Specific measures can then be put in place such as additional resources or changes to the delivery logic or changes in working patterns (shifts). At the end of the process a fully underpinned resource profile aligned to the delivery schedule should be available.

f. Maintenance of the Plan

During the construction and commissioning phases the resource plan needs to be maintained in response to slippages or efficiencies made in the delivery of the schedule. This will need to be monitored by the commissioning manager to ensure the resources at his disposal can deliver the projected work scope.

g. Commissioning Implementation Team Composition

The composition of each commissioning implementation team will vary depending on the size and complexity of the project. The team should comprise of those skills necessary to deliver the bulk of the work with specialism's brought in under other arrangements to fulfil any specialist skills required. The identified team structure will largely determine the team composition and roles required. Typical delivery team roles are detailed below and their key accountabilities.

Below are listed the core commissioning team roles and supporting roles. Not all of these positions will be applicable to every organisation. The size and complexity of the project will determine the mixture of team leaders, leads, engineers, technicians, craft and support staff and whether some of these roles can be omitted.

i. Commissioning Manager

The commissioning manager's role is to manage the delivery of a commissioning test programme in a safe and effective manner that confirms design intent against functional acceptance criteria to the customer. The commissioning manager also provides commissionability into the design, the knowledge, leadership, management and support required to ensure commissioning work is executed to meet company, legal, regulatory and project requirements.

ii. Commissioning Team Leader

The commissioning team leader will provide technical or functional leadership and will act as a delegate to the commissioning manager. The commissioning team leader carries out a managerial role to lead a commissioning team in the delivery of assigned commissioning projects in a safe and effective manner in line with the commissioning arrangements. This role may be granted delegated authority to accept commissioning test results on behalf of the designer or licensee.

iii. Lead Commissioning Engineer

The lead commissioning engineer functions individually or as part of a multi-disciplined team for the purpose of carrying out testing and validation activities. They will also direct technicians and engineering resources in the delivery of tests on plant/at works. These individuals through

knowledge and experience will have demonstrated their ability to act as technical experts in the field in which they are operating.

iv. Commissioning Engineer

The commissioning engineer functions individually or as part of a multi-disciplined team for the purpose of carrying out testing and validation activities in line with the commissioning arrangements. They may also direct craft resources in the delivery of tests on plant/at works.

v. Technicians and Craft

Electrical, control and instrumentation and mechanical technicians are members of a multi-disciplined team to carry out testing activities under the direction of the engineers to support setting to work and test activities.

h. Support to the Commissioning organisation

The commissioning support team member's role is to implement effective management systems for the commissioning processes and documentation.

i. Operations Team Member

The operations team member's role is to support the smooth transition of the plant and equipment into operations. They may report directly to the commissioning manager or to a dedicated operations manager. During testing they will work alongside the commissioning teams to validate developed operating and maintenance documentation to ensure the plant can be operated and maintained effectively once the plant goes live.

ii. Permit Office Controller

The permit office controller controls and coordinates activities on behalf of the commissioning manager. The permit office controller maintains oversight of plant activities to support coordination and safe 'release' of 'plant' and for the safe return of plant following work activities.

iii. Intelligent Customer

As a whole the team must also fulfil the role of Intelligent Customer (IC) to ensure that where a contractor is employed in relation to activities that may affect nuclear safety that they provide the necessary oversight before during and after implementation. Designated members of the commissioning team may have formally assigned IC roles.

i. Training and Qualification

The training arrangements put in place for the workforce must ensure that employees are competent to work safely and effectively. Arrangements must be put in place that describe the principles and approach to training, assessment, qualification and appointment of those holding key posts and roles. When developing the training programme particular emphasis should be given with regards how the individual(s) will satisfy their responsibilities in relation to health and safety legislation and the relevant License Conditions (LCs). The training required by the commissioning team can broadly be split up into three categories.

- Generic role training within the commissioning department should have a clear set of accountabilities, responsibilities, and authorisations. These form the basis for the training and qualification programmes for each employee and may also be used during the screening process for potential employees.

- Additional duties individually assigned that relate to specific tasks for example (electrical testing, lifting appliances, mechanical testing). The commissioning manager will need to engage the relevant subject matter experts to determine what training and assessment needs to be carried out and by whom.
- Plant/equipment specific training assigned to individuals to ensure safe operation.

Qualifications formally record a team member's ability to perform a particular role or skill. Qualifications are acquired through course assessments or assessment of an individual's competence. Each role within the commissioning organisation should describe the mandatory qualifications that are required before the individual can be classed as competent. Similarly, for any additional duties the subject matter experts (SME) will be required to specify any mandatory qualifications that must be completed prior to appointment of an individual.

It is the commissioning manager's responsibility to ensure that commissioning personnel are only deployed once they are trained and deemed to be competent for the task they have been asked to perform including successful completion of any mandatory qualifications.

j. Team Building

Team building is essential in order to promote effective teamwork and alignment to the project objectives. The team building activities will be conducted with various group or organisational levels. Ultimately it aims to ensure individuals understand their role in their immediate team and also as part of the wider integrated project team. What they need from other team members to allow them to deliver their role and the expectations of others as to what they need from the team to allow them to deliver their roles. Consideration should be given to how you make people feel part of a team and the creation of a team identity. It should consider how you bring new people in and how you will integrate contractors to create a transparent team aligned to the project objectives. These could include the following;

- Stakeholder interface,
- Project Management Team,
- Partners / joint ventures,
- Engineering team,
- Design Authority,
- Technical resource centres,
- Construction team,
- Suppliers / sub-contractors,

The Team building process should focus on:

- Developing and maintaining positive team dynamics,
- Maintain a shared vision and mission,
- Ensure good communication and conflict resolution,
- Eliminate barriers,
- Build trust and commitment.

4. Key Stakeholders and their drivers

Author: Sam Billington

This section looks at the key stakeholders for commissioning and what their aims for and interaction with the commissioning team are likely to be.

a. Office for Nuclear Regulation (ONR)

The Office for Nuclear Regulation (ONR) is the UK's nuclear regulator whose remit is established under the Nuclear Installations Act 1965 and extends to 37 nuclear licenced sites across England, Wales and Scotland. The ONR forms part of the Health & Safety Executive and as a result of this also enforces conventional or industrial safety on these sites. As part of a more recent change the ONR has taken on responsibility for the regulation of the security of nuclear licensed sites.

The ONR will conduct 2 types of inspections:

- Compliance Inspections which take place on a planned basis using inputs from safety cases or other operational. This will check that licensees are compliant with the LCs.
- Permissioning Inspections are those which take place prior to the ONR granting permission for a commencement of a significant activity.

In all cases the ONR's activities will be proportionate based on the significance of the potential consequences. So the ONR will focus its resources on the more hazardous nuclear activities. As a result of this the ONR will typically be interested in the higher safety case categories.

In a major difference to other countries nuclear regulators, in particular, the US Nuclear Regulatory Commission (NRC) there is no list of rules to follow instead the ONR publishes the ONR Handbook containing the 36 LCs, a set of Safety Assessment Principles and a suite of supporting Technical Assessment Guides (TAGs). The licensees are then inspected against these by the ONR using the Technical Inspection Guides (TIGs) to inform the outcome of the inspection. These guidance documents contain no definitive rules as such, instead they use terms such as appropriate, proportionate and reasonable and require the licensee to justify to the ONR through a safety case that these are adequate.

Should a licensee not meet the requirements then the ONR can pursue enforcement action. This typically goes through several escalation stages including an improvement notice and ultimately enforcement action. If a commissioning manager is in receipt of or at risk of receiving any improvement or enforcement notices special focus should be placed on their resolution. Where necessary extra resources or additional support from other licensee departments should be engaged. In all instances a proactive and transparent response to the notice or risk of notice is strongly advised.

The commissioning manager should be aware of the project's communication or regulator engagement plan to ensure that the projects are discussed with the ONR on a regular basis. For those licensees with a large portfolio of projects in or approaching commissioning then it would be considered best practice to engage the ONR on a regular basis either every quarter or half year to discuss these projects.

In all cases the commissioning manager should engage with the ONR on a proactive, open and honest basis. There should be 'no surprises'.

b. Environmental Regulator

The protection of the environment is a devolved activity so the following environmental regulators have authority:

- England – Environment Agency
- Wales – Natural Resources Wales

- SEPA – Scottish Environment Protection Agency
- Northern Ireland - Northern Ireland Environment Agency

Whilst each of these regulators will have their own processes and methods they are all responsible for the issue of discharge permits, monitoring compliance against these permits and working with licensees to reduce their impact on the environment.

The environmental regulator has enforcement authority over the licensee if there is a breach in the permit arrangements. In such circumstances impacting commissioning the commissioning manger should proactively engage with the regulator to resolve the issue prior to further escalation.

In the early stages of a project the project manager should consider the environmental impact and the requirements to submit a permit application. The commissioning manager should ensure that they understand their obligations under any environmental impact assessment or permit held. A proactive communication with the regulator either by the commissioning manager or via the project manager should be encouraged.

c. Licensee Executive

The licensee's executive will have many interests. They will typically be the holder of the nuclear site license and environmental permits so they will have these compliance drivers. At a lesser level they will also have consideration of the licensee's brand reputation which will be damaged by adverse media interest in incidents on site even if they do not attract regulator interest.

From a shareholder perspective the executive is responsible for the generation of profit and maintenance of the assets. To this end the executive will ensure that the money is spent on projects providing the best return where the definition of return is not limited to financial. As a result the executive will be keen to see completion of the project to time, cost, quality, safety, environmental and security standards. As the last project phase commissioning will therefore be a focus to achieve completion, stop the spend and start operations where the project benefit can be realised. The licensee's project management arrangements will require an initial benefit analysis prior to project initiation. The commissioning manager should be familiar with the project benefit as this should be demonstrated as part of commissioning.

Positive news such as reaching significant milestones or clearing project hold points provide easy demonstration of progress by the Executives to the shareholder, other stakeholders and interested parties. Where projects are behind schedule the Executive will typically increase focus and resources as well as the organisation on achieving key milestones in the project. This milestone chasing is always at the detriment of the project as the other project work is neglected unless the milestones are chosen very carefully. Typical error traps include bringing systems, rooms or buildings into active testing which increases the effort to perform work either remedial construction activities, commissioning or maintenance activities. This increased effort to perform work is caused by:

- increased access restrictions (radiation and security barriers, security clearances etc.).
- additional documentation to perform work as moving from construction permit to work system to a commissioning or operations system.
- The operations work management arrangements will apply a longer timescale to get work into the field slowing down maintenance, rectification and commissioning activities.
- the plant modification process moving from LC 19 (modification to design of plant under construction) to LC 22 (modification or experiment on existing plant).

d. Local Community

For new nuclear facilities where there is an approved Development Consent Order there will be a list of conditions and requirements attached which may impact commissioning. For other projects there may be a local planning application which will include a list of conditions and requirements. These will typically be based around the project impact on the local community.

The commissioning manager should understand and have planned any requirements placed on the project by the Development Consent Order or other planning application.

Where the projects include the construction of new nuclear facilities either a power station, intermediate waste storage or long term waste store such as the Geological Disposal Facility the impact on the local community should be understood. Whether there is support or hostility to a project will also depend on the lengthening of nuclear operations and the legacy of waste storage. This support or hostility will drive the level of local press interest in the project.

e. Engineering

For this manual, engineering is deemed to be the designer for the project. This could be a licensee department supported by a contractor. Regardless of the contracting basis engineering will aim for a perfect design which is almost always not be required. Towards the end of the design phase the commissioning manager should expect a large number of design change requests from the following sources:

- Design reviews. Significant comments made during a design review warrant a significant number of design changes which can come from a range of sources:
    - non-conformance with the required design standards,
    - poor understanding of how the system will be operated in reality resulting from commissioning, maintenance or operations comments.
    - the realisation that adjoining systems will not interface correctly
    - licensee comments increasing the scope or complexity due to personal preference. These are usual defined as ‘it would be good to have’.
- Performance or design improvements identified during the design review. This can often lead to significant design changes; these are often classified as opportunities. However, a late design change will have significant impact both cost and schedule to construction, commissioning and operations. This impact is often not understood or assessed by the design or project change board.
- Construction work. This is where clashes or other interfacing issues are discovered during construction which results in a field design change request.
- Operations review. Since operations are by their position in the project phasing the last team to mobilise they often do not have the opportunity to influence the design at the early stages and therefore miss out or are not resourced to perform an adequate operations review of the design. Typical omissions, particularly when a contractor performs the design is the application of mechanical and electrical safety rules.

The engineering team will continue to conduct design work until they believe that the design is perfect.

f. Design Authority

The Design Authority are the owners of the safety, environmental and security cases and therefore will ensure that the design is compliant against the claims in the cases. They will perform various assessments including the following:

- Internal and external hazards,
- Probabilistic Safety Assessment (PSA).

The output from these assessments may trigger a design change to ensure that the design remains ALARP.

The Design Authority's driver is to ensure that the various cases are suitably robust for presenting to the Nuclear Safety Committee and equivalent environmental and security committees and the regulators for the more significant projects. As a result the Design Authority will have a tendency to ask for significant or possibly disproportionate amount of evidence to support their cases.

The commissioning manager should understand the inputs necessary for the various cases and challenge the requirements where appropriate.

g. Construction

The drivers for construction will depend on the contracting or more importantly the payment mechanism. Typically, construction is paid on a time and materials basis with a benefit to install bulk materials rapidly. This leads to long pipe and cable runs being installed at the detriment of the more time consuming, fiddly completion and rectification activities. Also the construction contractor will focus on rooms and areas and not systems as required by commissioning.

To overcome this the construction manager should establish response teams (sometimes referred to as fix-it-now or tiger teams) to perform the completion activities and any snagging items.

h. Operations

Operations as the ultimate customer of the project will set a high bar in their requirements for the project, in particular the records provided and data stored correctly. Their previous experience on aging plant will drive their requirement to have access to lifetime records to justify future operations. They will strive to ensure that all documents, including design information, operating and maintenance manuals and other information is stored in the records system in a manner in which it can be easily retrieved.

Operations will have a separate budget to the project and commissioning budgets and the operations budget will also be accounted for differently as operating not capital expenditure. The operation budget will include routine maintenance and a provision for defect rectification so it will not include a budget to complete rectification of outstanding issues from a project. This will drive operations to only accept a perfect plant.

Operations typically will also require training and to have completed all the necessary competency assessments (Duly and Senior Authorised Persons etc.) before being able to take over the new plant. This will also require that the design and operating documentation has been updated.

i. Maintenance

As with the operations department the maintenance budget is unlikely to hold provision for any outstanding defects or issues from the project. Maintenance will be looking to ensure that the routine maintenance is up to date and recorded correctly. They will not take a handover and then have to perform a substantial amount of routine maintenance to satisfy regulations et PUWER, LOLER, PSSR etc. shortly after the handover.

Also they will look at the point at which routine maintenance will need to be conducted to ensure it aligns with the operations schedule. Therefore, a significant amount of routine maintenance may need to be conducted again to align component and test expiry dates with the operations schedule.

It is at this handover that gaps in maintenance or the records provided are likely to be highlighted. This is significant schedule risk to the project as a lack of records or maintenance will need to be justified and in worst case the component replaced.

5. Assessment, Oversight and Continuous Improvement

Author: Mark Gargaro

In the field of nuclear commissioning, compliance with LC 21 is the first requirement. It is the duty of the nuclear commissioning team to provide assurance of compliance to the licensee or their agent and ultimately, to demonstrate it to the Regulator. In order to demonstrate a compliant process, it is first necessary to monitor, measure and assess it against the clauses stipulated within the Licence Condition and compliance statement.

By employing a set of pre-determined metrics, measurements of how well commissioning responsibilities are being discharged can be made and the results used to understand how effectively Licence condition compliance is being met. Furthermore, these results can be used to underpin any corrective actions and subsequently drive continuous improvement.

It is important to understand that LC 21 is related to and underpinned by other Licence conditions which will need to be taken into consideration when monitoring and assessing the commissioning process. Other Licence Conditions to consider are:

- LC 6 - Documents, records, authorities and certificates
- LC 10 – Training
- LC 12 – Duly Authorised and other Suitably Qualified and Experienced Persons
- LC 14 – Safety Documentation
- LC 19 – Construction and Installation of New Plant
- LC 20 – Modification to Design of Plant under Construction
- LC 22 – Modification or Experiment on Existing Plant
- LC 24 – Operating Instructions
- LC 27 – Safety Mechanisms, Devices and Circuits
- LC 28 – Examination, Maintenance and Testing
- LC 35 - Decommissioning
- LC 36 – Organisational Capability

Identifying LC 21 dependencies and assessing their impact on the commissioning process could prove to be a difficult exercise given their number and complexity; however, if the process is to be better informed, consistent and robust, the assessment should incorporate these interdependencies.

The commissioning manager is an appointed role on the nuclear baseline and responsible for ensuring compliance with the arrangements on behalf of the licensee. The commissioning manager shall further ensure that all persons delivering commissioning activities are doing so safely and that their activities are inline and supportive of the Licence Condition.

a. Assessment of Commissioning Activities

Initially the risks that threaten the commissioning process need to be identified along with any mitigation or corrective measures that have put into place. How effectively the risks are being managed will need to be understood; the risks can be broadly categorised as follows:

- People,
- Planning,
- Process.

Organisational documentation, as informed by the arrangements, may typically consist of a commissioning arrangements, strategy and plans and these define how commissioning activities will be delivered effectively and safely. This documentation will be subject to a review and approval process to ensure it is suitable and sufficient to meet compliance. Similarly, the practical execution of written test instructions should be subject to monitoring and assessment since this is, potentially, an opportunity for poor practice.

The table 1 below presents some examples of risks that may threaten to undermine compliance with LC 21 and also details ways of mitigating these risks and assessing the effectiveness of the controls.

Risk	Issue	Shortfall	Mitigation	Means of Monitoring
People	Competency	Skill set mismatch	Completing and recording competency assessments	Internal audit
People	Behaviour	Due process not followed	Commissioning arrangements. Mandatory training	Planned and unplanned checks of commissioning activities
Planning	Timescales	Insufficient commissioning time.	Programme developed with reference to commissioning plans	Review commissioning performance against plan
Planning	Resource	Mismatch of type and/or quantity resource	Forward load against resource planning	Review workload to update resource requirement
Process	Test Anomalies / Observations	Outstanding commissioning reservations at Handover	Procedural control through Handover protocol	Internal / external audit

Risk	Issue	Shortfall	Mitigation	Means of Monitoring
Process	Safety	Failure to prove adequacy of safety systems	Commissioning documentation developed in accordance with a safety commissioning schedule (scs)	Review of test reports by T&CP against scs
Process (Documentation)	Quality	Insufficient / inadequate testing	Documentation is compiled by a SQEP resource and is subject to review and approval	Review of test reports by T&CP against requirements
People (Documentation)	Approval	Unapproved documents in use	A document approval process in place	Internal audit
People (Governance)	Stakeholders	Insufficient engagement	A quorate group required to review and approve commissioning documentation	Internal audit
Process (Governance)	Regulator	Poor engagement with Regulator	Existing regulatory framework that allows timely submission of documents to Regulator	Internal audit / internal regulator

Table 1: Threats to compliance with LC 21

b. Independent Oversight

Clearly, a robust and compliant commissioning process is essential, not only to provide assurances to the Regulator and licensee but to ensure the delivery of safe and effective, plant, equipment and facilities that meet their design intent. Whilst it is important that the commissioning department monitors and assesses their compliance against a known process, a true measure of how effective commissioning responsibilities are discharged will be achieved by an independent body.

Independent assessment will typically be carried out by the following groups:

- Internal stakeholder or customer,
- Internal regulator,
- External customer or appointed representative,
- External regulator.

High level commissioning documentation such as the strategy offer the assessor an overview of the commissioning process as well as allowing assessments to be made of what is stated within the arrangements and the practical implementation of the process. It might also invite comparisons with

best industry practice. Ultimately, a review of commissioning arrangements will expose the full suite of documentation that may include but not be limited to:

- Commissioning procedures,
- Test specifications and instructions,
- Test anomalies, observations and non-conformances,
- Test reports,
- Commissioning SQEP records.

An assessment of the suitability and use of documentation should be supported by an examination of working practices to properly determine compliance.

c. Continuous Improvement

Through the assessment process, the available feedback from either internal and external interventions or inspections will indicate how effectively license condition compliance is being achieved. Those responsible for leading the commissioning entity must determine the present strengths and weaknesses and provide the means of maintaining compliance through driving improvements where needed.

A set of metrics can be usefully employed to measure performance and compare against benchmarks to drive compliance through continuous improvement through active monitoring and assessment. For example, typical benchmarks could include:

- (People) – 100% completion of mandatory training,
- (Documentation) – No major non-conformances,
- (Process) – 100% completion (by due date) of commissioning test anomalies, observations and other non-conformances.

Through robust and meaningful surveillance activities, performance levels within the commissioning function can be understood and managed where necessary thus helping to ensure compliance with LC 21 and industry best practice.

Part 3 - People and Culture

Part 3 - People and Culture

The scope of commissioning is to test the plant installed or altered by the project, therefore the dominant aspect of commissioning are the people to manage, perform and support testing. The challenge is to ensure that the people engaged on the commissioning phase of projects are available when we need them and with the right experience and skills. This challenge does not stop with them arriving on site but as licensees we need to develop and train this highly mobile and international population in our requirements, standards, expectations and nuclear culture. The ability to ramp up a large group of people, get them delivering effectively as a newly formed cohesive team to achieve our requirements is key to the success of commissioning. This part sets out the best practice from a UK point of view.

1. Resource Planning

Author: Sam Billington

The key to a successful commissioning phase is to have the correct resources available at the right time along with the appropriate training, experience and appointments to meet project requirements.

a. Total head count

For a large new nuclear power station a commissioning team could be as many as 600 people and therefore having adequate plans in place for the recruitment, on-boarding, training and appointing is essential. Since a significant proportion (if not the majority) of the commissioning costs are the people it is essential to generate a resource profile early in the project to accurately estimate the requirement using the following parameters:

- Duration of engagement,
- Grades (and therefore salary / day rates),
- Skill sets,
- Head count.

To assist in the development of a detailed resource profile benchmarking should be conducted. For new nuclear power stations this should involve visits to other projects to better understand their organisations structure, skills sets and numbers. For nuclear facilities with limited comparable projects then previous resource profiles should be used or an estimate generated by a comparison of the number of similar systems for example:

- Building services systems,
- HVAC systems,
- Glove boxes,
- Cranes.
- Electrical distribution switchboards.

Benchmarking other sites and projects has its challenges in the interpretation of headcount. Each organisation has a different scope for commissioning which is based on local working practices and project contract strategies. For example, does the headcount provided by another site include the following:

- Project / commissioning management,

- Operations,
- Maintenance,
- Work Management and Permit for Work etc.,
- Handover,
- Recruitment, on-boarding and training,
- Contractor personnel based on scope of contractor scope of work in commissioning.

Care should also be taken to determine if other departments have 'free issued' personnel to commissioning to gain experience or to perform non-core commissioning activities and therefore these persons are not included in the organisation charts and resource profiles provided.

b. Source of resources

Finding the best and most knowledgeable personnel to perform commissioning is always a challenge. This section highlights some of the key sources of personnel and their advantages.

i. Licensee's Commissioning team

The licensee's own commissioning team should always be the first option for commissioning. Typically, they should fill the key leadership positions within a commissioning team. They will provide sound leadership and direction to those brought into the commissioning team. The benefits are as follows:

- Knowledge of site and management arrangements.
- Will hold the necessary qualifications and appointments so reducing the training burden.
- Know how to get things done on site by knowing the key persons and teams on which commissioning depends.
- Knowledge of systems (including limitations) which are supplied to the project site.
- Ability to set expectations and contract requirements in line with their management system.
- Have access to LFE from previous site projects.

The following downside to the licensee's commissioning teams are:

- They lack experience on complex or specialist equipment.
- May be ingrained in the corporate way and unaware / reluctant to try new methods.

ii. Licensee's Operations Team

ONR SAP 196(d) states that commissioning should:

> *Familiarise the operators with the operation of the facility or process.*

Therefore, there is an expectation that the future operations personnel are engaged in the commissioning activities. They may be used as operators in the true meaning (i.e. as control room operators or plant technicians) or they could be used to support commissioning tests and gain experience through testing of components, systems or the plant as a whole. This experience will be beneficial in the future operation of the plant as many of the commissioning tests are only performed once and therefore an understanding of the plant's response is gained. Experience in the operation of the plant will also be considered favourably in the assessment of competence of the operators as part of their qualifications, assessment and ultimate appointment.

Operations personnel also usually hold key appointments relating to plant isolation and operation ie authorised person(s) which are useful to commissioning as the time taken to be successfully

appointed can be several months. Having these competencies within and available to the commissioning team will provide for a more efficient commissioning phase.

iii. Licensee's Work Management team

Under licence onditions and CDM Regulations the control of the project site will remain with the licensee but the management of the project site may be transferred to a contractor. This is particularly true when the project is being operated in an EPCC or EPC model. In this case the authority to issue permits for work will rest with the contractor and not the licensee. So the commissioning manager should have a clear understanding of which entity is managing the project site and therefore which work management and permit for work process will be inforce at any time.

The licensee's work management team will have a sound understanding of the limitations of interfacing systems (for example, site steam, demineralised water etc.) and when these can be used by commissioning. They will also understand the future plan of maintenance activities which may affect services to the project site. Personnel who are part of the licensee's work management team will typically require a series of qualifications prior to being appointed to these posts. In this situation it is best that commissioning draw upon the work management team for support.

A third model is that commissioning control work management within a pre-agreed project boundary. In this case commissioning may be required to establish their own work management team. Due to the specialist nature of the personnel required they should be sourced from within the existing operations team.

Regardless of the model chosen commissioning should have a clear understanding of who is providing work management and permit for work activities and when the transition from construction to commissioning and then to operational arrangements takes place. If there is to be a commissioning work management and permit for work team then there should be a clear understanding of where the resource to perform these activities is to be sourced.

iv. Licensee's Maintenance team

The maintenance strategy for the project will typically have been defined at a project level and established through the scope of equipment supply and construction contracts. There are several options:

- Construction contractor / OEM continues to conduct routine and preventative maintenance on equipment supplied until handover at the end of the project.
- Construction contractor / OEM's scope of maintenance ends at the end of construction. There are therefore 2 options:
    - Maintenance scope becomes part of commissioning,
    - Maintenance scope is handed over the licensee's maintenance team.

The performance of maintenance during operation is a long term requirement and therefore the best practice position is that the licensee's maintenance team take over responsibility for maintenance from the construction team. To permit a good knowledge transfer it is suggested that the OEM's maintenance contract is extended to support the maintenance team and enable knowledge transfer. This has the added benefit of ensuring no double handling of maintenance records from contractor to commissioning and then to maintenance. This also ensures that maintenance receive the records they require from the contractor before the contractor demobilises.

Commissioning should be aware of the maintenance strategy and when transition from construction takes place and which team will perform maintenance until the facility is in operation.

v. Contract partner organisations

The ability to flex a skilled workforce along a resource curve or for the peaks and troughs of a portfolio of commissioning projects lends itself to a long term relationship with a contractor. These contractor(s) could either provide seconded personnel to embed within the licensee's organisation or provide personnel on a temporary basis to meet an expected peak in resource demand.

In each case there are significant benefits to developing a long term relationship with a contractor as they should aim to provide the same management and supervisory team on a succession of projects. The licensee's challenge with engaging a contractor is often a poor communication of requirements and expectations coupled with contractor personnel who are not aware of the requirements or behaviours necessary. By retaining or re-engaging a known contractor (not just the contract company but also the personnel) provides many opportunities:

- Development of experience of working with the licensee,
- Understanding of the requirements and behaviours,
- Reduced training burden as qualifications remain valid from previous projects,
- Retained understanding of how to get work done.

For long term embedded contractors then the licensee should give consideration to training and assessing them to become authorised persons, in particular with authorisation to isolate, reinstate and operate systems and components under commissioning's control.

vi. Similar licensee organisations (inbound secondments)

For large projects, for example new nuclear power stations, the developing licensee may choose to partner with another licensee. This provides many opportunities, in particular to access:

- established training material,
- personnel with appropriate nuclear culture and behaviours,
- knowledgeable operators, maintainers, engineers etc.,
- already worked out commissioning arrangements,
- contract requirements which have already been repeatedly used,
- learning from experience,
- experienced commissioning personnel,
- experienced persons who have been through similar projects and simply just know where to look for issues.

In certain situations, a partnership with another licensee would provide cross training opportunities in the new project and also allow the partner to deploy experienced, developing and new intake personnel to the project. This could therefore help develop their own personnel's experience and competence ready for their return after project completion.

vii. Similar licensee organisations (outbound secondments)

For a licensee who is trying to ramp up a large organisation consideration should be given to 'building your own' commissioning capability. The challenge is that there are not many commissioning engineers in the marketplace and even less available. Therefore, part of a resourcing strategy may be to hire junior engineers and train them to become commissioning engineers. In

such instances links to licensees with a pipeline of commissioning projects is invaluable as an opportunity to develop hands on commissioning experience on a licensed site.

This best works with a period of development with the employer and covering various aspects of commissioning before the secondment commences. The best practice is considered as a 12-month period with a licensee and working on a project preparing for commissioning and also in the system, integrated or active testing stages. The aim should be for the secondee to understand the following:

- Stages of commissioning,
- Planning of work in the field,
- Permit for work arrangements,
- Preparation, approval and conduct of test procedures,
- Witness testing such as FATs and SATs,
- Quality Assurance and life time record requirements,
- Importance of personal relationships in getting work done,
- Management and leadership of contractors and trade personnel.

viii. OEM organisations

The experience of the Original Equipment Manufacturer (OEM) personnel should not be underestimated as they will have witnessed a range of significant issues on many different client sites. The challenge for a licensee is to ensure that the OEM's personnel are available in a timely manner and have sufficient reach back to their organisations to resolve issues rapidly.

For FATs the licensee should ensure that these tests are witnessed by both an appointed commissioning person but also an operator and / or maintainer who will ultimately be responsible for the equipment. Whilst FATs are conducted in the OEM's facilities it is typical that the licensee should be looking over the shoulder of the OEM's personnel. Depending on the scope of the OEM's contract the licensee should aim to conduct SATs themselves with hands off support from the OEM's personnel. This support may also be necessary in system testing as the equipment will need to be set to work and operated as a system for the first time. The knowledge of the performance of the equipment once it becomes part of a system is vital for the commissioning and operation teams to understand.

c. Phasing of resourcing activities

The following section is broken down into the different phases of commissioning as described in Part 1 above. Whilst many licensees will already have well established content and deliverables for each stage of commissioning a possible route map is described in the following sub-sections.

i. Development of Commissioning

In this phase the commissioning manager should establish a clear set of interfaces and dependencies with other teams at a high level. Possible teams are as follows:

- Security,
- Regulatory affairs,
- Design Authority,
- Engineering,
- Operations,
- Maintenance,
- Training.

A full understanding of the interfaces and dependencies will allow commissioning to understand the scope of what is to be provided by commissioning and by others and therefore allows commissioning to understand the roles, functions, activities and deliverables it needs to provide.

Benchmarking or a desk based research or comparison activity to understand the size of the commissioning effort should be undertaken at this point. Comparisons could be based by comparing the new facilities systems and their position on the graded application.

With early engagement from commissioning the contracting strategy can be shaped but with a later engagement of commissioning the strategy will already have been established. At this point of a project the high level boundary of commissioning's scope should be clear. So the performance and witnessing of the following phases will have been defined:

- Factory Acceptance Testing,
- Site Acceptance Testing,
- System Testing,
- Integrated Testing,
- Active Testing.

At this point the commissioning team should have an understanding of how they plan to deliver commissioning so the following questions should be able to be answered at a high level:

- Are the existing commissioning arrangements going to be used? Or do project specific arrangements need to be developed and approved?
- The divisions of responsibility between commissioning and other key teams.
- The contracting strategy for commissioning.

Once these have been understood along with the anticipated project timescales a detailed resource plan can be constructed. This should be established in a profile form using:

- Expected grade bands,
- Benchmarked or agreed hourly / daily rates,
- Headcount based on benchmarked or previous comparable projects,
- Durations of commissioning activities.

ii. Preparation for Commissioning

Typically this stage will overlap with the project design stage and therefore the contracting strategy will have been agreed. This should then be used to inform any revision to the resource plan described earlier.

In this phase typically more experienced resources are deployed to ensure that any project specific arrangements and contract requirements are clearly established and communicated. These activities may well trigger nuclear baseline requirements and may be required to be conducted by an appointed commissioning person as defined in LC 21(5). Smaller and less nuclear, environmental or security significant projects may provide an opportunity to develop less experienced commissioning personnel in these areas under the guidance of a suitable mentor.

Where a significant peak is expected or an influx of new personnel there should be a plan for the development of less experienced personnel. This should be proactive and involve them undertaking activities which would lead to demonstrable competence and appointment under LC 21(5). The aim is to develop them towards senior commissioning engineers ready to develop / mentor new entries which arrive at a later date.

iii. Factory Acceptance Testing

The importance of licensee involvement in FATs cannot be underestimated. This is an opportunity for those personnel who are planned to perform commissioning on the related system(s) to start to learn the equipment and some of the behaviours in the factory whilst working alongside experienced personnel. Consideration should also be given to technicians and craft personnel attending FATs as their learning opportunity will be different from commissioning engineers.

The commissioning manager should therefore ensure that those who are expected to work on the system are assigned to witness the FATs. These commissioning engineers should also be able (if not appointed) to witness tests so that credit can be claimed at a later stage. With a protracted period of time in the factory the commissioning engineer should also focus on the lifetime records being generated both from manufacturing and testing. Any uncertainties or anomalies should be resolved at this point supported by the licensee's quality and or supply chain teams to ensure that all appropriate lifetime records are being complied for submission prior to factory release being granted.

The commissioning manager should therefore understand and plan for the resources necessary to participate in FATs and where necessary factory release. This may require the support of other departments and also the qualification of commissioning personnel to participate in FATs.

iv. Site Acceptance, Component, System and Integrated Testing

This is the period of time that the main testing will occur on site and therefore of the most interest for resource planning. The exact profile and skill set will depend on the contract strategy and roles / activities to be performed by (or paid for by) commissioning.

The resource profile should take cognisance of the stages of commissioning to be witnessed and those to be performed by the licensee. Activities will include the following:

- Preparation and approval or acceptance of test documentation.
- Preparation and approval or acceptance of test reports.
- Resolution (or management of) test anomalies or observations.
- Performance of testing by the licensee.
- Witnessing of testing performed by the contractor(s) by the licensee.
- Management of commissioning activities using a Commissioning Command Centre.

Other non-core commissioning activities which will be required by commissioning but may be paid for by commissioning are:

- Work management and permit for work office,
- Planning and performance of maintenance,
- Stores and spares management including goods inwards inspections,
- Training of operations and maintenance personnel.

v. Handover from Construction

The commissioning manager should recognise that the handover from construction to commissioning is one of the key barriers in ensuring that the project is a success. Therefore, the commissioning manager needs to ensure that adequate experience and focus is placed on the receipt of SSCs from construction. The resources used need to be cognisant of:

- Typical construction issues, anomalies, errors etc.

- An inquisitive mind set coupled with 'that does not look right'.
- Quality assurance / document checking for handover packs.
- A clear understanding of what the handover to operations requires to ensure that there are no shortfalls at this stage.
- Understanding the needs of the commissioning tests to reduce remedial work before testing can commence.

The type of resources best able to perform this may not be the typical commissioning engineer although a commissioning engineer's input will be required. In developing the resource estimate the commissioning manager should therefore consider how best to police the standard or work and records at this gate.

vi. Active Testing

With the introduction of radioactive fuel or process material the risk increases significantly for the licensee, project and commissioning. This risk is mitigated by increased checks and controls, procedures, training, experience and oversight.

When planning for this phase the commissioning manager should consider whether to retain the personnel used for systems testing or use a more experienced team supplemented by key persons from systems testing. The benefits of retaining system testing personnel is their experience developed during FATs and system testing but with the downside of not understanding nuclear requirements and behaviours.

When considering the resource estimate the commissioning manager should understand the business driver or constraints for the project and plan accordingly. Typically, there will only be 1 work front available during active testing so the main resourcing decision is the shift working pattern to be adopted.

vii. Handover to Operations

Depending on the project strategy this may be before or after active testing but the challenge of passing through this gate should not be underestimated. The resource knowledge and experience should be similar to that of handover from construction as it should be used to provide the commissioning manager with assurance that the work performed has been completed in accordance with the licensee's requirements.

The commissioning manager may opt to call upon the licensee's quality assurance team for a project level audit to check not only the records and readiness to handover to operations but also that the project has been conducted in accordance with the licensee's arrangements.

2. Training

Authors: Adam Daszkiewicz & Dave Brophy

a. Broad Training Requirements

Commissioning skills will form part of a wider skills matrix covering all licensee activities and the training required for commissioning will be closely linked to the licensee's other training programmes. For example, a commissioning engineer on a power station will be required to undertake systems engineering training which will be similar in many respects to that taken by operators and site engineers. Another example would be commissioning technician apprentices will

have completed the licensee's generic apprentice programme building on externally achieved qualifications such as GCSEs, HNCs etc.

The licensee's training and Human Resources team will perform assessments of the post profiles using tools such as Willis Towers Watson Skills Mapping to identify common skills as part of a post profile rationalisation programme. The aim of this mapping it to ensure cross business consistency of skills, expertise and qualifications for equal grades in similar roles.

b. Commissioning Specific Training Required

There should be a detailed analysis of the of the skills and knowledge required for those conducting commissioning and handover activities. Training should then be developed and provided to all personnel carrying out these activities to close any gaps in their knowledge. The training shall provide an in depth understanding of the following subject areas:

- Commissioning requirements
- Licence Conditions:
  - LC 21 - Commissioning
  - LC 6 – Documents, records, authorities and certificates
- The Competency Assessment process in relation to commissioning.
- The stages of commissioning and handover
- The role and purpose of the Test & Commissioning Panel.
- Commissioning arrangements
- Handover arrangements

The training shall be provided with examples and provide a clear, contextual understanding of how commissioning and handover activities are expected to be carried out across the business.

The training in question is also recommended for any project managers, site engineers or other individuals with projects or processes involving or interacting with commissioning and handover activities.

It should be noted that completion of the training alone does not render a person competent to carry out commissioning and handover activities as this is assessed via the licensee's competency assessment process.

c. Outline of Site-Specific Commissioning Courses

The following training may be required for commissioning engineers depending on the specific needs and considerations of their work location and tasking:

- Radiation classified worker training,
- Barrier procedure training,
- Radiological and criticality awareness training,
- Emergency evacuation training,
- Any further training requirements as determined by risk assessments or permit for work requirements.

d. Team Building

Regular team building events can be a very effective means of developing working relationships, encouraging cooperation and participation, boosting morale and consequently improving productivity, efficiency and effectiveness across the department.

Typical examples of team building events may include:

- The UK Team Challenge (www.ukchallenge.co.uk),
- Participation in events run by Professional Institutions.
- Department organised away days.
- Other locally run activities.

It is highly recommended that these events take place away from the normal working environment. Team building exercises do not necessarily have to tie directly into commissioning, as long as they achieve the required development goals.

e. Team Briefings

These are different to team building events as they are targeted at updating a whole team on a range of issues and identifying opportunity for improvements. These should be held off-site either once or twice a year and have clearly defined aims and agenda. They are particularly useful when:

- a team is rapidly expanding or is in different locations.
- team performance is not at the desired levels.
- there are significant organisation changes being implemented.
- significant changes to the management system or arrangements or IT tools etc.

These all team briefings can cover a range of topics such as:

- Annual business plans – company and department levels.
- Mid year progress reviews against plans.
- Forward work plans for teams.
- Updates or refreshers on management arrangements or other tools.
- Part of a forming and norming of a new project team.
- Gather suggestions from the team on what we could do better and what we are doing well.
- Develop improvement action plans.

Managers should also consider opportunities for team members' personal development in either leading a task or presenting.

3. Suitably Qualified and Experienced Persons

Author: Anthony Macey

a. What is competence?

Competence can be defined by the IAEA as: the combination of knowledge, skills and attitudes (KSAs) needed by a person to perform a particular activity. All three are important and interrelate.

- Knowledge is familiarity with something and can include facts, descriptions and information acquired through experience or education. It can refer to both the theoretical and the practical understanding of a subject.
- Skill is the learned capacity to perform a task to a specified standard.
- Attitude is the feelings, opinions, ways of thinking, perceptions, values, behaviour and interests of an individual which allow an activity or task to be undertaken to the best ability of that individual. Attitudes cannot wholly be taught directly and are partly a consequence of the organisational culture.

Competence can therefore broadly be equated to SQEP (Suitably Qualified and Experienced Person) as required by LC 12 (duly authorised and other suitably qualified and experienced persons).

b. How do we assess competency?

As new people join the commissioning team, or existing person's roles change, the commissioning manager will manage their training and development to the point at which they are assessed as competent and can be deployed to work independently (i.e. under normal levels of supervision). This process can be different in each case, depending on the individual, their experience, their learning style (and pace), the work (complexity and importance) and how they may fit in with an established team.

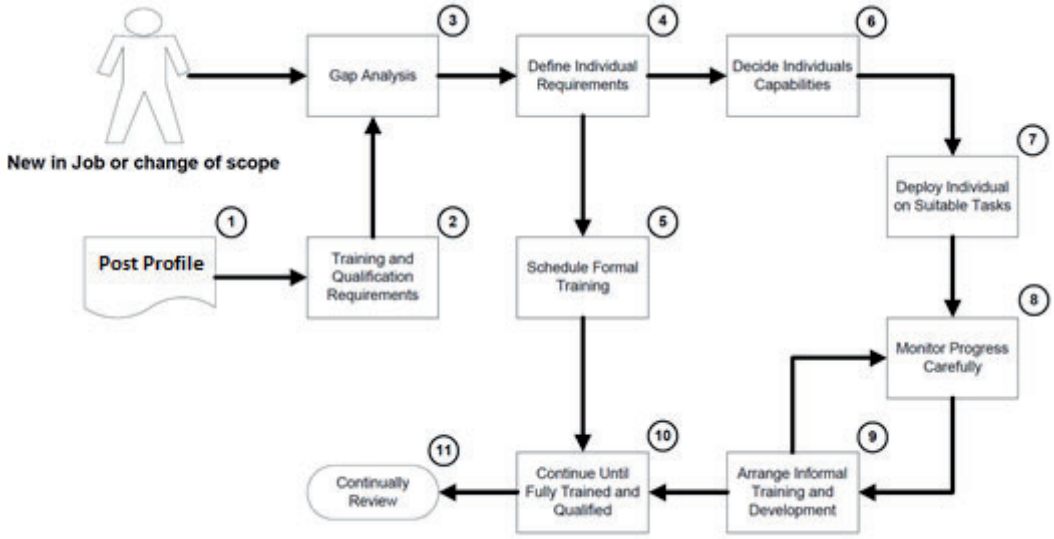

Figure 3: Competency Assessment

The approach taken should be to describe the roles associated with the post, responsibilities, accountabilities and authorisations as stated in post profiles. These cover the activities that each role associated with the post will need to perform. Using the post profile and associated role profiles, analysis will then be carried out to identify the skills and knowledge necessary to fulfil the post requirements and these will form the basis for any training and qualification requirements.

c. Gap Analysis

For each team member, the line manager carries out a 'gap analysis' of the post holder against the post and role profiles to determine what they may already be competent in, what current qualifications they have and what further training and development is required.

This will result in a list of courses or development requirements for an individual to achieve full competence in the post. The required training will need to be booked or arranged locally. It is important that the timing of this is considered so that there are opportunities for the team member to use the new skills and knowledge on return to the workplace. Having decided on the training and competence 'gaps' it must be decided what the individual is capable of in the meantime. Team members can be deployed on activities that they are trained and qualified for under 'normal levels of supervision'. Where an individual is partly trained, they must only be deployed under the supervision of a SQEP. The level of supervision required will be determined by the task (complexity, safety critical, importance, etc.) and a judgement of what the individual is capable of, taking into

account where they are in their training, previous experience, etc. The progress of the individual must be monitored at all times either through direct supervision; observation or discussion with their SQEP'd mentor.

Informal training, coaching and mentoring will continue to be provided and progress regularly discussed.

d. Assessment of competence following training.

On the job training is almost always followed by an assessment to confirm the trainee has met the required learning objectives. When the trainee has been successfully signed off against any given activity, they will be able to be deployed to work independently (or under normal levels of supervision).

For some roles and activities, there are sometimes other methods of ascertaining competence against given standards, e.g. interviews, written exams, task performance using simulators, discussions with Subject Matter Experts (SMEs), completion of mentor guides, etc.

e. Appointments.

On completion of training and assessment appointments must be put in place to authorise or appoint competent / SQEP role holders where there is a legal requirement to do so, or where a role holder carries out specific duties that fall under the requirements of LCs as is the case for commissioning LC 21(5). An appointment is defined as a written endorsement of the satisfactory achievement of qualification of a person to perform a function and includes a detailed description of the duties, scope, the qualifications, method of assessment required and the period for which the appointment is valid.

For commissioning an appointed commissioning person is required to control, witness, record and assess the results of commissioning tests.

The appointment process must be capable of recording new appointments/revocations and changes to the levels of authorisation associated with the SQEP role holder. These records must be retained in line with the LC requirements.

f. Ongoing Assurance

To confirm an individual's ongoing competence, formal reviews should be carried out periodically using an agreed process to assure that individual possess the experience, knowledge, skills and abilities that are necessary to discharge their accountabilities and responsibilities. These reviews should be carried out between the line manager and individual. Any gaps in the individual's skills, knowledge should be addressed through additional training.

g. Record Keeping

Accurate records for each team member must be kept of all completed training, assessments and appointments, these must be retained in accordance with the licensee's records retention policies. The record keeping system must be capable of keeping track of an individual's competency with the ability to add/revoke/modify/renew an individual's appointments. The record keeping system should also be capable of identifying in advance any appointments due to expire.

h. Building the Experience

Providing the right experiences within the workplace as part of an individual's or team's development is one of the most important factors in influencing competency acquisition. An experienced commissioning organisation over time can be achieved through the implementation of strategies tailored either to suit the individuals career stage or in response to gaps identified as part of the competency assessment. These may include the following;

i. Buddies

A buddy system is an on-boarding and knowledge sharing method used to orient new employees. It involves assigning him or her to a workplace buddy. The buddy is an existing employee with recent knowledge and experience of the tasks/role who guides the new employee through the first few weeks or months in post. They can help familiarise and guide the employee through all aspects of the role and can be used to support the individual until they are deemed competent. Buddies are typically of a similar grade and are not part of the new employee's line management chain.

ii. Mentors

Mentoring is a natural way of passing on skills and knowledge to others by someone with experience and specific skills. They can be used to support high flyers, personnel who need help and assistance or people moving into new roles. Mentoring usually takes place over a longer period of time. Mentors tend to be a grade or 2 above the mentee but again not in the mentee's line management chain.

iii. Development action plans

Development action plans are typically raised either on starting a new role or as part of the annual performance review and are used when personnel are:

- New to a particular post and or role(s).
- On the path the be assessed as competent.
- In need of a structured remedial learning pathway.
- Competent in their existing role but need to move towards a higher grade or add extra competencies due to a future planned role.
- Identified as part of a succession plan.

These should identify the following;

- The need i.e. is it a regulatory requirement, current post or role requirement or a career development requirement.
- The Action Plan i.e. how will it be achieved.
- Responsibilities. Who is responsible for the action and what other support you will need.
- Target date for completion.
- Measure of success. How will you know when your development need has been met? What is the level required?
- Review Period.

iv. Employee development groups

Depending on the scale of an organisation the licensee may also put in place employee development groups. The employee development group is set up for the purposes of broadening the skills of the employees across a large commissioning organisation and maximising opportunities.

The Employee Development Group will typically set direction in relation to the following;

- Graduate/Apprentice placement schemes.
- Identification of individuals with potential to progress who would benefit through placements/re-deployments to other departments/teams within the organisation.
- Putting in place a network of mentors and buddies to share their knowledge and experience to help steer inexperienced commissioning personnel through the early stages of their careers or to help existing experienced commissioners progress to take on new challenges or positions of responsibility.
- Work with external companies/organisations to offer opportunities for work experience elsewhere within similar industries.
- Ensuring people identified for progression have the correct attributes skills and training to progress.
- Working with internal/external providers to develop suitable training.
- Screening applicants applying for further education.

v. Commissioning Forums

Commissioning forums bring together managers and leads from across the organisation and can be used to share commissioning experiences, and best practice. They can also be used as a means of building knowledge in the team through the experiences of other knowledgeable individuals that act as SME's in areas of particular interest to the commissioning community (cranes, pressure systems, PUWER etc).

i. Typical Commissioning Posts and Activities

i. Commissioning Manager

Role: The commissioning manager's role is to manage the delivery of a commissioning test programme that confirms design intent against functional acceptance criteria to the customer. The commissioning manager also reviews the commissionability of the design and provides the knowledge, leadership, management and support required to ensure commissioning work is executed to meet company, legal, regulatory and project requirements.

Responsibilities: The commissioning manager is responsible for:

- The delivery of assigned commissioning projects in a safe and timely manner.
- Delivering the commissioning work scope to an agreed strategy and plan in a timely and cost-effective manner.
- Ensuring the relevant risks are identified early and managed/mitigated as appropriate. This includes regular monitoring of any residual risks.
- Ensuring a proactive and balanced approach to safety (nuclear, radiological, conventional and environmental) to ensure that safety is optimised during commissioning.
- Reviewing commissioning progress and performance and taking appropriate corrective actions where necessary.
- Planning, balancing and prioritising commissioning resources to support successful project delivery.
- Managing day to day liaison with personnel to obtain any necessary permissions and minimize impact to the project. Ensuring input to other project processes are incorporated, for example, design, commissionability, HAZOP, risk, contract and estimating, knowledge management etc.
- Ensure the implementation of 'best practice' in commissioning.

- Implement commissioning arrangements in compliance with LC 21.

Accountabilities: The commissioning manager is accountable for:

- The accurate inclusion of the full commissioning work scope within the project baseline.
- Leading and coaching their team to maximise their efficiency and effectiveness to meet or better the project commissioning element baseline cost, schedule and quality requirements.
- Developing and executing effective commissioning strategies and plans in line with the overall project strategies and plans.
- Reporting commissioning progress.
- Identifying commissioning scope of work and assessment criteria in invitations to tender and their subsequent assessments.
- Ensure the commissioning activities are performed in accordance with the approved testing and commissioning program: including meeting cost and schedule commitments, and to provide a reliable product that meets agreed test acceptance and performance criteria.
- Ensuring testing and commissioning meaningfully demonstrates that the installed systems meet functional configuration and performance requirements.
- Assessing, authorising and maintaining the competence (SQEP) of licensee and contractor commissioning resources.
- Ensuring shared best practice and commissioning methods and procedures are used in completing the project commissioning scope.
- Discharging all commissioning management Intelligent Customer duties including the oversight and assurance of contractors engaged in commissioning work.
- Implementation of commissioning arrangements compatible to the capability commissioning 'standard'; ensuring commissioning activities are conducted in accordance with company procedures, policy, legislative, regulatory, environmental, safety and quality requirements.
- Authorise expenditure up to the approved authority limit.
- Appointment of commissioning team members.
- Permit the commencement and cessation of commissioning work.

ii. Lead Commissioning Engineer

Role. The lead commissioning engineer, reporting to the commissioning manager or commissioning team leader, functions as part of a multi-disciplined team for the purpose of carrying out testing and validation activities in line with the commissioning plan.

Responsibilities: The lead commissioning engineer is responsible for:

- Supervision of commissioning engineers, technicians and support resources
- Co-ordination of training activities.
- Managing day to day liaison with personnel to obtain any necessary permissions and minimize impact to the project.
- Ensuring input to other project processes are incorporated, for example, design, HAZOP, risk, contract, estimating and knowledge management.
- Carrying out all testing activities throughout all stages of commissioning.
- Identification of faults and ability to propose and implement solutions.
- Production of test documentation.
- Initiation and implementation of commissioning reservations and observations.
- Witnessing of test activities.
- Recording of supporting data in accordance with test requirements.
- Validation of working level instructions
- Application and removal of temporary commissioning aids.

- Recording of supporting data in accordance with test requirements.

Accountabilities: the lead commissioning engineer is accountable for:

- Leading and coaching team members to maximise their efficiency.
- Reporting of commissioning progress.
- Execution of tests in accordance with written commissioning instructions.
- Commissioning activities performed in accordance with the approved testing and commissioning programme.
- Recording of test results in accordance with commissioning management arrangement and test documentation.

iii. Commissioning Engineer

Role. The commissioning engineer, reporting to the commissioning manager and commissioning team leader functions as part of a multi-disciplined team for the purpose of carrying out testing and validation activities in line with the commissioning plan.

Responsibilities: the Commissioning Engineer is responsible for:

- Carrying out all testing activities throughout all stages of commissioning.
- Identification of faults and ability to propose and implement solutions.
- Production of test documentation.
- Organisation of commissioning technicians and support resources.
- Initiation and implementation of commissioning reservations and observations.
- Witnessing of test activities.
- Validation of working level instructions.
- Application and removal of temporary commissioning aids.
- Recording of supporting data in accordance with test requirements.

Accountabilities: The commissioning engineer is accountable for:

- Execution of tests in accordance with written procedures.
- Commissioning activities performed in accordance with the approved testing and commissioning programme.
- Recording of test results in accordance with commissioning management arrangement and test documentation.

iv. Commissioning Technician

The commissioning technician functions as part of a multi-disciplined team to carry out testing activities, in line with the commissioning standard and support arrangements.

Responsibilities: the commissioning technician is responsible for:

- Carrying out all testing activities throughout all stages of commissioning.
- Highlighting areas of concern or faults/problems via the correct channels.
- To prepare and undertake testing as instructed by the commissioning engineer.
- Implementation of fault solutions using commissioning procedures.
- Application and removal of temporary commissioning aids.

Accountabilities: the commissioning technician is accountable for:

- Execution and recording of testing activities, within their own areas of expertise.

4. Culture

Author: Sam Billington

a. Why do we have and need a nuclear safety culture?

Sadly there have been several significant nuclear events in the world and after each one there has been a thorough investigation and analysis of what went wrong and why it went wrong. Every investigation identified many causes of the event but one of the common causes in every investigation was the culture of the licensee and their personnel. This has led over the past few decades to the idea of a 'nuclear safety culture' and this would now be recognisable across the international nuclear community. What a nuclear safety culture looks like varies slightly from country to country and then from licensee to licensee.

Whilst the drive to develop a nuclear safety culture resulted from the large nuclear events many of the incidents and near misses on UK licensed sites also are as a result of a lapse in the nuclear safety culture. As a result of this each UK licensee understands the need for a nuclear safety culture as a route to ensure nuclear safety and therefore are using this as one of several tools to eliminate events.

b. What is a nuclear safety culture?

This section has been deliberately placed after the training and competence sections as a culture cannot be trained into a person and it is hard to directly measure and assess at a personal level. Training courses can be attended and successfully completed, experience on site and the performance of set tasks under supervision can be completed and competency interviews can be passed. None of these can develop culture as it is a behavioural trait of the person which is difficult to measure.

A formal answer is provided by the World Association of Nuclear Operators (WANO) as:

> *'An organisation's values and behaviours – modelled by its leaders and internalised by its members – that serve to make nuclear safety an overriding priority.'*

c. International standards of Nuclear Safety Culture

WANO are have over the past few decades led the refinement and development of the nuclear safety culture and published their pocket guide entitled 'Traits of a Healthy Nuclear Safety Culture' [7] which is freely available to download.

Reference 7: https://www.wano.info/getmedia/49f169b0-a385-4cd2-a7d8-2f64b64cd8d2/WANO-PL-2013-1-Pocketbook-English.pdf.aspx

WANO clearly state that they will not prescribe the implementation methodology as this must remain with the licensees and at a national level with the regulators. WANO have been able to define what a healthy nuclear safety culture looks like at the licensee level.

This pocket guide breaks down the key factors as stated in the WANO pocket book are:

- An individual's accountability – Their authority and responsibility for nuclear safety is clearly understood. They understand the importance of nuclear safety and demonstrate personal

responsibility. They actively work across team boundaries ensuring nuclear safety is maintained.

- An individual's questioning attitude – They avoid complacency and challenge existing conditions, assumptions, anomalies and activities to identify discrepancies that may result in errors or inappropriate actions.
- Safety Communications – This covers formal and inform communication including job related, worker level communications and equipment labelling, operating experience and documentation.
- Leadership's accountability – Leaders demonstrate a commitment to nuclear safety in their decisions and behaviours. This is established in company policies and commonly communicated and reinforced.
- Leadership's decision making – Decisions that support or affect nuclear safety are systematic, rigorous, thorough and made in a conservative manner. Operators have authority to place the plant into a safe condition and these are supported by Leaders.
- Leadership's success in creating and maintaining a respectful working environment – This starts with trust and respect being established. Differing professional views are encouraged, discussed and resolved in a timely manner with employees being informed.
- A management system which promotes and adapts to continuous learning – Opportunities to continuously learn are valued, sought out and implemented. This includes self-assessments, training and benchmarking are used to stimulate learning and improve performance.
- Proactive identification and resolution of problems – Issues potentially impacting safety are promptly identified, fully evaluated and promptly resolved.
- A working environment which supports the raising of concerns – A working environment is created where personnel are feel free to raise nuclear safety concerns.
- Process of planning, executing and reviewing work performed – Work activities are identified, selected, planned, executed closed and critiqued in a deliberate process.

Further discussion on this important subject is beyond the scope of this manual and the reader is suggested to study reference 7 above for further information.

d. Licensee's implementation of a nuclear safety culture

Licensees will implement and maintain their nuclear safety culture using a series of methods. These will be part of initial training which starts with site inductions and new joiner training courses and then continues through further training and development. A well structured communications programme to employees from the senior leadership reinforces the nuclear safety culture and allows the flow of information to employees. The communication structure allows feedback and concerns to be raised to senior leadership. Licensees will typically seek formal feedback on an annual basis with the use of a survey / polling company managed anonymous questionnaires and employee surveys.

The licensee's management arrangements will clearly and formally delegate authority and responsibilities to various roles. These arrangements will also mandate a corrective action programme which creates a process for capturing, assessing, assigning actions for improvement and tracking them to closure. The input for these corrective actions will come from various sources:

- Events or near misses.
- Quality Assurance audits either non-conformances, observations or commissioning reservations.
- Quality Control inspections.

- Lessons learned and best practice observed elsewhere.

5. Vetting of resources

Author: Sam Billington

One of the challenges of recruitment and on-boarding of commissioning personnel is the requirement to complete pre-employment and vetting checks before access to a site can be granted. There are several levels of security vetting and these are directly linked to the role and/or work being conducted by the individual. The different levels of vetting are described below in ascending order.

The following section is for information only and may change depending on national and/or security requirements. Licensees are responsible for the security of their sites and will therefore keep their arrangements and requirements under constant review so the information in this manual is correct at the time of writing. Also several generalisations have been made to simplify the explanations across several UK licensees and also avoid raising the security classification of this manual.

In all cases contractors should discuss the security requirements with the licensee's security vetting team as early as possible.

a. Baseline Personnel Security Standard (BPSS)

The Baseline Personnel Security Standard (BPSS) is a pre-employment check and is the basis of all other vetting checks. It can take between 1 to 4 weeks to achieve, however this will depend on the circumstances of the applicant and some cases may take longer. Typically, this involves a Disclosure & Barring Service (DBS) Basic check (if you will work in England and Wales) or a Basic Disclosure certificate from Disclosure Scotland if you will work in Scotland. DBS Basic checks and Basic Disclosure certificates can be applied for on line and a certificate issued either to the applicant or the licensee. The licensee will ask for employment references covering three years, evidence of residency / right to work in the UK and as well a check of identification documentation (e.g. passport and driving licence etc.). BPSS level vetting is normally adequate for access to Magnox and EDF Energy sites. Whilst Sellafield accept BPSS this will provide only a limited access so a higher level of clearance may be more appropriate.

Typically, this will allow unescorted access to visit and work in non-sensitive locations on the site.

For an operational nuclear power station, access may not include the buildings and facilities housing the reactor, radioactive waste and important safety and security equipment.

BPSSs are held by the licensee and are only applicable to that licensee, so they cannot be transferred. If a person moves to another licensee, then another BPSS is usually required if there has been a change in both the employing company and the licensee.

b. Counter Terrorism Check (CTC) & Security Check (SC)

Counter Terrorism Check (CTC) and Security Check (SC) clearance are the first two levels of National Security Vetting (NSV) and are only issued by the UK Government or its agencies, armed forces or police. The checks are more stringent and in addition to the Basic Check above, will include checks against Security Service records and financial health checks (SC only) and may require the applicant to be interviewed. Checks are also made against those who you have a relationship with either, spouse, partner or co-habitants and parents. The time frame to achieve a CTC or SC could be 3

months, but may take longer. To be eligible to apply, applicants must have been resident in the UK for a minimum of 3 years (for CTC) or 5 years (for SC).

Most Tier 1 contractors will ensure that their employees who are engaged in nuclear or defence sector work will hold an SC level clearance. This is due to the ability of licensees to accept an existing and in-date NSV for access to their sites, and the ability to transfer NSV clearances between licensees. Contractors should ensure that these transfers are conducted when working with a new licensee.

A CTC or SC will typically allow access to work in and commission general nuclear facilities across operational nuclear power stations and decommissioning sites. This will also allow access to non-sensitive nuclear defence facilities

c. Developed Vetting

Developed Vetting (DV) is the highest level of NSV clearance. In addition to the assessments made during a CTC/SC, face to face interviews will be held with the individual, family, line manager etc. Reviews of an applicant's social media and internet habits may also be conducted.

This level of vetting will normally take at least 6 months to complete. The minimum UK residency requirement to apply for DV clearance is 10 years.

DV clearances may be transferred between licensees, and it is also possible for the CTC or SC elements of the DV to be extracted and transferred to another licensee.

This level of security clearance is typically required to work in highly sensitive nuclear facilities, typically those closely linked with development, maintenance and operation of nuclear weapons and facilities involved weapons grade nuclear materials.

d. International Resources

Over recent times there has been an increase in the number of international companies and personnel working in the UK nuclear supply chain. This is either from the supply of components, nuclear materials including fuel assemblies, research projects or reactor and equipment technologies. This brings with it additional security requirements and challenges to achieving security clearance. The commissioning manager should understand the nationalities involved in commissioning and ensure that plans are in place to ensure appropriate vetting competed in time. For the more challenging technologies and countries this may require UK government approval above that of the ONR and therefore a long time scale.

Licensees and the supply chain should also understand that the transfer of information or data into or out of the UK may be in breach of Export Control restrictions in the UK or the other country. It should also be noted that the technology and data which are subject to Export Control is broader than that covered by the UK security arrangements. In all cases the commissioning manager should check that appropriate permits are in place for the transfer of information and data to and from the licensee and the supply chain and where appropriate between supply chain contractors.

Part 4 - Delivery of Commissioning

Part 4 – Delivery of Commissioning

1. What are we testing?

Author: Sam Billington

The simple and very short answer to this question is only what we need to and as little as possible without affecting safety, security or performance of the plant. The question should be 'does this function if not tested have a negative impact on the performance of the plant?' If the answer is no then delete the test.

To provide a more constructive, informative and longer answer the commissioning manager needs to understand where the requirements originate and then ensure that the source of these requirements is communicated to the commissioning team. In the early stages of a project purely understanding where the requirements are coming from means that communication channels can be established and the format of input to commissioning can be agreed. In the later part of the project a detailed list of requirements needs to be provided and these should be treated as the scope of commissioning testing.

In providing a response to each requirement there needs to be an understanding that testing during commissioning can only provide part of the evidence and the others are:

- detailed theoretical analysis.
- evidence from construction testing.
- evidence from Factory Acceptance Testing.
- First of a kind testing conducted elsewhere.

The requirements for testing come from the following sources:

- Statutory / Regulatory requirements such as but not limited to:
  - LOLER – Lifting Operations and Lifting Equipment Regulations 1998.
  - PSSR - Pressure Systems Safety Regulations 2000.
  - PUWER - Provision and Use of Work Equipment Regulations 1998.
- Design Requirements are driven from:
  - Nuclear safety case and supporting analysis.
  - Security case and supporting analysis.
- Environmental requirements covered under a series of phased permits covering the construction and operational periods and relating to discharges of water, radioactive and non-radioactive substances as well as from combustion.
- Best Available Techniques (BAT) case for ensuring that the technology and methods used are of the lowest reasonable impact to the environment.
- Human Based Safety Claims is where claims are based on the ability of a person(s) to perform an activity correctly and in a set time scale. These are often incorporated directly in the nuclear safety and security cases.
- Planning approval from the Development Consent Order or Town & Country Planning process. Whilst submitted with the various environmental permits the application may include additional commissioning requirements.
- Business Case. This is the original business case for the project in which a defined benefit of conducting the project was identified and agreed. The top line may be a throughput of so many widgets or packages per week or an electrical export of a defined mega-watts to the

National Grid. The cost of operating the facility should also be measured in materials and resources consumed, including water and electrical power.

In addition to these items commissioning is also validating operating and maintenance instructions as well as the licensee's management system and other arrangements.

2. Design Change & Configuration Control Management

Author: Sam Billington

The challenge for the commissioning phase is that this is the first time the design, construction comes together in the same place and in addition the commissioning and operations documentation is available. There is a considerable risk that these 4 work streams have become out of step with each other.

a. Design Change

In small projects or those which have clearly defined design and construction phases design change can be more easily managed. During the design phase there are no construction activities being undertaken so the impact of a design change is the possibility of further schedule delay to the start of construction and the increased design effort. In these cases the commissioning manager should be aware that changes to the design may impact the commissionablity of the new plant. This means that the commissioning manager should have sight of all design changes, the majority of which will not have a detrimental impact and no response should be required.

For large projects the above remains true until around the point construction commences. After which a cultural shift is required which needs to include the impact on both construction and commissioning. The benefits of approving the changes needs to be weighed against significant cost and schedule impact of construction and to a lesser extent commissioning. At around this point the commissioning documentation will be being drafted based on defined test boundaries so changes may impact the handover boundary pack definitions and test documentation.

During later phases in the project changing the design will result in changes to the plant as constructed and require changes to the commissioning documentation. When the project, structure or system is approaching handover to commissioning then the question to be asked is if the plant has been modified in accordance with the approved design change(s).

Once in commissioning any design change will impact construction and commissioning. After approval of the design change the first decision is if construction or commissioning will perform the approved modification and also if the system or structure will be handed back to construction to perform the work. The commissioning and construction managers should ensure that a procedural route allows for this handback. Design changes in this phase are highly disruptive and should be limited to those to make the plant work or to rectify an unsafe design. The cost of a delay to the schedule as well as construction rework and any commissioning retesting should also be included in the impact of the design change. The commissioning manager should be actively involved in the design change process at this point and should receive the support of the project manager to stop or at worst minimise the number of design changes. For large capital projects an option considered may be to delay the implementation of the design modification until during the operating phase.

b. Configuration Control Management

As stated in the previous section the risk to commissioning is the large number of approved design changes. The impact can manifest itself in the following ways:

- Design documentation has not been updated to reflect the latest design changes.
- Approved design changes to structures and systems have not been implemented at the point of handover to commissioning.
- Design has been amended and implemented to the structures and systems but commissioning and operations documentation has not been updated.

The commissioning manager should develop an inquisitive culture that the plant as built may not be aligned with the design and commissioning documentation. A failure to understand and take precautions could result in the following consequences:

- Damage to people and or environment from isolations applied using a mismatched documentation and plant configurations.
- Damage to equipment from commissioning and operating using documentation mismatched from the plant configuration.

As a result there is a real challenge to keep all the documentation up to the same status as the design and plant. It is recommended that there are clearly defined and documented design configurations which include a list of design changes incorporated in the configuration. This will allow all personnel not just engineering to easily check that design changes have been completed.

There also needs to be an information flow from the construction team to say that the change has been implemented on plant.

Commissioning and operations documentation need to clearly identify the design configuration they have been developed against and if they include any additional approved design changes. Where design and construction design documentation is referenced then the revision number of the reference should be stated as well. This allows the commissioning team to ensure that the commissioning documents have been developed using the latest version of design documents.

The challenge for the commissioning manager is at which point to initiate the development of the test instructions as these will be heavily impacted by design changes. High level test descriptions and handover boundary packs are unlikely to change significantly through detailed design phase. To start the test instruction preparation early could lead to multiple revisions and increased effort but leaving the start date too late would put pressure on the commissioning teams to deliver the documentation in a timely manner.

Once in the field the commissioning teams should have the ingrained culture to check their documentation is the latest revision and that the plant is in a configuration as anticipated, i.e. that the design changes have been implemented. This will include any design or operations information relied upon during the testing.

Once the testing has been completed the commissioning manager should ensure that the configuration of the plant as tested has been recorded. Any changes to the configuration through implementation of approved design changes after testing has been completed will need to be assessed to see if any of the testing or part of the testing needs to be repeated.

3. Documentation & Information Required

Author: Sam Billington and Charlie Sanders

Whilst the scope of the deliverables from each contractor will depend on the contracting strategies the following documents described in this section will be required regardless of the source.

a. Project Documentation

The project will produce several documents with which commissioning will develop their strategy, prepare for and ultimately perform the commissioning activities. The following documents should be made available by the project.

i. Project Execution Plan

The Project Execution Plan (PEP) ensures that the high level aims and objectives of the project, at the early project stages are developed into an integrated solution with input from all relevant stakeholders such that there can be confidence that success can be achieved. This includes anticipated high level commissioning strategies which will be further developed in the Commissioning Strategy Document as the project progresses. For larger projects there will be a range of subsidiary documents reference from the PEP such as:

- Stakeholder Communications Plan,
- Quality Plan,
- Security Plan,
- Supply Chain strategy,
- Hold Point Plan.

Whilst the commissioning manager will prepare a Commissioning Plan the PEP may also refer to Engineering Design Plan, Manufacturing and Construction Plans and these should describe the interfaces with commissioning.

ii. Management Systems

These management systems will be that of the licensee and where necessary adapted to the requirements of the project. These form the basis of how the licensee including the project and commissioning performs its activities. They will also govern non-core commissioning activities such as recruitment, training and competency assessment as well as procurement, quality assurance and security requirements and also the governance applied to project and commissioning.

iii. Project Business Case and Budget

The Project Business Case will provide the business benefit of completing the project. This will include key milestone dates and budgets and performance criteria. As the project develops the annual or stage budget and schedule will provide the information relating to the financial constraints and the required timeline of the project, key milestones and hold points.

b. Design Documentation

The designers will prepare a range of documentation including:

- Structure or System Design Document – A design document which describes the function and requirements as well as performance and the design codes and standards to be applied. It is from this document that the requirements for testing are derived. There should also be inclusion of design requirements for commissioning.

- Process and Instrumentation Diagrams – Identifying the mechanical components and the instrumentation connected.
- Control Logic Diagrams – These diagrams will form the basis of how the system and plant is controlled, from where the data inputs are received how they are processed and how these signals are manipulated and the actions that are taken by the control system on the plant.
- Civil Layout Diagrams – These indicate the position of components (mostly the larger items) within the facility as well as building a floor plans and access routes.
- 3D Model – Depending on the level of detail specified the 3D model will show the mechanical components and piping as possibly the electrical switchboards, cable routes and control and instrumentation cabinets.
- Test specifications – These documents are typically prepared by the designers or engineering in EPC type contract structures but other cases may be prepared by commissioning (with an engineering review). These establish the tests to be performed, the functional requirement to be addressed by the testing, a high level description of the tests and the pass / fail criteria.

c. Requirements

There will be many sources of requirements that commissioning will have to demonstrate, from the design substantiation to evidence of regulatory compliance and the project business case. These are typically collated together into the project level or system level requirements by Engineering or the Design Authority into either a document(s) or appropriate software tool.

The commissioning manager should ensure that they understand the full scope of testing and that they understand how the requirements will be delivered to them.

Further information on requirements can be found in Part 4 Section 1.

d. Environmental Permits

It is a statutory requirement that the licensee, project and commissioning ensure compliance with the requirements of the various environmental permits for the facility. During the early stages of a new build project the commissioning manager will only have access to the draft permit applications as a construction permit or discharge permit(s) will not have been issued by the environmental regulator.

For minor projects that will be conducted under the existing operating permits the commissioning manager shall ensure that testing and flushing will not release chemicals which are not authorised. The commissioning manger should therefore understand the chemicals which are permitted and their constraints. When commissioning under an existing operating environmental permit the commissioning manager should understand their 'budget' for discharges. Taking a simplistic example of running diesel generators under an existing combustion permit there could well be a limit on the number of hours the diesel generators are run in a rolling 12 month period. Therefore, to replace the diesel generator and perform a test run for an extended duration (e.g. 5 days instead of a monthly 4 hour test) may well result in a breach to the permit either immediately or at some point in the next 12 months.

The commissioning manager should understand the point at which the construction and operations permits change over as this is likely to be in the commissioning phase of the project.

e. Development Consent Order and Planning Applications

Under the planning regime at the time of writing large nationally significant infrastructure projects are required to submit an application for Development Consent Order under the Planning Act 2008. For smaller projects they may be required to submit an application under the appropriate planning act dependant on the licensee's location:

- England & Wales - Town & Country Planning Act (1990).
- Wales – Planning Act (2015).
- Scotland - Planning Act (2006).
- Northern Ireland - Planning Act (Northern Ireland) (2011).

Further information on these processes and their requirements for submissions is beyond the scope of this manual.

Regardless of the planning route used the commissioning manager should be aware of any constraints, limitations or mandatory requirements proposed by the licensee or stated in the permits issued by the relevant authority. The commissioning manager should ensure that they are actively engaged in the review of these applications as the constraints and consents necessary for commissioning may not be included.

f. Equipment Vendor Documents

The following documents will be provided by the equipment OEMs or depending on the contract strategy the contractor responsible for the suppling the equipment:

- Operating & Maintenance (O&M) Manuals
- Plant Operating Instructions – these may be refined and developed into a licensee compliant format and language. The commissioning manager should understand whether this will be commissioning or operations scope of work.
- Plant Maintenance Schedule – this describes the maintenance required and the periodicity to perform the maintenance.
- Plant Maintenance Instructions – these describe how to safely perform maintenance on the equipment.
- Manufacturing Report – this report provides a record of the manufacturing process and testing conducted. After assessment and acceptance by the licensee, the licensee will issue an equipment release certificate allowing the equipment to be shipped from the factory.
- Factory Acceptance Test Report – this report will detail the testing and results obtained from the Factory Acceptance Testing conducted prior the equipment leaving the factory. The commissioning manager should understand which FAT results are claimable to prevent retesting. There should also the consideration of FATs which need to be repeated at the plant site, this may be to ensure no negative impacts during transport, storage and installation as well as a different operating environment.

g. Construction Information

The following information should be received from construction:

- As-built drawings – which organisation has the scope to provide the as-built drawings will depend on the contract strategy.
- Construction & maintenance records – these will mostly be required by maintenance and operations as part of lifetime records and not commissioning. However, the commissioning manager should understand and ensure that the construction contractor(s) are scoped to

provide the agreed information. This includes planned and emergent maintenance records as well as surveillance testing conducted.

- Design Changes – there will be many field design change requests. Commissioning should be part of the review process to assess the impact on commissioning. These will give commissioning an indication if the commissioning documentation needs to be amended and if there are any changes to the test pass / fail criteria.
- Handover information – this should include the status of the system and also any temporary modifications either of a physical, electrical, software or set points nature.
- List of defects and snagging items as agreed with commissioning, operations and maintenance during the handover process. This will need to be updated to reflect the items which have been agreed to have been closed out.
- Testing and flushing records – these should detail the testing conducted on the systems, the test results and any anomalies. Tests are typically flushing and chemical checks, pressure testing, load testing etc.
- Set Point lists.

4. Maintenance and Management of Assets

Author: Mark Gargaro

On a nuclear licenced site, the maintenance systems must comply with the requirements of LC 28 (Examination, Inspection, Maintenance and Testing). There are a number of other conditions that directly affect the delivery of maintenance activities such as those listed below (not exhaustive):

- LC 6: Documents, Records, Authorities and Certificates
- LC 14: Safety Documentation
- LC 27: Safety Mechanisms, Devices and Circuits

Understandably, maintenance activities on plant, equipment and facilities that have a nuclear safety function is an important and potentially hazardous process and is rightly subject to a high level of control and scrutiny. A maintenance team will typically carry out the following activities on a nuclear licensed site:

- Proof testing safety systems.
- Completing scheduled maintenance (sometimes referred to as preventative maintenance).
- Carry out fault diagnosis and repair (sometimes referred to as reactive maintenance).
- Undertaking modifications to plant and equipment.

What role does maintenance have during a commissioning phase? Clearly the justification for specifying and operating new plant and equipment in a nuclear facility will be partly based on maintenance considerations: maintainability; the type and frequency of maintenance that will be employed etc. The maintenance requirements will be established during the design review process and will ultimately be reflected in commissioning documentation to be verified and validated. Typically, maintenance requirements may take the following form:

- Accessibility – strategic parts should be accessible for routine and exceptional maintenance.
- Isolation – the ability to isolate and lock-off the system / sub-system.
- Ease – the replacement or overhaul of parts should not be unnecessarily difficult.
- Measurement – the availability of test and measurement points.
- Obsolescence – the equipment should be built with freely available components.
- Safety – will maintainers be exposed to hazards during their work?
- Reliability – how long with the system or component operate?

Furthermore, statutory requirements such as PUWER and LOLER often influence maintenance activities and therefore should be included during any maintenance and operational assessment. This will require the involvement of trained assessors.

Maintenance personnel can make a valuable contribution during the commissioning phase when these assessments are being made. Also, some maintenance activities can be demonstrated during the factory and site tests and their effectiveness and compliance against requirements can be properly assessed by SQEP maintainers. It is likely that a more detailed assessment can be made after on-site installation since other variables such as the availability of cranes and hoists or the proximity of other plant, equipment and services will affect a maintainability study.

The project commissioning phase also makes a valuable contribution to those charged with maintaining plant and equipment in the following ways:

- The results obtained during performance and safety testing on new or recently modified equipment can be considered the defining baseline for a given test under known conditions. This data offers maintenance teams a reference point as the equipment ages and performance drifts.
- Commissioning, particularly during the later stages, offers the possibility for maintenance work instructions, schedules and safe systems of work to be developed. Where necessary, maintenance tasks may also be proven.
- During commissioning, the commissioning engineer often becomes very familiar – in some cases an expert – with the plant and equipment under test and this acquired knowledge may prove very helpful to maintainers post hand-over. Furthermore a commissioning engineer can participate in the SQEPing process for maintenance staff – alongside competent trainers / instructors - since the knowledge and experience gained during the commissioning process leads to an understanding of required skills and of the hazards posed to the personnel and the equipment.

The presence of maintenance personnel during commissioning should be encouraged since it is likely to be beneficial to both parties.

With newly supplied equipment, it isn't often clear when the first maintenance should be carried out. Usually, once equipment is handed over to operations, the datum is reset to zero and the maintenance period is started. However, other circumstances may prevail, for example, if the equipment has been in storage or inactive for a long period of time before use, is it safe to energise and use the equipment? Before proceeding to use equipment under these circumstances, consideration should be given to the following (limited) list:

- Are statutory certificates (LOLER, PSSR etc.) still valid?
- Has the OEM's recommended period for maintenance been exceeded?
- Are supporting services (extract, cooling water etc.) available and in a maintained condition?
- Are calibration certificates valid?

Failure to properly consider the condition of equipment that has been out of service for an extended period could, potentially, have catastrophic consequences. Similarly during the commissioning phase, where equipment is out of service for extended periods, a similar risk to personnel and equipment is posed.

This risk needs to be properly managed such that the maintenance requirements are assessed at a sufficiently early stage to allow provision to be made for equipment maintenance, if required. Depending upon the nature of the equipment, whether or not it is connected to services and where

the equipment is located – at the vendors or clients site – the type of maintenance required can be determined. As minimum, an asset care regime may be put into operation – checking lubrication levels, rotating moving parts and general condition monitoring for example.

On the other hand, full OEM's recommended maintenance may be required to ensure that the equipment is safe to use. For some types of equipment, it may be sufficient to isolate it and lock it off.

In summary, those individuals commissioning plant, equipment and infrastructure have a responsibility to engage with maintainers to ensure that a proper maintainability assessment is conducted; to provide the opportunity for the development of maintenance schedules and instructions and to contribute, if required, in the training of maintenance personnel. A further requirement of a commissioning engineer is to understand what maintenance is necessary over a given period and to facilitate periodic asset care should it be necessary.

5. Handover / turnover

Author: Sam Billington

a. Determining the strategy for handovers

The structure of the handover from construction to commissioning can either be performed in a single step or divided into several steps. The strategy for the construction to commissioning handover needs to be clearly established and agreed across many departments including:

- Construction
- Commissioning
- Operations
- Maintenance
- Engineering

The following questions will need to be considered by the commissioning manager in developing the handover strategy for the project:

- Size and complexity of the new plant.
- Number of different contractors. If there are several different construction contractors then commissioning will need to conduct a handover with each contractor. For example, the civils contractor will be ready to handover well before a mechanical and electrical contractor is ready.
- Number of different buildings and areas. Commissioning may need access to buildings sooner or the contractors may have staged milestones for the handover of buildings or areas at different times.
- Contract scope may require the construction contractor to remain on site and perform maintenance during commissioning. In which case a separate handover at the end of construction and another one at the end of the maintenance scope may be required.
- The point at which work management transfers from contractor to licensee may help in determining the point of handover between the construction contractors and commissioning. The assumption made is that the licensee's commissioning work management system has been developed considering that the systems are energised and are therefore more suited to commissioning than construction.
- The changeover of the safety case from pre-construction safety report to pre-commissioning safety report.

- The changeover of licence conditions from 19 (Construction or installation of new plant) and 20 (Modification to design of plant under construction) to 21 (Commissioning) and 22 (Modification and experiment on existing plant).

The commissioning manager should test the handover strategy against the following questions:

- What value add does a back to back handover from construction to commissioning to operations add when balanced against increased effort of conducting two handovers?
- Can commissioning be left with a construction problem to solve? Do operations accept the construction at the point of handover to commissioning?
- For maintenance handover what are the licensee's maintenance department signing for? Are they accepting the maintenance records until the point of handover?
- Ensuring that the licensee's platforms are ready to receive the data at handover. It makes sense that activities, in particular maintenance are recorded on the licensee's systems therefore ensuring that there is a continuous record from the point of handover. This has the added benefit of commissioning not having to upload or transfer data to the licensee systems at the point to handover to operations or maintenance.

b. Defining a handover boundary

The key to success of a good transition from construction to commissioning is the definition and early communication of a practicable handover boundary. The commissioning manager should consider the following points when defining a handover boundary:

- The ability on completion of a handover to perform meaningful testing. The effort to conduct a handover must result in an ability to progress work.
- The subsequent tests should be able to be performed with suitable isolations within the handover boundary.
- The handover boundary should be closely aligned with a system as this is as they are designed. However, it may be wise to split a significant nuclear safety system into each of its divisions.
- The scope of each contractor should be considered. What is the impact of requiring an electrical supply to be connected to a motor? Is there a risk that the electrical contractor will be late and the handover delayed? Would it me more practical to have a separate but associated electrical handover boundary as it may focus on a different contractor.
- Security requirements should be considered as there may be an operational reason why a building or area are locked down to prevent malicious or accidental tampering with plant which would damage or have a detrimental impact on operations.
- Multiple plant operations. Where a project is a series of linked plants there needs to be a consideration of boundaries which will clearly separate different plants which are in construction and commissioning. The aim being to prevent construction activities impacting the commissioning or operation of the new plant or operations energising systems in the construction areas.

During the early part of the design process the boundaries of the handover should be defined and documented using Piping & Instrumentation Diagrams (P&IDs), electrical single line diagrams, logic diagrams and civil layout drawings. This should be agreed with the construction contractor(s) at the earliest possible opportunity.

For an efficient start to commissioning the commissioning manager should consider requesting that the systems are left in a configuration ready for commissioning. This will prevent commissioning breaking into systems to modify them prior to the start of commissioning.

To aid communications a handover boundary pack should be developed by commissioning and agreed with the construction contractor. This pack should include the following information:

- The exact boundary to be handed over to commissioning.
- A list of components within the boundary.
- Configuration of the system(s) to be handed over eg any changes or temporary fittings to be included or any equipment, components or parts of components to be removed.
- Material state of the system(s) eg dry or filled and vented with or without preservation in place.
- Any other systems needed.

c. Civils handover

There is very little that commissioning will do with a civil structure and therefore a decision needs to be stated in the handover strategy that civil structures when completed will either be handed over to commissioning or straight to operations. The optimum reason is to handover straight to operations as otherwise the commissioning team will take ownership of the structure with little added value before the handover to operations which is a double handover and double effort.

The licensee's practice to perform a handover from construction to commissioning and then on to operations may be driven by their work management systems as commissioning will be working in the structure. In this case best practice is for operations to accept the structure as built and fitted out at the point of handover to commissioning. It should be noted that at the point of handover from construction to commissioning the structure may well be in the commissioning configuration. At this point there should be a clear understanding of difference between the commissioning and operations configurations. For clarity, in this model control of work in the structure would transfer to commissioning under the commissioning work management arrangements and not operations.

This ensures that operations have accepted the build and the scope of handover from commissioning to operations only needs to focus on time when commissioning had ownership of the structure and the re-configuration of the structure to that required by operations. The benefit is that any issues identified by operations are documented in the snagging list and resolved prior to the construction contractor leaving site.

d. Maintenance handover

The maintenance handover could follow a similar logic to the civils handover where a direct handover to the licensee's maintenance team could be performed. The optimum strategy is to perform a single handover from the construction contractors or suppliers to the licensee's maintenance department. This ensures that the maintenance department accept the records required at the point of handover. This ensures that commissioning are not left to resolve issues surrounding incomplete maintenance or records.

For EPC contracts the handover from the EPC maintenance team to the licensee's maintenance team will be at a different point. The licensee should aim to second their maintenance personnel into the EPC maintenance organisation to gain experience. Whilst maintenance remains with the EPC contractor the EPC contractor remains liable for schedule delays and incorrect maintenance.

Should the licensee's practice be to perform a handover from construction to commissioning and then to maintenance then commissioning should use the maintenance departments platforms for recording maintenance activities. The maintenance department should also accept the performance and records of maintenance up to the point of handover to commissioning. This ensures that if

there are deficiencies in either the maintenance conducted or the records provided they can be resolved before the contractor leaves site. Also if there is a need to replace a component due to defective maintenance or records then this can be done prior to performing commissioning.

e. Handover for commissioning

The handover for commissioning signifies the start of commissioning on that section of the new plant. The commissioning manager should try and seek a balance of the timing of the first handover to commissioning. There is a tension between starting early to achieve a key project milestone and the construction contractor just not being ready to handover. The end result if handover is performed too early is the construction and commissioning teams tripping over each other in the plant areas. Also being too early means that construction will not be able to hand over areas and parts of systems fast enough to meet the ability to commissioning to start testing. The effect of this is a start stop for the commissioning teams.

The commissioning manager should insist that the construction contractor has dedicated completion teams who will operate to commissioning's requirements. This will ensure that bulk installation is then completed reducing the number of items on the snagging list.

The commissioning manager should develop a handover logic stating which systems are required in which order. Typically, these will start with auxiliary systems such as electrical distribution, compressed air and lighting. This should then be used to drive the priorities of the construction contractor towards the end of construction.

Best practice may be to perform a dry run either on plant or on simulated plant of a handover with the all parties to check understanding of the process and standards and expectations.

When handing over to commissioning construction should ensure that they clearly define the configuration and boundary of the plant they are handing over. This includes clearly stating the implemented approved design changes.

f. Hand back to Construction

Whilst every project and commissioning manager should plan for success there is risk that a system or area may need to be transferred back to the construction contractors. This may be pragmatic if there is a substantial amount of re-work required on a system. This would allow the construction contractor more time and to be more efficient in their work.

As with all handovers the boundaries need to be clearly agreed and communicated. The construction and commissioning teams should note that there may well be 2 different teams operating in the same area and some systems may be energised and or undergoing test. The process should clearly state the information to be provided by commissioning to construction to ensure their safety.

The handback process should also state the expected handover requirements of the system and records required when it is returned to commissioning. The return of systems and areas to commissioning should also follow the main procedure but only providing the construction records associated with the re-work.

g. Hand over from Commissioning to Operations

If operations and maintenance have been involved in the handovers from construction and have therefore accepted the state of the new plant at the end of construction then the aim of this handover should be to ensure acceptance of what has happened since that first handover.

A two stage walk down should be considered, the first, led by commissioning to verify that all items on the construction snagging lists have been fully completed and to identify any other snags which may have arisen since handover to commissioning. These will be agreed and resolved prior to handover.

The final walk down, led by operations and maintenance, should also check that any temporary items have been removed or correctly recorded in accordance with operations arrangements and that the snags identified in the first walk down have been resolved. The decision to accept each snag lies with the receiving department i.e. operations or maintenance.

The process of this should aim to be a readiness review for the systems to be taken over by operations as they have previously accepted the construction of the new plant. Therefore, it should only consider activities under taken during the time commissioning had control and it should not revisit the handover from construction to commissioning.

h. Conduct of a handover

The conduct of a handover should be clearly defined in a procedure and agreed with all the licensee's departments as stated in section 5a above as well as engagement with the construction contractors.

i. Steps during design and early construction

Early in the design phase the boundaries of handover shall be determined and agreed by the construction contractor and the commissioning department. The construction contractor shall plan to form a completions team to focus on the completion of works within the agreed handover boundary.

There shall also be an agreed set of checklists used for the handover which will typically be generic in nature and relate to specific components and structures. The construction contractors should then aim to use these checklists as a guide to ensuring that the construction is to the required standard prior to walk downs commencing.

ii. The walk downs

Ideally these should be performed in the following 3 steps.

The first is the walk down by the construction contractor's team which would take place 2 to 3 months before the planned handover. This will allow the construction contractor to focus their completions team on the resolving the outstanding issues.

The second in a walk down should be planned 1 month before handover by the following parties who have the following roles:

- Construction contractor – to identify and agree resolution of the snagging list.
- Commissioning – to ensure that it can be tested.
- Operations – to ensure that is can be safely operated and in accordance with safety rules.
- Maintenance – to ensure that it can be maintained.
- Engineering – ensure that is has been built as designed.

In this second walk down a snagging list should be developed based on any deviations from the generic checklists for the structures and components. This will then be signed by all parties. There needs to also be agreement on the categorisation of each item on the snagging list as follows:

- Rectify before handover to commissioning .
- Rectify before testing.
- Rectify before handover to operations.
- Rectify before an agreed project milestone.

The third walk down immediately prior to handover should ensure that nothing has been added to the list and that those items on the snagging list which were agreed to have been completed before handover have been completed satisfactorily. Also any other items on the snagging list which have been rectified satisfactorily should be accepted.

iii. Design considerations at handover

The handover should also take into consideration the status of the design documentation at the point of handover such as:

- How closely does the as built plant reflect the latest version of the design documentation?
- Have there been significant field modifications or design changes during construction?
- Which approved design changes have been implemented on the plant, or more importantly which have not?
- What design changes have been proposed but not yet approved?

The commissioning manager should use these questions to determine if it is appropriate to commence testing with the present state of documentation.

iv. Software consideration at the point of handover

With the increased reliance on plant operating software the licensee should ensure that they have adequate back versions of any plant control software to reinstate a previous version. The issue is that as components are brought into systems and then into an integrated plant the software systems will be revised to ensure the plant operates as designed. This means that component and system performance will have been successfully tested using different versions of the software. Commissioning therefore have confidence that previous versions of the software when coupled with a smaller groups of components functions correctly and therefore has the ability to step backwards if required.

To achieve this previous revisions of the plant control software must be included as part of the handover or preferably at the point at which the software is uploaded on the system. This will allow the licensee's IT security team adequate time to analyse and isolate the software prior to commissioning needing to upload it onto the platform.

v. Audits and record reviews

The licensee should ensure that they are satisfied with the records received from the contractor. The records received should reflect the requirements for lifetime records as stated in the contract. The licensee should ensure that the records have been accurately stored in their own records system.

There are several challenges with conducting these audits or reviews. The temptation to read every record should be avoided at all costs as the licensee should just check that the records exist and that they are complete in accordance with the contractual requirements. This audit or review should be conducted using a grade application. Any deficiencies identified should be added to the snagging list for completion prior to the agreed milestone.

Other challenges include changing contract requirements for the lifetime records. This typically occurs when the maintenance and operations team ramp up and have the capacity to engage at this contract level. Due to the increased personnel there could also be changing view points on what constitutes life time records. The temptation to require and keep everything must be avoided. The commissioning manager shall strive to fix and lock down the lifetime records requirements otherwise there is a risk that commissioning will be left to fund the identification and supply or records before handover to operations is accepted.

vi. Handover

A handover certificate should be prepared and signed by both the giving and receiving parties. Further signatures may be required but these would solely be for acknowledging the transfer of responsibility.

During the peak of handovers the communication of a handover completion must be quick to ensure that all groups understand who has responsibility for which parts of the plant. This will include:

- Engineering,
- Operations,
- Maintenance,
- Commissioning,
- Work Management,
- Commissioning command centre,
- Construction contractor(s),
- Internal communications – for inclusion on daily notices and intranet portals etc.

Immediately post handover the receiving party should place their tags (and if necessary locks) on the areas and components they have just received.

6. Commissioning Testing

Author: Anthony Macey

a. Stages of Commissioning Tests

Commissioning of the plant and equipment can be broken down into the following phases. Not all of these phases will be applicable for every system. The developed commissioning strategy and test logic will determine the requirements for each system(s).

- Factory Acceptance Testing (FAT),
- Site Acceptance Testing (SAT),
- Inactive Testing,
- Active Testing.

The key deliverables of each of the above commissioning phases are outlined below.

b. Factory Acceptance Testing Stage (FAT)

FAT should be considered for bespoke or complex systems to demonstrate that the equipment meets the design and functional performance requirements laid out in the contract specification. There may also be a benefit in executing tests at works where the environmental or radiological conditions or accessibility on plant impose limitations on the testing and troubleshooting that can be performed.

Quality inspections should be conducted during FAT including confirmation of equipment 'as built' status against the latest revision of approved drawings.

The client may also specify as part of the contract and agree with the contractor that they witness certain tests within the FAT. These can either be a repeat of some of the FATs or additional tests. The results should be reviewed and accepted by the client's design and or commissioning team prior to release for shipment to site or for further testing as part of Integrated Works Testing (IWT). In the selection of tests to be witnessed and the review of documentation the licensee should apply a graded approach to focus their efforts and resources at the most significant areas.

IWT requires the consolidation of items from multiple vendors at an agreed test location. This approach will allow the testing of interfaces and the integration of mechanical, electrical, I&C and software functions. IWT should be utilised where it is acknowledged there is benefit in the early setting to work of systems to minimise risk for both cost and schedule. IWT will be led by the client with the purpose of proving the functionality of the integrated system and any plant or process performance requirements. An agreed set of tests shall be produced by the client for this purpose.

Throughout works testing the commissioning team should provide support and appropriate oversight in accordance with an agreed plan. This will ensure that functionality of plant and equipment meets design intent, performance, safety requirements and appropriate completion prior to delivery of equipment to Site.

By implementing robust lock down arrangements during FAT, credit can, where appropriate, be taken for tests carried out off site negating the need for repeat testing when the equipment is installed on site.

Works testing should be used as an opportunity for training, operation and maintenance instruction validation, installation trials and O&M personnel familiarisation with plant. The operability and maintainability testing that is carried out during FAT and IWT will help facilitate the production of a suite of documents (instructions, training packages etc.) that can be taken forward to the inactive testing phase for final validation and approval.

c. Site Acceptance Testing Stage (SAT)

SAT takes place after the complete installation and final configuration. The SAT is conducted in accordance with the vendors approved test plan to show that the system is installed correctly and verify that no damage occurred during shipment and installation

Not all installed systems require the execution of SAT. The execution of SAT by vendor(s) is usually associated with complex systems, that require the vendors expertise to initially set the system to work to an agreed level of functionality after strip down and shipment to plant. SAT may also be required where certificates demonstrating compliance with mandatory standards need to be issued by the specialist vendor for example in the case of cranes and fire alarm systems.

SAT should be carried out by the equipment vendor(s) in accordance with vendor produced test documentation. SAT documentation should be subject to approvals via the appropriate T&CP, and testing witnessed by the commissioning team. The SAT will demonstrate that the system is installed correctly and verify that no damage has occurred during shipment and installation. Throughout installation and setting to work of equipment by vendors and specialist service providers, the commissioning team should provide oversight to ensure that functionality of plant and equipment

meets design intent, performance, safety requirements and appropriate completion prior to progression to the inactive testing stage.

SAT stage must consider demonstration and recording of results for the following;

- Pre-energisation Testing.
- Energisation Testing.
- Static Testing of any Control System Logic.
- Dynamic Functional Testing without Load.
- Operation of mechanical and electrical interlocking requirements associated with equipment protection and personnel safety.
- Dynamic Functional testing under load, including statutory inspections.
- Integrated testing of any sub-assemblies.
- All Post Test Statutory inspections and registration.

On satisfactory completion of the above testing a declaration of conformity should be issued by the vendor and equipment registered where required.

The commissioning team also need to make use of any opportunities to commission the people who will operate and maintain the equipment through O&M instruction validation, installation trials and O&M personnel familiarisation with plant.

d. Inactive Testing Stage

The Inactive Testing stage will include:

- Confirmation checks that lockdown arrangements have been maintained from site acceptance test.
- Confirmation of correct mechanical and electrical interface connections. Credit may be claimed for checks carried out during the installation of equipment.
- Energisation of individual Systems.
- Testing of emergency stop and interlock functionality where not previously tested.
- Component testing describes the first activities to be undertaken following the completion of the system installation and end of construction checks. It involves testing the basic operation of each component of the system individually, including all actuators and instrumentation as well as the input and output connections to the I&C systems. Process fluid and stored energy will normally not be introduced at this stage. Any equipment that requires calibration will be calibrated and alarm points confirmed.
- Flushing. The dynamic flushing of the system where applicable takes place when component commissioning is sufficiently complete and represents the first addition of stored energy into the system as a whole. This activity allows the leak-tightness of components not subject to hydrostatic testing to be checked while the appropriate level of cleanliness is achieved in the system.
- The partial system testing involves the gradual and progressive challenge of groups of components to perform their functions, usually with a simulant/dummy package introduced to the system. It allows the design and installation to be validated for the limited set of conditions possible when testing a sub-group of components, before moving to full system commissioning.
- System testing describes the process of systematically checking the functions of the system as a whole and will usually allow near operational conditions to be achieved. In many circumstances it may be appropriate to test a group of systems together to best approach

operational conditions. This will be followed by a full plant performance demonstration using dummy packages/simulants.

- For new nuclear reactors there will be specific integration tests that must be performed. Integrated testing is broken down into 3 stages;
    - Nuclear Circuit Cleaning (NCC), in which the auxiliary systems connected to the primary circuit will be flushed into the reactor pressure vessel and the reactor pressure vessel cleaned.
    - Cold Functional Testing, is where the primary circuit will be tested at temperatures well below those of normal operation with the reactor pressure vessel head removed and flow from safety injection systems into the primary circuit will be checked and adjusted. Then the reactor pressure vessel will be fitted, and the primary circuit will then be tested in a solid-state condition. This will include performing the primary circuit hydrostatic pressure test, in which the integrity of the primary circuit will be tested by taking the pressure in the system to well above normal operating pressure.
    - Hot Functional Testing (HFT), is where the primary circuit temperature and pressure is increased towards normal operating conditions using the pressuriser heaters and main coolant pumps. Primary circuit functionality is then tested at this operating point. The amount of heat energy added to the primary circuit during this stage is enough to turn the main turbine (but not to synchronise with National Grid) and conduct initial testing on the main turbine.
- Commissioning of the people and procedures consisting of the following;
    - Carry out validation of any operating and maintenance instructions not validated during Works or Site Acceptance Testing.
    - Train and assess operators, engineers and maintainers.
    - Human factors validations.
- Identify and put in place arrangements for the management of waste, radiological, appointments, emergencies.
- Implement operations and maintenance structure.
- Prepare for handover to operations team.

During this stage tests will challenge and confirm the features of the plant that define the safe operating envelope. These tests need to be designed to prove the functionality of the equipment identified in the safety case and to challenge its suitability to satisfy the requirements of the identified fault sequence. Testing should be carried out in accordance with the scope defined in the design requirements. Some licensees refer to these as safety tests which have a specific subset of requirements described in a Safety Commissioning Schedule (SCS).

Inactive testing can be deemed to be complete when the people, procedures, arrangements are in place, the plant and equipment has been demonstrated to perform repeatedly. The inactive testing period may also include a period of pseudo operations if deemed necessary.

e. Active Testing Stage

The active testing stage is required to verify assumptions made during inactive testing against an incremental increase of the challenge made by the nuclear inventory.

Active testing will include:

- Operation of the plant in active conditions to a standard operating process to demonstrate safe operation and throughput.
- Confirming the systems available to manage dose to operators (radiometrics and interlocks)

- Provide operators relevant experience as part of SQEP training.
- Prove key operational interfaces (Import & Export).
- Radiological data measured to support inactive assumptions e.g. radiometric instrument performance, background radiation levels and performance of installed shielding.
- Validation of procedures including Operating Instructions, Maintenance Instructions, Emergency Instructions and Proof Test Instructions under active conditions.
- Production of Active Safety Commissioning Report (ASCR) on operational arrangements to the Duty Holder in support of the Endorsement to Operate (ETO).

For new nuclear power stations active testing starts at delivery of nuclear fuel to site and is the stage in which the fuel will first be introduced to the reactor and the core brought to conditions of first criticality. Synchronisation and connection to the grid will occur, followed by a steady rise in reactor power until 100% nominal power is achieved. This represents the final stage in the commissioning of the unit, although some commissioning of auxiliary plant may continue during or after this stage.

Active testing includes:

- First fuel loading, in which nuclear fuel will first be introduced to the reactor vessel and the vessel is closed;
- Pre-critical tests, in which the characteristics of the primary circuit and the function of core equipment not installed until fuel is in place including control rods will be tested before any approach to criticality;
- First criticality, in which the core will be brought to the point of criticality at zero power and core instrumentation tested and calibrated;
- Boiling Water Reactors (BWRs) do not have the ability to perform Hot Functional Testing without using nuclear generated heat then the scope of Hot Functional Testing is conducted at this point of active testing.
- Gradual power raise before synchronisation, in which the unit's control and protection channels will be tested in stable and transient operating conditions at various power plateaus up to 25% nominal power;
- First synchronization, grid connection tests and (first) export of power at 25% nominal power; and
- Final power raise to 100% nominal power, in which the unit's control and protection channels will be tested in stable and transient operating conditions at various power plateaus above 25% nominal power before the reactor is raised to full operating power and the core is characterised in full operating conditions.

f. Review and Acceptance of Test Results

On completion of testing a review of the completed test document(s) must be carried out at the earliest opportunity to establish whether the results have adequately demonstrated any functional, safety and design performance requirements.

Test results must be clear and unambiguous, no test result shall be accepted without a full understanding of the functionality, even if this involves the execution of bespoke tests to verify a specific issue. On completion of testing the results will be passed to the commissioning manager for initial review. Depending on the scale, complexity and safety significance of the equipment being tested there may be a requirement for a detailed evaluation of results by the T&CP. In addition, it may be necessary to produce a summary report for a system or stages of testing encompassing multiple systems that demonstrate nuclear safety functionality. The production of these reports should be in line with the developed commissioning strategy and agreed regulatory hold points.

In the case of simple test documents with no safety implications it is generally considered acceptable for a review of the document and acceptance of the test results to take place outside of the committee review panel. The reviewer however must be someone with a level of independence from the test execution who has been formally nominated to carry out this duty.

g. Test Reports

Test Reports are required to confirm that the commissioning tests, have been carried out satisfactorily. Test reports may be produced for a single complex system or on an as needed basis. A test report will summarise the status of the tests scheduled to be completed during the commissioning stage and will provide a justification for moving to the next stage of commissioning.

Test reports are typically required following completion of inactive testing and active testing.

Additional test reports may be required at the request of the commissioning manager or as identified as part of the commissioning or project strategy.

For commissioning work associated with small scale modifications on existing plant the test report may take the form of a completed commissioning test document supported by a summary statement confirming that the commissioning tests have been successfully completed, the status of any temporary modifications and any faults raised during commissioning.

For a system or systems with significant contribution to nuclear safety functionality a formal report shall be produced when seeking to move between stages. The report shall detail the readiness of the plant, people and procedures and should cover the following topics:

- Executive summary,
- Scope of Testing,
- Summary of commissioning tests,
- Concessions i.e. any tests that it has not been possible to complete,
- Summary of changes and re-test,
- People and Procedures,
- Outstanding Issues,
- Conclusions,
- Recommendations.

The commissioning manager shall approve all reports prior to review/endorsement at the relevant T&CP. There may also be a requirement to submit the test report for regulatory approval as part of any agreed hold points requiring regulatory approval.

7. Employment of Contractors

Author – Sam Billington

There are several key areas for consideration of contacting models when establishing a commissioning organisation and these are highlighted in the following section. For all new build projects commissioning is between the construction and operation phases and therefore there is no clear-cut contracting strategy to complete commissioning.

It is standard practice that when nuclear fuel or radioactive material (i.e. process material and not radioactive NDT sources etc.) are brought on site then the licensee leads the commissioning in this active testing stage. Since this active testing is typically part of commissioning then there could well be a change-over of contracting strategy at the start of active testing.

The typical strategy is for the contractor to perform more of the testing in the earlier parts of commissioning with the licensee witnessing the testing. In the later parts of the commissioning phase the licensee will be perform the commissioning with support from contractors. The strategic decision to be taken is not just what the contracting strategies are but when the changeovers from contractor led to licensee led take place. Once these decisions have been made the opportunity for operations and maintenance personnel to gain experience should then be explored.

a. Delivery Models for new build projects and implications for commissioning

For large new build projects the strategy will be established by the project. The issue is that commissioning is often forgotten and is drowned out by the already established teams of engineering and construction. As a result of this the complexity of the contracting strategy for commissioning is not considered.

The first option is often a large single Engineering, Procurement, Construction and Commissioning (EPCC) contract for the design, construction and commissioning of the new project. This will still require active testing to be conducted by the licensee. Other sub-tier options are an Engineering, Procurement and Construction (EPC) contract with a separate commissioning contract.

The second option is to self-perform commissioning. Whilst it is typical for the licensee to self-perform active testing the cold and hot functional testing and component testing may be contracted out or self-performed by the licensee.

Whichever model is selected the changeover points should be clearly considered and understood. The aim should be to align contracting changes alongside the following to clearly defined points:

- Change from Licence Condition 19 (Construction or installation of new plant) to Licence Condition 21 (Commissioning).
- Change from contractor's working arrangements and management system (either at FATs or where a site is managed by the contractor, typically in an EPC format) to the licensee's.
- Changeover of safety cases from Pre-Construction Safety Report to Pre-Commissioning Safety Report for larger projects or Pre-Operational Safety Report for smaller projects.
- Change in control of the operation and maintenance of the project SSCs, this could be from a construction team to a commissioning team to an operations team.

For small projects these changeovers can be defined to a calendar day or clearance of a specified project hold point. For larger projects consideration should be given to SSCs transitioning in a batched or on a rolling basis. In such cases it is recommended that the changeover points occur as the SSCs transition and not on a particular point in time.

i. EPCC Contract

Where a licensee opts for an Engineering, Procurement, Construction and Commissioning (EPCC) contract then the aim for the commissioning team is to clearly establish the scope of the commissioning work. This will include the management system, deliverables list (and the content and structure of the documents), templates and writer's guides.

The focus should then be on developing a small but experienced team to oversight the works of the contractor. This team should have experience on setting detailed contract scope and standards and both witnessing testing and reviewing test documentation.

The above advice would also be true where an Engineering, Procurement, Construction contract is let and a separate commissioning contract is let. The additional challenge of this twin contract

model will be to extract the design and construction information from the EPC contractor, accept the information and transmit this to the Commissioning contractor in a timely manner. The licensee then becomes responsible for the integration including the timeliness, accuracy and clarity / detail of the information provided and the communication between the EPC and Commissioning contractors. The level of effort in managing this interface should not be underestimated by the licensee.

ii. Licensee Led

This licensee led model should be considered as 2 parts, the first for large projects and the second for those licensees who have a portfolio of projects and a separate commissioning department.

For a large scale project using a licensee led commissioning model there may well be an existing commissioning organisation, or this may need to be built from scratch. Where a commissioning team is built from scratch there should be a greater reliance on the supply chain knowledge both specific to the technology being deployed and general commissioning expertise. In this model the supply chain should be integrated into the licensee organisation and should have a hands role supported by licensee personnel to gain experience and facilitate knowledge transfer. The main challenge with a new commissioning organisation is to have the experience necessary to establish the detailed commissioning requirements and communicating these to the design and construction contractor(s). The licensee should consider drawing on any existing operations experience that it has available to provide capacity to commissioning. Should this not be available then partnering with another utility or organisation with experience of the appropriate of similar technology should be considered.

Where the licensee has an existing commissioning or operations organisation this should be the basis of the commissioning team and existing standards and practices should we widely adopted for the new project. In this case the licensee has significantly less risk around general commissioning but would need to consider their capacity to perform the commissioning in this contracting model. This includes ensuring that the management system and infrastructure (i.e. electronic systems) are optimised for a significantly increased volume of data. Once again specialist equipment commissioning should be conducted by the supplier either in FATs or using on-site support.

For those licensees who have an adequate pipeline of projects in the commissioning phase and therefore can justify a standing commissioning team the following principles typically apply. Licensees will typically lead the systems commissioning and all commissioning activities on their site. This will depend on the complexity of the structures, systems and components being commissioned and also the amount of FATs which has been conducted at the OEM's works as well as the oversight of the FATs. In this model the licensee will have developed considerable expertise in the commissioning process and retained this knowledge and experience in their own commissioning personnel. They will flex their resource through contracting personnel where there is a peak in demand. The benefit is that these licensees will have quick and easy access to all the documentation and understand the requirements of their management systems and stakeholders as well have all the templates already to hand. The downside to this is that the licensee will lack the detailed knowledge of the components, particularly the more complex equipment which is being supplied. The challenge is the integration of these complex components in to existing structures and systems where the interaction between the components and the existing systems cannot be reliably tested off site. Therefore, careful consideration of how the OEM's teams are contracted and retained to ensure smooth integration.

In all cases the licensee should critically assess their capability and capacity to commission systems and components which are supplied. They should aim to increase the amount of Factory Acceptance Testing performed by the OEM (ideally with licensee commissioning representation) to ensure that complex issues are resolved with the most knowledgeable persons available. This moves the focus of testing on site away from proving the equipment operates correctly towards proving the equipment integrates into the existing structures and systems.

b. Factory Acceptance Tests

In all cases the licensee should seek to increase the amount of FATs performed by the contractor at their or the OEM's works. This provides the following benefits:

- Easy and rapid access to OEM personnel with detailed knowledge and experience on the equipment so that faults can be identified and rectified.
- Increased confidence that the equipment functions correctly before connecting to the licensee's systems.
- Access to existing test rigs and systems to perform the testing without impact on the licensee's systems and on-going operations.
- Reduced cost as the OEM's test teams are not required to perform work on the licensee's site with increased time to induct, perform security checks and other site induction training activities.
- Reduced burden on the licensee's personnel as OEM's test personnel will not typically have authorisation to operate licensee systems or hold Senior Authorised Persons appointments under the licensee's mechanical and electrical safety rules.
- Reduced time lost due to ease of making changes to test procedures, test rigs and support systems in the OEM's facility.
- No issues with a failure which requires the equipment to be returned to the OEM being radiation contaminated or any issues around the OEM receiving equipment from a Licenced Site and therefore the risk of radiation contamination. The negated cost of disconnecting and preparing the equipment for shipment back to the OEM's works.

There is often a key project milestone surrounding the shipment to or receipt of equipment on site and therefore there is a temptation to 'hold the milestone date' by shipping equipment early. This is a false economy as work now has to be planned and executed using the licensee's management system, increasing the burden and cost of commissioning. There is also an increased risk of damage and poor maintenance whilst on site. This strategy also guarantees longer delays if a failure occurs in commissioning as the time taken to identify and rectify the fault and then retest is significantly increased on the licensee's site.

The licensee should also consider the qualification of their representative witnessing a test if they believe that the successful performance of a FAT would negate any on-site testing. Depending on the licensee's arrangements in some cases an authorised person, in addition to an appointed commissioning person, is required to witness a test if it is of a significant nuclear safety.

The licensee should consider the time and cost benefit of using the FATs as a basis to reduce amount of on-site construction tests and not to repeat FATs on their site. A possible strategy may be to conduct simple checks during cold commissioning to ensure that the FATs remain valid or claiming a successful FAT as a pre-requisite for a cold commissioning test.

Once FATs have been successfully completed and the equipment is ready to be shipped to the licensee's site (or other location) there needs to be a clear understanding of the preservation,

maintenance and cleanliness requirements for the equipment. The contract should clearly state these activities and standards to prevent the FATs being negated by a lack of maintenance and preservation.

c. Supply Chain Management

Where a licensee does not have an existing commissioning function it is essential that a small experienced commissioning function is established prior to placing design, procurement and construction contracts. It is project critical that commissioning deliverables are included in the scope of contracts as the timely delivery of key design and test documentation is essential to the development of safety cases and test procedures.

The particular focus of this commissioning team will be to develop the contract requirements and scope in relation to:

- The testing required should be identified and clarity on the division of testing scope performed by each contractor and also the licensee. This is particularly true if there are OEMs conducting FATs, a separate construction contractor and a separate commissioning contractor and then the licensee conducting active testing.
- Hold, witness and notification points. The licensee needs to clearly identify and communicate their requirements which are typically based on a graded approach.
- Requirements placed on the contractor's management system.
- List of deliverables from the contractor, their content and structure.
- Ability to witness tests and inspect equipment and components at a contractor's works on a risk / graded basis.
- Commissioning deliverables required as references to safety cases. Note that these may be required earlier than expected.
- Regulator access to contractor's works as the ONR may wish to witness specific safety significant tests or attend a licensee's audit on the Contractor.
- Flow down of contract terms from the tier 1 contractor to the tier 2 and 3 contractors.

For licensees which are conducting their first commissioning project the above bullet points need to be developed in detail. Where a licensee is undertaking a project which is substantially larger than their typical portfolio the above considerations need to be revisited and critically challenged, particularly if there is a different contracting strategy for this larger project. A larger project may involve different contractors performing commissioning activities and or an increased headcount in the commissioning organisation. In each case there will be a lack of familiarity with the licensee's processes, documentation and expectations.

A licensee should remember the following human performance error traps in dealing with their supply chain:

- Complacency surrounding the use of the same Contractor but the supervisor or team may be different,
- Inexperience / lack of knowledge of the contactor,
- Poor communications between licensee, tier 1 and those sub-contractors performing the work. This could relate to a failure to flow down requirements, the poor setting of expectations or the slow transmission of information such as design changes etc.
- Lack of oversight and engagement with the sub-contractors performing the work by either the licensee or tier 1 contractor.

This will be particularly important if the licensee has never dealt with that supplier before. On large projects or projects in an EPC / EPCC structure the team performing the commissioning activity is likely not to be the tier 1 contactor therefore the licensee should consider the following engagement:

- Contract or sub-contract initiation meeting,
- Pre-job brief for each type of activity which starts, e.g. development of the management system, preparation of test documentation, performance of testing, preparation of results packages and lifetime records,
- Early review of contractor templates,
- Delivering a first product set early to create an exemplar.

d. Oversight of Contractor Works

The old saying of, 'you get what you inspect and not what you expect' should remain in the forethoughts of all licensees. The lack of proper oversight of a contractor remains one of the key human performance error traps in a project.

A graded approach to the oversight should be considered not only on the nuclear, environmental or security significance of the works but also on the project significance of the works. Commissioning will always be to a greater or lesser extent on the project critical path and therefore a keen focus should be on ensuring that project work on or near the critical path is 'right first time'. The following points should be considered by the licensee in each project phase, from engineering, procurement / manufacture, transportation and storage, construction and cold commissioning:

- Audit of the sub-contractor to ensure requirements have been flowed down from the tier 1 contractor and are correctly applied in the management system.
- Early agreement of documentation, templates and contents.
- Early oversight of commissioning documentation and templates.
- SQEP assessments of key persons and or those performing the work.
- Adequacy and conduct of the contractor's and OEM's quality assurance / quality control mechanisms on the goods inwards checks from the previous phase or another contractor,
- Availability and competence of the licensee's representative witnessing testing, preservation, maintenance and storage etc.
- The required content of factory release and other project stage packs and lifetime records are agreed early to allow timely and complete transmission to the licensee.
- Compliance with any preservation, maintenance and cleanliness standards from the completion of FATs until turnover to the licensee.

8. Quality

Author: Sam Billington

Quality is a key item for the commissioning manager to consider throughout the whole project. The reason for this is that quality issues typically become apparent in the commissioning phase as a lack of detailed manufacturing or construction records. The commissioning manager should note that much of the nuclear supply chain does not understand the quality requirements of the nuclear industry. This is due to variation in or poorly specified requirements from licensees and requirements that they are buried in substantial contract documentation and are therefore forgotten about, not understood, ignored or not flowed down by the contractor. The significance of a nuclear safety culture, incorporating the high level of quality requirements needs constant reinforcement.

The regulators require that licensees develop their arrangements, assess and demonstrate that they are appropriate and then comply with them. Putting this simply, write down what you are going to do and then do what you have written down.

a. Quality Assurance

This should be split into 2 parts, the first the quality assurance of the commissioning team and the second that of the supply chain.

i. Quality Assurance of the Commissioning Team

The commissioning manager should ensure that the commissioning department are audited on a regular basis and have an appropriate suite of performance measures in place. This will not only give the commissioning manager but also the licensee confidence that the department are conducting their activities in a compliant basis.

The commissioning manager should consider having specific audits on the commissioning arrangements leading up to and during the commissioning phase. This is often a period of significant growth and change within a commissioning team and it is important that potential divergence from the agreed arrangements is controlled. Depending on the significance of the project and its size and duration the commissioning manager, in liaison with the project manager may opt to audit periodically as each stage progresses e.g.:

- Mid way through preparation stage,
- Mid way through system testing,
- Readiness for active testing,
- Mid way through active testing,
- Project completion.

Or as part of preparation for a hold point release where an audit would typically be conducted 3 to 6 months before the planned release of the hold point. This should give the commissioning manager confidence that the arrangements are being properly developed and that the activities conducted before a hold point have been conducted in a compliant manner.

Any action items from the audits should be recorded and tracked through resolution and close out.

ii. Quality Assurance of the tier 1 contractors

Licensees and their tier 1 contractors should ensure that they have properly scrutinised and accepted the quality arrangements for their supply chain. This should be on a graded basis considering the services to be provided and attention should be paid to the priority of company quality arrangements in alliances and joint ventures.

The commissioning manager should note that whilst the contractor may have ISO 9001 and similar credentials these standards are well below those expected in the nuclear industry. If the contractor is already on the preferred supplier list then care should be taken to ensure that the specific commissioning capabilities of the supplier have been audited.

For significant commissioning projects, the commissioning manager should consider a specific audit of the proposed contractors prior to contract award as this would focus on their specific arrangements for delivering the defined scope of the contract. This would also include recruitment, training, competence assessment and other elements that support the licensee's adherence to their licence conditions.

It is standard practice for a graded approach to be applied to the performance of quality assurance audits depending on the significance of the project and the work being conducted. The grading criteria will include nuclear safety, industrial safety, environmental and security categories but may also include business, schedule and capital risk. When this grading has been determined there should be a clear documented link to the appropriate requirements and these should then be used by the commissioning manager to instruct or conduct periodic audits.

iii. Quality Assurance of the tier 2 contractors

The commissioning manager should consider the scope of work which has been sub-contracted by the tier 1 contractor to their supply chain and should ensure that the graded approach is applied to the scope of tier 2 contractors. The tier 1 contractors audit arrangements of their tier 2 contractors should be described in the Contractors Quality Plan to ensure that appropriate Quality Arrangements are maintained.

The licensee's auditors should consider what requirements are necessary for an audit on a tier 2 contractor and to ensure that these are reflected in any audit conducted on them by the tier 1 contractor.

b. Quality Control

The commissioning manager should check that appropriate records are submitted by the contractor and that these are accepted by the licensee. It is essential that the records required to be submitted for commissioning are clearly specified in the contract deliverables. This could include the records of:

- any FATs conducted (e.g. procedures and completed test sheets and test reports).
- any regulatory compliance certificates, e.g. pressure tests or lifting certificates.

From a licensee's point of view the quality control is the evidence that the work required has been completed to the specified standard and has been verified as complete. This is essential as a life time record which the maintainers and operators will rely upon for the lifetime of the plant.

9. Non-conformance management, rework and troubleshooting

Author: Sam Billington and Dave Brophy

a. Non Conformance Process

All licensees will have a non-conformance process to follow. This will typically be driven by the quality department and therefore the commissioning process should integrate into this existing process as closely as possible. A detailed discussion on this quality process is beyond the scope of this manual but a high level summary of the steps are:

- Record, reject or accept and categorise the non-conformance.
- Identify and conduct a technical assessment.
- Accept or reject the item based on the outcome of the technical assessment, retaining appropriate records.
- If a component(s) is to be rejected, then ensure that it is identified and marked to ensure that it is not inadvertently introduced to plant and evidence of disposal (return to OEM, scrapping, recycling etc.) is retained.
- If rework is required, then this is planned and executed and appropriate records retained.
- Closure of the non-conformance is recorded.

The commissioning process, if not stated in the licensee's process, should state what commissioning events trigger the raising of a non-conformance. Ideally the commissioning process should be integral to the licensee's non-conformance process. Examples of the trigger events are listed below:

- The equipment does not function to the design intent.
- The commissioning acceptance criteria are not met.
- The equipment has intermittent fault(s).
- The operations, commissioning or other stakeholder questions the design intent.
- Omissions within construction prevent commissioning.
- A defect occurred during the testing including FATs and IWT.
- A safety related issue has been identified with equipment during Commissioning.
- (Dependant on the licensee's definitions) Raising of a commissioning reservation and or observation.

The process should clearly state who can raise the non-conformance and who approves the non-conformance.

There should be a grading process which for the most severe cases prevents further use of the equipment, less severe cases may prevent progressing to the next stage of testing or handover and those minor cases which have no safety and only minor operational and maintenance significance where operation can continue.

The process should also clearly state the departments and minimum grade or person to be informed and or consulted for each type of non-conformance.

To close out the non-conformance there should be an agreed list of person(s) who can close out the non-conformance.

b. Rework & Troubleshooting

Within the process there should be a route to perform troubleshooting after a non-conformance has been identified. This troubleshooting may take place on plant and therefore there should be a process in place to allow further investigation and operation.

Where the cause of the non-conformance is unclear a period of troubleshooting may be required. In this case the challenge will be accessing knowledgeable expertise in the components so the commissioning manager should ensure that there is a contractual route to access this expertise, in particular the OEMs. So for schedule critical projects consideration should be given to having the SQEP OEM personnel on site.

Rework may be necessary and this may then require repeating all or part of the testing and the process and the test procedures should allow for this eventuality.

Physical rework may also be required, for example the removal and replacement of a component and a procedural route for this should also be available both in the commissioning arrangements but also in the test procedure. In this instance, depending on the significance of the rework the commissioning manager may deem it appropriate to hand back (a part of) the system to construction to perform the rework.

In all cases the following will need to be considered:

- What testing can safely continue on the affected system?
- What testing can safely continue in the area of the re-work?

- Is the design going to change and if so what is the impact on the test procedure?
- What testing has been / will be invalidated and will need repeating?

In all cases the existing management systems should ensure that the appropriate records are detailed for retention.

c. Number of Issues

There will be a significant number of non-conformances and other issues raised during the commissioning phase. Benchmarking of new nuclear power stations suggests that around 5,000 issues (of which non-conformances are a sub-set) would be raised per month and large new process facilities may be around 250 per month during peak construction and through peak commissioning activities. The commissioning manager should take note of the magnitude of the issues and have in place the capability and capacity to administer these issues. There should also be the capacity and capability to assess the response and the impact on commissioning.

10. Security

Author: Sam Billington

a. Security Requirements

Security requirements are determined by a defined threat to the facility. The method of assessing the defined threat is classified so no further discussion of this can be undertaken in this document. The security design team will design the security systems to negate the defined threat and from this a series of system and layout requirements will be derived. The role of the commissioning tests is to ensure that system and layout requirements are met.

The requirements and the evidence from assessment and commissioning testing is gathered in a security case and assessed by the ONR. This process is similar to the nuclear safety case. The steps to perform and document the testing are therefore equivalent to those described elsewhere in this manual.

b. Contract Strategy

When there is a large project this will typically include additional or modifications to security systems, be those detection or access control or other devices. The commissioning manager should consider how to deliver the commissioning of security systems.

The following points may need to be understood and addressed:

- Security design teams are normally specialists and the type and scope of their contract needs to be understood, does this include the design, procurement, installation and commissioning?
- As these are specialist contractors they may well be engaged by the project via a separate contract. The commissioning manager should understand which department holds the security contract.
- The security clearance requirements and the very nature of the security systems and information handled will result in additional restrictions on those individuals and supply chain partners who can perform the scope of work. The impact of a tier 1 supplier sub-contracting this security work should also be considered as information will need to flow from the licensee through the tier 1 contractor to the tier 2 security contractor.

- Should the licensee decide to contract out the commissioning work then the commissioning manager should identify those persons in the licensee organisation who will act as the client (Intelligent Customer) and ensure that they have appropriate security clearances and at least have access to an appropriately secure location and IT system to perform the necessary work. The required security standards for the office location and IT systems should be agreed with the licensee's security team.

c. Security Design Team Location

The commissioning manager should understand and plan where the security design and commissioning teams will be based. The office space and IT network used will need additional security arrangements to be put in place as the security level of the information handled will typically be higher than that of the non-security systems being commissioned. This should be factored into the commissioning plans and costs estimates. The scope of establishing this secure work location and the time taken to accredit the facilities and IT systems should also be understood.

d. Step changes in increasing security requirements

One of the key challenges as mentioned throughout this manual is the understanding of the interfaces and requirements across different departments and teams during the works. The commissioning manager should be aware of when, in relation to a project milestone, the step up in security requirements will take place. This can have a significant impact on the security clearances required to access the project facility.

The project strategy for security should be understood by the commissioning manager and reflected in the commissioning plans. For example, a new build project which is fenced off from the secure area or outside the main facility fence will need to be brought (back) into the main security area. This will necessitate an increased level of security vetting and access restrictions.

The next step change will be prior to the arrival of or entry of nuclear or process material into the project facility at the start of active testing. The commissioning manager should liaise with the project manager and the security team to understand the trigger activity for the increased security arrangements and also the lead time before which the security arrangements need to be initiated. For example, in a new nuclear power station:

- Arrival of first nuclear fuel assembly on site.
- Placement of the first nuclear fuel assembly into the reactor.

And for a nuclear process facility:

- First cask, box or nuclear material / matter entry into the facility.
- First nuclear process effluent entry into the facility.

The commissioning manager should understand the impact of the change in security level to ensure that commissioning activities can continue beyond the change in security requirements. Where necessary the commissioning schedule may need to change so that tests requiring a large number of supply chain contractors are conducted before the increased security arrangements take place.

e. Project strategies to mitigate the increased requirements

Where there is an increased security access requirement the following considerations should be taken into account:

- Large new build sites, in particular twin unit power stations could erect a boundary fence between the two units allowing increased security arrangements in the first unit and continuing lower level security requirement on the second unit which is still in construction. This would effectively create a 'Berlin Wall' through the middle of the site.
- Can new fuel or casks etc be stored elsewhere on site in a temporary facility? This will allow construction and commissioning to continue until there is a more optimum time to bring them into the new facility. The real question to ask is; what are we trying to protect against? Is it someone stealing the nuclear fuel or is it the spread of fission products once it has started fission? Are we concerned about someone accessing the cask or the materials in the cask? Answers to these questions may lead to using a more optimum temporary storage solution.
- Do we need to secure the whole facility or just part of the facility? For a process plant if the boxes remained unopened in the store or for a power station the fuel assemblies remain in the fuel pool or reactor (before criticality) does the whole facility need to be secure or just the area surrounding the casks and assemblies. This would allow the process and waste treatment areas of the facility to remain at a lower security level.

11.Environmental Performance

Author: Sam Billington & Dave Brophy

During commissioning waste material will be produced and the safe disposal of this needs to be considered as part of the commissioning planning as required by the licensee's management arrangements.

The first consideration should be the waste hierarchy which will be familiar to many readers but there are many variants, one of which is described below:

- Reduce the amount of waste generated by reducing the materials and resources used, in particular, packaging and utilities.
- Reuse the materials and resources.
- Recycle the waste.
- Recover the energy from waste or by compositing.
- Disposal.

Taking the first point of the waste hierarchy of reduce the amount of waste produced the commissioning manager should consider how they will reduce the amount of resources used in particular:

- Electrical power,
- Water and demineralised water,
- Gases,
- Fuel and oils.

When considering waste streams the commissioning manager should consider and where necessary address the following points:

- Understand what the waste is going to be and if permits and disposal routes are available.
- Segregation of waste arising at source.
- Identify the opportunity for a supplier to take back an item, typically packaging and transport containers.
- Understand the operational waste produced during commissioning and what its disposal route will be.

- Are there any differences between commissioning and operational wastes? For example, could radioactive wastes be classified as very Low Level Waste instead of Low Level Waste? Are different chemicals e.g. tracers used that would be different to operations and how would this impact the waste?
- Disposal of waste which is not radioactive but in normal operation would be radioactive, for example, ion exchange resins.

Consideration should be given to the point at which radioactive material is introduced to the plant. This will impact the waste strategy as items which could have previously been directed to non-radioactive streams may now have to be sentenced using radioactive waste streams. Also the opportunity to remove wastes from a non-radioactive plant prior to nuclear material being introduced should be taken as this will reduce the burden on monitoring waste prior to leaving the plant and allow wastes to be sentenced using a non radioactive waste route.

Part 5 - Recommendations

Part 5 - Recommendations

The following recommendations are made:

- This manual is distributed amongst the UK nuclear commissioning community for further comment and wider peer review. Feedback would be welcomed by the Editor at the following email address: sam.billington@edf-energy.com
- An electronic copy of this manual is posted on the Nuclear Institute's website.
- An article is to be published in the Nuclear Institute's Nuclear Future magazine to inform the wider UK nuclear community of its publication.
- The NCEF agree to commence work on a further revision of this manual in 2021 with a view to publish in early 2022. This will allow adequate time for the industry to use the manual and to identify errors, inconstancies, omissions or overlaps.
- The NCEF agree that the next revision incorporates a method to allow benchmarking against this manual.

Glossary

Glossary

The following glossary has been developed using specific definitions provided by several licensees and also the IAEA glossary database. The Editor has developed the definitions below as a best fit between licensees' definitions and those of the IAEA's Safety Glossary. Alternative terms are those which are in common use in the UK nuclear industry and are broadly comparable to the term described.

Term	Abbreviation	Alternative Terms	Definition
Acceptance	-	-	The point at which the licensee states in writing that they are content with the work conducted by a contractor. This work can be a document which has been reviewed by the licensee and any issues adequately resolved by the contractor. The work may also relate to a physical item such as a structure, system or component.
Active test	-	-	A test conducted as part of commissioning which forms part active testing. It will be performed in accordance with an approved test procedure and will aim to demonstrate one or more design requirements.
Active testing	-	Active Commissioning	This is the final stage of commissioning and usually starts with the introduction of nuclear fuel or other radioactive material(s). The activities carried out demonstrate that the operation of the integrated structures, systems and components (and their supporting structures, systems and components) meet the requirements, functions and specifications as designed. This stage is conducted by the licensee.
Appointed Commissioning Person	-	-	A person who is competent and has been assessed as suitably qualified and experienced in accordance with LC21(5). Their role is to control, witness, record and assess the results of the commissioning tests. They have been appointed in writing.
Approval (of a document)	-	-	The activity where the appropriate person (either licensee or contractor) signs a document after it has been prepared and reviewed with all issues / comments

Term	Abbreviation	Alternative Terms	Definition
			adequately resolved. Approval of a licensee's document is typically the last step but for a contractor's document it will depending on a graded approach typically then need to be accepted by the licensee.
Area	-	Room(s)	A portion of a building or structure which may be a collection of rooms or part of large building. It may cover more than 1 floor. These areas are typically used by construction to plan the mechanical, electrical, C&I etc fit out.
Arrangements	-	Management / Contractor / Commissioning Arrangements	This is a general term which includes the management system and other documents which guide persons in how to perform the work. These will be developed by companies as well as departments.
Authorised Person	-	Authorised Person / Senior Authorised Person / Duly Authorised Person	A person who has been notified in writing by the licensee that they have been authorised to perform certain activities. Authorised and Senior Authorised Persons usually relate to conventional safety for example, isolating and returning plant to operations. Duly Authorised Persons usually relates to operation of the systems, nuclear material movements and nuclear operational safety. Appointment typically requires a predefined set of qualifications and experience as well as a period of time working under close supervision and successful completion of an assessment interview. Appointments are reviewed on a periodic basis and may be withdrawn by the licensee at any time. The requirement for appointments comes from comes from LC 12.
Business Case	-	Project Business Case	This is a document which is typically prepared early on in the project lifecycle and agreed by

Term	Abbreviation	Alternative Terms	Definition
			the Directors of the company. At a high level it justifies the expenditure for the project against the expected benefit gained as a result of successfully completing the project.
Capability	-	-	This is having the qualifications, knowledge, experience and know how to perform an activity.
Capacity	-	-	This is number of persons who have the capability to perform an activity.
Cold Commissioning	-	-	A stage of commissioning a new nuclear power stations after integrated testing where the performance of groups of systems is demonstrated. These tests are run at room temperature and low pressure, typically with the reactor pressure vessel head removed.
Commercial Operations Date	COD	-	A key milestone towards the end of the commissioning phase. For nuclear power stations this usually relates to achieving 100% reactor power. For nuclear process plant this can be interpreted as the ability of the plant to perform it's required functionality.
Commissioning	-	-	Process during which plant structures, components and systems, having been constructed or modified are made operational and verified to be in accordance with design requirements and to have met the appropriate safety (including nuclear, conventional, environmental) and security criteria. It also demonstrates that operating and maintenance procedures for the new plant are verified and put into practice and operators are made familiar with the operation of the plant.
Commissioning Arrangements	-	-	This suite of documents is part of the licensee's management system and state the how the roles and responsibilities of the commissioning organisation are discharged. The commissioning manual is the top tier document with supporting processes, procedures, templates and guides. There will also be additional documents specified in the commissioning manual which require

Term	Abbreviation	Alternative Terms	Definition
			additional actions or activities to be performed or place other requirements on the commissioning team.
Commissioning Department	-	-	A group of persons who is led by the Commissioning Manager (or Commissioning Director for large projects) and has responsibility to perform the commissioning of project(s) on the licensee's site. The commissioning department typically consists of multiple commissioning teams and supporting teams.
Commissioning Manager	-	Commissioning Director (for large scale projects).	A person who has overall accountability for the performance of commissioning on a site or project. They are the subject matter lead for commissioning and are accountable and or responsible for the compliance with LC 21 and equivalent environmental conditions. They are responsible for the safety, security, quality, time and cost performance of the commissioning department as well as developing the competency and experience of commissioning personnel. They are assessed as competent to approve test procedures, test reports and management systems under LC 21. The commissioning manager will typically maintain a relationship with the Regulators for all aspects of commissioning. They will chair the licensee's Test and Commissioning Panel. They are assessed as SQEP and appointed under LC 21(5).
Commissioning Reservation	-	Fault observation	When a structure, area, system or component fails to meet the requirement a Commissioning Reservation is raised. Typically these are raised by the licensee on their site and by the Contractor / OEM during a FAT. The completion of a commissioning reservation will initiate a non conformance process of reporting, clarification, assessment and remediation or concession.
Commissioning Stage	-	-	There are several commissioning stages which are a time frame where commissioning is

Term	Abbreviation	Alternative Terms	Definition
			developed and closed out as well as groups of similarly challenging tests are performed on the plant. Typical commissioning stages are: • Project Development • Factory Acceptance Tests • Site Acceptance • System Testing • Integrated / Station Testing • Active Testing • Project close out The end point of a commissioning stage is typically a hold point which requires either business, project and or regulatory assessments to be performed and accepted.
Commissioning Strategy	-	-	This is a high level document owned by the commissioning manager which describes how commissioning will be conducted. It will be produced during the Development Stage but is usually replaced with more detailed project documents and arrangements later in the project.
Competence	-	Suitably Qualified and Experienced Person (SQEP)	Competence is the combination of knowledge, skills and attitudes (KSAs) needed by a person to perform a particular post or role. All three are important and interrelate. • Knowledge is familiarity with something and can include facts, descriptions and information acquired through experience or education. It can refer to both the theoretical and the practical understanding of a subject. • Skill is the learned capacity to perform a task to a specified standard. • Attitude is the feelings, opinions, ways of thinking, perceptions, values, behaviour and interests of an individual which allow a role or task to be undertaken to the best ability of that individual. Attitudes cannot wholly be taught directly and are partly a consequence of the organizational culture.
Component Testing	-	-	This is a stage of commissioning where the performance of individual components is

Term	Abbreviation	Alternative Terms	Definition
			demonstrated. This is typically performed in a de-energised state.
Construction Contractor	-	-	An entity who, on behalf of the licensee, performs the construction and typically the installation of equipment scope of the project.
Construction Design and Maintenance Regulations	CDM Regulations	-	Construction Design and Maintenance Regulations Act 2015.
Construction Team	-	-	The group responsible for the construction / installation of the project typically on the licensee's site. This could be performed by the licensee, contracted out under the management of the licensee or fully contracted out as part of a larger engineering, procurement, construction contract and managed by a tier 1 contractor.
Design Authority	DA	-	A department in the licensee's organisation that develops the safety, security and environmental cases. The Design Authority therefore ensure that the design provided by the engineering team complies with various cases. Therefore, the Design Authority is separate from the engineering department. Note: For the purposes of this manual the Design Authority owns the all the relevant cases but the reader should note that some licensee's may have a separate department for the environmental and security cases.
Engineering, Procurement and Construction	EPC	-	A scope of work contracted out by the licensee to design, procure, build and install the equipment. The licensee will oversee these activities and will then perform the commissioning or contract out the inactive testing.
Engineering, Procurement, Construction and Commission	EPCC	-	A scope of work contracted out by the licensee to design, procure, build and install the equipment and then perform inactive testing. The licensee will oversee these activities and will then perform active testing.
Engineering	-	-	A department within the licensee's

Term	Abbreviation	Alternative Terms	Definition
Department			organisation responsible for setting design standards as well as the design of the structures, systems and components of the project to be commissioned. This could be performed by the licensee, contracted out under the management of the licensee or fully contracted out as part of a larger engineering, procurement, construction contract and managed by a tier 1 contractor.
Environmental Regulator	-	-	There are 4 environmental regulating bodies for the United Kingdom, the applicable body will depend on the location of the licensee's site: • England – Environment Agency • Scotland – Scottish Environment Protection Agency • Wales – Natural Resources Wales • Northern Island – Northern Island Environment Agency.
Embedded contractor	-	-	A person employed by a contractor who fills a post in the licensee's organisation and therefore works under the licensee's arrangements and will have delegations of authority similar to that of the licensee's employee and whose day to day activities are set by the licensee and not via a contracted scope of work.
Factory Acceptance Test	FAT	-	Testing at an off-site facility of individual or grouped systems or equipment that is controlled and documented to demonstrate that they meet required criteria. Typically these tests are run by the contractor and may be witnessed by the licensee and in the most significant cases by the ONR.
Factory Release	-	-	A process by which the OEM provides a manufacturing report and supporting evidence to the licensee. The licensee may audit the report and evidence on a graded basis. On satisfactory completion of their assessment the licensee will issue a release certificate to allow the OEM to ship the component(s) or

Term	Abbreviation	Alternative Terms	Definition
			equipment to the licensee.
Final Investment Decision	FID	-	A project hold point which requires shareholder and investor permission. This is typically when a more precise cost estimate has been developed and prior to a significant increase in spend rate caused by mobilising site works. By this point there is a much higher degree of design certainty.
Functional Requirement	-	-	A requirement placed on a structure, system or component to perform a function to achieve at least the minimum acceptable standard as stated in the design documentation. These functional requirements are derived as part of the design process to ensure nuclear, environmental and industrial safety. The significant proportion of commissioning tests will demonstrate that the plant meets the minimum requirements of the functional requirement.
Graded approach (to commissioning)	-	-	A licensee will have a structured method of categorising structures, systems and components based on their significance to a combination of nuclear, environmental, industrial safety or security. This can often be coupled with business criticality such as an expensive component with a long supply lead time or a single point vulnerability within a system which on failure will have a negative impact. By applying a graded approach to commissioning the licensee focuses its commissioning resources on the higher (ie more significant) grades. This is manifested as an increased level of review, witnessing and governance applied to the structure, system or component and its associated documentation and records.
Handover	-	-	A point in time where the responsibility for a structure, system or component transfers from one entity or department to another.

Term	Abbreviation	Alternative Terms	Definition
Handover Boundary	-	-	A set of defined points on a P&ID and or electrical single line diagram or layout diagram which are the limits of the structure(s) or system(s) being handed over.
Handover Boundary Pack	-	-	A document with supporting information written by commissioning and agreed with construction to aid communication of the state of the structure(s) and system(s) being handed over.
Hold Point	-	-	Hold Point is a mandatory verification point beyond which work cannot proceed without approval by a defined person or committee. The work cannot proceed until the quality of the completed work has been assessed as adequate.
Hot Commissioning	-	-	A stage of commissioning a new nuclear power stations after integrated testing where the performance of groups of systems is demonstrated. These tests are run with the reactor pressure vessel at or near normal operating temperature and pressure.
Inactive Testing	-	-	All testing which are conducted prior to the introduction of nuclear fuel or radioactive process material to the new plant.
Inactive test	-	-	A test which forms part of the inactive testing stage of commissioning.
Integrated Testing	-	-	This is a stage of commissioning after system testing and prior to nuclear material being introduced in which the interaction between multiple systems is tested. Typically, these are either to demonstrate an end to end process or high level plant response to a significant emergency such as a reactor coolant leak or loss of off-site power, the response to which requires the initiation of multiple different systems.
Integrated Works Testing	IWT	-	Where a group of components or equipment is brought together in an off-site location and tested, typically this will be designed to test a

Term	Abbreviation	Alternative Terms	Definition
			system or part of a system.
Post Profile	-	-	A document typically produced by the line manager and Human Resource which states the accountabilities, responsibilities and activities of the person(s) assigned to that post ie a box on the organisation chart and filled by 1 or more persons. It can also state qualifications, training and experience levels necessary and therefore forms an input to the recruitment for that post and also assessment of competence of the person(s) in that post. A post profile can be a collection of role profiles which describe similar groupings of activities to be performed by the post holder.
Licence Condition	LC	-	The licensee is granted a Nuclear Site License by the ONR under the Nuclear Installations Act 1965. This license has 36 conditions attached which must be met by the licensee.
Licensed Site	-	Nuclear Licensed Site	This is an area of land as defined in the Nuclear Site Licence and visibly marked on the ground (typically as a blue painted line) or sign posted boundary fence as required by LC 2. A licensed site is owned and operated by a single licensee.
Licensee	-	Nuclear Licence Holder, Site Licence Company (SLC)	A corporate entity which holds a Nuclear Site License granted by the ONR issued under the Nuclear Installations Act 1965.
Lifting Operations and Lifting Equipment Regulations	LOLER	-	Lifting Operations and Lifting Equipment Regulations (1998)
Management System	-	-	This will he headed by the licensee's company manual and policies, under which there will typically be directorate manuals then departmental manuals, processes, procedures, templates and guides.

Term	Abbreviation	Alternative Terms	Definition
			The licensee's management system (or parts thereof) is subject to ONR approval under LCs 17 and 21 amongst others.
Manufacturing Report	-	-	This is a document prepared by the OEM and is submitted to the licensee. It contains information and evidence of the work conducted to procure the materials, component(s) and assembly of the equipment. It is used by the licensee to ensure that the component and equipment have been correctly manufactured and if accepted the licensee will issue a release note allowing shipment of the component(s) and equipment to the licensee's site.
Maintenance	-	-	This is the collective activities which for the purposes of this manual include planned and emergent (ie defect rectification) work on SSCs as well as those of routine examination, inspection, maintenance and testing.
Maintenance Instruction	-	-	A written document which forms part of a hierarchy of documents which describes how the plant, structures, systems and components shall be maintained. The documents are prepared using design information from engineering or the contractor and are validated during the commissioning phase. This document suite is typically owned by the maintenance department.
Notification Point	-	-	Similar to a hold point but there is no mandatory requirement to wait for approval to pass through the Notification Point. The approving person or committee must be notified such that they are able to perform an assessment as necessary.
Nuclear Baseline	-	-	This is a subset of the licensee's organisation which perform key nuclear safety roles. Persons fulfilling these nuclear baseline posts or roles are subject to greater scrutiny of competence. Changes to the licensee's organisation which impact the nuclear baseline have to be assessed and approved.

Term	Abbreviation	Alternative Terms	Definition
			These arrangements are in compliance with LC36.
Nuclear Circuit Cleaning	NCC	-	A particular activity conducted during commissioning in which the systems connected to the primary circuit are flushed towards the Reactor Pressure Vessel and the Reactor Pressure Vessel is then subsequently cleaned.
Nuclear Safety Committee	NSC	-	A high level licensee committee which reviews the arrangements for all significant nuclear activities on the site. This is mandated by LC 13. The committee is composed of senior and experienced employees of the licensee as well as external members.
Observation	-	Commissioning Reservation	A record generated by the commissioning team (or other team) which identifies a condition which needs further investigation. It may not be a non-conformance against a specification or an anomaly identified during testing.
Operations Department	-	-	The group of licensee's employees who will operate the plant which is being commissioned. Typically, they are the customer of the commissioning team and as such will take handover of the SSCs from the commissioning team at the agreed time.
Operating Instruction	-	-	A written document which forms part of a hierarchy of documents which describes how the plant, systems and components shall be operated. The documents are prepared using design information from engineering or the contractor and are validated during the commissioning phase. This document suite is typically owned by the operations department.
Original Equipment Manufacturer	OEM	Supplier / vendor / manufacturer	The organisation which typically design but will also fabricate and assemble components or equipment ultimately to the project.
Performance Criteria	-	-	Structures, systems and components are required to achieve a minimum standard, this may be a defined flow rate at a certain pressure, detect and respond to an initiating

Term	Abbreviation	Alternative Terms	Definition
			event in a certain timeframe. These criteria will be defined in the design documentation and commissioning will aim to demonstrate that the performance criteria have been achieved. Failure to meet the minimum performance criteria will result in a non-conformance.
Permit for Work	PfW	Safe System of Work	The documented granting of permission to conduct an activity on or in an SSC. For the purposes of this manual it also includes the associated prior assessments of hot work and confined space clearances, working at height and over water etc., reviews of risk assessments and method statements well as control of entry into radioactive and or contaminated areas. This process forms a significant input into the work management process.
Phase	-	Project Phase	A project is divided into discreet phases, one of which is commissioning, others may be initiation, design and construction. The definition of the phases will be described in the licensee's arrangements.
Plant	-	-	A defined collection of structures, areas, systems and components which are part of the licensee's site and are owned and operated by the licensee.
Plant Test Schedule	-	-	A list of tests developed using the regulatory, business and functional requirements amongst other sources. This schedule is the scope of the commissioning testing.
Prepare (a document)	-	-	The activity associated with authoring a document, developing a spreadsheet or drawing a CAD file etc.
Pressure Systems Safety Regulations	PSSR	-	Pressure Systems Safety Regulations (2000)
Project Execution Plan	PEP	Project Plan	Every project should have a Project Execution Plan (or similar) there may well be a subsidiary Plans for significant projects, such as the

Term	Abbreviation	Alternative Terms	Definition
			design, construction and commissioning plans. The PEP contains a range of information regarding how the project will be conducted. This will include scope, strategy and engagement with other departments, contractors and stakeholders. The PEP and the subsidiary documents form part of the arrangements.
Provision and Use of Working Equipment Regulations	PUWER	-	Provision and Use of Working Equipment Regulations (1998)
Qualification	-	-	A certificate held by a person on successful completion of a training course and assessment. These can be either the licensee's own courses, those of an academic institution / organisation, external training organisation or professional body etc.
Site Acceptance Test	-	SATs	A test of the equipment on the licensee's site to check performance usually prior to acceptance of the equipment.
Site Safety Committee	-	-	This committee will approve low level safety significant documentation and review higher safety significant documentation. This committee is below the Nuclear Safety Committee and is typically chaired by the Site Director with representation from engineering, operations, maintenance, assurance, projects.
Stage	-	-	Part of the commissioning phase where similar activities are conducted. For example, preparation, Factory Acceptance Tests, Nuclear Circuit Cleaning etc.
Start of Nuclear Construction	-	-	This marks the start of construction of a nuclear significant structure or alteration to a nuclear significant plant. This is always a significant project hold point and is usually a high level regulatory hold point.
System Testing	-	-	Where a group of previously tested and connected components are tested as part of system or sub-system to demonstrate the

Term	Abbreviation	Alternative Terms	Definition
			performance requirements of that system or sub-system. This forms part of cold commissioning and is performed without radioactive material present so is also part of inactive testing.
Test Anomalies	-	Commissioning Reservations	When performing a test an event or indication(s) are identified which are not expected.
Test & Commissioning Panel	T&CP	Commissioning Committee	A panel chaired by the commissioning manager (or delegate) which the commissioning strategies, test documentation are scrutinised. Membership will typically include engineering, construction, design authority, commissioning, operations and maintenance.
Test Instruction	-	-	A step by step guide to the commissioning engineers and technicians on how to complete the commissioning test.
Test Report	-	Commissioning Report	A document prepared by commissioning which describes a test or group of tests which have been conducted on the new plant. This report contains amongst other things the test instruction, the test results and other appropriate information to allow assessment that the test has been conducted correctly and the results are acceptable. This forms part of the safety case and also the lifetime records.
Test Specification	-	-	These documents can be prepared by the designers or commissioning and contain the following information: • Brief description of the test(s). • Functional requirements to be demonstrated by the tests. • Pass fail criteria for the tests.
Tier 1 Contractor	-	-	A corporate entity contracted to provide significant works on a project or to provide a service to enhance skills and knowledge of a licensee. In a new build project this may be a specific contract for the design, construction or

Term	Abbreviation	Alternative Terms	Definition
			commissioning of plant. Or for business as usual this may the enhancement of resource to support the licensee skill sectors such as design, maintenance and project management. A tier 1 contractor will typically have a several sub-contractors supporting their scope for supply.
Validate	-	-	To perform an activity including testing either on plant or in a simulator to check that the item to be validated is correct.
Work Management	-	-	The activity of planning activities e.g. maintenance, EIMT, outages, plant operations in a controlled and deliberate manner (with appropriate assessments) to ensure nuclear, environmental, industrial safety and security are not compromised.

Appendices

Appendix 1 – Competency Assessment

This appendix provides a structure for an assessment template.

1. Scoring and definitions

This section establishes the scores required to demonstrate competence. The scores (or averages thereof) are used to determine the grade of the employee.

The following competency and grade descriptions are applied:

- Head of Commissioning Function - To lead, manage and provide direction within the Commissioning Function to meet the licensee's strategic goals. To provide due governance and management of the Commissioning Function to meet nuclear Licence Conditions, QMS and Project Delivery processes and procedures. Ability to manage a portfolio of projects and activities across the licensee's business to meet the safety, quality, cost, resource, programme and acceptance criteria within agreed scopes of work that demonstrates that the design intent has been achieved. To maintain and ensure the highest professional and ethical standards are met by all staff.
- Commissioning Manager - Holds an appropriate qualification in a relevant discipline accompanied normally [to be confirmed] years' experience in a commissioning environment. Has a proven track record of managing commissioning arrangements. Can lead a multi-discipline team to safely execute the commissioning. Has excellent awareness of Health and Safety Legislation. Ability to Chair a Test and Commissioning Panel. Communicates effectively with Stakeholders including other personnel representing other departments of the licensee, manufacturers and sub-contractors. Capable of managing one or multiple projects.
- Senior Commissioning Engineer - Holds an appropriate qualification in a relevant engineering discipline and at least [to be confirmed] years' experience in a commissioning environment. Has extensive knowledge of equipment to be commissioned on the licensee's sites or comparable external knowledge. Able to organise and execute complex commissioning tests and analyse results. Has good understanding of Health and Safety. Good communication skills. Ability to Chair a Test and Commissioning Panel when nominated by a commissioning manager.
- Commissioning Engineer - Holds an appropriate qualification in a relevant engineering discipline. Has [to be confirmed] years' experience in a commissioning environment. Ability to Chair a Test and Commissioning Panel when nominated by a commissioning manager. Able to undertake commissioning responsibilities from instigation to handover. Can originate and review test and commissioning documents.
- Commissioning Technician - A person with limited commissioning experience. Has a background in a relevant engineering discipline. Will work under the guidance of a person or persons competency assessed as a senior commissioning engineer or commissioning manager.

2. Qualifications, Legislation and Company Policies

The next section usually will focus on the general requirements across each of the grade definitions and will be a mandatory part of the assessment for all personnel such as:

- Training & Qualifications
- Academic qualifications

- Professional Memberships
- Demonstrable Commissioning experience
- Specific licensee training received
- Legislation
- Health & Safety at Work Act and associated regulations
- Statuary Bodies
- Licence Conditions
- Company Policy
- Company Policies
- Licensee's Management Systems & Guidance Documents
- Commissioning Manual, Procedures and Work Instructions
- Safe System of Work / Permit for Work process
- Risk Assessments & Method Statements etc.
- Safety Cases / Justification

3. Component and System Commissioning

For those managers, engineers and technicians working on Commissioning components and systems the following topic areas are assessed. The assessment looks at the equipment typically forming part of system and the order in which this shall be commissioned. Personnel are expected to achieve competence in 1 or more of the discipline areas:

- Building Services
- Nuclear plant ventilation
- Air Handling Units
- Refrigeration & Chillers
- Vacuum Systems
- Compressed Air systems
- Implications of working at height, in confined spaces, on MWUPs, on ladders, in hot and cold environments and using access platforms and scaffolding.
- Process & Mechanical
- Glove Boxes, Machine tools etc.
- Pump & Fan systems
- Fluid storage and piping systems, tank levels, valves etc.
- Cranes & Lifting devices
- Pressure testing (inc codes of practice and legislation)
- Electrical components
- Electrical Protection including fuses, Circuit Breakers and RCD.
- Un-interruptible Power Supplies (inc batteries, flywheel generators)
- Inverters
- Emergency lighting, battery and chargers and illumination levels.
- Electrical testing including live testing of circuits and authorisations required.
- Instrumentation and Controls
- Temperature control systems
- Controllers (programmable or PLC with Human Machine Interface)
- All subject areas need to understand the following:
- Temporary commissioning aids
- Modification process
- Safety Systems including industrial safety and safety mechanisms, devises and circuits (SMDCs).

- Specialist Areas
- Software
- Disaster Recovery procedures
- PCB
- Fire Systems
- Fire Alarms and Public Address systems
- Radiological (for the nuclear areas)
- Identify the radiological hazards and barriers.
- The successful completion of the appropriate the licensee courses

4. Management of Commissioning

The following topic areas are required for Commissioning Engineers, Managers and the Head of Commissioning Function:

- Technical Commissioning
- Pre-Commissioning Requirements such as test procedures, risk assessments, configured drawings, equipment manuals, construction handover certificate etc.
- Commissioning process and documentation such as design reviews, specifications, FATs, STW, SATs
- Test & Commissioning Panel and the activities controlled by the T&CP.
- Familiarisation (training) – Operators and Maintainers and validation of operating instructions.
- Resource Planning
- Budget and control including resource estimation, control and minimisation of costs
- Develop resource estimates for each discipline and timescales
- Service requirements – reducing the requirements, minimisation of usage and spares.

5. Leadership, Attitudes and Behaviours

The following topic areas are required for both Managers and the Head of Commissioning Function. These are typically measured against the licensee's leadership and behaviours model:

- A delivery focused on:
- Stakeholder engagement.
- Judgement and Decision making.
- Results focused.
- Building Function Capabilities
- Building engagement with other Departments
- Empowering and delegation to the team
- Champions diversity
- Effectiveness and Efficiency
- Leads innovation and change
- Leads high performance

6. Assessment and Actions

At the end of the assessment form there should be a verdict on the grade achieved and the assessment should be reviewed with the employee. Where the assessment is conducted as part of a new role or with a view to achieving promotion to the next grade then actions to close any gaps should be clearly stated.

Appendix 2 – Commissionability

A list of standard questions for commissionablity reviews are listed below. The licensee should consider developing these further or making them more focused. This also provides an ideal opportunity to apply captured learning from experience.

- Examine the commissioning logic diagram to ensure this is comprehensive and the most logical and efficient commissioning route and identifies those tests which must be carried out sequential or will be part of the critical path. The logic should identify significant hold points with key deliverables for their approval.
- Validate that the design as presented can be commissioned as installed.
- Check the system components will be compatible e.g. control systems and instrumentation and plant components.
- Check that the safety related systems and equipment are specifically identified and commissionable.
- Check that any proposed design change will not have adverse effects during commissioning, operation or fault conditions within the project scope.
- Check the control system will operate as designed against the functional requirements.
- Check the equipment is capable of being operated by a trained operator. Highlight any overcomplicated design or operating features which should be addressed by a human factors expert.
- Check that equipment is accessible and if access is difficult or limited, then highlight access provisions required. This may require scaffolding, platforms or plant changes, such as moving measuring or injection points to a more accessible location.
- Review access and egress provision to ensure that components can be safely moved into or out of position within the system, area, room and plant.
- Identify / check location of any specific measuring points, either for commissioning or to be used by operations and maintenance during operations.
- Identify any temporary commissioning aids, tools and equipment required for commissioning and where and how they will be fitted.