NOT MEASUREMENT SENSITIVE

DOE G 423.3-23
8-30-2019

Nuclear Facilities Commissioning

[This Guide describes acceptable, but not mandatory means for complying with requirements. Guides are not requirements documents and are not to be construed as requirements in any audit or appraisal for compliance with associated rules or directives.]

U.S. Department of Energy
Washington, DC

AVAILABLE ONLINE AT:
www.directives.doe.gov

INITIATED BY:
Office of Project Management

FOREWORD

This Department of Energy (DOE) Guide, for use by all DOE elements, assists with developing a checkout, testing, and commissioning plan in preparation for acceptance and turnover of the structures, systems, and components produced by the project in advance of startup.

This DOE Guide provides acceptable, but not mandatory, means for complying with requirements included in DOE Order 413.3B, *Program and Project Management for the Acquisition of Capital Assets*. This DOE Guide does not impose, but may cite, requirements. Guides neither substitute for requirements nor replace technical standards that implement requirements. Send citations of errors, omissions, ambiguities, and contradictions found in this guide to PMpolicy@hq.doe.gov.

CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

1. PURPOSE OF THE GUIDE

This guide addresses best practices for planning and executing the commissioning of equipment, components, structures, and systems comprising nuclear facilities. The best practices in this guide come from recent lessons learned from nuclear construction projects. The Department of Energy (DOE) has restarted or started up nearly 200 nuclear facilities since 1992. Projects that follow this non-mandatory guidance will have a thorough, carefully planned process for confirming that nuclear facilities conform to design requirements thus increasing the likelihood that they will perform as intended following the introduction of radioactive materials.

Commissioning occurs between construction and full operations although, preparations begin during conceptual design. Commissioning and startup bring a facility from the construction phase to stable operations in a manner that confirms attainment of functional requirements and design objectives, demonstrates system operability and reliability, and establishes a base for long term operation in accordance with contract requirements. This process ensures all facility equipment, structures, components, and systems perform interactively in accordance with the design documentation and intent, and in accordance with operational needs including training and preparation of operations personnel.

This guide primarily applies to new construction of Hazard Category 1, 2, and 3 nuclear facilities and below Hazard Category 3 nuclear facilities regardless of the source of the radioactivity.

For nuclear facilities, a readiness review (RR), either an operational readiness review (ORR) or a readiness assessment (RA), precedes authorization to operate and occurs concurrently with Critical Decision (CD)-4, *Approve Start of Operations or Project Completion*. Current project experience suggests that commissioning and startup planning should begin early in the design, continue through project completion, and involve research and development and operations personnel. Interfacing with these organizations early in the design will reduce startup and testing schedules because these organizations will have a better understanding of the facility, reducing rework, and improving process knowledge.

2. COMMISSIONING RELATED REQUIREMENTS IN DOE ORDER 413.3B

DOE Order 413.3B, *Program and Project Management for the Acquisition of Capital Assets*, includes requirements related to commissioning, not all of which this guide addresses.

Table 1: DOE Order 413.3B Requirements Related to Commissioning

Item Number	Requirement	Source	Deadline	Location in this Guide
1	"For nuclear facilities, develop a Checkout, Testing and Commissioning Plan in preparation for acceptance and turnover of the structures, systems and components at CD-4. (Refer to DOE-STD-1189-2016.)"	Appendix A, Table 2.1	Post-CD-1	Appendix D

Item Number	Requirement	Source	Deadline	Location in this Guide
2	"The Program Office must determine if hot commissioning (i.e., introduction of radioactive material) is a condition of CD-4. Ultimately, the capital asset must have the capability to meet the end-state capacity requirements approved in the CD-2 decision by the respective [Project Management Executive], but not as a condition of CD-4."	Appendix A, Section 5(d)	Pre-CD-2	The guide does not address hot commissioning
3	"The Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings . . . must be applied to the . . . commissioning of new facilities and major renovations of existing facilities."	Attachment 1, Section 15	Pre-CD-4	The guide does not address commissioning of conventional equipment and systems.
4	"[Other project costs] will include . . . commissioning costs."	Attachment 2, Definition 77	N/A	The guide does not address costs.

The Office of the Chief of Nuclear Safety, Office of Environmental Management (EM), published *Design and Commissioning Report*, Revision 1, in July 2017 to further identify commissioning plan needs. This report resolved an Office of the Inspector General finding related to EM projects and issues pertaining to commissioning and startup. The report, although written for the consideration of EM projects, may apply to other programs' capital acquisition projects. Using this report and the documents listed in Appendix B, a working group of the Energy Facilities Contractors Group prepared the first draft of this guide.

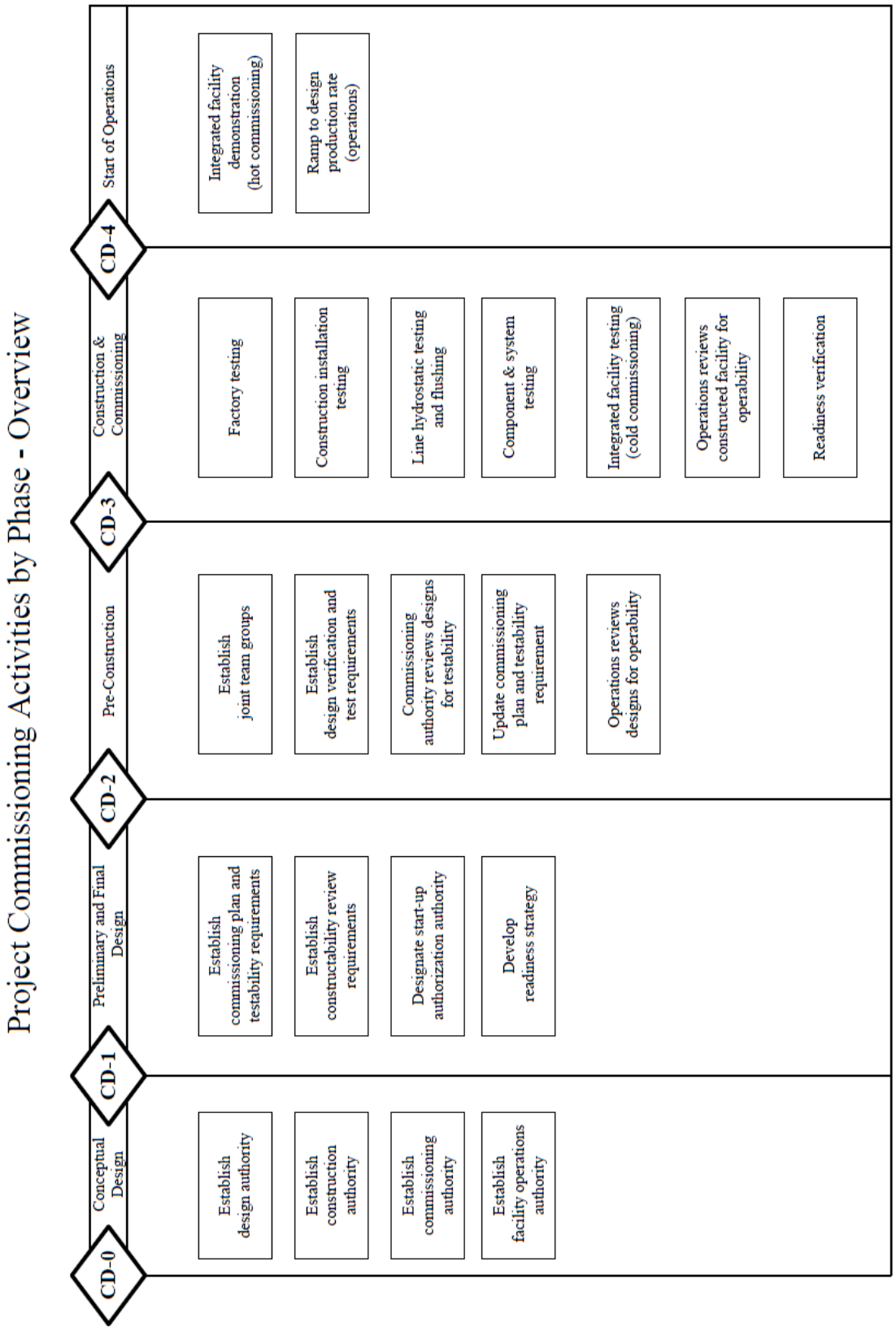

Figure 1: Commissioning Activities Overview

3. PROJECT MANAGEMENT CONSIDERATIONS FOR COMMISSIONING AND STARTUP

This section focuses on the activities in each project phase necessary to prepare a nuclear project for commissioning prior to the RR. Figure 1 depicts commissioning-related activities within the framework of critical decisions. Critical decisions structure this section.

3.1. Pre-CD-0: Initiation Phase

No commissioning-related activities occur prior to establishing a mission need.

3.2. Pre-CD-1: Definition Phase

While updates to the commissioning plan continue until prior to CD-4, the commissioning process begins early in the project in order for the transition to operations to occur efficiently. Prepare an initial commissioning plan in advance of the requirement to complete a commissioning plan following CD-1. Engage early with commissioning authorities to coordinate schedules and resource needs in advance of setting a performance baseline.

Following CD-0 during conceptual design, commissioning planning includes identifying federal personnel who will provide, track, and ensure fulfillment of commissioning related requirements along with developing an initial testing approach and set of testability requirements to inform the design process. This informs the approach to achieving the key performance parameters.

Best Practice: *Early in the definition phase, development of the checkout, testing, and commissioning plan begins with the initial evaluation of systems and identification of preliminary testing requirements.*

Identify early in the project initial considerations for developing an organizational structure that includes adequate design interfaces, testing, and operations. The testing program engages in the procurement process to ensure testability, maintainability, and operability of acquired components and general plant layout. The program can also engage in setting factory acceptance testing requirements to ensure a smooth transition to plant testing following equipment installation in the plant. Engineering defines the functional acceptance criteria for testing.

Best Practice: *Include in the project scope a simulator or pilot plant if the process or operating system has a low technical readiness level, has a high complexity, or large size. The simulator or pilot plant offers an opportunity to hone commissioning techniques planned.*

3.2.1. PH

Best Practice: *Use DOE's "Readiness Certification Assurance Process Tracking System (RCAPTS)" to retain documents and records in an easily retrievable way through hypertext links that establish a relationship between related test, performance, acceptance, procedural, and lessons learned information. Obtain from* https://go.usa.gov/xyQj2.

3.2.2. Pre-CD-1 Design Considerations

Perform an alternatives analysis for permanent plant design features or temporary modifications supportive of testing. Address the following factors that influence commissioning and startup processes in the alternatives analysis:

1. Technology Readiness Level for Systems – The level of experience with the specific processes, the degree of complexity, and the design maturity level of the components provide information relating to the need to incorporate a pilot facility in the project's scope.

2. Processing fluids – As the concentration of suspended and dissolved solids anticipated in the process lines increase, the complexity of commissioning and operations will likely increase.

3. Radiological conditions - Source term, radiation levels, material radiation tolerance and other special considerations addressed in the nuclear safety design strategy may require commissioning approaches which differ from consensus standards and industrial norms.

4. Obsolescence – Due to the length of nuclear facility projects, materials and equipment available during design may become obsolete prior to testing. Select easily replaced or upgraded instruments and control systems preferably situated outside of radiological zones.

5. Interface with existing facilities and systems – Hazards and regulatory requirements stemming from nearby existing facilities may impact new projects and their systems. Interfaces include:

    a. Systems such as waste transfer pipes to isolate the new facility from the existing facilities;

    b. Capacities of, and interface with, fire protection systems; and,

    c. Pressures in new systems connected to existing systems.

6. Configuration management – Maintaining configuration management will facilitate efficient commissioning. Have the cognizant system engineer define boundaries, operations system, and how they relate to functional areas and construction zones early. Establish a configuration control process to support tracking of design inputs, outputs, and validation via testing, inspection, calculation, or other means. Delineate a design change notification process. Retain assumptions used to develop the design or proof of process in a configuration management system that provides traceability later for system design description development and provides a basis for operation. DOE Guide 413.3-1, *Managing Design and Construction Using Systems Engineering*, addresses configuration management.

Best Practice*: Establish the code of record prior to CD-1 but consider proposals to update it if a project assumption does not bear out.*

7. Test requirements – Test requirements for commissioning, regardless of their origin, need documentation in the configuration management system, controls, and need to trace back to the design. Testing validates components against commercial grade dedication criteria. Having the

ability to isolate systems through valves or other testable boundary allows testing and turnover to occur at logical points and often allows for less complex individual testing prior to integrated tests.

Best Practice: *Have the design agency track design authority requirements on a system basis along with component and system test criteria during design. A joint board including engineering, configuration management, and startup or commissioning personnel ensures the efficacy of the test requirements prior to approving the criteria.*

3.2.3. Pre-CD-1 Construction Considerations

1. Acquisition and Tailoring Strategy – Projects planning to acquire multiple facilities, whether nuclear or non-nuclear, but do not anticipate placing all facilities into service contemporaneously, may benefit from phasing CD-4. This will simplify scheduling the startup authorization authority (SAA) approvals to start hot operations so that they occur shortly before CD-4 approval.

2. Accessibility – Accommodate testing and commissioning activities when considering plant and equipment layouts. Avoid minimizing the physical size of the facility at the expense of the ability of construction or testing staff to perform work. Verify related requirements with operations personnel. Select places for valves needed to isolate areas for testing.

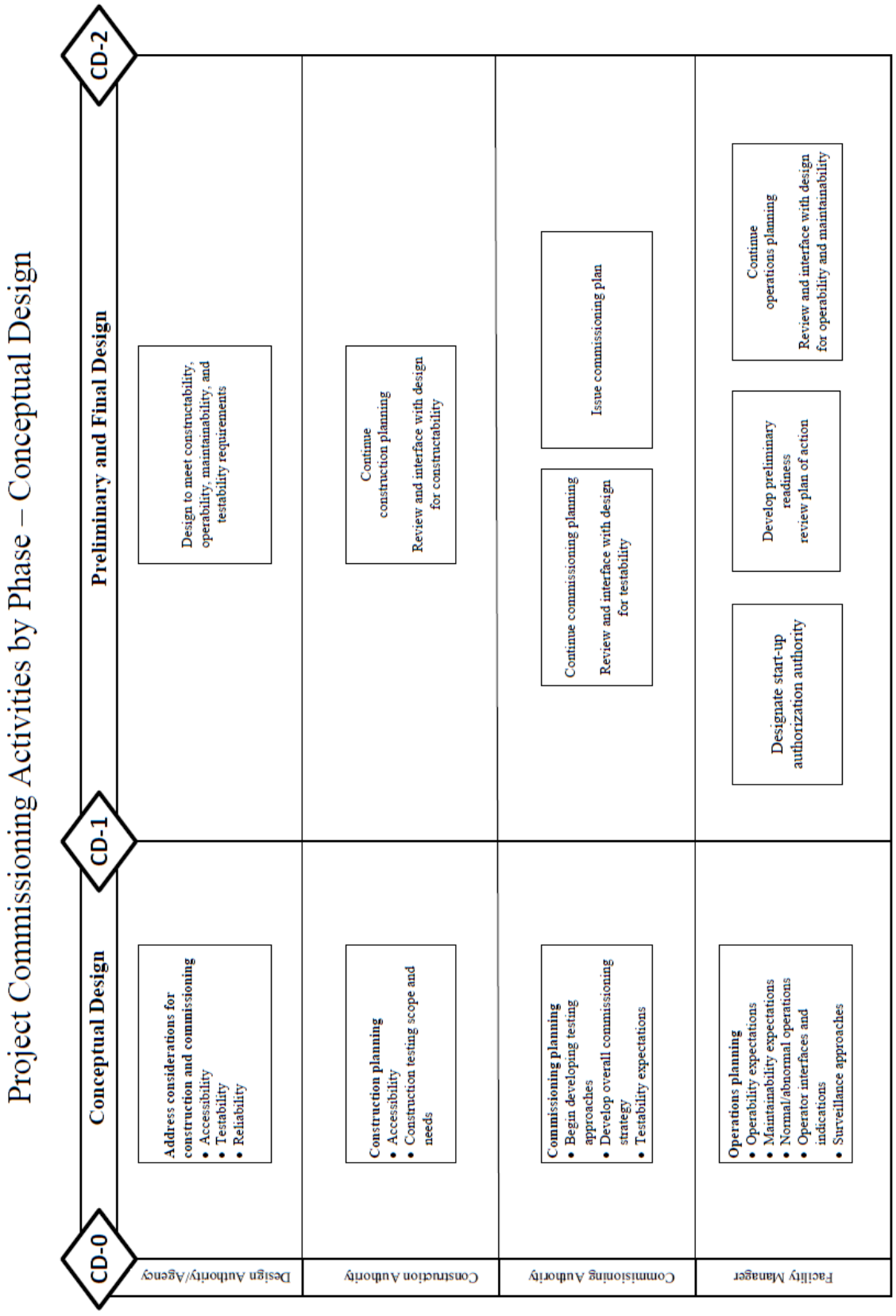

Figure 2: CD-0 to CD-2 Project Commissioning Activities by Organization

3. Constructability – Find opportunities to stagger system turnover to reduce peak labor burdens on the testing crews.

4. Construction testing scope and needs – At this stage, the development of the construction approach with consideration for testing begins. Identify in conjunction with commissioning personnel the tests and inspection points. Include equipment to support testing various aspects of the structure. Include inspections and materials tests in the project schedule.

3.2.4. Pre-CD-1 Operations Considerations

Having experienced operations personnel involved early in the conceptual design phase will lead to a smoother transition to operations.

3.3. Pre-CD-2: Execution Phase

Consider the resources required to complete commissioning prior to setting the performance baseline at CD-2. In this phase, start considering system boundaries or at least define the systems and key components. This section elaborates on the commissioning best practices between CD-1 and CD-2 depicted in Figure 2.

Complete an initial commissioning plan to document the commissioning and testing strategies under development following the structure and guidance found in Appendix D. Trace test requirements back to the engineering design. Control the test requirements flow down, whether from the design authority or another source. In addition, where engineering assumptions need validation or component commercial grade dedication needs system testing to validate criteria, the configuration management program records these validation needs and manages them appropriately.

Consider the following while planning commissioning pre-CD-2:

1. Division of required testing between pre-construction (vendor, factory, or other testing not performed in the permanent plant) and in-plant commissioning testing. This division may drive procurement specification requirements for vendor design/build systems, establishment of additional test platforms, or design features to support in-plant testing. Typically, in-plant testing most effectively demonstrates functional performance but costs the most by far and carries the highest risk. The testing approach balances these considerations based on mission value.

2. Provisions for testing and management. Designs may require special design provisions for testing of utility and process feeds or effluent disposal paths. Address in design provisions commissioning sequence, radiological conditions of interfacing processes, and required hazard controls. Provisions may impact physical layout of facilities and systems, piping system designs, commissioning sequence planning, and other design phase considerations. For example, valve placement to facilitate testing can make significant improvements in testing by zone versus system and increase overall schedule and manpower efficiency. Select interfaces that isolate adjacent systems to facilitate commissioning of completed systems when adjacent systems remain under construction.

3. Environmental permits. Plan to commission equipment and systems required by permits. Permits may require sampling and testing from emissions, effluents, and waste streams, stack certification, and destruction removal efficiency demonstrations. Since permits may not allow waste streams classified as radioactive and hazardous waste (mixed waste) to include non-hazardous or non-radioactive substances, ensure that all waste streams have disposal paths.

Best Practice: *Defining system boundaries on the piping and instrument diagrams prior to CD-2 enables a more efficient turnover from construction to operations/testing.*

3.3.1. Pre-CD-2 Commissioning Considerations

Identify the commissioning authority and its responsibilities. Develop the readiness review strategy. Devise a schedule for commissioning and estimate its budget. Define testable system boundaries so that relationships between the different boundaries become clear. Establish a process to ensure testing of each turned over system occurs.

1. Component and System Testing – Plan system tests that adhere to the assumptions in the conduct of operations section of the safety management plan (SMP).

2. Quality Assurance (QA) – Activities during testing and commissioning support QA. Identify commissioning elements in the QA requirements. Develop QA processes for testing and acceptance to ensure the final product meets the design and safety basis criteria regardless of who completed the work.

3. Procedure Development and Verification – Commissioning will need procedures for testing, operations, and maintenance during normal, off-normal and emergency operations. Start procedure development early, beginning with operational task analysis and establishment of operational jurisdictions as a basis for determining operational staffing levels.

4. Training and Qualification – Commissioning personnel need training on systems and operations of the plant. Leverage training intended for later delivery in support of transition to and initial operations.

5. Commissioning Phase Hazard Controls – Plan for the management of hazards as the facility incrementally introduces them during commissioning. DOE STD 3009 describes preparing a documented safety analysis useful for analyzing and controlling chemical as well as radiological hazards. Commissioning frequently introduces electrical, hydronic, pneumatic, and chemical hazards prior to introducing radiological hazards.

6. Simulants – Simulants represent radioactive materials for testing and demonstration purposes. Consider manufacturability, stability, hazardous characteristics, and impact to installed systems when selecting simulants. Obtain simulant approvals from DOE and regulatory entities as early as possible. Plan for the disposition of wastes generated through the use of simulants.

7. Simulators – Plan and budget for one or more process simulators to validate design assumptions, testing and process procedures, and support training development and execution including off-normal operator response in a safe environment.

3.3.2. Pre-CD-2 Design Considerations

Include in a requirements traceability matrix the methodology planned to demonstrate compliance. In some instances, the design validation cannot occur until after admitting radioactive material to the facility. Ensure designs include features supporting test requirements. Typical features include flushing spools, instrument test ports or taps, sample ports, tees and spools for chemical simulant introduction or secondary waste collection, and isolations for sub-system level testing. Layout the plant and space equipment to support testing needs. Inaccessible areas of the facility will need special testing planning to meet commissioning requirements.

Best Practice: *The use of a requirements traceability matrix as a means of linking design requirements through the review and validation process enables a successful commissioning program. The requirements traceability matrix also helps in the development of system design documents and validation files to support the RR process.*

Where radiation levels, chemical exposure, or other factors prevent safe direct access, the design may include a means to either remove the hazard prior to entry or maintain or repair systems using remotely controlled equipment (i.e., remotability). The effectiveness of the latter depends on the skill and proficiency of the operator. Address system controls in design documents. Include diagnostics where feasible.

Best Practice*: Follow the change control process when changing the code of record prior to CD-2.*

3.3.3. Pre-CD-2 Construction Considerations

Have an independent entity conduct constructability reviews at meaningful design milestones with the final constructability review occurring following completion of 90 percent design. Plan for the time and costs to complete commercial grade dedication.

The construction function at this stage will work with the commissioning function to determine test sequences, installations to support testing and other test requirements. Assign all equipment and systems an identifier recorded in a database. Complete the delineation of system boundaries and testable systems. Sequence system turnover in the commissioning plan.

Address commissioning and startup in contract documents. Have the contract specify delivery of operation and maintenance manuals within 30 to 60 calendar days of submittal approvals. This would give the commissioning manager early access to needed documentation to complete pre-functional and functional tests in a timely fashion.

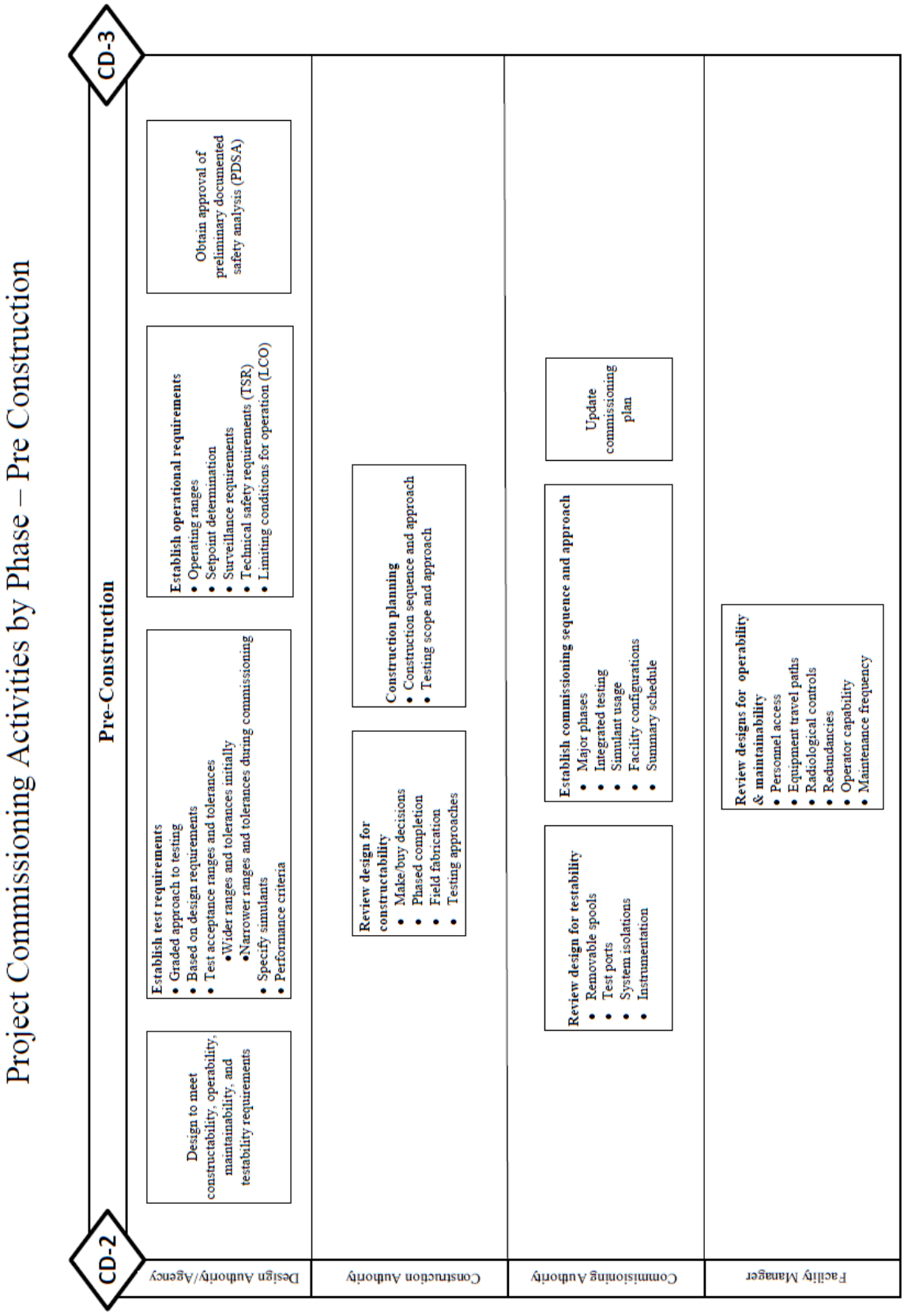

Figure 3: CD-2 to CD-3 Project Commissioning Activities by Organization

3.3.4. Pre-CD-2 Operation Considerations

Identify the SAA. For further details see DOE Order 425.1D, *Verification of Readiness to Start up or Restart Nuclear Facilities,* Section 4(b).

3.4. Pre-CD-3: Execution Phase

This section elaborates on the commissioning best practices between CD-2 and CD-3 depicted in Figure 3.

3.4.1. Pre-CD-3 Commissioning Considerations

1. Establish a Commissioning and Readiness Team - Staff the commissioning and readiness team with qualified personnel to manage all activities described in the commissioning plan.

2. Establish a Joint Test Group – Ensure through oversight of the commissioning test program receipt of valid results and prompt and effective resolution of related issues. A joint test group (JTG) comprised of key stakeholder organizations including operations, engineering, the design authority, and DOE validates procedures and provides oversight. Involve nuclear safety, environmental, or QA organizations when agenda items affect those functional areas. The JTG may draw conclusions about the whole from samples. Including DOE in the JTG exposes DOE to test results as the commissioning agent returns them and may result in less rework. The JTG makes decisions with a quorum present.

3. Site Integration – Identify in the commissioning plan the project's site interfaces and the testing required to confirm effective connections.

4. Update Commissioning Plan – Update the commissioning plan to reflect the project's final design and commissioning commitments.

5. Establish Commissioning Sequence and Schedule – Sequence the various commissioning phases in the plan to include simulant usage, facility configurations, and ramping system modes up to full capacity.

6. Temporary Modifications - Identify early temporary modifications and equipment specifically needed for testing for inclusion in procurement and installation schedules. Approval of modifications and system overrides occur prior to installation.

7. Review Design for Testability – Address in the commissioning plan how the commissioning team will test the systems. Include areas outside the main process area even if early design documents omitted their functions or when they may contain no safety class or safety significant components.

8. Finalize Test Requirements – Finalize test requirements that acknowledge access limitations in the design and limit conflicts with operations. Ensure testing demonstrates that the plant can operate within its design parameters pertinent to not just routine operations but also to transients and upsets.

3.4.2. Pre-CD-3 Design Considerations

Develop a field change notice process integrated with configuration management, documenting changes during construction ultimately recorded in as-built drawings and asset inventories.

3.4.3. Pre CD-3 Construction Considerations

Constructability - Have an independent entity supplemented with commissioning representatives conduct a constructability review. Include in the review the planned sequence of activities and construction methods.

Procurement - The nuclear supply chain has atrophied. Delayed delivery of materials and equipment require rescheduling work, changing craft assignments, and expediting new or revised work and instructions. Apply the best practices associated with CD-2 and CD-3 to any long lead procurement acquiring equipment even if the project has not received CD-2 or CD-3.

Best Practice: *Establish a process that enables acquisitions utilizing best value for vendor selection. This mitigates risk to the project associated with the limited number nuclear-related component suppliers.*

Best Practice: *Apply best practices and procedures outlined in this guide for CD-2 and CD-3 to any long lead equipment procurement.*

3.4.4. Pre-CD-3 Operation Considerations

Engage operations personnel in design reviews to ensure that the design adequately addresses operations requirements including those related to equipment access, adequacy of travel paths, maintainability of systems, redundancies allowing for downtime, and radiological controls. Provide training recommendations discerned during this engagement to operations management.

Ensure compatibility between the records management system(s) relied on by operations personnel and the records the project intends to turn over to operations. Take corrective actions where the review identifies incompatibilities.

3.5. Pre-CD-4: Execution Phase

Commissioning, testing, and verification activities typically proceed from lower to higher levels in terms of both systems and complexity. Construction and commissioning activities may overlap. Describe the interface points in the commissioning plan. The common order of testing follows:

1. Installation tests

2. Component tests (e.g., motors, actuators, sensors)

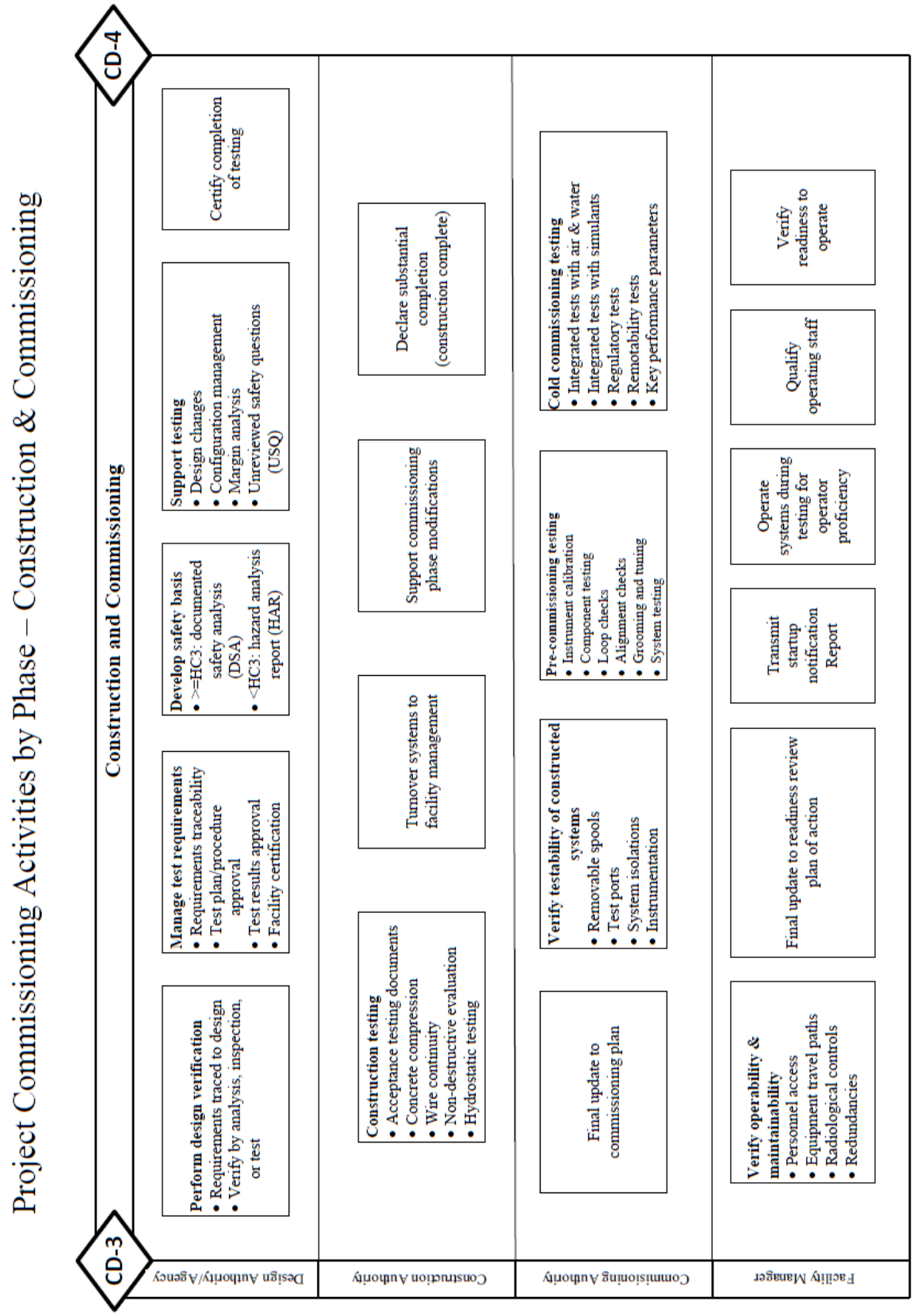

Figure 4: CD-3 to CD-4 Project Commissioning Activities by Organization

3. Calibration and alignment

4. Grooming and balancing

5. System functional performance tests

6. Cold commissioning tests

7. Simulant test

8. Testing with radioactive materials post CD-4 (outside the scope of this manual)

Figure 4 shows project commissioning activities between CD-3 and CD-4. The readiness process follows cold commissioning.

3.5.1. Pre-CD-4 Commissioning Considerations

1. Issue Final Commissioning Plan – Issue the final commissioning plan in a timely manner so that commissioning can proceed smoothly.

2. Turnover from Construction to Operations for Testing – Establish consistent standards regarding the completeness and quality of the systems deemed ready for turnover. Optimally, turnover occurs after construction completion. Include in the turnover:

    a. A report detailing which organizations visually inspected completed systems and when they completed their walk-down;

    b. Clear boundaries for each completed system deemed ready for turnover through verification and testing;

    c. Documentation suitable for inventorying, managing, and operating the completed systems;

    d. Documentation of incomplete[1] installations tracked through punchlists divided into:

        i. "A items" resolution of which must occur prior to turnover and

        ii. "B items" resolution of which may occur after turnover.[2]

    e. A budget estimate for resolving punchlist items;

[1] Incomplete encompasses work that fails to meet specifications including quality standards.

[2] The number of punchlist items at the time of turnover indicates progress towards construction completion. A lengthy punchlist log may indicate an unpreparedness for turning over scope.

f. A division of responsibilities made within the context of configuration management and documented in accordance with DOE Order 420.1C; and,

g. A statement estimating the readiness of the receiving organization for the management and maintenance of systems after turnover.

3. Lessons learned related to system turnover include:

a. Complete and have approved documentation associated with the applicable system before stakeholder and oversight inspections. When not practicable, identify paperwork that may remain incomplete while the inspections occur.

b. Engage the owner, stakeholders, and oversight personnel in developing the turnover process. Familiarize them with the systems and processes.

c. Include oversight team members in the decision to close punchlist "A" items.

d. Trace punchlist "B" items back to the original turnover scope. Once resolved, annotate installation records with pertinent information.

e. Manage all project documents electronically.

f. Practice system turnover procedures with interested personnel to ensure actual turnovers proceed as efficiently as possible.

g. Turnover each system to the entity identified in planning documents with the responsibility for testing that system. If the designated receiving entity cannot fulfill its assigned responsibility, either follow project change control procedures to reassign the responsibility or wait until it can.

Best Practice: *Use a configuration-controlled database to permit electronic review of turnover packages to make the receiving organization most efficient.*

4. Substantial Completion

a. Consider "construction complete" as a synonym for "substantial completion."

b. Define substantial completion in the contract as the point in time when the owner accepts the contractor's claim that a specific list of systems have attained a particular status indicated by evidence that specific inspection, testing, calibration, alignment, and grooming procedures have occurred and that the contractor has resolved any punchlist "A" items. See the American Institute of Architects (AIA) Document A201-2017, General Conditions of the Contract for Construction, §9.8, *Substantial Completion*, for adaptable language.

c. Include in the list of systems conventional structural, interior, mechanical, and electrical systems such as building shell, partition, heating, ventilation, and air conditioning,

plumbing, fire protection, electrical, lighting, communications, controls, and vertical transportation systems. The contracting officer in conjunction with the FPD may expand the list.

d. Direct the contractor to submit in writing its declaration of substantial completion. Base this declaration on AIA Document G704-2017, *Certificate of Substantial Completion*. Include in the declaration turnover acceptance forms, manuals, evidence of inspections, testing, calibration, grooming, and alignment, open punchlist items, schedule for resolving punchlist items, procedures for commissioning, schedule and cost information, and other documents specified in the contract as comprising the turnover package. Abide by time limits set in the contract for accepting or challenging the declaration. The federal project director and contracting officer issue the response to the contractor's declaration.

e. Provide additional guidance for rework through construction if testing reveals defects. Address different courses of action dependent on causes stemming from the design, component manufacturer, or the installation. Use a nonconformance process deemed acceptable under the project quality assurance program.

Best Practice: *Contractors should correct errors and omissions in work packages as soon as possible. Some projects hire clerical staff to review packages each night to catch and correct obvious problems.*

5. Commissioning Phase Modifications

a. Confirm procurement and installation schedules address all needed temporary modifications and equipment specifically needed for testing.

b. Approve modifications and system overrides prior to installation. Reloading baseline control software regularly ensures no software overrides or erroneous modifications remain in the system for prolonged periods during the testing phase.

c. Install and remove modifications to the physical plant as directed in a conduct of operations SMP. The conduct of operations SMP and the hazardous material protection SMP protects against spills, mis-transfers, and unplanned worker exposure to chemicals or industrial hazards during the commissioning phase.

6. Test Requirements Management – Ensure tests and results trace to testing requirements. NRC RG-1.68 Initial Test Programs for Water-Cooled Nuclear Power Plants provides examples of acceptable test requirements for possible benchmarking. Document the design authority's acceptance of test results as evidence of the project meeting its scope baseline requirements. The JTG actively contributes to the management of test requirements.

7. Commissioning Testing – Commissioning phase activities include integrated testing and demonstrating that systems, structures, and components meet functional requirements and performance criteria. Test in increments starting with installation testing, progressing through component testing, system testing, and then integrated facility testing. This approach reduces

risks by verifying the function of components and subcomponents before verifying the function of systems or facilities. Component testing may occur on multiple components in parallel leading to less work impacted by delays to address test failures or other issues. Projects need to balance using simulation, overlap tests, and similar methods to demonstrate function with less than fully integrated conditions with the need to provide adequate demonstration. Appropriate test conditions established during the design phase and traceable to test requirements, support finding this balance. Commission only following implementation of all system control software. The following sections discuss typical phases of, and considerations during, testing.

a. Installation Testing – Confirm proper construction and installation through appropriate tests such as hydrostatic testing, welding radiography, or cable continuity tests. Include in turnover packages records of these test results. Verify acceptable results prior to accepting a construction completion declaration.

b. Component Testing, Calibration, Alignment, and Grooming – Component testing confirms fitness for use, proper installation, and preparation for subsequent integrated testing through configuration and calibration. Component tests typically include electrical circuit scheme checks, insulation resistance testing, and mechanical run-in tests. Test components as early as practical, even during construction, to maximize the time available for resolving issues. Select initial calibrations that align with the operating phase calibration program. Grooming includes adjusting or aligning components to optimize their performance. Grooming includes setting limit switches, stroke and cycle timers, and dead-bands and also tuning component response parameters. In some cases, grooming may occur only after systems or sub-systems can provide complete control loops. Complete grooming as early as practical in the sequence to maximize the time available for resolving issues. Involve operations staff in grooming activities to improve its proficiency and the continuity of records.

c. System Testing – System testing follows component testing to demonstrate that systems meet system level and integrated system requirements. Like with component testing, test systems as early as practical to maximize the time available for resolving issues before integrated facility testing. System testing confirms achievement of design and operations requirements. Tune control loops to stabilize process controls through dynamic response to transients and upsets. Test mechanical handling systems to confirm remote operation, maintenance, and recovery features meet design requirements.

d. Technical Safety Requirement Surveillances – Verify under the test program that safety system maintenance and surveillance requirements, such as technical safety requirements (TSRs), demonstrate compliance and effectiveness.

Best Practice: *Perform TSR surveillances before documented safety analysis (DSA) implementation to reveal problems such as uninstalled or inaccessible test points or other interfering interlocks or functions. Ensure the surveillance tests the function or protective action on which the safety basis depends. Omit from surveillances invalid acceptance criteria that do not demonstrate the required functions.*

e. Hazardous Materials - Test systems with non-hazardous materials where practical. Where testing of control loops or functions must occur with hazardous materials, hazard controls protecting workers along with additional readiness verification and oversight will minimize the consequences of a test failure.

f. Hazard Review - A hazard review evaluates any hazards associated with pressurizing or energizing the equipment for testing. The review includes:

i. Determining the readiness of interfacing systems for testing;

ii. Confirming placement of area controls to exclude personnel not involved with the testing from the area;

iii. Approving testing procedures and test acceptance criteria;

iv. Confirming personnel responsible for executing the tests have received sufficient training; and,

v. Confirming the identification of post-testing actions needed to configure the facility and systems has occurred.

g. Equipment readiness evaluations (EREs) ensure that the safety structures, systems, and components (SSC) will operate in accordance with design and functional requirements and performance criteria. Turning over of equipment for testing follows completion and approval of the results of EREs.

i. EREs begin with identifying and validating the design and equipment performance requirements in need of verification.

ii. Approval for including the equipment in the cold commissioning process, including integrated system testing, follows successful equipment testing.

h. Ventilation System Testing – Incorporate in the integrated commissioning schedule ventilation testing such as volumetric flow adjustments and coarse and fine balancing since it will limit access to the facility. Ventilation testing may follow completion of the building shell including doors and access ports. Address confinement for normal and anticipated upset conditions in the testing. This may require final system balance verification during integrated facility demonstrations in cold commissioning.

i. Vendor Support for Testing – Plan and schedule vendor support for testing as early as practical. Vendors may provide technical support for specialized equipment, staff holding required certifications, or direct testing of installed systems and components.

Best Practices:

- *Obtain from vendors and their subcontracted suppliers early utility startup support.*
- *Understand the scope of vendor support for equipment startup to avoid delays.*

- *Confirm vendors complete updates to equipment they supply prior to transition.*
- *Include engineers in vendor training on procedures and process changes from construction to testing.*
- *Define testing and troubleshooting boundaries to avoid conflicts with interfacing or collocated systems not within the vendor's scope.*

j. Operations Personnel – To the extent practical, involve operations personnel in the testing program to teach them about the as-built configuration of the plant, system response, and component locations. However, operations personnel need to know how testing procedures differ from the conduct of operations SMP.

8. Cold Commissioning Testing

a. Background – Cold commissioning verifies achievability of the design capacity, process objectives, and environmental performance. Test procedures govern the test activities and ensure collection of all required data. Follow approved plant operating procedures during these tests. This testing may entail use of measuring and test equipment and temporary modifications or use of temporary test systems, structures, or analytical facilities. List in procurement documents commissioning testing requirements. Ensure the approved DSA or commissioning plan evaluates all SSCs. Address in the DSA any permanent operational changes resulting from the commissioning activities.

b. Timing and Schedule – Cold commissioning under the purview of the commissioning and operations groups begins after successful completion of individual component testing. Cold commissioning may occur in phases.

c. Overview – Cold commissioning entails integrated facility testing demonstrating integrated facility function and performance completed prior to introducing radioactive materials. These tests employ air, water, and simulants to confirm attainment of regulatory, maintainability, capacity, and key performance parameter (KPP) requirements.

d. Main objectives of cold commissioning –

i. Operate plant systems at design operating conditions (e.g., design flow rates, temperatures, and pressures) with the chosen simulant and non-nuclear process chemicals in accordance with approved procedures to verify that the process meets specifications;

ii. Identify deficiencies in the equipment, processes, or procedures and make corrective modifications before the facility goes hot (radioactive); and,

iii. Provide on the job training and assessments for operation, maintenance, administrative support, and training staff.

e. Simulants – Cold commissioning typically involves introducing hazardous simulants or process reagents or both. This may involve the introduction of greater than standard

industrial hazards and implementation of the authorization basis for environmental considerations and chemical hazard controls.

f. Documented Safety Analysis – Validation of many of the SMPs required for nuclear operations occurs in conjunction with cold commissioning. Practice implementing the DSA for cold commissioning hazard controls before actually implementing the DSA from a regulatory and reporting standpoint. Since the DSA governs industrial hazard control analysis and control requirements, leverage the DSA controls to control hazards, develop proficiency, and validate the procedures without requiring reporting issues under 10 CFR 830. While implementing cold commissioning hazard controls, maintain the scope baseline in alignment with the DSA.

g. Remotability – Demonstrate during cold commissioning not only that installed equipment functions as required, but that features supporting remotability, like cameras, operator aids, and human machine interfaces, adequately allow a trained operator to perform required tasks. Complete remotability tests early to take advantage of testable features evident during construction.

h. Resources - Plan for sufficient resources including time, personnel, and funds for cold commissioning to allow the project to fully demonstrate system capabilities, develop operator proficiency, and resolve emergent technical issues. Involve operations and maintenance staff and program personnel to the maximum practical extent in cold commissioning to develop their competencies and proficiencies in preparation for the RR. Initiate scheduled inspection and maintenance activities during lengthy cold commissioning of the systems and equipment in the facility. Ensure that equipment remains ready for startup following commissioning. Dispose of wastes generated through the use of simulants.

3.5.2. Pre-CD-4 Design Considerations

Confirm by examination of objective evidence that the project has fulfilled specified requirements. Add to the requirements traceability matrix verification and validation process results documenting satisfaction of the requirements. Testing and acceptance for requirements that will remain unverified until after the admission of radioactive material to the facility would occur post CD-4. Address these activities in the startup plan.

3.5.3. Pre-CD-4 Construction Considerations

1. Factory Acceptance Testing (FAT) - Ensure that FAT demonstrates attainment of quality requirements. Project, commissioning, operations, and maintenance staff may wish to observe this testing. FAT, conducted through approved final software, entails extended performance tests to demonstrate robustness, maintainability, acceptable system availability, and attainment of system performance parameters. Exercising equipment during FAT to the maximum extent possible can significantly reduce testing problems and rework during the commissioning phase. Resolving issues at the vendor's facility rather than during the commissioning phase compresses the project schedule and minimizes costs.

2. Construction Testing – Structural testing may examine compaction, concrete density and moisture, concrete, rebar inspections and locations, slab smoothness and flatness, masonry, asphalt, anchors, fire retardants and other. Schedule the tests to avoid rework and minimize schedule impacts. Hydrostatic testing of plumbing systems and electrical testing through wire conductivity and continuity also occurs at this point.

3. Documentation – Collect and manage construction acceptance testing documentation to associate records with specific components, systems, and facilities. Verify through non-destructive examinations (NDE) that the quality of installed commodities meet quality requirements. Pre-qualify suppliers against program requirements.

3.5.4. Pre-CD-4 Operation Considerations

As construction progresses, operations personnel added to the project will begin developing operating procedures and training while supporting commissioning. Hire sufficient operations personnel, as described in the commissioning plan, to develop a timely familiarity with the plan, operations training, and commissioning.

1. Verify Operability and Maintainability – During construction, operations personnel verify unfettered access to equipment, valves, gauges, sumps, valve pits, and other isolated locations. Design the plant to allow for the relocation of equipment where required for operations or maintenance.

2. Startup Plan – Develop a startup plan for review prior to the RR. The startup plan describes how the facility will introduce radioactive material, and the additional surveillance, oversight, hold points, and other key controls necessary to ensure safe performance of this major transition. The startup plan then guides subsequent activities conducted in preparation for demonstrating a readiness for routine operations with radioactive materials. Include in the startup plan criteria for release to normal operations within the constraints of the DSA. Include a procedure for confirming operator proficiency and the shift staff's capacity to accommodate the pace of the desired production rate.

3. Operations Preparations – To the extent practical, involve operations personnel in the testing program to teach them about the as-built configuration of the plant, system response, and component locations. However, operations personnel need to know how testing procedures differ from the conduct of operations SMP. As systems achieve readiness for operations, the facility will implement the SMPs as a part of plant operations. The facility will also need to determine whether it creates its own stand-alone safety management programs or incorporates any of the site's programs. Consider tasking maintenance personnel with early commissioning related activities like calibration to improve proficiency earlier.

4. Operations Procedures - Procedures direct operating systems and equipment during normal and postulated abnormal and emergency conditions to ensure that the facility operates within its design and safety bases. Review project or site quality assurance program documents as they may control aspects of the development, review, approval, issuance, implementation, and revision of operating procedures.

a. Procedure Development and Review

i. Write procedures in the sequence that steps and actions would occur. Qualified procedure writers aided by a team of qualified subject matter experts and those who will implement the procedures write operating procedures for the facility.

ii. Solicit, track, and incorporate feedback from the organization's functions responsible for safety, health and environmental requirements, design requirements and engineering documentation, and safety basis requirements. For example, the facility safety review committee or its equivalent reviews procedures that affect safety SSC or implement emergency responses.

iii. Commenters validate the technical content while confirming the procedures give adequate consideration to human factors. Proceed only after all required reviewers or functions have commented.

iv. Until DOE approves the DSA and operations procedures, follow a process similar to an unreviewed safety question (USQ) review.

b. Procedure Verification and Validation

i. Formally review, verify, and validate procedures. Include related activities supported by qualified resources in the integrated schedule.

ii. Match drawing and label-plate identifiers to components, use units consistent with those marked on applicable instrumentation, and include easily read and interpreted charts and graphs.

iii. Conduct a walk-through in the facility or through a simulator with qualified personnel to verify and validate the procedure and its sequence.

iv. Confirm plant configuration and labelling, procedure sequence, implementation of the safety basis and design basis requirements, and that procedures conform to the latest controlled version.

Best Practice: *Formal procedure verification and validation in the field by qualified personnel precedes readiness.*

c. Procedure Approval - Receive approval of new and revised procedures prior to implementation from the appropriate functional group managers. Develop and maintain a list of authorized approvers.

Best Practice: *Incorporate mature operating procedures in the testing procedures to allow operators to gain familiarity with the equipment and find issues with the procedures.*

5. Readiness - Simulated operations follow approved procedures to increase the proficiency of facility personnel. Readiness experts will confirm the state of procedure readiness through

drills that simulate both operations and upset conditions. Cold commissioning verifies performance reflects design, safety, and environmental requirements when conducted in accordance with approved procedures by qualified personnel under normal and abnormal conditions.

Best Practice: *Perform each procedure at least twice without intent changes, equipment failures, or operator errors. This provides a higher level of confidence that the operators will perform well during the readiness reviews.*

6. Introduction of Radioactive Materials – After satisfying the requirements of DOE Order 425.1D, *Verification of Readiness to Start Up or Restart Nuclear Facilities*, the SAA approves the introduction of radioactive materials into the facility.

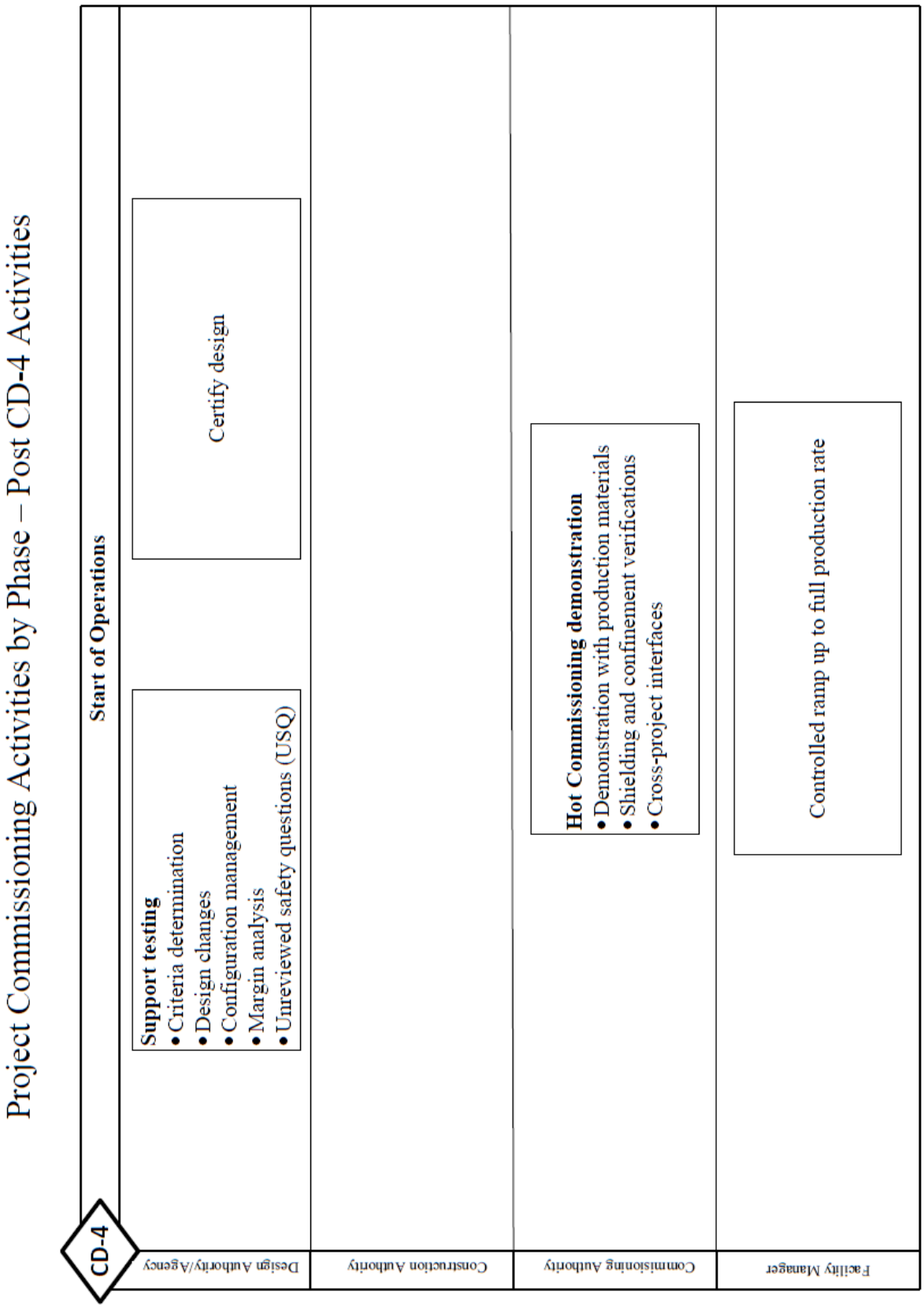

Figure 5: Post CD-4 Activities by Functional Area

3.6. Post CD-4: Closeout Phase

Achieving, validating, and verifying readiness to operate newly built projects consumes significant time and costs accounted for in the performance baseline. Figure 5 delineates activities for achieving and verifying readiness to operate.

3.6.1. Post CD-4 Commissioning Considerations

1. Demonstrations - Post CD-4 activities for commissioning may entail demonstrations with production materials, shielding and confinement appurtenances, and site interfaces. Startup plans required by DOE Order 425.1D addresses each of these.

2. Hot Commissioning, typically begun following CD-4, often includes verification of shielding, radioactive confinement and decontamination processes, and validation of process flowsheet modeling with actual material. Consider these activities as an extension of testing completed only in full compliance with the authorization basis under the operational configuration management and quality controls. This guide does not address the details of hot commissioning.

3.6.2. Post CD-4 Construction Considerations

Transfer as-built drawings, asset inventories, and testing documentation to operations personnel.

3.6.3. Post CD-4 Operations Considerations

1. Overview - Procedures direct operating systems and equipment during normal and postulated abnormal and emergency conditions to ensure that the facility operates within its design and safety bases. Review project or site quality assurance program documents as they may control aspects of revising operating procedures, training, or verifying operator proficiency.

2. Operator Proficiency - Maintain operator proficiency and the shift staff's capacity to accommodate the pace of the desired production rate.

3. Procedure Revisions - Changes to requirements, identification of efficiencies, discovery of errors or omissions, and acceptance of best practices lead to procedure changes.

    a. Perform an USQ review on all procedure revisions following approval of the DSA. Document the reason for revisions to procedures. Track procedure revisions over time.

    b. Implement procedure revisions concurrently with modifications. Handle procedure updates required by temporary modifications as a procedure revision implemented concurrently with the temporary modification.

    c. Communicate procedure revisions to appropriate facility personnel through formal means, such as in a class, or informal means, such as in a pre-shift briefing, in consultation with the training organization.

4. Procedure Configuration Management - Maintain configuration control for procedures to ensure personnel have access to current approved procedures.

    a. Classify procedures according to the methods they employ. Prior to performing work, verify the procedure reflects the current revision.

    b. Submit records of completed procedures to the facility records management organization.

    c. Give operators responsible for responding to alarms easy access to controlled alarm response procedure (ARP) information. Provide ARPs at local control panels, or, where not possible, at alternate locations convenient to the equipment operator.

5. Training and Proficiency - Training on new and revised procedures satisfy personnel qualification requirements for readiness to transfer to operations.

    a. Plan and schedule proficiency activities prior to and during commissioning.

    b. Include scenarios representative of normal, abnormal, and emergency conditions.

    c. Verify that operator proficiency has increased during cold commissioning, scheduled policy revisions, simulations, drills, and on-the-job training.

APPENDIX A: ACRONYMS

ARP	Alarm response procedures
ASME	American Society of Mechanical Engineers
CD	Critical decision
CFR	Code of Federal Regulations
CGD	Commercial grade dedication
CM	Configuration management
COR	Code of record
CP	Commissioning plan
CSE	Cognizant system engineer
DOE	Department of Energy
DSA	Documented safety analysis
EM	DOE Office of Environmental Management
ERE	Equipment readiness evaluations
FAT	Factory acceptance testing
FPD	Federal Project Director
HVAC	Heating, ventilation, and air conditioning
JTG	Joint test group
KPP	Key performance parameter
NDE	Non-destructive examination
NRC	Nuclear Regulatory Commission
ORR	Operational readiness review
QA	Quality assurance
RA	Readiness Assessment
RCAPTS	Readiness Certification Assurance Process Tracking System
RR	Readiness Review
SAA	Startup authorization authority
SDD	System design description
SER	Safety evaluation report
SMP	Safety management program
SOM	Shift operations manager
SSC	Structures, systems, and components
TRL	Technology readiness level
TSR	Technical safety requirement
USQ	Unreviewed safety question

APPENDIX B: SOURCES CONSULTED

Table 2: DOE Directive and Guidance Documents

#	Organization	Document Number	Title	Version
1	Department of Energy	DOE O 413.3B	Program and Project Management for the Acquisition of Capital Assets	04/12/2018 (Chg 5)
2	Department of Energy	DOE G 413.3 – 1	Managing Design and Construction Using Systems Engineering for Use with DOE O 413.3A	10/22/2015 (Chg 1)
3	Department of Energy	DOE G 413.3 – 16A	Project Completion and Closeout	10/22/2015 (Chg 1)
4	Department of Energy	DOE O 425.1D	Verification of Readiness to Start Up or Restart Nuclear Facilities	04/02/2013 (Chg 1)
5	Department of Energy	DOE O 426.2	Personnel Selection, Training, Qualification, and Certification Requirements for DOE Nuclear Facilities	07/29/2013 (Chg 1)
6	Department of Energy	DOE STD 1189	Integration of Safety into the Design Process	12/22/2016
7	Department of Energy	DOE STD 3006-2014	Planning and Conducting Readiness Reviews	11/12/2014
8	Department of Energy	DOE HDBK 3012-2015	Guide to Good Practices for Operational Readiness Reviews, Team Leader's Guide	11/24/2015
9	Department of Energy	DOE-CNS-Commissioning-2017	Design and Commissioning Report https://go.usa.gov/xmvw2	July 2017 (Rev 1)

Table 3: Non-DOE Standards and Informative Documents

#	Organization	Document Number	Title	Version
1	American Institute of Architects	A201	General Conditions of the Contract for Construction	2017
2	American Institute of Architects	G704	Certificate of Substantial Completion	2017
3	American Society of Heating, Refrigeration, Air	ASHRAE Guideline 1.1	HVAC&R Technical Requirements for The Commissioning Process	2007

#	Organization	Document Number	Title	Version
	Conditioning Engineers			
4	American Society of Heating, Refrigeration, Air Conditioning Engineers	ASHRAE Standard 202	Commissioning Process for Buildings and Systems	2013
5	Construction Industry Institute	CII 121 – 1	Planning for Startup: Overview of Research	
6	Construction Industry Institute	CII 121 – 2	Planning for Startup	April 1998
7	Construction Industry Institute	CII 312 – 2 Vol I	Achieving Success in the Commissioning and Startup of Capital Projects: Implementing Critical Success Factors	September 2015
8	Construction Industry Institute	CII 312 – 2 Vol II	Achieving Success in the Commissioning and Startup of Capital Projects: Mini – Case Studies	September 2015
9	Department of Defense Unified Facilities Guide Specifications	UFGS – 01 91 00.15	Total Building Commissioning	May 2016
10	Institute for Nuclear Power Operations	INPO 86 – 023 Vol 5	Guidelines for Nuclear Power Station Construction Projects, Volume 5, Startup Testing	October 1986
11	International Atomic Energy Agency	IAEA NS – G – 2.9	Commissioning for Nuclear Power Plants	2003
12	International Atomic Energy Agency	IAEA SSR – 2/2	Safety of Nuclear Power Plants: Commissioning and Operation	2007
13	National Electrical Contractors Association	NECA 90 – 2004	Commissioning Building Electrical Systems	2004
14	National Fire Protection Association	NFPA 3HB15	Commissioning and Integrated System Testing Handbook	2014
15	Nuclear Regulatory Commission	NRC RG 1.206, Part II.1	Inspections, Tests, Analyses, and Acceptance Criteria	June 2016
16	Nuclear Regulatory Commission	NRC RG 1.68	Initial Test Programs for Water-Cooled Nuclear Power Plants	June 2013

APPENDIX C: DEFINITIONS

Rely on definitions found in the APM Glossary of Terms (2014). Terms listed below do not appear in the glossary.

Acceptance criteria – The conditions for declaring that some aspect of the project meets defined requirements, thus permitting subsequent activities to proceed.

Authorization basis – Those aspects of the facility design basis and operational requirements important for safe facility operations and relied on by DOE to authorize operation. The facility safety analysis report and other safety analyses, hazard classification documents, the technical safety requirements, DOE issued safety evaluation reports, and facility-specific commitments made to comply with DOE Orders or policies contain the authorization basis.

Cold commissioning – Testing activities completed with non-radioactive chemical simulant materials to confirm attainment of certain requirements prior to introducing radioactive materials or hazards.

Commissioning authority – The entity responsible for developing and maintaining the commissioning plan and for advocating for commissioning.

Commissioning plan – A document developed by the commissioning authority establishing commissioning strategies, sequence, schedule, system design capabilities, and resources needed to complete the commissioning phase of a project. Updates to the commissioning plan may occur throughout the project as more project details become known.

Commissioning report – The final commissioning document which presents the commissioning requirements, process, documentation, findings, process results, compliance with the acceptance criteria, and actions taken to rectify any deficiencies.

Component testing (grooming) – Testing performed at the component level to confirm proper installation, serviceable condition, and ability to support system level testing.

Constructability – The effective and timely integration of construction knowledge into the conceptual planning, design, construction, and field operations of a project to achieve the overall project objectives in the best possible time and accuracy at the most cost-effective levels. (Source: CII)

Construction authority - The entity responsible for ensuring the constructability of the project.

Construction complete – See “Substantial completion.”

Construction testing – Testing performed by the construction organization prior to system turnover for commissioning that typically includes hydrostatic testing, flushing, wiring continuity checks, nondestructive weld examination through radiography, dye penetration, and ultrasonic methods, and similar tests.

Design agency – The organization responsible for developing design outputs implementing requirements established by the design authority.

Design verification – The process of tracing design requirements to placed scope through analysis, inspection, testing, or other specified approach.

Facility testing – Testing done on groups of systems to demonstrate achievement of facility level requirements related to product quality, environmental impact, and production capacity or throughput.

Factory acceptance tests (FATs) – Inspection and static or dynamic testing of systems or major system components to support the qualification of an equipment system conducted and documented at the supplier site or facility.

Grooming – See *component testing*.

Inspection – Verification of construction and installations to confirm their fidelity to the detailed design and specifications including quality requirements.

Integrated system testing – Tests to verify proper functional interface between systems that typically include reviewing building system responses to the loss of a utility, transfers to emergency power, transfers from emergency power to regular power and interfaces between HVAC, vertical transportation, and security controls and the emergency notification systems for equipment or system shutdown or lockdown.

Joint test group – Appointed representatives serving as the test authority who review and approve test documents prepared by the engineering, procurement, and construction testing organization.

Punchlist – A list of incomplete or unacceptable work and malfunctioning equipment or systems tracked through resolution.

Qualified person – A person with specific knowledge, skills, abilities, or credentials designated to fulfill specific duties and responsibilities.

Readiness verification – the process of establishing through either compliance or performance-based means that an activity, operation, or facility has achieved an adequate state of preparedness to advance.

Resolution – The implementation of corrective actions that correct a tested or observed deficiency in accordance with the contract or, when silent on the matter, to the mutual satisfaction of the owner and contractor.

Substantial completion – The point in time when the owner accepts the contractor’s claim that a list of systems have attained a particular status evidenced by desired outcomes of specific inspection, testing, calibration, grooming and alignment procedures all of which the contract enumerates and that the contractor has resolved punch list items preventing turnover.

System – Linked components that provide a required function or capability identified during the design process and isolatable from other systems to allow for independent inspection or confirmation of process function.

System Testing – System or subsystem level testing with integrated sets of components performed by entities identified in the contract to demonstrate attainment of requirements including, for example, balance of cooling loop flow or pressure, interlock and control logic verification, transfer pump performance, and safety function response time.

System Turnover – The transfer of jurisdictional control of a system from one organization to another, typically part of the phased transition of a project from construction through commissioning and into operations.

Testing – The determination of the capability of an item to meet specified requirements under a set of physical, chemical, environmental, or operational conditions.

APPENDIX D: SAMPLE COMMISSIONING PLAN OUTLINE

1. Introduction

    1.1. **Plan Purpose** – Identify objectives of the commissioning plan based on the applicable contract(s) and project execution plan.

    1.2. **Project Description** – Describe the project to provide context for the commissioning plan.

    1.3. **Scope** – List what the commissioning will and will not entail based on project documents including applicable contract(s).

2. Organization Roles

    2.1. **Current Phase Organization Roles** – Identify current project phase (e.g. pre-CD-2) organization roles, responsibilities, authorities, and accountabilities. Include the commissioning or operations organizations supporting design or construction activities.

    2.2. **Commissioning Phase Organization Roles** – List the roles, responsibilities, authorities, and accountabilities in the commissioning organization, especially with respect to commissioning deliverables. Address interfaces with client and regulatory entities. Describe the organization that will operate the facility during the integrated testing and readiness assessment activities associated with commissioning.

3. Commissioning Requirements Management

    3.1 **Programmatic Requirements** – List requirements made by reference to contract clauses, statute, regulation, directive, standard or code related to commissioning and describe how the project will manage these requirements. Address configuration management.

    3.2. **Technical Requirements** – List technical requirements related to commissioning and describe how the project will manage these requirements and the testing. Address utilities needed and remotability.

4. Commissioning Phase Execution

    4.1. **Turnover** – Describe the turnover of constructed systems, facilities, and associated documentation to include manuals to testing organizations and ultimately to the operating organization.

    4.2. **Testing** – Describe the test requirements management, test planning, types of tests, test execution, and test results collection, storage, and reporting. Include how the project will relate test results to test requirements.

4.3. **Safety Management** – Describe safety requirements and assumptions in addition to emergency preparedness needed for commissioning.

4.4. **Staff Training and Qualification** – Describe qualifications required of commissioning personnel and site or project specific training required to supplement those qualifications.

4.5. **Operating Scenarios** – Describe the full range of routine and non-routine operating scenarios.

4.6. **Operating Procedures** – Describe the development, validation, and approval of routine and non-routine operating procedures during commissioning.

4.7. **Readiness Reviews** – Identify the standards or handbooks such as DOE-STD-3006 or DOE-HDBK-3012 that will provide the procedures for the readiness reviews that will follow commissioning.

5. Commissioning Execution

5.1. **Commissioning Sequence** – Sequence commissioning activities from turnover through completion of commissioning. Include with each activity a description or reference to the applicable requirements. Include major integrated testing activities, operator proficiency demonstration periods, readiness verification activities, and major completion milestones.

5.2. **Commissioning Deliverables** – Describe commissioning deliverables including their requirements such as format and contents and the entities responsible for generating, reviewing, approving, and receiving the deliverables.

6. References

6.1. **Project Documents**

6.2. **Codes and Standards**

6.3. **Master equipment list with links to specifications and submittals**

6.4. **Other Documents**

Appendices

Appendix A: Commissioning Summary Schedule