Table of Contents

1.0 GENERAL 2
1.1 RESPONSIBLE PERSONNEL 2
1.2 DESCRIPTION 2
1.3 DEFINITIONS 4
1.4 COORDINATION 6
1.5 COMMISSIONING PROCESS 6
1.6 RELATED WORK 9
1.7 COMMISSIONING COMPLETION 9
1.8 *SYSTEMS TO BE COMMISSIONED 10
1.9 *RESPONSIBILITIES 11
1.10 MEETINGS 17
1.11 REPORTING 17
1.12 SUBMITTALS 17
1.13 TESTING REQUIREMENTS 17
1.14 TESTING PREREQUISITES 18
1.15 TEST EQUIPMENT 18
1.16 PRE-FUNCTIONAL CHECKLISTS, START-UP AND INITIAL CHECKOUT 18
1.17 FUNCTIONAL PERFORMANCE TESTING & INTEGRATED SYSTEMS TESTING 20
1.18 BAS EVALUATION 22
1.19 DOCUMENTATION, NON-CONFORMANCE AND APPROVAL OF TESTS 22
1.20 DEFERRED TESTING 24
1.21 *WRITTEN WORK PRODUCTS 25
2.0 OPERATION AND MAINTENANCE MANUALS 26
2.1 STANDARD O&M MANUALS 26
3.0 TRAINING 26
3.1 TRAINING OF HMS PERSONNEL 26

019113 – General Commissioning Requirements

1.0 GENERAL

A. This Cx specification is generally tailored to the larger construction projects having substantial mechanical, electrical, and plumbing (MEP) systems and sub-systems in the scope. Specific sections of this Cx specification may not apply to all projects and especially those with a minimal number of MEP systems involved. The Cx specification sections which depend on the size or scope of the project are denoted with an asterisk (*).

B. HMS Facilities in coordination with PD&C will decide on the required level of commissioning effort prior to project approval and the commencement of design phase. This decision will be made based on the project size, complexity, and scope.

C. Projects with no MEP scope will require no Cx effort and are not covered by this standard.

1.1 RESPONSIBLE PERSONNEL

A. Commissioning Authority: An independent commissioning authority/agent will be retained by the Owner (Harvard Medical School [HMS]) to act as the Commissioning Authority (CxA) for the Project. The CxA directs, documents, and approves the commissioning process and the functional testing.

B. Responsibility of Disciplines: The parties listed below are part of the commissioning team and are required to participate in the commissioning process. The responsibilities relative to commissioning for each of these parties are defined in this section in addition to those required elsewhere in the contract documents.

1. Harvard Medical School (Owner)
2. Construction Manager
3. General Contractor
4. Mechanical Contractor
5. Plumbing Contractor
6. Electrical Contractor
7. Controls Contractor
8. Testing, Adjusting and Balancing Contractor
9. All subcontractors, vendors and suppliers that are associated with the above disciplines.

1.2 DESCRIPTION

A. Commissioning: Commissioning is a systematic process of verifying that all building systems perform interactively according to the HMS project requirements, design intent, basis of design, and HMS's operational needs. This is achieved during the design, construction, acceptance and warranty phases through planning, documentation, verification of performance, and training. The commissioning process shall encompass and coordinate the functions of system documentation, equipment installation, equipment startup, control system calibration, testing and balancing, performance testing, integrated systems testing and staff training. The commissioning process composes the following phases:

1. Pre-design and Design Phase

2. Pre-Construction Phase

3. Construction and Acceptance Phase

4. Turnover and Occupancy

B. *Commissioning during the pre-design and design phase shall include the following elements and achieve the following objectives:

1. Perform a review of the Owner's Project Requirements (OPR), if available, and the Basis of Design (BOD) documents to document that the requirements of the OPR are reflected in the BOD.
2. Perform a review of the design documents and provide comments relative to conformance with the OPR and BOD.
3. Develop a commissioning plan and establish a commissioning team.

C. *Commissioning during the pre-construction phase shall include the following elements and achieve the following objectives:

1. Conduct a commissioning team kick-off meeting and maintain continuity throughout the duration of the project through additional meetings, produce and issue meeting minutes.
2. Perform a review of the contractor submittals for the systems to be commissioned.
3. Develop project specific construction checklists and functional performance testing scripts.

D. *Commissioning during the construction and through the turnover and occupancy phase shall as a minimum, achieve the following specific objectives in concert with the contract documents:

1. Verify that applicable equipment and systems are installed according to the manufacturer's recommendations, to industry accepted standards, per the contract documents and that they receive adequate operational checkout and testing by installing contractors and suppliers. Identify non-complying items.

2. Verify and document proper performance of each piece of equipment as well as all integrated operating systems.

3. Verify that the equipment and systems comply with the contract documents.

4. Document all deficiencies identified during inspections and testing have been addressed and resolved.

5. Verify that Operations and Maintenance (O&M) documentation delivered to HMS is complete and conforms with contract document requirements.

6. Verify that HMS's operations staff members are trained in conformance with contract document requirements.

E. Different levels of Cx effort and separate phases of Cx activities will be required for different projects and will depend on how HMS classifies its projects. HMS Facilities in coordination with PD&C will decide on the required level of commissioning effort prior to project approval and the commencement of design phase. This decision will be made based on the project size, complexity, and scope.

F. The commissioning process does not negate, take away from or reduce the responsibility of the system designers or installing contractors to provide a finished and fully functioning product as required by their contracts.

G. *A typical project will have selected building systems commissioned as noted in section 1.8 and in conformance with project scope of work (SOW). The Commissioning Authority will coordinate the commissioning process. All correspondence will flow through HMS Project Manager with copies to the Construction Manager.

H. A Commissioning Action List (CAL) will be maintained by the CxA throughout the construction and testing phase. The CAL will be updated regularly and will include a categorization of items based on criticality as well as a list with all resolutions.

I. Abbreviations: The following are common abbreviations used in the Specifications and in the commissioning process.

A/E	Architect and Design Engineers
BOD	Basis of Design
CxA	Commissioning Authority
CC	Controls Contractor
CM	Construction Manager (outside vendor)
Cx	Commissioning
EC	Electrical Contractor
ELC	Elevator Controls Contractor
FAC	Fire Alarm Contractor / Fire Alarm Distributer
FSC	Fire Sprinkler/Standpipe Systems Contractor
FPT	Functional Performance Test
GC	General Contractor
HMS	Harvard Medical School
IST	Integrated System Test
MC	Mechanical Contractor
O&M	Operation and Maintenance
OPR	Owner's Project Requirements
PC	Plumbing Contractor
PFC	Pre-Functional Checklist
PM	Project Manager (of the Owner)
RDP	Registered Design Professional
SI	Special Inspector
SOO	Sequence of Operations
Subs	Subcontractors to General
TAB	Test and Balance Contractor

1.3 DEFINITIONS

A. Acceptance Phase: Phase of construction after startup and initial checkout when functional performance tests, O&M documentation review and training occur.

B. Approval: Acceptance that a piece of equipment or system has been properly installed and is functioning in the tested modes according to the Contract Documents.

C. Basis of Design: The basis of design is the documentation of the primary thought processes and assumptions behind design decisions that were made to meet the design intent. The basis of design describes the systems, components, conditions, and methods chosen to meet the intent.

D. Control system: The building energy management control system.

E. Cx Process: Refers to the Commissioning Process.

F. Deferred Functional Tests: FPTs that are performed later, after substantial completion, due to partial occupancy, equipment, seasonal requirements, design, or other site conditions that disallow the test from being performed.

G. Deficiency: A condition in the installation or function of a component, piece of equipment or system that is not in compliance with the Contract Documents (that is, does not perform properly or is not complying with the design intent).

H. Design Intent: A dynamic document that provides the explanation of the ideas, concepts and criteria that are very important to HMS. It is initially the outcome of the programming and conceptual design phases.

I. Design Narrative or Design Documentation: Sections of either the Design Intent or Basis of Design.

J. Factory Testing: Testing of equipment on-site or at the factory, by factory personnel with an HMS representative present.

K. Functional Performance Test (FPT): Test of the dynamic function and operation of equipment and systems using manual (direct observation) or monitoring methods. Functional testing is the dynamic testing of systems (rather than just components) under full operation. Systems are tested under various modes, such as during cooling or heating loads, component failures, unoccupied, varying outside air temperatures, fire alarm, power failure, emergency power, etc. The systems are run through all the control system's sequences of operation and components are verified to be responding as the sequences state. The commissioning authority develops the functional test procedures in a sequential written form, coordinates, observes and documents the actual testing, which is performed by the installing contractor or vendor. FPTs are performed after pre-functional checklists and startups are complete.

L. Integrated Systems Test (IST): Integrated testing verifies the performance of systems operating in conjunction with one another under various modes of operation that conform with design documents. Final acceptance phase testing of systems interactively, using failure analysis and "what if" scenarios to determine the ability of systems to provide continuous and safe operation. ISTs follow successful completion of FPTs.

M. Manual Test: Using hand-held instruments, immediate control system readouts or direct observation to verify performance (contrasted to analyzing monitored data taken over time to make the "observation").

N. Monitoring: The recording of parameters (flow, current, status, pressure, etc.) of equipment operation using data loggers or the trending capabilities of control systems.

O. Non-Compliance or Non-Conformance: See Deficiency.

P. Over-written Value: Writing over a sensor value in the control system to see the response of a system (e.g., changing the outside air temperature value from 75°F to 50°F to verify economizer operation). See also "Simulated Signal."

Q. Owner-Contracted Tests: Tests paid for by the Owner outside the contractor's contract and for which the CxA does not observe. These tests will not be repeated during functional tests if properly documented.

R. Pre-functional Checklist (PFC): A list of items to inspect and component tests to conduct to verify proper installation of equipment, by the contractor. PFCs are used as installers' verification of completion prior to turnover for third party commissioning verification.

S. Sampling: Functionally testing only a fraction of the total number of identical or near identical pieces of equipment.

T. Seasonal Performance Tests: FPTs that are deferred until the system(s) experience conditions closer to their design conditions.

U. Simulated Condition: Condition that is created for the purpose of testing the response of a system (e.g., applying a hair blower to a space sensor to see the response in a VAV box).

V. Simulated Signal: Disconnecting a sensor and using a signal generator to send an amperage, resistance or pressure to the transducer and DDC system to simulate a sensor value.

W. Startup: The initial starting or activating of equipment, including executing pre-functional checklists.

X. Test Procedures: The step-by-step process, which must be executed to fulfill the test requirements. The CxA develops the test procedures.

Y. Test Requirements: Requirements specifying what modes and functions, etc. shall be tested. The test requirements are not the detailed test procedures.

1.4 COORDINATION

A. Management: The CM will coordinate the efforts of the contractors and vendors so that the commissioning process is executed according to the established Cx plan.

B. A full completion of Cx scope is desired in advance of the project's Substantial completion for the exception of identified deferred or seasonal testing items. When this is not possible due to the lagging items and the space needs to be occupied, the following conditions must be met:

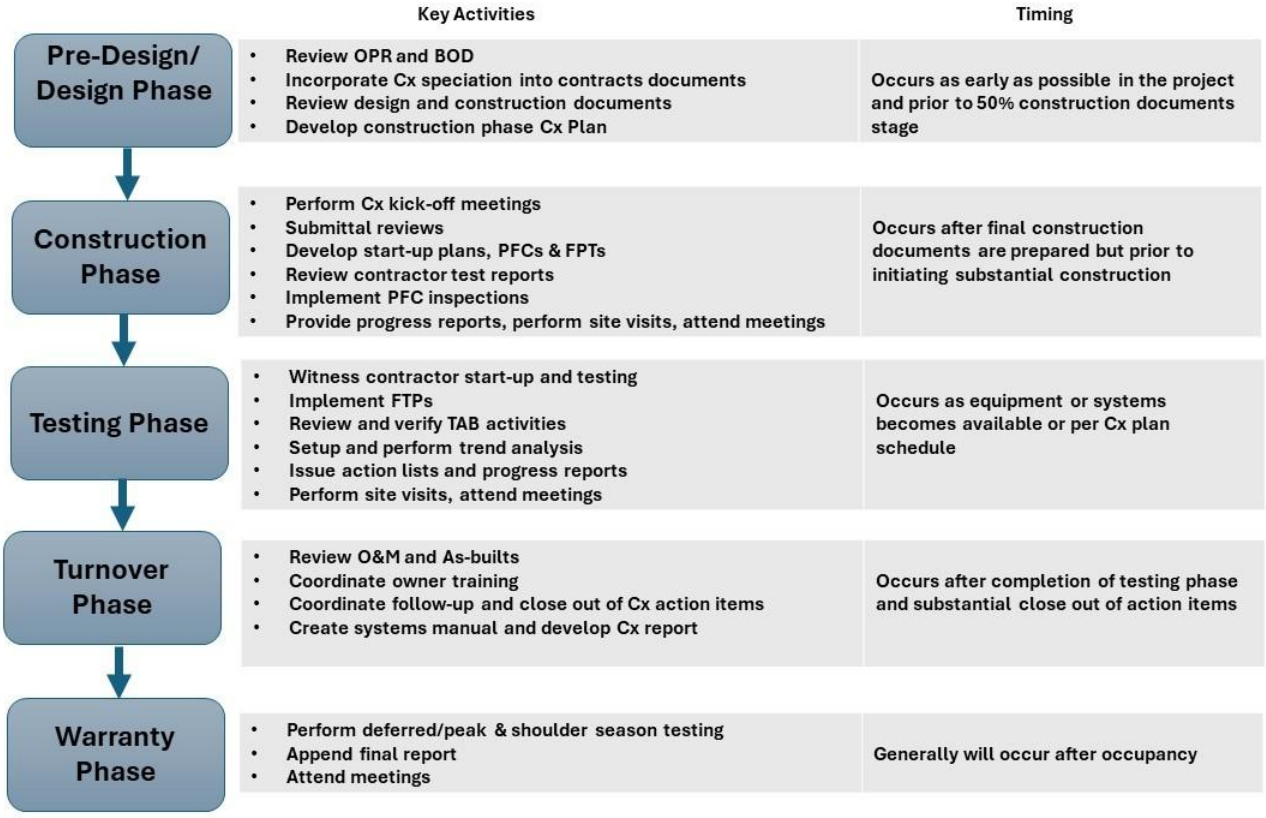
1. All functional testing has been completed, and all systems must be operational before systems are accepted for occupancy
2. A most recent Commissioning Action List has been provided to HMS Facilities

C. A full completion of Cx work is a requirement for project's Final Closeout.

D. Scheduling: The Cx process milestones shall be established and documented in the Cx Plan. These milestones shall serve as the basis for the detailed commissioning activities incorporated into the master project schedule by the CM. The schedule shall be updated throughout the project with input from the CxA, HMS and contractors during the commissioning meetings.

1.5 COMMISSIONING PROCESS

A. *Commissioning Process: The overall commissioning process for a typical project is presented in the following flow chart and shows the general order in which they shall occur. A brief overview of the typical commissioning tasks from pre-design/design through the warranty phases is also presented.



*Pre-Design/Design Phase

1. Ensure that HMS project requirements and basis of design documents are reflected in the contract documents through reviews of design development and contract document packages.

2. Create Commissioning Plan and update as required as design develops.

3. Ensure that a commissioning specification is incorporated into the final contract documents.

*Construction Phase

4. Commissioning during construction shall begin with a scoping meeting conducted by the CxA wherein the commissioning processes are reviewed with the commissioning team members.

5. Attend as needed scheduled meetings by the CM during construction, to plan, scope, coordinate, and schedule future activities and resolve problems.

6. Equipment documentation shall be submitted to the Engineer during normal submittals, including detailed start-up procedures. The CM shall copy the CxA on all equipment included in the commissioning scope. The CxA will review and comment on applicable items as appropriate concurrent with the design team review. Final approval of all equipment, shop drawings, coordination drawings, operations and maintenance manuals, etc. shall remain with the design team.

7. Develop Pre-Functional Checklists (PFCs) after final equipment submittals are approved for implementation by the applicable sub-contractors.

8. The CxA may request additional information for manufacturers test procedures by submitting all requests through the CM who will forward to the responsible contractor.

9. The Subcontractors shall develop startup plans and startup documentation formats and provide to the CM who will forward to the CxA.

10. The Subcontractors shall execute and document the pre-functional checklists prior to turnover of the systems to the CxA for acceptance testing.

Acceptance/Testing Phase

11. The CxA shall develop specific equipment and system functional performance test and integrated system test procedures after receipt of approved equipment and controls submittals. The Subcontractors shall review all applicable test procedures and plans.

12. The procedures shall be executed by the Subcontractors, under the observation of, and documented by, the CxA.

13. Items of non-compliance in material, installation or setup shall be corrected at the Sub's expense and the system retested.

*Turnover Phase

14. The CxA shall review the O&M documentation as prepared by the subcontractors and vendors for completeness and conformance with the contract documents.

15. Training of HMS personnel should be provided by the contractors, vendors and suppliers for all systems and equipment in conformance with the project contract requirements, approved by the design and construction teams and documented by the CxA. The list of personnel training items will be developed in coordination with HMS Facilities during the Design phase.

16. Seasonal testing shall be conducted in the opposite season from the initial functional performance tests.

*Warranty / Occupancy Phase

17. Perform warranty period review. At approximately the 10-month point of the warranty period, review operation of commissioned systems with HMS and the CM. Document all issues and recommendations for improvement to meet the HMS's project requirements and forward to HMS and CM.

18. Issue the final commissioning report inclusive of:

    a. Statement of compliance with contract documents and OPR

b. Summary of major issues
c. Summary of any outstanding non-compliant issues
d. All identified non-compliant issues, remediation status and recommendations
e. All completed functional performance and integrated testing forms

1.6 RELATED WORK

A. All of the following divisions apply to the Work of this section.

1. 010000 General Conditions
2. 010000 Closeout Procedures
3. 200000 Common Mechanical / Electrical Requirements
4. 210000 Fire Protection
5. 220000 Plumbing Systems
6. 230000 Heating, Ventilating, and Air Conditioning
7. 250000 Automatic Temperature Controls
8. 260000 Electrical

B. Commissioning intent must follow the guidelines of this HMS Standard and Construction Document Specifications.

1.7 COMMISSIONING COMPLETION

A. Prerequisites to functional completion

1. All TAB work and commissioning activities must be complete prior to Functional Completion, unless approved in writing by HMS. This includes for all systems, but is not limited to:

a. Completed and signed start-up and PFCs
b. Requested trend log data
c. Submission of final approved TAB report
d. Completion of all functional and integrated testing
e. Completion of point-to-point checkout.
f. Submission of the approved O&M manuals
g. Required training of HMS personnel completed and approved
h. Identified deficiencies have been corrected or are HMS approved.

2. Exceptions to the Functional Completion are the planned control system training performed after occupancy and any required seasonal or approved deferred testing.

B. The CM will determine the date of Functional Completion after reviewing the CxA's recommendation for Functional Completion.

C. Commissioning activities are non-compensable and cannot be a cause for delay claims.

1.8 *SYSTEMS TO BE COMMISSIONED

A. *The following systems as a minimum shall be commissioned in a typical project having extensive MEP systems and sub-systems. This list will change from project to project depending on project classification level and scop and will be developed in coordination with HMS Facilities during the Design phase.

B. The matrix below provides a listing of the systems. Preliminary testing requirements are part of this section. Each member of the commissioning team shall review all test procedures in this section to determine if his/her presence is required for each test. Certain tests of mechanical equipment may require the support of electrical personnel and vice versa.

NOTE: Testing listed below does not reduce or eliminate other testing requirements called for in any other section of this specification document.

Systems and Equipment to be Commissioned (REVISE TO TAILOR SCOPE)
Mechanical Systems and HVAC Systems
Air Handling Units
Exhaust Air Handling Units
Chillers
Cooling Towers
Boilers
Supply Fans (Stair Pressurization)
Smoke Exhaust Fans
Roof Exhaust Fans
Energy Recovery Skid
Pumps (HW/CHWP/CWP/BP/ACHWP/HWRP/FP)
Plate and Frame Heat Exchangers
Air Separator
Unit Heaters (Cabinet/Electric)
Space Testing – Shell Space Terminal Units (FCUs, VAVs, CAVs, etc)
Plumbing Systems
Domestic Gas Fired Hot Water/Electric Heater & Pump
Domestic Booster Pump
Ground Sump Pump
pH Neutralization Skid
Electrical Systems
House Emergency Generator
Tenant Emergency Generator
Automatic Transfer Switches
Service Switch Gear
Tenant Switch Gear
Fire Pump
Lights Out Test
Lighting Controls – Shell Spaces
Controls Systems
Building Automation Systems, including equipment control sequences, scheduling, and alarms

1.9 *RESPONSIBILITIES

A. All Parties

1. Attend commissioning meetings as required to facilitate the commissioning process.

B. Construction Manager (CM)

1. Design/Bidding Phase
   a. Ensure that all sub-contractor bids are complete and compliant with the requirements of the contract documents.
   b. CM will make certain that the installing Subcontractors are aware of the TAB and commissioning process and fully embody these requirements into their work effort and work schedule.

2. Construction Phase
   a. Facilitate the coordination of the commissioning work by the CxA, and, with the CxA, ensure that commissioning activities are being scheduled into the master construction schedule.
   b. Attend commissioning scoping meetings and other commissioning team meetings.
   c. Perform the thorough review of subcontractor submittals. Provide copies of subcontractor submittals and/ or data pertaining to all approved equipment that will be commissioned to the CxA.
   d. Coordinate a meeting with the DE, CC, TAB and CxA to review controls completion and readiness for TAB commencement.
   e. Observe and witness pre-functional checklists, installations/test preparations and startup of selected equipment.
   f. Coordinate resolution of all Commissioning Action List (CAL) items by the applicable construction team members.
   g. Inspect construction in accordance with contract documents and report deficiencies to HMS, CM, and CxA.
   h. Verify completion of the installed systems and transmit document of completion to the CxA

3. Acceptance / Testing Phase
   a. Review balancing, commissioning progress and deficiency reports.
   b. Sign-off (final approval) on individual commissioning tests as completed and passing.
   c. Coordinate resolution and diligently document of all Commissioning Action List (CAL) items by the applicable construction team members.
   d. Witness significant equipment start-ups and testing protocols as selected by HMS.
   e. Ensure contractor support for FPTs

4. Turnover/Post Construction/Warranty Phase
   a. Turnover Meeting coordinated and directed by the DE and CM - The purpose of the meeting is to review the requirements and activities of the Turnover process.
   b. Provide contact list of subcontractors and vendors to support post warranty issues. List shall include; name, title, telephone number, email address, and emergency contact information for after-hours service.
   c. Provide a warranty list of installed equipment. The list shall include; equipment type, vendor's name, contact information and email address, and warranty start and duration of individual components.

d. Assist the CxA as necessary in the seasonal or deferred testing and deficiency corrections required by the specifications. This is to include the testing in the "opposite" season.

C. Owner's Project Manager (OPM) or HMS Construction Manager

1. Planning/Design Phase
   a. Facilitate commissioning requirements with the A/E and construction teams.
2. Construction Phase
   a. Arrange for facility operating and maintenance personnel to attend various field commissioning activities and field training.
   b. Provide final approval for the completion of the balancing and commissioning work.
   c. Review Commissioning Action List (CAL) and provide feedback regarding acceptance or rejection of system installation.
   d. Coordinate all construction, CX, and integration meetings.
3. Acceptance Phase
   a. Ensure that any seasonal or deferred testing and any deficiency issues are addressed.
4. Post-Construction/Warrantee Phase
   a. Facilitate/support A/E, construction and commissioning teams in acquiring and documenting receipt of all deliverables as per the final contract requirements.

D. All Installing Subcontractors that have commissioning responsibilities: The commissioning responsibilities applicable to each of the subcontractors are as follows (all references apply to commissioned equipment only).

1. Construction Phase
   a. In each purchase order or subcontract written, include requirements for submittal data, commissioning documentation, O&M data, as-builts and training.

   b. Each subcontractor is to adhere to the Project Schedule prepared at the time of the bid as it relates to their trade. Each subcontractor is to verify in writing that the schedule complete with the commissioning activities is achievable.

   c. Attend commissioning scoping meetings and other meetings necessary to facilitate the Cx process.

   d. Contractors shall provide the CM with normal cut sheets and shop drawing submittals of all commissioned equipment. The CM will forward a copy to the CxA.

   e. Provide additional requested documentation, prior to normal O&M manual submittals, to the CM who will forward to the CxA for development of FPTs.

      1) As a minimum, this shall include detailed manufacturer installation and start-up, operating, troubleshooting and maintenance procedures, full details of any owner-contracted tests, fan and pump curves, full factory testing reports, if any, and full warranty information, including all responsibilities of the Owner to keep the warranty in force clearly identified. In addition, the installation, start-up and checkout materials that are shipped inside the

equipment and the actual field checkout sheet forms to be used by the factory or field technicians shall be submitted to the CxA.

f. Provide a copy of the O&M manuals and submittals of commissioned equipment, through normal channels, to the CxA for review.

g. Contractors shall assist (along with the design engineers) in clarifying the operation and control of commissioned equipment in areas where the specifications, control drawings or equipment documentation is not sufficient.

h. Help the CxA in preparing the specific mock-up and FPT procedures. Subs shall review test procedures to ensure feasibility, safety and equipment protection and provide necessary written alarm limits to be used during the tests.

i. Develop a full start-up and initial checkout plan using manufacturer's start-up procedures and the pre-functional checklists from the CxA for all commissioned equipment. Submit to CxA for review and approval prior to startup.

j. Execute and document the pre-functional checklists.

k. Verify all equipment and piping has manual isolation valves for work to be completed for maintenance, repair & replacement, work closely with facilities for review of this and recommend where these should be located or if needed.

l. Provide skilled technicians, tools, instrumentation, equipment, and materials necessary to execute the starting of equipment. Ensure that they are available and present during the agreed upon schedules and for sufficient duration to complete the necessary tests, adjustments and problem solving.

m. Ensure completion of all specification requirements related to "execution" and "field quality control" and delivery of all specified documentation.

n. Perform and clearly document all completed startup and system operational checkout procedures, providing a copy to the CxA.

o. Address current A/E punch list items before functional testing. Air and water TAB shall be completed with discrepancies and problems remedied before functional testing of the respective air- or water-related systems.

p. Provide completed pre-functional checklists and startup reports, signed by the responsible parties, indicating that systems are complete and ready for functional performance testing

2. Acceptance Phase

   a. Provide skilled technicians, tools, instrumentation, equipment and materials necessary to perform functional testing.

   b. Correct deficiencies (differences between specified and observed performance) as interpreted by the CxA, CM and A/E and retest the equipment.

   c. Prepare O&M manuals according to the Contract Documents, including clarifying and updating the original sequences of operation to as-built conditions. O&M manuals are to be complete and approved for use during owner training.

   d. During construction, maintain as-built red line drawings for all drawings and final CAD as-builts for contractor-generated coordination drawings. Update as-builts as required after completion of commissioning (excluding deferred testing).

   e. Provide training of the Owner's operating staff using expert qualified personnel.

   f. Coordinate with equipment manufacturers to determine specific requirements to maintain the validity of the warranty.

   g. Update and maintain the asset tracking sheet as required by HMS. The equipment tracking sheet will reflect all relevant information on the installed equipment including but not limited to unit ID, model number, serial number and systems served. This tracking sheet will be completed in coordination with the HMS Asset Manager; HMS has an Asset App that can be used for entering new equipment into HMS asset management system. The populated equipment tracking sheet will be turned over to HMS at the completion of the project

3. Warranty / Occupancy Phase

   a. Execute seasonal or deferred functional performance testing, witnessed by the CxA. The seasonal testing requirement will only apply to a specific class of equipment or systems which can only achieve their full functionality during a specific season (e.g. chillers, boilers, heat recovery, economizer systems, etc.). The list of equipment requiring a deferred or seasonal functional testing will be developed during the Design phase in coordination with HMS Facilities.

   b. If a system has not been verified during the performance testing phase, then it is on the CM/Sub to come back and demonstrate proper operation at a later season. Correct deficiencies and make necessary adjustments to O&M manuals and as-built drawings for applicable issues identified in any seasonal/deferred testing.

   c. Deliver all final equipment warrantees and as-built packages in compliance with final contract documents

   d. Provide required Written Work Products as outlined in Table 1.21 on page 26

E. Mechanical Contractor: The responsibilities of the mechanical contractor, during Construction Phases in addition to those listed in Paragraph D of this section above are:

1. Provide start-up for all HVAC equipment, except for the building automation control system.
2. Assist and cooperate with the TAB contractor and CxA by:
   a. Putting all HVAC equipment and systems into operation and continuing the operation during each working day of TAB and commissioning, as required.

   b. Providing necessary sheaves or belts that may be required by TAB.

   c. Providing test holes in ducts and plenums where directed by TAB to allow air measurements and air balancing. Providing an approved plug. Please mark all test holes and plugs outside of the insulation to ensure future balancers know that these holes are available for use.

   d. Providing temperature and pressure taps according to the Construction Documents for TAB and commissioning testing.

3. List and clearly identify on the as-built drawings the locations of all airflow stations

4. Notify the CM with adequate notice (>= 5 days), who will notify the CxA, of time and date for start-up of each piece of equipment. Be responsible to notify the CM ahead of time, when commissioning activities not yet performed or not yet scheduled will delay construction.

F. Controls Contractor

1. The commissioning responsibilities of the control's contractor, during Construction Phases in addition to those listed in Paragraph F of this section:

   a. Using a skilled technician who is familiar with this building, execute the FPTs of the controls system as specified for the controls contractor. Assist in the functional testing of all equipment specified. Provide two-way radios during the testing.

   b. Execute all control system trend logs specified.

2. The controls contractor shall prepare a written plan indicating in a step-by-step manner, the procedures that will be followed to test, checkout and adjust the control system prior to functional performance testing. At minimum, the plan shall include for each type of equipment controlled by the automatic controls.

3. Provide a signed and dated certification to the CM who will forward to the CxA upon completion of the checkout of all controlled devices, equipment and system prior to functional testing for each piece of equipment or system, that all system programming is complete as to all respects of the Contract Documents, except functional testing requirements.

4. Beyond the control points necessary to execute all documented control sequences, provide monitoring, control and virtual points as requested by the CxA to demonstrate system operation.

5. List and clearly identify on the as-built duct and piping drawings the locations of all key devices, fire dampers, including flow stations, static and differential pressure sensors (air, water and building pressure).

G. TAB Contractor

1. The commissioning responsibilities of the TAB contractor, in addition to those listed in Paragraph D of this section above are:

   a. Work with the CxA as necessary to spot check air and water flow readings.

   b. Communicate with the controls contractor and CxA during the acceptance phase to coordinate work and minimize interfering efforts.

   c. Attend Cx meetings as requested.

   d. Review the commissioning schedule, ensuring TAB work precedes scheduled commissioning events. Where this cannot be accomplished, clearly communicate the issues with the CxA, CM and controls contractor.

H. Electrical Contractor

1. The commissioning responsibilities of the Electrical contractor, in addition to those listed in Paragraph D of this section above are:

2. Provide start-ups for all Electrical equipment:

   a. Work with the CxA as necessary to address any noted deficiencies.

   b. Notify the CM with adequate notice (>= 5 days), who will notify the CxA, of time and date for start-up of each piece of equipment. Be responsible to notify the CM ahead.

   c. Notify the CM with adequate notice (>= 5 days), who will notify the CxA, of time and date for start-up of each piece of equipment. Be responsible to notify the CM ahead of time, when commissioning activities not yet performed or not yet scheduled will delay construction.

I. Plumbing Contractor

1. The commissioning responsibilities of the Plumbing contractor, in addition to those listed in Paragraph D of this section above are:

2. Provide start-up for all Plumbing equipment:

   a. Work with the CxA as necessary to address any noted deficiencies.

   b. Notify the CM with adequate notice (>= 5 days), who will notify the CxA, of time and date for start-up of each piece of equipment. Be responsible to notify the CM ahead.

   c. Notify the CM with adequate notice (>= 5 days), who will notify the CxA, of time and date for start-up of each piece of equipment. Be responsible to notify the CM ahead of time, when commissioning activities not yet performed or not yet scheduled will delay construction.

1.10 MEETINGS

A. Kick-Off Meeting

1. As early as possible in the Construction Phase and before rough -in work begins, ,CM will schedule commissioning Kick-Off meetings with entire commissioning team in attendance. CxA will discuss the commissioning plan and outline the commissioning expectations during this meeting. The CxA will distribute meeting minutes to all parties.

Miscellaneous Meetings

2. Other meetings will be planned and conducted by the CxA as construction progresses. These meetings shall cover coordination, deficiency resolution and planning issues with particular Subs. CxA will plan these meetings through HMS and CM and the CxA will distribute meeting minutes to all parties.

1.11 REPORTING

A. The CxA will provide regular reports and field notes to HMS (Owners & Facility Managers) and the CM, with increasing frequency as construction and the Cx progresses.

B. The CxA will regularly communicate with all members of the commissioning team, keeping them apprised of commissioning progress and scheduling changes through memos, progress reports, etc.

C. Testing or review approvals and non-conformance and deficiency reports are made regularly with the review and testing as described in later sections.

1.12 SUBMITTALS

A. The CxA will review submittals related to the commissioned equipment as it relates to the commissioning process, to the functional performance of the equipment and adequacy for developing test procedures. This review is intended primarily to aid in the development of functional testing procedures. Final approval of all equipment, shop drawings, coordination drawings, operations and maintenance manuals, etc. shall remain with the design team.

B. The CxA may request an additional design narrative from the A/E and Controls Contractor, depending on the completeness of the design intent documentation and sequences provided with the Specifications.

C. The O&M manuals and as-builts are the responsibility of the Contractor, though the CxA will review.

1.13 TESTING REQUIREMENTS

A. Specific functional testing requirements are provided for most systems found in the project. From these requirements, CxA will develop step-by-step procedures to be executed by the Subs. Additional testing requirements shall be provided by the CxA for those systems not detailed herein. The test requirements for each piece of equipment or system contain the following:

1. The contractors responsible to execute the tests.
2. A list of the integral components being tested.

3. Pre-functional checklists associated with the components.
4. Functions and modes to be tested.
5. Required conditions of the test for each mode.
6. Special procedures.
7. Required methods of testing.
8. Required monitoring.
9. Acceptance criteria.
10. Sampling strategies allowed.

B. The testing requirements specified for commissioning are in addition to and do not replace any testing requirements specified elsewhere.

1.14 TESTING PREREQUISITES

A. The following applicable generic prerequisite checklist items are required to be completed and checked off by the contractors prior to functional testing.

1. All related equipment has been started up and start-up reports and pre-functional checklists submitted and approved.

2. All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final set points, alarm points and schedules with debugging, loop tuning and sensor calibrations completed.

3. Test and balance (TAB) complete for associated HVAC air and water systems.

4. All primary CxA and A/E punch list items for this equipment corrected.

5. Systems to be commissioned are operating in their normal state, under automatic control with no anomalies and system overrides in place.

1.15 TEST EQUIPMENT

A. The applicable contractor shall provide all testing equipment required to perform startup, initial checkout and functional performance testing.

B. Special equipment, tools and instruments (only available from vendor, specific to a piece of equipment) required for testing equipment, according to these Contract Documents shall be included in the base bid price to the Contractor and left on site.

C. All testing equipment shall be of sufficient quality and accuracy to test and/or measure system performance with the tolerances specified in the applicable specifications section.

1.16 PRE-FUNCTIONAL CHECKLISTS, START-UP AND INITIAL CHECKOUT

A. The following procedures apply to all equipment to be commissioned.

B. Execution of Pre-Functional Checklists

1. Pre-Functional Checklists (PFCs) are required to verify that the equipment and systems are hooked up and operational. It ensures that functional performance testing may proceed without unnecessary delays. Each piece of equipment shall receive full pre-functional checkout. No sampling strategies are to be used and 100% of equipment needs to have a PFC. The PFCs for a given system must be successfully completed prior to formal functional performance testing of equipment or subsystems of the given system.

2. The execution of the PFCs are directed by the CxA and executed by the Subs.

3. Only individuals that have direct knowledge of the piece of equipment for which the PFC is being filled shall initial or check off items on that sheet. It is not acceptable for witnessing supervisors to fill out these forms. This is up to PDC, suggest to delete.

4. The CxA will approve pre-functional checklist completion by auditing the completed pre-functional checklist reports and by direct site observation.

C. Start-up and Initial Checkout Plan

1. The primary role of the CxA in this process is to verify that there is written documentation that each of the manufacturer-recommended procedures have been completed. Installing contractors shall follow the manufacturers' recommended startup procedures.

D. Sensor and Actuator Calibration

1. All field-installed temperature, relative humidity, CO, CO2 and pressure sensors and gages, and all actuators (dampers and valves) on all equipment shall be calibrated using approved methods. Sensors provided with calibration certification need not be field calibrated. Refer to Section 230900 for calibration requirements, more stringent shall apply.

2. All procedures used shall be fully documented on the pre-functional checklists or other suitable forms, clearly referencing the procedures followed and written documentation of initial, intermediate, and final results.

E. Valve and Damper Stroke Setup and Check

1. For all valve and damper actuator positions checked, verify the actual position against the BAS readout.

F. Execution of Startup

1. The Subs and vendors shall execute startup, complete the start-up checklist(s), and provide the materials to the prime Contractor. The prime Contractor will provide the CxA with a signed and dated copy of the completed start-up checklists.

2. Only individuals that have direct knowledge and witnessed that a line-item task on the start-up checklist was performed shall initial or check that item off. It is not acceptable for witnessing supervisors to fill out these forms.

G. Deficiencies, Non-Conformance and Approval in Checklists and Startup

1. The Subs shall clearly list any outstanding items of the initial start-up and pre-functional procedures that were not completed successfully, at the bottom of the procedures form or on an attached sheet. The procedures form and any outstanding deficiencies are provided to the CxA following checklist completion.

1.17 FUNCTIONAL PERFORMANCE TESTING & INTEGRATED SYSTEMS TESTING

A. This sub-section applies to all commissioning functional performance and integrated systems testing for all divisions.

B. The parties responsible to execute each test are listed with each test.

C. FPT Objectives and Scope

1. The Functional Performance Testing (FPT) shall demonstrate that each system is operating according to the design intent and Contract Documents. Functional testing facilitates bringing the systems from a state of substantial completion to full dynamic operation. Additionally, during the testing process, areas of deficient performance shall be identified and corrected, improving the operation and functioning of the systems.

2. Each system shall be operated through all modes of operation (seasonal, occupied, unoccupied, warm-up, cool-down, part- and full-load) where there is a specified system response. Verifying each sequence in the sequences of operation is required. Proper responses to such modes and conditions as power failure, freeze condition, low oil pressure, no flow, equipment failure, etc. shall also be tested.

D. Development of Test Procedures

1. Before test procedures are written, the CxA shall obtain all requested documentation and a current list of change orders affecting equipment or systems, including an updated points list, program code, control sequences and parameters.

2. The CxA shall develop specific test procedures and forms to verify and document proper operation of each piece of equipment and system. Each Sub or vendor responsible to execute a test shall provide assistance to the CxA during test execution.

3. The CxA shall review owner-contracted, factory testing or required HMS acceptance tests which the CxA is not responsible to oversee, including documentation format, and shall determine what further testing or format changes may be required to aid in the commissioning effort. Redundancy of testing shall be minimized.

4. The test procedure forms developed shall include (but not be limited to) the following information:

a. System and equipment or component name(s)
b. Equipment location and ID number
c. Date
d. Project name
e. Participating parties
f. Instructions for setting up the test.
g. Special cautions, alarm limits, etc.
h. Specific step-by-step procedures to execute the test, in a clear, sequential and repeatable format
i. Acceptance criteria of proper performance with a Yes / No (or Pass / Fail) check box to allow for clearly marking whether proper performance of each part of the test was achieved.
j. A section for comments

k. Signatures and date block

E. Test Methods

1. Functional performance testing and verification may be achieved by manual testing, monitoring, either or both as indicated in the procedure.

   a. Manual testing (persons manipulate the equipment and observe performance)

   b. Monitoring the performance and analyzing the results using the control system's trend log capabilities or by stand-alone data loggers. The CxA may substitute specified methods or require an additional method to be executed, other than what was specified.

2. Simulated Conditions

   a. Simulating conditions (not by an overwritten value) shall be allowed, though timing the testing to experience actual conditions is encouraged wherever practical.

3. Overwritten Values

   a. Overwriting sensor values to simulate a condition, such as overwriting the outside air temperature reading in a control system to be something other than it really is, shall be allowed, but shall be used with caution and avoided when possible, and immediately reset/released once work is complete

4. Altering Set points

   a. Rather than overwriting sensor values, and when simulating conditions is difficult, altering set points to test a sequence is acceptable. For example, to see the AC compressor lockout work at an outside air temperature below 55°F, when the outside air temperature is above 55°F, temporarily change the lockout set point to be 2°F above the current outside air temperature. Setpoints shall be restored to their intended settings.

5. Setup

   a. Each function and test shall be performed under conditions that simulate actual conditions as close as is practically possible. The Sub executing the test shall provide all necessary materials, system modifications, etc. to produce the necessary flows, pressures, temperatures, etc. necessary to execute the test according to the specified conditions. At completion of the test, the Sub shall return all affected building equipment and systems, due to these temporary modifications, to their pre-test condition.

6. *Sampling

   a. It is noted that no equipment sampling is allowed during the Functional Performance Testing process. 100% of all newly installed equipment needs to be tested and its proper operation verified as part of the Cx process.

b. If at any point, frequent failures occur and testing seems to be more about troubleshooting than verification, the CxA shall stop the testing and require the responsible Sub to perform and document a checkout of the remaining units, prior to continuing with functionally testing the remaining units.

F. Coordination and Scheduling

1. The Subs shall provide sufficient notice to the CxA and CM regarding their completion schedule for the startup of all equipment and systems. The CxA will schedule FPTs through the CM and affected Subs. The CxA shall direct, witness and document the FPTs and ISTs of all equipment and systems. The Sub or authorized agent of the manufacture shall execute the tests.

2. In general, FPTs are conducted after PFCs and startups have been satisfactorily completed. The control system is sufficiently tested and approved by the CxA before it is used for TAB or to verify performance of other components or systems.

G. Problem Solving

1. The CxA will recommend solutions to problems found, however the burden of responsibility to solve, correct and retest problems is with the CM/ Sub

1.18 BAS EVALUATION

A. The CxA shall review all BAS graphic screens for correctness and completeness. This includes verifying, but is not limited to, the following: Refer to the control drawings and specifications for requirements on graphics. More stringent shall apply.

1. Accuracy of graphics to installed systems including terminal unit and thermostat locations to ensure it accurately depicts the system and operation as provided.
2. Accuracy of sensor readings. Readings must correspond to the correct sensor in the field with accurate readings.
3. All required alarm points.
4. Existence of active alarms or errors on the system.
5. Consistency of graphic pages and links. (Are there the same points/links on similar pages?)
6. Correctness and completeness of page links. Links take you to correct location and that location has all the required information.
7. If new equipment will be part of load shed or isolation, it will be evaluated.

1.19 DOCUMENTATION, NON-CONFORMANCE AND APPROVAL OF TESTS

A. Documentation

1. The CxA shall witness and document the results of all FPTs using the specific procedural forms developed for that purpose. Prior to testing, these forms are provided to the CM and Subs for review.

B. Non-Conformance

1. The CxA will record the results of the FPT on the procedure or test form. All deficiencies or non-conformance issues shall be noted and reported to the CM & Owner on an agreed upon non-compliance form. This form may be the CxA's master deficiency and resolution log.

2. Corrections of minor deficiencies identified may be made during the tests at the discretion of the CxA. In such cases the deficiency and resolution will be documented on the procedure form.

3. Every effort will be made to expedite the testing process and minimize unnecessary delays, while not compromising the integrity of the procedures. However, the CxA will not be pressured into overlooking deficient work or loosening acceptance criteria to satisfy scheduling or cost issues.

4. As tests progress and a deficiency is identified, the CxA discusses the issue with the CM /Sub.

    a. When there is no dispute on the deficiency and the Sub accepts responsibility to correct it:

        1) The CxA documents the deficiency and the Sub's response and intentions and they go on to another test or sequence. The Sub corrects the deficiency, signs the non-compliance form or other approved document certifying that the equipment is ready to be retested and sends it back to the CxA.

        2) The CxA reschedules the test and the test is repeated.

        3) If the deficiency is identified during the retest, the cost for that retest, as well as any other retest effort, will be the responsibility of the installing contractor.

    b. If there is a dispute about a deficiency, regarding whether it is a deficiency or who is responsible:

        1) The deficiency shall be documented on the non-compliance form with the Sub's response and a copy given to the CM and to the Sub representative assumed to be responsible.

        2) Resolutions are made at the lowest management level possible. Other parties are brought into the discussions as needed. Final interpretive authority is with the A/E. Final acceptance authority is with HMS and the CxA.

        3) The CxA documents the resolution process.

        4) Once the interpretation and resolution have been decided, the appropriate party corrects the deficiency, signs the non-compliance form or other approved document and provides it to the CxA. The CxA reschedules the test and the test is repeated. If the deficiency is identified during the retest, the cost for that retest, as well as any other retest effort, will be as indicated below in Item 8 – Cost of Retesting

5. The Contractor shall respond in writing to the CxA and CM at least as often as commissioning meetings are scheduled concerning the status of each apparent outstanding discrepancy identified during commissioning. Discussion shall cover explanations of any disagreements and proposals for their resolution.

6. The CxA retains the original non-conformance forms until the end of the project.

7. Any required retesting by any contractor shall not be considered a justified reason for a claim of delay or for a time extension by the prime contractor.

C. Approval of the Test

1. The CxA notes each satisfactorily demonstrated function on the test form. Formal approval of the functional test is made later after review by the CxA and by the CM, if necessary. The CxA recommends acceptance of each test to the CM using a standard form. The CxA gives final approval on each test using the same form, providing a signed copy to the CM for inclusion in the final O&M.

1.20 DEFERRED TESTING

A. Unforeseen Deferred Tests

1. If any check or test cannot be completed due to the building structure, required occupancy condition or other deficiency, execution of checklists and functional testing may be delayed upon approval of the HMS CM and PM. These tests will be conducted in the same manner as the seasonal tests as soon as possible. Services of necessary parties will be negotiated.

B. Seasonal Testing

1. Seasonal testing (tests delayed until weather conditions are closer to the system's design) shall be completed as part of this contract. The CxA shall coordinate this activity. Tests will be executed, documented and deficiencies corrected by the appropriate Subs, with facilities staff and the CxA witnessing.

1.21 *WRITTEN WORK PRODUCTS

A. The commissioning process generates a number of written work products described in the Specifications. Below is a list of all the formal written work products and who is responsible to create them. In summary, the written products are:

Product	Developed By	Provide During
Commissioning meeting minutes	CxA	Throughout all phases
Commissioning schedules	CM with input from the CxA	During construction phase
Complete commissioning plan	CxA	Pre-design/design phase
Equipment documentation submittals	Subcontractors and vendors	Construction phase
Sequence clarifications	Subcontractors and A/E as needed	Construction phase
Basis of design documentation	A/E	Pre-design/design phase
Equipment startup and initial checkout plan	Subcontractors and vendors, review by CxA	Testing phase
Write PFCs	CxA with primary input from subcontractors	Construction phase
Executed PFCs	Subcontractors	Construction phase
TAB plan	TAB subcontractor	Construction phase
Final TAB report	TAB with verification by design team	Testing phase
Write functional performance tests	CxA	Construction phase
Executed functional performance tests	Subcontractors with verification by CxA	Testing phase
Write integrated systems testing protocols	CxA	Construction phase
Commissioning progress record	CxA	Throughout all phases
Deficiency reports	CxA	Construction and Testing phases
HMS Training Plan	CM and subcontractors	Turnover phase
O&M manuals	CM and Subcontractors	Turnover phase
Warranty List	CM and ubcontractors	Turnover phase
Systems Manual	CxA	Turnover phase
CFR – Current Facilities Requirements	CxA primary input from HMS on PM plan	Turnover phase (Required for LEED projects)
On Going Commissioning Plan	CxA	Turnover phase (Required for LEED projects)
Final commissioning report	CxA	Turnover phase for primary report, amended report during warranty phase as applicable

2.0 OPERATION AND MAINTENANCE MANUALS

2.1 STANDARD O&M MANUALS

A. The specific content and format requirements for the standard O&M manuals are detailed in each Section.

B. CxA Review

1. Prior to substantial completion, the CxA shall review the submitted O&M manuals, documentation to verify compliance with the Specifications. The CxA will communicate deficiencies in the manuals to HMS and A/E.

3.0 TRAINING

3.1 TRAINING OF HMS PERSONNEL

A. As mentioned in Paragraph 1.5 A.15, the list of personnel training items will be developed in coordination with HMS Facilities during the Design phase. The requirements for owner training is normally listed in the Project Specification document under the sections for the individual systems or sub-systems being specified

B. The CxA shall assist the CM in coordination and scheduling of training of HMS personnel for commissioned equipment including the content and adequacy of the training conforms to contract requirements. The CM shall be responsible for the training agenda, execution and scheduling and ultimately for ensuring that training is completed.

C. The training program set up will include the following primary components:

1. System design presentation of major components including one line diagram review and keyed floor plans.

2. System walk-through indicating location of all main components.

3. System operation demonstration.

D. The A/E + CM presentation may be required only for those projects which are significantly different in scope from regular renovation projects or have specialized non-standard equipment, space operating conditions, etc.

E. The Manager of Facilities Operation Planning will be the primary point of contact to coordinate the schedule and the training requirements for HMS Facilities or FMO personnel

F. In addition to these general requirements, the specific training requirements of HMS personnel by subs and vendors are specified in Divisions 1, 22, 23, 25 and 26.

END OF SECTION