Final Design Completion

The Comprehensive Final Design Review[1] (CFDR) marks the end of the final (detailed) design phase of system design. At this point, the system design should be defined in drawings and specifications. The CFDR will likely have been preceded by component/subassembly Final Design Reviews (FDRs) that were conducted to approve procurement packages. **The purpose of the CFDR is to assure that everything that needed to be accomplished in final design was indeed accomplished**. Plans should be in place (in the performance measurement baseline) for completing the next phase which is fabrication, assembly, integration, and test (FAIT) with minimum cost and schedule risk. **A successful CFDR is necessary to formally complete final design**.

The following elements are appropriate for review at the CFDR:

- System Requirements and Architecture
- Mechanical Design Elements
- Electrical Design Elements
- Software Design Elements
- Project Management Elements

These elements are discussed in the following paragraphs.

1 SYSTEM REQUIREMENTS AND ARCHITECTURE

The objective of this element is to show the key features of the system design and demonstrate how the system meets its requirements. The following documentation should be finalized:

- **System Design Description (SDD)**. This document provides an overview of the system design and explains how the system meets its requirements. Although not a controlled document, it should be updated for each major review, including the CFDR.
- **System Requirements Document (SRD)**. This document is a design-to specification that defines performance requirements and design constraints. It also defines how each system requirement will be verified, either by analysis, inspection, or test.
- **Product specifications.** Specifications describe the essential technical requirements for items, materials, and services including the procedures for verifying that the requirements have been met. Specifications are generally required when a product cannot be defined and accepted simply on the basis of a drawing and an inspection. All product specifications required for procurements and fabrications should be finalized by the time of the CFDR. Typically, product specifications and associated drawings will be the subject of FDRs conducted in advance of the CFDR to support timely initiation of procurements.
- **Analysis Reports**. A comprehensive set of formal analysis reports should be posted which provide a complete and satisfactory design basis for the system design. FMEAs should be performed and documented as appropriate. Analysis reports should be checked and signed. Data files should be archived with Technical Assurance (Art Brooks). Technical Assurance is also responsible for reviewing the suite of analysis reports to assure that they do indeed provide a complete and satisfactory design basis.
- **R&D Reports**. If R&D activities were necessary to underpin the design, the results of these activities should be documented in formal R&D reports.

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1 The Comprehensive Final Design Review (CFDR) is often referred to as the Critical Design Review. On NCSX, we chose to refer to it as the CFDR to avoid confusion with the Conceptual Design Review which would have the same acronym.

- **Interface Control Documents**. Formal documentation of interfaces should be provided to the extent determined by the cognizant engineers responsible for interfacing systems.

2 MECHANICAL DESIGN ELEMENTS

The mechanical design of NCSX components and assemblies is done exclusively within Pro/E, at least for the stellarator core and interfacing components. An integrated model of the stellarator core has been developed and has proven very beneficial from the standpoint of addressing interfaces and interferences. Drawings of parts and assemblies need to be developed in order for these things to be built. Bills of material for each assembly shall be generated from within Pro/E to provide a basis for generating a Master Bill of Material (see Project Management Elements).need to be generated to have a comprehensive listing of all the parts and assemblies.

A comprehensive mechanical drawing package of the system should be provided at the CFDR. Drawings should be reviewed, checked, and released for fabrication. Drawings should include:

- **Part drawings.** Part drawings provide the basis for part fabrication.
- **Assembly drawings.** Assembly drawings show how the constituent subassemblies and parts fit together.
- **Bills of materials.** Bills of material for each assembly should be generated from within Pro/E to provide a basis for generating a Master Bill of Material.
- **Piping and instrumentation diagrams (P&IDs)**. P&IDs show the interconnection of process equipment and the instrumentation used to control the process. P&IDs should be provided for any system with piping, e.g. for heating, cooling, or fluid power.

3 ELECTRICAL DESIGN ELEMENTS

A comprehensive electrical drawing package of the system should be provided at the CFDR. Drawings should be reviewed, checked, and released for fabrication. CFDR documentation should include the following:

- **General arrangement drawings.** These drawings show the arrangement of electrical equipment within the facility.
- **One line diagrams and electrical schematics**
- **Control wiring diagrams**
- **Physical drawings.** These drawings show the cable trays and conduits required to route cabling.
- **Cable and power panel lists**
- **Load lists**. Load lists (motors, solenoids, etc.) are generated so the demands for electrical power are systematically documented.

4 SOFTWARE DESIGN ELEMENTS (TBR)

Software specifications are usually captured in the form of flow charts and written documents that include the detail definition of each software element/subroutine. Such component definitions include the purpose of the software component, its inputs and outputs, its algorithm or pseudo-code, and a unit test plan. Software specifications and plans for how each software module will be tested and how the integrated software package will be tested should be provided at the CFDR.

5 PROJECT MANAGEMENT ELEMENTS

At the close of the CFDR, the system should be ready for the fabrication, assembly, integration, and test (FAIT) phase. Components and assemblies should be logically bundled for procurement. Procurement packages (specifications and drawings) should be prepared and approved for fabrication. All procurements should appear in the Performance Measurement Baseline (PMB). The appropriate budget, manpower, and timeline for these procurements should be reflected in the PMB.

Procedures will be needed for fabrication and assembly activities. Testing will be performed as parts and subassemblies are integrated into higher level assemblies. Completion of plans and procedures for fabrication, assembly, and testing should also appear in the PMB.

CFDR documentation should include the following:

- **Master Bill of Materials (MBOM).** Pro/Engineer generates bills of material (BOM) for mechanical assemblies and parts. In Pro/E, assemblies are made up of lower level assemblies (subassemblies) and parts. The BOM for the assembly will identify the subassemblies, but not the parts making up those subassemblies. To get a BOM for those parts, you need to look at the BOM for each subassembly. As a result, the BOM can be distributed over a wide number of drawings. The distributed BOM generated by Pro/E might also need editing. There will be instances where hardware (e.g., nuts and bolts) is purposely omitted to keep the model tractable. There will be other instances where an allowance for spares should be made. **On NCSX, we are asking WBS Managers to generate a Master Bill of Materials (MBOM) for each of their systems**. The MBOM should be in Excel format. The data from the distributed BOM in Pro/E should be copied directly – manual transcription of the entries should be avoided where possible. BOM entries for electrical equipment not appearing on mechanical drawings will need to be added manually. Quantities should be adjusted for modeling constraints and spares. The level of detail in the MBOM should correspond to the level at which parts will be ordered and received. For instance, if we are ordering a completed subassembly, there is no need to put every part in the subassembly in the MBOM. The MBOM should be formally checked to assure that no errors were made in generating the entries. The MBOM will have all the basic information required for submitting requisitions. It will be used as a checklist to ensure that every subassembly/part has been appropriately design reviewed; has an associated cost estimate; is associated with a procurement activity in the PMB; has been ordered; and has been received. The MBOM can be a valuable management tool for planning and tracking procurements and guarding against the risk of things "falling through the cracks".
- **Performance Measurement Baseline (PMB).** The PMB should be updated to reflect detailed plans in the FAIT phase of construction. All activities for procurements, developing plans and procedures, providing Title III engineering, and on-site fabrication, assembly, integration, and testing should appear in the PMB. Work Planning Forms (WPs) should be approved and jobs opened for work that is ongoing or scheduled to start upon successful completion of the CFDR.
- **Estimate to Complete (ETC).** The estimate to complete should be updated at the time of the CFDR to identify differences between what we anticipate the final costs to be and the costs in the PMB.