NCSX Design Maturity Assessment

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Design maturity is an important factor in evaluating the uncertainties and risks in the remaining NCSX work. While some NCSX systems are well into fabrication or even complete, others are still at a conceptual level.

The estimate uncertainty range for each work package is determined based on design maturity and complexity rankings assigned by the job manager. Low maturity, high complexity packages are more uncertain than high maturity, low complexity ones.

Design immaturity also contributes to risk. To the extent that estimates based on assembly plans or affected by interfaces are partly based on immature system or component designs, there is a risk that costs will grow when those designs mature and their details are better understood. The NCSX risk register includes several risks of this type.

Design Status Assessment

The design status of NCSX work packages is summarized in Table 1. Three zones are considered:

1. Inner Core: the stellarator core out to the modular coil shell and port flanges.
2. Outer Core: the stellarator core outside the modular coil shell and port flanges, and inside and including the cryostat.
3. Ancillary Systems: the facility beyond the stellarator core.

For each zone, the design status assessment considers the relevant systems, the relevant assembly tooling, and the relevant portions of the assembly sequence plan. Recent progress in advancing the design maturity is depicted by the type of cell entries used in the Table. As indicated by the cells marked with "X", the design maturity has advanced in FY-08 with the completion of several key reviews.

Inner Core Design Maturity

The inner core contains the two largest and riskiest systems, the vacuum vessel and the modular coils. Included are large, complex-shaped components featuring technically challenging designs, tight tolerances, multi-million dollar procurements and in-house manufacturing jobs. The two large procurements, the modular coils winding forms ($9M) and the vacuum vessel sub-assemblies ($5M), were completed a year ago. Installation of vacuum vessel services is complete. Sixteen modular coils have been fabricated with the last two in production and nearing completion. The last design task, the modular coil interface design, was completed in November, 2007.

Assembly of the vacuum vessel and modular coils, except for the final inter-period joint, will be performed in field period assembly Stations 2 and 3. The tooling for these stations is designed and procured; Station 2 is fully operational. The assembly sequence plans for these stations is very mature. Assembly is just starting.

The inner core is at a level of design maturity where the risk of further cost and schedule growth due to design changes is relatively small. Major risks in design and procurement have been retired, but assembly process-related risks remain.

Outer Core Design Maturity

The outer core contains several coil systems, coil services, support structures, the cryostat, and the neutral beam transition ducts. The individual systems are relatively conventional compared to the inner core systems, but multiple interfaces makes the overall assembly complex. The most mature of these system, the TF coils, are in production, but most of these are still in preliminary or final design.

Assembly of the outer core, including the final inter-period joint in the vacuum vessel and modular coils, is performed in field period assembly Stations 5 and machine assembly (Station 6). The tooling for these stations is being designed and the assembly sequence plans are not yet fully mature.

The outer core is at a level of design maturity where there remains significant risk of further cost and schedule growth as these designs mature. These are recognized in risk register entries. The project is currently focused on establishing space envelopes and interfaces for these systems. Many will complete FDRs by the end of FY-08, but a significant portion will only be completed in FY-09.

Ancillary Systems Design Maturity

The ancillary systems are conventional and very similar to systems constructed for other projects, including NSTX. The condition of legacy equipment to be used on NCSX is known as a result of testing that was completed early in the project. On that basis, the risks are relatively low even though most of the NCSX design work will only start in FY-09. The power systems design work has been started in FY-08 in order to establish interfaces and complete a PDR by the end of the year.

Table I. NCSX Design Status Summary

WBS	Scope	Job Mgr.	CDR	PDR	FDR	Free Float (days)	Start fab. / Award
Inner Core (Stellarator Core out to MC Shell & VV port flanges)							
12	Vacuum Vessel	Goranson					
14	Modular Coil Assemblies	Williamson					
14	MC AA, AB, BC Interface	Williamson / Cole		X	X	0	X
14	MC CC Interface	Williamson / Cole			X	0	X
18	FPA Tooling:						
18	Station 3 stands and lift fixtures	Brown			X	147	5/29/08
18	Station 3 module alignment syste	Brown			X	147	5/29/08
82	Assembly Sequence Plan Maturity		Assessment	Envisioned future changes			
82	Station 2	Brown	99%	probably none			
82	Station 3	Brown	90%	module alignment system			
Outer Core (Stellarator Core Beyond MC Shell & VV port flanges)							
12	NB Transition Ducts	Goranson		9/30/08	1/12/09	318	3/9/09
13	TF Coils	Kalish					
13	PF Coils	Chrzanowski		X	X	303	5/30/08
13	Trim Coils	Kalish	X	X	4/28/08	218	6/10/08
15	TF/PF Coil Structures	Dahlgren			6/16/08	188	9/2/08
15	Central Solenoid Structure	Dahlgren				188	9/2/08
16	LN2 Manifolds	Goranson		6/3/08	9/5/08	197	10/10/08
16	Electrical Leads	Goranson		8/22/08	3/27/09	337	9/30/09
17	Base Structure	Dahlgren		X	4/30/08	147	9/30/08
17	Cryostat	Raftopoulos	10/1/08	7/6/09	2/12/10	115	8/17/10
18	Assembly Tooling:						
18	Station 5	Brown		X	4/21/08	200	8/14/08
18	Station 6 module supports ("sled	Brown		6/10/08	7/8/08	255	9/30/08
18	Station 6 spool piece support	Brown		6/10/08	8/5/08	439	9/30/08
82	Assembly Sequence Plan Maturity		Assessment	Envisioned future changes			
82	Station 5	Brown	90%	coil support details, cryostat supports, lifting features			
82	Station 6	Brown	75%	cryostat details, carts-base integration, racks, cable trays, unknowns			
Ancillary Systems (Facility Beyond Stellarator Core)							
12	Heater control sys	Gernhardt		5/1/09	8/4/09	107	8/31/10
2	Fueling	Blanchard		4/29/09	6/29/09	318	1/13/10
2	Vacuum Pumping System	Blanchard		2/6/09	6/2/09	361	2/12/10
3	Diagnostics:						
3	VV spacer flux loops	Stratton		N/A	10/2/08	426	10/20/08
3	Visible camera system	Stratton		10/1/09	11/25/09	309	3/10/10
3	Electron beam mapping sys.	Stratton		4/27/09	6/24/09	372	10/1/10
4	Coil Protection System	Ramakrishnan	X	9/15/08			
4	Power Systems	Ramakrishnan		9/15/08			
5	Central I&C	Sichta		Jan-Dec. '09			
62	Cryogenic Systems	Raftopoulos	12/23/08	10/27/09	3/12/10	132	
63	Utility Systems	Dudek		10/29/10	11/15/10	134	
64	VV heating and cooling system	Kalish		2/4/10	5/14/10	221	10/1/10
85	Startup	Gentile	Starting safety docs. & ISTPs in FY-08				
			Legend				
				Completed prior to FY-08			
			X	**Completed in FY-08**			
			xx/xx/xx	**Current forecast date**			