U.S. DEPARTMENT OF ENERGY

OFFICE OF SCIENCE

Closeout Report for the National Spherical Torus Experiment (NSTX) Upgrade Project

Princeton Plasma Physics Laboratory

October 27, 2011

Stephen W. Meador, Chairperson

DOE/SC Review Committee

Office of Science, U.S. Department of Energy

http://www.science.doe.gov/opa/

Review Committee Participants

Department of Energy Stephen Meador, SC, Chairperson

Subcommittee 1: Technical
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Arnie Kellman, General Atomics

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Charge Questions

1. Final Design: Is the design sufficiently mature so that the project can pursue full procurement, fabrication and construction activities? For those elements of the design that are still not finalized, has the project convincingly shown that there are no major issues that need to be addressed and that they are on a clear path to final design?

2. Baseline Cost and Schedule: Are the current project cost and schedule projections consistent with the approved baseline cost and schedule? Is the contingency remaining adequate for the risks that remain?

3. Management: Evaluate the management structure as to its adequacy to deliver the proposed final design within specifications, budget and schedule. Has the project responded satisfactorily to the recommendations from the previous independent project review?

4. Documentation: Is the documentation required by DOE Order 413.3B for CD-3 complete? Has the CD-2 documentation been updated to reflect any changes resulting from the final design?

2. Technical Status

T. McManamy, ORNL/SC1, J. Irby, MIT, A. Kellman, GA

1. Final Design: Is the design sufficiently mature so that the project can pursue full procurement, fabrication and construction activities? For those elements of the design that are still not finalized, has the project convincingly shown that there are no major issues that need to be addressed and that they are on a clear path to final design?
   Yes - a final design review has been completed and overall the design does appear to be developed sufficiently to pursue full procurement, fabrication and construction . Design for the Digital Coil Protection System has not been completed and a final design review for it is scheduled for early 2012 but key performance parameters will be able to be met with the current design.

4. Documentation: Is the documentation required by DOE Order 413.3B for CD-3 complete? Has the CD-2 documentation been updated to reflect any changes resulting from the final design?
   The design documentation appears appropriate for CD-3 and CD-2 design issue resolved

2. Technical Status

T. McManamy, ORNL/SC1, J. Irby, MIT, A. Kellman, GA

Findings

- NSTX experienced a TF coil failure resulting in a decision to shut down and proceed with a start of NSTX Upgrade disassembly.
- A design review of the failure was conducted and potential vulnerability of the NSTXU coils reviewed resulting in recommendations to improve techniques for soldering cooling tubes in the TF conductor to prevent flux from contaminating coil insulation. The NSTXU design was found to be much less vulnerable to the type of failure experienced due to a single layer design and improved fabrication techniques (e.g. VPI, soldering process).
- An overall final design review has been conducted and all critical action items for CD-3 have been resolved and closed out.
- A friction stir welding technique has been developed for adding extensions to the TF coil conductor allowing full strength welds to be made. This change together with joints located at a greater radius, result in a factor of 5 safety factor for these critical components.

2. Technical Status

T. McManamy, ORNL/SC1, J. Irby, MIT, A. Kellman, GA

Findings

- An EDM machining process has been selected for the flexible joint leads and prototype fatigue testing has demonstrated required life
- Mockup and test winding will be used to validate the new TF/OH coil fabrication methods
- Although the DCPS design is not finalized, analysis performed to date has confirmed that induced currents and resulting loads in the coils and structures during disruptions will not prevent operation at full design parameters. Shims to constrain the motion of the center stack were added and the design of the passive plate mounting mechanism was modified to accommodate loads from halo currents and VDEs. Given the uncertainty in halo current calculations, the design approach is conservative.
- The largest single procurement is for the TF coil conductor and it has been placed

2. Technical Status

T. McManamy, ORNL/SC1, J. Irby, MIT, A. Kellman, GA

Comments

- The presentations detailed the technical aspects of the upgrade plan extremely well and the effort is appreciated
- The design appears to be well developed with no major outstanding issues
- All review recommendations have been tracked and nearly all resolved.
- The neutral beam refurbishment and relocation program seems sound
- Modifications to the vacuum vessel have been well thought out and a reduced scale Prototype of the new flange has been fabricated and the welding process tested successfully. Plans to leak check the new flanges have been well formulated and should quickly find any problems with the welds.
- The use of Aquapour to allow release of the OH stack from the core is an innovative concept. Though the initial small scale tests of this process were positive, a full scale test is certainly needed.

2. Technical Status

T. McManamy, ORNL/SC1, J. Irby, MIT, A. Kellman, GA

Comments

- Given the wide range of discharge parameters that are being considered (current, inductance, beta), it is desirable to develop a plan for measuring vessel displacement and disruption halo currents, in particular in the passive plates and the midplane near the centerstack.
- We have reviewed the Risk Registry and feel it covers all major issues. The cost estimates for rework seem reasonable but it surprised us that none of the items discussed affected the schedule.
- Finally, a 27% contingency for this upgrade appears adequate. There appear to be no show stopping R&D activities required.

2. Technical Status

T. McManamy, ORNL/SC1, J. Irby, MIT, A. Kellman, GA

Recommendations

1. Develop a plan for a set of diagnostics for measuring halo currents and vessel displacement to accommodate future installation by the DCPS final design review.
2. Evaluate procuring spare key fabrication tooling (e.g. induction heater) to reduce schedule risk from failures prior to start of fabrication.

3. ES&H

M. Andrews, FNAL

4. Documentation: Is the documentation required by DOE Order 413.3B for CD-3 complete? Has the CD-2 documentation been updated to reflect any changes resulting from the final design? No, the Project Hazard Analysis Report and the Construction Project Safety and Health Plan need to be completed and approved prior to CD-3.

- **Findings**
  - The Neutral beam decontamination was completed within the PPPL Radiation Protection Program and 10CFR835 Occupational Radiation Protection regulatory requirements.
  - All NSTX-U activities will be conducted utilizing PPPL's well-established ESH policies and procedures that apply the principles and core functions of ISM.

- **Findings**
  - ES&H subject matter experts have been assigned to the NSTX Upgrade Project to provide support and oversight in the areas of construction safety, industrial hygiene, and radiation safety.
  - A Security Vulnerability Assessment was completed for the project. The assessment found that Project presents no negative impact or increased cost to physical protection, personnel security, emergency operations or protective forces.
  - The NSTX facility is classified as “less than a category 3 Nuclear facility and will continue to classified as a “radiological facility”.
  - The Project installation plan includes integration of the job hazard analysis program into daily work planning meetings at both supervisory and work crews levels.

- **Comments**
  - A Hazard Analysis Report has been developed for the project; however, the document is incomplete. The HAR lacks a complete list of project hazards and mitigations. The document also needs to include a pre and post mitigation risk analysis and assessment. The analysis should include a complete list of hazards (e.g. confined space, material handling (crane and rigging operations), environmental, waste, hazardous materials/chemicals, etc.) and mitigations. The report should also define and include a risk analysis and assessment process which categorizes the projects risk (e.g. high, moderate, low).
  - A Construction Project Safety and Health Plan was developed but does not incorporate key ESH planning elements. The plan should include project specific organizational roles and responsibilities, standards and regulations, contractor responsibilities, job-specific work requirements (e.g. work planning, fall protection , hoisting/rigging, etc.), environmental and waste management.

- **Comments**
  - Oxygen Deficiency Hazards where added to the updated PHAR. The ODH analysis that was completed should be noted in the PHAR.
  - A project risk registry has been completed. An ESH risk referencing the occurrence of a serious incident that could initiate a DOE incident investigation and a significant schedule delay should be list in the registry.
  - The Project has developed a Project Operational Readiness Review process but needs to be clearly incorporated in to the HAR.
  - PPPL has a robust ISM and ESH program in place which needs to be linked to the Project Hazard Analysis Report and Construction Project Safety & Health Plan. This can be completed in a relatively short period of time

- **Recommendations**
  - Develop a complete Hazard Analysis Report for the Project as required for CD-3.
  - Develop Construction Project Safety and Health Plan as required for CD-3.
  - Clearly document the Operational Readiness Review process for the project including both PPPL and DOE requirements within the HAR.

Subcommittee: Cost, Schedule, and Funding

Kin Chao, DOE/SC
Tim Maier, DOE/BHSO
Darren Morton, DOE/OECM
Mark Whitson, DOE/OECM

3. Baseline Cost and Schedule: Are the current project cost and schedule projections consistent with the approved baseline cost and schedule? **Yes**

   Is the contingency remaining adequate for the risks that remain? **Yes**

4. Documentation: Is the documentation required by DOE Order 413.3B for CD-3 complete? Has the CD-2 documentation been updated to reflect any changes resulting from the final design? **Yes, cost, schedule, and funding documentation required by DOE 413.3B for CD-3 are complete and the documents have been updated.**

Cost, Schedule, and Funding

PROJECT STATUS (As of September 30, 2011)		
Project Type	MIE	
CD-1	Planned: January 2010	Actual: April 2010
CD-2	Planned: October 2010	Actual: 12/20/10
CD-3	Planned: January 2012	Actual:
CD-4	Planned: September 2015	Actual:
TPC Percent Complete	Planned: 28.7%	Actual: 27.4%
TPC Cost to Date	$21.1M	
TPC Committed to Date	$1.1M	
TPC	$94.3M	
TEC	$79.5M	
Contingency Cost (w/Mgmt Reserve)	$17.0 M ($18.4M after ECPs)	30% to go (26% after ECP)
Contingency Schedule	12 months	33.7%
CPI Cumulative	1.02	
SPI Cumulative	0.97	

Findings

- The **project has a risk registry** for the current baseline plans. For the **accelerated schedule, the project has qualitatively identified some risks**.

- As part of CD-2 baseline, **the project has documented scope contingency that can be used to mitigate cost**. However, in **case that more contingency becomes available, the project expect to return the funds for operations and thus little scope enhancements have been identified**.

- The project funding profile approved at CD-2 is follows:

	Prior Year	FY 10	FY 11	FY 12	FY 13	FY 14	FY 15	Total ($M)
Base Estimate	$5.10	$8.30	$8.70	$12.00	$20.70	$22.50		$77.30
Contingency			$0.90	$2.70	$4.50	$5.10	$3.80	$17.00
Total ($M)	**$5.10**	**$8.30**	**$9.60**	**$14.70**	**$25.20**	**$27.60**	**$3.80**	**$94.30**

Cost, Schedule, and Funding

- The **premature shutdown of the NSTX machine most likely will allow ~$9.4M of operations funds to be shifted** to the upgrade project and will support the project's plans to **accelerate the schedule by six months**. Office FES is in the process of reprogramming the funds for NSTX Upgrade project.

	Prior Year	FY 10	FY 11	FY 12	FY 13	FY 14	FY 15	Total ($M)
Baseline	$5.10	$8.30	$7.60	$14.60	$25.30	$27.60	$3.8	$92.30
Carryover				$3.00			$-1.0	$2.00
Reprogram from Operations				$7.00		($6.30)	($0.70)	$0.00
Total ($M)	**$5.10**	**$8.30**	**$7.60**	**$24.60**	**$25.30**	**$21.30**	**$2.10**	**$94.30**

Comments

- The current project cost and schedule projections are consistent with the approved baseline cost. The contingency remaining is adequate for the risks.
- Cost, schedule, and funding documentations required by DOE 413.3B for CD-3 are complete and the documents have been updated.
- There appears to be rigorous approach to maintenance of cost and schedule estimates by the project.
- The review committee has no problem with carrying the variance for early start as this show actual schedule progress compared to the approved baseline. If the team chooses not to re-baseline, EAC and BAC should be closely monitored.
- Risk registry for the baseline scenario only list risks ~ $3.7M of cost contingency and **appears to be lacking in a number of areas – particularly the funding constraints and in the potential for a project shutdown due to an accident.**

Comments continued

- While the aggressiveness in accelerating the schedule is admirable, **the amount of contingency funding in FY12 is a concern**. The project team needs to develop a plan to accommodate anticipated cost overruns and provide a priority of activities to slow down if the funding in FY12 does not materialize as anticipated.

- **Although summary level risks have been identified, quantitative risk should be developed for accelerated schedule** to better understand, mitigate, and plan for the project. For example, what are the concerns associated with procurement related tasks? Are there vendors involved? What are the specific funding risks—such as expected funding scenarios, delays, cuts, etc.

Recommendations

- Better quantify risks associated with the acceleration approach by February 2012.
- The project and the program need to start communication process for contingency usage proposals (wish list).

5. Management

F. Crescenzo, N. Larson, DOE

3. Management: Evaluate the management structure as to its adequacy to deliver the proposed final design within specifications, budget and schedule. Has the project responded satisfactorily to the recommendations from the previous independent project review? YES

4. Documentation: Is the documentation required by DOE Order 413.3B for CD-3 complete? YES, Well, mostly (EVMS, ESH). Has the CD-2 documentation been updated to reflect any changes resulting from the final design? YES

- **Findings**
  - The management team has been stable since baseline approval.

5. Management

F. Crescenzo, N. Larson, DOE

- **Findings (cont)**
  - All high risk designs are 95% complete.
  - The (independent) Final Design Review found the design sufficiently complete and ready for implementation.
  - OFES has been flexible in approving advancement of scope from post CD-3 baseline schedule.
  - The project is forecasting six month accelerated early finish relative to the baseline early finish assuming advanced funding in FY-12.
  - OFES and the project have agreed to pursue the accelerated early finish without changing the baseline.
  - There have been multiple independent reviews of the project since baseline approval (CD-2).

5. Management

F. Crescenzo, N. Larson, DOE

- **Findings (cont)**
  - The failure of the center stack unit was analyzed; the cause determined and process and conclusions peer reviewed.
- **Comments**
  - The management team is highly experienced, capable and stable.
  - The project team has successfully managed scope very similar to this project in the past.
  - The project is performing well, all management systems are operating effectively.
  - There are new risks potentially impacting the advanced early finish date.

5. Management

F. Crescenzo, N. Larson, DOE

- **Comments (cont)**
  - Project has not quantified schedule risks from advancing procurements.
  - There does not appear to be measurable risk to the baseline performance from the advancing the early finish.
  - Reasonable actions were taken to reduce technical risks including mock-ups of complex components.
  - The design appears adequately advanced to support CD-3.
  - The project has addressed the center stack unit failure in the design.
  - The project should consider implementing a post CD-3 peer review process.

5. Management

F. Crescenzo, N. Larson, DOE

- **Recommendations**
  - Proceed aggressively with the advanced early finish schedule.
  - Quantify and address procurement risks to the accelerated early completion schedule as soon as possible.
  - Request CD-3 approval after recommendations are completed.