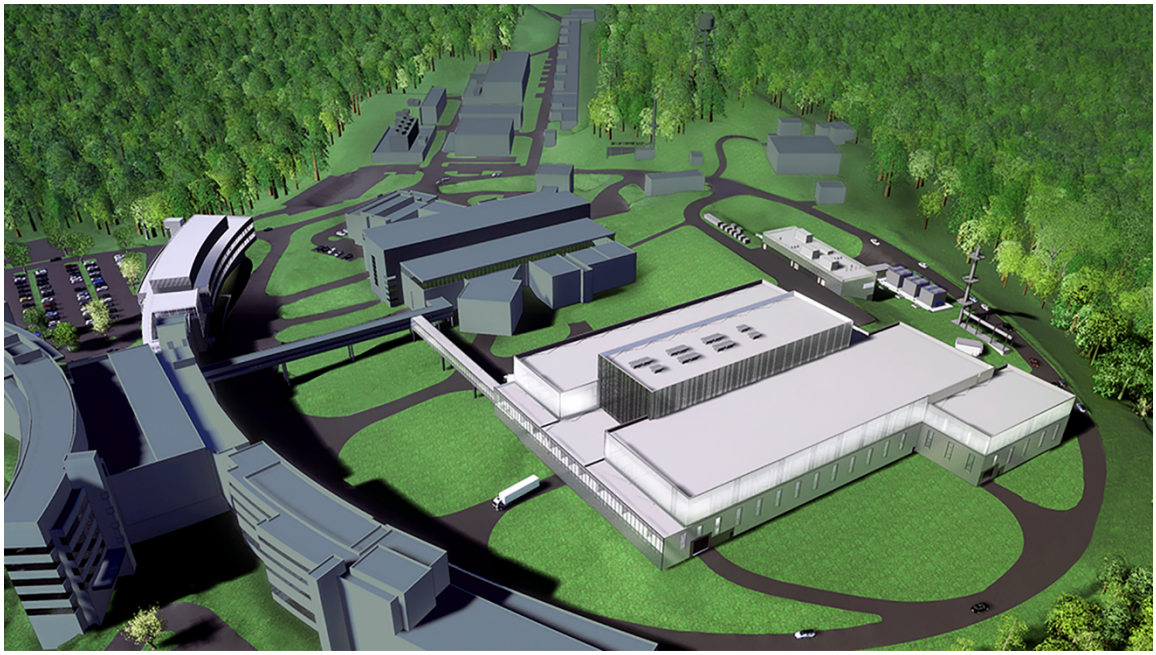
S03020000-DRD10000

Second Target Station Project: Target Assembly Preliminary Design Review Report



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June 2024

OAK RIDGE National Laboratory

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Second Target Station Project

SECOND TARGET STATION PROJECT: TARGET ASSEMBLY PRELIMINARY DESIGN REVIEW REPORT

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OAK RIDGE National Laboratory

Preliminary Design Review of STS Target Assembly

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June 20, 2024

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U.S. DEPARTMENT OF ENERGY

Key Points

- The design is well advanced, beyond the stage typically associated with completion of Preliminary Design, and is ready to proceed to Final Design.
- Thoughtful consideration has been given to the layout of the upper assembly, where functions (seals, drive, bearings) have been allocated to their own segments.
- Remote handling benefits greatly from the elimination of two-axis motion when inserting or extracting the target segments (and all components!) from the core vessel.
- The target segment has evolved into an elegant design that provides a one-piece integral unit with robust separation of water from tungsten.

Charge 1: Have system requirements been defined, and are they complete and adequate to ensure acceptable system performance?

Yes, generally.

- Findings
  - A comprehensive list of requirements has been developed, many of which include justification text. Only one TBD exists in the TA Design Description document (carried over from the PHAR)!
  - The project clearly identified which requirements are not satisfied with the current design.
  - Requirement 2301 specifies a dose limit at 15 years for a component with an expected lifetime of 10 years.
  - Occupational health and safety are not specifically mentioned in design requirements.

Charge 1: Have system requirements been defined, and are they complete and adequate to ensure acceptable system performance? (cont.)

- Comments
  - Ensure DPA-NRT is used when comparing simulated DPA values to published data which used the NRT standard.
  - Requirement 2301 should be updated to specify dose limits commensurate with expected component lifetimes.
  - The pressure drop requirement (1644) for the target assembly should specify a flow rate that matches the expected operational flow.
- Recommendations
  - None.

Charge 2: Has the PHAR process provided the appropriate Target Assembly requirements?

Yes, generally.

- Findings
  - The TA System Description clearly identifies PHAR inputs to TA design and maps them directly to requirements.
  - Two broad scenarios from the PHAR contribute requirements for the TA:
    - Seismic event causing a rupture and explosion of hydrogen moderator;
    - Loss of cooling to the target segments.
  - The target protection system is required to identify and respond to a variety of scenarios with a broad range of sensors. Rotation sensors are located within the vacuum space.
  - The decision to implement credited controls for the bounding scenarios is based on an assumed extrapolation of dose to WG1 based on the calculated dose to WG2.

Charge 2: Has the PHAR process provided the appropriate Target Assembly requirements? (cont.)

- Findings (cont.)
  - Table 4.5 in the PHAR identifies CECs for detection of target rotation out of range and improper valve orientation.
  - The PHAR primarily focuses on events during operations rather than during maintenance activities.
  - There is limited evaluation in the PHAR of the impact of changes in beam parameters as an aggressor to the target and the subsequent consequences.
  - Target hazard analysis is based upon a flood-cooling target design rather than the current tube-cooling approach.

Charge 2: Has the PHAR process provided the appropriate Target Assembly requirements? (cont.)

- Comments
  - Alignment on language around the hazard events, particularly the loss of cooling event(s), between the safety analysis and engineering design description would improve clarity and ensure consistency.
  - The PHAR needs to clarify connections from hazard events to CECs with well-defined safety functions that address the specific event.
  - Define the V&V for the requirements with respect to safety - how will each requirement be verified/validated?
  - Clarify how the policy for selecting credited controls handles events where the dose approaches but does not exceed a defined limit.

Charge 2: Has the PHAR process provided the appropriate Target Assembly requirements? (cont.)

- Comments (cont.)
  - The process by which functions are assigned to either the TPS or the TPPS should be clarified.
  - It would be advantageous to take a first look at events during target assembly maintenance. If it appears possible to manage such events within the scope of other design packages and/or via procedures, this will reduce the risk of late TA design requirements.
  - Re-evaluate event TS3-5 with respect to the outlet water temperature monitoring by the TPS. Check if this is the optimal detection method for the event(s) under evaluation or if alternatives are available.
  - Update the hazard analysis to reflect updates to target design, especially the separation of water and tungsten.

Charge 2: Has the PHAR process provided the appropriate Target Assembly requirements? (cont.)

- Comments (cont.)
  - Engineered controls to continuously monitor a non-dynamic condition, such as valve position or a missing segment, adds unnecessary complexity to the TPS.
- Recommendations
  - In the next revision of the PHAR, change the credited controls for valve position monitoring and detection of a missing target segment from engineered controls (CEC) to administrative controls (CAC).
  - In the next revision of the PHAR, supplement beam-related events by evaluating unsynchronized beam (beam between segments) and characterizing the potential for higher power beam on target.

Charge 3: Are interfaces properly identified and defined?

Yes, generally. Several interface sheets contain TBDs and TBRs (interfaces identified but not yet defined).

- Findings
  - Only Req. 1574 related to Segment Lifetime refers to the *Interface Sheet for Proton Beam Parameters*.
  - Acceptable water leakage from a target segment into interfacing systems is not specified.
- Comments
  - Critical interfaces have been defined. Remaining TBDs and TBRs are acceptable for this stage of the design and should be resolved during Final Design.

Charge 3: Are interfaces properly identified and defined? (cont.)

- Comments (cont.)
  - Ensure the TA is capable of operating under all allowable beam profile and position conditions identified in the Interface Sheet (with respect to, e.g., heat loads, prompt radiation).
  - Consider incorporating an expectation for water leakage tolerance in interfacing systems.
- Recommendations
  - None.

Charge 4: Is the proposed design expected to meet the requirements?

Yes, for the most part.

- Findings
  - Relevant design requirements have been identified in the reference documentation and in each presentation.
  - In each case, a clear indication has been given regarding whether the design does or does not meet the requirement, or that the requirement has not yet been evaluated (green, red, or white stop sign symbol).
  - A few requirements are not met with the current design, e.g. overall pressure drop, replacement time for rotation sensors in vacuum, cyclic loading, prompt dose rate in the high bay during operations.

Charge 4: Is the proposed design expected to meet the requirements? (cont.)

- Findings (cont.)
  - The disposal package formally qualifies as Class C-like when the entire target segment is included in the volume concentration; however, it is very close on the Nb-94 isotope requirement when assuming a 10-year segment life at full beam power.
- Comments
  - Some requirements do not appear to be aligned with the current design (e.g. pressure drop). This could be rectified by adapting either the requirement description or introducing modifications in the design.

Charge 4: Is the proposed design expected to meet the requirements? (cont.)

- Comments (cont.)
  - Undetermined design performance with respect to the requirements will require further analysis/assessment, e.g refining models and the seismic and streaming analyses. These should be, and often already are, planned for the final design phase.
  - A shorter run-time for the target segments would increase the margin of the Nb-94 limit for disposal.
  - The requirement for replacement time (10 hr) on the TPS rotation sensors is more likely to be met if they are located outside the vacuum environment. The TPS rotation sensors should be relocated outside the vacuum boundary.

Charge 4: Is the proposed design expected to meet the requirements? (cont.)

- Comments (cont.)
  - Of the requirements not yet met, none appear to be showstoppers.
- Recommendation
  - None.

Charge 5: Is the proposed design sufficiently mature to proceed to final design?

Yes, the design is well advanced and can be considered beyond the stage typically associated with completion of Preliminary Design.

- Findings
  - The target design utilizes a novel combination of materials, with multiple material interfaces. Detailed theory and part prototypes have been used to support this design choice. Manufacturing risks have been identified, and appropriate plans have been made for a move towards full-scale part prototypes in the near future.
  - Comprehensive finite element analyses were carried out for all parts of the target assembly, applying realistic and bounding case scenarios. Results are within allowable limits.

Charge 5: Is the proposed design sufficiently mature to proceed to final design? (cont.)

- Findings (cont.)
  - Detailed replacement plans have been developed for all necessary components.
  - Two possible disposal routes exist for spent targets. The current disposal plan meets the requirements of both routes.
  - There is an R&D plan to perform PIE on tungsten rods irradiated to 20 dpa at LANSCE.
  - Small- and large-scale models are being used to test aspects of the manufacturing process and the material properties.
  - No analysis has been carried out of the risk of target damage during installation.

Charge 5: Is the proposed design sufficiently mature to proceed to final design? (cont.)

- Findings (cont.)
  - For the current design, no analysis has been carried out of a beam strike between segments.
  - For the current design, two bounding beam spot sizes have been considered in the present analysis; 60 and 90 cm^2. The lifetime of the target may be reduced by spot sizes below 60 cm^2. Off-axis beams and variations in delivered beam profile have not been analyzed.
- Comments
  - Targets are installed remotely into a gap with very tight tolerances. Consider analyzing the risk of damage to the target segments, and mitigating this with handling aids such as guide rails or bumpers if required.

Charge 5: Is the proposed design sufficiently mature to proceed to final design? (cont.)

- Comments (cont.)
  - Consider including thermal diffusivity measurements in your PIE of LANSCE-irradiated tungsten rods.
  - Manufacturing prototyping is commendable and is providing valuable insight into the material properties and likely failure modes.
  - There is good alignment between the designed-in preferred failure mode of the target segments and the ability of interfacing systems to manage and identify water leaks without necessarily introducing a release of material from the facility.

Charge 5: Is the proposed design sufficiently mature to proceed to final design? (cont.)

- Comments (cont.)
  - Off-normal beam conditions which may adversely affect target lifetime and/or cause damage to the shaft should be simulated in more detail during Final Design.
  - FEA analyses are remarkably advanced. Approach to fatigue analyses is well developed. Ditto for neutronics analyses. Kudos to the design team!
- Recommendations
  - None.

Charge 6: Are the acquisition and manufacturing plans appropriate?

Yes, the acquisition and manufacturing plans appear appropriate at this stage.

- Findings
  - A preliminary manufacturing plan has been developed for the entire TA.
  - Each target segment is a complex component with many manufacturing operations. Several segments per year will be required to meet the target replacement schedule.
  - The team is in the process of getting a near full-scale HIPped prototype and estimates a 20-week timeline, not including the tungsten block which STS has in hand and will provide to the vendor.

Charge 6: Are the acquisition and manufacturing plans appropriate?

- Comments
  - The team is already working with a QA representative. Inspection points have been identified. The QA plan appears to be in a good state for this stage of the project.
  - The team has made a commendable effort to engage early with vendors. The most vendor-limited manufacturing processes have been identified.
  - The team has engaged with multiple vendors and is confident they can meet the required lead times.
- Recommendations
  - None.

Summary

- Two recommendations identified:
  - In the next revision of the PHAR, change the credited controls for valve position monitoring and detection of a missing target segment from engineered controls (CEC) to administrative controls (CAC).
  - In the next revision of the PHAR, supplement beam-related events by evaluating unsynchronized beam (beam between segments) and characterizing the potential for higher power beam on target.
- Excellent preparation and organization of this PDR, thanks to Aaron, Lindsay, and the entire team!