56 MHz Project Review

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Final Report

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Introduction

During a review held March 8 &9 at BNL, the committee examined the progress of the BNL 56 MHz Project. The project is well underway with most of the design completed and significant component construction begun. The committee was impressed by both the scope and quality of the work done to date. While much work needs to be done and challenges remain, the committee feels the project is on the right track to meeting its scope within cost and schedule. We found no potential show stoppers other than those already identified by the project.

Below, please find our response to the charge along with a list of recommendations that we think could increase the likelihood of success.

The committee would like to thank the project team and BNL for their hard work in gathering and presenting this material as well as for their hospitality and openness during the review. Please do not hesitate to contact us if you have any additional questions or comments on this report.

Response to Committee Charge

- **Are the cost and schedule reasonable for this stage of the project?**
  - Yes, the cost and schedules are well developed and detailed and appear reasonable. A fixed price contract for the Nb cavity and helium vessel has been awarded and progress at Niowave looks very good. This constitutes the highest cost and schedule risk. There are several areas where design solutions have yet to be developed or confirmed, but the time allotted for resolving these matters appears adequate.

- One place where the schedule has some risk is in the unknown number of cycles between cavity testing and processing but the time given for both cryomodule assembly and testing seems more than ample so there may be some schedule float available to compensate for this unknown.
- A fully loaded schedule including manpower still needs to be developed. See recommendations below.
- Cost contingency should be more explicitly called out in future presentations.

- **Review the testing and performance goals. Are proposed tests and procedures sufficient to reach those goals? Is tooling for the cavity processing and string assembly adequate? Does schedule provide enough time for testing?**
  - A list of quantitative performance/design goals was presented. A brief list of tests was mentioned, but with insufficient detail to enable a judgment of sufficiency. A detailed test plan is needed for demonstrating component, subsystem, and integrated system performance as early for each as possible. Specific test objectives should be identified for each, building confidence along the way toward system performance. Some of these tests need to be durability or robustness tests, e.g. thermal cycle testing of HOM couplers.
  - The tooling for string assembly appears to have been carefully considered, noting weight and support requirements at each step. There are thoughts toward tooling for cavity processing, but adequacy cannot be demonstrated yet.
- **Evaluate the cavity and helium vessel design, fabrication progress and schedule.**
  - They have done a very thorough job of analyzing the cavity and helium vessel design for structural, thermal and RF issues and this work seems well understood.
  - The cavity & helium vessel fabrication has begun at Niowave. Significant progress has been made and the work appears to be on schedule.
- **Evaluate the cryomodule design (tuner, vacuum vessel, shielding, support system).**
  - This work is based on both previous BNL SRF experience and on experience from other labs and seems to be in good shape and doesn't present a significant risk. Again, significant analysis on structural and thermal issues has been carried out.
  - The magnetic shielding design is not complete particularly regarding the end pieces. The actual background magnetic field in the tunnel still needs to be

verified and linked to the magnetic shielding design via an explicit cavity Q specification.

- **Review and comment on the designs of HOM and fundamental power dampers, FPC.**
  - Ancillary cavity parts such as the high pass filter HOM dampers, fundamental damper and fundamental power coupler are in various states of analysis and design.
  - The most complicated and furthest along is the HOM damper with analysis complete and mechanical design complete. This effort represents significant work and thought.
  - The design requires the conducting surfaces to remain superconducting. Because of the long thermal conduction paths, any increase in thermal loading due to multipactor, field emission, or unanticipated thermal impedance may lead to damper quench.
  - The HOM damper may be vulnerable to multipacting in the insulating vacuum portion of HOM damper, in particular the sapphire window and the sapphire filter capacitor blocks may be susceptible to multipacting.
  - The HOM damper appears to be the highest risk item remaining in the project at this point.
  - The new feedthrough being developed for FPC and the FDC is quite innovative though testing is still required.
- **Evaluate the use of an IR detector as a method to detect quench of HOM dampers.**
  - This is an interesting approach to this problem and still requires additional R&D including additional ANSYS thermal modeling. The project should also investigate other perhaps, simpler approaches to detecting the HOM quenches.
- **Review RF and vacuum sub-systems. Comment on soundness of their design and implementation.**
  - Both these areas use well established technology and present very little risk. They are well underway. The approach to particulate control seems appropriate and the understanding of the differences between this implementation and those at SNS is quite sound.

- **Are there open technical risks? If so, what additional steps are necessary to adequately answer them?**
    - While there are remaining risks (particularly with the HOM damper) these have been recognized by the project and are being addressed. Additional steps are listed in the recommendations below. Overall the committee finds no other potential "showstoppers"

Recommendations

1. Ensure that BNL understands and will commit to providing you with the necessary resources to meet your schedule. Produce a manpower loaded schedule and merge it into a broader one that includes all other BNL activities that may affect your resources. Explicitly track the progress of the VTA refrigerator.

2. Facilities for SCRF (clean rooms, assembly and test areas) should continue to be upgraded. While there appear to be work-arounds that will let this project move forward, additional dedicated facilities will improve efficiency, reduce risk and help ensure appropriate quality of construction. Later SCRF projects will also benefit from this investment.

3. Given the high risk of the HOM damper design (issues with potential multipacting, thermal environment, materials, etc.) a workshop or external review strictly on the HOM damper involving other members of the SCRF community is highly recommended.

4. The HOM design should be checked with the anisotropic characteristics of dielectric and coefficient of linear thermal expansion constants of sapphire.

5. Additional multipacting studies on the HOM damper should also be carried out. This should include the study of whether coating of the sapphire window needs to be carried out to bleed charge and/or prevent multipactor.

6. Develop an experiment with the HOM coupler and cavity in the vertical test facility that closely mimics the actual cooling techniques and operating conditions (particularly thermal ones) of the HOM coupler.

7. Evaluate whether use of simple temperature diodes on the Nb surface in insulating vacuum on the cooling conduction path would provide a more reliable and economical source of HOM damper quench interlock. Also, include consideration of how the cavity

loaded-Q will change with normal-conducting HOM loop and how the FPC RF control system might promptly sense that and provide an independent interlock condition.

8. It is strongly recommended to construct a dummy cavity from inexpensive materials with similar mass and interface points. The dummy cavity should be used to commission handling procedures, HPR procedures, and clean assembly procedures (including coupler insertion and mounting without cavity contact or particulate generation).
9. Specific test criteria that indicate success should be developed for each major component.
10. Consider the use of formed rather welded bellows in the FPC.
11. Analyze the HOM field penetration into the coaxial region formed by the FPC port and loop outer conductor.
12. Investigate the impact on radiation damage on the on the proposed optical encoder.
13. Review use of press fits on the coaxial cables and potential impact of differential thermal contraction upon cool down.