JPARC Materials and Life Science Facility Technical Advisory Committee (N-TAC)

Report on the Sixth Meeting

Held at JAEA Tokai Site
February 27-29, 2008

Executive Summary and Main Recommendations

The performance of the JSNS team has so far been outstanding. The team is to be congratulated for the accomplishments achieved to date.

All systems appear to be extremely well engineered. Fabrication and installation looks generally very professional and the level of cleanliness throughout the Project is outstanding. Changing from the gear pump in the mercury loop to a rotating magnet electromagnetic pump was an important step towards reliable and trouble-free operation of the loop. The successful development of this novel pump design at the required performance level is a remarkable achievement.

Adequate attention has been give to remote handling operations and maintenance.

The Committee concluded that, although the situation has now become extremely tight, if all open tests can be performed as planned and no further unexpected difficulties are encountered "*Readiness to accept beam on Day-1*" can be achieved around the end of May 2008 as planned. Any new difficulties, however, would pose a serious threat to this goal.

The next level of preparation will involve documenting operation and maintenance procedures and establishing operating limits and alarm levels for the process variables.

"*Readiness for sustained operation*" will require additional efforts, some of them based on the outcome of initial tests with beam.

In preparation for routine operation the Team has embarked on several improvement projects:

- Re-designing the proton beam window to incorporate more beam diagnostics for better protection of the target. This topic should be pursued with priority and the window should be exchanged as soon as the new one becomes available, preferably before high power operation (a few hundred kW) starts..

- Reduction of the waste volume at target shell exchange by introducing an additional connecting flange in the target. The Committee agrees that under the given boundary conditions the solution with a vertical flange arrangement seems to be the more promising one and should be pursued with priority.

- Redesign of the Moderator-reflector unit to bypass manufacturing difficulties with the present one. If this entrains penalties in neutronic performance, an alternative solution might be better Quality Assurance in the manufacturing process.
- Mitigation of cavitation erosion (CE) remains a major focus to secure sustained pulsed operation of a mercury target. More excellent progress was reported by the Team on the understanding of the CE-mechanism. This work has profited greatly from collaboration with universities and the SNS in the past, which should continue. *Important R&D to solve existing difficulties must be properly funded in order to secure successful full power operation and high availability of the facility in the future.*

Since the probable target life time is still difficult to predict due to unclear effects of geometry and flow conditions, measures foreseen to evaluate the damage potential on the real JSNS target during operation may prove extremely helpful. In the Committee's view they are comprehensive and look promising. *Nevertheless, the lack of a spare target remains a serious concern with respect to source availability once user operation starts*. The ongoing efforts of re-designing the target vessel to make replacement cheaper and faster have the full support of the Committee but should not distract from the necessity of having a spare target in stock, once operation at a few hundred kW starts.

The Committee was pleased to learn that recovery of the Linac full energy has been given a start by approving 1,8 Oku¥ (out of 85 Oku¥ required) in FY2008.

The team has – so far- managed to cope with severe budget restraints remarkably well, but one worrisome consequence clearly is the lack of spare parts in general. We feel that this might become a serious problem in terms of sustained facility operation.

The Committee was also concerned about an apparent understaffing of the LSF team. Many tasks rest on the shoulders of only a few people and documentation and production of operating procedures seems to be lagging behind. This bears the risk of too narrow a knowledge base which might become a real threat to sustained facility operation. The present concept seems to imply that the scientists and engineers responsible for building the facility will also be the operators of the future. The Committee is concerned that the qualifications required for the two types of tasks may not be the same.

Finally, while a certain work overload on the staff is normal towards the end of a project, the situation seems to be very tense in the LSF team. Care must be taken for it not to lead to dangerous shortcuts or unnecessary mistakes.

1. Introductory remarks

The N-TAC Committee, comprising the members

Dr. Günter S. BAUER (Chair)	ex Forschungszentrum Juelich GmbH, Germany
Dr. Timothy A. BROOME	ex ISIS, Rutherford Appleton Laboratory, UK
Dr. John M. CARPENTER	Argonne National Laboratory, USA
Mr. Hajo HEYCK	Paul Scherrer Institute, CH
Prof. Hiroaki KURISHITA	Tohoku University, Japan
Dr. Thomas J. MCMANAMY	SNS Project Oak Ridge, USA

was invited to hold its sixth meeting on Feb. 27-29, 2008, at the Tokai site of JAEA, Ibaraki Prefecture. All members attended the meeting, except for J. Carpenter, from whom apologies were received.

As in the past, the Committee felt very well received and preparations by the Project Team were excellent. Once again we wish to express our sincere gratitude to the Project Management and its supporting organizing team for a smooth and effective meeting and the continuing confidence put in us as an Advisory Team.

The comprehensive written response to the N-TAC5 recommendations is much appreciated.

The presentations to the Committee (in English!) were well prepared and generally very clear, revealing that the presenters fully command their subjects, even in cases where they had to stand in for the persons actually in charge. Facility construction is nearing completion on all fronts as evidenced by a most impressive visit to the site. The Committee was highly impressed by a demonstration of the removal of the lower moderator from the reflector plug by remote handling.

The main topic of the meeting was “Readiness for beam on Day 1”, which seems to be generally on good track. Other issues dealt with were “Facility Diagnostics” and “R&D for the Future”. Here, again, it became clear that the Team is fully aware of the needs and possibilities and make every effort to secure safe, reliable and economic operation of the facility. In the present report “Facility Diagnostics” is included in the “Readiness” chapter, because of its close relation to this topic.

The relative shortness of the present report (as compared to earlier ones) should be taken as a sign of the maturity of the Project.

2. General Findings and Comments

2.1 Schedule

Relative to the previous N-TAC meeting in Nov. 2006, the Team reported a schedule delay of 1 month, which is in fact more like 2 months, because the planned durations for several of the remaining activities have been shortened significantly. While the Committee did not judge it impossible to achieve the current schedule, the schedule risk has risen considerably.

Most members of the Team are now working in a high stress situation, which clearly increases the risk of mistakes being made and (dangerous?) shortcuts being taken. In particular activities in the hot cell will require very careful planning since they can hardly be accelerated and there may well be competition for resources (e. g. the power manipulator). Shortcuts here could fire back!

2.2 Budget

The budget has become extremely tight, to an extent that does not allow procurement even of the most essential spare parts, like a second target shell.

The Committee has concerns about the ensuing spare part policy of the Project: While spares are not directly related to readiness for beam, they are quite important for reasons of both, budget and availability. Presently spares seem to be missing almost completely.

We fully understand that in some cases, like the target shell, there is a temptation to wait for the re-design to be completed before a second copy is ordered. However we consider this a risky procedure because there is no guarantee for either the point in time when the spare will become necessary nor when the new design will be fully functional.

Also, it must be taken into account that vendors and suppliers can go out of market and spares will not be available sometimes even after short time (for example the moderator AlC vendor, where the Project was lucky to find another vendor).

At least for the future, as far as the operating budget allows, most critical parts should be kept in stock to remain independent from vendor and delivery time.

The spare part problem concerns especially electronic equipment, where products life cycle becomes shorter from year to year. The Project should, therefore, be prepared to having to find alternative suppliers in some cases and, as a general rule, provide as much flexibility in the systems as possible to adapt to other products (e.g. space and connectors allowing installation of other products).

Furthermore, important activities have been delayed due to lack of staff, such as

- as-built documentation,
- keeping a list of ‘vulnerable’ activities i.e. those where recovery from equipment failure would be particularly difficult,

- preparation of system operating procedures for normal and off normal events, which is considered as essential before beam operation.

Finally, funding of important R&D, in particular pressure wave damage mitigation seems to be suffering from the severe budget situation. This issue must be resolved because the design of the next generation target shell, which cannot be delayed, depends on the outcome of this research.

2.3 Technical

The team is to be congratulated for the accomplishments achieved to date.

All systems appear to be extremely well engineered. Fabrication and installation looks very professional and the level of cleanliness is exceptional.

Adequate attention has been given to remote handling operations and maintenance Assuming success for the hydrogen system testing (see below), the systems can be expected to be ready for beam in May.

The next level of preparation will involve documenting procedures and establishing operating limits and alarm levels for the process variables

Ground settling has been serious in the past but seems to level off now as expected. Extensive realignment of the proton beam transport from the muon target to the neutron target would be extremely difficult and time consuming if the settling would turn out significantly worse than predicted.

Equipment developed and built for neutron target system maintenance seems to be in good shape and appropriate to accomplish the necessary tasks.

The Committee was pleased to learn that a Rotating Magnet EM-pump for the mercury loop has been developed successfully and has been installed and tested with very good results prior to activating the mercury loop.

The hot cell will have to be used for maintenance and repair of neutron target system components as well as of muon target system components and beam transport line components. So far demonstrations seem to have been carried out only for neutron target system components.

3. Readiness

3.1 Definition of “Readiness”

From the presentations given and the overall schedule shown for the Project, the Committee concluded that “Readiness”, the main subject of the present review, was currently defined as “*Readiness to accept beam on Day-1*”. This means that all

components should be available and all tests carried out that are necessary to obtain permission to put a (low intensity and low total charge) beam on target in order to demonstrate neutron production and to verify basic design parameters.

This is clearly different from *"Readiness for sustained operation with high availability for users",* which is the final goal of the Project. This will include several additional conditions and measures, some of which will be based on experience that will have to accrue from low power test operations. It should be preceded by another review.

3.2 Readiness Management

In the Committee's view the project is taking a very defendable approach to achieve *Readiness to accept beam on Day-1*:

A "Readiness Checklist" has been prepared, listing conditions for the different subsystems and components that must be fulfilled in order to be "ready". In this list items are classed in two categories:

A: Indispensable for Day 1
B: Preferably completed by Day 1

The status of every item is traced and is marked in the list as:
A: completed,
B: conditionally completed, or
C: not yet completed

While this list still seemed to be incomplete and lack some essential criteria at the date of the review, it is continuously being improved and updated, based in intense discussions within the Project and with the licensing authorities.

It was not possible for the Committee to scrutinize the full list -nor was this within our remit-. However, we would like to offer a few general comments:

- Consider having a review to ensure all 'indispensable' items have been identified and whether some could be re-classified as 'preferable'
- The classing of the various items should be re-examined. Some of the items classed as "A (Indispensable for Day-1)" might be downgraded as "indispensable for sustained operation", while others which seem to be missing, such as the commissioning of the muon target replacement should be included as "A".
- The readiness checklist should include preparation of any required operational procedures and criteria *with numbers* as well as the set-points (H,HH & L,LL) for alarms and system actions.
- There should be one single open issue list to keep track of the progress made. Decisions made by system engineers and project management about handling the issues should be documented, including the underlying arguments.
- Consider keeping a master list of just the remaining status B and C items.

3.3 General Status of "Readiness To Accept Beam on Day 1"

The Committee concluded that, although the situation has now become extremely tight, there is a realistic chance that all open tests can be performed as planned. If no further unexpected difficulties are encountered *"Readiness to accept beam on Day-1"* can be achieved around the end of May 2008 as planned. Any new difficulties, however, would pose a serious threat to this goal.

"*Readiness for sustained operation*" will require additional efforts, some of them based on the outcome of initial tests with beam. The current goal for this status is the end of 2008.

3.4 Readiness of Subsystems and Tasks

3.4.1 Hg Target Vessel and Trolley

The target vessel structure, seal performance, remote handling, alignment, target vessel maintenance and trolley maintenance, functional performance and installation alignment readiness checklists all completed. Achieving all of this was a major accomplishment and the team should be congratulated for this.

However, we recommend to ensure that there are system operating procedures for normal and off normal events before beam operation.

Upon completion of these checklist items these systems should be ready to accept beam.

3.4.2 Mercury circulation System

Checklists for local and remote operation have been completed. Testing included replacing the gear pump with a PM pump and demonstrating its smooth operation. Completing the pump replacement prior to beam operation was a significant achievement and should result in much more reliable operation.
Draining and filling operations of the mercury loop have been demonstrated.
The maintenance checklist has been conditionally completed with additional improvements identified for smooth pump replacement needed by Day-1.

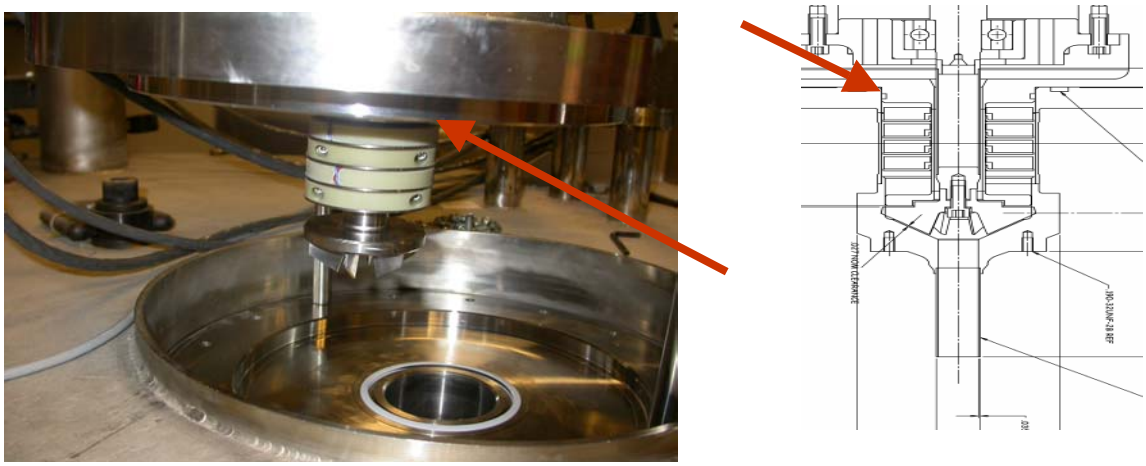
The Committee's comments and recommendations are:

- If there is schedule time available, consider running the loop at close to operating temperature by not cooling the secondary side of the heat exchanger. This would check the integrity of the seals with the piping thermal expansions to be expected in operation.
- Evaluate testing the ability to remotely transfer mercury from the spill collection tank to the system or a disposal path.
- Ensure there are system operating procedures for normal and off normal events before beam operation.

Upon completion of the identified items, the system will be ready for beam operation

3.4.3 Cryogenic Hydrogen System

Progress on this subsystem has suffered from difficulties with hydrogen pump tightness at low temperatures. An O-ring of Butyl rubber rated for >-40C is being added near the shaft of the hydrogen to correct the leakage problem This problem and solution is similar to the experience with the SNS circulators. SNS added a silicon O-ring which has a similar temperature rating and this corrected the problem.



SNS Circulator with added silicon o-ring

The SNS experience gives a high confidence that the proposed change will be successful.

At the time of the review

- The helium refrigeration system checklist and moderator system status checklist have been completed
- The vacuum systems operation checklist has been conditionally completed.
- The circulation system tests have not been completed because of the hydrogen pump leak during the last test.

Recommendation: After completing system testing ensure there are system operating procedures for normal and off normal events before beam operation

Completion of the design changes and system testing is required to be ready for beam operation.

3.4.4 Moderator and Helium Vessel and Shield & Top Plate

Readiness checklists have been completed for all installation activities, air tightness, cooling capability.

Moderator operational integrity testing with hydrogen had to be delayed until hydrogen loop testing can be done (April). Preliminary 20 K testing with He was successful, however.

Replacement checklists are partially completed.

The demonstration of moderator and reflector replacement was a significant achievement.

These systems should be ready for beam after completion of the hydrogen testing and checklists.

3.4.5 Shutter Vessel and Window

The shutter control system checklist has been completed with conditional completion for operation from instrument locations.
Shutter and vessel window vacuum systems checklists have been completed.
Shutter maintenance and vessel window checklists are complete except for the addition of some local shielding.

These systems should be ready for beam by end of May.

3.4.6 Remote Handling

The Project has provided truly impressive remote handling facilities – the Committee highly appreciates this great work!

Excellent progress has also been made with remote handling devices; equipment to replace the major components is in good shape.

The Committee's comments and recommendations are:

- While a lot of progress is being made, a great deal of detailed commissioning work remains to be done in the hot cell areas. Time is limited and there may well be competition for resources (e.g. the power manipulator); so detailed management will be required.

- Some difficulties have been found often with viewing – consideration should be given to installing a movable camera (e.g. held by a master slave manipulator or on a tripod).

- Maintenance of some of the services in the hot cell (e.g. cameras, cabling) appears to be very difficult by remote means – the requirements should be checked.

- During testing consider keeping a list of 'vulnerable' activities – i.e. those where recovery from equipment failure would be particularly difficult.

- Target Trolley remote handling checklist tasks remaining are grease application to the trolley rail and replacement of the slide unit. Greasing with remote handling tooling can be difficult and this testing should be done early to determine if tooling modifications are needed.

- Perform remote handling testing of the ability to grease the bearings for the pump.

- For the moderator change some work is needed to improve the collection of residual water from the circuits, after drain down, to limit spillage.

- Remote handling of Muon target and components in the hot cell remains to be demonstrated.

- Consider making commissioning of the muon target replacement in the hot cell 'indispensable' for Day-1

Completing the great deal of work in the hot cells that still needs to be done to demonstrate readiness for beam on Day-1 is a challenge. However, all relevant equipment seems to be in place and with proper activity management the goal of end of May 2008 is not unrealistic.

3.4.7 Service Facilities

Commissioning of the ancillary services presented is nearly complete.

The MLF General Control System is in good shape and it appears that the remaining work can be completed in time.

A comprehensive and well documented test of the interlock and safety systems is a prerequisite for the first day beam on target.

Recording signal trends and events during commissioning tests and integrated tests help to diagnose malfunctions and unforeseen effects and save a lot of time for trouble shooting getting the readiness for beam.

More attention must be paid to collection of residual water from circuits – acceptance criterion not yet met.

Ground settlement is close to the predicted values and is leveling off as expected. Re-alignment of the proton beam in the MLF building may be required as the loading on the building floor changes. This is a long term issue and may become difficult if the load becomes higher than currently anticipated.

Distortion (uneven settlement and thermal effects) of the experimental hall floor is within acceptable limits.

Most of the readiness criteria have been met. It should be possible to complete the missing ones in time.

3.4.8 *Radiation Control and Licensing*

Instrumental diagnosis for radiation safety seems to be very well prepared.
The first beam on target is in some respects the only moment to measure primary radiation sources from interaction of protons and neutrons before activation and contamination effects (Ar-41, Be-7) starts to influence the measured dose rates.

The Committee has the following comments and recommendations:

- There should be shielding in place around the mercury filters and the molecular sieve column in the off gas process system before medium power levels (ca. 100 kW) are reached.

- Silicagel absorbs not only HTO but also H_2O and D_2O, which should be considered in the capacity estimates for the projected operating period of the systems ability to hold back tritium.

- The hot cell ventilation system should be monitored for mercury to estimate the loading of the filters (e.g. by air sampling).

- Gold contamination which is difficult to remove, should be anticipated from deposition of volatile radioactive mercury in the air and in vacuum space.

- Water chemistry (pH & conductivity) is an important factor in the effectiveness of filters and ion exchangers and in radiation control to avoid release and spreading of radioactive corrosion or spallation products.

- Be-7 tends to plate out in pipes and heat exchangers due to temperature gradients. Prolonged operation of clean up systems after beam on periods reduces doses to personnel during maintenance periods significantly.

- Gamma spectroscopy should be prepared for analysis of samples taken after the first beam on period to identify nuclides (noble gases like Xe) which are relevant for doses and emission from the stack.

- Forming an in-house group (the “NOBORU-men”) to support and co-operate with Health Physics was a good move. However, the distribution of responsibilities between the NOBORU-men and the regular Health Physics group should be clearly defined from the beginning to avoid unproductive interference.

A staged procedure is being pursued in the licensing process. This implies a preliminary license for Day-1 operation and a final one for routine operation. Experience and information obtained during the test runs with beam will be used to

establish proper conditions for the final license. This is a natural way to proceed and has the full support of the Committee. The Committee was pleased to learn that working relations with the regulators are very good and that regular consultations are taking place.

Radiation Control is being paid proper attention to and will be an ongoing effort after beginning of operation. The relevant systems seem to be ready for beam on Day-1 but will have to be looked after and improved, based on early experience with low intensity beam. No problems were seen in the preparations to obtain a license to put beam on target at Day-1.

4. R&D for the Future

4.1 Proton beam Window

A problem with the current beam line setup is a certain lack of reliable on line diagnostics of the beam parameters, which might pose a threat to the target. Re-designing the proton beam window to incorporate more beam diagnostics as proposed is a good idea.
The topic should be pursued with priority and the window should be exchanged as soon as the new one becomes available, preferably before high power operation (a few hundred kW) starts. The present one can then be kept as a backup/spare.

4.2 Cavitation erosion

Cavitation erosion (CE) still remains the major concern for sustained pulsed operation of a mercury target and its mitigation must remain a top priority of the Project. The probable target life time is still difficult to predict due to unclear effects of geometry and flow conditions.

Measures foreseen to evaluate damage potential on the real JSNS target are comprehensive and look promising.

More excellent progress was reported by the Team on the understanding of the CE-mechanism. An important conclusion is that a broader distribution of bubble sizes may be most effective in overall damage mitigation. This puts less stringent conditions on the design of the bubble generator than a narrow distribution width.

The new pressure wave generator (AUTOLITH® spark device) is a perfect complement to MIMTM. Plans for future investigations (effect of pulse duration and bubble transport in target) and are well thought through and should be fully supported.

An effort is being made to determine the life time of bubbles in mercury in order to help the decision on the proper location of the bubble generator in the loop. However, it is important to remember that bubble life time as determined in stagnant mercury

may not be relevant under flowing conditions due to segregation and coalescence effects! Bubble generation close to where they are needed may still be the best bet.

The work has profited greatly from collaboration with universities in the past, which should continue. Similarly, collaboration with SNS (Oak Ridge) remains very important, also because it gives the JSNS Team access to the use of the full size Target Test Facility (TTF) and the in-beam test location at WNR in Los Alamos.

4.3 Post Irradiation Examination (PIE)

Preparations for PIE on the first JSNS target have been started. Taking samples by core drilling is a technique also used at SINQ; it was not clear, however, why JSNS apparently plans to do it in a vertical arrangement. This seems to bear a high risl of unwanted spill of any residual mercury left in the target shell.

Apart from examining samples we recommend also to try to look at the whole inner target surface to identify locations of high damage. This may even help to identify locations from which samples should be taken. This not trivial and requires careful planning and preparation.

PIE on the first SNS-Target will probably precede PIE on the JSNS target. Nevertheless examining the first irradiated JSNS target remains important, in particular in view of the different flow conditions inside the target.

The Committee recommends close collaboration with the SNS PIE team.

4.4 New Target Vessel Design

The present target shell unit is rather large and requires a big shielding cask when exchanged and put in storage. Introducing an additional coupling flange in the target as presently pursued by the design team has a dual advantage:

- reduction of waste volume
- possibility to replace the contact surface of the seal if it gets damaged.

Of the two options examined, the one with a vertical flange seems to be preferable, if all remote handling issues can be solved satisfactorily.

Design details like the seal gasket and mercury drip capture tray still need more studies, but the overall concept looks attractive. *Leakage of mercury into the He-vessel must be avoided under all circumstances.*

The inner structure of the front part of the target shell still needs to be worked out depending on the final pressure wave mitigation technique chosen.

4.5 Revised Moderator- Reflector Design

Difficulties encountered with the manufacturing and assembly have prompted the Team to embark on a re-design of the moderator reflector unit, possibly avoiding the

future use of the Ag-In-Cd (AIC) decoupler, and increasing the clearance between the reflector and the moderators.

In doing so, it should be born in mind that the present Target-Moderator-Reflector unit was carefully optimized with respect to materials and dimensions Difficulties with welds on the present moderators might be solvable by other means (e.g. improved Quality Assurance) than by increasing the clearance (which will affect moderator-reflector coupling).

The choice of AIC for decoupler had a big effect on other design features of the target station (flask, crane, building etc.) and was claimed to be highly beneficial for overall source performance. If this is still correct, searching for ways to resolve the present manufacturing and supply difficulties might be a better solution than abandoning the concept. Experience shows that new solutions usually have their own problems. For example, canned B_4C powder, as considered as a potential replacement for the AIC may be quite difficult to implement.

Proposed changes should be examined carefully with respect to potential neutronic penalties for the users.

5. Conclusions and Final Remarks

Despite some schedule slip relative to the previous meeting, mainly caused by difficulties with the tightness of the liquid hydrogen pump, the goal of first beam by end of May 2008 seems still attainable if the licensing procedure continues in a smooth way as expected and no new technical difficulties occur. The approach to ensuring “Readiness for Beam on Day-1” is very thorough and systematic and has largely been completed. Work still to be done is well planned and organized. A problem might arise with the preparation of documented operating and maintenance procedures if those are required by the licensing authorities as a prerequisite for permission to run a test beam.

The team has – so far- managed to cope with severe budget restraints remarkably well, but one worrisome consequence clearly is the lack of spare parts in general and of a replacement target shell in particular. We feel that this might become a serious problem in terms of sustained facility operation.

The remarkable progress made in the quest to mitigate cavitation erosion in the target justifies hopes that a final concept for the system will be in place before the beam power becomes high enough to seriously affect the life time of the target shell. Preparations made to study the effect on the real system are excellent and hold a promise to produce valuable information. The Committee wishes to underline the importance of continued adequate funding for the pertinent R&D because timely success on this front is crucial to the success of the MLF as a whole, including the muon facility, which cannot operate at full power without a neutron target that can take this power.

The Committee was also concerned about an apparent understaffing of the MLF team. Although progress in the Project continues to be impressive, it became clear that this is brought about by an extremely high work load on its staff. While a certain

work overload on the staff is normal towards the end of a project, the Committee has concerns that this might lead to (unnecessary) mistakes and/or dangerous shortcuts. Many tasks rest on the shoulders of only a few people and (in part as a consequence of this) documentation and production of operating procedures seems to be lagging behind. This bears the risk of too narrow a knowledge base which might become a real threat to sustained facility operation. The present concept seems to imply that the scientists and engineers responsible for building the facility will also be the operators of the future. The Committee is concerned that the qualifications required for the two types of tasks may not be the same.

Finally, the Committee welcomes the ongoing efforts to improve certain system components in order to secure reliable, sustained and economic operation of the facility. It is highly desirable to put the new proton beam window and target shell in place as soon as possible.

END OF THE REPORT

Waldshut, April 15, 2008

Günter Bauer

on behalf of the Committee