Report of the Neutron International Advisory Committee
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Overview

The importance of neutron methods for studying the structure and dynamics of materials which arises from the unique properties of the neutron is widely recognized. Unfortunately, it is difficult to produce neutrons in the quantities needed for modern materials research. Thus neutron methods are pursued primarily in large centralized facilities. Typically these facilities, often in partnership with other organizations, develop a variety of instrumentation, each optimized for making a particular type of measurement. Scientists from academia, industry, and government then apply for time to pursue their research agenda. The efficacy of this access model has been widely demonstrated and thus this approach has been widely adopted.

Due to the large national and even international investment in the construction and operation of these facilities, it is important that they be designed to optimize the quality and quantity of scientific and technical results that these sources produce. The staff of J-PARC and the Materials and Life Sciences Facility (MLF) has done an admirable job in this regard. The target and moderator systems promise superior performance, the instrument designs are impressive, and the device development activities are similarly world-class.

The last year has seen the MLF achieve many key milestones on the road to making the transition from a design, development, and construction project to a scientific organization dedicated to user service and research excellence, while continually improving the neutron instrumentation. These include: the first publication reporting data from an MLF instrument which reported the first demonstration of the repetition rate multiplication; the demonstration of energy-dispersive imaging; exceptional programs in device development, best exemplified by the outstanding work on scintillation detectors; and securing funding for the construction of two new instruments bringing the total number of funded instruments to 17. In addition, excellent progress has been achieved on many issues with the accelerator and source. This is best exemplified by routine operation at 120 kW achieved for the last three run cycles and brief operations at 300 kW. No less important have been the technical achievements on the target. Most importantly, these include impressive progress on a bubbler system and new data on the role of flow in suppressing cavitation, indicating that the lifetime of the mercury target will be much less of an issue than previously feared.

The rest of this report is divided into sections concerning the transition to operations, comments on the instruments and device development activities, and issues with the target and moderator systems. Recommendations in each area are italicized.

Instruments and Operations

Significant progress has been made in constructing, commissioning, and operating new beam line instruments at the MLF. Funding has been secured to construct instruments at 17 of the 23 available beam lines. Of these 17 instruments, 9 are already in the general user program, 3 are in the commissioning phase, 3 are under construction, and 2 are in the design stage with construction planned to start during FY2010. Funding for the most recently approved instruments has been obtained through the newly amended law referred to as the "Law for the Promotion of Public Utilization of the Specific Advanced Large Facilities (LPULF)."

Some progress has also been achieved in adding staff to provide a more supportive user environment. However, because of limited budgets, providing adequate support for the operating instruments remains a challenge. Scientific staff members are typically involved in multiple activities ranging from data acquisition, sample environment, detectors, safety committees, as well as operating specific instruments. Although this has system integration and interface management benefits, having some dedicated staff members in centralized groups focusing on these core areas would significantly benefit the entire enterprise. For example, strengthening these centralized groups would facilitate equipment sharing across the entire suite of instruments and bolster collaboration with international partners in specific areas. The new funding source (LPULF) provides the means to more fully staff the operating instruments. This is an excellent outcome, but it comes with some new challenges. Management of these funds and associated organizational elements will be somewhat independent of the existing funding agencies: JAEA; KEK; and Ibaraki prefecture, thereby further complicating the organizational structure at J-PARC. Nevertheless, staff members should be encouraged and must find a way to collaborate with each other and support core groups in standardizing data acquisition, sample environment, detectors, safety committees, etc.

> *Now that additional funding is becoming available through the LPULF, NIAC recommends that a detailed, time-phased plan be developed and implemented to increase instrument support, including both staff dedicated to specific instruments as well as those needed for core support groups such as data acquisition, sample environment, and detectors. The plan should be used to help prioritize hiring, as more funds become available. The plan must incorporate the types of activities that will be provided by each funding source. We also note that international best practice for operating a neutron user facility is at least six staff per instrument.*

The difficulties in providing adequate staff for robust user operations also makes it imperative that the management of MLF carefully consider what mix of being a "user facility" as opposed to a "development laboratory", they wish to achieve. Within the available funding, it is likely impossible to be truly excellent at both.

Neutron instrument operations proceeded quite well in 2009, with 6 run cycles of ~ 20 days duration. The FY10 plan calls for 6 cycles, which represents a reduction from the original plan of 9 cycles, due to budget limitations. Facility reliability for the last three 2009 cycles, which were categorized as higher power (120 kW) cycles, was in the range of ~90 %. This degree of reliability is quite impressive for a facility of this type, at such an early stage of operation. It should be noted, however, that the facility operated at much lower power than 120 kW during significant portions of this period, presumably to maintain high reliability. Although this may be a valid means of ensuring uninterrupted user operation, a proper "operations metric" that reflects the integrated fluence provided to users would be very useful in tracking progress towards meeting long-term user-program goals. Statistics related to equipment and system failures by facility element are being tracked well and should prove useful in focusing efforts for reliability improvements.

> *The NIAC suggests that, in addition to tracking overall facility reliability, namely provided hours vs. scheduled hour, the MLF develop and report other source*

performance metrics: such as tracking MW-hours provided vs. planned, average length of unplanned outages etc. This will help reveal if the operational goals are satisfied.

- comment for the NIAC committee: for the time being hours and MWh are good measures – when in full user operation J-PARC will have to measure hours/MWh towards a schedule i.e. are the (MW)hours delivered when at the time promised to the users.

J-PARC achieved almost 21,000 person-days of user participation with about 30% associated with the MLF. It is also noteworthy that 30% of the users of the MLF were from industry. These are very impressive accomplishments, considering the limited number of instruments in the user program at this early stage, and the number of days of user program operation. The typical neutron production rhythm in FY2009 consisted of two days of user operation followed by a day of RF conditioning for the accelerator. These short (2 day) user program periods are likely rather disruptive to many of the neutron scattering experiments, so it is good to see that the FY2010 plan calls for a rhythm of 6 days in user mode followed by a day of RF conditioning.

The balance among diffractometers and inelastic scattering instruments seems reasonable. Ten of the 17 currently funded instruments utilize elastic neutron scattering, including six diffractometers, one total scattering instrument, two relectometers, and one SANS instrument. Five of these are in the general user program, one is undergoing commissioning, two others are under construction, and two are still in the design process. The high resolution available with Super HRPD and high intensity available on the NOVA instrument are world leading, while the sample-exchange robot available on iMATERIA makes it a highly productive instrument. It is worth noting that iMATERIA is committed to serving industrial users for 80% of its operating time, leaving only 20% of its time for the general user program. In addition to the above three powder instruments, a group from Kyoto University will construct another powder instrument in collaboration with KEK. This instrument will be dedicated to the study of Li-batteries, in a fashion similar to the hydrogen-related program on the NOVA instrument. Therefore, the beam time allocable for general users on this instrument will also be limited to about 20%.

Given the restricted use of the existing and planned powder instruments within the general user program, the facility will lack a general-purpose, workhorse powder diffractometer for the foreseeable future. Therefore, the committee recommends that J-PARC consider use of one of the remaining beam lines for a general user program powder instrument.

The seven inelastic instruments include three chopper spectrometers, one backscattering instrument, the diagnostic instrument NOBORU, the nuclear data instrument NNRI, and the fundamental neutron physics instrument. The committee applauds the demonstration of the use of repetition rate multiplication (RRM) on the 4SEASONS Fermi chopper spectrometer, where initial work using this technique resulted in the first MLF publication. This clearly demonstrated the measurement efficiency enhancement and flexibility possible with the use of single event data recording.

Over 120 proposals have been received for the upcoming operations period. This is roughly what was received for previous run periods and is fully satisfactory, at this early stage of operations. Of course, the number of proposals will grow as more instruments are offered to the scientific community, and as the utility of these new instruments becomes apparent to potential users. The number of days requested significantly exceeds the number of days that are available. To date, this has been reconciled by approving most proposals and providing each fewer days than requested. This is fine for now, as the community and the instrument scientists learn the capabilities of the instruments. However, in the not too distant future, it will be possible to predict more accurately the length of time that a proposed experiment will take.   At this point, in order to optimize the productivity of the instruments, the approved experiments must get enough time to produce scientifically meaningful results. This will require more proposals to be declined.

Data acquisition and Data analysis software

With event recording, 100Mbit/sec TCP/IP data transfer rate the MLF has developed an excellent high-speed, efficient, low-power-consumption data-acquisition system, which will cope with the amount of data produced at the MLF. The use of event-mode data collection is very flexible and has made it possible to collect data at multiple incidents energies in a single measurement on the chopper instrument 4SEASONS. The data-acquisition software is adequate for user operations and with appropriate continued development and maintenance it appears that it will remain so into the foreseeable future. Ensuring that this software remains common across instruments using the same technique, such spectroscopy and powder diffraction is important to enable users to move seamlessly from one instrument to another.

Over the last few years the instrument scientists have worked very hard to develop software to reduce and visualize data and thus the MLF is well-positioned for the start of user operations. While the software to perform basic manipulations on the data is in place, the current software is still basic in many areas and further attention is necessary to provide for full featured data reduction and visualization packages.

The situation for data analysis is also adequate for this stage in the MLF's life. However it is clear that no one facility can supply all of the data analysis software that the scientific community will require to get the most science possible from the data. The problem of how to provide adequate resources will be exacerbated as the MLF moves into an operational phase and the instrument scientists necessarily concentrate on user service and have less time to develop software.

> *In light of the staffing issues at the MLF, it is essential that the MLF employ data-visualization and -analysis software developed at other facilities. In those cases where the available software is inadequate for MLF's needs, the MLF should participate in multi-facility software development efforts. In addition, it will almost certainly be necessary to add staff whose primary responsibilities are for developing and maintaining software.*

The choice of a similar framework (based on Python and C++) to that used at ISIS and the SNS means that the MLF is well placed to collaborate and make use of software development at these facilities. Perhaps more important are the collaborations that have already been developed with HANARO.   The NIAC applauds these efforts and encourages the MLF to continue to look for such opportunities. It is important to ensure as much commonality of software across the facility as possible, particularly within groups of instrument that share the same technique.

Devices

We applaud J-PARC for the provision of the NOBORU and NOP instruments, both of which can be used for device development and testing

Regarding the provision of polarised beams and polarisation analysis, we recommend that J-PARC come up with a comprehensive plan, based on estimates of user need or demand, across the facility, for the provision of polarisation and analysis instrument by instrument. This should include prioritisation and an assessment of which polarisation technology (^{3}He, supermirrors, polarising cavities, etc.) is likely to be employed on which instruments.

Polarised ^{3}He is a good choice for many, but not all, applications and we endorse the choice of the spin-exchange optical pumping (SEOP) method at J-PARC. ^{3}He polarisation of 60% in simple cells with lifetimes approaching 400 hours has been achieved. However, most other laboratories around the world now achieve ^{3}He polarisations of ~80%.

> *The NIAC recommends that the MLF team interact more strongly with laboratories that are leading the development of SEOP (NIST and/or Jülich) in order to approach the state-of-the-art more quickly.*

The MLF is equipped with state-of-the-art neutron guides – both in terms of coatings and geometry. The numerically controlled polishing technique and high-*m* sputtering capability allow for the fabrication of short, supermirror focusing devices. The very high quality of the polarising mirrors from the KURRI group allows for their use as a spin-flip chopper and in a MIEZE-type spin-echo setup. Unfortunately, two of the guides are badly misaligned reducing the available neutron flux by a factor of two or more.

> *The NIAC recommends that every effort be made to realign the two misaligned guides at the earliest opportunity.*

Many instruments are functioning at a fraction of their ultimate capabilities due to the lack of funding for a full complement of detectors. In some cases, the detector coverage is a small fraction of the ultimate detector coverage. We realize that there is currently a shortage of ^{3}He on the world market, but feel that adding more detectors is a simple way to boost instrumental performance.

> *The NIAC recommends that the MLF develop a prioritized plan to acquire and install the full detector complement on all of the neutron scattering instruments.*

The lack of funding for operations also makes it difficult to sustain a broad program of device development activities at the MLF.

> *Thus the NIAC recommends developing a long-term strategy for instrumentation and utilization and using this to identify the devices necessary to realize their vision. J-PARC should then pursue, in collaboration with partners, the development of devices that cannot be procured elsewhere.*

One area that is essential to the long term health of neutron scattering in general, and the MLF in particular, is the continued development of new detector technologies. Here, excellent progress has been made through a variety of collaborations. The development spans the range from long, linear PSD ^{3}He tubes (collaboration TOSHIBA), an improved version of the Engine-X (ISIS) scintillation detector for TAKUMI, the neutron imaging detector for iBIX and new fast scintillation monitors, which will all be extensively used in the current instrument suites, to a number of concepts for future use.

Sample Environment

Sample environment is one of the key components of the success of a neutron scattering facility. A survey of the neutron publications in high impact journals shows that some 50% use some form of complex sample environment, either in the form of extreme environments, or the simultaneous measurement of some other control parameter, or *in-situ* measurements where materials are studied in situations that are close to their real world use.

The MLF has started to collect some of the basic pieces of sample environment equipment necessary to start their user programme and have set up a small sample environment group to ensure that there are common standards across the different instruments. This is a good start but it is clear that this will not be sufficient to support a successful and diverse scientific programme with international impact.

> *The current level of resourcing, both in terms of budget and manpower and the provision of laboratory and workshop space is clearly inadequate and must be dramatically increased.*

The funding and organisational structure of the MLF appears to provide barriers to effective collaboration between instruments and groups. The tradition at JRR-3M is to allow various stakeholders to develop and run their own sample environment, and it looks like the MLF may inherit this structure. This will make it difficult to make effective use of the limited resources. One obvious way to expedite the build up a strong sample environment support system and enable the facility to cover a wider area of advanced sample environment would be to have a joint sample environment group between the MLF and JRR-3M.

> *The MLF should aim to centralize at least some of its more complex sample environments so that expertise and best practice can be shared amongst all the instruments and so that resources can be used to best effect. This could include creating a joint sample environment group and facilities with JRR-3M.*

A balance must always be struck between the provision of standard items such as cryostats and more specialised equipment. Even at the larger and more established neutron sources it is not possible to be world-leading in all types of sample environments. Thus choices about priorities have to be made. Such decisions depend on the nature of the facilities' user community and on its access to particular areas of expertise, either in-house or through affiliated industrial or academic groups. The proposal to build a diffractometer for battery research with advanced *in-situ* electrochemical abilities is an excellent example of an advanced sample environment that would establish the MLF as a leader in a particular research area. In addition, there appear to be excellent collaborations in place with certain university groups. These links should be encouraged and exploited to the benefit of both parties. Ultimately some of this expertise and equipment should be drawn into the facility so that the whole user community can benefit rather than just specific groups.

> *The MLF should develop a clear set of priorities for sample environment equipment in conjunction with its user community. This should involve looking at best practice at other facilities and using this knowledge to create a long term plan to achieve similar levels of resourcing over some reasonable timescale. This strategy should incorporate opportunities for partnering with other organizations that have particular expertise.*

Safety and Sample Handling

The present paper-based sample tracking system will likely present difficulties as the number of samples brought to the facility grows.

> *The MLF should give active consideration to establishing a fully electronic system for sample handling, tracking, return and/or disposal. For instance, this could be based on bar codes, RFIDs or other technologies.*

We are concerned that the present regulations seem to preclude many powder diffraction experiments and reflectivity experiments on free-liquid surfaces, even though such experiments are routine at JRR-3M and other neutron facilities. MLF will be at a great competitive disadvantage if this situation cannot be sorted out.

Currently there is no expertise at the MLF to assess risks associated with biohazards connected with work on pathogens, toxins, genetically modified organisms and materials produced via genetic modification, and work involving live animals and/or products derived from live animals (including humans). We believe that a stronger framework for assessing biological hazards, and the regulatory requirements associated with them, is needed at the MLF.

User support and infrastructure

User support in sample environment, sample preparation laboratories, software and data acquisition, deuterium laboratory, facilities for daily life such as accommodation and restaurants, and transportation are indispensable for the MLF to produce excellent science. Last year, the committee recommended preparing a comprehensive plan for user support. A great deal of progress has been achieved towards providing many of the elements necessary to be a leading facility. In particular, the MLF prepared non radioactive and radioactive controlled experimental laboratories in both the IQBRC and MLF buildings and created a discussion and nap area in the MLF building. Plans have been developed for a rest house, near the MLF building, which should be completed by September. J-PARC has also created a support software system for user access to the MLF and for submitting and reviewing proposals. In addition, a building with 50 rooms will be built for user accommodations near the IQBRC. This is excellent progress which will be much appreciated by the users.

However, many problems remain unsolved. In particular, the user building has not yet been funded. This building is essential if MLF is to provide its users with the excellent scientific experience that leads to world class science, in addition to the provision of neutrons. Furthermore, the radioactive device handling and interim storage building is not yet approved. The deuterium laboratory is one of the most important facilities for soft matter users. When asked, the MLF mentioned that they were continuing discussions with user group members to develop specifications and a budget. The NIAC feels this process needs to be accelerated.

It must be emphasized that restaurants are not yet planned near the MLF buildings, and the planned accommodation is likely insufficient. In addition, transportation is not convenient from the user office and the planned accommodations to the MLF building and from the JR Tokai station to the MLF building. This situation must be improved.

> *The committee recommends that the MLF arrange to construct a user building much closer to the MLF and prepare key user support infrastructure, especially the*

deuterium laboratory, along with facilities for daily life including restaurants, and transportation.

We also recommend that a system to provide rapid feedback on users experience at J-PARC be implemented with the information going directly both to MLF management and to the user society. This should quickly reveal what issues are of greatest concern to the users, and give MLF management the opportunity to respond very quickly.

The J-PARC/MLF is not organized by one institute but co-organized by JAEA and KEK, and instruments in the MLF were and will be funded by JAEA, KEK, Ibaraki prefecture and an organization under the new law regarding promotion of common use. The budgets for KEK and JAEA are independent. This presents severe challenges in providing a common user experience at the MLF. In the case of the proposal system, this is working well, as both organizations use the same process for general user proposals. However, some key information is not shared – for example at the recent NIAC meeting, JAEA representatives did not know the KEK budget for operations at the MLF. While the committee understands that these are independent institutions, the present situation does not bode well for providing MLF users a uniform experience. In addition, a new organization will be established under the recent law relating to the common use, and it will become yet another organization operating instruments at the MLF. While this will help the financial situation substantially, it will make management of the user program even more complicated. The essential point is that user support must be essentially equal for all instruments, regardless of the source of funding and all of the institutions building and operating instruments at the MLF should work to achieve this goal.

The committee recommends that the MLF work to establish a system guaranteeing equal user support for all instrument before, during and after experiments. This will likely require the establishment of a system for harmonized operations of all instruments at the MLF.

Complementary use of both MLF and JRR-3M is also indispensable for producing flagship neutron science, expansion of the research fields pursued and the education of young scientists. Therefore, easy access to both facilities by neutron beam users is necessary, preferably using a unified registration and training system. In addition, easy transfer of experiments between the two facilities is necessary to achieve truly complementary use.

The NIAC recommends that the JAEA management consider which parts of the JRR-3M and the MLF could and should operate under a unified management system, as occurs for instance between HFIR and SNS at Oak Ridge.

At a minimum, it seems that there would be tremendous benefit for the users, if the user-access process, provision of sample-environment apparatus, and some other activities, could be fully integrated across the two facilities.

Outreach

We applaud the MLF for the high levels of industrial usage being achieved particularly by the Ibaraki instruments. However, since the most of users from industry are not familiar with neutron scattering, aftercare of the experiment is important to solve their own issues, or to get useful information from the obtained neutron data. If these users succeed in obtaining reasonably good results, they may in time become “regular customers” of the MLF.

We are also quite impressed by the community's response to open days, TV exposure and the local community. This is a testament to the effectiveness of J-PARC's outreach efforts to the general public. This excellent program could possibly be enhanced by creating regular MLF newsletters aimed at the general public and, for example, delivered to schools in the Ibaraki Prefecture.

Scientific success requires efforts to reach out to the scientific community to grow the number of scientists who use neutron scattering at the MLF. One approach would be to attract outstanding scientists in fields in which neutron scattering can play a role but who are not currently using neutrons in their research. If excellent results are achieved, their presentations and publications will attract other scientists to neutrons.

> *The NIAC recommends that the MLF make a systematic effort to identify influential scientists that do not currently use neutron scattering, but who work in a field where neutrons can make a strong contribution and attempt to attract them to use the MLF.*

Given the size of the Japanese population and economy, we believe a target size for the Japan Society for Neutron Science (JSNS) membership should be in excess of 1000. At present, there are a number of overlapping user organizations, in addition to the JSNS. It is highly desirable that cooperation between these groups be enhanced. The committee suggests that the MLF devise ways for these organizations to strengthen the intercommunication, for instance via a common annual joint user meeting.

The NIAC also believes that, for the MLF to realize its vision of being one of the world's leading neutron facilities, it must enhance its outreach efforts outside of Japan. Some ways of doing this are simple. For example, the MLF should make the international neutron scattering community more aware of their proposal deadlines. This can be done by posting its calls and deadlines for proposals on both the internet and broad-reach e-mail in the same way as other leading neutron user facilities around the world.

In addition, the MLF should work with other regional players (e.g. HANARO and Bragg Institute) on a Pan-Asian approach towards promoting neutron scattering throughout Asia, especially through the medium of Pan-Asian scientific meetings (e.g. AsCA meetings, MRS meetings held in Singapore, and so on), in addition to national scientific meetings in other countries outside of Japan. This is a particularly opportune time for these efforts, as China is currently developing two new neutron sources.

Target

The target has been a cause of significant concerns in the past because: 1) a sufficient number of spare target shells were not available; 2) the very large size of the target shell was likely to cause difficulties in waste storage and disposal; 3) cavitation erosion was considered a major threat to the service life of the target shell; and 4) failures of the target container might not be detected until the outer enclosure fails.

The NIAC was pleased to note that since the last meeting (NTAC-7) the team has made good progress on all of these fronts:

1) A spare target shell (of somewhat simplified design relative to the one presently in use) has been bought and is now available, in case an emergency replacement becomes necessary. This is an important factor to secure ongoing user operation of the facility.

2) Good progress was made in the design of a segmented target shell, which consists of a front part conceived for regular replacement and a rear part which can be replaced but is expected to remain in place barring an unexpected event.

3) Efforts to develop mitigation schemes for cavitation erosion caused by the intense pressure waves during each proton pulse have produced very promising results, both from the team's own research as well as from examination of the first target shell removed from the SNS at Oak Ridge.

4) A leak detection system based on gamma-spectroscopy of the helium gas between the target container and the outer shell has been shown to be very sensitive to spallation products sputtering off the wall material. It can be tuned to heavier volatile isotopes from mercury spallation and thus holds the promise to detect even small cracks in the target container.

The Committee would like to congratulate the JSNS team on this progress and express its confidence that reliable operation of the mercury target can be achieved in the not too distant future. Unfortunately progress is limited by extremely tight funds and a shortage of man power.

Cavitation Erosion

Two factors have been identified to have a mitigating effect on the damage caused to the target shell by collapsing cavitation bubbles, which are generated during the depletion phase of pressure waves near the target wall:

1) (Shear) flow along the wall is expected to deform the bubbles and to reduce the impact on the wall of the high speed jet that traverses the bubble when it collapses. This effect seems to have been confirmed in the first target of SNS, where severe damage was found on the inner wall where the flow has a stagnation region, but no obvious damage could be detected in regions where shear flow prevailed. This is a very important finding for the MLF, as the flow configuration in the target is such that no stagnation point occurs anywhere in the region of the proton beam footprint. Therefore one may expect a beneficial effect of flow on the whole window surface.

2) A small amount of gas bubbles of suitable size (~100 microns) is expected to successfully suppress pressure build-up by rapid compression of the bubbles. To develop this technology, the MLF team has shown that a swirl bubbler system produces bubbles having the appropriate size and has demonstrated the mitigation effect of such bubbles on pressure build-up in off-line experiments with water. The task (by no means a trivial one) is now to incorporate such a system into the target design.

The Team is now planning to incorporate a bubbler system in the design of the first segmented target and to install the helium circulation system on the rear of the target trolley.

> *The NIAC recommends that everything that needs to be done or can possibly be done in the service cell before the first target exchange, and while Target 1 is still in its operating position. This will most certainly reduce radiation exposure of the workers, because there is a risk of Hg contamination resulting from the target exchange.*

In addition, the MLF should consider a second enclosure for the bubbler helium circuit to limit any contamination that might result from a leak in this loop to a defined volume and make it easier to detect. The MLF should also consider the potential merits of adding an absorber to the bubbler helium loop, to purify the helium taken from the surge tank and thus minimize contamination of the pump and release of radioactivity in case of a leak..

Target Service Life

Currently there is still a large uncertainty in the expected service life of the first target. The MLF is therefore considering a very conservative approach to extend this period until the new type target is available. The MLF is using / developing several advanced systems to monitor the target and detect potential changes in the target response to the proton pulses. These include optical analysis of the vibration of the shell as well as acoustic survey of target "ringing" after each proton pulse, along with a survey of the helium in the target shell interspace for isotopes resulting from mercury spallation.

While the various monitoring systems obviously still require a certain learning process in their practical effectiveness, the combination of them holds good prospects to detect not only the end of the target service life but also any changes in the target shell's response to the pulse load over time.

Unfortunately the first reflecting mirror used for the laser Doppler reflectometer showed strong corrosion during operation. This was attributed to having about 5% of air in the helium vessel and the radiochemical processes in it. The cause of this contamination is not clear; some of it might just be desorbed gas from the surfaces. Although a new type of mirror has been developed which is claimed to be more corrosion resistant, online monitoring and eventually purifying the helium atmosphere should be considered, since radiolytic corrosion may also affect other parts in the vessel.

> *In view of the importance of the target vibration monitoring system, the MLF should consider online surveying and eventually purifying the helium in the helium tank, in order to prevent the Doppler mirror from degrading (and to avoid similar problems on other components).*

The MLF team has analysed the anticipated damage progression in their target, based on the experience and beam history of the first SNS target. The result is that, with a proton pulse power density of 3 kJ/cc/pulse, the maximum damage depth would reach 2.5 mm (the wall thickness of the target container) after about 9 000 hours of operation (i.e. after July 2011, the point in time when the first segmented target will be available, according to present planning). This takes no account for the mitigating effect of the flow seen on the SNS target, making this estimate very pessimistic. Nonetheless, to be on the safe side, the team proposes limiting the pulse power density to 2 kJ/cc/pulse. According to their estimate, this restriction would lead to a maximum erosion depth of 0.7 mm after a total of 10 000 hours, without accounting for flow, and of 0.3 mm allowing for the effect of flow derived from model experiments at Los Alamos, rather than what seems to have been observed in the SNS target in a real situation.

In view of this situation the Committee concludes that the limitation to 2 kJ/cc/pulse is overly pessimistic and will constitute an unnecessary reduction of source performance, assuming that the accelerator can deliver more power in the near future.

In this context, it should be noted that the MLF is currently running with a beam profile that is much more peaked than the design goal agreed upon with the accelerator (proton beam line) team: at 120 kW the peak power density is ca. 3.5 kJ/cc/pulse while the design goal is ca 1.2 kJ/cc/pulse - meaning that the limitation to 2 kJ/cc/pulse would correspond to only ca. 70 kW of beam power. Clearly such a restriction would most likely lead to great frustration among the users and hence should be avoided.

Given the fact that, according to the present power ramp up plan, 300 kW will only be reached by mid-2011 and the erosion estimates are overly pessimistic, the Committee makes the following recommendation:

> *For the time being, the MLF should run the target at the full power (120 kW) that the accelerator can deliver. The MLF should also increase the maximum allowable power density to 3 kJ/cc/pulse and make every effort to flatten the beam profile to its design value as quickly as possible in order to be able to accommodate the planned power increase of the accelerator in the near future (up to 300 kW by mid-2011).*

According to present planning, 300 kW will be the maximum power the present target will experience shortly before being replaced by the new target which is expected to be ready by mid-2011. Therefore, the risk of Target 1 failing before this point in time is small, even following the above recommendation. In the worst case, the present spare target will have to be used.

Given the importance of peak power density, the Committee is somewhat concerned that MLF has no reliable method of actually measuring the intensity distribution in the proton beam. Although the Multi Wire Profile Monitor (MWPM) was shown to yield reasonably good agreement with a temporarily installed imaging plate, it is located rather far from the target and does not account for factors such as beam scattering in the proton beam window. Also the correction for the beam divergence is not an experimental one but based on calculation. Furthermore, it is a system which integrates along each wire and hence gives essentially 1-D information. The same reservations hold true for the Segmented Ionization Profile Monitor (SIMP) now under development, which has the advantage of being fully non-invasive to the proton beam and hence is expected to have a much longer life time than the MWPM. The Committee would prefer seeing a truly 2-D system at the position of the target, like the one developed at SNS.

> *The NIAC recommends incorporating a similar target (beam profile) viewing system as developed for SNS in order to ensure maximum protection against undesirable proton beam peaking.*

<u>New Target</u>

In an effort to minimize radioactive waste, the team has embarked on a redesign of the target with the goal of increasing its service life by incorporating a bubble generation system and of replacing a smaller portion of it (~25% of the mass of the present target) at each target exchange. This new, segmented target is now entering its detailed-design phase after a series of conceptual studies have shown its viability. The Committee fully concurs with this plan, but is somewhat concerned about the rate of progress in this effort: The current schedule displays a possible delay of 1 year in the design effort which is starting now and has a total duration of 1 year. This will not meet the goal of having this new target ready by mid-2011. Meeting this date is crucial for accommodating the planned power ramp-up and hence maximizing neutron production.

There was little detail given on the evaluation of the design of the target itself, so the Committee can only make a few remarks:

1) From the sketch of the connecting flange and the metal gasket, it appears that the water cooling for the protective shroud is supplied via four separate connections which must fit precisely and must be connected remotely. This will, in all likelihood require bellows-type sections and difficult to match seals, which are always prone to damage and leakage.

2) The multiple penetrations flange will be tightened by means of 18 bolts fastened from different sides at the top and bottom on the one hand and at the sides on the other. This is clearly a tricky situation for remote handling and makes it difficult to apply the necessary uniform pressure increase over the whole area of the flange.

3) In its previous report (NTAC-7) the Committee recommended a careful review of the design of the segmented target before giving it to the manufacturer for detailing. In its response the team stated that the design and remote handling scenario will be presented during the current session, but did not report on any review process. This suggests that no such formal review actually took place.

4) The concept for incorporating the He-bubbler seems to be still under development, which may be one of the causes of the scheduling uncertainty mentioned above.

The NIAC recommends that the MLF urgently carry out a design review of the segmented target using external experts, including (if possible) representatives from industry, and document the outcome of this review.

Do not allow the bubbler concept to delay procurement of the first (front part) segmented target. If necessary, go for a copy without a bubbler, as the beneficial effect of flow is likely to be greater in the real situation than derived from the model experiments.

In the Committee's view it is more important to have the first segmented target available when the beam power reaches 300 kW than to build it in its full glory, but accept a one year's delay. This is clearly preferable to either limiting the beam power or using the current spare target.

The general concept of remotely replacing the front part of the segmented target which was presented to the NIAC appears likely to work. Nevertheless the Committee would like to draw attention to the fact that the MLF target handling bay is designed for limited entry of personnel even after prolonged use. SNS experience has shown that mercury vapour contamination is a great risk (the font part of the target shell is at elevated temperature during the exchange process).

Thus the NIAC recommends carrying out a careful assessment of possible spills during the target exchange process and providing comprehensive protection against them. Consider protecting against uncontrolled spreading of mercury vapour by employing a system which ensures controlled air flow over a suitable filter.

Moderators

The high-efficiency, coupled, super-critical para-hydrogen, cold moderator with water pre-moderator is a signature feature of the MLF. The diffraction data obtained on the Super High Resolution Powder Diffractometer relocated from KEK indicates the superiority of the para-hydrogen. The continuing efforts to fix problems and to improve the moderator systems have achieved laudable results since the NTAC-7 report. .

Cryogenic moderator system

The problems with excessive vibrations in the cryogenic pumps reported at the previous meeting were clarified and shown to be transient. Resetting the fault conditions slightly has greatly increased the reliability of the cryogenic system.

The instability in the operation of the He refrigerator has also been resolved. It was caused by air contamination in the He likely arising from contamination on the walls of the system when it was fabricated. Therefore, it is expected that the refrigerator will operate reliably much longer than 45 days. To verify this, it is only necessary to monitor the performance of the refrigerator. If it seems that the He must be regularly purified, one can always equip the refrigerator with a simple purification system in order to shorten the time required to remove the contaminants from the system.

Difficulties with the accumulator have occurred unexpectedly early. A quick recovery is very important for the users. So, we agree with the recovery scenario. Furthermore, inspection to look for the reason is important. Then and/or based on the experiences, a new method will likely need to be designed.

Spare moderators

The revised design of the moderator, which uses Invar to reduce the large changes arising from thermal expansion, is much simpler and thus much improved over the current design. Thus we endorse the proposed design which, in addition to reducing thermal expansion issues, also eliminates a thermal shield. The simpler fabrication may compensate for the higher price of the materials. The only comment is that the activation of Ni in the Invar should be evaluated, especially near the moderator.

As all of the moderators were optimized assuming all para-hydrogen, the ortho-para ratio is a key parameter for their performance. Thus it is essential to measure the ortho-para ratio in the MLF cold moderators. Moreover the MLF is the only facility in the world capable of providing detailed information on the transition rate as a function of accelerator power. Therefore, the MLF should develop a system that will make reliable measurements over the wide power range from ≈ 20 kW to 1 MW. As the ortho-para ratio may be affected by transferring the hydrogen over the long distance from the moderator to the measurement area, measurements of the neutronic performance are also essential. The NIAC believes that these measurements should not take more than a few days, and can take place during "machine time" rather than during user time. We also note that it is not necessary to measure the spectral intensity changes and the pulse shape changes for controlled ortho-para ratios, a process that could take as much as 30 days.

Low activation decoupler

The reduction of the activity of the decoupler has been strongly desired for a long time. AuIC is good candidate. However, ^{198}Au is mother nucleus of ^{198}Hg. Before proceeding, one should understand the metallurgical and structural effects of Hg in the AuIC decoupler. This should be done for the amount of Hg that is expected to be present near the end of the decoupler's service life. If the amount is not negligible, it is recommended to perform a neutron irradiation experiment.

Issues of off gas process

The release of tritium is a serious regulatory issue. Thus obtaining a good understanding of HT in the system is critical. However, the difference in the amounts of T observed and that expected is enormous. Therefore, it is essential to locate the T in the Hg circulation system.

Concluding Remarks

The committee would like to extend their gratitude to the MLF team for their openness and clear, carefully prepared presentations and for their hospitality during our stay. We applaud the MLF staff for the way in which our recommendations from the previous NTAC meeting have been addressed and communicated back to us. It is clear that in terms of the source and instrumentation, the MLF will be an internationally competitive neutron scattering facility. We have every confidence that, with an appropriate level of support, the team will be able to successfully realize their goal of becoming one of the world's premier neutron scattering facilities.