# Report of the Canadian Light source Machine Advisory Committee 4-5 May 2016

**MAC Members Present**

Greg LeBlanc (chair)

Bob Hettel

Peter Kuske

Simon Leemann

Bob Laxdal

**Summary**

The Machine Advisory Committee appreciates all of the work behind the presentations. There has been enough time since the appointment of a new director and the organisational changes made that the effects should be known and a more steady state of activity is expected.

The overlap of the Machine Advisory Committee with the Science Advisory Committee is appreciated and we believe gives both committees insights that otherwise might not be shared.

The improvements in the machine availability are encouraging. Operation in the last six months reached 96% availability with 50 hours as the mean time between trips, the best performance on record. The Project Plan was presented and is a progressive step that should bear fruit in the long run. A resource loaded schedule would be the next step towards a proactive approach to planning. The Project Plan would benefit from the inclusion of a few measurable beam quality goals.

The MAC strongly recommends that machine availability & reliability remain a focus of AOD. The remainder of the report is arranged according to the broad themes that appeared in the presentations. Specific recommendations from the MAC will be identified as such at the end of each of the following sections.

**Staffing**

There are issues with regards to staffing in AOD, particularly with the disruption to individual schedules necessitated by covering night and weekend shifts. A pool of dedicated accelerator operators would allow AOD to develop a systematic approach to identifying and prioritising issues with the accelerator systems. By recruiting operators with skill sets, AOD could apply more resources to activities to maintain and improve the systems. Allowing the more experienced accelerator personnel to remain on normal shifts and liaise with the technical support personnel should help to establish a more proactive approach to improvements in performance and reliability. The AOD manager is one of the most experienced accelerator physicists at the CLS and allowing more time to concentrate on ~~the technical~~ issues related to the future development of the source by reducing the administrative burden of management seems like a better use of that skill set.

Right now the accelerator team is trying to float but they need some hope that one day they can fly. The result is that their existing approach is largely reactive as they put out fires. New hires like dedicated operators and at least one accelerator physicist specialized in beam dynamics filling in the vacant position in the AOD group would allow the team to move to a more systematic and proactive approach.

***Recommendations:***

* ***Consideration should be given to hiring dedicated accelerator operators to allow AOD to come up with a more systematic approach to accelerator system optimization.***
* ***The AOD manager should be given more time to apply to accelerator physics issues and spend less time with administrative tasks.***
* ***In view of the plans for new beam lines and a future 4th generation light source consideration should be given to strengthen the AOD group by one accelerator physicist specialized in beam dynamics.***

**Machine Performance** (Peter)

There have been improvements in the machine performance. The reliability reached a record in 2015 and the Mean Time Between Trips of 50 h compares well with other light sources. There is still a need for a more structured, systematic approach to identifying, prioritising and resolving issues. Statements that the performance of various systems are not an issue at present and don’t affect the beamlines, while they may be accurate, will not be helpful in applying a concentrated effort to getting all of the accelerator systems to the point where they can for example support reliable top-up operations. Even in the short run there will be many challenges with the installation and implementation of the new EPUs. Mastering these challenges will require focusing the lean AOD-group with their limited resources to the most relevant and most burning issues.

Recent observations of beam stability and noise of the electron as well as the photon beam were presented to the MAC. The performance of the "fast" orbit correction in operation at the CLS is quite disappointing. The system rather controls slow drifts and will certainly help to mitigate the impact of IDs on the orbit, however, does not do any good in the frequency range of a few Hz where one would expect at least some improvements given the update rate of 18 Hz. This update rate is comparatively low. Orbit feedback systems installed at other facilities update at much higher rates of up to 1-10 kHz. In spring 2015 the MAC heard that an upgrade to 40 Hz is expected by the end of that year and now wonders why this did not happen. In order to reach a beam stability in the frequency range of up to 10 or 20Hz which is comparable to other light sources the fast orbit feedback at the CLS needs considerable improvements. The existing hardware seems not yet to be at their limits.

***Recommendations:***

* ***A list of systems that need improved performance and reliability to support top-up should be developed and prioritized.***
* ***As proposed by Les Dallin a metrics should be developed with the Science Division to track beam stability and beam intensity effects. The outcome should be a list of indispensible and continuously archived diagnostics of the electron and the photon beams.***

**Risk matrix feeding priority list** (Bob Hettel)

The Accelerator Division has prepared a matrix spreadsheet identifying main sub-system components for the Linac, Booster and Ring and their responsible maintenance managers, evaluating the likelihood of failure, risk to operations and mitigating measures. The list was delivered to the Committee several days after the end of the MAC meeting, so no related discussion took place during the meeting.

Items on the list that could have a high impact on operations - e.g. a Booster RF cavity, electron gun HV power supply, Linac RF drive, etc. – have been tagged with “High Risk Plan”. Some of the less impactful components have action plans, such as “find new supplier”, etc., associated with them. Many components have no specific action plans, presumably because sufficient failure mitigation is on hand. Interestingly there are no high-risk components or specific action plans identified for any of the Storage Ring components. In particular, the SC RF cavities and cryogenic system do not appear to be on the list.

Comments:

* It appears that the component risk matrix is incomplete, requiring further input. For example some sub-system components have not been listed, like ID motion control systems, and others do not have complete risk/mitigation evaluations.
* It is not clear to the MAC how the high-risk components are accounted for on the Project Priority table that was presented at the meeting, other than as part of “Accelerator Preventive Maintenance”.
* The MAC notes that the Medical Isotope Project (MIP) and Canadian Isotope Innovation (CII) initiative appear on the Project Priority list. The MAC was under the impression that these initiatives are no longer part of the CLSI mission.

Recommendations:

* Complete sub-system identification, risk evaluations and mitigating measures for all accelerator systems as needed.
* Ensure that the risk matrix is periodically reviewed and updated and that progress on all action items is tracked.
* Create a completion schedule that can be tracked for each action item.
* Update the Project Priority list as necessary to account for a high-risk-related action items and to eliminate initiatives unrelated to the CLSI mission.

**SRF** (Bob Laxdal)

Question on warm vs cold rf system: It was reported that the AOD team has considered the rf technology used for the ring and decided to maintain SRF technology. The MAC agrees with the decision with the proviso that more effort be put into establishing a credible service strategy for the cryomodules. It is noted that TRIUMF has the expertise and infrastructure to design and assemble cryomodules for SRF application. A potential way forward would be to collaborate with TRIUMF as part of a long term SRF strategy. More explicit considerations are presented below.

There is presently one CESR-B SRF cryomodule installed in the ring housing a single 500MHz cavity. Another refurbished cryomodule has been received from RI. This cryomodule is sitting as an off-line spare. The off-line spare has been successfully tested at ~~Daresbury~~ Diamond but not tested as yet at CLS. In the present configuration a failure in the cavity, cryomodule, rf system or cryogenics makes operation vulnerable to significant downtime especially with regard to a problem with a cryomodule. If the cryomodule fault forced a swap to the off-line module time would be required to warm the system, remove the existing module, install the spare module, cooldown and condition the cavity to voltage. An added risk is the fact that the off-line cryomodule is as yet untested at CLS after shipping and could potentially have been damaged or could potentially be polluted during installation. For this reason the SRF system has been correctly identified as the biggest risk in the accelerator operations risk matrix.

Despite the high risk, the Project Plan does not include action items that would address the situation directly. The only item in the high priority list is an off-line test of the refurbished cryomodule. The test would involve cooling down the cryomodule off-line and performing signal level tests to establish the rf frequency of the cavity. The planned off-line test would not guarantee that the accelerating gradient could be reached and in the present high priority plan this would only be known after the module has been swapped out. Certainly the off-line test reduces but does not eliminate the risk. An off-line test bunker equipped with cryogenic and rf feed would help mitigate this risk further.

Two other mitigation strategies were mentioned as long term solutions. The first involves ordering a new (third) module as a back-up to the off-line (second) module. The argument is that a third module reduces the risk inherent in not having a repair facility that forces repair at RI where turn-around has been very slow. The solution does not reduce the risk of down-time if the on-line module develops a problem. It only reduces the risk of severe downtime due to slow repair times. The second solution involves outfitting a 2nd rf station in the ring complete with cryo-feed and rf source. In this solution the off-line module would be installed on-line, cooled down and made operational so that either the main module or the back-up module could be used at any time. This would mean that down-time from failure in one module could be virtually eliminated. Also the second module could be used to augment the cavity voltage should the cavity performance degrade over time.

Of the various strategies presented the installation of the second module to a new rf station delivers the biggest risk mitigation and should be pursued. In parallel a credible repair strategy should be identified. The strategy could involve the following staged approach:

* Collaborate with TRIUMF to develop a Canadian cryomodule repair strategy at TRIUMF
* Develop an off-line test bunker at CLS including cryogenic and rf feed for full power rf tests
* Consider an in house repair facility
* A third cryomodule purchase could be considered but in this case (given the inherent risk in the RI module performance) a `Made in Canada’ approach should be considered. In this case the modules would be fabricated in a collaboration between TRIUMF, PAVAC and CLS and the cryomodule repair strategy could be developed within the collaboration

Recommendation:

* Proceed with outfitting the second rf station in the ring
* Develop a credible cryomodule repair strategy

**Future Plans for a ring upgrade** (Simon)

Les Dallin presented a technical outline derived from the science case for a potential CLS upgrade. The science case calls for a high-brightness source that allows for coherent x-ray diffraction imaging, and offers both a smaller beam as well as a coherent beam to resolve dynamic processes. The conclusion drawn is that these goals cannot be achieved by an upgrade of the storage ring within the boundary constraints of the existing CLS tunnel or by the existing beamlines. This is motivated by a study revealing that, within the existing tunnel, a 5BA could deliver about 1.65 nm rad at 2.9 GeV. This is then contrasted by stipulating a requirement of at least 100 pm in order to be diffraction-limited at roughly 1 keV, thereby rendering roughly 30 micron beam size and 20% transverse coherence at 1 keV.

Following this line of reasoning, several studies were shown where the same basic state-of-the-art 5BA lattice was used to build up several 3 GeV storage rings with varying size. Depending on the resulting circumference, a growing number of ID straights and a decreasing lattice emittance were demonstrated. These designs ranged from 508 pm at 368 m (20 ID straights) to 127 pm at 589 m (32 ID straights). Obviously, while larger circumference can render higher brightness, it also increases the cost of a new facility. However, a rough budget frame was not supplied.

Preliminary nonlinear optics studies revealed that while the higher-emittance lattices appeared to show sufficient DA for off-axis injection, the 127 pm lattice did not. Octupoles to mitigate were mentioned as a topic for future studies. The insufficient DA reported in the lowest-emittance case is compounded by the fact that these studies did not include any errors. However, in all presented cases the required magnet gradients were considered feasible.

While a convincing case can be made that the existing CLS tunnel cannot adequately be used to house the magnetic lattice of a 4th-generation storage ring, the science case would need to supply more concrete deliverables (including key performance parameters) in order to focus machine design efforts and ensure these are always well motivated.

Recommendations:

* Collect a clear set of target parameters motivated by the science case.
* Include errors (magnetic, alignment) and effects of strong IDs (steering, focusing, nonlinear) in DA and MA studies.
* A more detailed nonlinear optimization campaign needs to be carried out before the workability of a lattice can be gauged. This needs to be interleaved with error studies to ensure that optimization results actually hold under realistic conditions.

**Suggestions for other MAC members:** (I left this here since we discussed MAC membership, who would be best to cover ID’s?)

Francis Perez, ALBA

Dave Robin, ALS

Marco Pedrozzi, (PSI), RF expert

Günther Rehm, (DLS)

Glenn Decker (APS)

Nick Sereno (APS)

Dave Robin (ALS)

Fernando Sannibale (ALS)

Riccardo Bartolini (Diamond)