

### 3. Maximize the Performance and Availability of the Facility

#### 3.1 Increase Accelerator Availability

1. To remain competitive with other synchrotron light source facilities world-wide, the CLS facilities must operate 24/7 for a significant fraction of each year.

This requires reliable equipment and a good maintenance process to ensure that all major equipment operates as intended when needed. CLS has set the goal of 5000 hours of user operation per year (typical of other mature facilities) with up to an additional 1000 hours of operation for developing, commissioning and improving the accelerator systems. This goal was achieved in 2008, but it is essential to continue to meet this goal in subsequent years. This level of operation leaves approximately 12 weeks of the year for major equipment maintenance, installation of new facilities, and shut-downs. Typically, CLS has two major maintenance outages of 4–5 weeks in April and October, and a 2–3 week shutdown at the end of the year over Christmas and the New Year. This pattern is expected to continue for a few years, but some possible major accelerator upgrades may require a longer outage.

*Deliverables/Milestones:*

- Annually deliver 5000 hours for user operations, 1000 hours for accelerator development, per year.

2. Ensure accelerator system operates reliably with a minimum number of trips resulting in beam loss.

The accelerator systems must not only operate, but they must operate reliably with a minimum number of trips resulting in beam loss. Although recovery from a trip is quite fast, typically 5–10 minutes, the disruption for many experiments can be much longer. When some users have only a few shifts within which to conduct their experiments, any unplanned loss of beam is significant. During the initial operation of CLS, the average time between trips was unacceptably low (less than 10 hours). Since 2007, the operations staff has increased the mean time between trips to around 30 hours, which is more acceptable to most users. However, most other facilities have a target mean time between trips of greater than 100 hours--challenging but not impossible. Achieving this target will require ongoing analysis of all trips and modifications to systems and procedures to reduce the likelihood of future trips. For now, the goal will be to increase the mean time between trips by at least 10 hours each year.

*Deliverables/Milestones:*

- Conduct ongoing analysis of all trips and modifications to systems and procedures to reduce the likelihood of future trips
- Increase the mean time between trips by at least 10 hours each year:
- Minimum Mean Time Between Trips in User Operation:
  - > 40 hours 2009-2010
  - > 50 hours 2010-2011

- > 60 hours    2011-2012
- > 70 hours    2012-2013

### 3. Minimize the recovery time between system trips

Equally important is the recovery time from trips. For simple trips, like vacuum spikes or human error, the recovery can be quite fast. However, if the trip occurs because of equipment failure then the recovery time can be more significant (hours or days). The mean time to recover can be used as a measure, but the total time lost to recovery is a more convenient measure. CLS has only recently starting monitoring the recovery time, so that past statistics are not available. Data acquired to date indicate that around 3% of the operating time is lost to unplanned trips. This would represent approximately 150 hours per year. Until more data are accumulated, a reasonable goal would be a total time lost to recovery from unplanned trips during user operation of less than 100 hours per year.

*Deliverables/Milestones:*

- Total time lost to recovery from unplanned trips during user operations < 100 hours per year
- Monitor total time lost to system trips

### 4. Improve the reliability of accelerator system components

Experience over the first five years of operation has highlighted several areas where work needs to be done to improve the reliability of accelerator system components. Although they have not generally had a major impact on user operation, they remain a concern for reliable, consistent operation of the facility. The primary concern is old equipment from the Saskatchewan Accelerator Laboratory that was incorporated into the CLS facility. Some of this equipment is over 40 years old with no spare parts available from any source. In other cases, the performance of the equipment has been shown to be inadequate for CLS applications (e.g. insufficient stability in power supplies).

CLS technical staff has reviewed the suitability of all the old equipment, and have started a replacement program to ensure good, ongoing performance and reliability from all accelerator systems. The major components that have been identified in this process are: magnet power supplies reused from SAL, three of the six linear accelerator (linac) sections, the six linac modulators, and the linac ACIS (Access Control Interlock System). The replacement program should be completed by 2012--the schedule is extended to reduce the impact on facility operations. Most of the changes are essential for moving to "top-up" operation, which requires a much more stable and reliable injector system.

*Deliverables/Milestones:*

- Complete Linac-LTB ACIS upgrade (CD: Q3 2009/10)
- Complete replacement of Linac-LTB power supplies (CD: Q4 2010/11)

- Complete modulator replacement (CD: Q3 2010/2011)
- Linac section replacement and diagnostics upgrade (CD: 2012/13)
- Complete replacement of older power supplies servicing SR1 and BTS (CD:2010/2011)
- Install BTS collimator/slit (CD: Q3 2010/2011)
- Assessment of BR1 RF system (CD: Q4 2010/2011)
- Upgrade of BR1 RF system (CD: 2012/13)\*

#### 5. Increase availability of the main storage ring (SR1)

Several items require modification to ensure continued good availability of the main storage ring (SR1). Work over the past year on the water system has identified several deficiencies that are being addressed. Already, pH and oxygen content are monitored on the storage ring cooling system and are within design specifications. However, the water flow and particulate content are both too high. The original water system design did not account for the reduced demand as a consequence of using superconducting cavities, which need no water cooling. As a result, the high water flow is causing problems with turbulence, the effectiveness of the particulate filters, and possible erosion in certain areas. The changes to reduce the flow are complicated, as some of the magnets require the current pressure in the water system for design operation. It is expected that it will take several semi-annual outages to make all the required changes in the SR1 cooling system.

##### *Deliverables/Milestones:*

- Plan for SR1 and beamline water system upgrades complete (CD: Q1 2010/11)
- Modifications of SR1 and beamline water systems complete (CD: 2011/12)
- Establishing better filtration in LCW systems complete (CD: 2010/11)
- RF Cavity Arc detection modifications complete (CD: Q2 2010/11)
- Installation of back-up PCT (CD: Q3 2010/2011)\*

### **3.2 Increase Accelerator Performance**

There are several different aspects of accelerator performance that can or may be improved at CLS. Previous feedback from the User Advisory Committee indicated that the priority for users was increased availability and reliability (see previous sections), increased stability, top-up operation and increased current.

#### 1. Increase beam stability

Several projects are already in progress for improving beam stability. There are two main approaches: eliminate the causes of instability, and provide feedback systems to increase beam stability. The main known causes of beam instability are inadequate power supply regulation, and vibration primarily caused by water turbulence in the

storage ring water cooling system. All of the power supply feedback systems are being reviewed for possible improvements to the digital feedback system algorithms and to correct some known deficiencies. Water turbulence is being addressed by the work on the storage ring water systems noted in the previous section. There are also two main beam feedback systems that are used for improving orbit stability: the global orbit feedback system and the transverse feedback system.

CLS has operated with a preliminary version of the global orbit feedback system, which is quite slow (updates are once every 0.5 seconds). This has been adequate for removing long-term drifts in the beam position, which have been reduced to below the original target stability of 10% of the beam size (horizontal and vertical). There is additional faster motion of the beam, estimated to be approximately 0.6  $\mu\text{m}$  rms horizontally and 0.5  $\mu\text{m}$  rms vertically in the frequency band between 1 Hz and 1000 Hz. While this is within the original specification, some beamlines are starting to detect this motion, and it has the potential of affecting some experiments. A faster global orbit feedback system was envisioned in the original CLS plan, and work has continued towards implementing this system with low priority. Initially it will be implemented with approximately 100 updates per second, with an evaluation of the improved performance and an analysis of the options to increase the update rate.

The transverse feedback system has been under development for the past two years, and some preliminary tests have already been carried out on the beam. It can be used to increase the single bunch purity in the storage ring (already used in this mode for single bunch experiments), to provide a continuous monitor of the transverse tunes of the storage ring (useful for monitoring storage ring performance) and to reduce the transverse damping time for beam perturbations. This last use is important for keeping the beam size at the minimum consistent with the storage ring tunes, as well as reducing the transients on the beam position during injections, which becomes very important when CLS moves to top-up operation.

*Deliverables/Milestones:*

- Implementation of the global orbit feedback system with an update rate greater than 100 per second. (Q2 2010/1011)
- Evaluation of fast feedback system (Q3 2010/2011)
- Analysis of options for increasing the feedback rate (Q3 2010/2011)
- Deployment of transverse feedback system for Normal operation (Q4 2009/10)
- Evaluation of transverse feedback system performance (Q2 2010/11)

2. Increase average current through more frequent (top-up) injections and operating at higher initial current (500 mA operations).

CLS currently operates with a maximum injected current of  $\sim 250$  mA, although the storage ring (with the exception of the installed RF power) was designed for 500 mA. Over the typical 8-hour fill period, the current decays down to approximately 150 mA because of the finite lifetime of the beam. The beam lifetime is approximately 12–14 hours at 250 mA, in good agreement with the original design calculations.

There are two main strategies for achieving significantly higher average current: more frequent injections to compensate for the beam current decay, and operating at a higher initial current. In addition, some modest improvements may be possible by finding improved configurations of the storage ring beam optics and beam fill pattern.

Increasing the average current by more frequent injections ("top-up" is simply injection once every minute or two to keep the beam current constant to within 1% or less) requires the ability to inject while keeping all the beamline shutters open. This mode of operation is not permitted under the current CLS operating license, and a revision to the license with a revised safety report and safety analysis of this mode is required. Accelerator Operations staff have tested topping up injections during accelerator development shifts and can keep the current constant to within 1%. HSE staff made some preliminary radiation measurements during injections with shutters open and no significant radiation hazards were found. Nonetheless, a more detailed plan of work for revising the operating license is needed to better estimate the time and effort needed to implement top-up operation. Top-up operation can also result in significant improvements in the long-term beam stability, as thermal drifts are reduced substantially when the beam current is essentially constant.

The other strategy to increase the beam current is to increase the installed RF power in the storage ring. At present, the total RF power available to the storage ring is 300 kW. This power is sufficient to store over 300 mA in the storage ring (with the present insertion devices). At 300 mA there is overheating of the kicker ceramics that will be replaced in the upcoming year. As well, as additional insertion devices (especially high power wigglers) are added to the ring, the total radiated power for a given beam current increases, so the maximum current for a given installed RF capacity decreases. Analysis of the current and planned insertion devices shows that 250 mA should still be possible with the presently installed 300 kW RF power. When constructing CLS, the option of installing a second RF cavity was considered, but there was insufficient budget for the second 300 kW RF transmitter. Nonetheless, a second superconducting cavity was purchased (as a spare) and the cryoplant design allows an easy upgrade for sufficient capacity for two cavities. An upgrade for 500 mA operation is possible with the procurement of a second 300 kW RF transmitter, modification of the storage ring services in sector 2 to accommodate the second cavity, and an upgrade of the cryogenic distribution system and cryoplant to service two cavities. A conceptual layout has been developed for these modifications, but no detailed design or planning has been done. Since discussions with the User Advisory Committee indicated that users were more interested in top-up than 500 mA operation, the 500 mA upgrade work has not been allocated any resources.

There are some barriers to the implementation of either of these strategies. During high beam current tests with no uses, over 300 mA beam current has been achieved for several minutes before the beam tripped. Originally it was assumed that the trip was related to the limitations of the RF system. However, Accelerator Operations staff have since found that the trip was caused by overheating of the injection kicker ceramic chambers, because the titanium coating for wall current bypass was too thin. All four kicker ceramic chambers need to be replaced before any normal operations above 250 mA. Replacement chambers have been ordered and will be installed at the most convenient time.

*Deliverables/Milestones:*

- Dynamic Aperture studies of standard tune completed (CD: Q1 2010/11)
- New injection kicker ceramics installed (CD: Q3 2010/11)
- Develop licensing amendment plan for top-up operation (CD: Q1 2010/11)
- Request license amendment for top-up operations (CD: Q3 2010/11)
- Receive Top-up license amendment (anticipated CD 2011/12)
- Start of Normal Operation in Top-up (CD: Q4 2011/12)
- Decision on proceeding with 500 mA operation (Q1 2010/11)
- Procure second 300 kW RF transmitter\*
- Install second RF cavity\*
- Commission to 500 mA operations\*

### 3. Reduce beam emittance

The CLS horizontal beam emittance is substantially higher than all other recent 3 GeV light sources ( $\sim 18$  nm compared to 0.8 – 4 nm), primarily because of the small size of the storage ring. As a consequence, the beam size is approximately twice as large as that in other sources leading to potentially lower X-ray flux density and brightness. Some reduction in the horizontal emittance may improve the performance of some CLS beamlines. During the original design, an alternate operating point was analysed that had significantly lower emittance ( $\sim 13.5$  nm), which may be a better operating point for most beamlines. Attempts to operate the storage ring at this alternate point were not successful several years ago. Since then, the likely reason for the lack of success was discovered and corrected but no further work has yet been done to examine this operating point again. Even if the storage ring can be operated at this point, additional work is needed to demonstrate the improvement (or non-deleterious effects) on each beamline. A more significant decrease in the horizontal emittance might be possible with major changes to the storage ring lattice (i.e. changes to the storage ring magnets) which will probably require major changes in design and/or magnet technology. Possible alternatives will be evaluated over the longer term, along with the potential associated improvement to the beamlines' performance.

*Deliverables/Milestones:*

- Successfully set up storage ring for high horizontal tune operation (CD: Q4 2009/10)
- Assess performance effects on beamlines for new tune (CD: Q3 2010/11)
- Design report on alternative storage ring upgrade designs (CD: 2011/12)

### 3.3 Optimize the existing infrastructure to keep the CLS in a state of readiness

1. Implement an asset management system to maintain a reliable facility.

The CLS facility consists of a mixture of new equipment from recent beamline projects, moderately-aged equipment from our Phase I construction, and aging equipment inherited from the Saskatchewan Accelerator Laboratory. The CLS is no longer in the favorable situation of having the bulk of the systems new and expected to operate relatively worry free. Maintaining the same level of performance requires continued effort and a balance between cost, risks and production. Establishing a balance between these competing factors requires focused data collection and monitoring to allow a meaningful evaluation of the condition of the key components and systems that leads to an informed risk assessment of those systems and sets priorities for maintaining operations.

*Deliverables/Milestones:*

- Work order system operational (2010/11)
- Perform a risk assessment on equipment and compile an asset registry for high priority assets complete (2010/11)
- Establish Preliminary maintenance management system focusing on high priority assets complete (2010)
- Implement a fully integrated system including aligning inventory and purchasing with a maintenance plan, complete (2011/13)

2. Develop laboratory and support infrastructure.

The CLS continues to expand its number of operational beamlines and increasing its user program. It must be ready to service its customers. This requires continued laboratory development within the current structural envelope, addition of new spaces and functional areas, along with revitalizing aging infrastructure. Addressing the structural concerns at the CLS will be a focus in the next 3 years.

*Deliverables/Milestones:*

- Refurbish linac hall and sub-basement (Plan: 2010; Complete Implementation: 2011/13)
- Phase III facility expansion (Start construction: 2010; CD 2012)
- Upgrades to SAL building to address storage, landscaping and parking (2010/12)
- Facility Vacuum Assembly Room/Cleaning Room construction complete (2010/2011)
- CLS bio-chem laboratory construction complete (2010/11)
- BMIT interior development implementation (2010/12)
- BMIT landscaping and exterior development (2010/11)
- Establish new office spaces in second floor of Phase II expansion (2010/11)

3. Upgrade and enhance the facility's electrical and mechanical services.

Along with structural concerns, the CLS requires upgrades and enhancements to the electrical and mechanical services within the facility. These are needed to enhance

operations by improving system performance, increase reliability of system operation, and address capacity concerns for future expansion.

There are a number of HVAC upgrades required to address safety, and comfort concerns of the CLS staff, as well as to result in operational savings by allowing the reclaiming of heat from internal air before it is exhausted. The existing system in the old SAL building is 100% outdoor air and there is a need to have air returned from the office areas for energy savings and to help with the positive air control on the main hall. The welding area and chemical cleaning area is in need of a designated exhaust.

*Deliverables/Milestones:*

- Improve backup power systems (Plan: 2010; CD 2011/13)
- Get alternate facility electrical feed operational (2010)
- Implement voltage stabilization for the SR1 power service (Analysis: 2010; Complete implementation: 2011/13)
- Upgrade LCW capacity to service future beamlines (Research and analyze: 2010; Implementation: 2011/13)
- Machinshop/Linac HVAC upgrades (2010/11)
- LINAC Basement Air Handling Unit upgrades (2011/12)
- Main hall exhaust heat reclamation (2011/12)

4. Support the informational technology needs of the scientific program and CLS staff.

The Information Technology (IT) department is almost fully engaged in the maintenance of existing systems. The major areas this covers are serving the computer needs of the existing staff and adding services for additional staff, summer students, etc. Maintaining phone services, mail services, servers, file servers, and the computer network are all under the responsibility of the IT staff. Our Controls Instrumentation and Development division also has a major role in addressing the computer needs for the scientific program. This includes such things as data acquisition and data transfer.

*Deliverables/Milestones:*

- Improve data acquisition software and data transfer (2010/12)
- Establish a second server room (2011/13)
- Improve data logging
- Maintain ongoing system upgrades (Ongoing)