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# CLS OPERATIONAL STATUS AND FUTURE OPERATIONAL PLANS*

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*Abstract*

The Canadian Light Source (CLS) has been in operation for users since 2005 and recently commissioned its 22nd photon beamline. In 2021 the CLS implemented and commenced top-up operations at 220 mA. This new mode, for CLS, has been extremely well received by our scientific users. The storage ring is still RF power limited and require a second RF cavity to move towards realising the design goal of 500 mA. The 250 MeV electron injector complex for the CLS booster synchrotron ring dates back to the original linac from 1962 and the Saskatchewan Accelerator Laboratory and is in needs of an upgrade. This paper will give an overview of the present status of the accelerator systems for user operations and the operational improvement plans for a second RF cavity in the storage ring and a new linac.

## INTRODUCTION

The CLS [1] has been in operation since 2005 but is only now starting to realise some of the design goals for the machine (Fig. 1). The primary goal has been the completion of the 22 beamlines [2], the last of which was completed in 2021. Also realised in 2021 is Top-Up Mode (Fig. 2), which has drastically improved the performance of the machine and provide a better quality beam for our users. Yet the facility to be able to stay competitive need to operate with at least 220 mA of current in any given configuration of the insertion devices installed in 9 straights of 12. The machine is powered by one Superconducting RF cavity and a second one is needed to reach higher beam currents due to power limits. Yet the machine has been designed for a 500 mA of operation and getting more RF power from new type of RF power system like Solid State amplifier will definitely be a game changer in terms of performance and reliability.

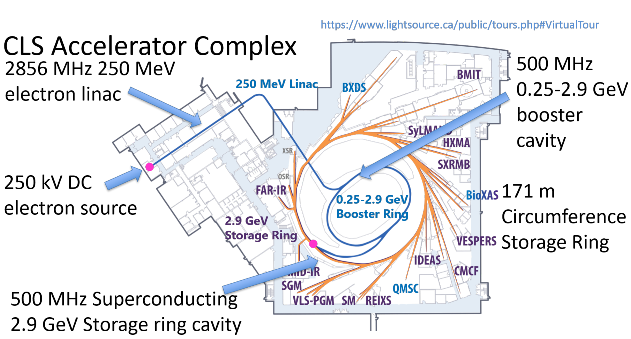


Figure 1: CLS accelerator complex overview.

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## PRESENT STATUS OF OPERATIONS

The CLS injector [3] makes use of the repurposed linac from the Saskatchewan Accelerator Laboratory which was established in 1964. Some improvements have been made to increase the performance of the linac over the years. For example two of the last three original 5 m long 2856 MHz Varian accelerating structures from 1964 have been replaced by two 3 m long 2856 MHz SLAC structures. The original structures were suffering from corrosion, vacuum leaks and water leaks, requiring regular RF reconditioning to reach full power. The space created by using shorter SLAC structures allowed for the installation of additional diagnostics, including YAG screens and cameras, FCTs and cavity BPMs in between each of the new structures.

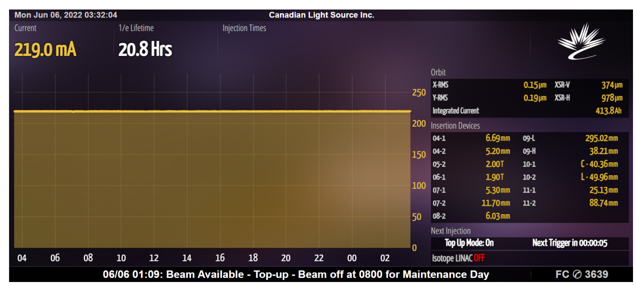


Figure 2: Typical 24 hours of user top-up mode.

One of the statistic that is of utmost importance for a research infrastructure which duty is to be a production facility of science is the up-time of its tools. All facilities aim to have an up-time or availability to be 100% meaning that all scheduled time for the photon user community is delivered. CLS aimed at delivering up to 4200 hrs of user beam with an uptime above 95%. The integrated hours planned and delivered up to June 2022 for this year is shown in Fig. 3.

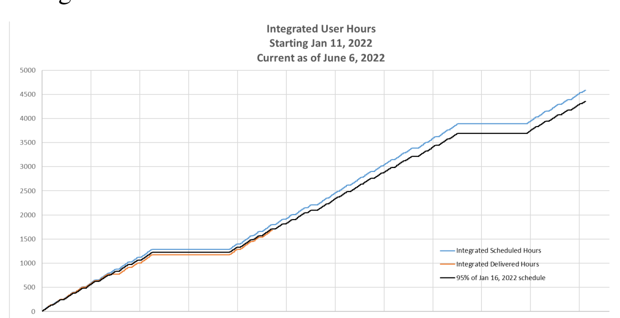


Figure 3: User beam availability and integrated beam delivered for 2022.

The uptime of CLS is provided in Fig.4 since 2017. Another important consideration is the comparison of this beam availability to other facilities. It is to be noted that most of the photon user facilities aim to deliver between 4000 to

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5000 hours of beam to its user community. Not being able to follow the reliability trend can be detrimental to scientific excellence and may also affect revenue through the "pay for beam" access mode. This last access mode is usually used by the private sector, and reliability and repeatability of the photon beam shot by shot is crucial.

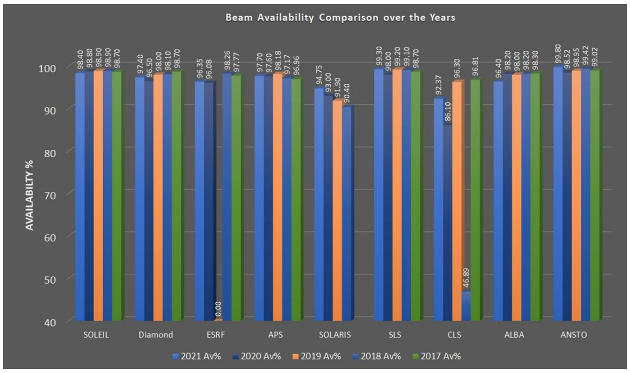


Figure 4: CLS Beam Availability compared to selected labs.

In 2018, the CLS suffered 7 months of no user beam due to a failure of the 1978 era e-gun. Due to the high profile of CLS in Canada, the failure made local and national press [4, 5] and accounted for very low beam availability that year. In 2020, the COVID-19 pandemic also hampered beam delivery. CLS was in the middle of replacing an ID when restrictions came into force and the machine was out of operations for many months until staff could return to complete the work. User beam was resorted for a special COVID-19 only run which lasted several months before more maintenance was required on IDs for the new beamlines. In 2021, the Liquid Helium cryogenic transfer line broke at the end of a maintenance shutdown and two months of operation were lost to repairs.

Despite its age, the lack of redundancy in some critical systems, CLS remains competitive for its uptime and in providing quality beam to its advanced beamlines. In international bench marking, CLS users have a very high scientific output with many high impact journal publications and citations.

A compliment to the beam availability statistics is the Mean Time Between Failure (MTBF) and Mean Time to Recover (MTTR) from a failure or trip. Although, not all facilities may count the same way, CLS considers a failure or a trip each time the beam in the storage ring is lost. The following figures allows for the comparison of those statistics between facilities in Fig. 5 and Fig. 6.

CLS tends not to suffer from many trips and they are in general fixed very quickly allowing for rapid beam recovery – thanks to the good response and knowledge of the staff. However, due to ageing components, some repairs require extensive work as replacement parts are not always available. The absence of redundancy for many key systems, for example a second RF cavity or a second e-gun, have resulted in long down time – sometimes over one week and several time over a few months. This is a very difficult situation both for the Machine Division as well as for the Science Division that has the duty to provide beam for the external

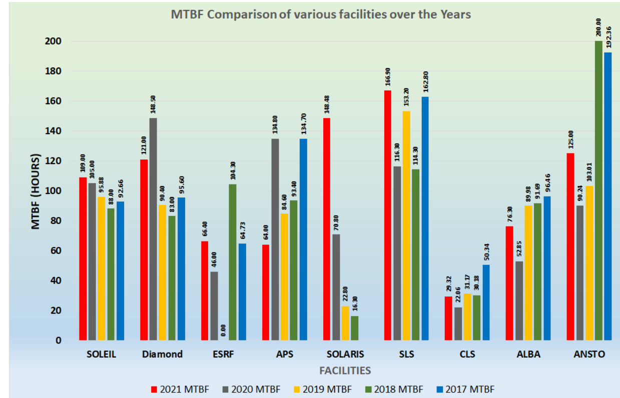


Figure 5: CLS MTBF compared to selected labs.

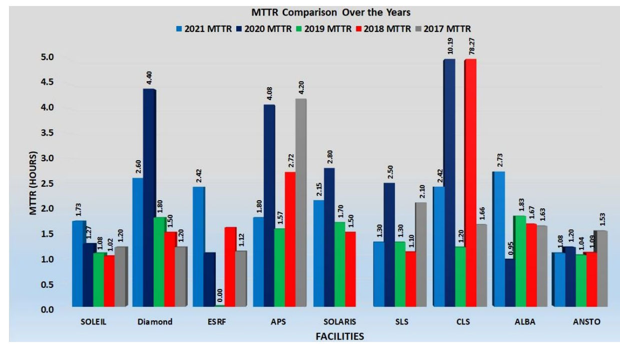


Figure 6: CLS MTTR compared to selected labs.

users. CLS attempts to alleviates the issues, by prioritising the procurement of newer components or upgrading system through either i) in-house development (e.g. orbit correction system [6]) or ii) collaboration projects [7]. During user runs, CLS usually reserves one 8 hour shift per week to maintenance and another three development shifts, either for maintaining reliability of the machine or for photon beam quality by tackling noise issues, beam alignment or curbing loss of flux etc.

### *Completed Upgrades*

Not discussing the installation of new components, two major upgrade were delivered. In mid-2021, CLS started top-up mode for users as the standard operating mode at 2.9 GeV and 220 mA. The beam current is now limited by the RF power we can deliver from one cavity and will be increased with the installation of a second cavity which in the process of being delivered. The top-up consolidation campaign shall be finished by the end of June 2022, but already many users have been praising this mode which has been promised since 2005. Since our user run start in January 2022, over the 1452 hours of beam delivered 1232 hours were in top-up.

The second project that has seen completion is the orbit correction system. The new system, although not as fast as the one installed in other facilities, due to the limitation by our existing electronic, allows a much better control of our beam orbit and gives us the possibility to introduce noise at different frequency and with different amplitude for diagnostics. This has provided the machine group an

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invaluable tool to help determine if noise seen at a beam line is due to the electron beam.

## FUTURE UPGRADE PLANS 2023-2029

So far some of the causes of the most common trips of the Storage ring is due to power supplies of various magnets (~ 75%) as shown in Fig. 7 and Fig. 8. Although those trips are not dominating the statistics for the number of trips, they do result in the most hours of lost beamtime.

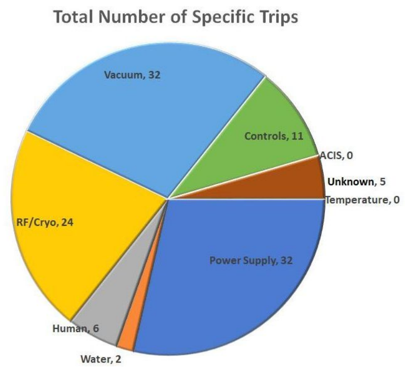


Figure 7: Categorised number of trips from 2018-01-18 to 2022-05-22.

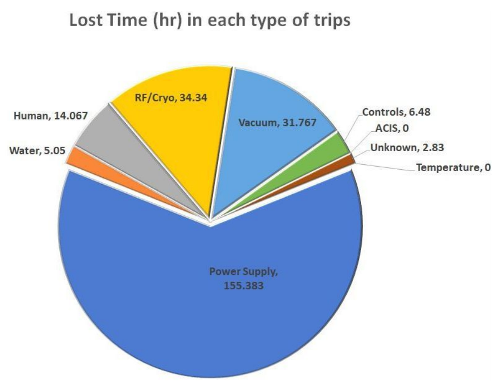


Figure 8: Hours lost by categories from 2018-01-18 to 2022-05-22.

To remediate to this issue, CLS plans to upgrade the power supplies of its correctors and is currently putting is effort and resources on working on the power supply bank that feeds our Storage ring bend dipoles. This particularly old power supply caused a loss of almost a week of beam operation with 2 days being user operation.

A upgrade of the Low Level RF (LLRF) system for the CLS booster ring was recently completed [7] and on the back of this success an upgrade of the storage ring LLRF is also planed. CLS has purchased from Research Instrument GmbH a new superconducting RF (SRF) cavity and cryomodule which is expected to be installed in the ring in the coming years. It shall release the stress of operation of the current SRF cavity and shall improve the reliability of the operation. In addition, it will enable the storage beam current to be increased above 220 mA which is now limited by RF power. In order for this activity to have any impact, a second RF amplifier is also required. The present SRF cavity is fed by a klystron, however for the new cavity the plan is to install a solid state amplifier to take advantage of the modern modular technology and remove another single point of failure. In the past year CLS has suffered a klystron and a sklystron high voltage supply failure, so for emergency has secured an spare klystron from the Paul Scherrer Institute.

Finally, CLS is preparing the purchase of a new linac and electron source to be able to operate between 1 Hz to 60 Hz. The CLS injection system can only operate at a 1 Hz repetition rate, but for RF conditioning and possible future expansion to a higher rep-rate short pulse facility, higher repetition rates should be possible. The new linac will be normal conducting and SLED driven [8] as to save cost on RF stations. The new linac will be operating at a harmonic of the 500.040 MHz RF frequency of the booster and storage ring. The current linac from the 1960's is not synchronized, hence a lot of charge is lost at injection into the booster synchrotron. In addition, the existing e-gun has a continuous S-band bunch train, while the new linac and e-gun specification is for a 500 MHz sub-harmonic bunching system from the start of the linac to more efficiently deliver beam to the 500 MHz booster ring. Presently the booster capture efficiency is around 40% due to a combination of a frequency mismatch, transfer line optics and energy spread mismatch and large a dispersion function at points in the booster ring. The new linac project will provide an opportunity to re-tune the injection system and install any additional new diagnostics required to improve the injection efficiency.

## SUMMARY

In 2021 the CLS completed the primary goals of the facility to be operating 22 beamlines in top-up operations for users. A concerted effort is now being made to improve the beam availability above 95% through replacing end-of-life components and building in redundancy on the machine. The coming period to the end of the decade the main CLS plans include the replacement of the linac, the addition of a second SRF cavity to the storage ring and the installation of an RF solid state amplifier for the storage ring.

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