

Accelerator Reliability Workshop

Sunday 10 April 2011 - Friday 15 April 2011

iThemba LABS



Book of Abstracts

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Welcome and opening

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The electronic logbook revisited

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Electronic logbooks have progressively replaced paper logbooks in the past decade. Many logbook applications, mostly web based, have been presented at various workshops and conferences. So all has been said and done?

Modern electronic logbooks come with a large number of features, to be configured according to the needs of the customers.

But how to use those features efficiently for the operation of an accelerator facility? The presentation will evaluate the possible gain from an extensive use of electronic logbooks in operation and will show operation applications of e-logbooks beyond the classical shift summaries. The impact of these applications on the long term availability of accelerator facilities will be discussed.

The presentation will focus on the desired functionality, independent of the electronic logbook implementation. Examples will be shown for the electronic logbook that comes as part of the Debian Linux distribution, ELOG.

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Availability Performance of SLAC's LCLS X-ray FEL

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The Linac Coherent Light Source (LCLS) X-ray FEL, in operation since spring 2009, is in the middle of its 3rd user run. Availability and hardware reliability performance of the machine are reviewed. Work under way that is expected to improve availability and reliability is described. The high flexibility of the parameter space that the machine can deliver; as well as the multiplicity of different users' requirements; present an interesting question on the figures of merit for availability determination. An attempt is made on defining X-ray availability for the LCLS FEL. Expected X-ray beam quality may be included on availability determinations.

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REDEPLOYMENT OF DUAL ENERGY RFQ ACCELERATOR SYSTEMS: LESSONS LEARNT.

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In 2007 Necsa was given the opportunity to take over two separate RFQ accelerator systems designed to generate intense pulses of pseudo monoenergetic neutrons. Both systems, though similar, were unique in their design and established mode of operation. Each accelerator system consisted of two RFQ linear accelerators connected in tandem and linked to a windowless high pressure gas cell target. As such it was important to maintain a reliable high vacuum system for the accelerators and also ensure that the target gas retained its purity so as to minimize unwanted radiation. The shielding requirements for such a facility was an important feature of the overall installation. Aspects of the operation of the accelerator under these conditions will be presented.

One of the systems had to be dismantled and rebuilt at a new location. The experience and lessons learnt in undertaking this task will also be presented.

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Operating the superconducting electron accelerator S-DALINAC - built, improved and operated mainly by students

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Since the 1980s, the superconducting electron accelerator S-DALINAC was built and continuously improved at the Technical University of Darmstadt mainly by students in the framework of their master and Ph.D. thesis. With only limited technical assistance, this created operational challenges to face ever since: many subsystems have a poor design, some operate below specifications while others require high expertise of the user. Moreover, as the accelerator runs in an academic environment, technical details are mostly not documented while the students implementing new systems leave the institute once they got their degree. Nevertheless, the machine delivers roughly 2500 h beam on target yearly.

We will report on the daily operational issues, the methods developed to keep the knowledge and training the students, operating the machine.

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Organizational Structures at GSI Concerning Accelerator Maintenance and Reliability

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The GSI Helmholtz Center for Heavy Ion Research GmbH at Darmstadt, Germany, operates three accelerators, the main linac UNILAC (UNiversal Linear ACcelerator) with two injectors (high current injector HSI, high charge state injector HLI), the heavy ion synchrotron SIS18 and the experimental storage ring ESR. Due to a time-sharing mode up to five experiments can be performed in parallel. Thus, the total experimental beam time per year varied from 11900 to 15500 hours during the last 5 years. To manage beam time scheduling, commissioning, breakdown events, maintenance, and shutdown periods a dedicated organizational structure has been developed for many years. It comprises several daily, weekly and long term meetings as well as responsible persons for beam time, machine, and shutdown coordination, and for safety issues. The operation crew is supported by call on duty personnel of each technical department. Within this contribution this organizational structure is presented in more details with respect to maintenance and reliability.

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RAM METHODOLOGY AND ACTIVITIES FOR IFMIF ENGINEERING DESIGN

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IFMIF (International Fusion Materials Irradiation Facility) will be an accelerator-based neutron source to test fusion candidate materials. It consists on a set of two parallel deuteron accelerators (40 MeV, 125 mA, CW) bringing the beam to a liquid lithium target. The interaction between the deuterons and the lithium generates a flux of neutrons whose spectrum is rather well suited with fusion needs. This flux irradiates the samples hosted in the test facilities.

The Engineering Validation and Engineering Design Activities of IFMIF are aimed to deliver the complete engineering design file of this major facility. This engineering design will be validated by the design, the construction and the operation of three prototypes representative of the main challenging systems of IFMIF, including the low energy part of the accelerator (up to 9 MeV), tested at full current (125mA) in continuous wave at Rokkasho, Japan.

Achieving a high level of availability and reliability is a key point for IFMIF mission. A goal of 70% of availability (including schedule maintenance time) has been established. In order to fulfill the availability requirements, RAM has to be considered during the engineering design phase. This paper summarizes the proposed process aimed at including RAM methodology in the design of IFMIF, as well as the activities performed in this framework.

Technical guidelines have been developed for the designers' consideration during the engineering design phase. As a first step for the iterative process of RAM analysis of IFMIF design, an independent fault tree model based on a new reliability database has been developed with Risk Spectrum®. The result is a first assessment of the availability and first allocation of RAM requirements. On the other hand, data capture methodology has been proposed for IFMIF prototypes in order to improve IFMIF database.

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CORRECTIVE & PREVENTIVE MAINTENANCE AT THE NSCL

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The National Superconducting Cyclotron Laboratory (NSCL) is a world leader in rare isotope research and nuclear science education. Located on the campus of Michigan State University, NSCL scientists and researchers employ a wide range of tools for conducting advanced research in fundamental nuclear science, nuclear astrophysics, and accelerator physics. Robust preventive and corrective maintenance practices are crucial to meeting NSCL Quality Management System goal of greater than 90% availability. To achieve this goal, a coordinated interaction of the laboratory's maintenance tools with its procedures and organizational structure is required. The tools and procedures employed at the NSCL have been refined through many years of experience. Web based software applications have been developed in-house to allow breakdown tracking as well as facility status logging and reporting. Off the shelf software tools allow the efficient planning of preventive maintenance activities and upgrade implementation. Committees to provide oversight ensure the laboratory's corrective and preventive actions are effective. Close cooperation between various departments within the laboratory and Michigan State University; provide complete coverage for any maintenance need. Maintenance shutdowns are planned with input from all departments whose resources are then gathered into a single resource pool for scheduling. The coordination and planning of maintenance activities for the Coupled Cyclotron Facility is the responsibility of the Maintenance Group within the Operations Department.

Summary:

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2011 Accelerator Reliability Workshop
ORAL PRESENTATION
Session 17

Improving reliability: CTRLM, call systems, spare parts, training, procedures

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Treatment and development: a reasonable equation for Particle Therapy ?

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From its early stages, Particle Therapy (PT) has combined the treatment activity with the developments of the treatment devices. The new expectations in term of number of patients to be treated (so in term of reliability) and in term of conformity (so in term of quality assurance and regulations to follow) asks the legitimacy of this combined approach.

The Institut Curie-CPO has now finished his major project of extension. It now includes a new accelerator (cyclotron 230 MeV from IBA), a gantry (IBA), the two existing fix beam rooms and a

medical wing in order to have a full hospital environment. The target activity is around 700 patients per year with a significant part of complex pediatry treatments.

According the different features of the facility, we will discuss cases where the constraints conformity-reliability-development are in stress:

- operation and maintenance of the facility including the accelerator (shared contract of maintenance with the supplier IBA)
- mode of planning and use of the facility towards the different activities (tuning, QA, treatment, maintenance, development,...), mode (clinical/service) and users.
- process of upgrades of the I.T. systems
- management and referring to regulatory authorities

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Can you rely upon reliability in a medical proton accelerator system

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The probability of a system performing as expected, when it is needed, depends on proper design, appropriate implementation and rigorous maintenance. Measuring this system performance requires that performance goals have to be defined. These are based on clinical, operational and technical desires. Data characterising the system functioning, or metrics, have to be defined and analysed. The analysis may be subject to interpretation, but the trick is to predict the system performance based upon the current knowledge of the system. With this prediction, a plan of action can be developed to improve the system. What is the appropriate information to gather? How is this knowledge obtained? How can this be done in the context of an operating system? Does anyone have time for this, or conversely how many people are necessary to perform the task adequately?

The current experience at the Burr Proton Therapy Center will be reviewed with respect to what we have affectionately termed, the “ilities”. Availability results from a combination of maintainability, reliability, and other ilities. A concrete understanding of what these ilities actually mean in a practical sense is necessary. Initial design decisions can have a big impact on the work needed to achieve the desired performance. However, it may not be until operation has started, that the full realization of which aspects of the ilities are relevant for the desired availability.

While one may never reach the goal of 100% availability, one can at least optimize reliability and maintainability. Part of this has to be an approach to system design that allows simple validation and verification of system performance. Examples will be given highlighting the importance of diagnostics capability in reducing the downtime. The information needed spans the domains of clinical physics to accelerator physics and we will show how data in both areas are needed to monitor and diagnose system performance. Quality assurance and preventive maintenance are inseparable. Time is a key issue as well. In a normal clinical operational environment, the time available for daily maintenance is small and the time available for extended maintenance is non-existent. How does one work within these constraints and what are the expected results? Is there a difference, if in addition to all the above, one is continuing to develop the system?

Summary:

Aspects of reliability and availability, measurement and design, will be discussed for a medical proton accelerator system, from the perspective of the technical operations staff of an operating medical proton therapy system.

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Measurement of magnetic field deviation and the effect at HIMAC synchrotron

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At HIMAC synchrotron, the status of device is monitored to ensure the reliability of beam for therapy by operators and control systems. Although we are monitoring a current output of each power supplies of dipole and quadrupole magnets, we have been aware that there is a difference between the monitoring current and the actual magnetic fields through information from a beam. However, we could not know the actual magnet field and handle the problem with theoretical support, because we had no suitable monitoring system for magnetic fields. So we have developed an NMR system to directly measure dipole magnets fields both injection and extraction fields, thus we have become able to deduce quadrupole magnet fields from comparing the dipole field with measurements of beam behavior. This has made us possible to know a long term drift of magnetic fields and lag of a magnetic field from a current of pattern operated magnets in synchrotron. As a result, we can correct a change of beam behavior caused by magnet field change. In addition, due to the measurement of the magnetic fields deviation, we will be able to optimize the synchrotron current pattern without special skills of experienced operators. In this report, we will present the method and the results of the measurement and perspective into the future.

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LHC intervention scheduling with the Work Acceptance Tool

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The start of LHC operation after ten years of installation and commissioning introduced new actors and new procedures within the accelerator complex operation. It revealed the need to ease the information flow across the different teams in charge of intervention co-ordination: corrective and preventive maintenance, upgrades and consolidation interventions needing technical validation, discussion between stakeholders, scheduling, safety checking and follow-up. In 2010, a new tool was developed for intervention scheduling (Work Acceptance Tool), providing a central point of information and decision. This paper will describe the different actors and their roles, the new tool in place, the benefits gained and it will draw the first conclusions after its first use during the LHC technical stop.

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Design and Development of a Remotely Controlled Thermal Imaging Platform

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A remote control, mobile, thermal imaging camera platform has been developed to survey and investigate the Diamond Light Source accelerator components when beam is present. The platform consists of a small battery powered, PC operated, wheeled base unit onto which a height adjustable camera mount has been fitted. Visible light and thermal imaging cameras are located on the camera mount. The platform is 'free roaming' and operated remotely from the control room via LAN and WLAN connections. The facility to recharge the onboard batteries has been built in thereby allowing the unit to be fielded for extended periods of time. The platform has been in use during machine run periods for approximately one year and has been employed in monitoring various areas of the Booster and Storage Ring.

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Software Reliability: Tools and Practices in the real world of Software Development

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Physicists and engineers often end up writing their own software for the particle accelerator industry. While this has the benefit that their practical know how gained in the industry is immediate, they undergo the trouble of finding out the difficulties of software development through trial and error.

We present an expose of tools and methodology for improving software reliability from a professional software development standpoint using the Particle Accelerator E Logbook as an example.

The expose covers best practices for Design Processes, Development Processes and Standards, Testing and Quality Assurance Methodology, Automated Testing, Reporting and Support Issues highlighting pitfalls and sharing lessons learned.

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Existing and Future Trends in E-Logbooks and how these have and will improve Accelerator Reliability

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This paper will focus on the evolution of E-logbooks and the features and benefits specific to the Accelerator Industry.

Initially, we will give a history of the status of modern E-Logbooks using real-life results from the industry. We will then discuss the future trend of E-Logbooks both in the Particle Accelerator Business as well as in other industries.

Finally, we will be putting forward some conceptual ideas on a Software as a Service (SaaS) E-Logbook for the industry and discuss the potentially huge benefits of such a concept.

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Oxygen deficiency monitoring at TRIUMF

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Cryogenic equipment is used in many modern accelerator facilities. A release of cryogenics may cause an oxygen deficient atmosphere resulting in a hazardous work environment. A well designed oxygen deficiency monitoring system will allow a facility to run efficiently while still permitting workers access to operate and service the equipment in a safe manner.

TRIUMF is in the process of upgrading the operation of its oxygen monitoring system. I will give an overview of the design process including hazard analysis, sensor selection, monitoring options, annunciations of alarms, what happens during a low O₂ alarm, active monitoring versus procedural planning, and servicing and calibration requirements.

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Backup systems for the reliability of the SPring-8 accelerators

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It is important for accelerator reliability, especially of public facilities like light sources or medical accelerators, not only to eliminate machine down but also to shorten down time. Moreover, at the SPring-8 the top-up operation, where the beam injection to the storage ring is continuing during user time to keep the stored current constant, is going on. Since the users of the SPring-8 strongly require the stability of the source intensity, i.e. the stored current, the reliability of the injector becomes more essential to the stable operation of SPring-8 storage ring. Hence we prepare the backup systems for the accelerators as much as possible. For example, in order to keep a top-up operation, we have installed an additional electron gun system in the linac. We review the backup systems of the SPring-8 accelerators prepared for improving the availability of the injector as well as for reducing the down time of the storage ring.

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Do you believe in Operation Statistics?

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Normally it is expected for scientific publications to publish the evaluated data together with statistical evaluation of the data. This allows the community to reproduce and verify the data analysis. It allows as well to broaden the analysis and to compare the results from different publications. There are of course exceptions, for example when the data is considered to be confidential like for medical studies, that prohibits the publication of the original data. The presentation will analyse the current best practises for the publication of operation statistics of synchrotron light sources. It will be shown that they are rarely ever published together with the underlying data. The authors are convinced that the actual failure data would be very helpful for the community. It would allow a better comparison of the operation metrics of different facilities, it would enable meta analysis of failure rates to find the best solutions for all subsystems and it would increase the general faith into operation statistics.

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The SNS Reliability Program

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The Spallation Neutron Source accelerator systems consist of a ~1GeV H⁻, pulsed, superconducting Linac, with ~1000 turn H⁻ injection stripping accumulator ring and single-turn extraction to a Hg target. It has operated recently for extended periods at ~1MW with ~ 90% availability. The approach to reliable operation at the SNS will be discussed including RAMI Modeling, Management Information Systems, Metrics, Configuration Control, Work Control and the Spares Policy.

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SLAC Accelerators Power Electronic System Operation for Reliability

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SLAC National Accelerator Laboratory is home to a two-mile linear accelerator—the longest in the world. Originally a particle physics research center, SLAC is now a multipurpose laboratory for astrophysics, photon science, accelerator and particle physics research. SLAC mission as National Laboratory seeks to be a leader in exploring frontier questions of science that are important to the nation.

The major particle accelerator relates programs SLAC currently undertakes to achieve its vision are:

- Linac Coherent Light Source (LCLS)
- Stanford Synchrotron Radiation Lightsource (SSRL)
- Experimental Particle Physics:
 - o Facility for Advanced Accelerator Experimental Tests (FACET)
 - o Next Linear Collider Test Facility (NLCTA)

Power Conversion Department (PCD), provide power conversion talent and systems for high energy

physics LINACs and storage rings. Maintain technical/engineering expertise for existing and future power conversion applications. Design, document, install, and maintain: Low and high power DC systems for beam generation, transport, shaping and delivery, Fast kicker, RF modulator pulsed systems, Power system control, monitoring, protection and raceway systems.

This paper will cover PCD organization, Tools and Policies, Metrics and Plans for SLAC accelerator power systems Operation management, Performance, Improvements and long term support plans.

Summary:

Power Conversion at SLAC has develop a model to maintain the accelerator machines in two folds:

- 1) Service Level Agreement - Where the goals with our internal costumers (scientific programs) are set.
- 2) Sustaining Engineering Model - Where every single equipment have been assigned a System Manager and an A&S, supported by a 24/7 Maintenance Group.

The presentation will cover, SLAC

- 1) SLAC overview and Machines Availability Goals
- 2) PCD Sustaining Engineering Organization
- 3) Reliability/safety tools and Policies
- 4) Reliability Metrics
- 5) Upgrade program
- 6) Design for reliability
- 7) Conclusions

Magnets and interlock / 31

LHC Machine Interlocks and Beam Operation

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The correct functioning of the Machine Interlocks (MI) is vital for safe operation throughout all operational phases of the Large Hadron Collider (LHC). The two main components composing the MI are the LHC Beam Interlock System and the LHC Powering interlock systems, both for super conducting and normal conducting magnets, The first one is highly reliable and fast. It relays Permit signals from the connected subsystems in case of failure for emergency extraction of beam to the LHC beam dump block. The second one is reliable as well and is essential for safe commissioning and operation of the magnet system. It protects about 1700 electrical circuits powering almost 10000 magnets.

The presentation reports on the operational experience with the MI systems, and details the tests and the diagnostic tools deployed to validate correct functionality. It also reports on the automated software tools, used on a regular basis to assess the readiness for beam operation. It demonstrates that MI systems have been not only designed to be reliable but to be also helpful and valuable for having efficient machine operation.

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Incident follow up with Major Event Reports

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The technical infrastructure operators in the CCC edit what is known as “Major Event Reports” for events that result in downtime of accelerators, physics or other important installations. Each event will be analyzed by all involved parties, the TI operators, equipment groups concerned affected users such as the cryogenics, accelerators or experiments. The event is treated in the Technical Infrastructure Operations Committee, TIOC. Conclusions are drawn and actions are decided. The major event reports are also used to provide statistics on beam down time giving per event not only the duration but also an indication on what the problem was, what group was concerned and what type of fault it was. Major Event Reports were put in place in 2002 and has been in constant use ever since, providing a thorough history on major incidents ever since. This talk will describe the process, the tools and give some examples of incidents and improvements made as a result of the major event reporting.

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CERN Intervention Priority Management

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It is the mission of the technical infrastructure service to minimize the impact of technical breakdowns on accelerators and other important installations at CERN and to co-ordinate interventions during major breakdowns. This requires an understanding of the operation of the important facilities and an up-to-date knowledge of operational priorities and on-going activities. In case of a major power outage at CERN where all or most of the installations are affected, the technical infrastructure operator on shift needs to know in what order to start up facilities. A CERN Panel for Intervention Priorities decides on a high level list of what is most important. The Technical Infrastructure operators have elaborated a check list from the priority list adding detailed information about “what do check”, “how to check it”, “what action to take”, “whom to contact”. This talk will show the CERN priority list, the corresponding check list and the tools used by operators to diagnose a situation and to manage the co-ordination of activities.

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Approaches to the maintenance at LNL.

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The Laboratori Nazionali di Legnaro (LNL) is a centre for applied and nuclear physics founded in 1960 in Legnaro, Padova (Italy). At the beginning the centre was equipped with a 7MV Van de Graaf accelerator and, since then, a new machine has been installed roughly every 10 years, namely a 2MV van de Graaf accelerator, a 14MV Tandem XTU, a super-conducting 58MV booster (ALPI) and finally a super-conducting 12MV injector (PIAVE). Because of the different wear of these accelerators due both to use and age, various approaches to their maintenance have been envisaged: planned, opportunistic preventive, recovery after failure and radical update/upgrade. In this paper we analyze these methods applied to specific cases and we describe the smooth transition from an all-on-paper to all-on-DB logbook of the daily activities and faults. In addition the Work Permitting procedures in force at the moment at LNL are explained.

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TWO YEARS OPERATION AND RELIABILITY OF SSRF

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SSRF, a 3.5GeV, 3.9nm.rad synchrotron light source, has been operated for users since May, 2009. The accelerator was operated in decay mode with machine availability of 95.7% and MTBF of 40hours. Most of the beam downs are triggered by the interlock in the super-conducting RF system. The main contribution to the MDT is the failure of LHe cryogenic system. The power supply system for magnets and the beam diagnostic system also influence the MTBF in operation. The top-up operation mode is being commissioned to increase the beam orbit stability. The reliability of injector will be upgraded to ensure the top-up operation mode opened for users. The detail operation performance, the main faults and the solutions are described in this paper.

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Maintenance and Support for Increased Reliability

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Many factors affecting accelerator performance are associated with maintenance, repair and other support activities. At Brookhaven National Laboratory, the Collider Accelerator Department (CAD) is home to several accelerators including the Relativistic Heavy Ion Collider (RHIC). At CAD, the overall organization and coordination of these tasks are the responsibility of the Maintenance and Accelerator Support Group (MSG). In order to assure overall reliability in an accelerator complex, an approach to maintenance and repair must be structured and systematic while maintaining flexibility. It is the change of the MSG to attain this goal. This talk will discuss the evolution of this process at CAD. An overview of methods for planning, execution and recovery from maintenance periods will be given. There will be a discussion of this methods effectiveness, as measured by increased reliability. Other topics mentioned will include: maximizing availability in a multi-user facility, minimizing the impact of new systems commissioning, streamlining accelerator start-up and plans for improvement.

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IMPROVING THE RELIABILITY OF PARTICLE ACCELERATOR MAGNETS

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Whether one is using electromagnets in a small accelerator to produce synchrotron radiation or in a very large accelerator to produce high energy particles for basic research experiments, or in

a proton therapy medical device, their availability is paramount to the overall success of the machine. Availability is defined as the average ratio of the time that the system or component is usable to the total amount of time that it is needed. The availability A is calculated using two other parameters, the Mean Time Between Failures (MTBF) and the Mean Time To Repair (MTTR): $A = (MTBF)/(MTBF+MTTR)$. The MTBF is the inverse of the failure rate and improving the reliability of any device means to reduce its failure rate. There are many ways that an electromagnet, which is comprised of several different components, can fail. So a magnet engineer who is designing a new style of magnet must use their knowledge of the failure modes of older styles of magnets to influence the design of the new style so as to avoid the known types of failures and decrease the failure rate.

A structured, qualitative procedure for identifying the root causes of magnet failures is called Failure Modes and Effects Analysis (FMEA). We carried out a FMEA on typical electromagnets designed and fabricated at the SLAC National Accelerator Laboratory. This procedure identified the failure-prone features in SLAC magnets. In order to learn from the experiences of other labs regarding their magnets' failure modes and how they have dealt with them, a survey will be carried out of designers and users of accelerator magnets worldwide in the weeks just before this ARW. The questions on this survey will cover both common and rarer ways that magnets break down and will seek descriptions of successful solutions and improved performance achieved by other users. This talk will use SLAC's magnet experiences and the answers to this survey to provide advice on how to improve the reliability of accelerator magnets.

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Practical Realization of Service Concepts for the Siemens Particle Therapy (PT) Systems

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The Siemens Company (SAG) is currently building and commissioning particle therapy facilities for cancer treatment at Marburg and Kiel in Germany and at Shanghai / China. The accelerator of these facilities consists basically of a combination of Electron Cyclotron Resonance Ion Sources (ECRIS) and Radio Frequency Quadrupole (RFQ) together with Interdigital - H (IH) accelerators as injector for a synchrotron which delivers up to 250 MeV protons or 430 MeV/u carbon ions respectively. The accelerator design is based on a prototype at HIT (Heidelberger Ionenstrahl Therapie), where patients are treated since Nov. 2009, mainly with carbon ion beams.

What all PT facilities have in common is the required high uptime to allow for a maximum number of patients to be treated during the year and to strictly avoid incomplete treatment fractions. To achieve these high uptimes and ensure a high reliability and reproducibility, a lot of effort has been spent during the design phase, introducing technically innovative components like e.g. a digital low level rf-system for the Linac amplifiers and an Accelerator Control System (ACS) which is designed to log almost all available machine data for preventive maintenance purposes.

In parallel to technical considerations a maintenance concept was developed which combines preventive maintenance aspects from SAG power plant operation (Siemens Energy) with dedicated new maintenance models from our accelerator group at PT.

The poster will describe our PT accelerator and give an overview of the maintenance concepts and tools we use to optimize uptime and reliability of our therapy system.

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Fluka studies on LHC Asynchronous Beam Dump

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The LHC is a record-breaking machine for energy and intensity. It is very complex and any problem could potentially be very harmful. These possibilities have to be considered in advance and need to be investigated with simulations. These simulations are performed using the FLUKA Monte Carlo code. It has been chosen because of the high reliability of its results and the ease to custom detailed simulations all along hundreds of meters of beam line. Out of the many studies realized for the LHC, we will mainly focus on the investigation of the effects of an asynchronous beam dump. The energy stored in the LHC is of the order of hundreds of MegaJoules; in the event of an asynchronous beam dump it can be instantaneously released over the cryogenic magnets, up to some Joule cm⁻³ where the quench limit is of the order of the milliJoule cm⁻³. Quenching the magnets would not only cause a beam loss, but could also seriously damage the accelerator. Therefore, it is very important to precisely evaluate the energy released and to study whether the shielding provided by collimators and the security mechanisms enforced are sufficient to grant the accelerator safety or further actions are needed.

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A brief history of accelerator reliability

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Reliability concept was born with world war II. The first reliability models were developed to improve the V2 rockets. Until the years 70s, accelerator reliability was not even considered. Increasing the energy and intensity were the only goals. After the 70s, with the first Users and experimenters, the need of reliability became important (medical accelerator, X-ray sources, etc). Reliability progressively became a major concern for accelerator engineers. Whilst present X-ray sources can tolerate several tens of failures per year, future ADS will not tolerate more than one short failure per year ! I will

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LHC commissioning reliability

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Following 6 years of construction and testing starting in 2002, the LHC commissioning with beam started in the third quarter of 2008 and again in late 2009. On both occasions, first circulating beam was preceded by a major campaign of equipment tests. These included extensive powering tests of the 1620 superconducting electrical circuits during the LHC Hardware Commissioning. Prior to these tests the electrical quality assurance was performed for all circuits. Once the cryogenic system was ready and the magnet strings cooled to 1.9K, an extremely detailed program of more than 10.000 individual powering tests could start to check the integrity of Power Converters, Quench Protection System and the Powering Interlock System. Only once these tests are completed the magnet powering system is operational for injection of the first proton beams.

In the following, a full machine checkout of all major accelerator systems was performed. These tests, extending over many months, proved to be essential and undoubtedly made a major contribution to the rapid and successful start to beam commissioning.

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The Survey of the Power Supply Reliability at SSRF

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The Shanghai Synchrotron Radiation Facility (SSRF) has built and operation for more than two years. The availability was close to 96% at last year. There are more than 650 DC and pulsed power supplies for magnets. The failure ratio of power supply is 9% of total failure time. This paper will presents the power supply operational statistics and describes fault analysis.

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Many Years of Experiences with UNILAC Operation

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The GSI UNILAC (Universal Linear Accelerator) is in operation since 1974. By different enhancements its performance was increased from a machine accelerating only one heavy ion species beam to a specified energy to a pulse-to-pulse switching machine. Up to three different ion species beams generated in three ion source terminals are accelerated to different energies up to 12 MeV/u in a defined sequence basing on a 50 Hz cycle. Furthermore the beam intensity was increased to the 1 MW beam power region. The talk gives an overview of active and dynamic beam protection equipments, major breakdown reasons, and aging implicated failures. Also improvements of component cohorts initiated by operational experiences and the effects on beam availability are reported.

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ONLINE INTEGRATION OF RADIATION SAFETY WORK CONTROL FORMS

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Prior to this year, the SLAC National Accelerator Laboratory employed paper-based Radiation Safety Work Control Forms (RSWCFs) to manage work on radiation safety systems for the linear accelerator facility. In January, we introduced an online version of the RSWCFs that was developed using Oracle Application Express (APEX) and is accessible from any computer connected to the SLAC internal network. The goal of this transition from paper-based to electronic RSWCFs is to expedite the initiation, approval, and completion of the work control process for these critical systems without compromising safety or configuration control. This paper reports on our experience with this new electronic version of the Radiation Safety Work Control Forms.

Summary:

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Practical Applications of Reliability Theory

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Reliability Theory provides many practical applications and tools to assist with important questions which arise from the initial design to the eventual steady state operation particle accelerators. These include:

- Reliability Modeling as a tool for evaluating system performance
 - o In the design phase what are the tradeoffs of cost vs. reliability performance?
 - o In the operational phase, does the performance meet expectations?
- Analysis of the failure rate of systems or components
 - o How do systems fail?
 - o Is the failure rate “reasonable” ?
- Analytical calculation for the number of Spares
 - o What kinds of spares are there?
 - o What is a “reasonable” number of spares?

Approaches to the techniques used to answer these important questions will be discussed.

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Reliable operation of the rf system for Heavy Ion Cyclotrons at RIBF

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This paper describes our effort to achieve reliable operation of RF system for Cyclotrons at RIKEN Radio Isotope Beam Factory (RIBF).

The accelerator complex of RIBF which consists of superconducting ring cyclotron (SRC), intermediate-stage ring cyclotron (IRC) and Fixed-frequency booster ring cyclotron (FRC) provides heavy ion beams like uranium with a energy of 345 MeV/u.

Beam loss in the acceleration by cyclotrons mainly occurs at the electric static deflector at extraction and damages the deflector septum. In order to reduce the loss at deflectors, high voltage acceleration with a harmonic flattop field play an important role. For the SRC, four acceleration single-gap cavities and a third harmonic flattop cavity are installed. The maximum voltage is 600 kVp at 36.5 MHz. A long term stability is also important and the obtained stability of voltage and phase are $\pm 0.5\%$ and ± 0.1 deg.

In the case of uranium acceleration 25 cavities are employed. It is crucial to have reliable operation of all the cavities to handle high power beams. Discussion will be made on what we do for operation of the cavities and how we confirm the reliable operation of the rf system.

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New Radiation Safety Interlock System for the SPring-8 Accelerator Complex

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Radiation safety interlock system for the SPring-8 accelerators, which protects workers from radiation hazard induced by electron beams and synchrotron radiation, has been operating over a decade. In the past 10 years, the radiation controlled area in SPring-8 expanded to cover five accelerator/beam-transport areas including two storage rings: SPring-8 storage ring and NewSUBARU storage ring. Moreover, the injection beam transportation can be frequently changed between the two storage rings. The extended radiation safety interlock system had the complicated safety logic to handle such a switching operation and wider accelerator/beam-transport areas because the system was closely related to the combination of accelerator areas in operation: "Operation MODE". In order to cover an additional accelerator/beam-transport area efficiently in the future, the functional independence of each accelerator/beam-transport area has to be well established for easy integration and simple maintenance. This circumstance provoked extensive discussions on the design of new radiation safety interlock system to satisfy the requirements and smooth migration from the old system to the new one. The construction of the new radiation safety interlock system was finalized in September 2010. And the system started the user operation in October 2010. We will report the design of the new radiation safety interlock system and the process of the system construction.

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Reliability issues at the accelerator facility of iThemba LABS

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A variable energy K200 separated sector cyclotron and its two associated injector cyclotrons at iThemba LABS have been utilized for radioisotope production, nuclear physics research, and proton and neutron therapy for nearly 25 years. For proton therapy a 200 MeV proton beam is used. For neutron therapy and radioisotope production a 66 MeV proton beam is available. Low intensity beams of light and heavy ions as well as polarized protons are available for nuclear physics research. Beams are delivered to the different user groups for 24 hours per day and seven days per week. During recent years extensive development work has been carried out on these machines to improve the intensity, quality and variety of the beams for basic and applied research, particle therapy and radioisotope production. The aging systems now require continual upgrading and replacement to limit interruptions to the scheduled beam delivery. The status of the facilities as well as an analysis of beam interruptions and methods taken to improve the reliability of the facility will be presented.

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LHC Cryogenics, the approach towards reliability

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In line with the excellent results of LHC operation so far, the LHC cryogenic system has reached in the last years a level of availability that is surely compatible with first LHC physics program. The LHC cryogenic system - largest worldwide - will be briefly presented with a focus on design parameters and strategy intended to provide a high level of availability for the given specific boundary conditions. The global approach for operation, maintenance and evolution of this system will be described with particular emphasis on how to improve the reliability. Present results including indicators, statistics and tools will be presented with tendency and considered improvements.

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Spare parts and redundancy at TSL - Uppsala University

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The beams from the Gustaf Werner cyclotron at TSL are today mainly used for proton therapy, in collaboration with the hospital, and for irradiation tests of semiconductors and electronic equipment, for industrial users. This situation means that reliability and quality of the delivered beams are of high importance. In this article we discuss how to achieve this. We will look at different strategies for

spare parts and redundancy as well as documentation and knowledge transfer, our chosen strategy in this respect and possible effects on our beam delivery statistics.

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The Automation Paradox

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Automated software and routines aim to replace the human operator manual control. As the Australian Synchrotron increases reliable automation, the paradoxical issue whether automation is a benefit or hindrance has risen.

This paper discusses the ways in which automation may actually magnify problems rather than eliminate them. The more reliable and advanced the automated system is, the less the human operator can contribute to the success of that system. This results in less human operator interaction with the system, and inherently decreases familiarity in the system. Thus, the contribution of the human operator becomes more crucial to the successful operation of the system.

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A Large Scale UPS for the Australian Synchrotron

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At The Australian Synchrotron we routinely deliver around 98% of scheduled beam time to users. As many internal causes of beam loss have been eliminated, the major cause of lost time is now due to beam loss from incoming power disturbances.

A project has been underway for the last 18 months to gain a greater understanding of the failure patterns of different systems of the accelerator and to ensure that an Uninterruptible Power Supply (UPS) will protect the Facility from most external power disturbances.

A large UPS system is being installed at the Australian Synchrotron. This paper will discuss our findings and highlight the factors influencing our decisions and tradeoffs inherent in deciding upon a suitable solution.

Summary:

A large UPS system is being installed at the Australian Synchrotron.

Why is it needed and what benefits do we hope to achieve?

What are the requirements to achieve our goals and what downsides are inevitable for any solution?

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Front End Limitations for High Power, High Intensity Operation in Proton Linacs

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The demand for high power, high intensity and high reliability proton linacs has been driven by a variety of applications from spallation sources to ADSRs. Several machines have recently been commissioned or are currently being designed and built worldwide. Historically, to golden rule of thumb to avoid activation has been to limit the losses to 1W/m. However, the growing requirements for the next generation of proton linacs will make this criterion hard to meet. In this paper, we will discuss essential aspects of the front end design that have to be addressed in modern linacs intended for high power and high reliability operation.

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Operational Experience with PSI High Intensity Proton Accelerator

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The Paul Scherrer Institute operates a 590 MeV high intensity proton accelerator with a beam current of up to 2.4 mA. During the past years an availability of around 90% of the facility was achieved. The high beam power of 1.3 MW demands a careful operation to protect the accelerator complex. We will report on the operational experience with the facility and the measures taken to allow a safe and reliable operation. Procedures of handling beam interruptions due to the failure of components as well as strategies to further improve the reliability of the facility will be discussed.

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What we did right and wrong

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Distributed Software Reliability :

The ESRF is a 3rd generation synchrotron source. It relies extensively on software to function. The ESRF has developed two distributed control system toolkits - TACO and now TANGO, to control the accelerator complex. TANGO has been adopted by at least 9 institutes in the area of synchrotron radiation, laser facilities and experiments. This talk will present what special measure were taken to ensure reliable software in a distributed environment to control and run the ESRF accelerators. It will also present what measures could have been taken but were not taken. Finally it will present how software reliability will be maintained and improved in the future at the ESRF.

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RELIABILITY OF THE FACILITY FOR PROTON THERAPY AT THE HELMHOLTZ-ZENTRUM BERLIN

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Since 1998, the accelerator complex at the Helmholtz-Zentrum Berlin (HZB), the former Hahn-Meitner-Institut, is employed for proton therapy of ocular melanomas. For this reason, an increase of the up-times of the accelerator, which were in the order of about 90 %, was desirable. Up-grades and refinements were made on all sub-systems: sources, injectors, RF systems, power supplies, and vacuum. Over 10 years, the up-time/ availability could be raised from 90 % to more than 95 %.

Until the end of 2006, the use of the accelerator for tumour therapy was only a small part of the overall beam time. Thus, the running of the accelerator for medical purposes was embedded in the operation for solid state physics experiments. The cessation of the physics programme at the end of 2006 had severe consequences: A cooperation contract between the Charité and the HZB assures the continuity of the eye tumour therapy – at the moment still the only facility in Germany – but the boundary conditions changed tremendously. Beam time, and consecutively funds, man-power, and resources were cut-down remarkably. Nevertheless, keeping a high reliability was the fundamental goal. Although major breakdowns, e.g. a water leak in the cyclotron, have a huge impact on the up-time due to the small number of beam time hours, breakdowns over the past years amounted to 5 % or less of the beam time.

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Accelerator control systems reliability at iThemba LABS

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The cyclotrons of the iThemba Laboratory for Accelerator-Based Sciences have been in operation for approximately 25 years, and provide particle beams for basic and applied research, hadron radiotherapy and the production of radioactive isotopes. Over the years the control systems of these accelerators have been continuously developed and adapted to meet operational requirements and the impact of evolving technology. In addition, the control systems of the two old electrostatic accelerators have been computerized and totally refurbished in recent years. The implementation of formal reliability procedures within the design of the iThemba LABS accelerator control systems has never been undertaken. Nevertheless, these systems have of course been developed to deliver reliable accelerated particle beams to the diverse communities of users. Past and present experience of delivering reliable beams by the control systems of these accelerators will be presented, together with some examples of current plans to enhance beam delivery.

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Accelerator Reliability in the Fermilab Complex and Future Plans

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The Fermilab accelerator complex has one of the longest running and reliable machine systems using a variety of accelerator components. This presentation will summarize the current operating effort and highlight details that impact that reliability. Some information will also be presented that help in our planning for future facilities with more intense particle beams.

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Maintainability and customer service operations at IBA

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Throughout the 25 years of IBA's history, the installed base of the company's main accelerator based products (Proton therapy Centres, radioisotope producing cyclotrons as well as sterilization and ionisation e-beam solutions) has known a continuous growth. Indeed, currently, the number of systems is just under the 200 mark, spread over all continents. Moreover, the future looks quite bright thus pushing this barrier further and further. So amidst the continuous mission of being number one in developing high end accelerator based medical and industrial solutions, IBA must also strive to develop robust, reliable and maintainable systems necessary for a sustainable growth. Up to now the activities supposed to enforce these attributes were spread around the organization leading to an enormous amount of uncoordinated efforts that have nevertheless contributed positively to the products quality. On the other hand, it has become quite clear that a coordinated program is necessary to better concentrate the organizations investments. For this reason, a dedicated group named Maintainability has been created to lead the way to highly reliable, robust and maintainable products. More than influencing the development phases of a product the group must also play an important role in improving the installed base through close relations with the Customer Service Operations group whose main goal is customer satisfaction. This group constituted of highly trained personnel in various areas (field engineers, spare parts management, configuration management) equipped with the right tools (CMMS, IBA Store) and clear operating procedures as well as sitting on an efficient back office, is becoming the main focal point for the improvement of the way products are designed to be more reliable and maintainable. A part from their day to day mission they feed the development teams with all their rich experiences from the field. The mission of the maintainability group will thus be to make sure that the right pains are addressed in order to increase the value of our products in the eyes of our clients.