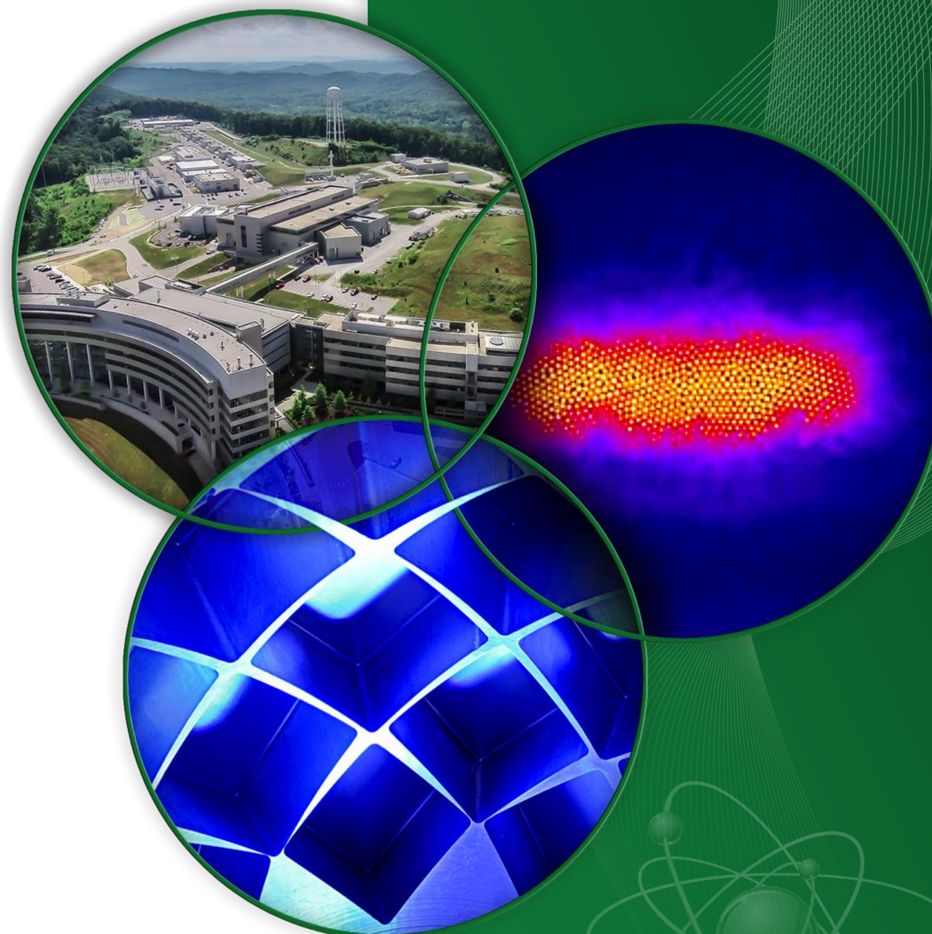
ARW 2015 Workshop Summary

George Dodson

ARW 2015

Workshop Summary



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Oak Ridge National Laboratory | Spallation Neutron Source

On Monday:

- From ALBA, we heard about improvements to
  - water cooling systems, including flow redirection and bubble reduction to eliminate stagnant zones and improve cooling
  - their IOT based RF systems and an unexpectedly high failure rate in the tubes
  - the radiation shielding of their Kickers
- Operational Reliability at the SSRF including:
  - Their operation at 240mA with their fast-feedback system
  - Their Machine Study program which includes
    - Integration of new devices
    - Maintenance
    - Accelerator Physics
  - How they deal with the 840 power supplies
  - Their Real-Time Failure Monitoring System

- There was a formalism for evaluating “New Better than Used”
  - Data were evaluated from failures at the SNS ODH system, including the ODH Sensors and PLC Systems

- We heard about the development of the Beam Loss Diagnostic System at the BEPCII Storage Ring
  - The Beam Trip Diagnostic System was described, which is essential to prevent beam induced damage to accelerator systems.
  - They analyze bunch –by-bunch events failures, e.g. an RF Trip.

- Don showed us the advantages of a FMEA
  - He showed how and to what level faults were analyzed
  - He said that performing the FMEA really helped with buy-in from peers at the group and team level about priorities.
  - This also helped with Obsolescence, Spares and PM issues
  - He offers up the Excel template to anyone who writes to him
- We heard about the refurbishment of cavities and tuners at Fermilab's Booster
  - They are doing an excellent job of keeping the critical Booster up and running, with an expected life of at least 15 years.
  - Must be getting old….

- We saw the LHC Availabilities Study program from the Availability Working Group
  - Difficulties with consolidating fault reporting, many diverse groups with “Old Habits”
  - Accelerator Fault Tracker, very controversial, many ways of showing downtime are “not fair”
  - Properly attributing downtime is very difficult at the LHC, even down to “slow operators”
  - Showed the MPS Cardiogram
- We learned about the IFMIF facility
  - Dual D^+ 40 MeV beams, 20-30 DPA= 1 Full Power Year!
  - They estimate 70% Availability of Full Power (can run with 1 beam only while repairing the other

- Ken showed us a process for good decision making using the Analytical Hierarchy Process (AHP):
  - a multi-criteria decision making (MCDM) methodology used by decision analysts to rank alternatives.
  - Uses pairwise comparison for Showed an example of analysis of 3 maintenance strategies and a scale for ranking the comparisons.
  - I creates a Priority Vector and does Consistency Checking and allows you to rank the Alternatives.

- We heard about automated data taking and retrieval developed by Operations at the SNS
  - Intelligent Data Logging facilitates in-depth analysis in support:
    - Understand Failure Mechanisms, Failure Rates to proactively schedule Preventative Maintenance
    - Understanding the interdependence of one sub-system to another

- Annika gave a presentation and led a discussion on fault studies and predictions at the ESS
  - She showed a long list of Failure Analysis methodologies
  - Showed STPA-System Theoretic Process Analysis
    - KISS

On Tuesday:

- We heard about the ESS approach to Availability Reliability
  - A 5MW, 2GeV, 2.86mS, 14Hz, Rotating W Target machine with a 1.8B €
  - First neutrons 2019, first users 2023, complete 2025
  - Neutron beam requirements driven by user requirements
    - Kinetic: 90% Failure is Beam trip with a duration of more than 1/10th of the measurement length
    - Integrated Flux:90% and 80% average beam power for the duration of the experiments Failure is Beam unavailable: power less than 50% for more than one minute
  - Trip Duration vs. Number of Trips allocation table led to Requirements Allocation table
  - RAMI analysis – FMEA as input to ReliaSoft Block Simulation

The ITER Interlock System, Main Sources of Risk

- Magnets, 10 G Joule, the energy stored in the CERN LHC magnet system. Sufficient to heat up and melt 12 tons of Copper – Can only survive a small number of trips
- Plasma Heating System
- Solution- Central Interlock System
  - Interlock Hierarchy
    - 1. Slow & Medium Complexity PLC
    - 2. Fast & Medium Complexity → FPGA
    - 3. Slow/Fast & Low Complexity → Current loops
    - 4. Slow/Fast & High Complexity → R&D going on (tbc)
  - Showed Prototypes and Test Platforms, many countries involved
- An eclectic collection of actions.
- The not-so-safe fail safe states
- Interlock Dependability Analysis
- Design Complete Mar 2016

HL-LHC Performance and Availability

- 250-300 fb-1 per year (400 for ultimate parameters) • 3000 fb-1 over about 10 years of operation •
- The total integrated luminosity produced by the LHC in 2010-2012 is around 30 fb-1 •
- First accelerator with an explicit integrated luminosity goal

- Performance
  - Intensity is X2, Peal Luminosity with Crab is X 19
  - Levelled Luminosity is 5E 34
  - 5.5 Hours turnaround (average)
  - Machine Failure Rate (MFR) = fraction of premature dumps = 70 %
  - Monte Carlo model for integrated luminosity estimates
  - Used MC to optimize stable beam performance!

Reliability and Fault-Tolerance Strategy in the MYRRHA Superconducting Linac

- ADS-ATW-Energy Amplifier - 600 MeV, 0.1-4.0mA
- Big Challenge: less than 10 beam trips > 2 sec in 3 mos!
- Solution:
  - Robust design i.e. robust optics, simplicity, low thermal stress, operation margins…
  - Redundancy (serial where possible, or parallel) to be able to tolerate/mitigate failures
  - Reparability (on-line where possible) and efficient maintenance schemes
- Design - Dual Injectors ,4 Rod RFQ ,DTL, SCL
- Rely on FAST Recovery-Retune-Compensation

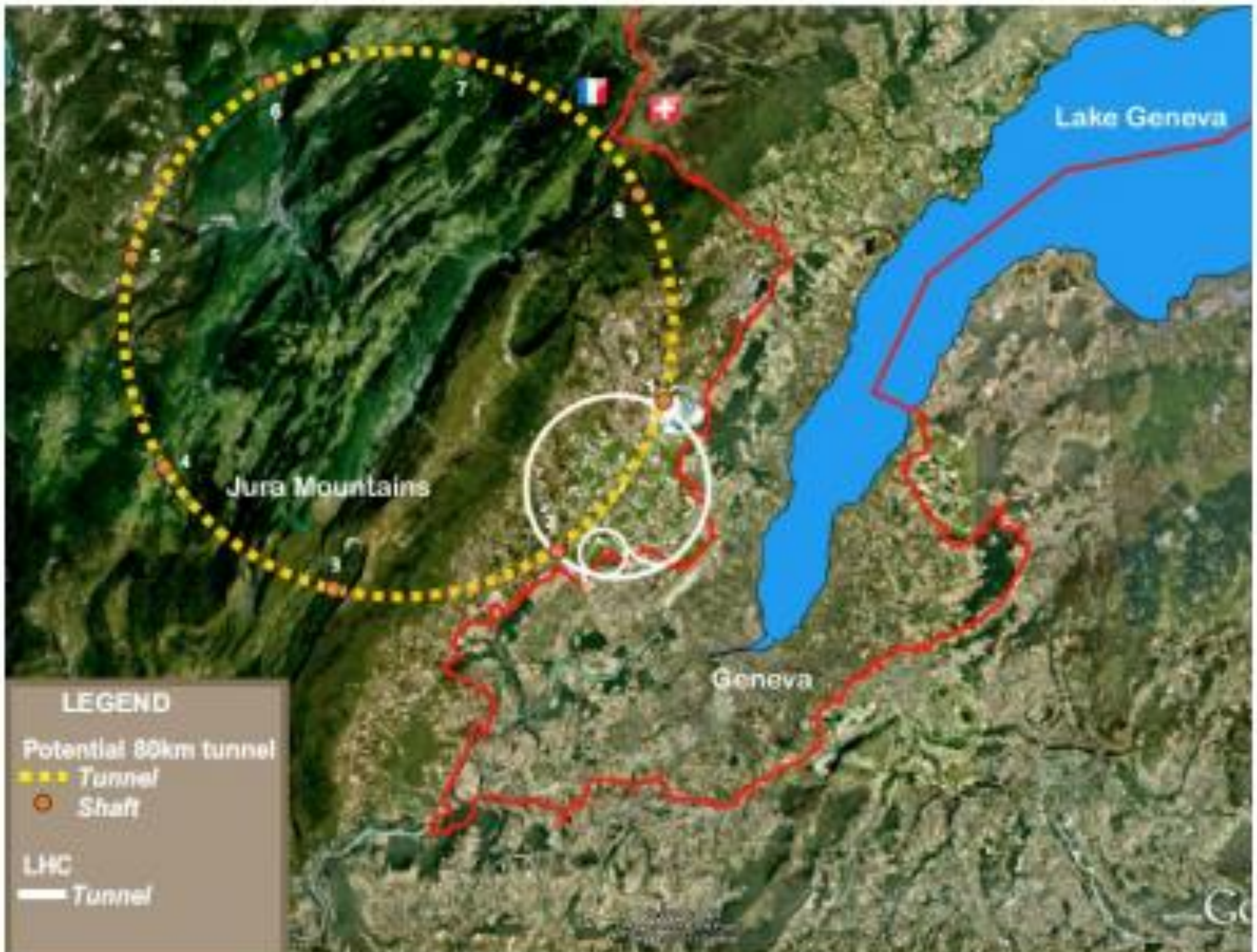
- **Using Quality Design and Build Practices at TRIUMF**
- Dependencies between Reliability and Quality
  - Design Requirements
  - Quality Requirements
  - Radiation Requirements
    - Use the Radiation Index (RI)
    - Keep equipment out of harm's way
    - Safety Factors and Redundancy
    - Ease of Installation and Repair
    - Easy to Identify Services
    - Blocking other Equipment
    - Standardization of Parts – the good and the bad
    - Cleaning
    - Alignment

Reliability of a Future Circular Collider – The FCC

- FCC-hh: 100 TeV pp collider
- FCC-ee: e +e - collider, potential intermediate step FCC-he: integration aspects of pe collisions ambitious post-LHC accelerator
- 16 Tesla magnets for 100 TeV pp in 100 km
- Phase 1 (baseline): 5 E34 cm-2s -1 (peak), 250 fb-1 /year (averaged)
- Phase 2 (ultimate): ~2.5 E35 cm-2s -1 (peak), 1000 fb-1 /year (averaged)
- FCC-hh = 4xLHC in terms of equipment

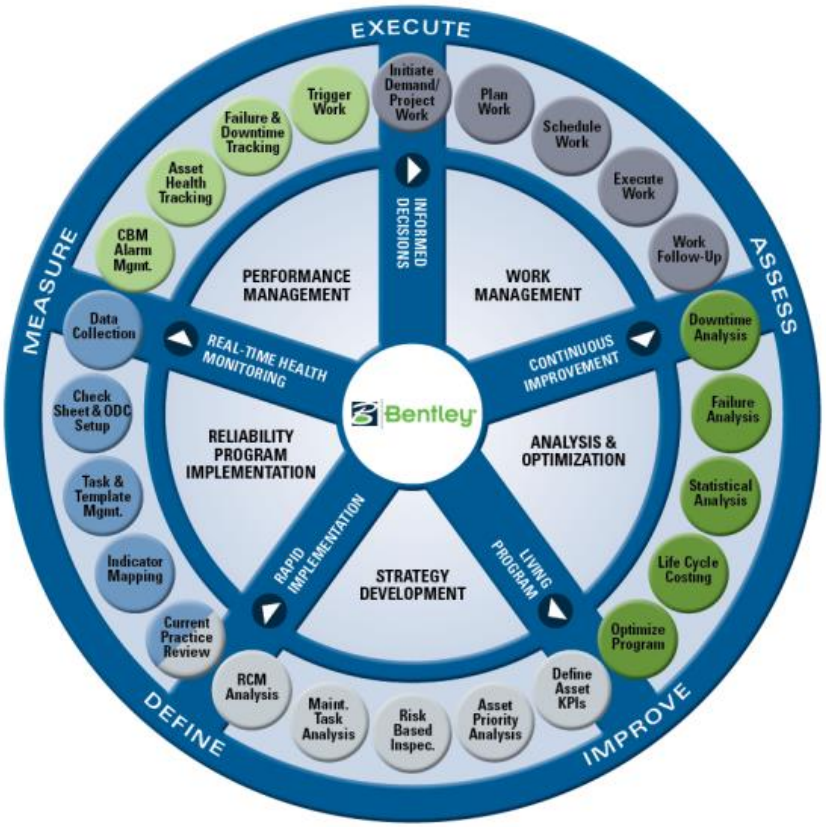
- Assess if and how industrial RAMS methods can be used for the FCC
  - Modeling an existing accelerator will tell if the methods are applicable

So you thought that the LHC was BIG!



Option 1: 80km Jura

- We heard from Bentley Systems about: A Strategic Asset Management Plan
- Asset Performance Management in nine steps:



They sell software that supports Asset Performance Management to meet the new DOE Asset Management requirements.

Nuclear Power Reactors – An Example of Improvements in Reliability and Potential for Improvement

- 100 Commercial Nuclear Power Reactors in the U.S, 5 under construction
- Downtime for refueling down by X2 and 5GW added due to uprating reactor power limits since 1990.
- SCRAMS and Unplanned Capability loss more or less constant since 1990
- Reliability focus has been on Fuel Reliability, showed failure modes and areas of focus.
- Talked about the CASL collaboration and the future of commercial nuclear power.

Radiation Tolerant Power Converter Design for the LHC

- 1700 total Power Converters, 1050 in Rad Areas, Mixed-Field radiation composed of n, p, pi+, pi
- In 2012 run 35 beam dumps due to power converters. In HL-LHC would expect 90-190! Need new rad-tolerant controllers
- Have 2.3 E6 Components, No Rad-Hard ASICs, FPGA-based for flexibility, based on COTS (cost)
- Showed a **Standard** and a **Rad Tolerant** Design Flow including a Component Selection Process and a Radiation Risk Classification matrix
- Discussed the complications of COTS procurements, (tracking and testing). Had to build testing infrastructure.
- Offered process tips on system specifications.

LIPAc Control Systems

- Accelerator facility validation at Rokkasho.
  - Have an Integrated Team (Japan-Europe) for”
    - Design Verification, Installation coordination & QA, Commissioning, Operation and Systems maintenance.
- Showed an overview of LIPAc Control Systems
    - Modular design, following the architecture of the whole LIPAc
    - Based on EPICS and CSS for software applications (OPI, archiving, alarms…)
    - 20,000 process variables managed globally
    - MPS fastest response (beam shutdown, hardwired loop) of around 20us

The Impact of Machine Protection on Accelerator Reliability and Beam Availability

- Showed a number of pictures of MPS Architectures
- Advocated the use of an e-log based fault-event post mortem
- Discussed the relationship between reliability and availability in Storage Rings vs. Linacs
- Advocated a Rigorous analysis of fault events
- Predicted unexpected faults e.g. UFOs at LHC and Integrated losses at SNS
- Advocates redundancy and simplicity of design

Vacuum System Reliability Illustrated with LHC

1. Study, Design, Procurement & Installation
2. Design study-199, Conceptual Dedsign-1995, Design project-2004 -- Defining and understanding the machine parameters impacting the vacuum system was a crucial part of the project
    1. Expertise: Intersecting Storage Rings
    2. More Expertise: Large Electron Positron Collider
    3. LHC Design Value : a Challenge with p Beams
        1. LHC Dipole Vacuum System, New Beam Screens, NEGs
        2. Base Line Validation, Quality Assurance Plan, Acceptance Tests, Installation and Quality Control
3. Operation
    1. Vacuum Monitoring – Stand-By,
    2. Follow-Up, Pressure, Checking Design, Expertise, Performance with Beams
4. Repairs, Consolidation & Upgrade
    1. Fast Intervention
    2. Repair of Non-Conformities
    3. Pumping System Consolidation
    4. Upgrade to HL-LHC

Operation Reliability of J-PARC Main Ring

1. Reliability review of J-PARC
    1. User availability
2. The long beam stop
    1. 1. Megaquake 286 days to recover
        1. Deformation of linac, ring and beamlines
    2. 2. Radiation Accident at Hadron Hall 686 days to recover
    3. 3. Fire in the 2nd experimental hall in of MLF (Meson and Life science Facility) 35 days to recover

LIPAc Grounding Network

1. **Goal:** Availability of the Facility >70%

2. **Steady State Electrical Network**: About 3.5 MVA continuous power Main consumers: • Cooling water system • Radio Frequency chains, HEBT, Cryoplant • Building services

3. **Pulsed Power Electrical Network**: About 6 MVA peak pulse Main consumers: • Radio Frequency

4. **Two independent grounding networks** were installed The two grounding networks were unified possibly because of misunderstanding of the TN-S distribution system not frequent in Japan. No specific EMC recommendations were observed

5. Ion source and LEBT under commissioning on p+ on-going Ion source and power supplies cooling skids are running RF power system (RFQ, MEBT and SRF Linac) starting June 2015

6. The grounding network at Lipac will be updated to include EMC **considerations The lack of an own EMC guideline makes it the usual excuse to explain faults, downtime and signal distortion** However, simple solutions can still be implemented to protect the electronics against the observed EMI issues

Automatic Phasing of SCRF Cavities

1. The Isotope Separator and Accelerator (ISAC) is an ISOL Facility at TRIUMF. It is a 480 MeV proton beam, proton currents of up to 100 µA (dictated by upper limit of license)
2. Beam accelerated to 150 keV/u in a RFQ then injected into the Superconducting Linac at the full DTL energy (1.5 MeV/u). The SCL has 40 cavities with betas from 0.057 to 0.110 with individual phase and amplitude control. Setup is from 8 to 16 Hours
3. **A failed cavity results in:**
    1. Option 1: Reduce the cavity amplitude to 90.6% its initial value, and adjust the cavity phase from -25˚ to 0˚. Downtime = 0.5 hours.
    2. Option 2: Re-tune the Linac from the failed cavity on. Downtime = 4 – 24(+) hours.
4. The Linac phasing program logs cavity phases, amplitudes, and energies. Created a Re-Phase program calculates new phase setpoints. Tested with a 16O4+ beam, 17 cavities energy of 4.50 MeV/u with 100% transmission. The 6th cavity was turned off. The Re-Phase program produced a 4.41 MeV/u. beam with 95% transmission.

UPGRADING THE OPERATIONAL HYDROGEN GAS MANAGEMENT FOR SNS TARGET MODERATOR

1. The need to upgrade started with a request from the operations team to change a process variable for better pressure control while charging the moderator with hydrogen.

2. Goal: Make a better system.

3. Considerations: Safety approved operational system.

4. Task: Duplicate operational parameters that is conducive to maintainability.

5. Modified:
    1. Hydrogen gas supply "system"
    2. the warm helium compressor, and the 120VAC voltage supply
    3. The exhaust safety fan system
    4. Commutations main interface
    5. Cleaned up and replaced the ageing and mixed hardware.
    6. Simplified control network architecture
    7. Improved/simplified operations EPICS screens

LHC 1st shutdown

1. Take all measures for a safe and reliable operation of LHC @ 6.5TeV
    1. Consolidate superconducting magnets and circuits
    2. Relocate radiation sensitive electronics **R2E**
    3. Perform full maintenance of all equipment
    4. Consolidate and upgrade the equipment
2. R2E: Radiation to Electronics
    1. Relocate and protect the SEE sensitive equipment
    2. More than 100 racks relocated, Additional shielding
3. LS1 phases
    1. LS1 Scoping phase
    2. Preparation phase
    3. Implementation phase
        1. **IMPACT system • Intervention Management Planning And Coordination Tool • Mandatory for any intervention at CERN**
    4. Closure phase

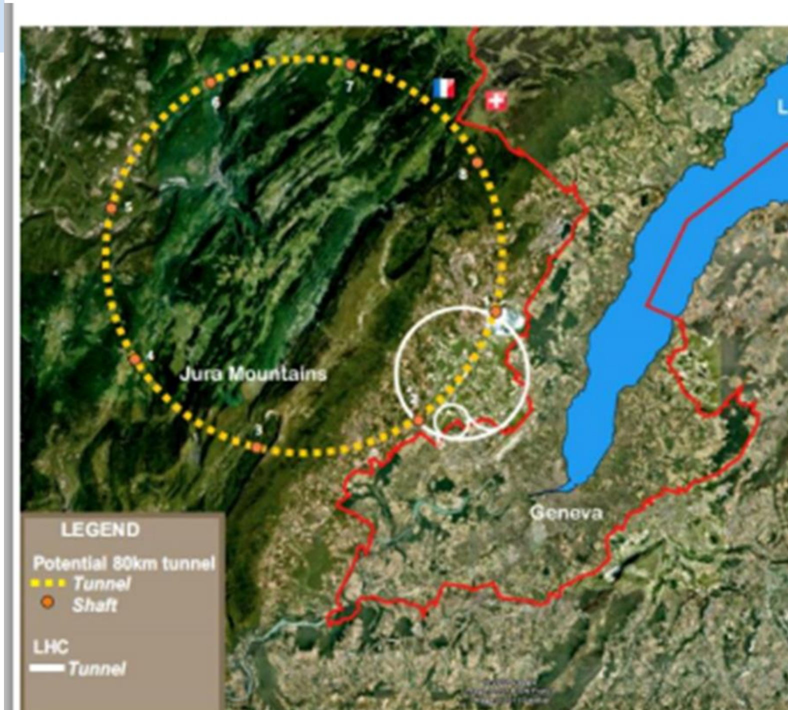
Scheduling and Tracing of Maintenance Tasks in Long Shutdowns at GSI

1. Issues:
   1. maintenance of legacy machines
   2. beginning civil construction for FAIR
   3. Reliability 2012 – 75%, 2014 - 70%
2. Breakdown statistics shown by system
3. 4 maintenance periods per anno (duration: min. 2 weeks) Shutdown Coordination
   1. preparation phase - Offline-MS Project plan
   2. weekly Shutdown Meeting
   3. Use for the Major Shutdown
      1. min.1.5 years of UNILAC shutdown starting in 2016
      2. min. 2.5 years of SIS18/ESR shutdown since 2014
      3. factor of 50 more tasks (10000) ? unmanageable dependencies? never-ending shutdown meetings?

Evolution of Maintenance for RHIC

1. Showed the evolution of CAD from Cosmotron to RHIC
2. 2007-present MSG Role
    1. Work Planning, Scheduling.
    2. Scheduled periodic Maintenance. • All work on all systems documented, scheduled, tracked.
    3. Shutdowns treated similar to Maintenance Days.
    4. Project Management.
    5. Commissioning Management.
    6. Major failure, unscheduled maintenance coordination.
    7. Coordinate job closeout, resolution and return to operation.
    8. Formalized hand over for Operations.
3. Showed RHIC Availability/Luminosity Improvement plot 2008-1015

Oh how we have changed!



John Osborne (CERN-GS)

ARW April 28 2015

Option 1: 80k

Reliability of the accelerator facilities at iThemba LABS

6 accelerators, 4 Cyclotrons, 1 Tandem, 1 Van deGraaff. Old infrastructure. Mission is Nuclear Physics, Neutron Therapy, Proton Therapy NS Isotope Production (and changing the machine energy)

(2008 to 2014)-(81 to 86)% Availability

Serious AC delivery problems.. led to purchase of 4MW UPS

(2009 to 2014)-(20-34) power dips that even the UPS couldn't handle

Batteries were initially replaced by maintenance free gel batteries. These batteries only lasted 4 years. Alternative to the UPS Diesel generator and flywheel system R56M

Replacing Cooling Towers and Chillers (new chillers use less power!)

RF interruptions, largely problems with the two SSC RF amplifiers building new spare amplifiers for the SSC and SPC1.

New Digital Low Level RF Control System and EPICS controls help with the RF

Showed Neutron Therapy statistics.

The Clinical Medical Physicist's Perspective on Designing a Proton Therapy System

Showed:

- Incorrect Operational Approaches / Paradigms
- "Fail Safe" thinking
- Learning From the Airline Industry
- The Radiation Therapy Reality
- Challenge - Design a traffic light
- Control systems are in Full control – Why not ?
- Limiting Capabilities improve safety
- Slowing things down improve safety
- More Checks are More Safe ?
- New Thinking - FMEA must be done with the emphasis on completing a treatment
- Use cases
- Down-Time tracking / Management
- Downtime Duration vs Frequency
- Desired Uptime
- Conclusions

A Reliability Retrospective

1. Why does reliability matter? Unreliability contributes to human misery
   1. Showed treatment cancellations vs. Reliability
   2. Comparison with Research Facilities
   3. IBA's Proton Therapy Solutions
   4. Reliability Retrospective
   5. Extended loss of availability in 2014
   6. Our Continuous Improvement Program
   7. Sources of data
   8. Specific Examples
   9. Where are we going in the future?

A Medical Device Manufacturer's Perspective of an Accelerator Laboratory

1. What is Pro Nova Solutions?
2. Mission and Vision for More Than 40 Provision Center for Proton Therapy – 65 patients/day
3. SC360 Efficient 1, 2, 3 + Room Solution
4. Superconducting Magnet Production/Mounting on Gantry/in Achromat
5. ProNova R&D and Manufacturing Facility/Manufacturing Facility
6. Medical Device Manufacturer Drivers
7. Servicing and Reliability Factors
8. Regulatory Compliance CFR
9. Verification and Validation for First Device
10. Airliner = Proton Therapy System?
11. Tools - Jazz CCM/RM/QM/Doors (IBM Product – Change Management)

Water Cooling System Upgrades, Successes, and Lessons Learned From The Los Alamos Neutron Science Center

Target 1 water systems upgrades and lessons learned

LINAC water systems upgrades and lessons learned

Target 4 water systems upgrades and lessons learned

Visualizing Tunes

Two on-line target stations, one off-line • 17 experiments • 15 separate beam paths, Roughly one setup per 10 days (usually with differentA/q's

We're particularly concerned with incorrectly set beamline optics values. Transport sections make up most of our beam paths.

Matching sections allow us to shape the beam for optimal transmission through transport sections for low loss. Tunes can be scaled from one A/q to the next

Created TuneDisplay to generate a visual representation of the tune & its overall quality & steering. Computes theory values for quads & compares them to current values.

Planned Developments:

- #0 Fix bugs
- #1 Elegant element name display
- #2 Superimpose cup readings
- #3 Tie-in with ISAC ops beam envelope calculator

Availability Challenges and Solutions Associated with the High Voltage Converter Modulator at the Spallation Neutron Source

- Provides up to 135 kV, 1.35 ms pulses at 60 Hz to amplify RF up to 5 MW

•Designed and procured by LANL, Build-to-print on modulator, Subsystems installed, integrated, and tested at ORNL. Installation November 2002 – April2 005

Operation currently at 60 Hz (began April 2008 at 200 khours total) with varying duty cycles •Full 1.4 MW of beam delivery demonstrated with ~2 years of operation at that setpoint

HVCM Fire Causes –

1. Bus Arcing was an early failure mechanism
2. Capacitors failures were quite catastrophic and identified low MTBF component
3. IGBT failures created serious challenges and “false alarms”, revealed over voltage problem and workmanship concerns

Parallel Session: Communication after the Workshop

We agreed to make another attempt to start an accelerator reliability forum hosted on Confluence, a web based forum software that is purchase under license. Anita and Henrique will set up a forum site from their CERN site, use 2 other ARW members to provide feedback and then open a limited email list contributors availability to about 20 people so as to add content and check for interest and ease of use. Julian and Kenneth with keep this first stage driving forward and inform you of progress. We hope to offer a starting point within 3 months.

Parallel Sessions: Open Software Control Systems and FPGA

- Open *software* is also template for open-*hardware* (www.ohwr.org)
- And this in itself leads to open programmable logic development (FPGAs)
- Collaborative approaches look ultimately inevitable… and could mean:
  - more eyes looking over a problem
  - better chances of mistakes being found = **higher reliability**
  - at the same time it needs **strong ownership** to avoid divergence

ARW Human Performance Open Discussion.

A question was posed to the group: what was the threshold to classify a failure as human error?

It was interesting to note one laboratory avoided the use of "human error" in their downtime failure classification.

In general the attendees agreed that a mistake that stops the beam was a threshold for classifying a fault as human error. Delays in making repairs due to mistakes or faulty knowledge was attributed to the group that services the equipment.

A good portion of the discussion was centered on the plight of the manager in dealing with human error in way that encourages workers to learn, without confrontation, from their mistakes.

Dissolved Gas-in-Oil Analysis for Preventative Maintenance of the Los Alamos Neutron Science Center (LANSCE) High Voltage Systems

- Life of a transformer
  - Failure of paper insulator, heat, O2, moisture, oxidation products
- Quantitative and Qualitative Gas Analysis
- IEEE standard for dissolved gasses in oil
- Quantitative Analysis
- Qualitative Analysis
- Rate of Rise Analysis
- Moisture Analysis
- Mitigation with filtering, reducing air/oil leaks

ISIS Main Ring Dipole Coil Failures

- Replacement for one of the four tanks in the 70 MeV DTL • Redesigned in 6 x 2m sections • Copper plated steel
- Concrete Magnets, Epoxy is damaged by radiation • The "normal" solution is to use Mineral Insulated Conductor • MIC is expensive, hard to get hold of and difficult to work with. Solution was "cast in concrete"
- Ceramics, cheaper to buy new…
- Dipole Coils
  - 20 x Dipole Coils in the Ring • Current varies from 269 to 1067 A on a 50 Hz Sine wave • 14.7 kV rms (max Vpp in coil = 16.5 kV) • ~4.5 m long
  - Constructed using a Mica / Glass tape then vacuum impregnated in 1980s
  - Failures in 2002, March 2003 and October 2004
  - New coils made without Mica
  - First new coil fails in Nov 2013
  - MTBF Original Coils ~ 10,000 Hours • MTBF New Coils ~ 2,000 Hours
  - 10 out of 17 failures happen during start-up (not in cycle)
  - • Procuring more coils – delivery due soon
  - Investigating difference in insulation designs / systems using PD measurements to get a better understanding and confidence Running ISIS accelerator in a mode to reduce electrical stress to coils

MEBT Water to Vacuum Leak at the SNS

- Accelerator off for unplanned target change • Routine maintenance and RF conditioning in progress
- Alarms rang in, water found leaking OUT OF MEBT
- Careful hazard assessment and development of an energy control and LO/TO plan to mitigate the hazard
- MEBT Chopper Target Failure, Front plate: TZM (molybdenum alloyed with titanium and zirconium) • with 0.5 mm water-cooling micro channels
- Vacuumed out as much water as possible • Took off vacuum pumps at bottom of beampipe • Disassembled entire beam line except for rebuncher cavities to remove water from inaccessible bellows, o-rings, etc. • Vacuum baked all equipment to be put back in
- Dewatered Rebunchers
- Down from September 15-October 17
- Lessons Learned • Remove legacy equipment from beamline • Keep drawings up to date, make drawings if you don't have them, capture knowledge • Interlock for water cooled devices inside beam line •

Trend Analysis Software.

- Over 110,000 Process Variables (PV's) are Archived
- Just looking at Storage Ring Temperatures, as an example. • Approx. 1300 temperature pvs are Archived. Using Archive viewer to examine 1300 PVs is impractical.
- Trend Analysis Software:
- Provide early indication/warning of potential problems.
  - Read archive data on weekly basis
  - Beam conditions tend to change weekly.
  - Provide indication of: • Rising / Falling trends, • 'Out of character' data. • Requests most recent 250 data points per pv. • Number actually returned depends on archiving method •
  - Takes ~30s to retrieve data for ~300 pvs. • Written in python.
- Clicking on an Indicator opens Archive data for that one PV
- Mouseover Left Indicator Shows % Change of linear fit, Right Indicator Shows % Spread in data
- High Density Display, not always as obvious

Reliability concerns with the SNS Machine Protection System

Leading causes of reliability issues at SNS

1. False trips
2. Excessive trip delays
   A. Hardware modifications did not match approved architecture
3. Fail to deliver fault status
   A. Firmware implementation did not match the architecture approved by the review committee
4. Additional reliability issues at SNS listed
5. Methods for improving system reliability
6. Modernization is imperative to achieve high reliability and maintainability
7. Proposed Architecture Achieves a Significant Reduction in Hardware

SNS 2nd Generation System

Loads of improvements, COTS, Standardization etc….

System Downtime Management at 12 GeV CEBAF

- Gather statistics, analyze **(Make the machine run better)**
- From the analysis, allocate resources and investigate changes in equipment maintenance, selection, or design
- Upgrade components to improve individual systems availability, influencing overall accelerator availability**.**
- Beam Time Accounting is tracked for the accelerator program and delivered beam time; CEBAF 'Timesheet.'
- System Downtime is tracked for any system failure
- Accelerator Operability: Tracking System
  - initial data entered by Operators; ~75% of entries required review and correction.
  - Improved System Downtime Tracking process:
- Improved System Downtime Tracking process:
  - Align information with model database (CED)
  - Develop web database interface (input, management, and reporting)
  - Develop System Downtime Guidance document
  - Train Accelerator Operators, System Owners