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JEFFERSON LABORATORY: MAINTENANCE OVERVIEW

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Abstract

Maintenance, repair, and upgrades to the Thomas Jefferson National Accelerator Facility, a DOE laboratory located in Newport News, VA, USA, is based upon a two week run cycle followed by a one shift maintenance period. The rationale for this approach will be presented including a brief look at the maintenance funding, support staff, and beam availability. Means for improving the machine will be presented including record keeping of downtime, compilation of data, dissemination of findings, and allocation of resources. Maintenance problems facing Jefferson Lab will be presented.

INTRODUCTION

Jefferson Lab is the Department of Energy's new national laboratory for nuclear physics located in Newport News, VA, USA. As a facility used by scientists worldwide, its primary mission is to conduct basic research that builds a comprehensive understanding of the atom's nucleus. Using a 200 μA, 4 GeV CW electron beam, powered by superconducting radio frequency cavities at 2 Kelvin, Jefferson Lab is able to study the subnuclear realm, revealing for the first time how quarks make up protons, neutrons, and the nucleus itself.

Jefferson Lab represents a $600 million investment, and has an operating budget from the DOE of approximately $70 million per year. Table 1 shows the yearly profile of beam goals, budget, and staffing for both the laboratory and the Accelerator Operations Department.

The DOE contract with Jefferson Lab is performance based, and future funding is closely tied to the ability to perform to the expectations of the physics community. As a result, machine availability and maintenance activities[1] are closely linked and receive considerable attention labwide.

Table 1. Funding, Staff, Machine Operation Hours, Availability

	FY '96	FY '97	FY '98 (Q1, Q2)	FY '99 (projected)
TJNAF Budget	$67 M	$68 M	$69 M	$71 M
Operations Budget	$10 M	$9.7 M	$9.3 M	$10.2 M
TJNAF Staff	525	541	532	524
Operations Staff	98	99	108	103
Availability Goal	55%	72%	73%	80%
Actual	65%	68%	68%	---

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[1] Maintenance, as used in this paper, refers to any task performed to improve a system or component. This would include both repairs and upgrades.

MAJOR SYSTEMS AT JEFFERSON LAB

The following briefly describes the major systems of the Jefferson Lab accelerator:
Plant: Tunnel 1.4 km long, 10 m underground, 40 MW site power, LCW 1 MΩ - 400,000 liters.
Beamline: 7 km at 10^{-6} to 10^{-13} torr.
Electron Sources: Thermionic cathode, Photocathode for polarized electrons.
Acceleration: 42 Cryomodules. Eight 5-cell superconducting Niobium cavities each.
Cryogenics: 2 K Helium Refrig. Plant, 80,000 liquid liters, 200 grams/sec.
RF: 338 5 kW klystrons each with independent controls.
Beam Transport: ~ 2000 room temperature magnets.
Diagnostics: ~ 800 beam position monitors, current and profile monitors, viewers, etc.
Controls: EPICS based. 100,000 I/O points with 80 IOC's. CAMAC and VME.

MAINTENANCE HISTORY AT JEFFERSON LAB

Early commissioning at Jefferson Lab, then known as CEBAF, began in parallel with ongoing installation activities in the balance of the accelerator (1991). Our philosophy was "run it until it breaks," and we were often in the repair mode. Furthermore, machine reproducibility was always in question due to the lack of adequate setup and operating procedures. We kept a Standby Task List for maintenance and installation activities and brought in support staff whenever the opportunity for repair arose. This approach, due to the newness of the machine and high failure frequency, was very demanding on the support staff and showed little promise for improving machine performance.

Two things were clear. First, procedures for repair, setup, and operation of the machine were critical to the success of the lab. Second, the accelerator systems needed to be able to run without significant problems for longer duration. In 1994, it was decided that a two-week cycle would be adopted for planned maintenance activities. This change gave the system owners and maintenance groups a goal to shoot for: two weeks of running with minimal interruptions.

Jefferson Lab continues to operate on a two-week maintenance cycle. In addition, there are two significant shutdowns per year: January (4 weeks) and July (1 week) that are used for major upgrades, safety system certifications, and routine tasks. The shutdowns are arranged so that they follow lab holidays to allow for additional radiation decay time prior to work taking place.

Jefferson Lab has been successful in keeping the post-maintenance recovery time to a minimum. Demonstrating fast recovery has been critical for defending the planned maintenance approach. For example, following last January's month long shutdown, beam was re-established and ready for accelerator physics studies nine hours after starting back up. Recovery after a typical maintenance day can extend to between four and eight hours. This time includes hot checkout of systems to ensure readiness prior to beam operations. Often there is a period of machine development following a maintenance day. This time is spent studying new optics or performing accelerator tests that use the beam as a diagnostic tool.

The two-week maintenance cycle approach has made a significant improvement to the way we do business, but it is by no means ideal. Recent discussions with the support groups have led to plans for changing the maintenance schedule to longer, less frequent maintenance periods beginning in July 1998. Specifically, three days per month will be designated for repairs, upgrades, and testing. Also, every month there will be dedicated time for software development and testing. Decoupled from the maintenance days, software testing should be more efficient and make machine recovery easier.

JEFFERSON LAB MAINTENANCE

Maintenance of any facility depends on being able to identify the item in need of attention, document the situation, assign a priority to the item, track trends, and have the support staff necessary to perform the maintenance. Jefferson Lab recognizes the benefit of early detection and intervention before a problem significantly impacts machine operation[2].

Diagnostic Tools, Documentation Resources, Notification, Time Accounting

The diagnostic tools for monitoring the health of the Jefferson Lab accelerator range from simple warning lights and operator 'walk-arounds' to sophisticated programs that can regularly check system status. EPICS includes an alarm handler that warns the operators whenever a component goes out of regulation. Examples include magnet current, site power, and computer memory. Next, the Machine Protection System automatically turns off the machine when there is beam loss or RF problems. CHIME, a configurable alarm and control program, is used to alert the operator if a record being monitored strays from a desired value. A time plot program, Striptool, is widely used to watch short-term trends.

Documenting machine status is critical to the flow of information when problems arise. Jefferson Lab's documentation ranges from electronic, web based logs (Elogs) to hand written logs for access control. Other documentation resources available to support staff include an EPICS archiver that makes an automatic entry every 6 minutes for off-line analysis and a tool which logs machine status changes.

Jefferson Lab began using electronic logbooks in 1996. This provides for screen capture, search engines, web access, and improved legibility. Information is easily entered and quickly accessed. A notification program, CATER[3], is used to inform support groups of problems.

Two major tools are in use for time accounting at Jefferson Lab: DTL (Downtime Log) and BOOM (Beam Operations Objective Monitor). Together they are the accounting tools needed to: 1) document sources of lost accelerator time, and 2) accurately collect beam delivery statistics used to compile performance metrics for Jefferson Lab's DOE contract. A third tool for tracking subsystem component failure rates is in use by Jefferson Lab's support groups[4].

DTL is a powerful tool for improving accelerator availability. Operations staff make entries whenever a problem occurs which affects the machine for more than 5 minutes. The DTL entry (made from a pull down menu or an electronic template) includes the date; time of failure, restoration, and resumption of operation; system information; and a description of the problem.

There is on-line access to the DTL database and it is emailed to interested parties once per day. From the email, the entries can be ported into an Excel spreadsheet and used for tracking trends, identifying major problems, recommending improvements, and justifying budgets. Pareto charts are used extensively to focus attention on areas of concern and summaries are provided via oral presentations and email.

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[2] A full description of Jefferson Lab's maintenance can be found in the *Accelerator Operations Directives*, available upon request from the author.

[3] CATER (Computer Aided Tracking and Error Reporting) was developed at SLAC and is VMS based. Jefferson Lab will be replacing CATER in 1998.

[4] B. Cumbia and M. Memory, WAO '98 Poster, "Using ACCESS to Aid in Problem Solving".

Maintenance Support Groups

The ability to identify and respond to maintenance problems falls first to a well-trained operations staff[5]. At Jefferson Lab, the operators replace simple components, update documentation, assist support groups, and perform radiological control functions.

Hardware problems are dealt with by the AES[6] group, a shop of 25 highly skilled, cross trained individuals who maintain all RF, magnets, vacuum, diagnostic, and most control network equipment. They are on site two shifts per day (weekdays). All support groups (AES, Software[7], Safety, Cryogenics, Radiation Control, Plant) are on call 24 hours per day. All groups are represented on site after major shutdowns to assist in recovery. In the event a problem takes longer that two hours to solve, system experts are called in to assist. Repair Escalation Reports are written after most significant problems occur and are distributed to a broad audience to foster discussion and improvements.

Planning

Jefferson Lab holds a daily morning meeting to review the previous 24 hours. Problems are discussed and plans for repairs (if needed) are made. Once a week, a maintenance-planning meeting is held to review machine performance and proposed maintenance tasks. Long-range planning for major shutdowns is centered on improving machine availability, implementing machine upgrades, and scheduling considerations (resources, safety certifications, and tours).

Maintenance Problems at Jefferson Lab

The major problems facing the Jefferson Lab maintenance system are as follows: obtaining adequate funding for spare parts; dedicating resources for documentation, procedures, and training; providing adequate recovery, machine study, and software development time; and balancing the conflicting goals of machine stability and machine upgrades. This final issue, machine upgrades, will continue well into the next century as Jefferson Lab makes plans for energy upgrades from 4 GeV to 24 GeV by 2016.

Conclusion

Jefferson Lab continues to strive to reach the aggressive availability numbers in their DOE contract while balancing an ever changing machine configuration. By utilizing tools for problem diagnosis and by evaluating trends based on actual lost time, the operations staff and support groups are able to maintain and improve the accelerator at Jefferson Lab.

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[5] M. Spata, WAO'98 Poster, "Training at TJNAF".

[6] Accelerator Electronics Support.

[7] See K. S. White, H. Areti, O. Garza "Control System Reliability at Jefferson Lab", ICALEPCS Proceedings, November 1997.