AVAILABILITY RESULTS FOR THE LANSCE ACCELERATOR COMPLEX

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Abstract

The results of an analysis of operations data from the 1996 run-cycle of the LANSCE accelerator complex will be presented. Frequency and history of operational events including system and component failures which affect beam availability have been tracked. Some of the significant downtime incidents will be described and analyzed in detail. These results will be used to improve future operations and beam availability.

1 INTRODUCTION

The Los Alamos Neutron Science Center (LANSCE) accelerator complex (formerly known as LAMPF) consists of an 800-MeV linear accelerator, a proton storage ring (PSR), and a variety of production targets and experimental areas. Two beams are presently accelerated simultaneously on alternating cycles of the rf.

The linear accelerator consists of two 0.75-MeV Cockroft-Walton injectors, one supplying H^+ ions while the other supplies H^- ions, a separate low-energy beam transport (LEBT) line for each beam species, a 0.75 to 100-MeV drift-tube linac (DTL) operating at 201.25 MHz, a 100-MeV transition region (TR), and a 100 to 800-MeV side-coupled linac (SCL) operating at 805 MHz. Peak beam currents typically range from 12 to 18 mA for varying duty factors to give a maximum average beam current of 1 mA. The number of particles per bunch is of the order of 10^8 in the linac.

Beams from the linac are directed to various experimental areas and into the PSR via a beam switchyard. The 800-MeV H^+ beam is presently sent to an experimental area (Area A) where it interacts with a series of different target materials for the Accelerator Production of Tritium (APT) program. Up to 3 μA of the 800-MeV H^- beam is sent to the Weapons Neutron Research Facility (WNR) where it strikes a target producing an intense white-neutron source. Since variable proton pulse widths are available, time-of-flight experiments for neutron energies ranging from a few MeV to 800 MeV are possible.

The PSR functions as a high-current accumulator or pulse compressor to provide intense pulses of 800-MeV protons to the Manual Lujan Jr. Neutron Scattering Center (Lujan) spallation neutron-production target. The 800-MeV H^- ions from the linac are transported to a high-field stripper magnet where they are converted to H^o ions. The H^o beam then enters the magnet focusing lattice of the ring through a dipole where the final stripping to H^+ occurs. The PSR operates at a repetition rate of 20 Hz. An entire linac macropulse is accumulated per turn with up to 2800 turns accumulated prior to single-turn extraction.

In addition to the accelerator, as with any complex facility, there are major support systems which must be functioning properly and which affect beam delivery and availability. These systems include cooling water, ventilation, rf power, magnet power supplies, vacuum, and safety systems. Tracking of the effects of these systems on beam availability is important for reliable operation.

2 AVAILABILITY TRACKING

During scheduled operation of the LANSCE accelerator complex, an availability logging (AVL) system [1] utilizing automatically archived accelerator data and electronic control room log entries, is used to track the frequency and causes of accelerator and facility downtime. Beam availability is defined as the fraction of scheduled beam time delivered.

Historically, such data was manually collected by the accelerator operators. The AVL system is intended to automatically gather and report most of the data. The main shortcoming of the AVL system is its inability to automatically assign causes of downtime. Therefore, manual input of information by the accelerator operators is still necessary and the availability tracking is done using a combination of the automated software programs, written specifically for this purpose, and a spreadsheet for final data analysis and plotting. The AVL system consists of two major subsystems: Data Acquisition and Data Analysis software. These are discussed in the sections below.

2.1 Data Acquisition Components

The data acquisition subsystem consists of three programs which interact to gather data while the facility is in operation. These programs are started when the control system is booted and run either as background or interactive processes.

The program AVL_LOGGER runs as a background process and writes output to files. Data is acquired once per minute. The top-level equipment readiness status of each section of the facility (i.e., major areas like the linac, a beam transport line, etc.) is interrogated. If any top-level status is found to be "bad," a script is executed for that section, all "bad" statuses are logged, and output is written to a file. The AVL_LOGGER program does not do any data analysis; it only logs the data to a file on disk.

The program CMLOGGER also runs in background once per minute. This program reads a number of current monitors, logic states, and the beam duty factors. This information is also written to a file. CMLOGGER compares the operation production current thresholds, which are maintained in a data system, in real-time with the current monitor values. The program sends a message to the CCRLOG program, which maintains an electronic log of control room activities, when beam currents drop below or rise above the specified production current thresholds.

The CCRLOG program displays messages in the log corresponding to the change in the production states of the beams. If beam currents are out of production tolerances for more than 2 minutes, the program prompts the operator for information about the causes of downtime since the system can not do this automatically.

2.2 Data Analysis Components

The data analysis subsystem consists of a set of sorts and filters on the raw data to collect and tabulate information both by cause of downtime and fraction of total downtime. The analysis is performed by a set of command files, most often run automatically as a batch job. The final stage of analysis is to use a spreadsheet to produce graphs which are displayed to track availability, for maintenance, and for historical archiving.

3 DATA ANALYSIS FOR 1996

Data from the AVL system has been compiled and analyzed [2] for the 1996 calendar year. Each calendar year of operation of the LANSCE accelerator complex is subdivided into several “run-cycles.” Each run-cycle is generally followed by a period of equipment maintenance. The calculated availability for each run cycle for each area where beam was delivered and the cumulative 1996 results are shown in Table 1. The availability is calculated by taking the ratio of the amount of time the beam current was above the specified production threshold and the total scheduled beam time. Beam time to each area is generally scheduled months in advance of production. Our operations goal for 1996 was to provide greater than 80% availability for all beams delivered. These goals were met with the exception of beam delivery to Area A which will be discussed in detail in the next section.

The AVL system allows tracking and categorization of downtime by system. This data is useful in determining which systems are the most frequent causes of facility downtime. Figures 1-3 are plots of percentage of scheduled operation lost (downtime) as a function of subsystems of the LANSCE accelerator complex. Downtime caused by subsystems of the accelerator affect delivery of beam to all areas. These sources of downtime are common to all three plots. For example, failures of rf system components (labeled RF-201 and RF-805 in the figures) in the accelerator will affect beam availability to all three experimental areas.

Table 1 - Summary of LANSCE beam availability for 1996. Availability is calculated for each experimental area where beam is delivered using the time the beam current was above the specified production threshold.

	Area A (%)	WNR (%)	Lujan (%)
Cycle 71	-	73.2	69.0
Cycle 72	87.2	87.4	88.7
Cycle 73	31.8	89.3	88.9
1996 Ave	63.5	82.2	81.4

As can be seen in Figure 1, a significant source of beam downtime for Area A (>30% of scheduled production) was due to problems related to target operations. For both the WNR area (data shown in Figure 2) and the Lujan area (data shown in Figure 3), beam availability was generally high with 4-4.5% downtime attributed to DC magnet power supply failures.

During every operating period of the LANSCE accelerator there are also many short beam interruptions lasting 1-2 minutes in duration. This is not apparent from the figures above. For example, during one run cycle there were 330 total periods of downtime. Of these, 199 were of short duration and contributed to only 0.46% of the total downtime. These short-duration downtime periods are primarily caused by a machine “Fast Protect” where beam is automatically gated off due to an out-of-tolerance condition. Most of these events are transient in nature and usually require no operator intervention to be corrected.

4 SIGNIFICANT DOWNTIME INCIDENTS

Two significant downtime incidents are discussed in detail below. Each of these incidents caused extended periods of downtime which significantly affected beam availability of the LANSCE accelerator complex during 1996 operations.

4.1 Area A - H^+ Beam Delivery

A series of highly successful experiments were run in Area A in 1996. The experiments consisted of placing a group of stacked inserts, each made of a different target material, into the H^+ beam. Metallurgical and corrosion studies were carried out on the various inserts.

The success of these experiments relied on control of the environment surrounding each insert. Five periods of downtime were caused by water leaks of unknown origin (perhaps from localized heating by the beam) developing in the first insert (tungsten). Although the accelerator maintained the capability to deliver beam as scheduled, the target requirements for these experiments precluded beam delivery. The accumulated downtime from these five periods was approximately 24.2 days, which is 28.9% of the total run-cycle time.

This failure falls into the category of unanticipated equipment failures. Since these target inserts are often of a unique mechanical design, easily replaceable spares often do not exist. Failures of this kind demonstrate the importance of proper water system design and maintenance.

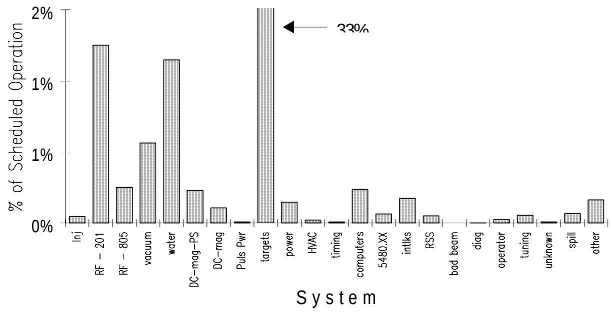

Figure 1: Causes of downtime for H^+ beam delivery to Area A histogrammed by system.

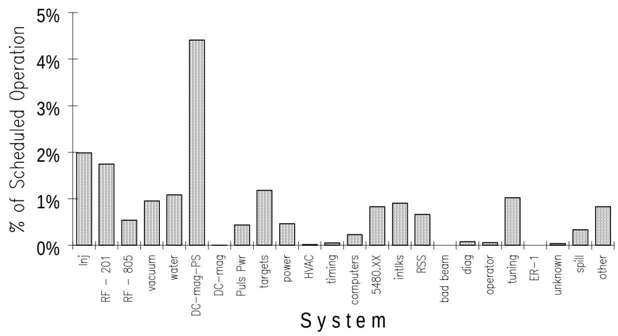

Figure 2: Causes of downtime for H^- beam delivery to the WNR area histogrammed by system.

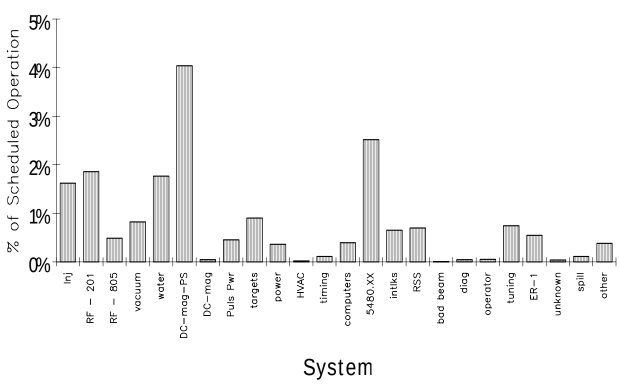

Figure 3: Causes of downtime for H^- beam delivery to the Lujan area histogrammed by system.

4.2 Lujan - H^- Beam Delivery

Although the average availability of beam during 1996, as seen in Table 1 above, to the Lujan area was high, the significantly lower availability during Cycle 71 was caused by a catastrophic failure of a magnet power supply for the main benders of the PSR. This caused approximately 6.3 days of downtime.

The current regulation capability of the power supply was lost due to component failure of the controller and subsequently it tripped off-line. In an attempt to diagnose the problem, repair technicians re-energized the power supply. Because of the loss of current regulation, 40% of the output capacitors, a 75-volt power supply and fuses for some of the magnet shunts were destroyed.

Replacement of the capacitors and fuses was carried out using parts on hand. The power supply was ordered from the vendor, was readily available, and was shipped overnight. The power supply controller was determined to be a custom designed part for LANSCE and was not immediately available from the vendor. A replacement IC was not immediately available. About four days were required to design and fabricate a robust substitute circuit at LANSCE for use in the interim.

This failure emphasizes the importance of refresher training for problems which are not common and to review knowledge which is not often used [3]. Also, having spare parts on hand is required for timely failure recovery and high availability. It may also be of value to periodically review availability of replacement parts for aging systems and upgrading or replacing them with more readily available parts.

5 SUMMARY

The AVL system described in this paper has been used to track beam availability and to identify the most frequent system failures affecting availability at the LANSCE accelerator complex during the 1996 operating period. It is our goal to further develop the AVL system capabilities so that predictions, such as mean-time-between-failures, may be made in the future. We also hope to use our availability data and past lessons-learned to help implement a more structured system of preventative and corrective maintenance, and to identify systems or components in need of upgrade or replacement.

REFERENCES

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[2] M. A. Oothoudt and K. W. Jones, “Los Alamos Neutron Science Center Availability for 1996,” Los Alamos National Laboratory Report, AOT-6-97-49-TR, February 1997.

[3] J. C. Sturrock, Los Alamos National Laboratory Report, AOT-6-96-41-IR, August 1996.