UNDERSTANDING ACCELERATOR RELIABILITY

Christopher M. Piaszczyk
Advanced Science & Technology Center
Northrop Grumman Corporation
Bethpage, NY

Abstract

The event data collected during operation of the LANSCE accelerator facility are being analyzed as part of an effort to understand accelerator reliability in support of current design activities for future large scale accelerator systems. In this paper, the sequence of failures and repairs of the system is represented as a composition of alternating stochastic failures and repairs processes and the process parameters are estimated. The derived estimates can also be used for practical maintenance planning.

1 PREAMBLE

Previous work [1] has identified the current state of the art as lacking in the area of reliability database information for components typically used in rf accelerator systems, such as rf stations, rf drives, rf transport, cooling, vacuum systems, magnets, and magnet power supplies. This led to intensive data collection efforts [2]. The data has already been used to derive initial estimates of failure and repair rates for typical individual accelerator components [3].

The present paper examines the data set of failure events for Cycle #71 for the complete LANSCE 800 MeV DTL/SCL accelerator facility. Instead of deriving failure and repair rates for individual components, we estimate here the parameters of the failures and repairs processes for the complete system [4].

2 ESTIMATING THE FAILURES/REPAIRS PROCESS

An accelerator is an example of a repairable system [5]. Reliability of a non-repairable system is determined by reliabilities of its individual components and the typical problem of interest for this kind of system is that of the first failure. For a repairable system, the analysis must also include the interactions between the system and the repair policies, maintenance procedures, spare parts policies, etc.

2.1 The Failures Process

We tend to think of a complex, repairable system such as an accelerator facility as a set of sockets, each carrying its corresponding part. The cycle of operation and repair of the component in each socket is described as a superposition of two alternating Poisson processes: one consisting of times between failures and the other consisting of down times. Each one is generally a nonhomogenous Poisson process (NHPP), with the number of failure events per unit time, typically called the rate of occurrence of failures (ROCOF), and the rate of "occurrence" of repairs (ROCOR), functions of time. The two processes are usually uncorrelated.

Thus, the analysis of data collected for a repairable system seeks to determine the type of the stochastic process represented by the data, rather than estimates of component population statistics. Of particular interest is the existence of any trends. If ROCOF is increasing, it is an indication of the system's deterioration and a potential basis for a significant action, such as a major improvement program (or abandonment: for example, by sending an old car to the junk yard). Decreasing ROCOF, on the other hand, is an indication of reliability growth.

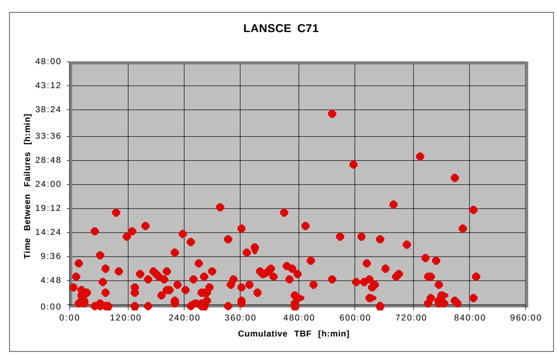

Figure 1. Times Between Failures

Application of this analysis procedure is illustrated here with the LANSCE Cycle 71 data. This data set was selected because it provides an example where the failures process is truly nonstationary. Over long periods of time stretching over many cycles, the observed tendencies are more balanced.

Raw data comes in the form of a sequence of times of occurrence of the failure events. One can extract from this data the sequence of times between failures shown in Figure 1.

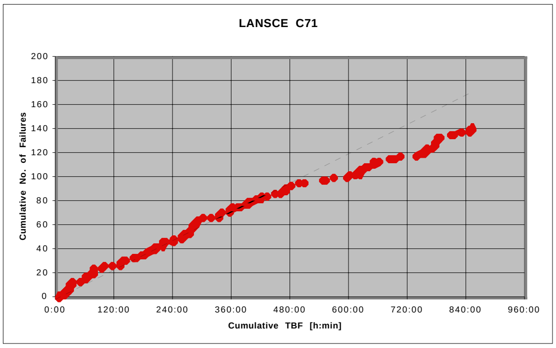

Figure 2. Cumulative Number of Failures

Figure 2 shows the cumulative number of failures as a function of cumulative operating time (sum of the times between failures). Comparison with the straight line fit indicates that the rate of occurrence of failures drops with time (after about 480 hours of operation).

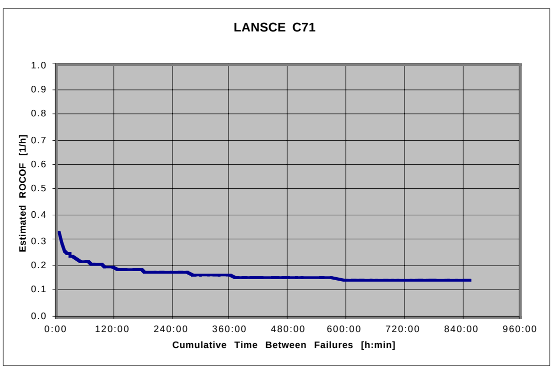

Figure 3. Estimated ROCOF

The Rate of Occurrence of Failures (ROCOF) is the limit of a series of discrete functions obtained by dividing the number of failures counted over a fixed delta interval when the length of the interval tends to zero.

Searching for ROCOF as a limit of the sequence of such discrete approximations is not practical. Direct statistical estimate of the parameters of the ROCOF assumed in the power form:

$$\lambda(t) = \alpha\beta t^{\beta}$$

results in $\alpha = 0.5036$, and $\beta = 0.8339$, which is shown in Figure 3.

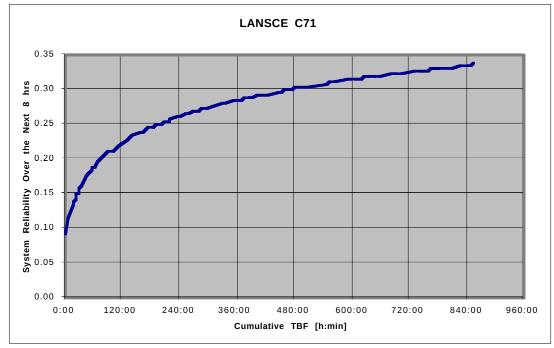

Figure 4. Expected Reliability over the Next 8 Hours

Once an estimate of ROCOF is obtained, we can use it to predict the system behavior, such as the expected number of failures in the next 8 hours or the expected system reliability in the next 8 hours for any desired instant of time shown in Figure 4 (since ROCOF is a function of time, both are functions of time as well).

Assuming a power relationship for MTBF(t) one can estimate the constants from the sample (resulting fit is shown in Figure 5):

$$MTBF(t) = 0.1056\, t^{0.2457}$$

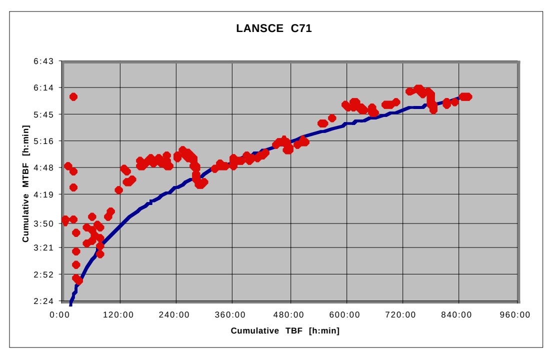

Figure 5. Estimating MTBF (t)

2.2 The Repairs Process

Figure 6 shows the cumulative number of repairs as a function of the cumulative down time (sum of the down times).

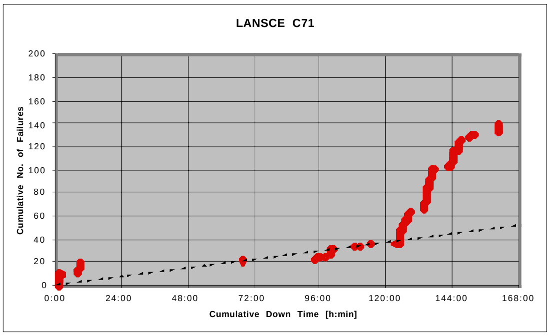

Figure 6. Cumulative Down Times

The down times are random just like the times between failures. However, in LANSCE Cycle 71, the down times history is dominated by a long 59 hour down time in the beginning of the cycle caused by the Magnet Power controller.

The ROCOR can still be assumed in the form of a power law. This time, this function is growing, indicating that the durations of the individual down times have a diminishing trend:

$$\mu(t) = 0.24114\, t^{1.3063}$$

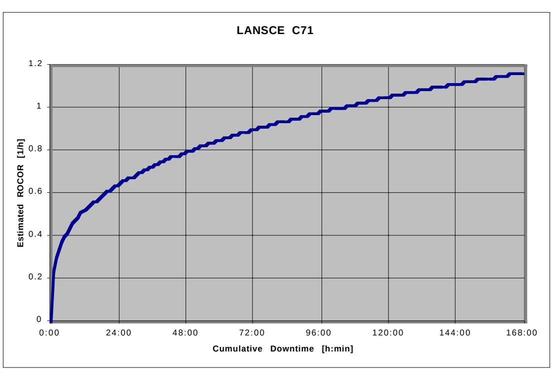

Figure 7. Estimated ROCOR - Rate of Occurrence of Repairs

A diminishing system MDT(t) can be fitted to the last part of the data (past 96 hours):

$$MDT(t) = 5.7302\, t^{-2.5186}$$

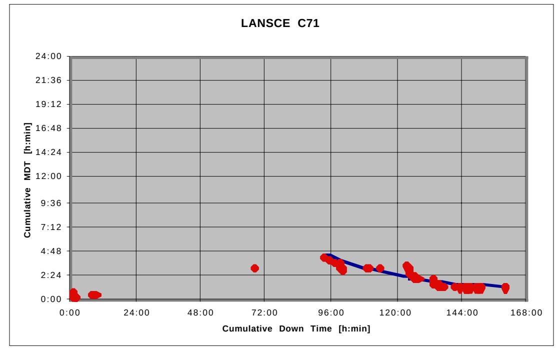

Figure 8. Estimated MDT(t)

3 CONCLUSIONS

The capability to predict the behavior of a repairable system is important for many reasons. Maintenance scheduling, advance spare parts procurement, and early detection of trends are essential in management and operation of the facility and planning for reliability improvement. The type of analysis presented in this paper may be used to gain such a capability from records of operational data.

REFERENCES

[1] C. M. Piaszczyk, “Reliability Analysis of the IFMIF”, AccApp ‘98, 2nd Topical Meeting on Nuclear Applications of Accelerator Technology, September 20-23, 1998, Gatlinburg, TN

[2] C. M. Piaszczyk, “Reliability Survey of Accelerator Facilities”, Maintenance and Reliability Conference, May 12-14, 1998, Knoxville, TN

[3] M. Eriksson and C.M. Piaszczyk, “Reliability Assessment of the LANSCE Accelerator System”, AccApp ‘98, 2nd Topical Meeting on Nuclear Applications of Accelerator Technology, September 20-23, 1998, Gatlinburg, TN

[4] P. Tobias and D.C. Trindade, “Applied Reliability”, Van Nostrand Reinhold, 1995

[5] H. Asher and H. Feingold, “Repairable Systems Reliability”, Marcel Dekker, Inc. 1984