AN ANALYSIS OF THE QUANTITATIVE MAINTAINABILITY AND SUPPORTABILITY CHARACTERISTICS OF A WEAPON SYSTEM TRAINER

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You may have been asking yourself, Why all the emphasis lately at the Center in specifying Device Maintainability; especially Quantitative Values. The answer, in a word, Gentlemen, is utilization. The device that can be repaired more quickly will be utilized more, because the training organization utilizing it will have increased confidence in the device. They will know they can successfully accomplish their training program on-time, every time, and will confidently regard the device as a vital part of that training program. Additionally, the device which requires a shorter Preventive Maintenance Program to keep it operational will be utilized more, simply by being "available" for training more hours.

But, again, Why Quantitative Values? It is true that Qualitative features can be designed into trainers to improve their maintainability, such as modular construction, roll-out shelves, fasteners with quick-disconnect features, ad infinitum. However, this tells us nothing, other than the fact that we have facilitated the maintenance man's tasks. But how much—and how effectively?—We don't know, and you don't know! Then how can we find out? By putting in the Qualitative design features, and putting numbers on them. Next, test to see if the estimated values are valid. When they are good, excellent! We can reuse these features again with confidence. When they are bad, then we will definitely know they are bad, and we know where to improve on our efforts in the future. In essence, we have put a handle on how and where to progressively improve the device in a manner which can show us, with each successive step, where to next direct our efforts, to achieve the greatest advancement, toward our goal of greater utilization.

Today I will show you the depth of insight given us to improve training device utilization through Quantitative Maintainability Analysis. The data used to illustrate this comes from the first Training Device Maintainability Demonstration test, completed four months ago. It ran for sixty-one consecutively scheduled utilization days, using the normal utilization environment, with no simulated failures. Navy TRADEVMEN (TD's) performed all of the maintenance. Two NTDC and two Contractor representatives witnessed the test, as observers, and recorded the data. Contractually, we specified a maximum fixed number of Maintenance Man Minutes (MMM), allowable to keep the trainer operational, for each hour it was utilized. MMM is the product of the number of TD's performing a task, times the clock minutes required to perform it. Two TD's performing a task, 15 minutes long, is 2 x 15 or 30 MMM. The contractual results are shown in Figure 164.

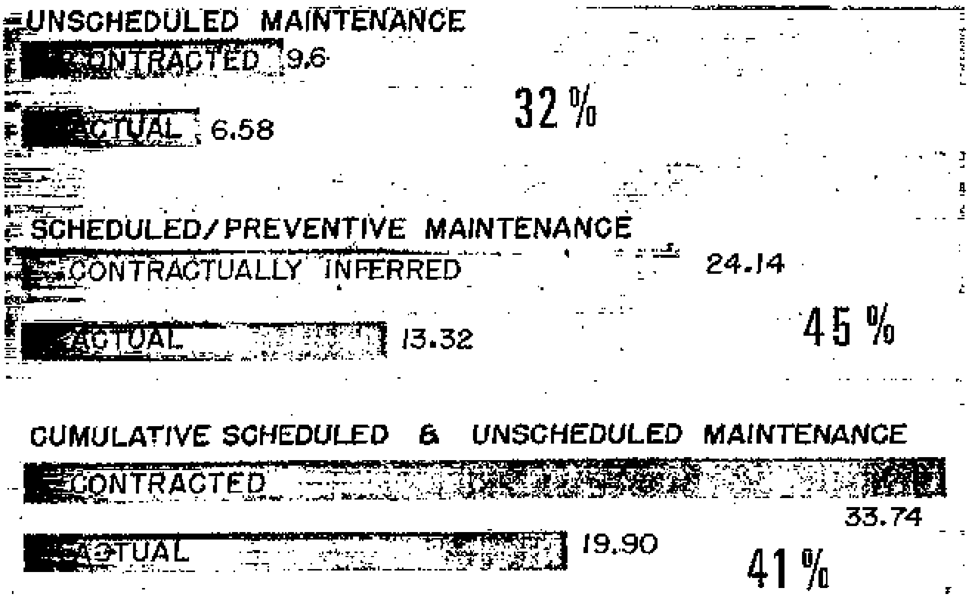

Figure 164. Device 2F84 (Flight)
Maintainability Index, Maintenance-Man-Minutes/Utilization Hour

(1) The Unscheduled Maintenance limit shown at the top, was 9.6 Maintenance Man Minutes per Utilization Hour (MMM/UH). The actual required effort was only 6.58; an improvement of 32 percent.

(2) The other contracted value shown at the bottom was for the combined Scheduled and Unscheduled effort not to exceed 33.75 MMM/UH. The actual effort required was 19.9; an improvement of 41 percent.

(3) By the two contracted values, it was inferred that Scheduled maintenance alone would be 24.14 MMM/UH. The actual results here were 13-32 MMM, an improvement of 45 percent under our inferred limit.

The admirable performance by the contractor in surpassing our goals is worthy of note here. However, as you can see, this only tells us the man-effort required to keep the device operational on an overall basis. This data alone does not tell us how often maintenance was required, what the TD work load looks like or how to specifically improve on this effort. The wealth of data collected during the demonstration does permit us to perform a more in-depth analysis of the Device Maintainability beyond that required by the contract. Parenthetically, this extended approach is the type employed as the basis for Demonstrations in accordance with MIL-STD-471, which the Center is now specifying in all future maintainability programs.

First, we will begin with the Scheduled Preventive Maintenance effort. The data were separated into the daily checks and other Preventive Maintenance (PM) efforts. The histogram of the daily check distribution by 1/4 hour intervals is shown in Figure 165. Both the actual clock time and the maintainability index expressed here in Maintenance Man Hours (MM) are equally distributed about the 1/2 hour point. From this we now know that the average daily check is 1/2 hour long, requiring one TD to perform it.

The other PM efforts are shown in Figure 166 histogram which is more complex. Not as obviously as before, but numerically the 50 percent middle-point in the elapsed clock distribution is again about 1/2 hour, actually 33 minutes. The Maintainability Index mid point occurs at 3/4 of a man-hour. This indicates the use of 1 1/2 TD's in the average PM task.

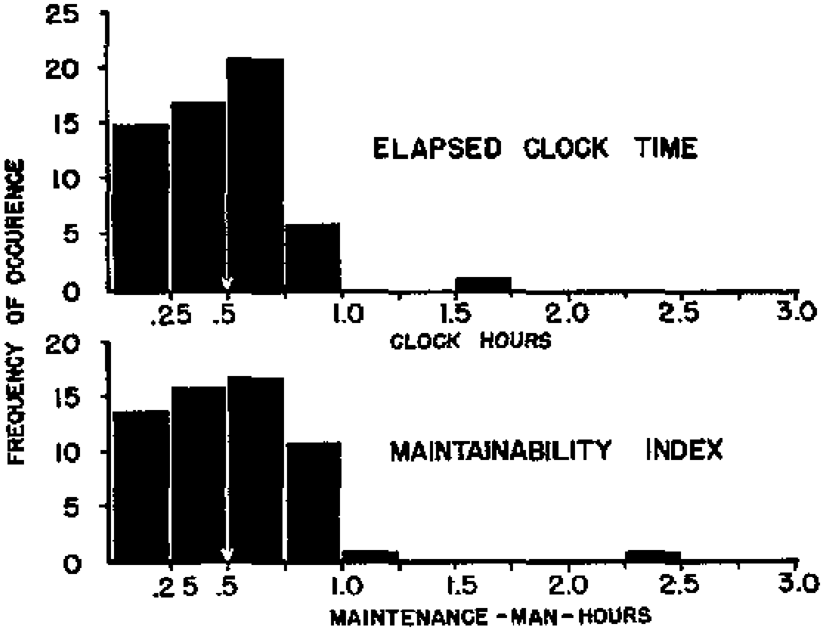

Figure 165. Daily (Scheduled) Maintenance Frequency Distribution

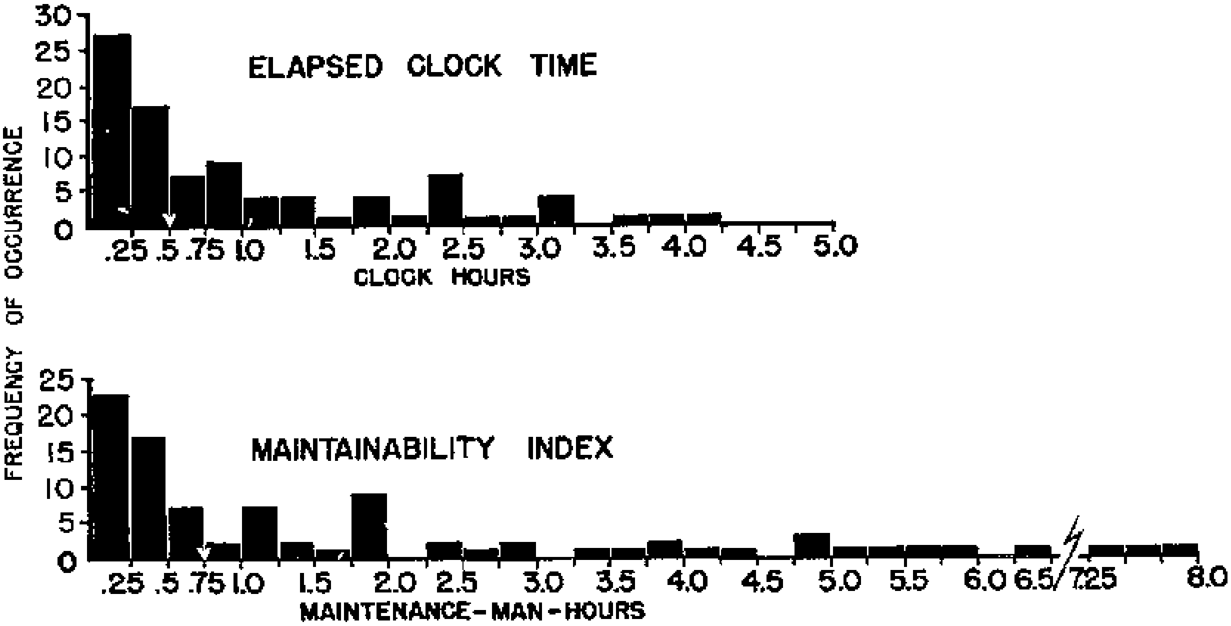

Figure 166. Preventive Maintenance Frequency Distribution

Next, arithmetically averaging all the tasks, we calculated a mean value of 63 clock minutes and 100 MMM. This indicates the usage of 1 2/3 TD's in a PM task. Finally, averaging all the discrete tasks shown over the test period, yields 1 1/2 PM actions for each 16 hours of Utilization. These 3 pieces of information, plus the daily check, permit us to describe the average PM scheduled effort as follows:

A 1/2 hour daily check, using 1 TD, followed by an overall average of one hour PM requiring the availability of 2 TD's for each 11 hours of Utilization. However, this additional PM action will vary as follows: actually only 1/2 hour or less 50 percent of the time; from 1/2 to 1 hour 25 percent of the time; and from 1 to 4 hours the final 25 percent of the time. This variance in PM task times is not conducive to the efficient Scheduling and Utilization of TD's. A prudently developed schedule is required here to perform the appropriate PM at the required time while still programming the task to provide an equal time effort every day. This is, therefore, one area noted as requiring further review to improve our Maintainability and provide a more consistently available device for utilization.

Next, the Unscheduled Corrective Maintenance effort was analyzed. Thirty-eight independent corrective maintenance actions were recorded in the 3 month test period. Data was again arranged in ascending order by 15 minute intervals and the histogram is shown in Figure 167.

Once again the middle 50 percent point was 1/2 hour elapsed clock time requiring 1 1/2 TD's to perform the task. Further review of the test data yielded a Mean Time Between Repairs (MTBR) of 24.4 hours.

Therefore the average corrective maintenance effort can be described as follows: One action each 24 utilization hours, normally requiring the availability of 2 TD's for 30 minutes to correct the problem.

A further analysis of the elapsed clock time data by its three component parts followed. But first, please note the form of the elapsed clock time distribution; continuous to 1 1/2 hours with subsequent discrete actions to 4 hours. Figure 168 shows the breakdown of this elapsed clock time by its three components: Fault Location, Repair and Check-out Time. You will note the Fault Location histogram shown at the bottom closely resembles the overall elapsed clock time histogram. This is because it is the most significant component part. Fifty-seven percent of the average corrective maintenance action time was spent in locating the Fault; 34 percent in effecting the repair, and 9 percent in post repair checkout. This makes a very strong point for automatic fault detection and locating equipment in the design of training devices. Inclusion of this type of equipment in the trainer hardware could immediately cut Corrective Maintenance (CM) time by 50 percent. Further, the present TD crew was trained in a formal course on the equipment. Their replacements will be mainly on-the-job trained and fault location time will increase accordingly. By comparison, where automatic fault detection and locating equipment is used in a device, the fault location time will remain constant for the life cycle of the device, becoming even more important as the device ages and starts into the wear-out portion of its curve with the less proficient maintenance personnel attending it. A further cost effectiveness study is indicated here on the value of automatic fault detection and locating equipment versus increased utilization.

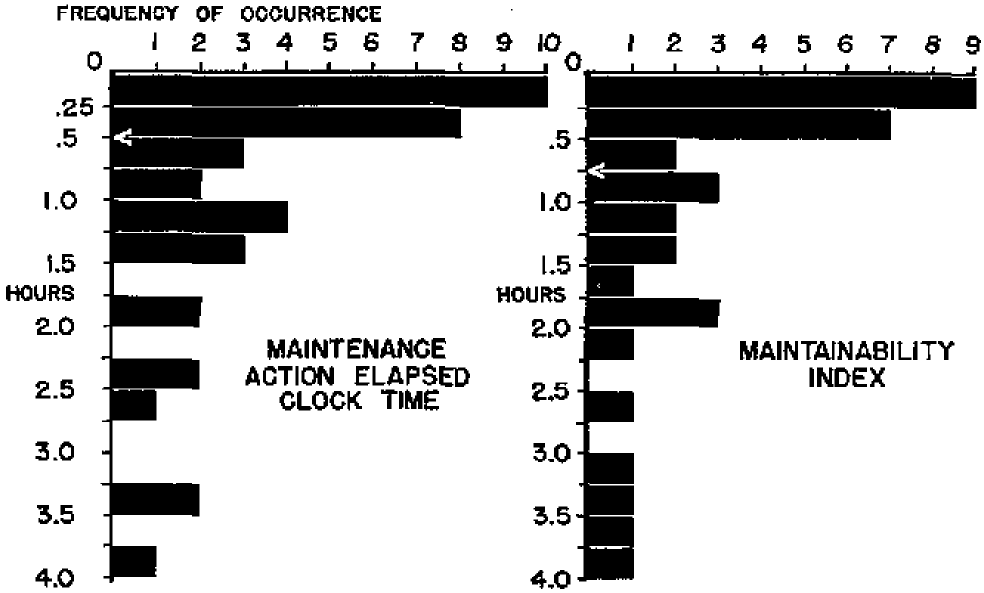

Figure 167. Corrective Maintenance Histograms

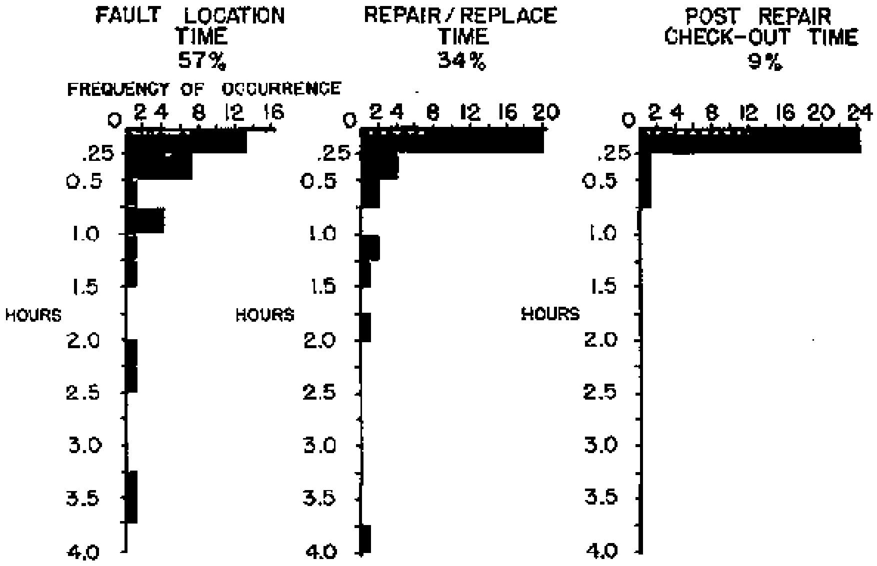

Figure 168. Components of Elapse Clock Times

All the histograms so far have shown the bulk of data grouped in a low time interval, with less frequent occurrences spreading out over longer time intervals. This is the characteristic distribution of electronic-and electromechanical equipment—The Log. —Normal distribution. Figure 169 is this characteristic curve. Since the raw data obviously evidenced this distribution so well, a final analysis can also be performed which is by far the most significant toward isolating the areas which require an improvement on our efforts.

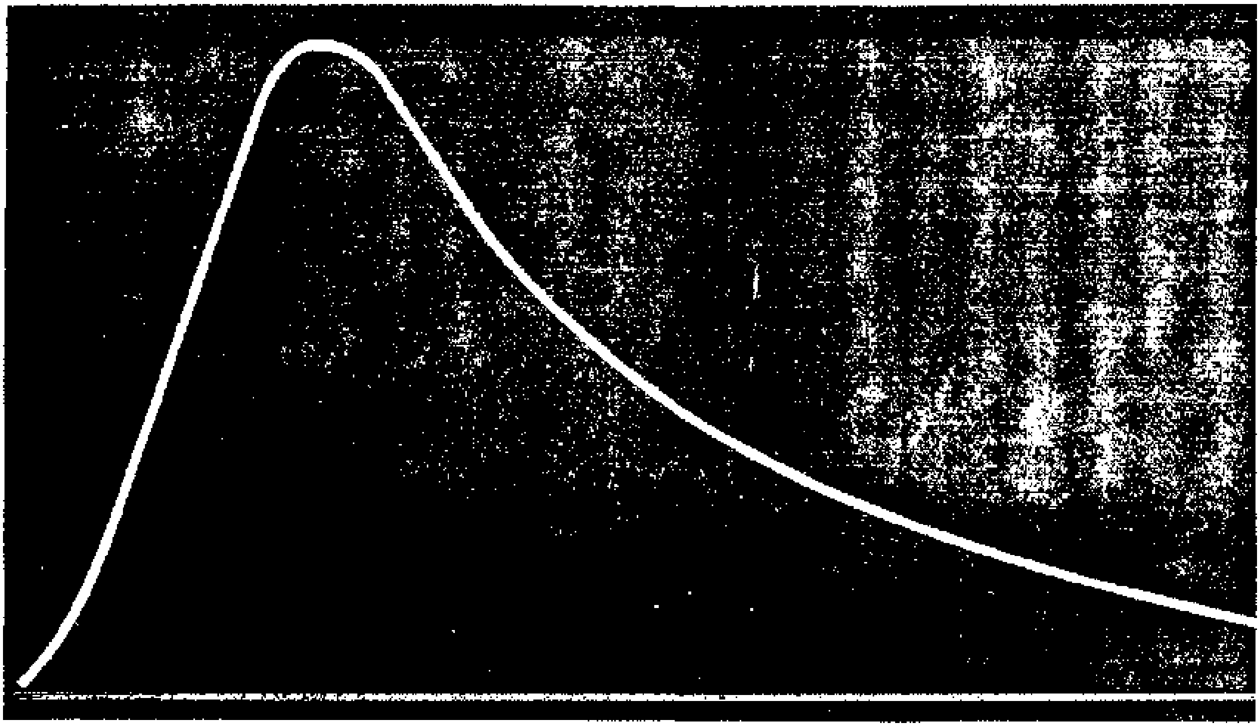

Figure 169. Log Normal Distribution

Taking our sample of CM repairs actually effected, a cumulative probability of accomplishing a repair within a given time or less was plotted. This is the Maintainability Function shown in Figure 170. This curve can be interpreted in two ways: The first is—When any fault is detected, there is a 50 percent probability that the repair can be accomplished in 32 minutes or less and a 90 percent probability of repair in 2 1/2 hours or less. The second way—Of any 100 probable failures, 50 will be repaired in 32 minutes or less, and 90 will be repaired in 2 1/2 hours or less. We are now beginning to put a quantitative value on the down times we can expect to experience. This curve is good for any percentage, of course, however, its accuracy is subject to the engineer's judgment of what curve best "fits" into the limited number of plotted points. Also, it tells us nothing about the accuracy of the sample data we are using for our predictions. To achieve a greater degree of accuracy and confidence, the original data points are again plotted on Log-Normal Probability graph paper shown in Figure 171. The paper is preprinted with a Log distribution on the abscissa and percent Normal Probability distributed as the ordinate axis. The points as plotted on this preprinted distribution paper should be a straight line, indicating that the data has a unity correlation with the log-normal characteristic curve describing electronic equipment. Here is where the reliability or "goodness" of the data sample is put to the test. In arbitrarily taking a limited sample from anything, there is always the possibility of selecting

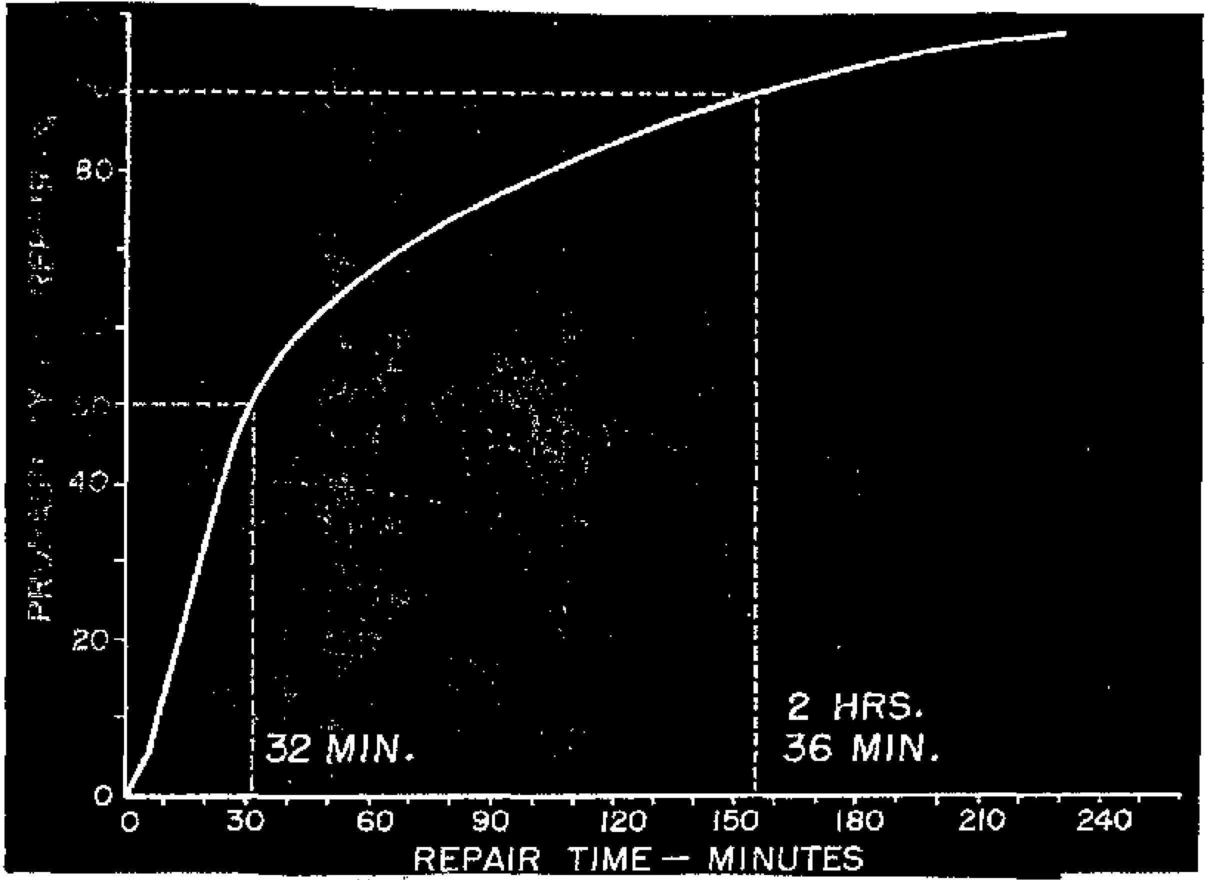

Figure 170. Maintainability Function, Device 2F84 (Flight)

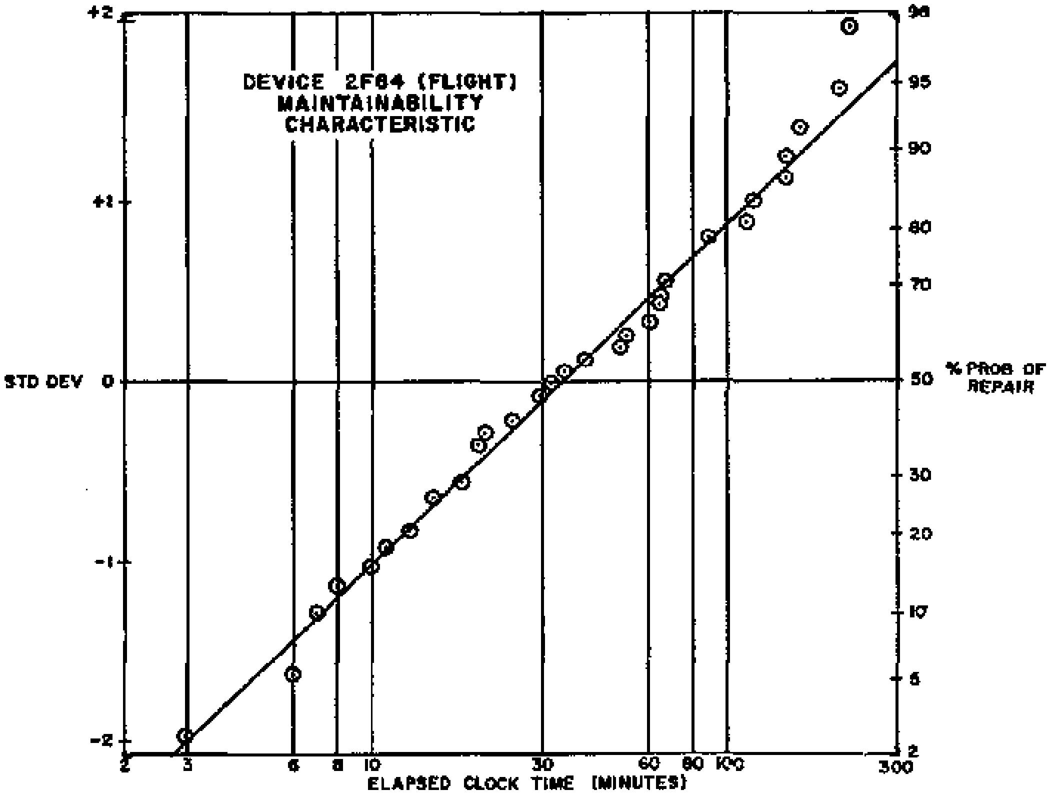

Figure 171. Device 2F84(Flight)Maintainability Characteristic

or collecting some pieces of information which may be the actual oddball happenings rather than the run-of-the-mill happenings in that situation. In the present case, if the plot of the raw data points clearly defines a straight line, we know we have a collected representative sample. If it is only broadly indicative of a straight line, the data is not totally representative, and the accuracy of any further interpretations is not to be taken too literally. Fortunately, our data samples do sharply indicate a straight line plot as now shown.

At this point, knowing we have a valid sample of the device maintainability, we draw in this indicated straight line, and in doing so, pass from the realm of simply observing what has occurred, into a new realm of accurate prediction of what will occur concerning this device's maintenance, justified by the natural law of the normal distribution. This straight line plot is called the Maintainability Characteristic.

Figure 172 illustrates the broad range of knowledge we now possess about this device. This is again a "duo-gram" which can be read in 2 ways. The first way; 32 minutes is the Geometric mean repair time. About this average point, we can predict that 25 percent of all CM actions will take no less than 23 minutes, but no longer than 48 minutes to accomplish a repair. Fifty percent of the CM actions (of which we have already defined the center 25 percent) will take no less than 15 minutes and no more than 75 minutes to accomplish a repair. We can similarly predict any desired percentage asymptotically approaching 100 percent. The second method of interpretation is shown across the botton. Twenty-five percent of all CM actions will require 15 minutes or less to accomplish a repair. Fifty percent will require 32 minutes or less to accomplish a repair, and so on. Of the failures as shown here, 95.4 percent will be repairable in approximately 6 1/4 hours or less.

The door is now opened to the accurate determination of our down time and such related items as the appropriate utilization schedule. As noted previously, we will average 1 failure for each 24.4 hours of utilization. Twenty-five percent of the failures will not affect utilization as they will be corrected in 15 minutes or less—our tolerance being 15 minutes before a training period is lost. The second 25 percent will require from 15 to 32 minutes to effect a repair and these periods will be lost. Continuing in this analysis, it is found that cumulatively 10 percent of the training periods will be lost over any reasonable period of time. Therefore, schedules developed with 10 percent positive slack can be accomplished on time every time.

We can also analyze the TD work load more accurately and schedule our personnel accordingly, and most significantly, we can go back into the device with time studies to isolate the repair areas by their time to be accomplished, and, from this information, determine where improvements are required to effect the best improvement in utilization. The most rewarding areas will be the repairs between 15 and 32 minutes. Reducing these times to 15 minutes or less will result in an additional hour of utilization for each improvement of, at most, about 17 minutes. By comparison, 75 minute jobs would require a decrease of 60 minutes in order to realize that same additional hour of utilization, and would probably cost a lot more to achieve. Obviously repairs of less than 15 minutes require no improvement.

The salient point here is that, even as we advance toward more solid state and integrated circuitry in any contemporary group of NTDC training devices, of which most are considered to be in the category of one or two of a kind the hardware guts of the devices which generate different simulations are the same equipment, reused again and again for years at a time in various combinations, with minor modifications, to achieve individual results. An improvement in these basic building block areas in one device will also be realized again in the next devices using that improved design. Additionally, costs, which may now appear as excessive for a single device improvement if in the basic areas, can be reviewed for their benefit to future devices and in actuality may be a real savings worthy of the initial cost. One example here is the application of the automatic fault detection and locating equipment mentioned previously.

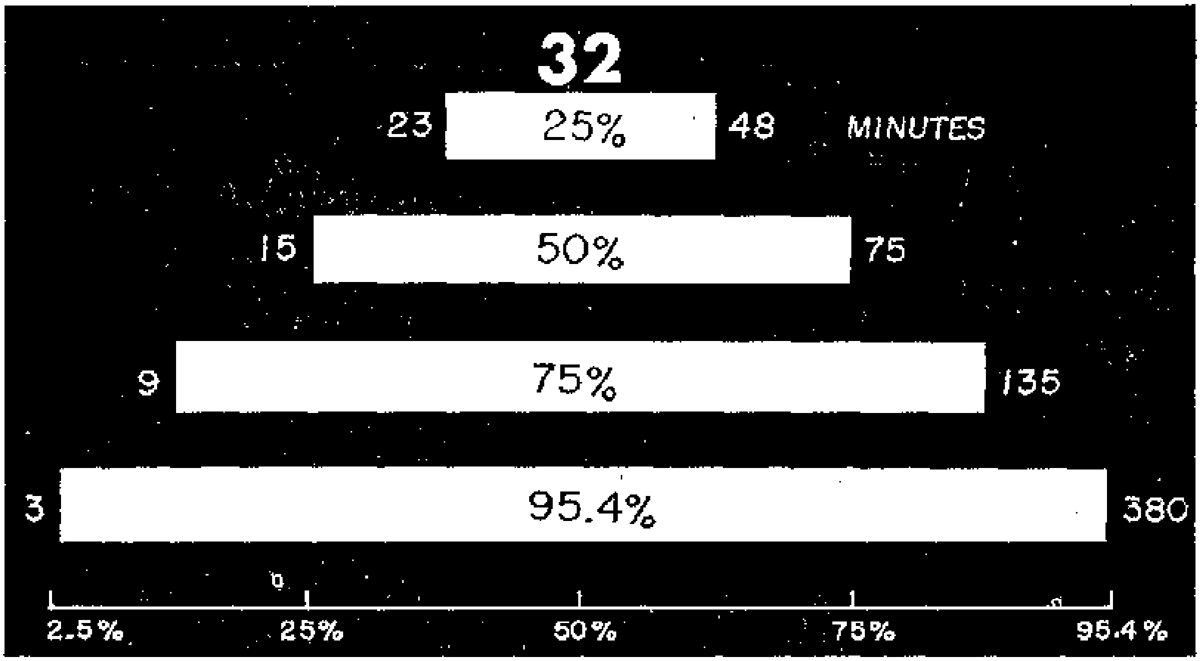

Figure 172. Device 2F84(Flight) Distribution of Corrective Maintenance Actions

From this viewpoint we can now see how this advancement toward that minimum maintenance—maximum utilization goal can be realized in an ever advancing technology in confident, progressive, quantitative increments.

In summation, the first Maintainability Demonstration served primarily to confirm the satisfaction of contractual requirements. However, it also served as a feasibility study in the concepts of Maintainability and its value to the overall device and training program. The results of this study are:

(1) Work load distributions and schedules can be derived to maximize man-power utilization of TD's.

(2) Devices do conform to the log—normal distribution and there is therefore a built in check of the accuracy of data samples taken in a demonstration through the plotting of the log—normal maintainability characteristic.

(3) Based on the confidence determined from the log—normal maintainability characteristic, the corrective maintenance down time can be predicted. From this information, training programs can be confidently scheduled accordingly.

(4) Areas warranting improvement can be better identified as to the amount needed to effect an increase in utilization. Realistic cost-effectiveness studies can be applied to these improvements because quantitative values are employed in the analysis.

(5) Problem areas can and will be improved in subsequent procurements through improved specification writing at NTDC and contractor redesign of the basic building blocks for simulation.

These vital characteristics now bared to inspection and review show us how to progressively improve our training programs and device availability characteristics by measurable means; and NTDC can more firmly advance toward its goal of better tools for more effective training through the application of Quantitative Maintainability Analysis.