Technique for Evaluation and Analysis of Maintainability (TEAM)

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Introduction

THE effectiveness of a maintainability program is measured by the ease with which maintenance can be performed. The actual determination, then, is an after-the-fact operation. Without a technique that can be applied effectively throughout the design of an equipment, and unless application of the techniques leads to a solution to the problems, the maintainability program will be a failure.

There is a great need for an approach to the problem of maintainability which will indicate trouble areas in the early design stages of the equipment. In this paper we will not deal with the very basics of good maintainability design. We will be concerned with the obscure problems that only become evident after the equipment is designed and with the elimination of these problems by use of the TEAM approach during the design stages. This paper will show further the procedure for developing a TEAM diagram and all other areas that should be considered as applicable to its development. In addition, an actual TEAM diagram is included and explained as it was developed for Martin's random access and correlation for extended performance (RACEP) SK660 unit.

Development of a TEAM Diagram

To develop a TEAM diagram, the maintainability engineer first must develop or be familiar with an operational checkout procedure for the equipment to which the TEAM diagram will be applied. In developing this checkout procedure, all inherent test features should be considered. This will point out readily any test features necessary to assure a complete operational check of any equipment.

The TEAM diagram is prepared in bubble-chart fashion, with the failure symptoms as the start of each chain and with all items that can cause the failure symptom included in the particular chain. Generally, it is required to furnish mean time to repair (MTTR) and other pertinent maintainability data on an equipment to the organizational or black-box level. Therefore, the first TEAM diagram developed should be to this level. From this, other TEAM diagrams can be developed, depending on customer and/or project requirements.

The accuracy and completeness of the TEAM diagram will determine the accuracy with which maintainability can be predicted. To achieve accuracy and completeness, the following guidelines should be followed in the development of a TEAM diagram. (Figure 1 is a TEAM diagram of RACEP SK660 to which the following paragraphs are related.)

During an operational checkout (simulated during proposal and design stages), determine all possible symptoms that can be derived from the checkout. List all symptoms as starting points of a troubleshooting path. From each of the symptoms which was apparent during the operational checkout, proceed along the most logical path of troubleshooting to repair the trouble. In each of these chains, include all cards, modules, chassis, etc., that could give the symptoms.

Perform actions necessary to reduce possible troubles. As the actions are performed, new indications are observed which cause new chains to be formed. Arrange serial paths for each group of cards, chassis, etc., the failure of which would result in the same indication. Show all actions (replacement of a card, chassis, etc.) and reactions (verification that trouble is remedied) in bubble-chart fashion. Do not proceed from an action until all previous reactions have been established as true. If an action remedies a trouble, proceed to the checkout bubble.

If the equipment is in the design stage, it will be necessary to estimate action and reaction times. After the prototype has been manufactured, more accurate times could and should be obtained by actual timing of each action and reaction. Place these items on the diagram on the line preceding the action or reaction.

Compute the failure rate (F_r) of each item considered to be a replaceable part (card, chassis, etc.). This information may be computed, using the handbook *Reliability Application and Analysis Guide*[1] or other similar handbooks as guides. Failure rate data may be available from the reliability group on your project. However, the material referred to previously supplies adequate information for compilation of the needed data.

The failure rates and repair times are important in the development of a TEAM diagram, since these factors determine the order in which cards, chassis, etc., appear in a serial path. For example, a chassis that has the highest failure rate of all items in a chain should appear first, since the trouble symptom more often will be a result of a failure in this chassis than it will in a chassis with a lower failure rate in this same chain.

One of the major tasks in any maintainability program is estimating the MTTR for all failures that can occur in an equipment. This presently is being accomplished by developing a maintenance task breakdown for all potential failures and by estimating the MTTR of each task. Although adequate, this technique is extremely cumbersome and because it does not tie the system together, does not give the over-all picture readily.

The TEAM approach overcomes the inadequacies of the method presently in use by charting the logical troubleshooting procedures the maintenance man is to follow. The different paths, indicated by different symptoms, encompass all possible malfunctions the maintenance man has the responsibility to correct. Once the chart has been completed, it is a simple matter to write in the times required to perform each step along the maintenance paths. The repair time (R_t) of an item is the simple addition of the times of all steps in the chain up to the successful completion of the particular check. The MTTR for any part or section of equipment then can be calculated by a simple mathematical formula. Compute the MTTR, using the following formula: $\mathrm{MTTR} = \Sigma F_r R_t / \Sigma F_r$. It also is advantageous to compute the MTTR of each chain so that critical paths can be determined. Critical paths and their control will be covered in the following section of this paper. A worksheet for computation of the MTTR's would expedite the computation, and also would serve as a record and/or report. Figure 2 is the worksheet for computing the MTTR of RACEP SK660 and is related directly to the chains on Fig. 1.

Application of TEAM Data to the Product

Now that development of a TEAM diagram on an equipment has been shown, the information it contains must be applied to the product to enhance the design and to gain optimum maintainability. The critical paths are the ones that potentially have the most detrimental effect on the maintainability of the product.

The longest troubleshooting and repair paths are critical inasmuch as the longer it takes to locate and repair a trouble, the higher the MTTR for that path. If any repair time can be shortened, the total MTTR likewise would be shortened. After a critical path is determined, several actions could be used to shorten it. Critical repair time paths can be shortened by adding test circuitry to isolate troubles in subassemblies having longer repair times.

Example: Fig. 1) If a test feature were added to check the output of the Exciter before checking the output of the Power Amplifier, the R_t of the chain would be reduced by 5.25

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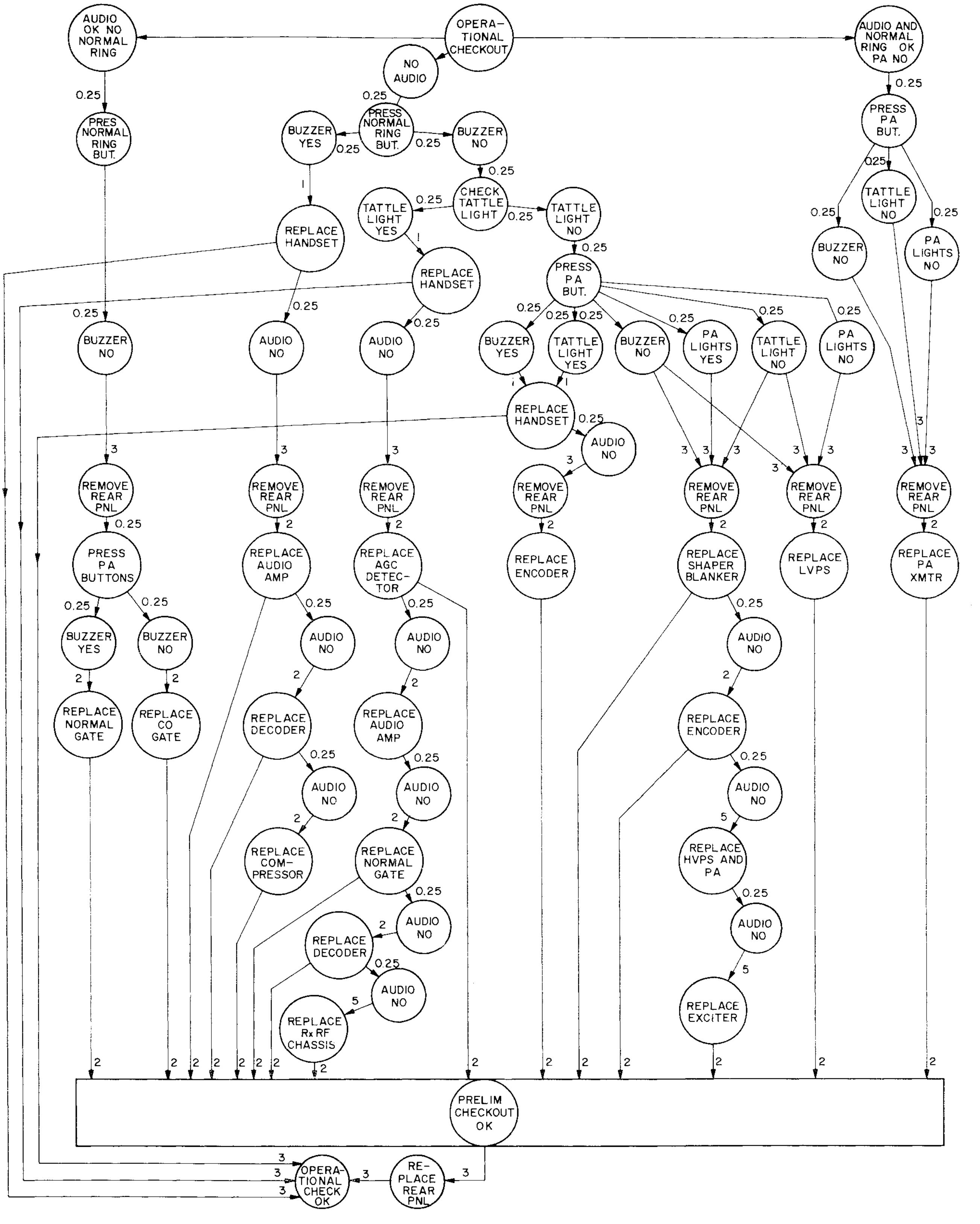

Fig. 1 TEAM diagram of RACEP SK660.

min. This would result in a 2 min reduction of the MTTR of the chain, and a 0.3-min reduction of the MTTR of the unit.

Where practical, the circuitry should be arranged so as to prevent any card or subchassis from appearing in more than one chain of the chart. In some cases, the circuitry on two or more cards could be combined on one card, thereby shortening the R_t of a chain.

Example: Fig. 1) The Audio Amplifier and Decoder both are included in chains 5 and 6. If they could be repackaged to include all circuitry that would affect these chains on the same card, the R_t of both chains would be shortened by 2.25 min.

All cards and subchassis with high F_r should be reviewed to determine if components with higher reliability are avail-

		RACEP				
		R_t	F_r	$F_r R_t$		
	RACEP Card or Subchassis	Repair Time (min)	Failure Rate/ 1,000 (hr)		MTTR for Chain	MTTR for Unit (min)
1	Propagated alert transmitter	13.5	0.315	4.2525	13.5	
2	Low voltage power supply	17.5	0.102	1.785	17.5	
3	Shaper blanker	14.5	0.250	3.625		
	Encoder	16.75	0.195	3.26625		
	High voltage PS and power amplifier	22.0	0.368	8.096	19.88	
	Exciter	27.25	0.160	4.36		
4	Handset	5.5	0.124	0.682	11.77	
	Encoder	15.75	0.195	3.07125		
5	Handset	5.0	0.124	0.62		
	AGC detector	15.25	0.230	3.5075		
	Audio amplifier	17.5	0.218	3.815	19.48	
	Normal gate	19.75	0.214	4.2265		
	Decoder	22.0	0.137	3.014		
	Rx RF chassis	27.25	0.360	9.81		
6	Handset	4.5	0.124	0.558		
	Audio amplifier	14.75	0.218	3.2155	13.89	
	Decoder	17.0	0.137	2.329		
	Audio compressor	19.25	0.103	1.98275		
7	Command override gate	14.0	0.213	2.982	14.0	
8	Normal gate	14.0	0.214	2.996	14.0	
	Totals		4.001	68.20425		17.05

Fig. 2 RACEP worksheet.

able for use in manufacturing these cards and subchassis. It is possible that some cards and subchassis could not be checked with available features. All cards and subchassis should appear in at least one of the chains of the TEAM chart. If they do not so appear, additional features or procedures are needed to check out the unit completely.

The suggestions for application of TEAM data to product, as outlined previously, can be useful for presentation of the maintainability of a product to engineering and to management for tradeoff discussions and for design changes necessary to meet the desired goals.

Summary

RACEP, a concept in radio communications, was selected as the trial system for this approach to maintainability. This application, covered in Figs. 1 and 2, revealed several items that degraded the maintainability of the product and pointed out areas requiring redesign in later systems. As a result, the RACEP production model (482L-type developed for the U.S. Air Force) has been designed with additional features that enhance its maintainability. In addition to the improvements that were determined to be needed by the evaluation of the prototype equipment, the TEAM technique was used on the RACEP 482L program for control of the design for better maintainability. As a further application, the TEAM technique was applied to the RADA design study program and was included as the maintainability input in technical volumes of the RADA System Design Plan (OR 3758B).

Reference

[1] Earles, D. R., *Reliability Application and Analysis Guide,* MI-60-54(Rev. 1), Martin Co., Denver, Colo. (1961).