

VALUE ANALYSIS IN SYSTEM EQUIPMENT MAINTENANCE

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ABSTRACT

In this paper, a flight simulator has been chosen as an example of system equipment maintenance, a Value Engineering (VE) basic equation is constructed and a maintenance value analysis (VA) is conducted. To obtain maintenance value, parameters are set, case studies are performed and an evaluation is made employing a life cycle cost. This paper presents an approach to provide an answer to the question: what is the maintenance value of a system equipment?

INTRODUCTION

Maintainability of system equipment has been receiving equal attention to the function and performance of the equipment. Obviously, the aim of maintenance is to improve the availability and the maintenance elements include maintenance personnel, logistic support, tools and engineering data. In the past, functions and performance have been regarded as the primary values, however, operability in terms of ease of utilization and long term maintainability are receiving more attention in recent years.

Major work for maintenance includes regularly scheduled preventive maintenance to eliminate the occurrence of failures and repair work of failed parts. The aim of maintenance is to improve the availability of the system employing the effective use of maintenance elements including maintenance personnel, logistic support, tools and engineering data.

A flight simulator is one of the system equipment categories. A flight simulator is the system equipment which can provide operational feelings of an actual aircraft in a repetitive manner, on the ground. A flight simulator is safe, compatible with the environment, cost effective and no pilot training can be conducted without it. Flight simulators have been receiving more attentions than before to achieve effective pilot training and simulator maintenance has become one of the paramount factors. In this expectation on the maintenance, fulfillment of diagnostic functions, construction of maintenance data to speed up the work to overcome the failure and the modification work to improve functions may be included. This paper shows the maintenance value using a flight simulator as an example.

**MAINTENANCE WORK OF A FLIGHT
SIMULATOR**

A flight simulator can be expressed in one paragraph, i.e.: Flying by electronic equipment. When a pilot, seated in a replica of the aircraft cockpit, initiates a flight in accordance with set procedures, indicators move, acceleration sensation is imposed on the cockpit crews and the out-of-the window scene changes. A flight simulator is an organic combination of computers, graphics and mechatronics systems.

A conceptual drawing of a flight simulator is presented in Figure 1.

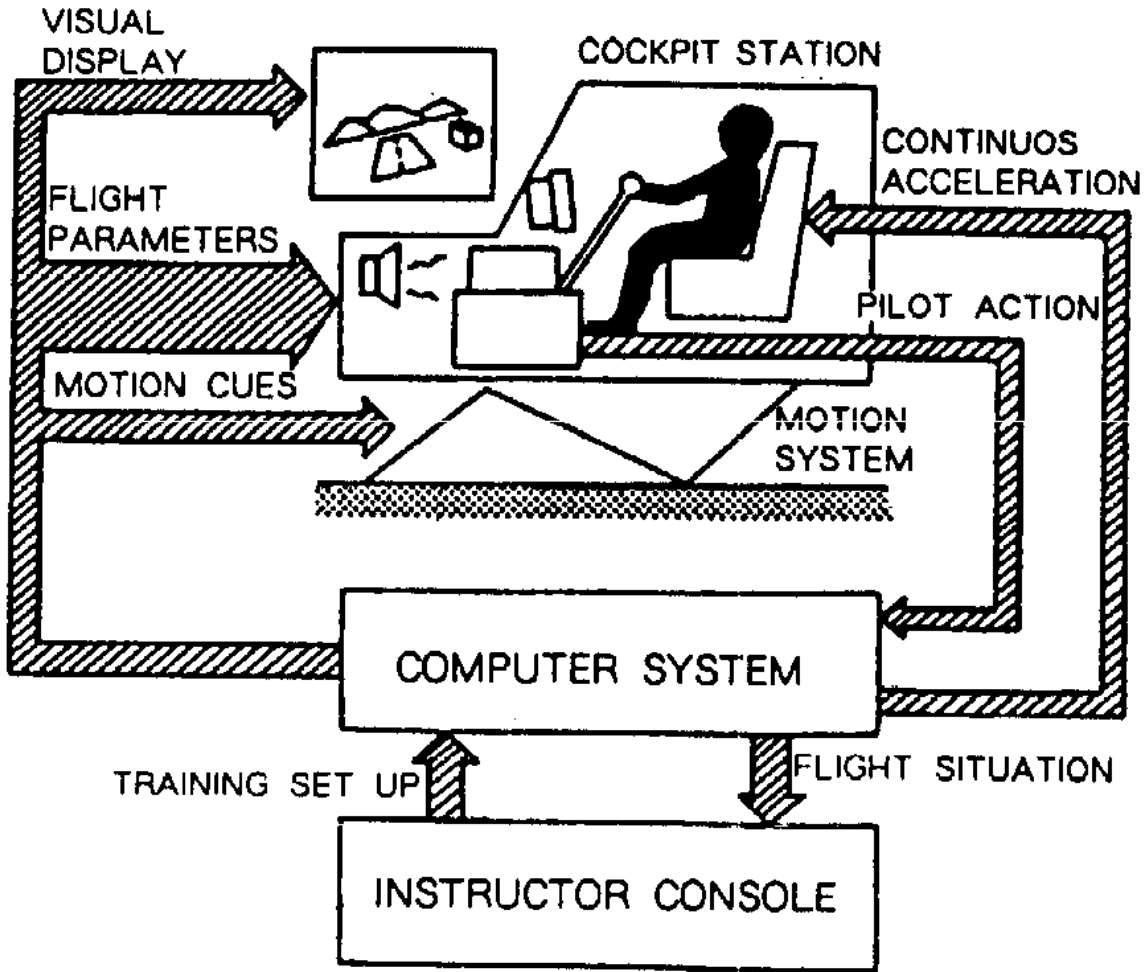


FIGURE 1. FLIGHT SIMULATOR CONCEPT

Under a normal condition, a flight simulator is maintained by personnel stationed at the simulator site. This is because simulator maintenance requires specialized engineering and proper support to the training is the paramount importance. The maintenance work may be divided into three groups, i.e., preventive maintenance, corrective maintenance and other maintenance related work as shown:

Preventive maintenance

This is a regularly scheduled maintenance to find the clue of the beginning of a failure. It includes prescribed maintenance and parts replacement prior to the failure so as to realize the cost effectiveness of the system.

Corrective maintenance

This is an unscheduled maintenance which is required to restore equipment to an acceptable standard of performance to meet the operational demands. It normally includes an analysis to pin point the cause of a failure, repair or replacement of the failed parts and readjustment of the system, if required.

Other related maintenance

This type of maintenance work includes training support of equipment operations performed from the instructor's console,

monitoring the performance of various equipment, maintenance planning and maintenance of documents needed for maintenance work.

HOW TO IMPROVE THE AVAILABILITY

The most important point in the maintenance of a flight simulator is availability. In general, availability can be divided into an inherent availability and operational availability. The inherent availability can be expressed by the equation:

$$\text{Inherent availability} = \frac{\text{System up time}}{\text{System up time} + \text{System down time}} \dots (1)$$

where the system up time is defined as the sum of the actual training hours and the waiting hours.

The system down time is the total hours used to perform maintenance and includes maintenance down time, logistic delay time and administrative delay time. Mean time before failure (MTBF) and mean time to repair (MTTR) are often referenced. The operational availability, closely related to the maintenance of a flight simulator, can be computed employing MTBF and MTTR as shown in equation (2)

$$\text{Operational availability} = \text{MTBF} / (\text{MTBF} + \text{MTTR}) \dots(2)$$

As can be seen from equations (1) and (2), an improvement of availability can be realized by reducing maintenance and repair time, if a failure occurs. Availability of a flight simulator varies from simulator to simulator and the maintenance organization, however, more than 98% is realized under the normal circumstances.¹

SYSTEM UPKEEP

Nowadays, maintenance of system equipment requires not only maintenance to satisfy function and performance of the equipment at the time of delivery, but also improvement to operational and maintenance effects. The aim of this is to enhance the value of the system for many years by re-evaluating the operability and safety of the program, timely improvement of the system to meet the operational requirements and to add additional functions for maintenance.

In this paper, this is called "system upkeep". System upkeep includes fulfillment of diagnostic functions, preventing schemes for malfunction, compiling maintenance data, improvement proposal, execution of the improvement and configuration control. To realize a perfect system upkeep, improvement in MTBF and MTTR must be considered during the development phase of the system and the emphasis must be placed on data analysis procedures and network construction from the beginning of the system development. Furthermore, it would be ideal to have a group of specialty personnel stationed at the site in addition to the regular maintenance crew. What would happen to the flight simulator, if this system upkeep is applied? We hope the system quality including the availability will be improved although the initial development cost may be increased slightly.

The basic equation of a flight simulator maintenance value. It can be expressed using the VE equation:

$$V = F / C.$$

Setting up two cases

The scope of the case study presented here deals with not only the maintenance of a single flight simulator but also the total maintenance configuration including a management center staffed with engineering personnel. Two cases are considered: first an ordinary maintenance approach whereby an emphasis is placed on keeping the function and performance of the simulator when it was delivered. The other case is to consider constructive modifications of the simulator after it is delivered.

Evaluation

Maintenance value will be evaluated by the availability and life cycle cost.

BASIC EQUATION OF MAINTENANCE VALUE

The maintenance value of a flight simulator can be obtained by the following equation:

$$V_s = F_s / C_s \dots\dots(3)$$

Maintenance value of a flight simulator. (Vs)

The objective of the maintenance is to improve availability and to maximize the training hours. Therefore, the maintenance value can be considered to have a training cost in its base rather than maintenance cost. In general, the largest difference between the maintenance cost and the training cost is that the training cost includes the development and production cost, training instructor's salary and modification cost to improve the function of the simulator. In this paper, a general maintenance value is defined by maintenance function divided by training cost.

Maintenance function of a flight simulator (Fs)

The maintenance function includes the operational needs, i.e., training. The maintenance function is defined as the function of availability and the extent of modification executed. The extent of modification can be evaluated by the extent of contribution toward training operations, for example, after delivery of the simulator, how many and when were the desired modifications performed.

$$F_s = f \text{ (availability and the extent of modification executed) } \dots\dots(4)$$

Training cost of a flight simulator (Cs)

Per hour training cost can be computed by the equation:

$$C_s = \text{Total training cost} / \text{Training hours} \dots\dots(5)$$

This value has a very significant meaning. For example, during the introduction of a flight simulator for pilot training, this value can be compared against the per hour training cost using an actual aircraft so as to justify the introduction of the simulator for the training.

Due to the varying types of aircraft and training contents, quantitative training comparison can not be done easily, however, flight simulator training cost is approximately 8 % of the training cost using aircraft according to one data.²

SETTING UP THE CASES AND COMPUTATIONAL RESULTS

Assumptions are listed below :

Production / Installation

Ten flight simulators are to be produced and each of the simulators will be installed at 10 different sites.

On site personnel

Maintenance personnel and training instructors will be stationed at each installation site.

Management center

The management center supports the operations and maintenance of the simulator.

Training hours

Planned training hours are assumed to be 1,500 hours for the two cases.

Case A

This is an ordinary approach case whereby maintenance will be performed to maintain the function and the performance of the simulator when it was delivered to the site. Each site will be manned by 5 maintenance / training instructor personnel. The management center will have 5 engineering personnel and will support corrective work of failures and logistics.

Case B

This is a maintenance approach whereby system upkeep is employed throughout the development, production, operations and maintenance phases. The development and production cost is slightly higher than case A, however, MTBF value is larger and MTTR value is smaller. As a result, the availability is improved and cost for logistic support becomes lower. Ten engineering personnel are located at the management center and this team performs preventive maintenance, replaces failed parts of each simulator and conducts constructive modifications. One less number of maintenance personnel than case A are stationed at each site.

Flight simulator maintenance value is evaluated for each of the model cases using equation (3) and the results are shown in Table 1.

TABLE 1. COMPUTATIONAL RESULT

<u>Cost Category</u>	<u>Case A</u>	<u>Case B</u>
<input type="checkbox"/> Parameters		
• maintenance and training personnel (men)	50	40
• engineering staff (men)	5	10
• training hours (Th) (hours)	1,500	1,500
• MTBF (hours)	90	100
• MTTR (hours)	1.25	1.0
• availability (%) $A = MTBF / (MTBF + MTTR)$	98.6	99.0
• extent of modification (M)	1.0	1.05
<input type="checkbox"/> Development & Production Cost, estimated		
• Development & Production Cost	\$ 83.3M	\$ 91.7M
<input type="checkbox"/> Operator & Maintenance Cost, estimated		
• manpower cost	\$ 89.4M	\$ 81.2M
• spare & repair parts cost	\$ 12.5M	\$ 6.9M
• recurring maintenance and modification cost	\$ 1.3M	\$ 1.4M
<input type="checkbox"/> Analysis		
• total training cost (Ct)	\$ 186.5M	\$ 181.2M
• simulator training cost $C_s = C_t / (Th \times 15)$	\$ 8.3K	\$ 8.1K
• simulator maintenance function $F_s = A \times M$	98.6	104
• simulator maintenance value $V_s = F_s / C_s$	11.9	12.8

Availabilities that are important to set parameters become 98.6 % for case A and 99.0 % for case B. It is relatively difficult to compute the cost effectiveness for the extent of modification executed (which is called parameters sensitivity), however, it is assumed that case B is better than case A by a factor of 1.05. To estimate the cost, a 15 year life cycle cost is used. As can be seen from Table 1, case B has a larger maintenance value than case A.

EVALUATION EMPLOYING AVAILABILITY AND LIFE CYCLE COST

The 0.4 % higher availability of case B compared with case A can be evaluated as follows.

The planned training hours of 1,500 hours are multiplied by this 0.4 % to obtain a value of 6 hours, which is an increase of training hours per simulator. From Table 1, the training cost per hour of flight simulator is approximately \$ 8,000 (Japanese yen of 960,000 is converted by a 120 yen to one dollar exchange rate). Therefore, \$ 48,000 expected effect is realizable per year. Life cycle consideration is important for the system equipment which requires a large sum of operation and maintenance cost.⁽³⁾ To evaluate a life cycle cost, a life cycle duration is set, yearly generated cost is computed and a cumulative cost is obtained. Figure 2 shows cost generated yearly for case A to cover the development, production, operation and maintenance phases.

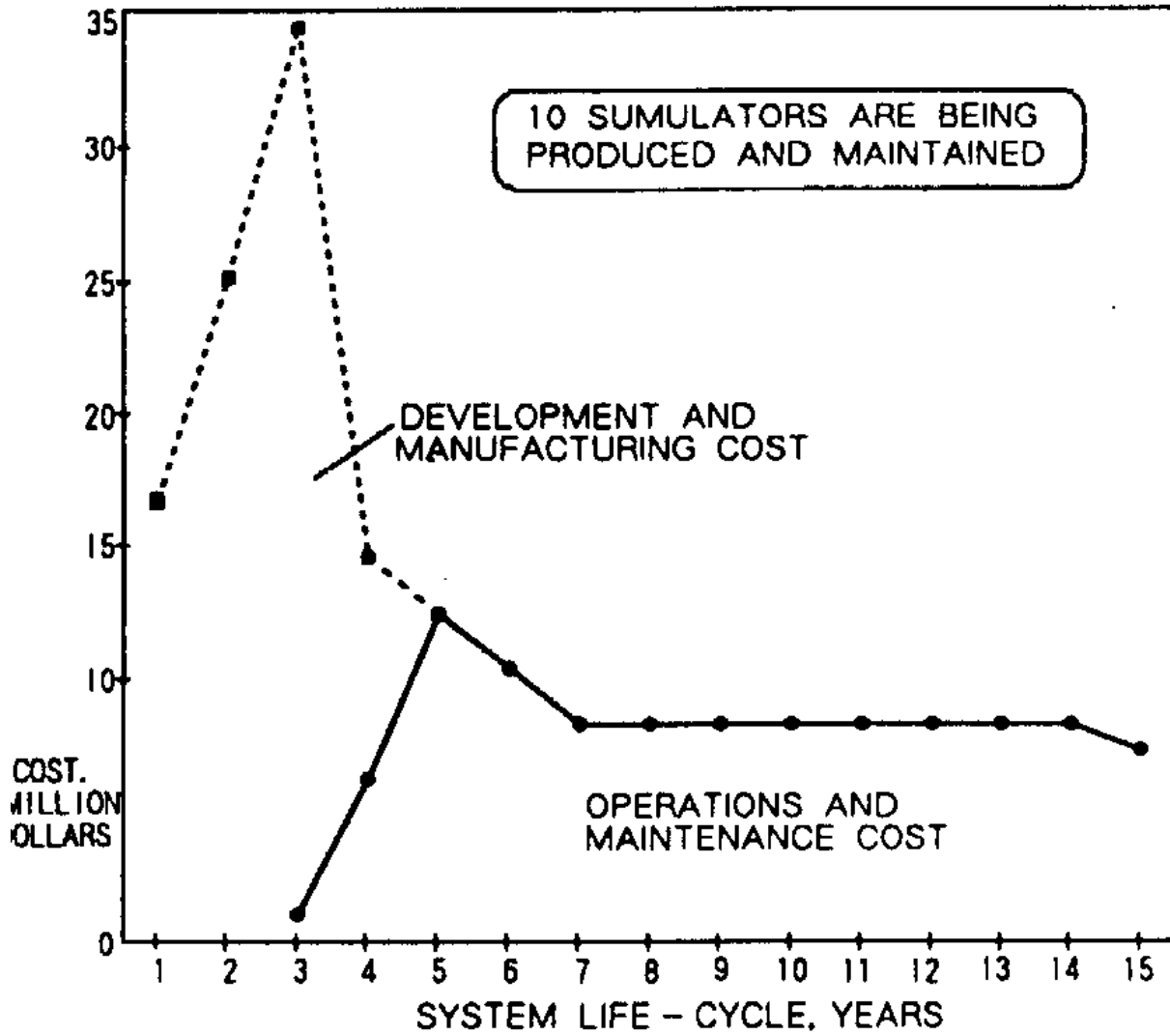


FIGURE 2. COST PROFILE FOR CASE A.

The cumulative cost comparison of cases A and B, life cycle cost comparison is shown in Figure 3.

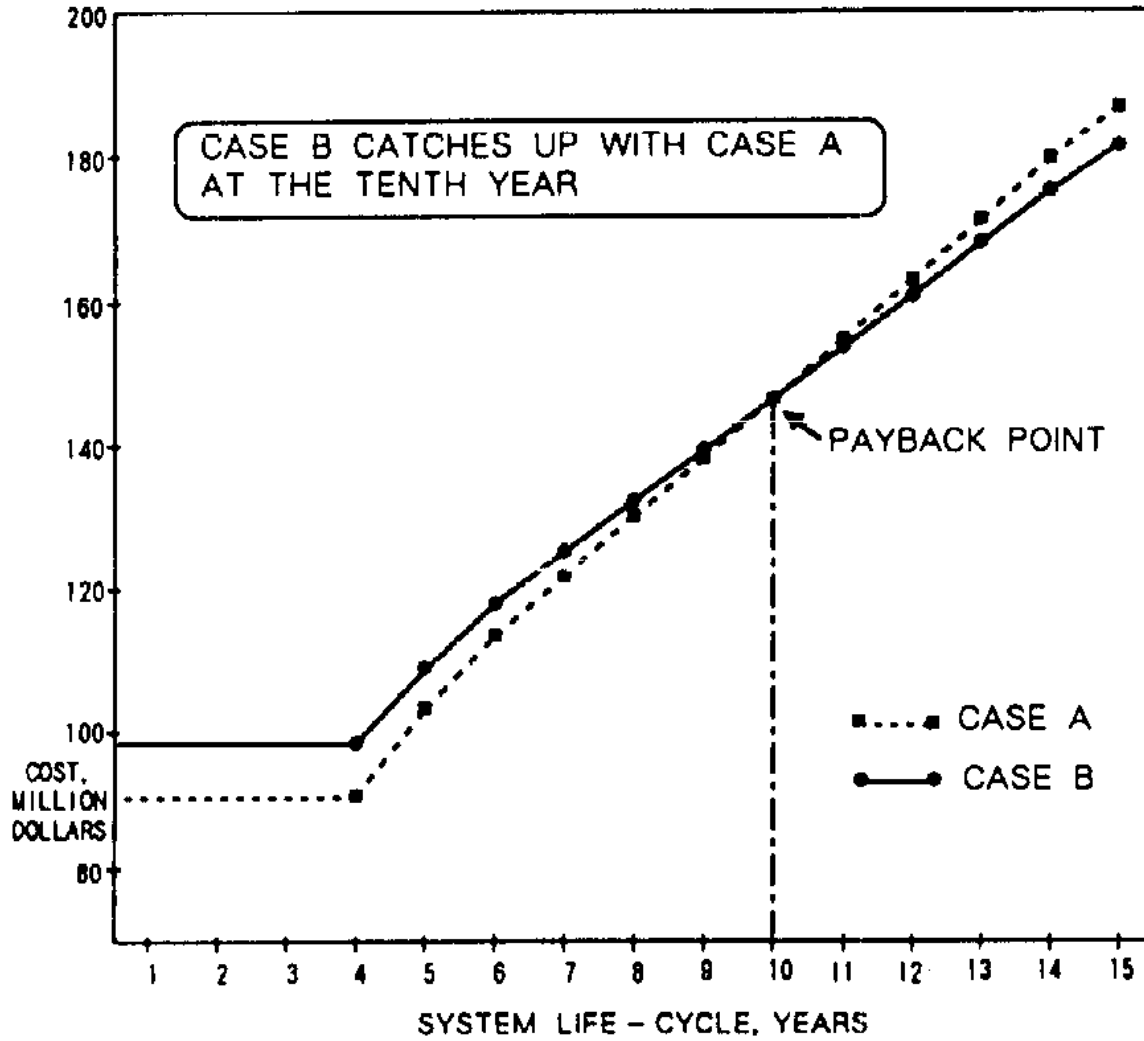


FIGURE 3. LIFE CYCLE COST ANALYSIS

Please note that the important point is not the comparison of the total cost of cases A and B, rather, it is when case B with its higher initial cost catches up with case A (payback point).

As can be seen from the result of Figure 3, case B catches up with case A at the 10th year and the total cost of case B will be lower than case A after that.

FOR THE FUTURE

What would be the future trend in the maintenance of system equipment? Artificial intelligence and network technology will advance greatly and the maintenance support system will expand immensely. Figure 4 depicts a typical flight simulator maintenance support system in the future.

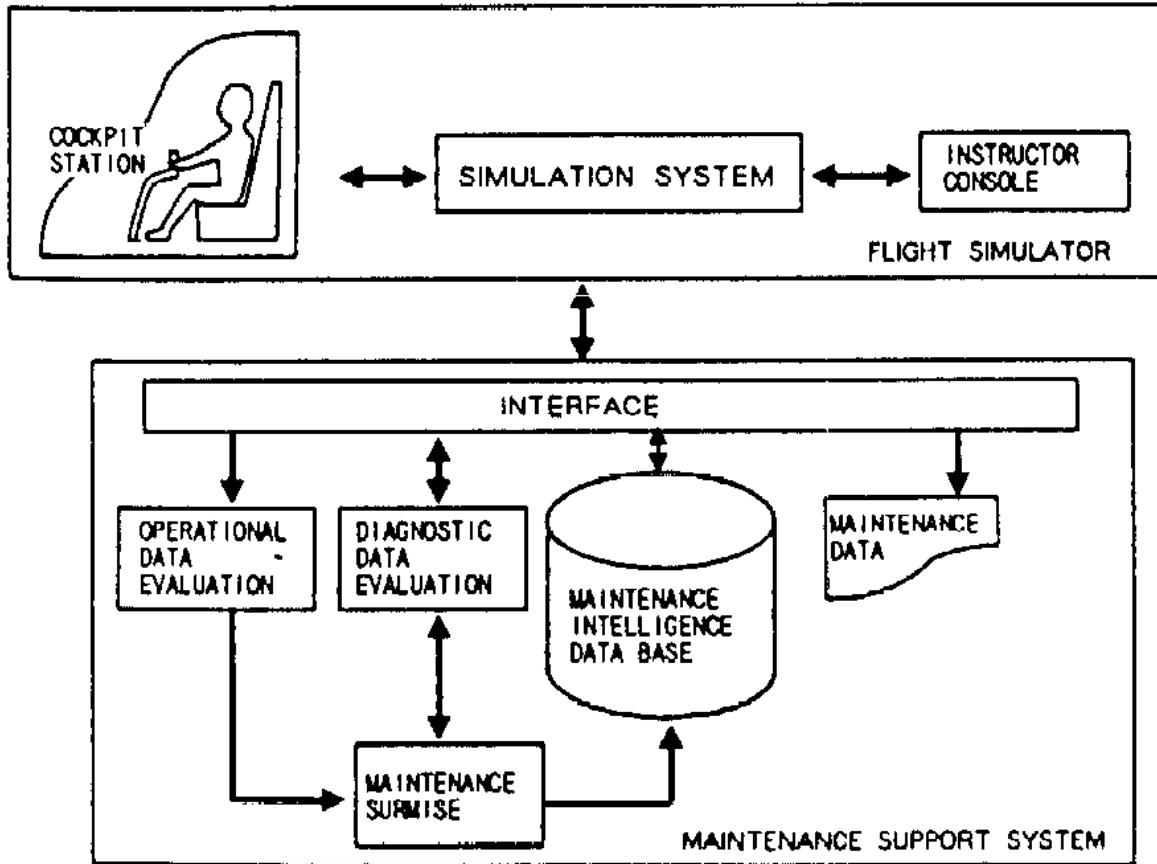


FIGURE 4. MAINTENANCE SUPPORT SYSTEM

Operational data and diagnostic data is taken during the operation, analysis is made and failure prediction and a quick reaction against the failure can be accomplished. As a result, diagnostics of failures can be performed automatically, quality improvement in spare parts supply, man power planning and maintenance training will be realized and constructive maintenance data can be supplied. This will enable one to achieve a close to 100 % availability, minimum life cycle cost and cost effective maintenance support system.

Maintenance is closely related to marketing. Should the aim of system upkeep be value enhancement, customer's trust can be obtained and a new market may be realized. Thus, maintenance could contribute to the marketing from the beginning and the emphasis on maintenance will be increased in the future.

ACCOMPLISHMENT

The following has been accomplished:

The basic equation to obtain maintenance value has been set up and a case study has been made.

A maintenance cost analysis has been performed emphasizing operational aspect of system equipment.

Life cycle cost has been evaluated.

In the evaluation of system equipment effectiveness, life

cycle cost may play a larger role even though there exists a higher initial development cost. This basic thinking is applied from the maintenance point of view.

EPILOGUE

Let me review the history of marketing in Japan. Till 1970s, mass production and high quality were important factors and how to manufacture these products was the main goal. In the 1980s, higher value added was the main theme and what to produce was the primary concern. In the 1990s, customer's satisfaction are the key words and product value has a higher priority than product price. Creation of a value is an eternal theme and no exception exists in the maintenance field. In the future of system equipment maintenance, what sort of value should be found in which portion of the system will be the main problem.

In this paper one way of thinking about system equipment maintenance value has been described and a case study examined. It is hoped that this will contribute to the many discussions that will take place to define the value of maintenance of system equipment.

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