KERNFORSCHUNGSZENTRUM

KARLSRUHE

Oktober 1973

KFK 1929
EUR 4972

Institut für Angewandte Systemtechnik und Reaktorphysik
Projekt Schneller Brüter

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CONSIDERATIONS FOR AN EUROPEAN CENTRALIZED RELIABILITY DATA BANK SYSTEM

by

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Paper published in the proceedings of the "International Seminar on Reliability Data Banks" - held in Stockholm from the 15th to the 17th October 1973.

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Abstract

Today's reliability data banks are still unsatisfactory. The disadvantages of these banks are briefly analyzed and it is concluded that future banks may improve the quality of their services, if they are more specialized, and connected through a centralized system. In this way it should be possible to satisfy the more severe reliability requirements which are continuously requested for technological applications in highly reliable systems, such as energy systems, transportation systems and computer industry. This can be obtained by a high degree of knowledge of the device's properties based on past experience. In order to acquire this high degree of knowledge, the knowledge of the manufacturer and that of the user must merge together through an integrated learning process. This process requires the complete exchange of information between the manufacturer of a given device and the user.

In the case of replaceable devices, new (not yet used) devices will be tested only initially in order to provide sufficient knowledge to render the devices operationable. Later, since the preventative maintenance policy will be currently adopted, lifetests will be carried out preferably on used devices, which were dismissed before failure after having been used for the allowed length of time. It turns out that the learning process takes in this case the form of a cycle. The cycle begins when a new device starts operation in the user's plant, and it ends when the information gained from the lifetests, carried out in the laboratory on the same device (now called "used device"), reaches the user through the "bank". Information will be produced continuously, and the speed of learning will be a function of the flow of devices in the cycle, that is to the ratio between the number of devices present in the cycle and their residence time in the cycle. Various strategies of learning are therefore possible, and some of them are also discussed.

Finally the motivations are analyzed for establishing a centralized system, and the associated problems discussed.

BETRACHTUNGEN ÜBER EIN ZENTRALISIERTES EUROPÄISCHES ZUVERLÄSSIGKEITSDATENBANKSYSTEM

Zusammenfassung

Die heute bestehenden Zuverlässigkeitsdatenbanken sind noch unbefriedigend. Die Nachteile dieser Datenbanken werden kurz analysiert, und der Autor gelangt zu der Schlußfolgerung, daß künftige Datenbanken die Qualität ihrer Dienstleistungen verbessern können, wenn sie stärker spezialisiert und über ein zentralisiertes System miteinander verbunden sind. Auf diese Weise dürfte es möglich sein, die immer strengeren Anforderungen an die Zuverlässigkeit zu erfüllen, die an die Technik in den mit hoher Zuverlässigkeit arbeitenden Systemen, beispielsweise Energiesysteme, Transportsysteme und Computerindustrie, gestellt werden. Dies ist erreichbar durch einen hohen, auf früheren Erfahrungen beruhenden Kenntnisstand hinsichtlich der Eigenschaften einer Komponente. Um diesen hohen Kenntnisstand zu ermöglichen, müssen die Kenntnisse des Herstellers und des Benutzers über einen integrierten Lernprozeß zusammenfließen. Dieser Prozeß macht den vollständigen Informationsaustausch zwischen dem Hersteller einer bestimmten Komponente und dessen Benutzer erforderlich.

Bei austauschbaren Komponenten werden neue (ungebrauchte) Komponenten nur zu Anfang getestet, damit die zur Inbetriebnahme erforderlichen Kenntnisse erworben werden. Da die Methode der präventiven Wartung in zunehmendem Maße angewandt wird, werden später Tests zur Bestimmung der Lebensdauer vorzugsweise an gebrauchten Komponenten durchgeführt, die nach der Benutzung während der zulässigen Zeit vor dem Ausfall entfernt wurden. Dabei zeigt sich, daß der Lernprozeß in diesem Fall die Form eines Zyklus hat. Der Zyklus beginnt, wenn ein neuer Teil in der Anlage des Benutzers in Betrieb genommen wird. Er endet, wenn die Information, die aus Lebensdauertests im Labor gewonnen und von denselben Komponenten durchgeführt wurde - (jetzt gebrauchte Komponenten genannt) -, den Benutzer über die Bank erreichen. Die Informationen werden ständig hervorgebracht, und die Lerngeschwindigkeit richtet sich nach dem Fluß der Komponente im Zyklus, d.h. nach dem Verhältnis zwischen der Anzahl der im Zyklus vorhandenen Komponente und ihrer Verweilzeit im Zyklus. Deshalb sind verschiedene Lernstrategien möglich und einige davon werden auch diskutiert.

Schließlich werden die Gründe für die Einrichtung eines zentralisierten Systems untersucht und die dabei auftretenden Probleme diskutiert.

Manuskript z.Druck einger. 4.2.74

Contents

1. Foreword

This paper has been written because of a special request made to the autor by Dr. Olle Björklund, chairman of the "International Seminar on Reliability Data Banks", held in Stockholm, the 15th - 17th October 1973.

At this conference a paper was presented by Mr. Olle Loftsjö of the swedish firm "AB Teleplan" with the following title "The search for reliability data on equipment units intended for complex systems". At the end of his presentation, Mr. Loftsjö asked for a stronger national and international cooperation among various firms, as a means of improving the effectiveness of the application of the reliability methods. Particularly, he pointed out that to organize centralized reliability data bank systems could be perhaps the rigth thing to do.

After Mr. Loftsjö's paper, there was a long discussion among the participants during which the writer pointed out that a proposal for an european centralized reliability data bank system has already been proposed by him to the Commission of the European Community in Brussels. The writer has called this system "European Reliability Network" (E.R.N).

The present paper is a summary of the ideas on which the author's proposal is based.

2. Introduction

Modern technology continuously request higher and higher degrees of reliability. Clear examples are the nuclear, computer, airplane and rocket industries, where reliability plays a vital role. No one in fact would let a company build a nuclear plant, if it is not possible to prove that the probability of an accident is below the threshold of acceptance. No one would fly in an airplane, if they were not sure that the probability of an accident during the trip was so low, that they would be prepared to accept this risk against the advantage of considerable less travel time than by other means, such as a train or ship.

The request of reliability is also dictated by economical considerations, which are extremely important to modern society. If one thinks for example of the enormous economical loss due to the unplanned shut down of a 1000 MWe electric nuclear power plant for only a few hours, one would immediately recognize that the plant must be designed and operated in such a way that the probability of an unwanted shut down is very low.

For these reasons people want to be able to predict as precisely as possible the time of failure of the various devices incorporated in a complex system, as well as the time needed for their repair.

Data about the operating history of the devices and about lifetests results are therefore being collected and stored in "data banks", where they can also be processed to give the desired prediction. Today's banks are still very primitive. Data belonging to any type of device used in any industrial branch are being collected and stored in these banks. However for each device only relatively few data are being collected, so that predictions are still inaccurate. In order to improve the situation, more data should be collected by using more reliable methods of collection, and these data should be analysed in a more sophysticated way. Future banks should be perhaps more specialized. Each bank should deal with a lower number of device types, and therefore be able to collect more data about each type. In addition, data should be analyzed using correct theoretical models. In this way it should be possible to improve the precision of the predictions, especially in the case of extrapolating results from the known behaviour of a device under given operating conditions to predict the still unknown behaviour of the same device under different operating conditions.

Present banks act independently, so that their systems of collecting, handling and processing data are not always compatible. This makes more difficult the exchange of information among different banks. Further, it has already been observed that data which were given from one bank to another, were offered later as new data to the first one from a third bank.

A centralized reliability data bank system would have the great advantage of easing the exchange of information because of the full standardization of definitions, terminologies and of the methods of collecting, handling and processing the data. In addition, circulation of false information would certainly be reduced, if not completely eliminated.

3. Basic features of an "European Centralized Reliability Data Bank System"

Fig 1 shows a tentative schematic block diagram for an "European Reliability Network" (E.R.N). Manufactures, users, banks and laboratories are all indicated by means of boxes. They will be called simply "units". A manufacturer may be a firm which produces valves or pumps or electric motors, and a user may be an airline company or an electricity producer, which uses these components. The information accumulated during the past about a given component is stored in the data banks. Components can be analysed and tested in the laboratories. Tests can also be lifetests. Banks, manufacturers, laboratories and users can be connected in any possible wanted combination through the "Coordination and Synthesis Center" (C.S.C.). A typical connection is that shown in Fig. 2, which allows for a fully integrated learning process. Solid lines in Fig. 2 indicate flow of materials, while the dotted lines indicate flow of information. The C.S.C. has not been shown in Fig. 2. Let us now examine how the diagram of Fig. 2 functions.

The manufacturer "A" gives a sample of new devices (for example "valves") to the laboratory where liefetests are carried out. The information gained from these tests, together with that coming from the manufacturer, is stored in the "Bank" where it is processed and made available to the user "B", who buys the device from A. The user B operates the device for a length of time determined by the desired level of reliability and then replaces the device with a new one (preventative maintenance). The used device is then given to the laboratory, while the information on the operating experience of the device is given to the bank. The laboratory will perform a lifetest on the used device and will give the information gained from these tests to the bank. Information about devices which eventually fail during operation in the user's plant is also given to the bank. Failed devices may also be given to the laboratory to better analyze causes of failure. The information stored in the bank is available to the laboratory, to A and to B.

With the cheme of Fig. 2 only a limited number of new devices must be sacrificed initially in order to get an initial amount of knowledge about the characteristics of the device. Later, further testing of new devices is not needed, since used devices will be tested instead. The integrated learning process of Fig. 2 has the form of a cycle. The cycle begins when the new devices enter the cycle at "E", where they start to be operated by the user, and it ends when the information gained from the lifetests, carried out in the laboratory on the same devices (now called "used devices"), reaches the user through the bank. Based on the information in the bank, the user will revise the operating time of other new devices arriving at "E". This starts a new cycle, characterized by a higher level of knowledge. This process can be repeated continuously and indefinitely.

A second path is possible, in which the user is by-passed, (path CD) and where the new devices are given directly to the laboratory. This path will be used especially at the beginning to obtain initial information. If we neglect the initial period in which only the new devices are tested, the rate of increase of knowledge will be a function of the flow N/T of the devices in the cycle, where "N" is the number of devices which are present in the cycle at a given time, and "T" is the amount of time a device resides in the cycle, including the operating time. Since lifetests will be accelerated, the longer the operating time, the longer T. At the beginning, the degree of knowledge is low and therefore the incentive to know more about the device is very high. On the other hand, since the properties of the device are not well known and since the user is bound to operate the device with a preestablished degree of reliability, he will tend to operate the device for a shorter time. This produces a high rate of increase of knowledge. The level of knowledge will increase and this in turn will produce a longer operating time. The higher the level of knowledge, the longer the operating time, and therefore the lower the rate of increase of knowledge. When the knowledge has reached a very high level, the operating time will be long and the rate of increase of knowledge will be low. The incentive to know more about the device's properties is decreased, because a high level of knowledge has already been reached. The above discussion gives an idea of the dynamics of the process, when the degree of reliability imposed on the user is the only criterion which is used to decide the length of the operating time.

But one can also think of other strategies. For example it may be economically more convenient to artificially reduce the operating time at the beginning in order to reach a given level of knowledge faster. An extreme case is the path CD (Fig. 2), where the operating time is zero. The loss due to a shorter operating time at the beginning must be counterbalanced by increased operation over a longer period of time.

Fig. 3 shows various paths of a learning process by giving the allowed operating time of a device as a function of the time. A path is that indicated with OBDE. This would correspond to the case in which the operation of the devices is started after one has obtained their reliability by measn of lifetests performed on new devices over the time interval OB. At the time corresponding to the point B the knowledge has been gained which would allow one to operate the device in the user's plant up to the final value of its operating time with the associated maximum allowed value of the failure rate, which may dictated to the user by safety regulations or by economical considerations. This would correspond in Fig. 2 to the case in which only the path CD is used. This learning process is very safe, but it may also be very expensive. If instead, one makes use of the path CD (Fig. 2) only at the beginning to acquire an initial knowledge and then takes advantage of the cycle by making lifetests on the used devices, one would get a path in Fig. 3 of the type OFGCE. New devices will be tested (path CD in Fig. 2) until the time corresponding to the point F is reached. At this time, for a given maximum value of the failure rate, the allowed operating time of each device is lower than its final value.

The allowed operating time now increases with time (GC in Fig. 3) because of the knowledge continuously gained by means of the lifetests on the used devices (cycle in Fig. 2).
For a given maximum failure rate there is a family of learning paths of the type OFGCE, which may be obtained by properly choosing the stress levels in the laboratory for lifetests (accelerated tests). The learning path also depends upon the number of devices which are put into operation. Among all possible paths belonging to a given family, the most economical path should be chosen. The "integrated learning process" of Fig. 2 provides also a means to quickly diagnose devices that need improvement, and provides useful information for their redesign.

The decision wether or not a new type of device can be introduced in the market will be made easier. Knowledge about its properties will be lower than that of other types of devices which have been on the market for a long time. Only if the properties of the new type of device are decisively better and if its cost is decisively lower,will it be possible to overcame the initial disadvantage of the lower level of knowledge.

The schematic diagram of Fig. 2 does not represent by any means the only possible type of connection among the various units of the E.R.N., but only one of the its most appealing features. Situations may also arise in which laboratory tests on used devices are not feasible, or economically not convenient, or in which devices are allowed to fail during operation. Another function of the C.S.C. is that of promoting the exchange of information among the various units of Fig. 1, so that, for example, sets of data stored in two or more banks can be processed in order to produce new results, which synthetize the information contained in the old sets.
"Integrated learning processes" can also be organized in which many manufacturers, users, banks and laboratories are involved.

4. Motivations for establishing a centralized system,and associated problems

The idea of organizing an european centralized reliability data bank system is very appealing, because it has the potential of promoting "integrated learning processes", which will increase considerably the reliability and availability of devices and systems. (1)
In order to make these "integrated learning processes" more effective, a higher level of standardization is required in the fabrication processes of technical devices, and in their installation methods and maintenanance procedures. Lifetime data must be analyzed, as much as possible, by means of correct theoretical models. Diagnostic tests during device operation are also highly desirable, because these may improve the knowledge of the state of the devices during operation.
However the main improvements are needed in the areas of collecting, handling and processing the data. Information must be handled with a formal and universal language; it must be precise, complete, and the access to it must be easy and free (as much as possible).
Free access to the information is of course the ideal objective to be achieved. There are however serious difficulties in pursuing this goal. A manufacturer is reluctant to release information about its own products to its competitors, because of the commercial value of it. On the other hand it is evident that all manufacturers of a given device would benefit from the exchange of information, because this would accelerate the learning process and would certainly reduce its costs. A compromise must be found. People must learn how to attribute a value to a given information, in order to be able to sell and buy it quickly through a centralized reliability data bank system. Modern technology provides means which can allow a fast and effective exchange of information. This is economically possible also because in the field of computers, the cost per bit is expected to fall by a factor 1000 in the next decade. (2)
The main delays come now from the calculation of the commercial value of the information, on which the two contracting parties must agree, before they can exchange this information.
Another important point it that which may arise from safety considerations. Consider for instance the case of devices, which contribute significantly to

(1) Caldarola "New definition of reliability, continuous lifetime prediction and learning processes" International NATO Conference on Reliability, University of Liverpool, England 16-27 July 1973, KFK 1847 and EUR 4969e

(2) Alan J. Perlis, "Computers", 1973, Britanica Yearbook of Science and the Future.

the safety of ariplanes or of nuclear power stations. The user of the planes is an airline company and the consumers are those who travel with these planes. They are the persons who risk their lifes when travelling, and have therefore the right to be assured that the planes have really the reliability which is declared to the public. This is a very delicate point. The reliability of the plane is a function of the whole knowledge which has been accumulated during the past. (3) If somebody inserts some false information into the banks, a reliability may be calculated which is higher than the true one.

This argument is of crucial importance, and should be therefore sufficient to reach the conclusion that, in the cases in which safety considerations are predominant, an independent and impartial national or international organization should have some kind of control on the information flowing in the reliability network of Fig. 1, so that there can be a sufficient guarantee for everybody that the information is produced, handled, and processed in an impartial manner.

This guarantee is necessary for the "public acceptance" of the risks associated with the use of advanced technological systems. In these last years there has been a lot of concern about these risks. Advanced technological projects have been cancelled in the USA, because of the pressure of public opinion against them. Some authors (4) have started to develop risk versus benefit analysis in a quantitative way. The imput data to these analysis comes from the banks, and public opinion would become very suspicious if the control of the information is completely left in the hands of profit making private enterprises.

(3) See the new definition of reliability in the previously cited publication of the author.

(4) Chauncey Starr "Benefit-cost studies in socio-technical systems" Colloquium on Benefit-Risk Relationships for decision making - Washington D.C. USA, April 1971.

5. Conclusions

The adoption of a centralized reliability data bank system will be a revolution in the fields of design, production and operation of technical devices. Further, the important problem must be solved to find a compromise between the opposing requirements of the free circulation of information on one side, and the natural tendency to withhold information on the other side, that manufacturers are bound to have because of the competitive nature of the western society.

We have also seen that the main motivations for establishing a centralized system are essentially twofold

(1) To rationalize the learning processes and to reduce their costs.

(2) To guarantee the public that information is produced, handled and processed in an impartial manner. This is the case in which safety considerations are predominant.

All the existing human scientific and technical knowledge must be organized in the banks, and more information must be produced at high rates to make the learning processes more effective. This is a gigantic task, which will require a tremendous coordinated effort in all fields of scientific and technical research.

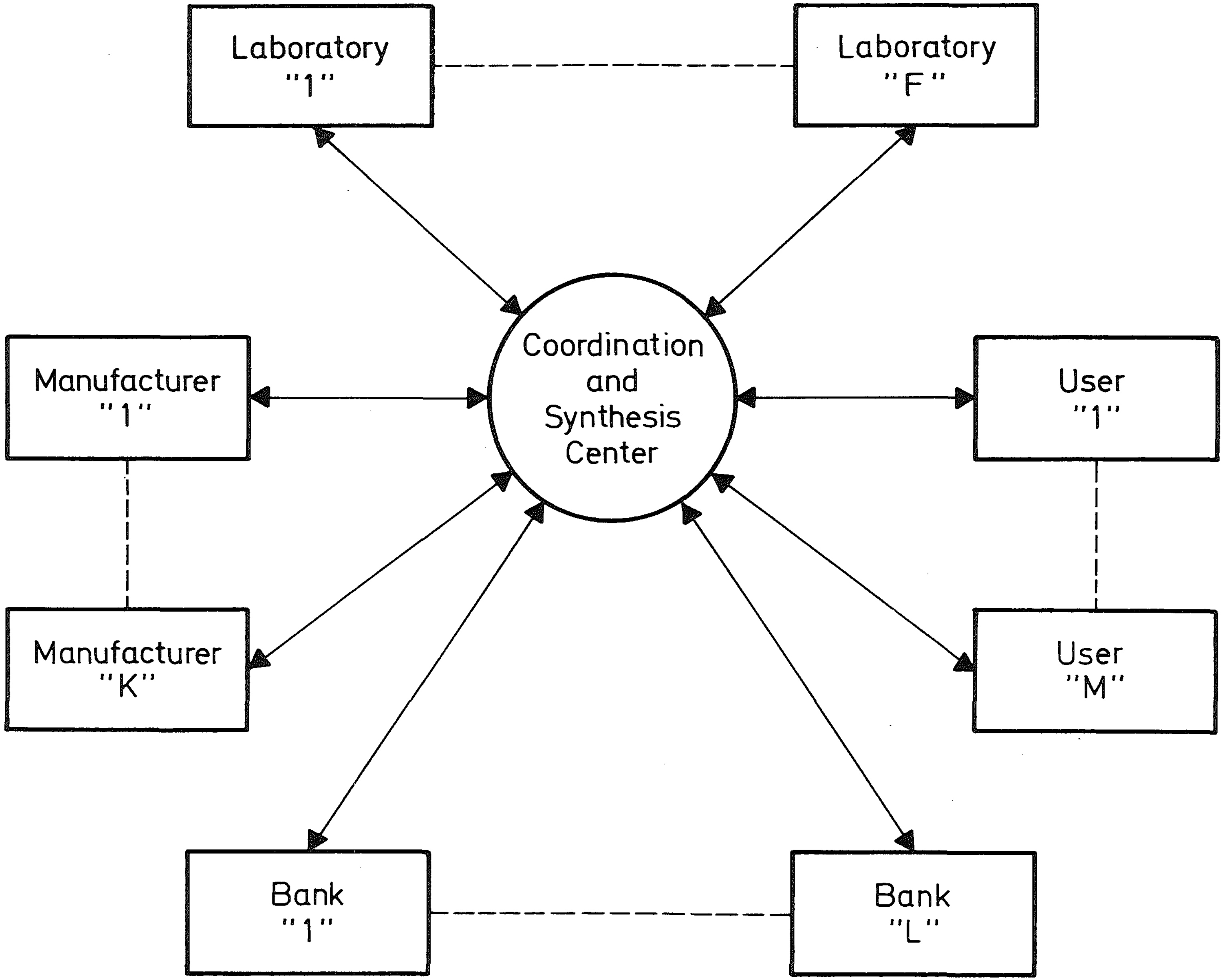

Fig.1 Schematic Diagram for an "European Reliability Network" (E.R.N.)

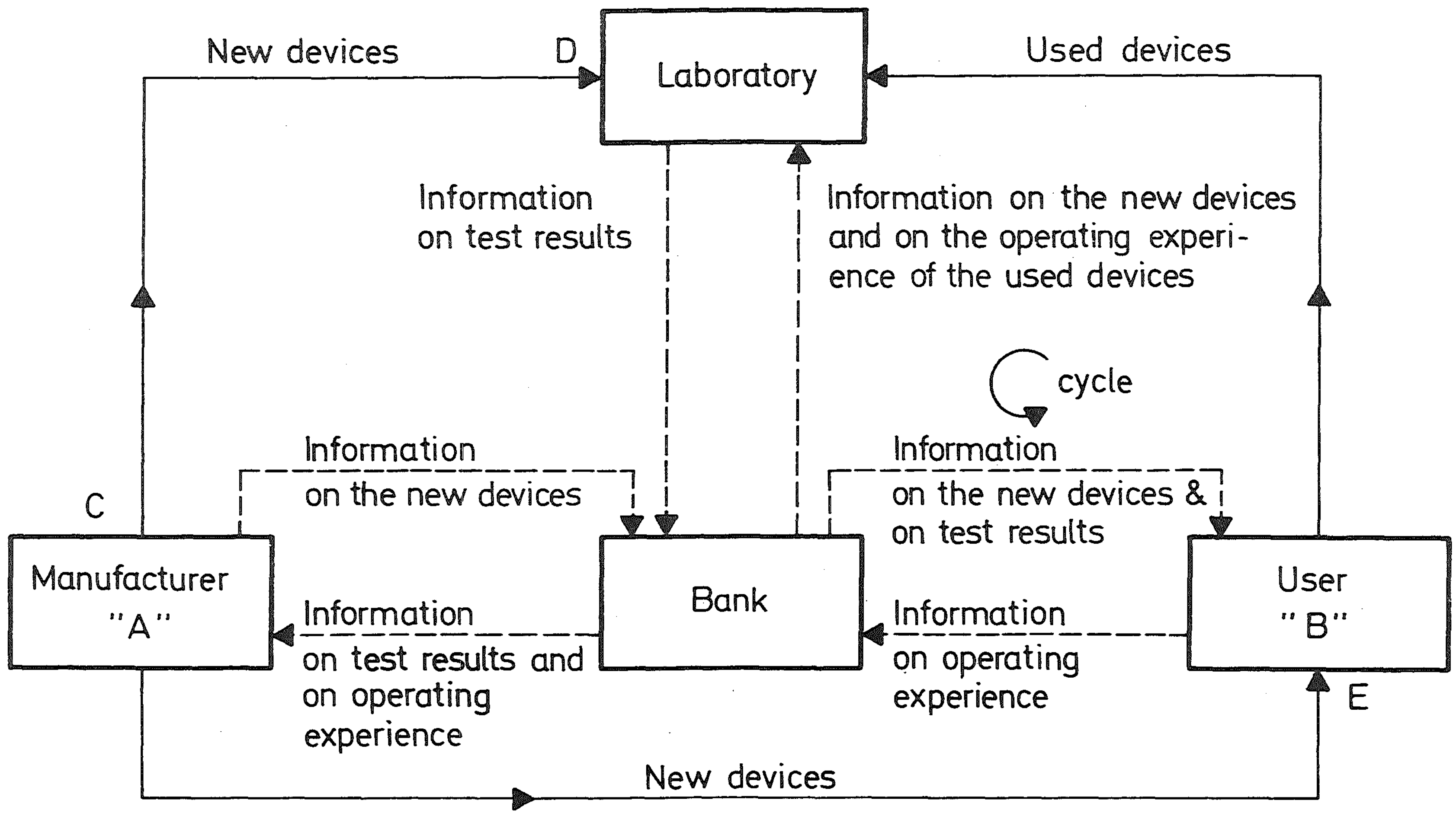

Fig.2 Schematic Diagram of an Integrated Learning Process.

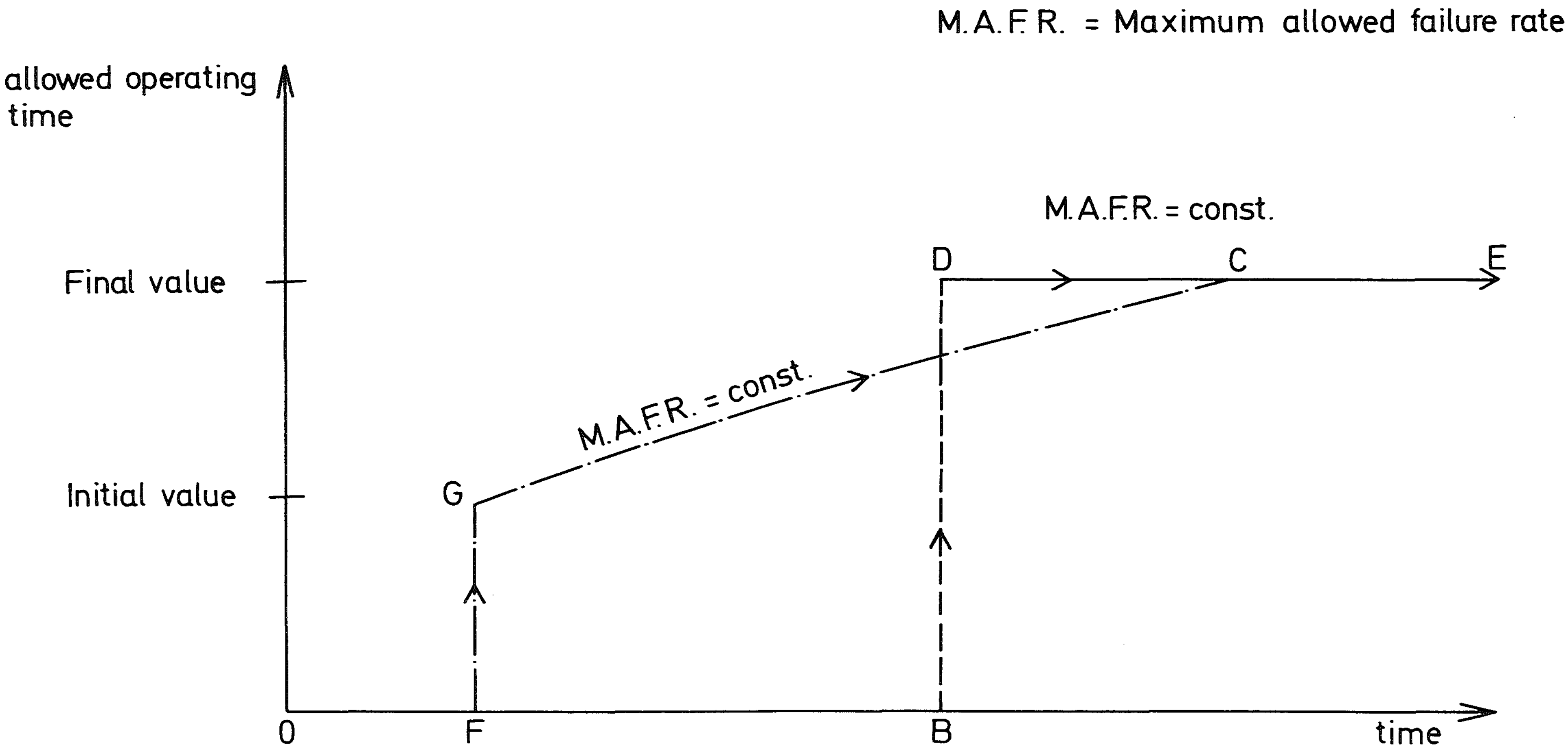

Fig.3 Various Paths of a Learning Process