

## MAINTAINABILITY, MAINTENANCE, AND RELIABILITY

Maintainability is becoming increasingly important because of the alarmingly صور high operating and support costs of systems and equipment. For example, each year the U.S. industry spends over \$300 billion on plant maintenance and operations, and for the fiscal المالية year 1997, the operation and maintenance budget request of the U.S. Department of Defense was \$79 billion. Thus, some of the objectives for applying maintainability engineering principles to systems and equipment are to reduce projected maintenance cost and time through design modifications directed at maintenance simplifications, to use maintainability data for estimating equipment availability or unavailability, and to determine labor hours and other related resources required to perform the projected maintenance.

Since the Industrial Revolution, maintenance of engineering systems has been a continuous challenge. Although impressive progress has been made in maintaining equipment in the field, maintenance of equipment is still a challenging issue because of various factors including complexity, cost, and competition. Each year billions of dollars are spent on engineering equipment maintenance worldwide, and it means there is a definite need for effective asset management and maintenance practices that can positively influence success factors such as quality, safety, price, speed of innovation الابتكار , reliable delivery, and profitability.

The reliability of engineering systems has become an important issue during the design process because of the increasing dependence of our daily lives and schedules on the satisfactory functioning of these systems. **Some examples of these systems are computers, aircraft, space satellites, nuclear power-generating reactors, automobiles, and trains.** Some of the specific factors that play, directly or indirectly, an instrumental role in increasing the importance of reliability in designed systems include high acquisition شراء cost; complexity; safety-, reliability-, and quality-related lawsuits دعوي قضائية ; public pressures; and global competition المنافسة العالمية .

These factors clearly indicate a definite need for **maintainability, maintenance,** and reliability professionals to work closely during **the product design and operation phases.** To achieve this goal successfully, it is absolutely essential that they have some understanding of each other's discipline انضباط . Once this goal is achieved, many of these professionals' work-related difficulties will be reduced to a tolerable مقبول level or disappear تختفي altogether, thus resulting in more reliable and maintainable or maintained systems.

## HISTORY

This section presents an overview of historical developments in maintainability, maintenance, and reliability.

### 1. MAINTAINABILITY

An early reference to maintainability may be traced back to 1901 to the Army Signal Corps contract for development of the Wright brothers' airplane, in which it was clearly stated that the aircraft should be “**simple to operate and maintain**”. In the modern context, the beginning of the maintainability discipline may be traced back to the period between World War II and the 1950s, when various efforts directly or indirectly concerned with maintainability were initiated. One example of these efforts is a **12-part series of articles that appeared in *Machine Design*** in 1956 and covered topics such as design of electronic equipment for maintainability, recommendations for designing maintenance access in electronic equipment, and designing for installation.

In 1960 the U.S. Air Force (USAF) initiated a program for developing an effective systems approach to maintainability that ultimately resulted in the development of maintainability specification MIL-M-26512. Many other military documents concerning maintainability appeared in the latter part of the 1960s. Two examples of these documents are MIL-STD-470 and MIL-HDBK-472.

The first commercially available book on maintainability, *Electronic Maintainability* appeared in 1960. Over the years many other developments in the maintainability field have taken place.

### 2. MAINTENANCE

Although humans have felt the need to maintain their equipment since the beginning of time, the beginning of modern engineering maintenance may be regarded as the development of the **steam engine by James Watt** (1736–1819) in 1769 in Great Britain [9]. In the United States the magazine *Factory* first appeared in 1882 and has played a pivotal role in the development of the maintenance field. In 1886 a book on maintenance of railways was published.

In the 1950s **the term preventive maintenance** was coined, and in 1957 a handbook on maintenance engineering was published. Over the years many other developments in the field of engineering maintenance have taken place, and today many universities and other institutions offer academic programs on the subject.

### 3. RELIABILITY

The history of reliability engineering may be traced back to World War II, when the **Germans** are reported to have first introduced the reliability concept to

improve the reliability of their **V1 and V2 rockets**. In 1950 the U.S. Department of Defense established an ad hoc مخصص committee on reliability, and in 1952 it was transformed to a permanent group called the **Advisory Committee on the Reliability of Electronic Equipment (AGREE)**. The committee released its report in 1957.

In 1954 a national symposium ندوة on reliability was held for the first time in the United States, and in 1957 the USAF released the first military specification (MILR-25717 [USAF]), **“Reliability Assurance Program for Electronic Equipment”**.

In 1962 the first master’s degree program in system reliability engineering was started at the Air Force Institute of Technology in Dayton, Ohio.

Over the years many other developments in reliability engineering have occurred.

## **MAINTAINABILITY, MAINTENANCE, AND RELIABILITY TERMS AND DEFINITIONS:**

Many terms and definitions are used in maintainability, maintenance, and reliability engineering work. The followings are some of the frequently used terms and definitions in these three areas taken from various sources:

### **Maintainability:**

The **probability** that a failed item will be restored استعادة to its **satisfactory operational state**

### **Maintenance:**

All **actions** necessary for retaining الاحتفاظ an item or equipment in, or restoring it to, a **specified condition** شرط محدد

### **Reliability:**

The **probability** that an item **will perform** its assigned mission مهمة satisfactorily for the stated time period when used according to the specified conditions

### **Availability:**

The **probability** that an item is available توفر for use when required

### **Mission time:**

The time during which the item is carrying out its assigned mission

### **Downtime:** التوقف

The total time during which the item is not in satisfactory operating state

### **Logistic time:**

The portion of downtime occupied by the **wait** for a required part or tool

### **Failure:** الفشل

The inability of an item to operate within the defined guidelines مبادئ توجيهية محددة

### **Serviceability:** للخدمة

The degree of ease or difficulty with which an item can be restored استعادة to its working condition

**Redundancy:** التكرار

The existence of more than one means for accomplishing انجاز a stated function

**Failure mode:** وضع الفشل

The abnormality الشاذ of an item's performance اداء that causes the item to be considered to have failed

**Human reliability:**

The **probability** of accomplishing انجاز a task successfully by humans at any required stage in the system operation with a given minimum time limit (if the time requirement is stated)

**Useful life:**

The **length of time** a product operates within a tolerable level of failure rate مستوى مقبول من نسبة الفشل

**Maintenance concept:**

A statement of the overall concept المفهوم العام of the product specification or policy that controls the type of maintenance action to be taken for the product under consideration

**Corrective maintenance:**

The repair or unscheduled maintenance to return items or equipment to a specified state, performed because maintenance personnel or others perceived deficiencies اوجه القصور المتصورة or failures

**Continuous task:**

A task that involves some kind of tracking تتبع activity (e.g., monitoring a changing situation)

**Human performance:**

A **measure** of human functions and actions under some specified conditions

**Active redundancy:**

A type of redundancy in which all redundant units are functioning simultaneously متزامنة

**Human error:**

The failure to carry out a specified task (or the performance of a forbidden ممنوع action) that could result in disruption انقطاع of scheduled operations or damage to property or equipment

**Active repair time:**

The period of downtime when repair personnel are active to effect a repair

**Inspection:**

The **qualitative observation** مراقبة نوعية of an item's condition or performance

**Overhaul:**

A **comprehensive** شاملة inspection and restoration استعادة of a piece of equipment or an item to an acceptable level at a durability متانة time or usage limit.