# Evaluation of Stress Affecting Aircraft Maintenance Technician's Performance

Ebru YAZGAN and Mehmet Şerif KAVSAOĞLU

***Abstract*—**The technology used in aviation has changed markedly over the past 50 years, particularly in terms of its reliability. Researches has shown that the internal reliability of humans has not improved noticeably over the same period. Thus engines, airframes and aircraft systems have contributed progressively less to the accident rate, the proportion of accidents attributable to human error has necessarily increased [1]. According to International Ergonomics Association [2] "Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance". "The overall goal of Aviation Maintenance human factors research is to identify and optimize the factors that affect human performance in maintenance and inspection" [3]. Human factors affect the quality of the jobs performed by the aircraft maintenance technicians, pilots and flight engineers.

The aircraft maintenance technician is the center part of the aircraft maintenance system. It is very important to understand how human body and mental process function and how performance limitations can influence a technician's effectiveness at work [4].

Several factors can affect a maintenance technician's performance. A person's vision, hearing, information processing, attention and perception, memory, judgement and decision making are among the physical and mental human performance characteristics which are likely to affect the quality of his work.

Stress, time pressure, workload, fatigue, distraction, overconfidence, lack of communication and awareness etc. may affect a technician's performance. In this study, the impacts of stress on the quality of the work performed by an aircraft maintenance technician are investigated. Some aviation accidents, for which this factor is causal or contributory, is studied along with the desired requirements in aviation legislation. Thus, it has been tried to emphasize the importance of human factors in aircraft maintenance. It is expected that these studies on human factors and accidents will induce more research work on aviation safety**.**

***Index Terms*—** Human factor, Stress, Aircraft Maintenance Technician.

## I. Introduction

### *A. Human Factors In Aviation Maintenance*

Ergonomics (also called human factors or human engineering in United States) is the application of scientific principles, methods, and data drawn from variety of disciplines to the development of engineering systems in which people play significant role [5]. The scope of human factors is to consider the relationship of the discipline with other related domains of science and engineering. This is shown in Figure 1.

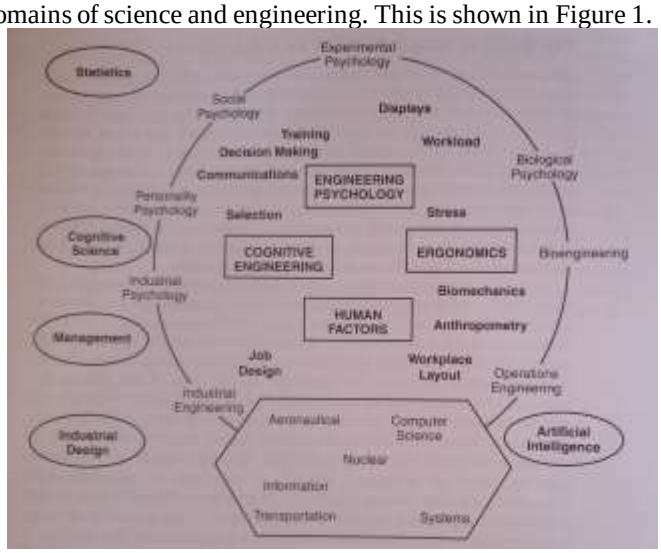


Fig.1 The relationship between human factors shown at the center, and other related disciplines of study [6].

Every day millions of people travel by land, water, and air. Aviation safety depends greatly on the efforts of everyone in the system, which unfortunately cannot be made risk-free. It is well known that human factors, which can be causal factors, are involved in aviation accidents [7]. Gramopadhy and Drury [8] stated that traditionally concentrated on the errors of flight deck personnel and air traffic controllers, but an increasing number of maintenance and inspection errors have led to a rise in research on and interventions in the area of human factors.

The use of the term "human factors" in the context of aviation maintenance operations is relatively new. Accidents such as that of Aloha Airlines Flight 243 in 1988 and the BAC 1-11 windscreen accident in June 1990 brought the need to address human factors in this environment into sharp focus. This does not imply that human factors were not present before these dates nor that human error did not contribute to other incidents; it merely shows that it took specific accidents to draw attention to these problems and potential solutions [9]. we have learned that maintenance error contributes to 15% of air carrier accidents and that maintenance error costs the US industry more than 2 billion dollars per year [10]. "Human factors" covers a vast range of activities, and they impinge on everything AMTs do on the job, from communicating

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effectively with colleagues to ensuring that they have adequate lighting to work accurately and efficiently [7].

The human factors approach in maintenance research considers the human as the center of the system as Fig. 2 indicates. The inputs to the system are aircraft, shown to the left of the human. System outputs are safe aircraft. Not only can human factors research have a significant effect on the design of new systems but it can also mitigate problems found in the sub-optimal designs of current systems

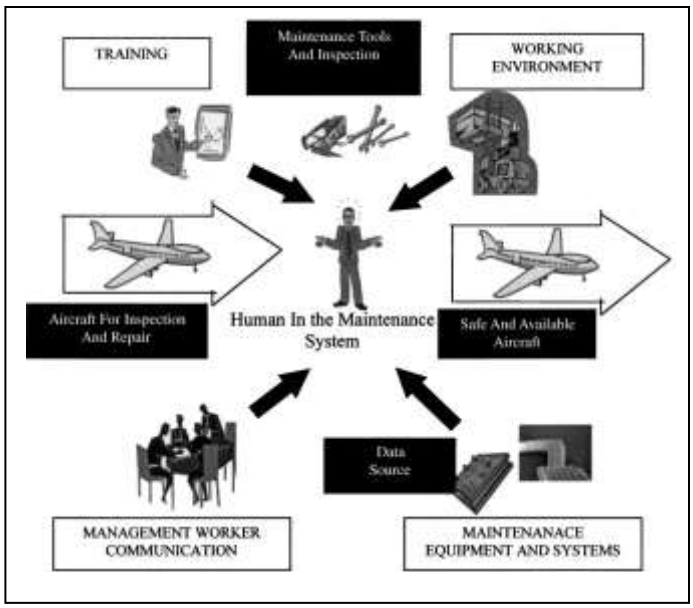


Fig. 2 Human in the maintenance system [8]

*B. Aircraft Maintenance Technician*

Aircraft maintenance is an essential component of the global aviation industry. Aviation maintenance is a complex organization in which individuals perform varied tasks in an environment with time pressures, minimal feedback, and sometimes difficult ambient [11]. The main role of the maintenance technicians is to categorize and judge critical problems that can threaten the airworthiness of the aircraft, and if found critical perform appropriate maintenance so that the aircraft can continue operations [12].

Aviation is controlled by a complex web of national and international laws and agreements, which are intended to facilitate smooth, trouble-free air travel to the highest standards [13].

The rapid growth of the airline industry has emphasized the importance of effective and efficient maintenance. Revenue, passenger miles flown, and the number of aircraft have all exceed the overall growth of the Aircraft maintenance technician (AMT) workforce. Furthermore, new skills and knowledge are required to maintain the modern technologically advanced aircraft. Finally, there has been a continuing decline in both the number of people applying to training programs for AMTs and the percentage of program graduates who stay in aviation. An obvious conclusion is that AMTs must raise efficiency to match the increasing workload [8].

Chang and Wang [7] developed the SHELLO model, which incorporates the human factors of AMTs, with liveware at the center. The model consists of the key primitive liveware of SHELL and its five interactive dimensions: the core capacity of AMTs (Liveware, L), interaction between AMTs and software (Liveware–Software, L–S), interaction between AMTs and hardware (Liveware–Hardware, L–H), interaction between AMTs and the environment (Liveware–Environment, L–E), interaction between AMTs and others (Liveware–Liveware, L–L), and interaction between AMTs and the organization (Liveware–Organization, L–O). They have categorized and examined 77 preliminary and 46 primary risk factors using a modified human factors SHELL model and a quantifiable evaluation approach. The empirical findings of a questionnaire survey of 107 senior professionals and experts in Taiwan show that the model and approach are both strategically effective and practically acceptable for categorizing and ranking the risk factors for AMTs. Their findings also suggest that the Civil Aviation Authority may consider asking management-level groups in airline companies, such as the human resources and maintenance departments, to focus on risk factors to improve aircraft maintenance performance.

*C. Aviation Accidents*

The National Transportation Safety Board (NTSB) conducts corresponding investigations for accidents in air transport and ground vehicles The Aviation Safety Reporting System (ASRS) run by NASA collects aviation incidents data [6]. The NTSB reports all civilian aviation crashes using a set of standard forms. A crash ("accident" in NTSB terminology) is defined as an event associated with operation of an aircraft that results in personal death or serious injury, or substantial aircraft damage [14].

Wiegmann and Shappell [15] indicated that human error has been implicated in 60% to 80% of both military and civil aviation accidents. Although the overall rate of aviation accidents has declined steadily during the past 20 years, reductions in human error-related accidents have not paralleled those related to mechanical and environmental factors. If aviation accidents are to be reduced further, more needs to be done to prevent the occurrence of human error and to design more error-tolerant systems.

The frequency of aviation accidents was significantly reduced due to major technological advances and enhancements to safety regulations. Aviation became a safer mode of transportation, and the focus of safety endeavours was extended to include human factors issues including the man/machine interface. This led to a search for safety information beyond that which was generated by the earlier accident investigation process. Despite the investment of resources in error mitigation, human performance continued to be cited as a recurring factor in accidents [16].

Feggetter [17] has developed the check list after reviewing the relevant literature and has been modified by personal experience derived from the investigation of Army aircraft accidents and incidents in which human factors have played an important part. The check list is based on a systems approach to

understanding human error and includes such headings as 'stress' (including life events), 'fatigue', 'arousal' and 'personality'. This study is hoped that further improvements will be made to the check list to enable it to be used not only within the specific area of aircraft accidents and incidents.

The classic term, "pilot error" or "human error", is attributed to accidents or incidents over 75% of the time; however, a recent study in the United States found that 18% of all accidents indicate maintenance factors as a contributing agent [18]; [19].

It is well-known that a significant proportion of aviation accidents and incidents are tied to human error. In flight operations, research of operational errors have shown that so-called "pilot error" often involves a variety of human factors issues and not a simple lack of individual technical skills. In maintenance operations, there is similar concern that maintenance errors which may lead to incidents and accidents are related to a large variety of human factors [20].

### *D. Aircraft Maintenance Technician's Performance*

Guastello [21] has stated in his book logically applies to the entirety of the field: the design and the engineering of human-machine systems for the purpose of enhancing human performance. The central criterion plays out in three forms: human performance itself, industry standards, and legal responsibility. Performance criteria include maximizing output, minimizing error, ensuring safety, and devising training programs to meet these standards.

The dirty dozen are the 12 most common causes of a maintenance person making an error in judgment which results in a maintenance error [21]. It introduced "The Dirty Dozen", which are 12 areas of potential problems in human factors [9]. The Table 1 below provides a comprehensive description of the Dirty Dozen Human Factors.

The dirty dozen factors have long since been identified but yet can be seen from the examples of accidents contributed. It is imperative that maintenance organizations inculcate a working environment that reiterates these factors holistically. So that they are ingrained in the maintenance personnel. This can be done through human factors training workshops by reiterating these factors and showing the aviation accidents they have caused [23].

Stress and many more factors can affect a maintenance technician's performance. In this study we have examined aviation accidents, for which stress is causal or contributory.

In addition to this factor is studied along with the desired requirements in aviation legislation.

TABLE I
THE DIRTY DOZEN HUMAN FACTORS

| | | |
|---|---|---|
| 1.Lack of communication | 5.Complacency | 9. Lack of knowledge |
| 2.Distraction | 6.Lack of teamwork | 10. Fatigue |
| 3. Lack of resources | 7. Pressure | 11. Lack of assertiveness |
| 4. Stress | 8. Lack of awareness | 12. Norm |

## II. EVALUATION OF STRESS AFFECTING AIRCRAFT MAINTENANCE TECHNICIAN'S PERFORMANCE

In this section, stress and stress effects are explained. Then examples of important aviation accidents caused by stress are given for aircraft maintanence technicians.

### *A. Stress*

Stress, according to classical definition, is the nonspecific reaction of an organism to any environmental demand [21]. From a human viewpoint, stress results from the imposition of any demand or set of demands which require us to react, adapt or behave in a particular manner in order to cope with or satisfy them. Up to a point, such demands are stimulating and useful, but if the demands are beyond our personal capacity to deal with them, the resulting stress is a problem.

Types of stressors

- *Physical:* heat, noise, vibration, etc.
- *Social:* anxiety, incentives, group pressures.
- *Drugs:* alcohol, nicotine, medication, etc.
- *Work:* boredom, fatigue, sleep deprivation too much to do in too little time.
- *Body clock:* shift changes, jet lag.
- *Personal:* domestic worries, aches and pains, feeling under the weather, etc. [4]

The concept of stress is most easily understood in the context of Figure 3. On the left of the figure is set of stressors, influences on information availability and processing that are not inherent in the content of that information. Stressors may include such influences as noise, vibration, heat and dim lighting as well as such psychological factors as anxiety, fatigue, frustration. Such forces typically have four effects (1) They produce a psychological experience. For example we are usually able to report a feeling of frustration or arousal as a consequence of a stressor. (2) Closely linked, a change in physiology is often observable. This might be a short-term change such as the increase in heart rate associated with taking the controls of an aircraft or the stress of air controllers in high load situations. (3) Stressors affect the efficiency of information processing, generally by degrating performance. (4) The stressors may have long term negative consequences for health.

As the figure shows these effects may be direct or indirect. Direct effects influence the quality of information received by the receptors or the precision of the response. For example

vibration reduces the quality of visual input and motor output, and noise does the same of auditory input.Some of these direct effect physical stressors as well as others for which no direct effect can be observed appear to show more indirect effects. This effects influence the effiency of information processing through mechanisms that have not yet been described [6].

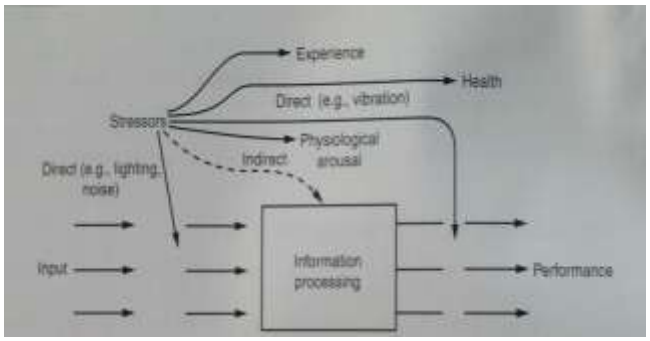


Fig.3.Representation of stress effects [6]

Another researchers suggest the simple model shown in Figure 4. If the job demands (work stress) exactly match the person's capabilities and attitude, proper "strain" exists and the on the job performance is satisfying, both objectively and subjectively [5].

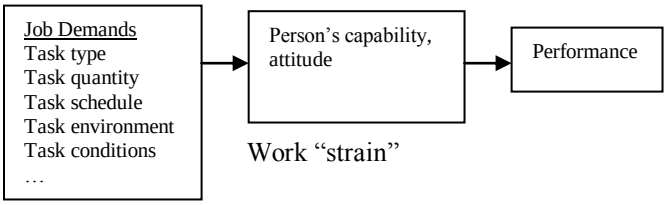


Fig.4 Simple model of the realtion between job demands (stress), human responses (strain), and procedures.

Stress is usually inferred by a decrease in task performance. In the aviation maintenance environment, there are many identifiable stressors. Fatigue caused by working at night and time pressure to get aircraft back into revenue service are two obvious conditions almost certain to cause stress. In stressful circumstances, it is very important that jobs, workplaces, work schedules, tools, facilities, and procedures incorporate human factors principles [24].

Aviation maintenance is a stressful task due to the fact that aircraft make money flying instead of being tended to in the hangar; hence there is enormous stress in finishing maintenance within a short timeframe and get the aircraft functional and flyable to avoid flight delays and cancellations. Whilst doing the job, there are also many things to be careful about in terms of using the correct tool, installing the correct parts whilst working in dark tight spaces. The stress can be self-imposed by increasing one's expectations of themselves and working harder than necessary to complete the job in the required time frame. The stress can also be from the manner or method that a manager uses to organise the employees. By not having the "people" skills to effectively communicate information or tasks to the engineers on the hangar floor, the manager risks stressing the engineers out by a lack of information [25].

When the literature is examined stresss found to be related to accidents and performance decrease result from stress.In this study we will try to explain briefly the important aircraft accidents with the reasons caused by the stressful maintanence tasks for aircraft maintanence technicians.

The purpose of this study is to emphasize the importance of stress for aircraft maintenance technician by explaining the serious airplane accidents caused by stress. Also this study aims to reduce possible the aircraft events and accidents due to the stress by increasing the situational awareness of aircraft maintenance technicians.

*B. Maintenance Accidents in Relation to Stress*

Several of the major accidents because of stressors as a significant causal facto r are summarized from the United States National Transportation Safety Board (NTSB) and Australian Transport Safety Bureau (ATSB) Transport Safety Report below:

**1. BAC 1-11, Didcot, U.K., 10 June 1990 (Ref. U.K. AAIB/AAR 1/92)**

2. In June 1990, a windscreen of a British Airways jet blew out as the aircraft was climbing to its cruising altitude, partially ejecting the pilot through the open window. During the previous night shift, the windscreen had been installed by a maintenance shift manager. The night shift was short-staffed and the manager was attempting to help out by performing the work himself. He did not thoroughly check the maintenance manual before performing the task and did not refer to the illustrated parts catalogue to confirm the type of bolts required to hold the windscreen in place. He selected the bolts by attempting to physically match them against a bolt that had been fitted to the old windscreen, assuming that the old bolt was the correct type, and ignoring the advice of a stores supervisor who had tried to tell him the correct bolt specifications for the job. In the event, most of the bolts he used to secure the windscreen were approximately 0.026 inches (0.66 mm) smaller in diameter than the required bolts. [26].

3. The cause of the windscreen blew out was because the sizes of the bolts for the windscreen were wrongly replaced the night before the flight. the replacements of the bolts on the windscreen could not support the decompression of the cabin. The engineer who embedded these bolts ignored the procedures and professional advice, fitting the wrong size of bolt to the windscreen while he was working under pressure, he made the decision due to the strong psychological believe he had in his own knowledge and expertises. This was the first accident report which involved Human Factors in Maintenance and Engineering department of the aviation system [27].

**2. Alaska Airlines Flight 261, McDonnell Douglas MD-83, N963AS, about 2.7 miles north of Anacapa Island, California, January 31, 2000**

3. The 2 pilots, 3 cabin crewmembers, and 83 passengers on board were killed, and the airplane was destroyed by impact

forces. Flight 261 was operating as a scheduled international passenger flight under the provisions of 14 Code of Federal Regulations Part 121 from Lic Gustavo Diaz Ordaz International Airport, Puerto Vallarta, Mexico, to Seattle-Tacoma International Airport, Seattle, Washington, with an intermediate stop planned at San Francisco International Airport, San Francisco, California. Visual meteorological conditions prevailed for the flight, which operated on an instrument flight rules flight plan.

4. Probable Cause:The National Transportation Safety Board determines that the probable cause of this accident was a loss of airplane pitch control resulting from the in-flight failure of the horizontal stabilizer trim system jackscrew assembly's acme nut threads. The thread failure was caused by excessive wear resulting from Alaska Airlines' insufficient lubrication of the jackscrew assembly.

5. Contributing to the accident were Alaska Airlines' extended lubrication interval and the Federal Aviation Administration's (FAA) approval of that extension, which increased the likelihood that a missed or inadequate lubrication would result in excessive wear of the acme nut threads, and Alaska Airlines' extended end play check interval and the FAA's approval of that extension, which allowed the excessive wear of the acme nut threads to progress to failure without the opportunity for detection. Also contributing to the accident was the absence on the McDonnell Douglas MD-80 of a fail-safe mechanism to prevent the catastrophic effects of total acme nut thread loss [28].

6. In the aviation maintenance industry, there is immense pressure to rectify, maintain and deliver aircraft in a timely manner to ensure scheduled departure times are met. In this incident, pressure to make a scheduled return to service date resulted in records to be falsified to ensure that the aircraft passed the inspection. This was evident as initial measurements of the jackscrew showed that it was on the brink of wearing out and that a new jackscrew needed to be ordered; but because this would delay the departure of the aircraft, the next log in maintenance records found the plane to be airworthy. Pressure to allow the plane to be able to fly had resulted in deviation in records and allowed the jackscrew assembly to be on the aircraft for a longer amount of time than it should have instead of being replaced and contributed to the crash. Pressure from the company in times of financial crisis in economic downturn also results in cutting of costs with the aim of keeping the plane longer in the air to fly more intensively instead of having it longer in maintenance. In this incident, the company, to save lubrication costs extended the lubrication interval and as a result contributed in excessive wear of the acme nut threads to failure due to inadequate lubrication. The video also mentions that 6/34 of the fleet of jackscrew assembly after facing new inspections in the aftermath of the crash [29].

### 3. Air Midwest Flight 5481, Charlotte, N.C, Jan. 8, 2003

On 8 January 2003, Air Midwest flight 5481 crashed shortly after takeoff from Charlotte, North Carolina, killing the two crewmembers and all 19 passengers aboard. The NTSB established that after takeoff, the pilots had been unable to control the pitch of the aircraft. There were two reasons for this. First, the aircraft was overloaded and had an aft centre of gravity that exceeded limits. Second, the elevator control system did not have the full range of nose-down travel, due to incorrect rigging that had occurred during a maintenance visit just over 24 hours prior to the accident. The accident flight was the aircraft's tenth flight after the maintenance work, yet the previous nine flights all involved lower passenger loads and a centre of gravity that was further forward [26].

Fatigue causes slower reaction times, reduced vigilance and slower processing of information whilst performing one's tasks. In this case, The technician working on the elevator system had worked in a three day period, 17.5 , 8 and 14 hours days respectively which was more than the acceptable duration of 10 – 12 hours working day. Hence, fatigued, the technician was in no position to perform the tasks properly of for that matter question the wisdom of the inspector skipping pertinent steps as his body was telling him to get the job as quick as he could so that he could rest sooner [30].

## III. Conclusion

Human factors directly cause or contribute to many aviation accidents. Aviation maintenance is a stressful task due to many factors. Stress is the subconscious response to the demands placed on a person. Aircraft must be functional and flying in order for airlines to make money, which means that maintenance must be done within a short timeframe to avoid flight delays and cancellations. Fast-paced technology that is always changing can add stress to technicians. This demands that aviation maintenance technicians stay trained on the latest equipment. Other stressors include working in dark, tight spaces, lack of resources to get the repair done correctly, and long hours. The ultimate stress of aviation maintenance is knowing that the work done, if not done correctly, could result in tragedy [31].

As can be seen from the aircraft accidents in this study, stress is an important factor causing aircraft accidents. Time pressure one of the stressors is predominant contributing factors. In the aviation maintenance environment, there are many identifiable stressors. Fatigue caused by working at night and time pressure to get aircraft back into revenue service are two obvious conditions almost certain to cause stress. Further studies are necessary to investigate how time pressure influences AMTs' safety behaviors in detail. In this study, it was aimed to increase situational awareness of managers and technicians by emphasizing that the effect of stress on aircraft maintenance technicians is very important with the help of examples of accidents.

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