# ENGINEERING AVAILABILITY OF AIRCRAFTS

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***Abstract***

*Engineering availability and operational readiness of an aircraft are requisites for its ability to operate. After the aircraft has been supplied, both features determine airworthiness of the aircraft, in compliance with the ARC (Airworthiness Review Certificate).*

*Improvement in methods of maintaining the aircraft availability proceeds in compliance with the MSG (Maintenance Steering Group) rules. The paper has been intended to outline the process of maintaining the engineering availability of the aircraft, with account taken of: aircraft maintainability, importance of the engineering diagnostics, and evaluation rates for different maintenance patterns.*

*Maintaining technical ability/ airworthiness of an aircraft, ground service of aircrafts, service-friendliness of an aircraft, unfitness and damages to an aircraft, ground diagnostic and provision equipment for A-380, computer aided verification of an inspection of a front undercarriage (B) of an aircraft (A) and service of the B-787 aircraft (C), percentage for composite material portion in the structure of some aircrafts and helicopters, positions of composite material airframe elements in B-757/767, B-777, B-787 are presented in the paper.*

***Keywords:*** *transport, aircraft, diagnostics, failure*

## 1. Introduction

Operating aircrafts by civil operators and national air forces is therefore confronted with new challenges and it evolves continuously as an interdisciplinary sector of human activity. Requirements of the economy with the profit of a civil operator as their main characteristic feature on the one hand and low cost of the availability for e.g. passengers on the other hand lead to financially reasonable, safe and reliable realization of tasks. The way and pattern aircrafts are operated by a user - who has at his disposal a fleet of airplanes - becomes to a significant extent the key to it.

Main operational – aircraft service related - requirements are determined by an engineering designer, who, when designing a new product should, first of all, think in terms of operating an aircraft. [1]. within this field, one observes an integration of aspects of economy and organization, developing as a response to complex and costly tasks. Leading creators and manufacturers of aircrafts, especially those of civil aviation airplanes, impose to a significant degree - even by influencing legislating bodies - aircraft aviation operational systems they developed, including requirements of technology and organization, and requirements for staff qualifications. In order for the airworthiness of a given aircraft does not violate relevant law regulations in force these systems have to be abided by. Therefore the managing of a fleet of aircrafts by a user with it being essentially influenced by the abovementioned systems has to currently apply scientifically methods adopted for practical uses.

A prerequisite for operating a plane (SP) is its technical airworthiness, which is ensured by a subsystem of maintaining it and the aircraft operational airworthiness.

## 2. Maintaining technical ability/ airworthiness of an aircraft

Maintaining the technical fitness for use (polish: ZTSP) of an aircraft (polish: SP) and its airworthiness (polish: ZSPL) is realized through execution of a number of steps included in the operational program (polish: PE). The goal of such a set of steps, operations („SP" service) is to ensure the technical fitness for use at a given time in order to enable a flight mission, to prevent a cessation of the operational fitness of aircraft systems, structural groups and aircraft installations and to restore the said fitness for use or airworthiness.

The technical – functional fitness for use signifies a status of an aircraft at which it is capable of performing its flight mission, provided it is properly controlled, supplied, also at possible interferences at a given time, and with a required effectiveness.

The airworthiness of an aircraft signifies an aircraft status at which it is capable of execution a required mission at a determined ambience impact and after having been adequately provided, whilst fulfilling adequacy requirements.

The scope of steps/operations of an operational program (*PE*) is formulated according the criterion of maintaining adequate reliability status – SP. According to this criterion the technical fitness for use (SP) i.e. a set of parameters determining the status $<W>$ within a $\Delta W$ interval, despite changes caused by operation-related changes, must be maintained. The change of the $W$ status operation as a function of time is given by: The status change $W$ as a function of time can be expressed symbolically as:

$$\frac{\mathrm{d}W(t)}{\mathrm{d}t} = f\left[W(t_0), E(t), Z(t_0), A(t_0), t\right], \tag{1}$$

where:
$W(t)$ - a set of status parameters;
$W(t_0)$ - status parameters set at the operation start time $t_0$;
$E(t)$ - destructive operational factors;
$Z(t)$ - destructive ambient factors;
$A(t)$ - destructive human engineering factors (e.g. human factor, operation rules etc.).

The initial aircraft status $W(t_0)$ is determined by construction solutions or an aircraft design, production technology, transport conditions etc. Taking into account all factors, which influence on the aircraft status – these can vary significantly for different aviation systems – after an equal operation time a status of an aircraft can be different. This statement justifies the purposefulness of operating aircrafts according to their technical condition and not to their a priori overhaul time schedules and calendar schedules.

There are many strategies (patterns) of carrying out actions/steps to maintain the aircraft technical fitness for use [6, 9]:

- a preventive strategy based on equal time intervals and including diagnosing and forecasting, despite the fact that up to 95% technical parameters remain within standards – the strategy of operation according to the overhaul life (SEWR),
- based on the knowledge on the object technical condition (aircraft, systems, installations) – operation strategy according to the technical condition (SEWST),
- after a damage/failure – a passive strategy consisting in a renovation (replacement, repair, adjustment).

For all these strategies the goal for all aviation systems is always identical:

- to shorten the time of servicing,
- to maintain a proper reliability level of aircrafts,
- to decrease the service labor consumption and material demand,
- to increase the service capacity of a service personnel (quicker attaining of flight readiness).

Aircraft elements, groups, and systems should be of an equal service life and their damage rate should be as well identical. However, practically, for a number of reasons this cannot be achieved. Mechanical loads, electrical loads etc. are different, aircraft parts wear rate is different t (e.g. due to friction), they corrode etc. (they are defined as ageing elements) [1-4, 11]. Provided the reliability can be described as a function of normal distribution as generally the damage rate of ageing parts $\lambda(t)$ is a random variable:

$$\lambda(t) = \frac{f(t)}{1 - F(t)}, \tag{2}$$

where:
$F(t)$ - function of the ability time,
$f(t)$ - function of the probability density of a damage/failure time random variable [$f(t) = \frac{\mathrm{d}F(t)}{\mathrm{d}t}$].

The optimum value of time $\omega$, after which an element ageing during operation should be renewed, is obtained from the following formula:

$$\frac{T_2}{T_1 + \omega} \cong 1 - \frac{1}{1 - F(\omega) + \lambda(\omega)\int_0^{\omega}[1 - F(t)]\mathrm{d}t}, \tag{3}$$

where:
$T_1$ - average interval time for replacing fit elements,
$T_1$ - average interval time of replacing damaged parts,
$F(\omega)$ - ability time function,
$\lambda(\omega)$ - ageing element damage rate.

## 3. Ground service of aircrafts

The ground service of aircrafts requires a set of tools – a smaller or a wider one. For an *A-380* contemporary passenger plane this is very ample equipment – shown in Fig. 1. This equipment serves to:

- a better and fuller provision of an aircraft and preparing it to a flight – to meet the condition of a full airworthiness,
- to detect damages and reasons for them as soon as possible,
- objectifications of the evaluation of the technical condition of aircraft groups, systems etc.,
- to ensure proper quality of carried out service steps/operations,
- to limit the effort of ground personnel,
- to shorten the service time,
- to ensure a planned flight safety level.

The set of technical service means (STO) must meet the requirements specified in the MEL regulations (binding for civil aviation) [7]. Some deviations from the original set of these means are allowed, however, only to the extent of the requirements of the *Minimum Equipment List* (MMEL). The MMEL set enables to continue a flight to an airport, where a damage-related service can be carried out. A STO set is prepared according to MEL (MMEL) requirements for every type of an aircraft. Such a set must meet the conditions as follows:

- it must be used for aircrafts of a given user and for operations/steps as specified in the documentation,
- it must contain clear guidelines for a ground personnel and flight crews.

In order to prepare a set of service, preventive and repair steps/operations one should check whether they could be carried out under all conditions, which can occur during operation of aircrafts (different ambient temperatures – from very low to high, rainfall, fog, high humidity, etc.). Such verification is conducted during operational testing of aircraft prototypes [9]. Prior to such tests computer aided simulation tests shall be carried out. With modern computer technology we can follow the entire process of service steps in space (3D) and time environment. Fig. 2 shows exemplary verification of some service steps on a forward aircraft undercarriage.


*Fig. 1. Ground diagnostic and provision equipment for A-380 (drawing from the original A-380 Manual)*

## 4. Service-friendliness of an aircraft

One of measures of the aircraft operational value is its operation-friendliness including the technical service friendliness, which we understand as friendliness to steps in order to maintain the craft technical fitness for flight (technical condition), which in turn consists of three components: diagnostic friendliness [9, 12], prophylactic friendliness and technical fitness for use/flight [8, 10]. These features are influenced by the aircraft design, and used methods and technical tooling/equipment. The aircraft service-friendliness is high, when a required aircraft condition can be restored under all conditions, which can possibly occur during aircraft operation. The loss of airworthiness after a completed service evolves only slowly (long operation of an aircraft possible) and a restoration to such a status should not take long and at a low effort and with limited means.

The global indicator of the aircraft operational friendliness – ”PE” - is given by the total work time under this operational friendliness per one flight hour:

$$MMHFH = \frac{\text{work - hours per year}}{\text{flight hours per year}}. \tag{4}$$


*Fig. 2. Computer aided verification of an inspection of a front undercarriage (B) of an aircraft (A) and service of the B-787 aircraft (C). [By permission of UGS the PLM Company]*

## 5. Unfitness and damages to an aircraft

The labor demand for maintaining the airworthiness is a derivative of planned preventive measures and the number of occurring failures [2-4]. Sometimes it is necessary to modify the operational schedule. Especially nowadays these programs gain in importance as the range of composite materials in manufacture of aircrafts is significantly expanding. For example Fig. 3 and 4 show the growing percentage of the use of composite materials in Boeing and other companies' airplanes[1]. Gliders are made of composite material in total. Typical examples are Polish gliders *PW-5* and *PW-6*, *Diana 2* and other. The use of composite materials significantly extended the time of operation of aircrafts to the first and general repair.

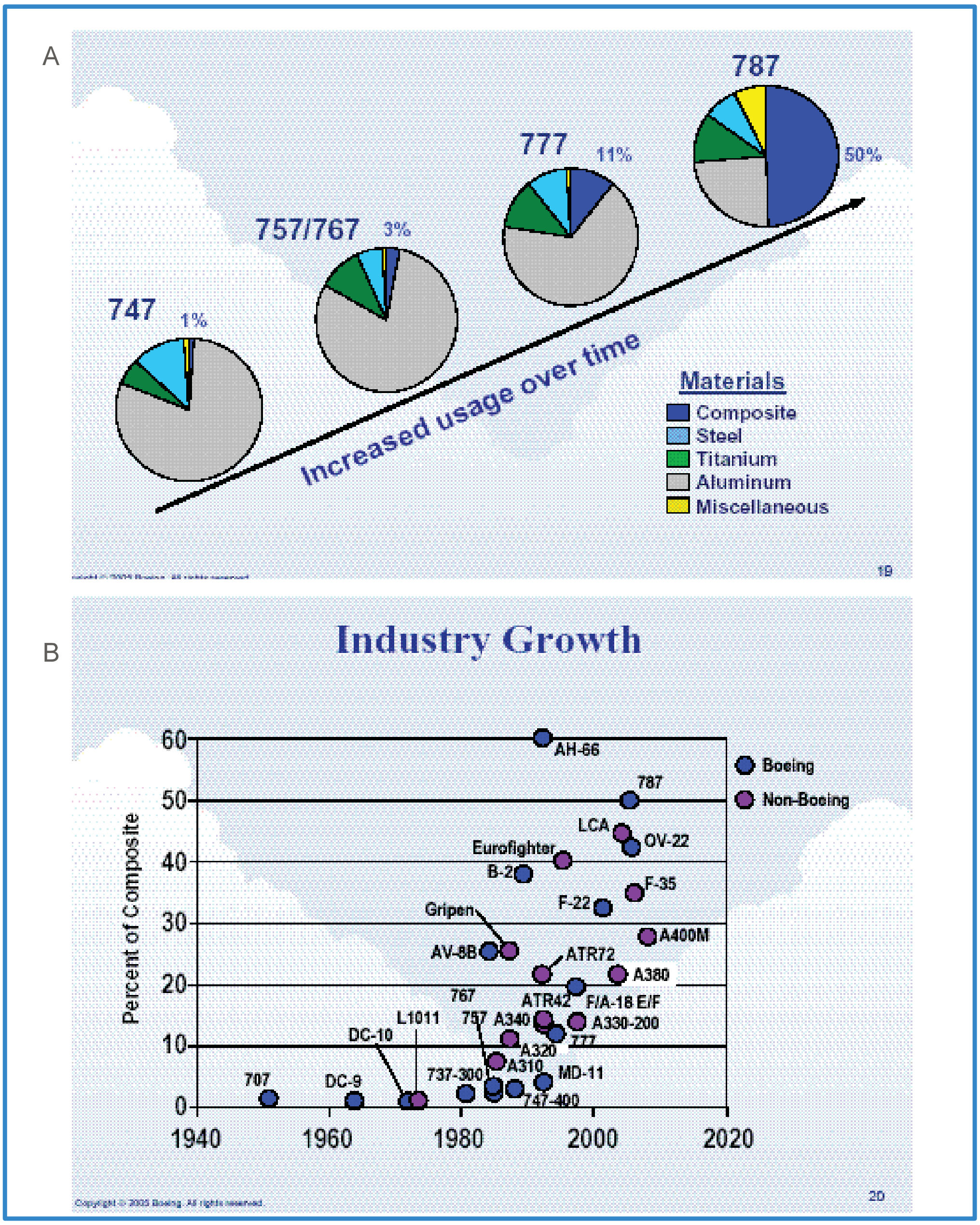


*Fig. 3. Percentage: Composite material portion in the structure of some aircrafts and helicopters (civil and combat) of Boeing (A) and other companies (B)*

[1] Fig. 3 and 4 by permission of the author S.Ford: Maintenance B-787. Seminarium w PLL LOT, Warszawa 2007.

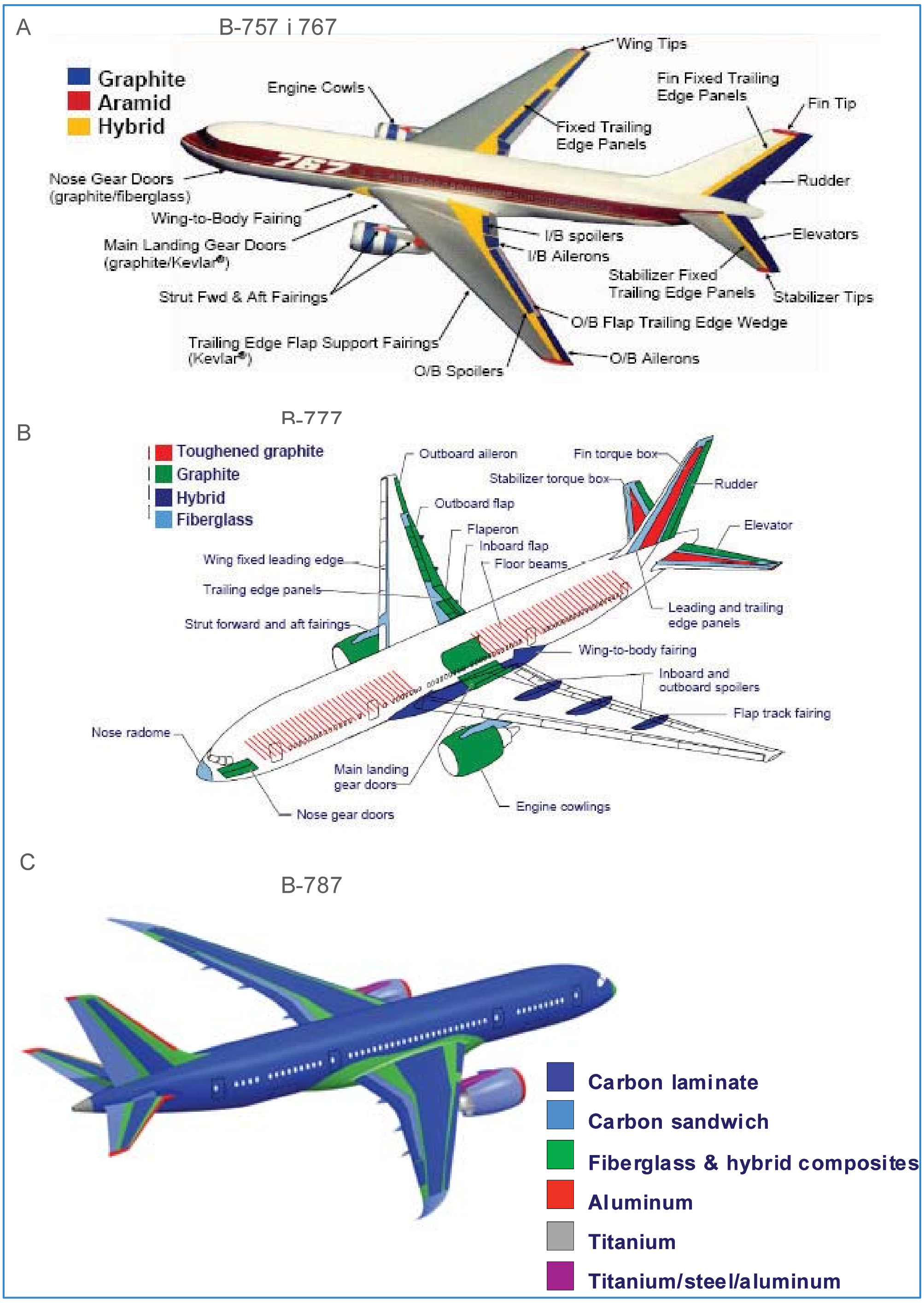


*Fig. 4. Positions of composite material airframe elements in B-757/767, B-777, B-787*

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