# DIAGNOSIS ON NEW CIVIL AIRPLANES

## ECONOMIC ASPECTS

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## INTRODUCTION

So far you have heard of sophisticated technologies on new generation airplanes.

The utilization of high speed microprocessors associated to high density memories offers quite unlimited calculation and storage capability on board an aircraft.

The utilization of cathode ray tubes associated to alphanumeric key-boards offers an optimum man-machine interface.

These technologies permit to decrease the direct maintenance cost due to :

- component standardization which give interchangeability,
- improved reliability which give higher MTBF,
- centralized maintenance which give a better fault detection and isolation capability at LRU level.

However, these advantages are not always reflected in the day-to-day life of an aircraft. We have to consider the actual airline problems, more especially during its first days in an airline.

## ON BOARD DIAGNOSIS CENTRALIZED MAINTENANCE

On the A320 Airbus aircraft all the systems that contain avionics are connected to a single means of accessing maintenance information :
the Centralized Fault Display System (CFDS).

The operation is facilitated by :

- use of plain English, rather than fault codes,
- display of data correlated to pilots' reports,
- clear identification of the faulty LRU by description, and part-number,
- use of a printer for hard copy.

The CFDS may be connected to an ACARS data link to inform the maintenance staff prior to arrival of the aircraft.

Centralized on-board maintenance data processing brings the following advantages :

- less training required,
- improved MTBUR,
- shorter times to repair.

## PROBLEMS FREQUENCY IN AN AIRCRAFT LIFE

There are 3 distinct periods :

- Period 1 - introduction of the aircraft : numerous initial problems, decreasing rapidly in number.
- Period 2 - new increase in problems frequency : corresponds generally to the end of the warranty period (three years) and the first structural checks (4 years).
- Period 3 - maturity : after 4 to 5 years, a few known problems with known solutions.

We will consider only the first period corresponding to the introduction of the new aircraft type in an airline.

The subject is important. The airlines usually take the necessary actions, either with their own personnel, or with the help of the manufacturer, or other airlines or specialised maintenance organisations, to make sure they have at all time enough trained and competent staff. The learning curve shows that for any airline, the proficiency and efficiency of its maintenance teams increase regularly and rapidly.

The most troublesome difficulties are maintenance problems : they come, most of the time, from the non-availibility of spare parts when they are needed.

## SPARES SUPPLY

Under the general name of spares, we usually consider, not only the components supplied to replace a unit having a failure, but also any kind of equipment, tool, ground support equipment, consumable, hardware, raw material necessary to operate and maintain an aircraft.

To make you better understand the scope and difficulties of the spares provisioning process, we will consider one particular family of spare parts : the so-called LRUs (Line Replaceable Units). These are complete units, such as pumps, or computers, or radio receivers for instance, that are replaced or repaired as a whole. They are usually manufactured by a large number of equipment vendors, not by the aircraft manufacturer, and they constitute about 80 % of the value of the total spare parts, except the engine spares which are dealt w ith directly between the airline and the engine supplier.

### Ideal provisioning

Ideal spares provisioning is composed of one and only one unit on the store shelf. This implies the simultaneous following operations :

| | | | |
|---|---|---|---|
| Faulty equipment | : Aircraft | --- | Store |
| Repaired equipment | : Store | --- | Aircraft |
| Faulty equipment | : Store | --- | Repair Center |
| New/Repaired equip.t | : Repair Center | --- | Store |

This theoretical scheme is of course impossible to apply, because if a unit is given with a MTBF of, say 1,000 hours, the failure can happen after 100 hours, or 10 hours, or 10,000 hours, you have to speculate, the result of such speculation is the spares provisioning recommendation.

Provisioning recommendation

Formula used for spares recommendation :

$$E = \frac{N \times n \times H}{MTBUR} \times \frac{TAT}{W} \quad \text{in which :}$$

E = Average demand for any given type of component,
N = Number of aircraft,
n = number of components per aircraft,
MTBUR = Mean Time Between Unscheduled Removal,
TAT = Turn Around Time,
H = Number of flight hours, per aircraft, per year,
W = Calendar days per year (365).

As can be seen in the formula, the average demand E, based on average numbers (TAT and MTBUR), will give an average availability of components, which means that 50 % of the time, there will be a possibility of stock-out with a resulting potential Aircraft On the Ground (the both famous and infamous AOG in aviation industry jargon).

To reduce that totally unacceptable risk, the laws of probability are applied to E in order to obtain a protection level, corresponding to the chances of stock-out the operator chooses to accept.

Protection level

Whatever is mathematical definition, the "protection level" comes as a quantity of money to invest. The more money you invest, the higher the protection level you will get. However, whatever the amount of money involved, you will never reach 100 % protection level and there will always be AOGs.

Most operators choose a protection level of 96 %.

Turn Around Time

If we go back to the provisioning formula we see that the average demand is directly proportional to the TAT. What is exactly the TAT...

TAT = TTR + pipeline time
TTR = Workshop/Repair Center : average 1 month
Pipeline = one week to several months : removal -- store -- papers -- decision -- customs -- forwarders -- transportation -- back to store.

Here again, variations in TAT have a direct effect on invested money. But the important thing to remember is that once you have made your initial provisioning computations and you have received the amount of spare parts you have ordered, if your actual TAT is greater than your scheduled TAT, you are bound to trouble : you will necessarily have spares stock-out and AOGs : that is what happens to most airlines in the early ages of a new aircraft life. To correct the situation, new additional provisioning based on actual data valid for the airline have to be made.

MTBUR

The last factor to be considered is the MTBUR. Going back again to the provisioning formula, it is obvious that the less often you have to remove an equipment, the less spares you are going to need. But when do you remove an equipment from an aircraft ? When the system in which the equipment is fitted is not operating properly and you suspect that equipment might cause the trouble.

The removed equipment will be tested : if faulty it will be repaired, if not it will be fitted back into the aircraft or stored for future use. This brings us to consider a new factor : the confirmed removal rate or MTBUR ratio.

Every time you remove from an aircraft an equipment that is not faulty, you are wasting time and money, especially if you have to send it abroad for testing (think of the pipeline time).

In the early ages of aviation history, with conventional equipment the confirmed removal rate was as low as 25 %, which means that 3 times out 4, the removed equipment was operating perfectly.

With analogue electronic equipment, the confirmed removal rate was between 40 % to 50 %.

With modern digital avionics plus the action of BITE (Built In Test Equipment) the confirmed removal rate reaches 70 %.

With Centralized Fault Monitoring Systems, similar to those put on board the Airbus A320, that rate will reach 85 %.

Whatever the technology you will always have a certain amount of unnecessary removals, and consequently a certain amount of units sent for repair without any reason.

This again costs time and money and increases the risks of AOGs.

Maintenance hysteresis

To be complete with the spares provisioning subject we have to say a few words about maintenance hysteresis.

The introduction of digital avionics brings in potential gains in MTBF and in confirmed unscheduled removal rate. Unfortunately, most of the time, it is not accompanied by a synchronised introduction of in-house maintenance capabilities : the delays in test equipment availability, not to speak of repair workshop, can sometimes go up to several years.

This time lag, also called Maintenance Hysteresis between system introduction and maintenance readiness is responsible for :

- extra vendor support required,
- unnecessary logistics activities related to outside repair,
- adverse effect on system availability,
- delay in gaining experience on trouble-shooting.

It is one of the top priorities of airline managements to try to reduce that Maintenance Hysteresis as much as possible, this means they have to be in a position to invest the necessary money.

## OPERATIONAL PROBLEMS

Strangely enough, these are not the main cause of concern. Pilots and cabin crews are highly trained specialists with internationally approved training courses and recurrent training : they are not a major source of problems.

The actual operational problems come from the ground preparation of the flight :

- passengers handling,
- bagage handling,
- aircraft servicing.

Most of the time, upon introduction, the turn around times that are scheduled are not realistic because the less qualified people have not had time enough to be properly trained.

Usually, this is settled after a few weeks of operation. It can also be overcome by a careful preliminary planning.

## CONCLUSION

The purchase of a new aircraft represents a very large investment, very often possible only at the scale of a nation's resources. To take full advantage of that huge investment and obtain the return it is designed to bring, the new aircraft must not be purchased as an isolated tool, such as a car, or a TV set, but considered as a system : it requires a sufficient amount of spares and also it requires, as early as possible, the availability of adequate maintenance facilities.