Low fuel situations awareness

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1 | Introduction

One easily understands that lack of fuel may seriously impair the safety of a flight.
Monitoring the fuel status all along a mission is therefore one of the critical tasks of the crew. The challenge of this monitoring is that fuel status may be adversely affected by a very wide variety of factors.
This article will briefly review the factors affecting fuel status, and will then stress :

- The importance of fuel checks, developed to ensure timely detection of a low fuel situation
- The limits in the use of the FMS in Fuel On Board projections under degraded conditions

This article is a complement to the presentation titled “Detecting and managing situations of low usable fuel” given during the 14th Flight Safety Conference in Barcelona on October 2007.

2 | Fuel status variables

The factors affecting the fuel status may be sorted out in two classes.

- Those linked with the operating context such as :
  - Delays induced by ground operations factors at departure airport
  - Air Traffic Control constraints modifying the scheduled flight plan
  - Meteorological factors
  - Congestion at the destination airport leading to holding or diverting.

- And those linked with the aircraft like :
  - Airplane ageing: mainly the engines, but also the airframe and nacelles
  - Airplane flying under conditions of the Minimum Equipment List (MEL) or Configuration Deviation List (CDL)
  - Aircraft speed not in accordance with the scheduled flight plan
  - Overweight compared to flight plan

  but also
  - In-flight failures with an effect on fuel consumption
  - In-flight failures with an effect on the fuel available for the mission (e.g. fuel leaks leading to fuel being trapped).

3 | Standard Operating Procedures (SOPs)

Because of the variety of causes that may lead to a low fuel situation, and in view of the configuration of the fuel system, several means must be used to maximise the chance of an early detection.

According to the SOPs for the cruise phase, 3 types of check have to be performed when over flying a waypoint, or every 30 minutes:
1. Fuel On Board
2. FMS Fuel prediction
3. Fuel On Board/Fuel Used

The above checks need to be performed as well each time a FUEL IMBALANCE procedure is necessary, and they should be performed before applying the Fuel Imbalance procedure.

Note: On the A300-600/A310/A320family/ A330/A340 and A380 aircraft, FUEL IMBALANCE detection is available as an "advisory" message associated with the Fuel System page on the System Display. On the A340-500/600 and A380, it triggers as well an amber caution appearing on the ECAM.
No such alarm is available on the A320 family for the time being.

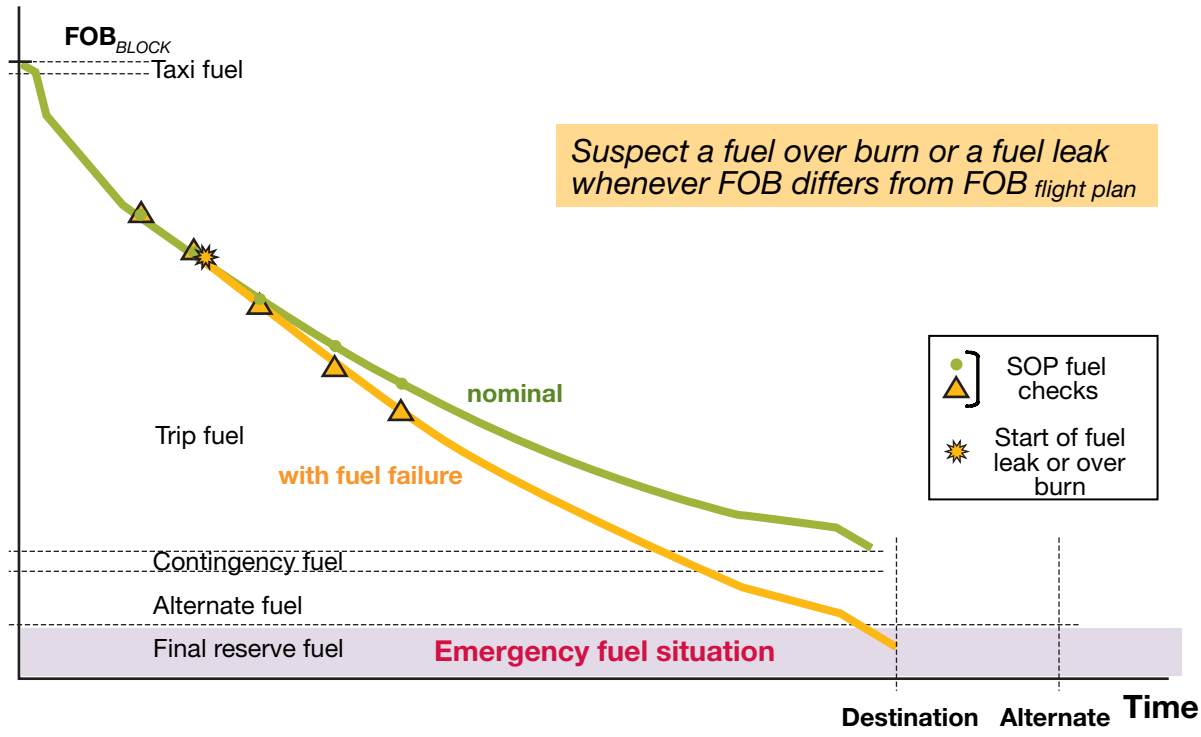
3.1 First check: Fuel On Board

Cruise SOP FCOM 3.03.15 P1 (SA/LR) FCOM 2.03.15 P1 (WB)[1] :
"Check Fuel on Board (ECAM)… and compare with the computer flight plan or the FCOM In-Cruise Quick-Check Table."

Any marked difference in FOB quantity compared to the flight plan prediction may reveal either:

- A fuel over-burn, which may be explained by:
  - Some significant deviations from the initial flight plan, due for instance to restrictions from Air Traffic Control, degradations of meteorological conditions, engine failure
  - An airplane configuration degradation, due for instance to an aerodynamic drag increase coming from flight control surfaces permanently deflected, a landing gear or gear doors partially extended, ice accretion.

- An external fuel leakage



[1] SA: Single Aisle : A318/A319/A320/A321
LR: Long Range : A330/A340
WB: Wide Body : A300/A310

3.2 Second check: FMS Fuel prediction

Cruise SOP FCOM 3.03.15 P1 (SA/LR) FCOM 2.03.15 P1 (WB):
"Check… fuel prediction (FMGC) and compare to the computer flight plan or the FCOM In-Cruise Quick-Check Table."

The FMS is able to make FOB predictions at point along the flight plan: waypoints, destination (DEST EFOB) or alternates. It considers the entered flight plan and assumes a nominal aircraft (potentially customized to monitored performance level through individual PERF factor) i.e. without failure.
It is updated permanently from the measured FOB and from modifications of the flight plan entered into the FMS, if any. In nominal conditions, without flight plan update, DEST EFOB should not show any marked evolution throughout the flight.
Hence, in case of fuel over-burn due, for instance, to a drag increase, DEST EFOB will decrease permanently at the same rate the actual FOB is drifting away from the initial flight plan prediction. The same behaviour would happen for a fuel leak.

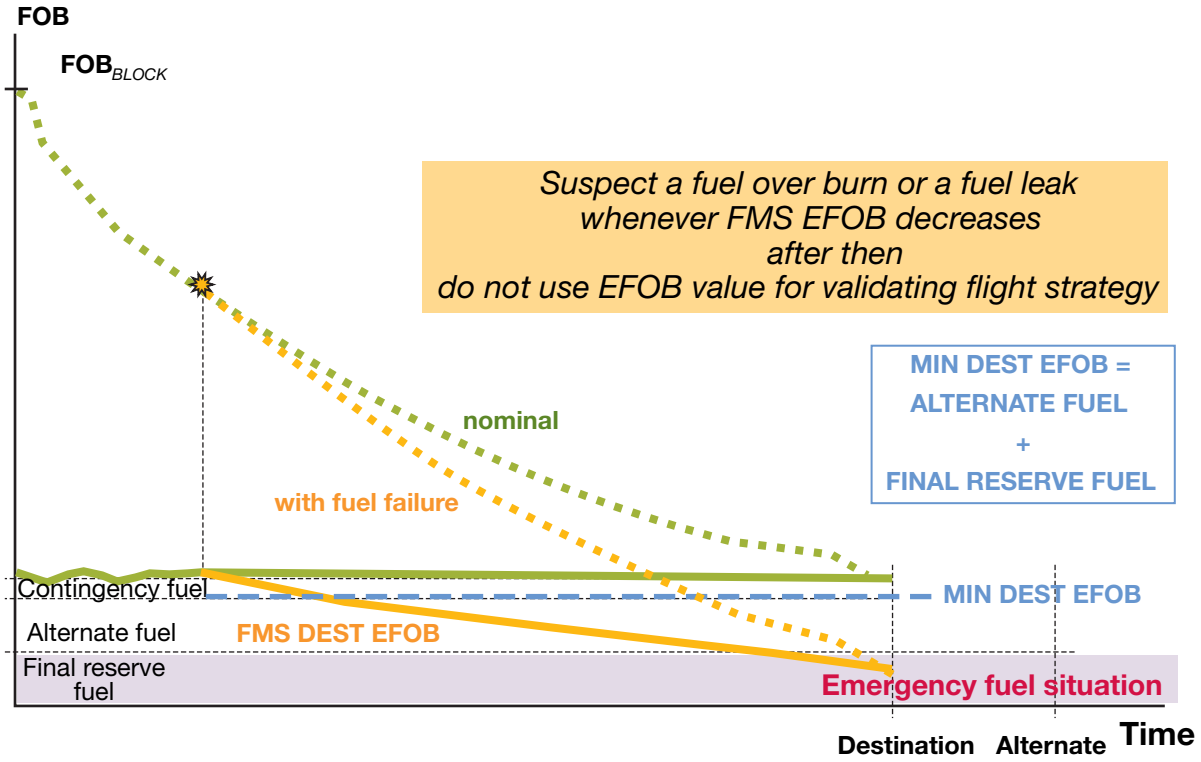
Important note:

FMS prediction is a projection of actual FOB that never takes into account any degraded state of the aircraft, even when due to a failure that is monitored and shown on the cockpit panel or ECAM displays.

This rule has only one exception: engine failure, once confirmed in the FMS.

Decreasing DEST EFOB indication is a sign of degrading fuel situation.
For the above-mentioned reasons, it also means that the displayed DEST EFOB value cannot be used to anticipate the fuel status at destination. The same is true for all other EFOB projections, like at waypoints or alternates.

Note: DEST EFOB displayed on FMS pages turn to amber if it becomes lower than the sum of Alternate and Final reserves fuel entered in the FMS: it indicates that contingency fuel and extra fuel reserves are no more available.



3.3 Third check: Fuel On Board/Fuel Used

Cruise SOP FCOM 3.03.15 P1 (SA/LR) FCOM 2.03.15 P1 (WB):
"Check that the sum of the Fuel On Board and the Fuel Used is consistent with the Fuel On Board at departure… If the sum is either unusually smaller than the FOB at departure, or if it decreases, suspect a fuel leak."

A higher sum may provide the indication of a frozen fuel quantity parameter leading to a wrong FOB data.

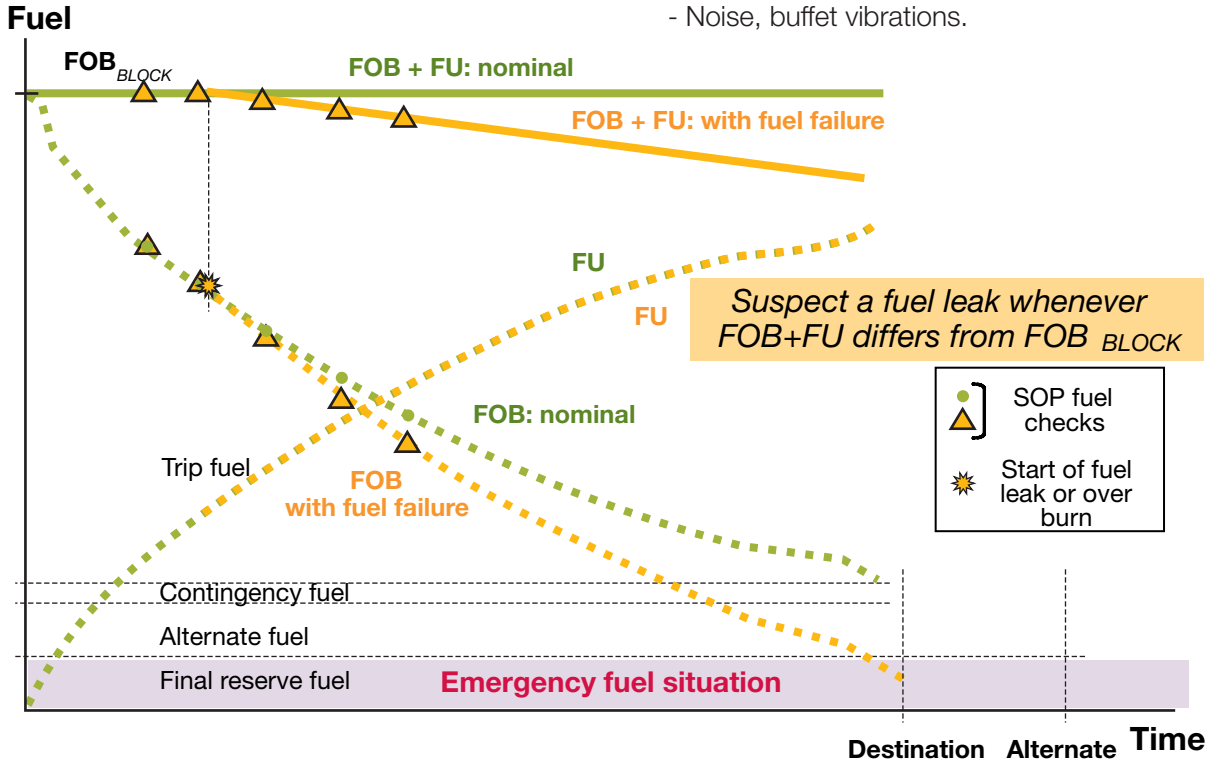
Note: The amber caution F. USED/FOB DISAGREE exists basically on the A340-500/600 and A380.
On the A330 and A340-200/300, they have to be activated, provided the aircraft are equipped with the following minimum standards: FCMC 9.0 and FWC K5-5 (A330) or L8-0 (A340).
This caution does not replace the SOP check, but may allow an earlier detection of a fuel leak.

Important note:

A fuel leak downstream of the Flow Meter will not be detected through this check. It will, however, be revealed through an excessive fuel flow on one of the engines.

Indeed, an unexpected engine fuel flow level may be caused by:

- A fuel leak, downstream of the Flow Meter, sometimes confirmed by:
  - Fuel spray visible from the cabin coming from engine or pylon
  - Fuel smell in the cabin
- But also a fuel over-burn associated with a failure impacting the aircraft aerodynamics or engine performance with the following possible indications:
  - Step or steep increase of engine control parameter
  - Difficulty to maintain ceiling or Mach number
  - Time or distance increase during step climbs
  - Aircraft asymmetry along roll or yaw axis visible sometimes only through compensation by control surfaces
  - Noise, buffet vibrations.



4 Fuel On Board versus available fuel

The three checks described above all assume that the FOB is available to fly the aircraft. This may not always be the case as some fuel may be trapped or transferring too slowly due to an anomaly in the transfer sequence such as :

- Non operating transfer device (blocked or clogged transfer valve etc…)
- Ruptured or cracked transfer line in a fuel tank.

These situations may be detected through :

- A faulty equipment message on the Fuel page of the System Display
- A developing fuel imbalance when one of the wing tanks is affected
- A deviation in the fuel transfer sequence.

5 Conclusion

The FOB, Fuel prediction and FOB/FU checks in cruise provide powerful means for detecting an abnormal fuel situation. These checks, included in the cruise phase SOPs, should be adhered to without exceeding the indicated interval of 30 minutes.

These checks should be performed as well after detection of an abnormal fuel status.
They will allow, after the corrective measures have been taken, to ensure that the procedures applied have reached the expected results.

It is also important to bear in mind that:

- FMS EFOB predictions do not take into account non-nominal aircraft conditions (except engine failures once confirmed in the FMS) and have to be corrected to take into account the consequences of excessive fuel consumption or fuel leaks.
- FOB/FU checks will not detect fuel leaks or excessive fuel burn downstream of the Flow Meter and should therefore be complemented by engine fuel flow checks.

With the rising price of fuel, there is a high chance for extra fuel reserves to be more and more challenged: in this evolving context, it is certainly worth developing crew awareness in terms of fuel monitoring to maintain a high level of safety in aircraft operation.

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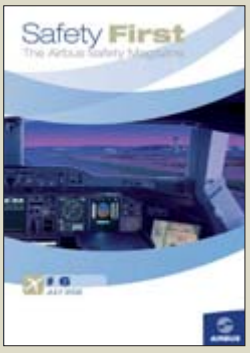

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