Advanced Diagnostics in the SNECMA M-88 Engine of the Rafale Fighter

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1.0 GENERAL SYSTEM DESCRIPTION

The SNECMA M-88 engine for the Rafale fighter is integrated with condition monitoring and prognostic systems. These systems work together to reduce maintenance downtime and improve mission reliability.

The integrated maintenance system on the M-88 is referred to as the Engine Condition Monitoring System (ECMS), and has two parts, as shown in Figure 1. One part is referred to as "O level" (Operational) and the other as "I level" (Industrial). On O level there is on-board diagnosis, and ongoing diagnosis and prognosis. On I level there is the capability for complementary tests, performed without a test bench and with the engine turned off. The tests include fuel leakage tests, fault localization tests, control loop tests (e.g. inlet air control system), tests of the anti-icing vane, tests of the fuel flow meter, etc.

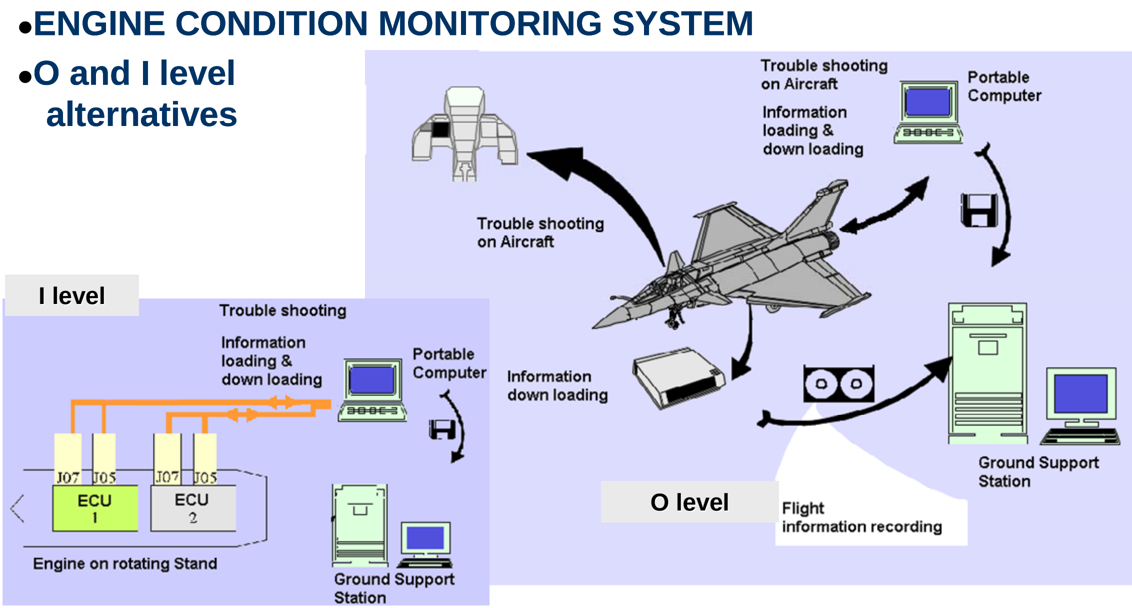


Figure 1: Integrated maintenance concept.

Some ground support equipment for transportation, rotation, and complementary testing are shown in Figure 2.

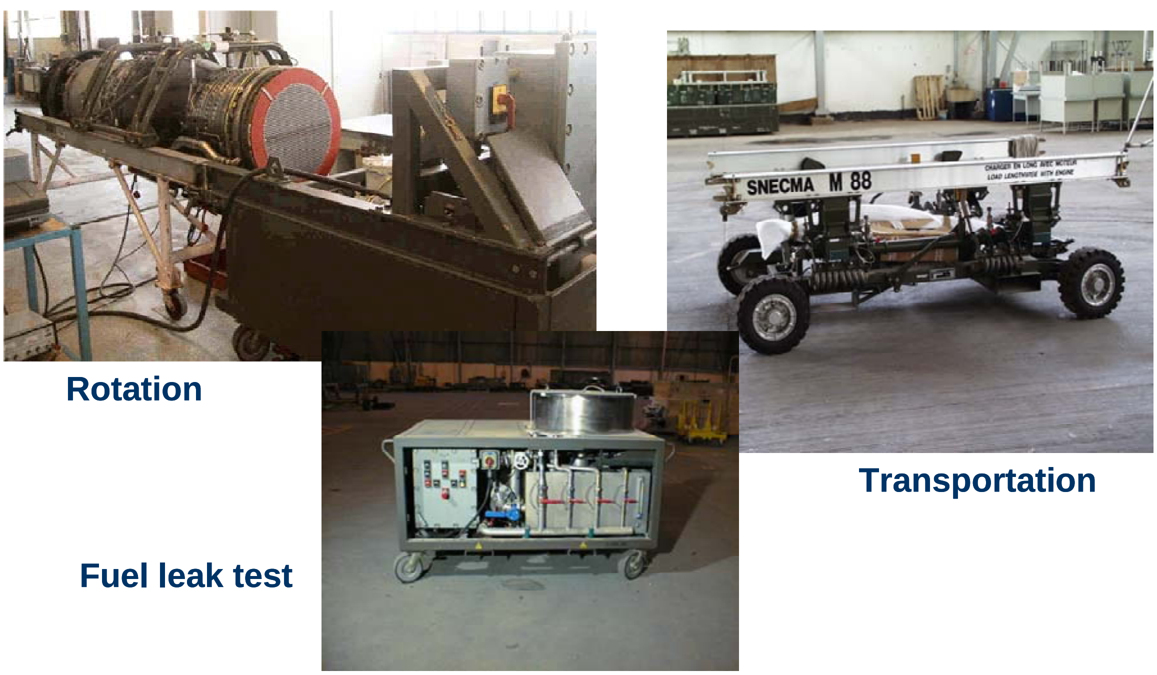


Figure 2: Ground, I Level, test utilities for trouble shooting.

2.0 ON-BOARD DIAGNOSTICS

On-board diagnosis uses the same sensors as those for engine monitoring (Figure 3). There are a few sensors for vibration surveys, which are very useful for finding bearing degradation. Periods of inverted flight are also recorded, because these are detrimental to the lubrication of the bearings. There are also electrical oil and fuel filter-clogging indicators.

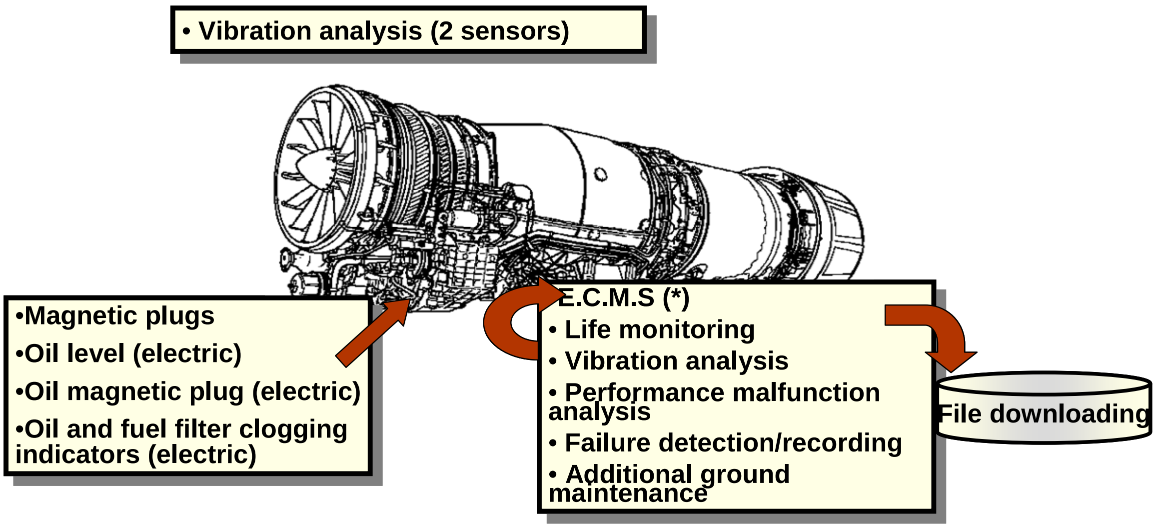


Figure 3: On-board diagnosis – specific sensors and indicators in addition to engine controls.

There is a comprehensive set of in-flight tests. For example, accelerometers are used to monitor shaft balance for the HP and LP shafts. Imbalance triggers an alarm.

The system incorporates usage monitoring. This is very crucial on a fighter, because those stresses from one flight to the other may vary by a factor of 80. The usage data includes flight hours, the number of post combustion lightings, and the number of engine starts. The data is used in models of general fatigue, high cycle fatigue, and crack propagation.

There is also some performance malfunction analysis. Various malfunctions are recorded for this purpose. They include start sequence anomalies, such as overheating, stall, and slow start. They include other performance anomalies such as long rotation, turbine overheat, electronic control unit overheating, compressor stall, HP or LP shaft overspeed, and post-combustion anomalies. To minimize false alarms, there are two monitoring channels, which are compared. If necessary, other data is used to resolve discrepancies between channels. If there is a control loop malfunction, a snapshot of all data at the moment of the event is recorded.

3.0 GROUND-BASED DIAGNOSTICS AND MAINTENANCE DECISION SUPPORT

For full prognosis (estimation of remaining life), the SIAD system is interfaced with the ground-support system HARPAGON (Figure 4).

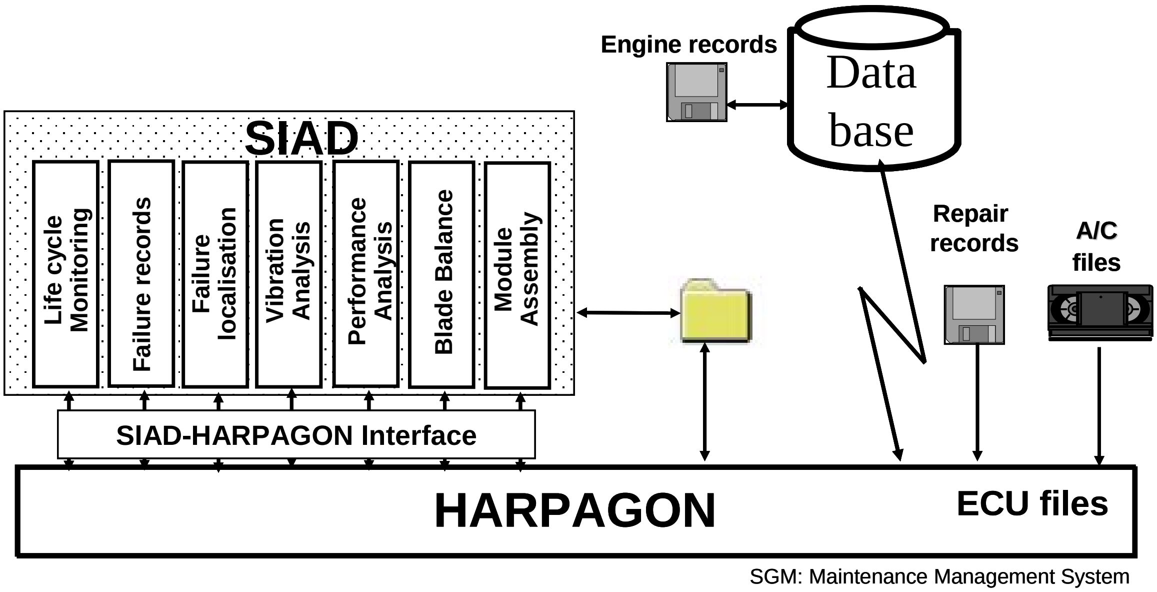


Figure 4: Ground support station.

HARPAGON also performs additional analysis of failure, vibration, usage, and performance data. In Figure 5 there is an example of output data that indicates some imbalance on the low-pressure shaft.

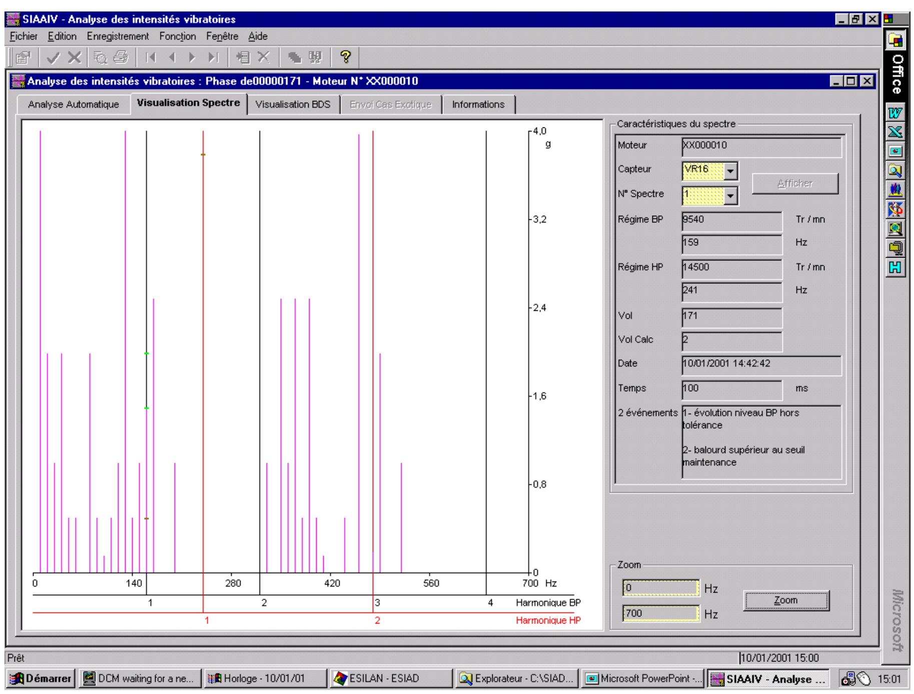


Figure 5: Example of analytical output from HARPAGON, showing imbalance in the LP shaft.

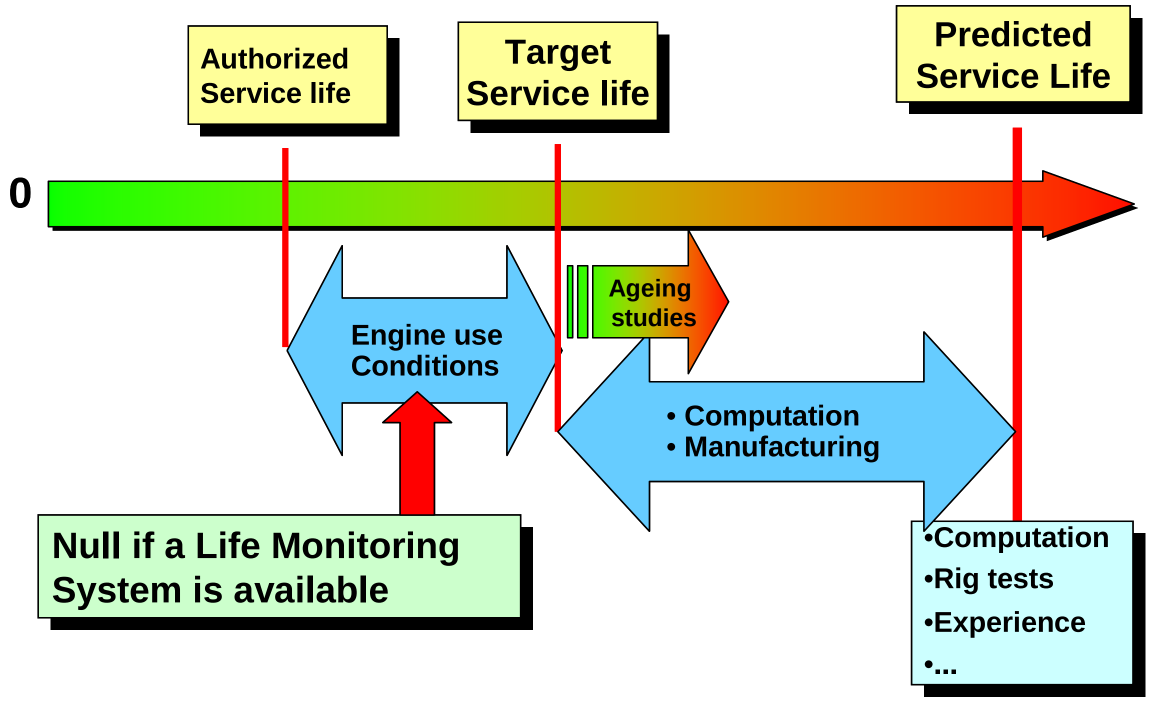
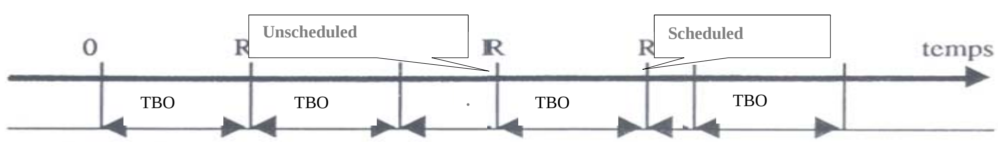


Figure 6: Downtime reduction by extending the useful lives of engine components.

It also allows the time between overhaul (TBO) of components to be increased (Figure 7). This in turn provides the flexibility to increase the installed time of the engine and/or manage the maintenance of the engine and its modules so as to optimize aircraft availability and life-cycle cost.



Replacement of constant TBO by "Soft" TBO

•Longer → Down time reduction

•Shorter → Mission reliability improvement

Figure 7: Reduction of downtime and improvement of mission reliability.