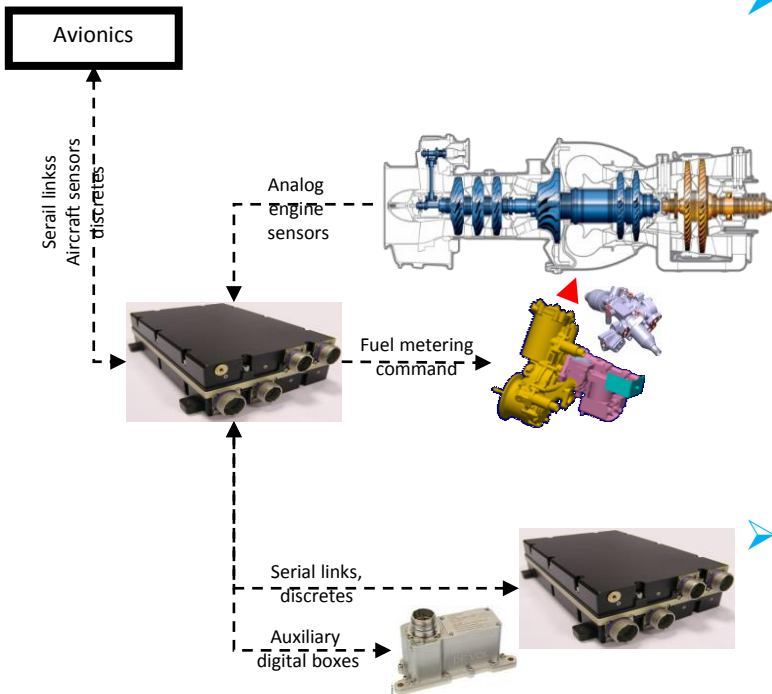


Control system certification

SAFRAN Helicopter Engines – Jean-Luc THOUVENOT



➤ Typical engine control system architecture (Twin-engine rotorcraft)



➤ Main engine control system functions

- Automatic start and restart
- Control of fuel flow to maintain torque/ rotor speeds / gas temperatures within limits
- Control of constant output shaft speed
- Fuel and oil system monitoring
- Protection against surge and flame-out
- Indication to the aircraft/pilot
- Maintenance/troubleshooting

➤ Overall architecture

- One central dual-channel electronic unit (EECU)
- Analog sensors and actuators
- Auxiliary electronic units for data recording or backup engine control
- Point-to-point serial link with the avionics



➤ Typical control system certification at SafranHE

- Global functional validation (CS-E 50, E60 and E 170) by engine tests and control system integration bench tests
- Environmental tests, generally at equipment level (CS-E 80 and E170, ED 14 /DO 160), complemented by analyses
- Software (DO 160/ED 12) and complex electronic hardware (DO 254/ED 80) qualification
- Fuel circuit certification, by engine tests and partial rig tests (CS-E 560, E660 and E670)
- Safety analyses (CS-E 50, E 510, and E 1030, ED-79A/ARP 4754A)



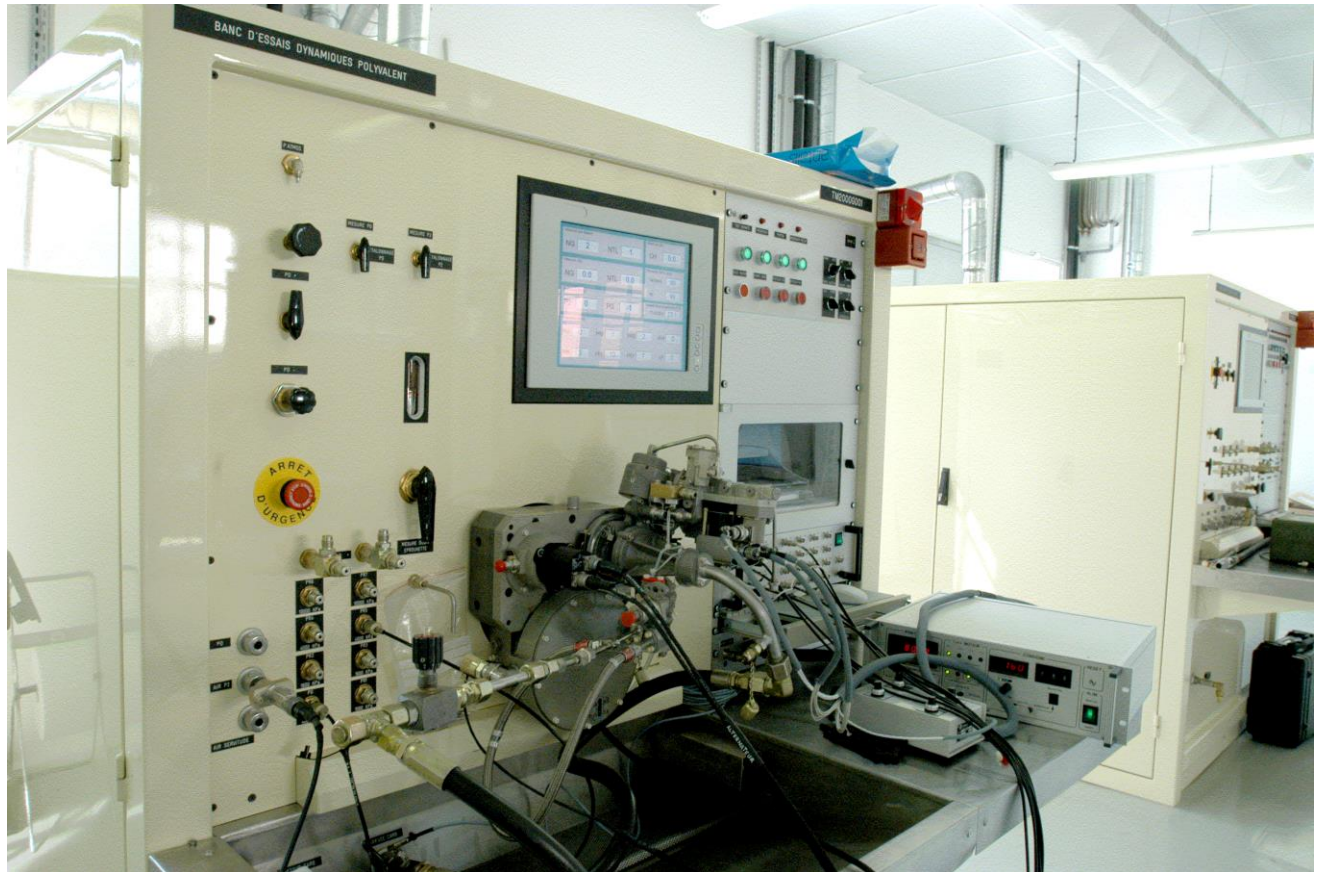
➤ Functional validation

- Global functional validation to verify the satisfactory operation in normal mode and under system failures mode (CS-E 50, E 60 and CS-E 170)
 - On engine test bench
 - On control system integration test bench
 - On simulated altitude engine bench
- The satisfactory operation is also checked during
 - The 150h endurance test (CS-E 740)
 - The accelerated mission test (CS-E 25)
 - The flight tests



➤ Control system integration test bench (BISR)

Closed-loop control system test bench including hydromechanical equipment



➤ Functional validation under failure modes

- Failure tests are performed at the control system test bench (BISR) and at the engine test bench
 - All EECU input and output signals are tested
 - These failures include the loss of electrical power supply to the EECU from the aircraft, the failure of any data coming from the aircraft and the failures leading to switching EECU channels.
 - The correct indication and management of failures and OEI ratings (CS-E 60(d)) is checked
- Most failures are tested at the control system test bench
- Failures tested on engine test bench are failures from sensors and actuators for which BISR is not representative enough, e.g.:
 - Torque sensors,
 - Oil temperature and pressure sensors,
 - Gas temperature sensors.



➤ Satisfactory operation of the control system (1/3)

- The control system has to allow controlling the engine with sufficient sensitivity and accuracy in idle mode, in normal mode and in failure mode

	Idle mode	N2 stability	N2 accuracy	Power oscillations / power variations
Main objectives	Output speed (N2) is controlled with adequate accuracy at the N2 idle datum	Check that no unacceptable power oscillations occur in different phases: normal mode, auxiliary mode, back-up mode	Check that N2 speed is maintained at its N2 demand (fixed value) when required or at variable N2 demand (rotorcraft N2 datum) by default with the required accuracy.	The engine behaviour is tested during in-flight tests, under the rotorcraft manufacturer responsibility, to ensure that the engine control is compliant with the rotorcraft requirements in terms of piloting. Normal mode and auxiliary mode are tested.
Means of compliance	Engine test bench / BISR	Engine test bench / BISR/150h endurance tests/altitude tests	Engine test bench / BISR	Engine flight tests



➤ Satisfactory operation of the control system (2/3)

- The control system ability to maintain the engine automatic control over the whole flight domain and under all the pilot solicitations is linked to the engine ability to maintain the output N2 speed on its datum over the whole flight domain under all the load conditions within the engine limits

	Engine limits	Engine acceleration / deceleration
Main objectives	<p>Check of engine toppings (rotor speeds/torque/gas temperature)</p> <p>Ability to keep the engine within its limits</p> <p>Correct behaviour of engine starts/restarts/transients</p>	<p>Check the engine protection against surge and flame-out, including under some failure conditions</p> <p>Transitions between automatic mode and auxiliary mode and between power ratings</p> <p>Acceleration / deceleration</p>
Means of compliance	<p>Engine test bench / BISR</p> <p>150h endurance test</p> <p>Accelerated mission test</p> <p>Altitude test bench</p>	<p>Engine test bench / BISR</p> <p>150h endurance test</p> <p>Altitude test bench</p>



➤ Satisfactory operation of the control system (3/3)

- The control system ability to start and restart the engine is checked in the starting envelope during the altitude test (CS-E 770 and E910) and on ground during the 150H endurance test (CS-E 750)
- When there is no mechanical overspeed protection, the correct operation of the electronic engine overspeed protection is demonstrated by a specific engine test , combined with partial rig tests on the EECU.



➤ Fuel circuit certification

➤ Objectives:

- Demonstrate that fuel contamination by ice or liquid water will not cause engine malfunctioning (CS –E 560 and E 670)
- Demonstrate that the fuel system is capable of functioning satisfactorily with fuel containing the maximum quantity of solid contamination (CS –E 560 and E 670)
- Establish the minimum and maximum fuel pressure and fuel temperature limits to be approved for the Engine (fuel suction capability) (CS –E 660)

Ice in the fuel	Liquid water contamination	Solid contamination	Fuel suction capability
Analysis	Analysis to cover the whole operating envelope	Partial Test bench	Test performed on the fuel pump
Altitude bench test	Analysis to cover any malfunctioning of the equipment	Analysis for the auxiliary system	Altitude bench test
Partial Test bench	Engine test		150h endurance test





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End

Jean-Luc THOUVENOT
VP Airworthiness
Jean-luc.thouvenot@safrangroup.com



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