ERF91-52

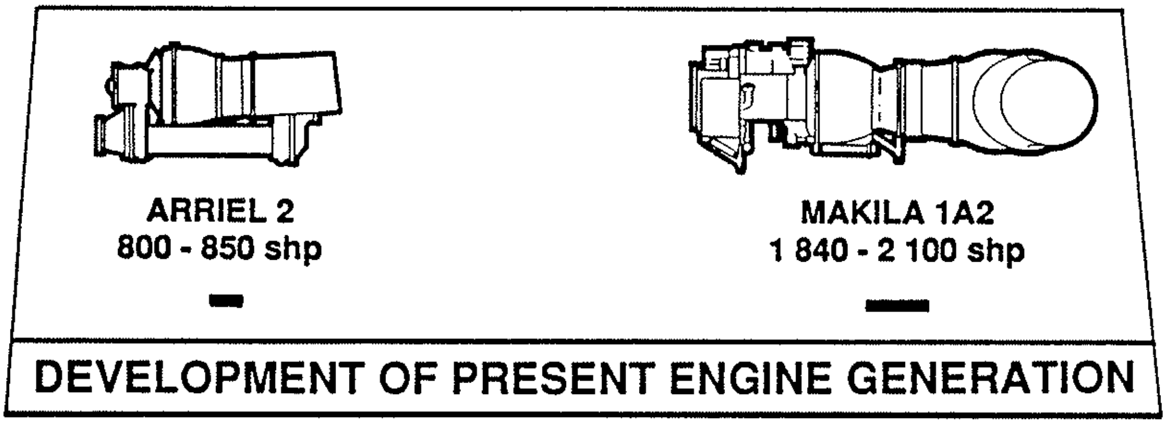
THE ADVANTAGES OF DIGITAL ENGINE CONTROL AS COMPARED WITH TRADITIONAL SYSTEMS (HYDRAULIC OR PNEUMATIC)

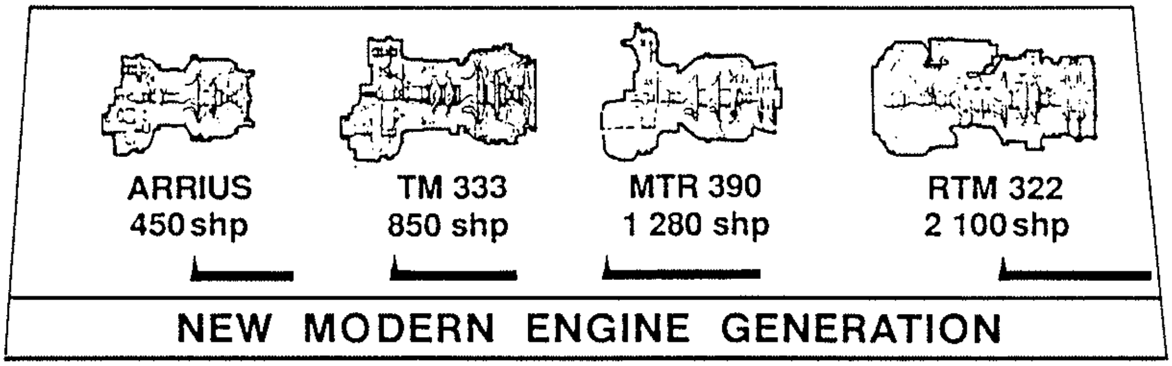
M. Barral, J.P. Ramond
TURBOMECA

Turbomeca has always designed and built its own control systems for its helicopter engines.

Very early we turned to electronic systems and on July 3, 1980 I flew an AS 341 Gazelle Helicopter with a Full Authority Digital Electronic Control system. We think it was a first. This was a single engine, single shaft exercise. We then went to a more difficult subject experimentally controlling two Makila free turbine engines on a Puma. Since then we have fully developed Digital Engine Control Units (DECU) which control twin helicopter engines :

Makila 1A2 (powèr turbine and topping part of the control) ; TM 333 ; Arrius (TM 319) ; RTM 322 and MTR 390.





This paper tries to explain the advantages offered, by using a Digital Electronic Control Unit instead of a traditional hydraumechanical system :

- to the pilot
- to the operator
- to the manufacturer

1. ADVANTAGES TO THE PILOT

1.1 Generals

In order to improve at the same time :

- flight safety and
- mission effectiveness

it is important :

- to decrease the pilot's workload. He will then be able to devote himself to tasks more essential to the accomplishment of his mission.
- to optimise the operation of the engine in failure cases.
- to train the pilot as efficiently as possible.

1.2 Pilot workload

Piloting a helicopter is sometimes a high workload job, for instance in such cases as :

- Take-off and approach, especially on platforms
- Cargo sling operation
- IFR flights
- Nap of the earth flying
- Night flying
- Use of armament
- SONAR Dipping
- Mountain work

In all these cases and many others a pilot is happy to forget about his engines.

The DECU is built to help the pilot everytime it is needed and be forgotten at other times.

When you energize the helicopter the DECU will self test and tell you if anything is wrong.

To start the engine you just select "**IDLE**" or "**FLIGHT**" at your choice and the DEC will do it for you. This start is very consistent, T4 is controlled and the risk of overheating is practically nil.

If you selected "**FLIGHT**", as soon as the engine reaches Idle, rotor run-up begins. This also is automatic, giving a smooth and constant acceleration, acceptable both in high wind and iced ground conditions.

For instance on the AS 355 N, starting the two engines up to 100 % NR, ready to take off, takes exactly one minute.

If you prefer, you can select "**IDLE**" first and the rotor will run up only after you select "**FLIGHT**".

Again, to ease the pilot's work, engine limitations are presented on one instrument only. For Turbomeca engines the unique limiting parameter is Gas Generator Speed (NG). So the limitation instrument shows NG, as a difference between present NG and the take-off limit NG. The scale is highly expanded around the limits and the precision is that of modern electronics (0.1%)

In flight it is possible to change NR for operational reasons, (fuel consumption, lower efficiency etc...). It is also possible to trim the engines differentially in order to match what the pilot wants (NG, Torque, etc...). These settings remain constant in time and are independant from each other. For instance, on the AS 355 N, if the pilot matches torques at take-off, they stay matched for weeks (if nobody changed it...).

1.3 Failure cases operation

1.3.1 DECU failures

They are classified in three categories :

- *Redundancy :*

  One of the redundant transducers or circuits has failed : the DEC switches automatically to the alternate. The pilot doesn't need to know it, as he has nothing special to do. The failure is signaled at the end of the flight for the maintenance crew.

- *Minor failure :*

  This failure has no effect on the performance level of the engine. It may have an effect on handling possibilities. The pilot has to use the engine with care. This is signaled by a code number. The codes are listed in the Flight Manual with corresponding eventual procedure.

- *Major failure :*

  In this case the fuel metering system is frozen. Thus the fuel flow is what was necessary immediately before the failure, and immediate pilot action is nil or minimal. This case is signaled.

The pilot can then go on flying, while controlling the engine manually :

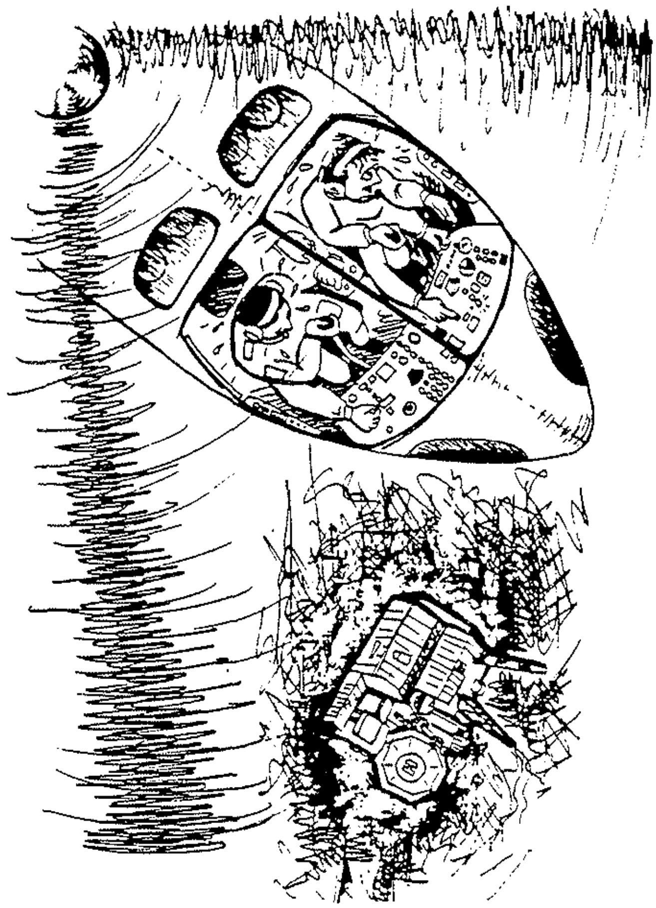
- The failed engine's manual lever is lit, to help the pilot choose the right one.

- The manual control has full authority, it is possible to give maximum power, or to idle and cut the engine, whatever was the fuel flow at the time of the freeze. It is even possible to relight it on manual control.

- Some care is still necessary when controlling manually. But of course the other engine is still controlled automatically (on multi-engined helicopters).

1.3.2.Engine failure

When using All Engines Operative (AEO) limits (take-off, max continuous) it is preferable that these limits are pilot controlled. In the case of One Engine Inoperative (OEI) operation it is essential that at the same time the engine delivers its max contingency power, and no more, and the pilot devotes himself to piloting the helicopter, so the OEI ratings are DEC topped and the pilot only controls rotor RPM, slightly below normal flight value.



We found that this method is much less difficult than trying to stabilize engine power around red lines.

Max contingency is normally set by the DEC and the pilot switches to intermediate contingency in due time, time limit is signaled by the DEC, or when max contingency is no longer necessary. It is possible to go back to max contingency if the pilot chooses so.

1.3.3 Restarting an engine in flight

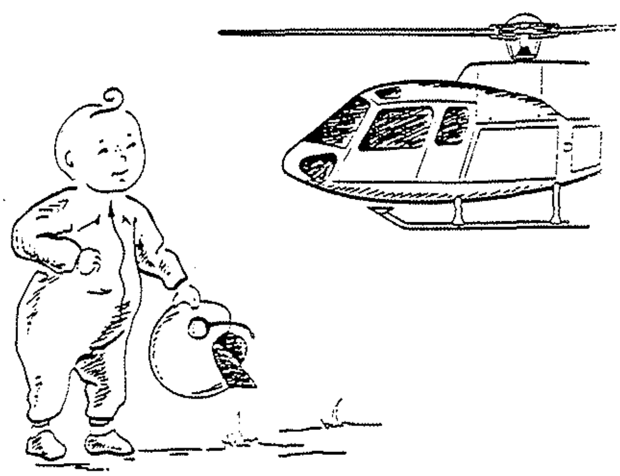
This needs only simple pilot action : select the flamed out engine from **"FLIGHT"** to **"STOP"** and to **"FLIGHT"** again.

The automatic sequence will restart the engine much better than a stressed pilot. The pilot can devote himself to piloting the helicopter during this OEI phase of operation.

1.4 Pilot training

1.4.1 Training for OEI operation

Life of the engines and main gear box, as well as civil regulations, limit the use of OEI ratings to the cases of real OEI flight.



As training for OEI operation is essential for pilot proficiency, the OEI ratings, including the maximum torque limitation, can be lowered. This, associated with lower grossweight allows a representative training.

The trajectory is identical, the "power to weight" ratio being the same.

NR RPM piloting technique is the same. Instruments indication are biased to be identical. In the case of a "trained pilot" error, if rotor RPM drops too low, the idled engine will automatically restore its power up to max OEI rating, if necessary.

The "training" configuration (lowered toppings on the "sound" engine + training idle on the other) can be canceled at any time by any of the pilots by just selecting the idled engine to **"FLIGHT"**.

1.4.2 Training for simulated DEC failure

A DEC can be frozen by selecting "MANUAL" to simulate its failure at any time. The engine can then, for training, be controlled manually for instance to simulate a landing with one engine in manual mode..

Also at any time, by selecting the engine back to "NORMAL" and setting the manual lever back to the NORMAL position, any of the pilots will restore normal operation.

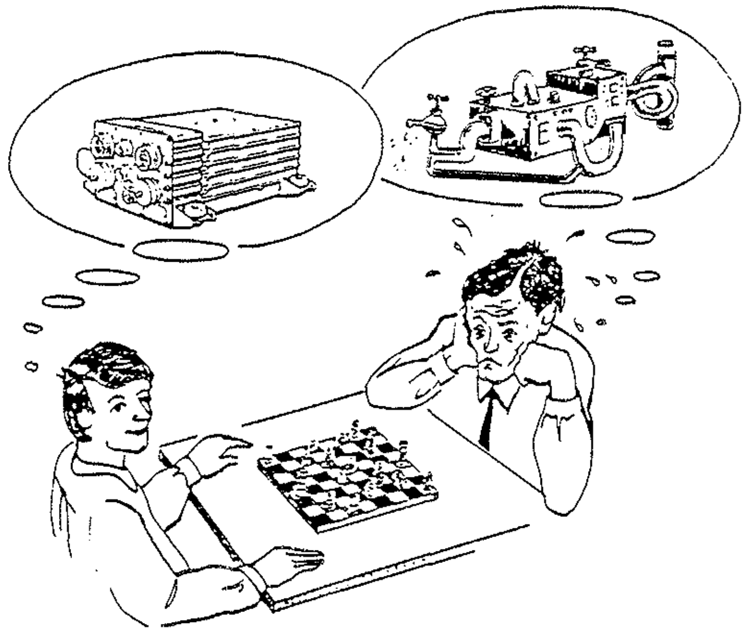
1.5 Flight safety

Decreasing the pilot work load, having a sound reaction to possible failures, with simple and fool-proof pilot action, making possible a realistic pilot training as frequent as necessary without consuming high power life, all of those concurr to improve flight safety.

2. ADVANTAGES FOR THE OPERATOR

We already cited :

- Automatic starting, with no overheating, improves the real life of the engine
- The training mode, while allowing very efficient pilot training, is very thrifty on high power hours. It is a real engine life time saver.
- OEI ratings, being DEC limited are never exceeded.



Moreover the DEC, being a powerful computer, can give additional precious help :

2.1 Engine power check

The DEC can elaborate the torque and turbine temperature that the minimum guaranteed engine should deliver in those flight conditions, and compare them with the actual values.

2.2 Health monitoring system

The DEC can log hours, starts, cycles, to calculate crack and creep elapsed life.

2.3 Help to maintenance

The DEC, at the end of each flight, displays any control system defect, so the maintenance crew can fix it without losing a precious time trouble shooting.

2.4 Fuel system

Though this is not directly related to the DEC, the new generation of TURBOMECA fuel systems includes :

- The possibility of operation without helicopter booster pump (fuel succion system). This is an important safety factor in the case of a crash, as it allows no fuel to be spilt from broken pipes, and starves the engines off.
- A fuel filter, engine mounted, with preclogging indication and automatic by pass. Its location (beside the oil filter) and the use of an ejector in the low pressure fuel circuit, heat the fuel so that, down to a limit varying with each engine (- 20°C on ARRIUS), there is no need to use anti-ice additive in the fuel.

Increasing the life of the engine and saving time for maintenance have direct financial advantages for the operator.

3. ADVANTAGES FOR THE HELICOPTER MANUFACTURER

The DEC is also beneficial to the manufacturer by improving the adaptation of the engine to the airframe :

- The engine, being controlled with more precision can be used at the best of its possibilities : for instance, for a given engine, **better response** to a collective increase can be obtained, **without transient overtorque**

- The control system can be isolated from **torsional unstability** frequencies, easing a very difficult problem

- Helicopter limitations can be met with better precision : better and more reliable **engines matching** ; more precise and elaborate topping of engine power in **OEI operations.**

- The training mode can save some **main gear box life.**

- **Rotor efficiency** can be improved by trimming NR, manually for aerodynamics of the main rotor, or automatically, for instance by foot pedal action, to improve lateral wind capacity.

- New functions can be introduced : even the control mode can be changed, for instance the control loop can change **from proportional to integral** when necessary.

- In the case of a **generalized management system**, all the engine parameters can be forwarded by the DEC through a data link.

- The **fuel system** of the helicopter can be **simplified** : fuel filter is on the engine, the engine is capable of fuel succion.

- The improvement of precision and versatility of the control systems is such that new OEI very high power ratings (**30 sec. OEI ratings**) have been made possible. Such a rating has already been certified by TURBOMECA for the MAKILA 1A2. This, again, is a first for a civil engine.

4. TECHNOLOGICAL DEVELOPMENTS AND PROGRESS WITH EQUIPMENT

Technological developments allow the pursuit of progress with control equipment in order to decrease the weight and/or the cost of the equipment and to ensure better protection from external electromagnetic attacks.

We would like just to point out, as far as this is concerned :

- The use of new materials of a lighter voluminal weight like for example, composite fire-resistant materials with satisfactory behaviour and ageing in an engine environment.

- The use of servo-system fluids, of higher pressure (of around 200 bar). This will essentially be used for power components with variable geometry.

- The development of optronics, fitted to the engines, which will permit the high temperature components to link themselves.

Another generation of sensors will be created : entirely optical ones which will no longer need any electricity ; supply and output signals will be the optical signals which the central control unit will deal to reconstitute the measurement value.

The link between the engine control unit and the aircraft central control unit will also be able to operate with multi-signal or multi-mode optical fibres.

For the more distant future, the extension, finally, towards higher temperatures for superconduction techniques, allowing high power with low currents, will also revive the interest in "entirely electrical" systems, when their weight-power ratio will become competitive with that of today's systems.

CONCLUSION

The DEC :

- decreases the pilot work load
- highly improves the training possibilities,

improving flight safety

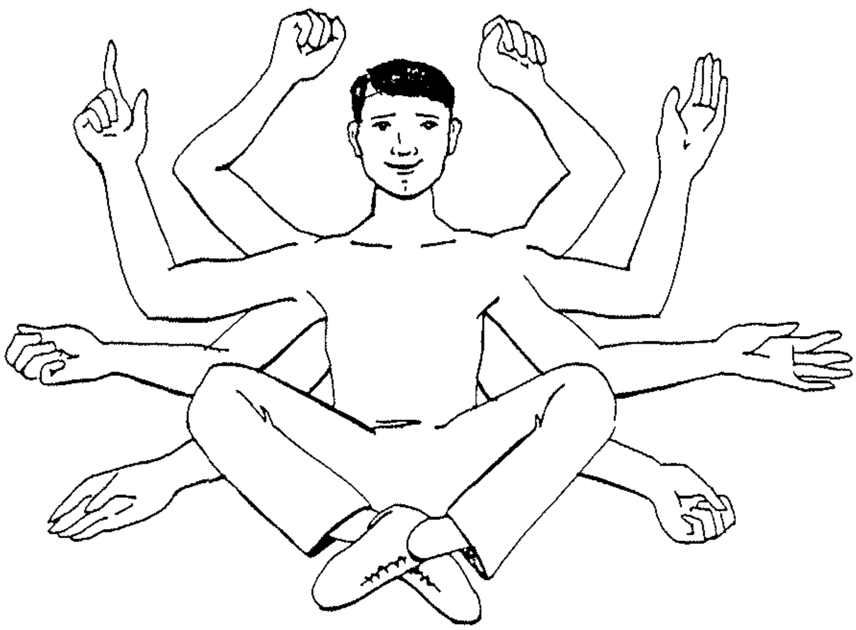
- saves high power life time on the engine and transmission
- eases maintenance,

improving the operating costs

- improves the adaptation of the engine to the airframe
- gives new possibilities to the helicopter.

improving the performance of the total system

The pilots, operators and helicopter manufacturer, after using TURBOMECA DEC or similar systems will never want to go back to hydromechanics.



Forget your stress,
DEC : The most simple way to fly

Michel BARRAL .Flight test pilot