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BENCH AND FLIGHT TEST EXPERIENCE AND PROGRAMME STATUS OF THE MTR390

by

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## BENCH AND FLIGHT TEST EXPERIENCE AND PROGRAMME STATUS OF THE MTR390

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### ABSTRACT

The MTR390 is a 1000 kW class engine being jointly developed by three leading engine manufacturers: MTU (Germany), Turbomeca (France) and Rolls-Royce (UK), initially as the powerplant for the Tiger/Gerfaut attack helicopter.

A joint company (MTR GmbH) has been founded to co-ordinate the development, marketing and production of the engine, and to act as contractor for the German and French Governments and other customers.

Besides the initial application in the Tiger, the engine is designed to meet all the challenges of today's market for civil helicopters in the 2.5 to 7.5 tonne weight class, having a light-weight, compact, non-handed installation; high 30 second emergency power; rapid surge free acceleration; high reliability; ease of maintenance through simple modular design and a flexible electronic control and monitoring system.

In the past, many airframe development programmes have been launched using existing fully developed engines to reduce the risk of powerplant development problems causing delays in the airframe programme, losing the advantages of more modern engine technology.

As the MTR390 engine development programme nears its completion, the decision to launch concurrently the engine and Tiger/Gerfaut airframe development can be judged to have had several beneficial influences on the success of the engine programme with none of the associated problems and risks to the aircraft programme previously assumed to be present.

A strong design base and strict (fixed price and specification) programme control can be utilised by engine constructors which makes the previously assumed wisdom of separated programmes unnecessary.

After the first engine run two months ahead of schedule in December '89 and first flights in February '91 in the Panther flying testbed and in April '91 in the Tiger prototype, the engine testing has progressed on schedule. All important certification tests have been successfully completed. By the end of July '93 the engine has accumulated 840 flight hours and 4800 total running hours. The programme continues with 2400 hours accelerated mission testing and other application associated testing.

At entry into service with the Franco-German armies, the engine will have accumulated more than 16000 hours, 25% of which will have been in flight.

### 1. INTRODUCTION

The MTR390 is a new turboshaft engine in the 1000 kW range being developed for the French-German anti-tank helicopter TIGER and its combat version, the GERFAUT. The installation in the helicopter shows the inlet protection of the engine, the excellent accessibility to line replaceable units (LRU) and the reduction of the infrared emission (Fig. 1).

Besides this application the MTR390 is designed to meet all challenges of the military and civil market for helicopters in the 2.5 to 7.5 tonne weight class in the next 20 to 30 years. Therefore the engine meets requirements based on both civil and military standards as well as matching or exceeding targets in terms

of performance, installation, maintainability, durability and cost of operation.

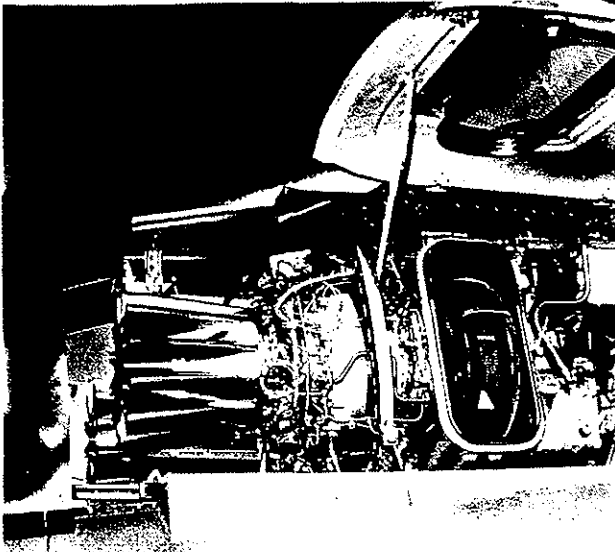


Fig. 1: Engine installation

## 2. MTR390 COMPANY

The MTR390 is jointly developed by three of the largest European aero-engine companies: MTU in Germany, Turbomeca in France and Rolls-Royce in United Kingdom. In 1989 these companies founded with equal shares MTU Turbomeca Rolls-Royce GmbH (MTR) which is registered in Germany and has its headquarter in Munich. This joint company directs and co-ordinates the development, production, marketing, sales and customer support of the engine for the French-German helicopter programme and all other future applications.

The programme is far from being the first co-operation between the three companies which have been working together for more than 25 years on several programmes among which are: Adour, Larzac, RTM322, RB199 and EJ200. The partners have set up a functional structure which guarantees a sound management of the programme (Fig. 2). Regular joint review meetings are held to ensure that the best available technology and the combined experience from all partners are used throughout.

The design, production and the product support of the MTR390 is ba-

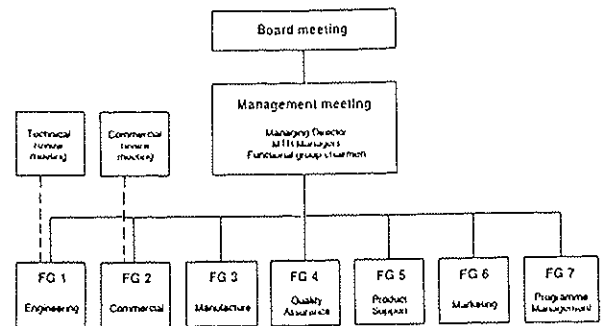
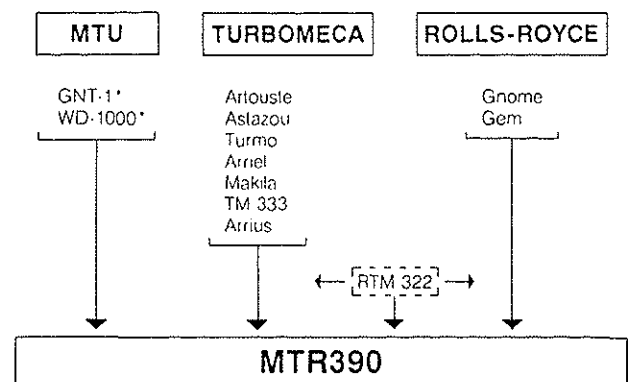


Fig. 2: MTR joint company - functional structure

sed on the considerable common experience with helicopter engines, which the partner companies have gained over the years (Fig. 3 and Fig. 4).



\*Experimental

Fig. 3: Genealogy of the MTR390

## 3. ENGINE DESCRIPTION

The configuration which was chosen for the engine is the result of the main requirements which were essential for the installation in the TIGER (Fig. 5).

All the detailed requirements the engine has to meet and to prove in a comprehensive test programme are laid down in detailed specifications which are based on civil and military standards:

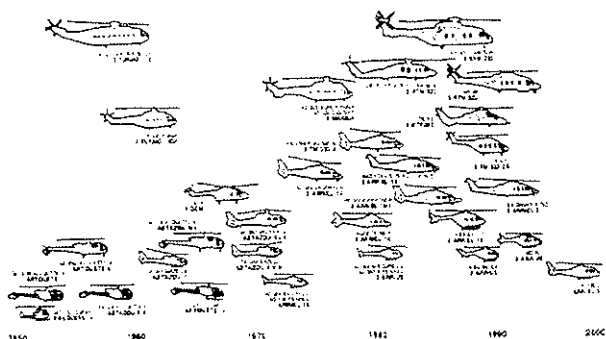


Fig. 4: A unique experience with helicopter engines

- o JAR-E for airworthiness and certification
- o MIL-E-8593 A and E for further requirements which are necessary for military operation
- o and in supplement various others like AIR, BCAR, FAR and Defence Standards.

From these requirements emerged a design which gives a compact, simple, battle-tolerant engine with high specific power and low specific fuel consumption, with high reliability and ample growth potential up to 50% for future needs (Fig. 6).

The **compressor** is a two stage centrifugal system which has benefits compared to an axial-centrifugal type: simple and rugged design, low parts count, damage tolerant rotors, erosion and FOD resistance and insensitivity to air inlet distortion. This design is backed by over 40 years of Turbomeca experience and benefits directly from their TM333 and TM319 new generation engines.

The annular reverse flow **combustor** reduces the engine length and with its improved cooling configuration provides for high life. Modern air blast fuel injectors give low emission characteristics and good

- Ample emergency power for OEI
- High component cyclic lives
- Low fuel consumption under part load
- Good acceleration characteristics
- Low life cycle cost
- Easy handling
- Simple maintenance

Fig. 5: Main requirements for the engine design

dirt tolerance. The combustor performance was successfully verified in rigs and demonstrator engines with over 10 years experience with this configuration.

Marked progress in turbine aerodynamics, based on refined analytical design methods and test results, as well as the availability of improved materials, like powder metal, directionally solidified and single crystal materials, paved the way for a change from the traditional two stage **gas generator turbine** in this power class to a single stage design providing weight and cost advantages with no loss in engine performance. Development of this transonic turbine with cooled vanes and blades was started in 1982.

The **free power turbine** is a two stage uncooled design, the aerodynamics of which have been optimised to give a flat efficiency characteristic from cruise power upwards. This reliable design is scaled down from the RTM 322 engine with the same aerodynamic loadings and efficiency demonstrated in many running hours.

The power turbine shaft drives forward through the centre of the gas generator into the reduction **gearbox**.

In the upper part of this module the accessory gearbox is located which provides the support and drive for all engine equipment. All LRUs are grouped around the gearbox casing with no accessibility problems for regular maintenance and easy change without engine removal already demonstrated in various "Maintainability Assessment Exercises" (Fig. 6).

The engine comprises all systems which are necessary for an autonomous operation. The control and monitoring functions are performed by the electronic control and monitoring unit. It has a responsive, high-reliability full authority digital electronic control (FADEC) and an engine monitoring system for fault localization, engine limits over-riding record, performance check and onboard damage computation.

The development and production workshare assigns the dual centrifugal compressor and the gearbox to Turbomeca, the combustor and the single stage gas generator turbine to MTU and the power turbine to Rolls-Royce. As a proportion of the workload, this gives 40% each to the French and the German partners, with Rolls-Royce taking the remaining 20% (Fig. 7).

The various engine ratings (Fig. 8) have been set such that the high emergency power in the event of failure of one engine of the helicopter, which operates predominantly at low altitudes, will not result in critical situations. This is equally an important feature for all civil helicopters when a safe category A take-off operation is required. The chosen gas temperature rating and design concept are the basis for considerable power growth potential up to 50%.

#### 4. DERIVATIVES

Design studies have been extended to examine derivatives for other applications. A 6000 rpm drive version can be offered simply by changing four gear wheels in the main reduction gearbox. A direct drive version has also been defined. MTR

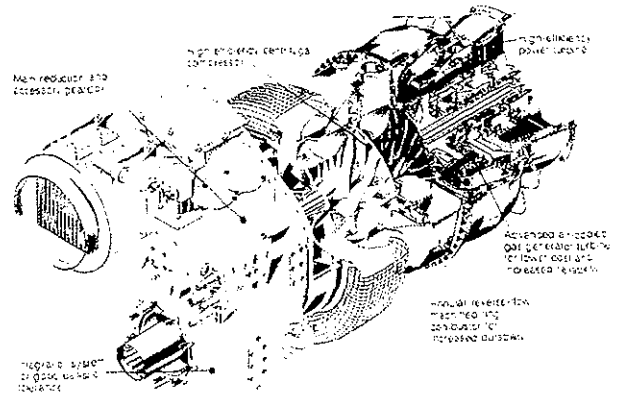


Fig. 6: The MTR390 is a compact and lightweight two spool turbo-shaft of modular construction

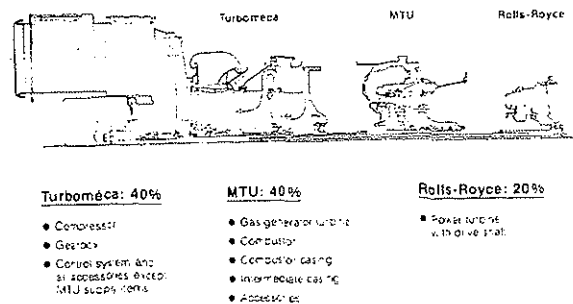


Fig. 7: Workshare between the partners

has proposed the engine to various helicopter manufacturers for consideration in any future military or civil programme.

Minimum new engine

Ratings	Output shaft power		Specific fuel consumption	
	kW	shp	g/kW-h	lb/shp-h
Normal operation				
Take-off (5 min)	958	1285	280	0.460
Maximum continuous	873	1171	284	0.467
One engine inoperative				
Super emergency	1160	1556	-	-
Contingency (2.5 min)	1027	1378	-	-
Intermediate (30 min)	958	1285	280	0.460

SLS/ISA  
Uninstalled  
Output shaft speed 8 000 rpm

Fig. 8: Engine performance

## 5. MODULARITY / MAINTAINABILITY / ILS

The MTR390 is fully modular and comprises three easily changeable modules:

gearbox - gas generator - power turbine

The modules are interchangeable between engines in the field. To facilitate removal and replacement in minimum time, the module fastenings have been kept to minimum, no special checks and adjustments are necessary on module change, the rotatives are balanced and self-contained and no bench test is required.

The engine has been designed for on-condition maintenance. In addition to the maintenance aid system integrated in the electronic control and monitoring unit the engine is equipped with ample devices for monitoring the mechanical health.

From the very beginning of the design maintenance studies have been carried out to facilitate maintenance operations on the installed engine and in the shop. Exercises on mock-ups and flight engines are carried out at level 1 (on helicopter) and level 2 (off helicopter) to check the maintainability of components, accessories and the easy accessibility to the installed engine, in order to ensure a high availability rate and a reduction in the user's operation cost. These Maintainability Assess-

ment Exercises (MAE) are completed by the official maintainability demonstration test.

The results of the first three MAEs showed that no major design changes are necessary and that only minor alterations to clippings electric harness etc. had to be made and they proved the excellent maintainability of the engine:

- o all LRUs can be changed without engine removal
- o no accesibility problems for regular maintenance
- o a complete change of all modules can be carried out with minimum standard tool set, ground equipment and spares.

The engine is being developed together with a comprehensive Integrated Logistics Support (ILS) programme which has been structured and staffed to optimize engine support resources. In place support system procedures optimize requirements for support equipment, spare parts, personel and other related logistics resources. To ensure operational supportability a Logistics Support Analysis (LSA) programme and a reporting LSAR according to Mil-Std-1388-2A is required. This assures that all support requirements have been identified and provide support data compatible with user data systems. In the maintainability demonstrations the task times, skill levels, training, technical manuals, support equipment and spare parts requirements are validated.

## 6. TESTING

The certification testing of the MTR390 is now complete. Development testing is continuing on the 6000 hour programme with an additional 2400 hours accelerated mission testing (AMT) before entry into service.

The running experience up to the end of July 1993 is shown in Fig. 9. The first bench engine ran on 19th December 1989, approximately 2 months ahead of the target date set by the contracting authority.

- First engine run: December 1989
- First flight in Panther flying test bed: February 1991
- First flight in Tiger prototype: April 1991
- Engine qualification testing completed: August 1993

Status of running hours on 31st July 1993:

• Development bench engines		3210	hours
• Flight engines	Bench & Ground	750	hours
	Flying experience	840	hours
Total		4800	hours

Fig. 9: MTR390 running experience

With engines running at the facilities of MTU, Turbomeca and Rolls-Royce rapid experience could be gained. On the basis of this information design changes could be defined immediately and incorporated in the first flight engines. It should be noted that such changes were minimised thanks to the excellent overall test behaviour of the initial engines. To simulate the flight conditions the engine was intensively tested in an altitude test cell. In February 1991 the engine was flown for the first time when tests in the flying test bed, Eurocopter Panther helicopter (a military version of the well known SA 365 Dauphin) commenced with two preliminary flight rated MTR390 engines. This flying test bed will contribute to the Tiger/Gerfaut programme until the end of 1994. Two months later the prototype 1 (PT 1) of the Tiger/Gerfaut programme was airborne for the first time. Helicopter testing could be made as planned without any major problem and the engine has now experienced a total of 840 flying hours at the end of July 1993. All engine characteristics could be tested and the test results showed that the engine is in line with the requirements. A short survey on the most important tests with these helicopters is given in Fig. 10. Three flight engines were stripped down and inspected and were found to be in excellent mechanical condition. The performance deterioration was below 1%.

- FLIGHT ENVELOPE  
0 to 20 000 ft,  $\pm 1.35^{\circ}\text{C}$  ambient  
Hover to 160 kts
- STARTING  
Over 1000 starts, 200 in flight  
0 to 15 000 ft, ISA  $+20^{\circ}\text{C}$  to ISA  $-6^{\circ}\text{C}$
- PERFORMANCE  
To 15 000 ft, ISA  $+12^{\circ}\text{C}$  to ISA  $-9^{\circ}\text{C}$
- HOT FUEL  
 $50^{\circ}\text{C}$
- MANOEUVRE  
Spec. requirement
- CONTROL SYSTEM  
Stability, matching, transients, failure cases
- 14 FLIGHT ENGINES IN USE  
3 stripped down after 110 hours, excellent mechanical condition
- Less than 1% power degradation (still more than 100% power)
- 840 TOTAL ENGINE FLIGHT HOURS

Fig. 10: MTR390 flight experience

In parallel with the flight testing 10 bench engines are running at the test beds of MTU, Turbomeca and Rolls-Royce where the engines passed successfully a great variety of mechanical and aero/thermodynamic tests. With these tests of which Fig. 11 gives a brief overview, the engine completed the qualification testing programme in August 1993.

Test	Result	Highlights
Water and ice ingestion	Passed	Good surge margin
Full flight envelope	Passed	Meets perf and starting spec
Blade resonance	Passed	Resonance free
Emergency shut downs	Passed	Problem free
Emergency power	Passed	Parts in excellent condition
Oil/fuel clearance	Passed	Spec cleared
Bird ingestion	Passed	No mechanical problems
150 hour qual	Passed	No performance deterioration

Fig. 11: Main engine test results

Some of the most important tests so far are the endurance tests and AMTs. These tests were carried out at full rated temperatures and all specified powers have been demonstrated including the super emergency power as well as the specified uninstalled acceleration rates (Fig. 12). Performance tests around the flight envelope were finished successfully demonstrating the specified power re-



quirements. All tests have demonstrated the reliability and the good mechanical behaviour and integrity of the engine.

A layout of parts after the 150 hours endurance run to type test schedule was prepared for the customer. All parts were found in excellent condition. Fig. 13 shows as an example the air-cooled gas generator nozzle guide vanes and the bladed rotor of the single stage HP turbine.

## 7. PROGRAMME STATUS

The development, ground and flight testing is in line with the programme which was set up when the development contract was signed in December 1989.

The engine is gaining more running experience in the Tiger prototypes and in further bench tests at the three partner companies. Fig. 14 gives a summary of this future testing.

- 5 Qualification schedule tests completed
- 2 Accelerated mission tests completed  
(Total experience: equivalent to more than 2000 mission flight hours)
- 3210 Total bench hours by the end of July '93

Fig. 12: Bench endurance tests

## 8. CONCLUSION

A combination of the inter-company design expertise and tight programme control has resulted in the completion of the engine qualification testing phase in mid '93, the date originally programmed at the start of the contract 4 years ago.

The programme continues to build up experience as maturity and flight support testing goes on towards production launch.

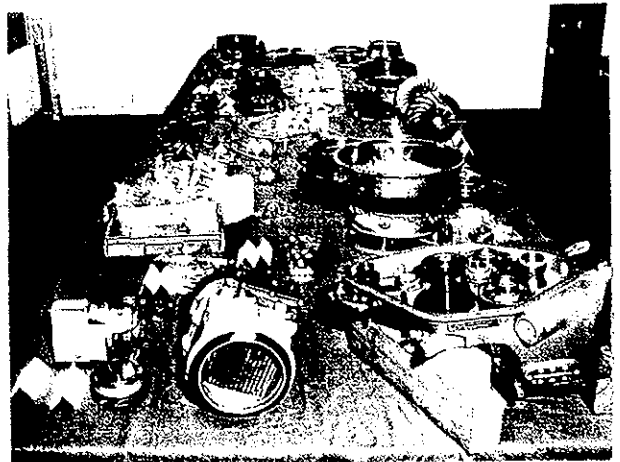


Fig. 13: Parts layout after endurance test

MTR and its partner companies are confident that the engine will find new applications over the next few years, setting new standards for simplicity, reliability and low cost of ownership in its power class.

### **The major part for the testing in the future includes:**

- Completion of 2400 hours AMT on 2 engines
- Application testing related for the Tiger/Gerfaut operation (e.g. sand ingestion test with sand filter etc.)
- Maintainability demonstration testing
- Continuation of fine tuning of control system (FADEC) in compliance with the helicopter requirements.

Fig. 14: Targets for future engine testing

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