

# FOX THREE

N°2

p.2/3



**M88**

p.4/5



**RBE2**

p.6



**Fire Power**

p.7



**DataLink**

## Conformal *Fuel Tanks*: the latest innovation tested on Rafale

During combat operations, it clearly appeared that fighters were required to hit distant targets, and tankers were in very high demand. Air forces soon realised that they had become dependent on extremely vulnerable assets, and that long-range strike fighters were necessary to overcome this worrying trend.

Thankfully, the Dassault Rafale was conceived from the start to carry an extremely large fuel load, as the internal tanks of a single-seater contain 5,750 litres (1,519 US gallons). Additionally, the fighter is equipped with no fewer than

five wet points, and two types of external tanks are available: 1,250 litre (330 US gallon) supersonic tanks may be carried on any of the five wet pylons, and 2,000 litre (528 US gallon) drop tanks can be mounted on the centreline and inner wing stations. A pressure refuelling system is fitted as standard for both internal and external fuel tanks, and internal tanks can be refilled in four minutes only. Finally, the Rafale is equipped with an in-flight refuelling probe located to the right of the nose, ahead of the windscreen.

For air forces in need of an even larger capacity, Dassault Aviation has designed two 1,150 litre (303 US gallon) detachable Conformal Fuel Tanks (CFTs) which can be mounted on the upper surface of wing/fuselage blend, causing less drag than traditional tanks, and freeing underwing stations for armament. CFTs bring the Rafale's maximal external fuel load to an astonishing 10,800 litres (2,853 US gallons), and they

can be mounted or removed in less than two hours. All Rafales have a built-in CFT capability: CFTs can be adapted to any variant of the fighter, including naval and two-seat versions.

The CFTs are being tested at the Dassault Test Centre in Istres, and the first flight of a Rafale fitted with CFTs took place on April 18, 2001, with pilot Eric Gérard at the controls. Supersonic speeds have been evaluated, and various configurations have already been successfully tested: long-range strike with three 2,000 litre drop tanks, four Mica and two Scalp stand-off missiles, and air-to-air configurations with Mica missiles. It has been determined that the CFTs had negligible impact on aircraft handling.

With CFTs and drop tanks, the Rafale boasts an unrivalled range for such a compact aircraft, offering Commanders greater flexibility, and giving aircrews unprecedented deep strike capabilities.



# RBE2

## A revolutionary leap in radar technologies

*Designed and produced by Thales, the RBE2 (Radar à Balayage Electronique 2 plans, two axis electronic scanning radar) enables Rafale pilots to accurately detect, track and engage airborne and ground threats from very long ranges.*

*Compared with classic radar sets, phased array radars represent a major leap in efficiency: they are inherently more reliable and more stealthy, and do not need complex gimbal systems to point the antenna. The beam shifting of the phased array radar is extremely precise and instantaneous, in both vertical and horizontal planes. Even more important is the capability to share time between modes, thus carrying out different tasks simultaneously. Powerful data processors and unmatched beam agility allow the*



*Rafale to fully interleave functions within a given mode: the radar combines search, track and missile guidance functions, processing them simultaneously to assist the crew in achieving air-dominance. It also features a superior fighter/missile data link which gives better fire control capabilities in adverse environment, thus increasing the overall lethality of the Rafale's weapon system. Finally, fixed arrays considerably reduce radar returns towards enemy aircraft. All these factors contribute to the enhancement of the Rafale's combat efficiency and stealthiness compared with fighters fitted with outdated mechanical planar radar antennas.*

### **RBE2 Functions**

Thanks to its unique waveform design and electronic scanning management, the RBE2 radar performs long-range detection and tracking of up to 40 air targets in look-down or look-up aspects, in all weathers, and in severe jamming environments. Interception data are calculated for eight priority targets which can be engaged with Mica BVR / air combat active radar seeker and IR missiles fired in quick succession. With its electronic scanning antenna, the radar is fully capable of tracking the other 32 targets, wherever they are located, while updating

the Micas with the dedicated, mid-course, secure, radar-to-missile link which allows very long-range multiple firings with an exceptionally high probability kill rate. This gives the Rafale a unique combined situational awareness and combat capability/efficiency while considerably reducing aircrew workload, especially in complex situations.

For air-to-surface attacks, the radar has specific functions for navigation, target-aiming, searching and tracking of moving and fixed targets, ranging, and terrain-avoidance/following. With its open

architecture, the RBE2 has been designed for growth. For instance, a Synthetic Aperture Radar mapping mode is actively being developed. It will allow Rafale aircrews to "paint" revealing high-resolution maps of surface targets from stand-off distances.

In the terrain-avoidance/following mode, the RBE2 looks ahead to build a constantly changing, wide-angle, 3-D profile of the terrain to be overflowed. With the electronic scanning technology, terrain avoidance is optimised to improve survivability while flying at very low altitude and very high speed.

## Active Array

Although the innovative RBE2 already represents a giant leap forward compared with older mechanical scanning radars, the adoption of an active array will ensure that the design remains fully effective in the long term. Thales started studies on active array technology in 1990, and has been constantly progressing in this field with several ongoing operational programmes for ground/naval and airborne applications. In 1999, it was decided to offer the active antenna technology on the Rafale to boost export prospects. «The new active array to be integrated in the RBE2 has many significant advantages over the current passive antenna», says Philippe Ramstein, Thales Director of the Rafale programme. «It is composed of about 1,000 solid-state transmit/receive modules which offer considerably increased power and detection range. Reliability will also benefit from the introduction of the new antenna: whereas a failure of the receiver or of the transceiver makes most radars useless, a percentage of an active array radar's transmit/receive modules may fail without significant effect on radar performance. Moreover, direction of the radiation beam from each module is very accurately controlled by computer, making



it possible to scan an extremely wide area at very high speed.» «Our active array compares favourably with the latest American technology. When combined with the functionalities developed for the French Forces, it will bring a unique efficiency to the Rafale's already impressive capabilities», stresses Philippe Ramstein.

The RBE2's open architecture will facilitate upgrading, and the new array is totally 'plug and play'. It can be readily adapted to standard RBE2 radar sets without any changes to the processing equipment, a crucial advantage for customers in need of a radar update as this can be achieved in a very short time.

*The RBE2 is now totally qualified for air-to-air combat, while air-to-surface functions are being developed for F2 standard aircraft. The first production RBE2 was delivered in 1997, and the radar is already in operational service with the French Naval Aviation. Navy pilots are actively developing new air-combat tactics to match the formidable capabilities offered by the Rafale's unique radar, and it is widely anticipated that the French Armed Forces will switch to active radar technology. By embracing open architecture and commercially off the shelves (COTS) technology, Thales has designed a highly evolutive multimode radar which will satisfy even the most stringent requirements. From 2006 onwards, the active array will be available, bringing Rafale operators into the era of total supremacy.*

# Power *On!*

## M88 omnirole thrust

*The Rafale's stringent air-combat and low-altitude penetration performance requirements have imposed an innovative powerplant, prompting Snecma to design the state-of-the-art M88 twin-spool turbofan. This revolutionary engine, which powers every Rafale variant, represents the third generation of French fighter engines, after the acclaimed Atar family of the Mirage III/IV/V/F1 (now totalling over six million flying hours), and the successful M53 of the Mirage 2000.*

*The M88 development programme was launched in 1986, and qualification was obtained in early 1996. The first production engine was delivered at the end of the same year, and, as of May 2001, 56 turbofans had been built. The test programme has proved highly successful, and development and production engines have accumulated 22,000 functioning hours, including 8,000 hours of bench running, 11,000 flying hours logged by prototype engines, and 3,000 flying hours by series M88-2s. So far, Snecma has secured orders for 160 M88s, and the French MoD will eventually acquire about 700 engines for its 294 Rafales. Production currently runs at four a month, but will later stabilise at six a month to satisfy the French requirements. This output can be rapidly increased to respond to any export contract.*

### **M88-2**

The M88-2 is a light, compact, fuel efficient powerplant rated at 50 kN (11,250 lb) dry and 75 kN (17,000 lb) with afterburner. It was clear from the outset that, compared with the M53, the M88 would have to run at much higher temperatures. This represented a challenge, but Snecma came out with innovative solutions

to improve performance and durability: the engine incorporates advanced technologies such as integrally-bladed compressor disks ('blisks'), low-pollution combustor, single-crystal high-pressure turbine blades, ceramic coatings, revolutionary powder metallurgy disks, and composite materials. Additionally, the M88 has been optimised so that its small infrared signature does not compromise the Rafale's overall IR signature. The M88 is equipped with a Snecma-developed FADEC (Full Authority Digital Engine Control) which allows it to accelerate from idle to full afterburner in less than three seconds. Numerous foreign test pilots have already evaluated the Rafale, and they all praise the M88 extremely

short response time and pilotability: whatever the speed or altitude, there is no throttle movement restriction. The FADEC has also proved essential for mission effectiveness, safety and reliability. For instance, the FADEC is fully capable of handling minor engine faults without a need to warn the pilot. For the M88-2, a staged approach was chosen from the start: the first 29 production engines were of the M88-2 Step 1 standard, but all subsequent turbofans ordered by the French Ministry of Defence will be built to the improved M88-2 Step 4 standard which will feature extended time between overhauls (TBO), thanks to its redesigned high-pressure compressor and turbine.



## Up-rated M88-3

For customers requiring more power, Snecma has launched the development of a growth variant of the M88. Called M88-3, it will be rated at 90 kN (20,000 lb) with afterburner, a 20% increase over the original M88-2. Improvements are not limited to power output, and durability is also expected to be improved. The customer can select a 75 kN peacetime rating to boost

even further engine TBO.

Although the M88-3 is much more powerful, it will have the same specific fuel-consumption as the M88-2. This is an overall improvement which will help reduce operating costs while increasing the radius of action.

«Every effort has been made to retain a high degree of commonality between the M88-2 and the M88-3, and the two

variants have about 40% parts in common», explains Jacques Desclaux, Director of the M88 programme. The M88-3 features a redesigned low-pressure compressor for a higher airflow (72 kg/sec instead of 65 kg/sec), a new high-pressure turbine, a new stator vane stage, a modified afterburner, and an adapted nozzle.

The M88-2 and M88-3 are interchangeable, but the introduction of the M88-3 will impose the adoption of slightly enlarged air-intakes to allow for the higher airflow. These intakes, which can be easily retrofitted to existing airframes, will retain the same drag and low observable characteristics, as the previous one.

The Snecma M88 has now successfully entered operational service with the French Navy, and, looking further ahead, other variants could give even more power. Tailored to simultaneously excel in low-altitude and air-combat flight regimes, this outstanding turbofan offers a combination of extremely high thrust and very low cost of ownership.



Thanks to its advanced conception, the M88 can be replaced in under an hour.

### Long Engine Life

*In an effort to reduce costs of ownership, the M88 has been designed with ease of maintenance in mind. The engine comprises 21 modules, interchangeable without a need for balancing and re-calibration. Some of these modules can even be changed without removing the engine from the airframe, and a M88 can be replaced in less than an hour. After maintenance, there is no need to check the turbofan in a test bench before it is installed back on the aircraft. M88 reliability is such that, even for sustained combat operations, only limited quantities of spare parts and spare engines are required.*

*«When introducing into service such an advanced engine, you have to be very cautious at first», explains Jacques Desclaux. «For the M88, we have selected new technologies such as powder metallurgy, and we want to be certain that problems do not appear. This is why the engine initially had to be inspected every 150 hours, but in January 2001 this interval was raised to 500 hours, corresponding to roughly two/three years of operational use. As experience builds up, it will be progressively extended to 800 hours or 1,000 hours, depending on the components. In comparison with the Rafale, when the Mirage 2000 entered service, the M53 had to be checked every 75 hours.»*

# Astounding *Fire Power*

Over the years, cannons have proved essential in a number of scenarios when missiles were either too expensive or unable to hit targets at very close range. As a direct consequence, guns are still considered ideal for the interception of slow and low-flying targets, such

optimise hit probabilities. The 120 kg (264 lb), gas-powered gun is autonomous, and its effective air-to-air range is 2,500 m (8,200 ft). The firing-rate is instantaneously reached, and 21 rounds are fired in 0.5 sec (the normal burst duration). The powerful 30 M 791 is mounted on the

a faulty round after a short safety time period.

The 30 M 791 has been extensively tested in extreme conditions to check that it could resist corrosion, shocks and quick temperature changes. Numerous firing campaigns have been conducted at the Cazaux Flight



The powerful 30 M 791

as helicopters or transport aircraft. Additionally, guns are still regarded as being useful and highly-effective weapons for use against ground and unprotected naval targets.

For the Rafale, GIAT Industries of France has developed the new 30 M 791 seven-chamber revolver cannon, the world's only single-barrel 30 mm weapon capable of firing at a rate of 2,500 rounds/minute. The cannon is designed to offer maximum efficiency in air-to-air combat, and its very high firing-rate and high initial velocity (1,025 m/s, 3,360 ft/min)

side of the starboard engine duct in all Rafale versions, apart from the two-seat naval Rafale N.

The technically advanced 30 M 791 gun fires the powerful 30 x 150 range of ammunition designed specifically for the Rafale. These new ammunitions have high penetration and incendiary effects, and provide an excellent compromise between their splinter effects and detonation powers. A total of 125 rounds are carried, and ammunition ignition is electrical. The gun is equipped with a pyrotechnical rearming device which ejects

Test Centre, in the South-west of France, and final approval for the operational use was granted in mid-2000.

The 30 M 791 is now in full-scale production, and has entered operational service with the French Naval Aviation.

Even for such an advanced fighter, the gun definitely remains a highly cost-effective weapon, and the high-tech 30 M 791 cannon certainly places the Rafale in a class of its own among the latest combat aircraft.

# Ultimate *Dominance*

Rafale masters the world of connectivity

In modern combat, information and situational awareness are essential for immediate and total success, and the futuristic network-centric warfare concept is a key enabler. One of the most significant advances in technology, the advent of this global military info-sphere will shape the future of combat operations, allowing assets to exchange and share tactical data at very high rates, and bringing together all forces in the "battlespace" in a very efficient way. Thanks to advanced sensor data fusion technology, the Rafale has the edge over competing designs, and the introduction of a tactical datalink will boost its already impressive capabilities.

The Rafale was designed from the outset for NATO compatibility: for France and other NATO-approved countries, it will shortly be equipped with the secure, interoperable MIDS-LVT (Multifunction Information Distribution System - Low Volume Terminal) Link 16 system. Jointly developed by France, Germany, Italy, Spain, and the USA, the lightweight (29 kg, 64 lb) LVT can transmit and receive data at a rate of 200 Kbits/s. In France, the MIDS-LVT will eventually equip numerous platforms: Mirage

2000-5Fs, Mirage 2000Ds, AWACSSs, A400Ms, tankers, combat-SAR helicopters, and various warships. With the MIDS-LVT, each Rafale in a formation will have access to the sensor data of other aircraft, ground stations, and AWACSSs.

fully operational on standard F2 aircraft. For countries with no NATO approval, Thales and Dassault have designed the LX-UHF tactical datalink, which has already been selected by two customers for their Mirage 2000s. This high-tech,



Mastering digital technologies has proved essential when designing the MIDS, and Thales and its partners came out with the very light LVT, which also includes a TACAN. The LVT and its two associated antennas offer a 360° coverage. Flight testing of the MIDS has already started with systems mounted on Falcon 20 and Mirage 2000 test beds. Additionally, an airborne Rafale has successfully exchanged data with a C<sup>2</sup> simulator and an integration rig. The first production MIDS-LVT for the Rafale will be delivered in 2003, and the system will be

jam-resistant, line-of-sight system is Link 16 comparable. The introduction of datalinks is recognised as a fundamental change in air warfare tactics, and Rafale pilots will have access to far more tactical information than their predecessors, with the MIDS-LVT or the LX-UHF considerably enhancing their combat effectiveness. In future improvements, the Rafale's information-sharing capabilities will be developed even further thanks to the adoption of an advanced satellite communication system.

Dassault Aviation • Snecma • Thales



**RAFALE**   
INTERNATIONAL

GIE - Rafale International  
78, quai Marcel Dassault 92552 Saint-Cloud cedex 300 - France

[www.dassault-aviation.com](http://www.dassault-aviation.com)  
[www.snecma.com](http://www.snecma.com)  
[www.thalesgroup.com](http://www.thalesgroup.com)