Fox Three
Rafale INTERNATIONAL
N° 1

Rafale keeps on moving ahead

Flight testing of the Rafale has been gaining momentum in Istres in the last months with entry into service on the Charles-de-Gaulle carrier slated for mid-2001. Significant test hurdles have been cleared as the LRIP programme unfolds and intense marketing activity has taken place with more customer evaluations and out-of-country deployments. To date, the Rafale has been deployed on 17 occasions abroad, the last major two being Asian Aerospace 2000 and the hot weather trials in July 1999 in the UAE.

The programme is mature enough for the aircraft to become a familiar sight at air shows around the world, from the UK and the Netherlands to Dubai, Singapore and Seoul. Twelve countries have been visited so far, with local air force pilots and officials performing familiarization sorties, thanks to the quick-to-learn pilot interface, carefree handling and inherent safety features. In all, the Rafale has been put through its paces to date by 75 air force evaluator pilots from outside France.

The development aircraft have been joined by instrumented production aircraft to cope with the aggressive schedule of flight testing (at the Istres Flight Test Center) and demos during the past years.

Test highlights include the firing of active seeker Mica against twin targets in electronic warfare environment, and live GBU-12 firing at the Cazaux test range in southwestern France. The airframe (which has 80% commonality between all versions) has been certified to 9g with a demonstrated margin of 90% on top of that, after 10,000 hours of testing on the fatigue test rig - the cycles were typical of carrier-based operations with stress loads simulating catapult launches and arrested deck landings, more than will be endured by any land-based fighter. Separation trials of the Scalp missile have also been carried out as a risk reduction measure in anticipation of the final Scalp integration tests.

A surprising number of groundbreaking Rafale features are now considered ordinary by test pilots and specialists at the Dassault flight test center who deal with them everyday on a routine basis : the Direct Voice Input in the cockpit, the production RBE2 radar with its electronically steered array - it has been flying on the Rafale since late 1997 - and the sensor fusion which blends target data provided by the RBE2, the front sector optronic system and the Spectra EW system.

Coming up next on the flight test schedule are the conformal fuel tanks (CFTs) which have passed wind tunnel tests and are now cleared for flights. As a matter of fact, CFTs boost the deterrence value of fighters by freeing up hardpoints for extra drop tanks and/or weapons, thereby significantly increasing their range vs. weaponload performance ■

Mica and PGM live firings have been successfully completed as Rafale entry into service nears.

The Spectra: a digital revolution

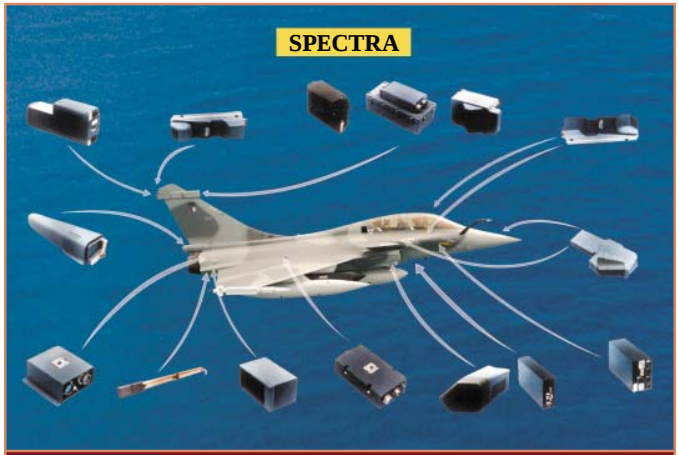
Modern air warfare places a severe requirement on aircraft self-defence capabilities, and only the most modern fighters will survive any major conflict. Dassault Aviation Mirage 2000-5 and Rafale combat aircraft are equipped with highly-automated systems which provide an unprecedented level of protection against threats likely to appear in the future.

The Spectra - Self-Protection Equipment Countering Threats of Rafale Aircraft - state-of-the-art self-defence system mounted on the Rafale is a complete and totally integrated electronic warfare suite designed and produced jointly by Thales and Matra Bae Dynamics. The system, which offers a dramatic increase in survivability against modern and emerging threats, is entirely mounted internally in an effort to keep weapon stations free, a big improvement over older designs such as Jaguars, Mirage F1s and Super Etendards which all needed external jammers and chaff/flare dispensers. It ensures efficient electromagnetic detection, laser warning, IR detection for missile warning, jamming and chaff/flare dispensing, even in the most demanding multi-threats environment. Spectra is divided into different modules and sensors strategically positioned throughout the airframe to provide all-round coverage. The latest advances in micro-electronic technology have led to a new system which is much lighter, more compact and less demanding than its ancestors in terms of electrical and cooling powers. Thanks to its advanced digital technology, Spectra provides passive long-range detection, identification and localisation of threats, and allows the pilot or system to react immediately with the best defensive

Rafale M: First two accepted into service.

In a ceremony held in December 2000 at Landivisiau Naval Air Station, the French Navy has accepted into service its first two Rafale M combat aircraft. This crucial event marks the beginning of an extensive fleet renewal programme encompassing the successive replacement of F-8E Crusader fighters, Etendard IVPM reconnaissance aircraft and Super Etendard strike fighters. A total of six pilots, including two French Air Force exchange officers, are currently involved in a Navy operational evaluation and tactics elaboration campaign which will culminate in complex air-defence exercises with multi-target multi-threat engagements.

From January 2001 onwards, Rafale fighters will be delivered at the rate of one every two months, and the first front-line Squadron, Flottille 12F, will be officially reborn at Landivisiau in June. By the beginning of 2002, this unit will have taken delivery of ten Rafales out of 60 planned by the French Navy, bringing it to full operational status.



The Spectra System and its various components, on board the Rafale.

measures: jamming, decoys, evasive manoeuvres and/or any combination of these actions. Moreover, SPECTRA features accurate Direction-finding and reduced time for signal identification.

Additionally, very high processing power gives excellent detection and jamming performance, optimising the response to match the threat: incoming electromagnetic signals are analysed, and the bearing and location of the emitters are determined with great precision.

The proliferation of new generation weapons such as man-portable surface-to-air missiles has raised concern among key decision makers. Both laser and IR missile warning systems have been mounted on the fighter. They provide 360 degree coverage and ensure detection/warning of incoming threats. The IR missile warner ensures high probability of detection and low false alarm rate, even against totally passive IR-guided weapons. Four upward-firing launcher modules for various types of decoys - are built into the airframe, and the Rafale is equipped with internal chaff dispensers. The exact location and types of systems detected by Spectra can be recorded for later analysis, giving Rafale operators a substantial built-in SIGINT/ELINT capability while completing specialised dedicated intelligence platforms.

But Spectra is much more than a traditional self-defence system as it is closely integrated with the primary sensors also supplied by Thales, the RBE2 multimode electronic scanning radar and the FSO passive front sector optronics system. As such, it considerably improves pilot situational awareness: all data obtained thanks to the various means are fused into a single tactical picture, offering the pilot a clear image of the evolving tactical situation. Spectra identifies the type of air-defence weapon, that has been detected; it takes the local terrain configuration into account and displays the lethality zones on a colour tactical screen, enabling the aircrew to avoid dangerous areas. This smart data fusion significantly increases mission success rates through enhanced crew awareness and improved aircraft survivability.

The first Spectra flight onboard a Rafale took place in September 1996, after M02 prototype had been retrofitted. Since then, the system has been thoroughly tested in very complex electronic warfare scenarios and environments. For instance, Rafale M02 was pitted against a wide variety of the latest IR-defence systems during the NATO Mace X trial organised in August 2000 in Southwest France, and its self-defence suite performed flawlessly. It is now in full production, and is already entering operational service onboard French Navy Rafale. Spectra, a particularly cost effective system, has been designed with growth in mind to keep the Rafale abreast of emerging threats ■

Rafale demonstrates Precision-Guided Munitions capabilities

GBU-12s - included here in a swing-role configuration - provide precision strike capability with minimal collateral damages.

Dassault Aviation has completed a series of test flights on the Rafale, dedicated to GBU-12s' certification. The first LGB firings were carried out with the Rafale B01 development aircraft on the Cazaux test range in south western France and involved several swing role configurations, with Mica BVR missiles and 2000 l (530 USG) fuel tanks.

The GBU-12 is a 500 lb Paveway 2 laser-guided bomb which is fast becoming one of the most widely used weapons in precision strike operations, because of its pinpoint accuracy, low cost and widespread availability. Compared to heavier conventional bombs, it has the advantage of reduced collateral damage while retaining the same lethality against point targets due to its precision guidance.

This development effort comes in the wake of the French Air Force engagements in joint operations over Bosnia and Kosovo stressing the political implications of precision strike capability. A fast track GBU-12 upgrade had to be fielded on Air Force Mirage F1CTs and Navy Super Etendards and the Rafale development agenda was also reshuffled according to lessons learned in combat by including the PGM capability into the definition of the first air force batch. One of the configurations cleared during the recent separation trials featured 4 mid-wing mounted GBU-12s together with 4 AAMs (2 Mica and 2 Magic 2 - the wing-tip Magic are to be replaced by IR-guided Mica on the production aircraft) and three 2000 l tanks. Combat radius is quoted at 800 nm unrefuelled, with up to 4 ground targets assigned and a solid self-escort capability resting on the BVR Mica. Thanks to its carrying capability, stealth performance and multisensor fusion, Rafale brings an unprecedent level of tasking flexibility and of lethality. Risk reduction work had been performed prior to the test flights, with simulation runs using computational fluid dynamics software and with in-house GBU-12 experience on other aircraft types. The PGM capability programme has been pushed on hard with guided GBU-12 releases performed in late 2000 at Cazaux using a forward air controller. Self-designation of laser guided weapons is to be performed with the Thomson-CSF Damocles LDP now in development and available for test flights from 2002, well in time for export deliveries slated for 2004 ■

DASSAULT AVIATION snecma THALES

Rafale INTERNATIONAL

GIE - Rafale International - 78 quai Marcel Dassault - 92210 St Cloud - France

RAFALE INTERNATIONAL

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 overflown. 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.

Uprated 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 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.

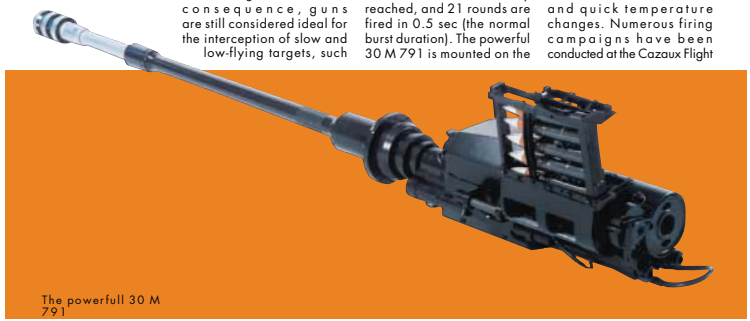
For the Rafale, GIAT Industries of France has developed the new 30 M 791 seven-chamber revolver cannon, the world's only single-barrel 30 mm weapon capable of firing at a rate of 2,500 rounds/minute. The cannon is designed to offer maximum efficiency in air-to-air combat, and its very high firing-rate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



The powerfull 30 M 791

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, AWACSs, 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 AWACSs.

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 C²simulator and an integration rig. The first production MIDS-LVT for the Rafale will be delivered in 2003, and the system will be 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, 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.

RAFALE INTERNATIONAL

FOX THREE

N°3

p.2 / 3

Maintenance

p.4

Voice **Magics**

RAFALE : MULTINATIONAL SUCCESS

From May 21 to June 2, 2001, the French Navy participated for the first time in a major training exercise with its state-of-the-art Dassault Aviation Rafale fighters. *Trident d'Or* (Golden Trident) was one of the largest international exercises ever held in the Mediterranean, involving warships from ten nations. Among the vessels taking part was the nuclear-powered aircraft-carrier *Charles de Gaulle*, the French Navy flagship. With its embarked air-group, the *Charles de Gaulle* played a pivotal role in this event, carrying out air-defence, strike, combat SAR, and surveillance missions.

On May 18, 2001, Flottille 12F, the first Rafale naval fighter squadron, recreated at Landivisiau. Just a few days later, the unit deployed on board aircraft-carrier *Charles de Gaulle* with the first six Rafale pilots and their aircraft. During *Trident d'Or*, Flottille 12F personnel trained and evaluated the fighter's weapon system. They encountered AV-8B+ Harriers and F/A-18 Hornets, simulating interception profiles. Both the Thales RBE2 electronic scanning radar and the Spectra electronic warfare suite were extensively tested, and performed flawlessly. The Rafales were flown in various configurations, sometimes heavily loaded with external fuel tanks. To extend mission duration, the Rafales took advantage of the buddy-buddy refuelling capabilities offered by the carrier-borne Super Etendard Modernisé fighters. In-flight refuellings from French Air Force Boeing C-135FR Stratotankers were also performed. Additionally, French naval aviators demonstrated the Rafale hot refuelling procedure during the exercise. At the time of writing, seven Rafales had been delivered to the French Navy, and ten pilots had converted to the type. Deliveries are continuing, and, by mid-2002, Flottille 12F will be fully operational with a complement of 10 Rafales.

SUSTAINING THE EFFORT

Capitalising on the Mirage 2000 impeccable track record, Dassault Aviation, Snecma and Thales have designed the Rafale omnirole fighter to offer unprecedented reliability, supportability, testability, sustainability and deployability levels. Customer and product support considerations have influenced the design of the aircraft from the outset, and the Rafale will undoubtedly set new reliability and maintainability standards.

Excellent supportability

Thanks to advanced technologies, the Rafale's supportability will be boosted by about 30 percent compared with that of the Mirage 2000. Dassault engineers have developed a very simple fighter with fixed air intakes and no dedicated airbrake, helping reduce maintenance requirements.

«The Rafale has been conceived for naval operations, and even the Air Force ground-based variants benefit from the naval characteristics: rugged airframe, excellent corrosion protection, and aircraft-carrier electromagnetic compatibility», explains Xavier Labourdette, International Support Manager. The Rafale has been built to last, and features a fully automatic, non-dedicated structural monitoring system which provides individual follow-up of airframe components, facilitating fatigue index surveillance throughout the 7,000 flying hour service life.

Fault detection is a key aspect of modern aircraft maintainability, and all Rafale systems are monitored in real-time by the IHUMS - Integrated Health and Usage Monitoring System - which ensures clean and unambiguous failure detection. This unique and fully automatic monitoring system helps reduce turnaround times by easing troubleshooting and repair, drastically minimising the need for ground support equipment. Testability targets call for a 95 percent fault detection, plus the ability to detect all safety-critical failures.

With the Rafale, Dassault has pioneered the use of revolutionary advances such as the fully redundant, very high pressure (350 bar / 5,000 PSI) hydraulic systems and the variable frequency alternators which all boost reliability and safety. These advances have proved so successful that they have been adopted as standard by other aircraft manufacturers, and, for instance, they have been specified for the Airbus A380.

A single test bench capable of dealing with all electronic equipment has been developed, allowing specialists to determine which component in a Line Replaceable Unit (LRU) is defective. The first one is already fully operational with the French Navy. A similar bench has been selected for the Tiger and NH90 helicopters, and for the French E-2C Hawkeye. It is also the baseline for that of the French Army Leclerc main battle tank.

The selection of the uprated Snecma M88-3 engine and of a state-of-the-art Active Electronic Scanning Antenna (AESA) for the Thales RBE2 radar also contributes to the overall improvement of aircraft reliability.

Unrivalled deployability

Stringent carrier requirements have had a positive impact on Rafale maintainability.

In the past 30 years, the French Armed Forces have participated in countless operations far from their national support infrastructure, gaining considerable experience in forward deployments. As a direct result, the French requirement for the Rafale called for significant built-in deployability and self-supportability, and Dassault and its partners have taken advantage of their undisputed know-how to develop a fighter with an extremely low logistic footprint. This is a crucial advantage which will prove less constraining for strategic airlift assets as only four C-130 Hercules loads are necessary to carry equipment and spares for 20 Rafales for 30 days. For example, no integral engine test cell is required for the M88 turbofans. Additionally, thanks to unrivalled manufacturing and assembly techniques, there is no need to check equipment boresighting after replacement, and no complex external testers are required for Flight Line or Organisational level maintenance.

For self-supportability, the Rafale is designed to require the minimum of ground support equipment: it is equipped with an on-board oxygen generation system, and with a closed-loop cooling fluid system for on-board coolanol and nitrogen circuits. The built-in auxiliary power unit provides electrical power until the engine-driven generators come on line.

For future operators, the Rafale's unmatched reliability, maintainability and testability will ensure an extremely high availability, allowing sorties to be conducted at a sustained tempo for extended periods of time. Full scale in-country maintenance will be carried out by customers, and the local industry will benefit from technology transfers: French authorities have already approved source codes transfers, and even radar cross section reduction material will be maintained locally. The electronic warfare suite can be programmed by indigenous experts, and new weapons can be easily integrated. This facilitates transparent decision making process and support through the life of the aircraft.

Unmatched Affordability

An extremely reliable and easily maintainable fighter invariably translates into considerably lower maintenance costs. Numerous maintenance/support aspects contribute to the Rafale's incredibly low life-cycle costs:

- There is no complete airframe or engine depot level inspection required throughout the aircraft service life, and only specific components such as Shop Replaceable Units (SRUs) are returned for maintenance/repair. This is a remarkable achievement that will reduce the amount of time during which the aircraft is not available. The same philosophy applies to the M88 turbofan composed of 21 modules, interchangeable without needing full balancing and re-calibration. For maintenance and repair, only modules or parts are returned to the depot/manufacturer.

- The minimum spare part requirements allow a reduction in spares inventory, and the very high commonality between variants minimises the number of spare items. Similarly, changing, at flight-line level, printed circuit boards within a LRU instead of replacing the LRU itself lessens the need for complete spare units (radar, Spectra, modular computers).

- The fighter is extremely reliable, and easy to maintain and repair, ensuring reduced manning levels (minus 30 percent compared with the Mirage 2000), and lowered mechanics training requirements. For instance, the side opening canopy facilitates ejection-seat removal.

VOICE MAGICS

Compared with earlier generation systems fitted to other fighters, the Rafale's Man-Machine Interface has been tuned to considerably reduce aircrew workload. One of the most innovative choices made by Dassault Aviation is the introduction of the combined Voice, Throttle and Stick (VTAS) system which drastically eases data entry and systems selections.

«As an alternative to using manual methods, the direct voice input technology allows the pilot to activate data entry functions, and select non-safety-critical modes», explains Philippe Rebourg, Dassault Chief Test Pilot for Military Aircraft. «In some demanding combat scenarios, manual actions can prove painfully slow, and the voice command system increases overall effectiveness: the pilot does not have to look into the cockpit any more. That enables him to focus on the mission and on systems operation.»

Developing such an advanced tool was a challenge since the various speech recognition algorithms had to cope with the noises of the cockpit environment as well as with the stress and the high g-loads that can affect pilots' voice. But Dassault and Thales engineers overcame all hurdles, and two production Rafales, two-seaters B301 and B302, are currently equipped with the direct voice input system. «These two aircraft allow us to push development even further», says Philippe Rebourg. «Numerous foreign test pilots have evaluated the system, and they all praise its efficiency: word recognition rates are better than 95 percent, and, depending on the customer's requirements, the system boasts a vocabulary of between 50 and 300 words. The response time is extremely short (less than 200 ms), and critical voice command selections are confirmed by visual feedback.» Display management, navigation tasking and mode switching are even quicker. A typical example is radio and navigation aids selection: a single pressure on a button on the throttle activates the voice input system, and, with chosen code words, the pilot can instantly reprogram the flight-plan or select various autopilot modes or radio/IFF frequencies.

«As an added bonus, the voice command system proves also extremely useful by reducing high pilot workload during emergency situations», says Gérard Dailloux, Dassault Flight Safety Vice-President.

The direct voice input system will be available on export Rafale Block 05s, and, although Dassault has mainly concentrated on the Rafale so far, it could be adopted at some stage on the Mirage 2000-5 Mk2 and on the future Falcon 7X long-range business jet, helping reduce cost by increasing series production.

PEMA - 2b - Photos:E.Robineau - Dassault Aviation - Alain Ernoult - aerospictures.com - Christian Boiselon.

RAFALE INTERNATIONAL

GIE - Rafale International
78, quai Marcel Dassault 92552 Saint-Cloud cedex 300 - France
www.dassault-aviation.com
www.snecma.com
www.thalesgroup.com

RAFALE INTERNATIONAL

FOX THREE

N°4

p.2 / 3

Quality Process

p.4

The **survivor**

THE FIRST OPERATIONAL DEPLOYMENT IS A SUCCESS

In the aftermath of the September 11, 2001 attack, the French authorities decided to support the American war effort against terrorist groups, and the aircraft-carrier Charles de Gaulle was sent to the Indian Ocean to participate in combat operations over Afghanistan. Equipped with Dassault Rafale fighters, Flottille 12F is the spearhead of the French carrier air group. "When the Charles de Gaulle left her home port in November 2001, we were caught in the middle of a comprehensive update programme, says Commander Denis Planchon, Officer Commanding Flottille 12F. This is the reason why only two Rafales were on board the vessel at that time. However, Dassault and the Navy accelerated the upgrade programme, and we were soon able to increase the number of deployed fighters." In March 2002, the number of Rafales on board the aircraft-carrier had grown to seven. The reinforcement Rafales were sent directly to the Charles de Gaulle from continental France, and four in-flight refuellings were required on average. "Initially, we were a bit worried about landing on a carrier after a seven hour flight, but the Rafale's cockpit is very comfortable, allowing us to remain fully alert, and we experienced no problem at all", says Commander Planchon. Clearly demonstrating the Rafale's deployability, this long-range effort was a first for the French Navy. The seven fighters are equipped with two variants of the Snecma M88 turbofan, the M88-2 Stage 1 and the M88-2 Stage 4 which features increased time between overhauls.

With only a couple of serviceable, outdated fighters, the Taliban Air Force was not a threat, and there was no need to engage air-superiority assets over Afghanistan. As a result, the Rafales do not participate in full-scale operations over that country. They are nevertheless kept extremely busy, and they regularly practise dissimilar air-combat training against American fighters from USS Theodore Roosevelt and USS John C. Stennis and AV-8B+ Harrier IIs from Italian carrier Garibaldi. According to the pilots, the F-14 Tomcats, F-18 Hornets and AV-8B+ Harriers are no match for the Rafales: thanks to their high thrust-to-weight ratio, low wing loading, and extreme agility, the Rafales quickly gain the upper hand. On board the Charles de Gaulle, the pilots have a combat simulator at their disposal where they can train in a number of scenarios : catapult shots, carrier landings, navigation, and BVR combat. After the acceptance into full operational service of the Rafale fighter, the French Naval Aviation has gained unmatched air-defence capabilities, and, with its Rafales, Super Etendards, and E-2C Hawkeyes, the Charles de Gaulle's Air Group is among the most powerful air wings operating in the World.

When Quality *Comes First*

The Dassault Acceptance Team in Bordeaux-Mérignac, in south-west of France, is in charge of flight testing every aircraft coming out of the Dassault assembly lines, be it a Mirage 2000-5 Mk 2, a Rafale or a Falcon business jet. The purpose of the acceptance process is to check that a new aircraft is up to full specifications: thanks to this practice, any potential fault will be detected before the aircraft is delivered to the customer. Four Test and Acceptance Pilots undertake the numerous test sorties flown out of Mérignac. They are helped in their daunting tasks by highly qualified Test Engineers, Flight Test Engineers, and 'Inspecteurs Mécaniciens'.

A Test Engineer is responsible for a Standard F1 Rafale M from the moment it leaves the assembly line until it is delivered to the customer. He manages the acceptance programme, prepares the flights, briefs the Test Pilot, and supervises the sorties from the monitoring room. When the aircraft has landed, he debriefs the team, checks the recorded parameters, and ensures any fault is rectified by the maintenance specialists. The mission of the 'Inspecteurs Mécaniciens' - 'inspector engineers' - starts as soon as the Rafale leaves the assembly line. They are in charge of making sure the aircraft is trouble-free. The fighter is first tested in a hush test facility where the engines and the various components, including the weapon system, are thoroughly verified. Dassault fully complies with the latest environmental protection laws, and the Thales RBE2 radar and Spectra electronic warfare suite are not cleared to emit while on the ground. The Snecma M88 reactors are run from idle up to full afterburner power, and the 'logics' of the electronic systems are tested. When this is completed, the aircraft is towed back to the assembly floor to undergo the "debugging" process. The fighter is then jacked up for the security check, and all the systems are once again tested, including landing gear retraction. Every single access panel will be opened in search of any snag, such as forgotten foreign objects. The 'Inspecteur Mécanicien' and his team will then ready the aircraft (this is called the 'Security Inspection') for the first trial by a Test Pilot.

Ground run

The acceptance programme of a Rafale, a lengthy process spread over about a month, is divided into a ground run and three flights. The ground run commences half an hour before the planned start-up time, when the Test Pilot meets with the 'Inspecteur Mécanicien' and his team, and climbs into the cockpit. He totally trusts the engineers and, as a consequence, a pilot preflight check is not deemed necessary. A ground power unit is switched on for the system check during which the Test Pilot communicates with a Test Engineer sitting in the monitoring room, both making sure everything goes according to the book. The switches in the cockpit are set to simulate a quick reaction alert, and the Rafale taxies out to the runway to accelerate to 30 knots in full dry power. Then, it returns to its starting point and accelerates, this time up to 90 knots with full afterburner selected, before applying the brakes. During this run, the pilot carefully monitors the Jx, the longitudinal acceleration of the aircraft. This helps ensure that the M88 turbofans are delivering their normal maximum thrust, and that they spool up in the required amount of time. When the aircraft is back to the Dassault flightline, the engineers make certain the flight data recorder is working as it should be. The Test Pilot and the Test Engineer will then debrief, and the engineers will correct any fault.

First flight

This important mission is carefully planned by the Test Pilot, the Test Engineer, and the other members of the team. The sortie is followed by an air traffic controller who has undergone a special 'acceptance' training. His mission is to ensure the dedicated flight test airspace used by the aircraft is clear of any other traffic.
This first mission is a flight envelope sortie during which the aerodynamic performance and behaviour of the fighter are checked. After a full reheated takeoff during which the acceleration (Jx) is again monitored, the fighter climbs nearly vertically to 10,000 feet, and the pilot performs tight turns in the two flight control modes available: 'air-air', with no limits, and 'weapons', simulating a load of drop tanks or ordnance (with reduced g, angle-of-attack and roll rate limits). The autopilot and the airbrakes are then verified, and the pilot enters 360 deg turns to automatically calibrate the magnetometer. At the end of the last turn, the Rafale starts climbing again in full dry power up to Flight Level 360. The pilot levels off at 36,000 feet, checks the altitude hold mode of the autopilot, and verifies again the agility of the fighter in the two flight control modes. Full afterburner is then selected to accelerate from Mach 0.7 to Mach 1.4 before easing back the throttle to decelerate to Mach 0.8 and climb up to Flight Level 500 where the air-conditioning and pressurisation systems are checked. Manoeuvring aggressively all the way down, the pilot descends to FL330 where he makes tight turns to decelerate to 110 knots to initiate an engine test during which he slams the throttle open from idle to full afterburner power to ensure that the M88s are trouble-free. Then, the throttle is brought out of afterburner, and the pilot descends down to FL200 where he tests the slow speed and high alpha flying qualities of the Rafale before cycling the undercarriage. The descent is continued down to 2,000 feet where the Test Pilot checks the anemometric data while accelerating from 250 to 450 knots. After a few minutes of low-level flight to analyse the ride quality and the precision of the navigation equipment, the one-hour long mission is concluded with an ILS approach to Mérignac.

Second and third flights

The second sortie is also a flight envelope mission during which the Rafale reaches Mach 1.6 at 36,000 feet. The Rafale M is cleared for hands-off sea-surface following, and this dedicated mode is checked during the second sortie.
The third mission is a 'système' flight during which the fighter's combat capabilities are fully tested. The sortie is divided into two parts. For the first one, the Standard F1 Rafale M is accompanied by an Alpha Jet which acts as an exercise target to check the performance of the RBE2 radar. Also flown by a Test Pilot, the Alpha Jet flies an extremely accurate profile, and the RBE2 acquires its target in various conditions using the different radar modes: look up, look down, air-combat and interception. Targets of opportunity, generally Armée de l'Air fighters operating out of Cazaux Air Base, are acquired in the Search While Scan mode. For the second part of the sortie, an Air Force Mirage 2000C uses its RDI radar to check the Rafale's radar-warning receiver and jammer. When Standard F2 Rafales are delivered, weapon system testing will be expanded to include air-to-surface armament modes.
In the highly competitive market of the combat aircraft, everything has to be done to ensure that the customer is satisfied, and the acceptance process represents the best way of checking the quality of the end product. Dassault's 'know-how' is not limited to the Mirages and Rafales, and the Falcon business jets are also built and tested in exactly the same rigorous way.

THE SURVIVOR

Survivability is the key to modern air-warfare, and the Rafale fighter is well equipped to slip undetected through dense air-defence networks and survive, even against the latest threats.

Avoid Detection

The French fighter is definitely a 'low-observable' aircraft, and its systems will set new standards in terms of low-observability and survivability. Every effort has been made by the engineers to minimise its infrared and radar signatures. The objective was not to make the aircraft undetectable or to match the Radar Cross Section (RCS) of the F-117 or B-2, but to significantly reduce the detection and tracking range of hostile air-defences. Accordingly, the airframe has been carefully shaped to cut down its RCS. Other signature reduction measures include state-of-the-art Radar-Absorbing Materials in various areas of the airframe, 'sawtooth' edges on the foreplanes, on the flaperons, and on some access panels and doors, specially treated canopy, plus 'double-S' shaped air-intake ducts to hide the engine compressor faces. Thanks to the Hot Spot treatment, infrared signature is minimised, and the Snecma M88 turbofans have been optimised to limit infrared detectability.

Rafale measurements in anechoic chamber.

Dodge the Threat

But low-observability is definitely not the only way to boost survivability. As radar and radio emissions can betray the position of a fighter, the designers have adopted for the Rafale a wide range of unique passive sensors and missiles: the passive Front Sector Optronics used in conjunction with the long-range, infrared-guided Mica IR missile gives Rafale pilots unprecedented capabilities, allowing totally silent interceptions to be performed, especially when accurate targetting data is received via a datalink. Additionally, radar emissions can be carefully controlled, and emission limitations can even be programmed on a data transfer cartridge before the mission.

The Rafale is fitted with a discrete terrain avoidance/following system optimised to improve survivability while flying at extremely low altitude and very high speed. For threat avoidance, the Thales Spectra electronic warfare suite is capable of accurately localising and targetting enemy radar emitters (both surface-to-air and airborne systems). Lethality zones, determined by Spectra according to the performance of the air-defence weapon types detected and the local terrain, are displayed on the colour tactical screens, enabling the aircrew to avoid dangerous areas without being detected.

Survive damages

The 'fail-safe' concept has been implemented to simultaneously increase redundancy and reduce vulnerability: the dual redundant hydraulic and electric systems ensure maximum safety, even if combat damages have been inflicted to the aircraft. The advanced fault management system can automatically reconfigure the fly-by-wire control system if a control surface is damaged. When used in conjunction, all these advanced redundancy and signature reduction technologies significantly increase the Rafale's effectiveness and survivability. In the not too distant future, other refinements might be introduced, such as a new system to shroud external weapons to reduce radar cross-section, the stealthy shapes being ejected before weapon release. Alternatively, tube-launched and 'cocooned' missiles could also be adopted.

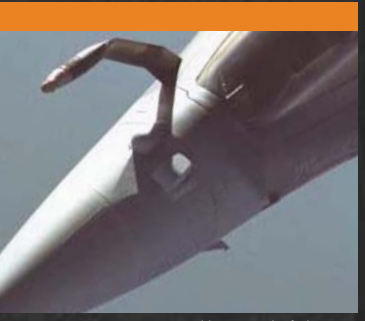
PEMA 26 - Photos : H.P. Grolleau - Studio Pons

RAFALE INTERNATIONAL

GIE - Rafale International
78, quai Marcel Dassault 92552 Saint-Cloud cedex 300 - France
www.dassault-aviation.com
www.snecma.com
www.thalesgroup.com

A TRULY *PASSIVE RADAR*

To complement its multisensor avionics suite that includes the RBE2 multimode electronic scanning radar and the Spectra electronic warfare system, the Rafale is fitted with the Front Sector Optronics (FSO), a state-of-the-art passive system. Operating in different infrared wavelengths, the FSO provides discreet long-range detection, multi-target angular tracking and range-finding for air and surface targets, considerably enhancing the Rafale's stealthiness as the fighter can covertly detect, track and identify enemy aircraft without using its own radar which would betray its presence. Additionally, the entire system is immune to radio-frequency jamming.



The FSO comprises two modules mounted on top of the Rafale's nose, ahead of the windshield, to offer an unobstructed view of the forward sector: the infrared sensor (Infra-Red Search and Track), and the TV sensor coupled with an eyesafe laser rangefinder. The functions of the two modules are clearly complementary:
- surveillance and high-accuracy, multi-target automatic tracking by the starboard IR surveillance module
- target tracking, identification and ranging by the port TV/laser module.

The latest 3rd generation matrix detector technology has been chosen for future versions of the FSO to ensure extended detection ranges, and the IR module is fully capable of operating in hot and humid climate/conditions.
The TV sensor has an exceptional long-range identification capability, allowing a high-resolution image of the target to be displayed on any of the cockpit's three screens. Target counting for raid assessment is also a key advantage of the FSO, and tracking of low radar cross-section aircraft is a distinct possibility. Similarly, hostile fighters performing a defensive 'beam' manoeuvre will be tracked easily. In the air-to-surface mode, targets can be pinpointed at stand-off ranges thanks to the outstanding angular accuracy and resolution of the TV/identification channel, and target designation can be performed for air-to-ground weapons.
The FSO is an integral part of the Rafale's mission system as it is closely integrated with the other primary sensors, the RBE2 radar and the Spectra Electronic Warfare suite. As such, it considerably improves pilot situational awareness: all sensors' data is fused into a single tactical picture displayed on the central wide-angle colour screen, offering the pilot a clear image of the evolving tactical situation. This smart data fusion significantly increases mission success rates through better understanding of enemy tactics.
Whatever the rules of engagement, the FSO minimises the risks of fratricides (blues on blues) in both air-to-air and air-to-surface modes, and it allows instantaneous battle damage assessment to be performed. This unique surveillance and identification system has been thoroughly tested on board various testbeds and Rafale prototypes M02 and B01, plus two-seaters B301 and B302 production aircraft. The FSO will be introduced into F2 Standard Rafales.

PSMA 2b - Photos F. Robineau - Dassault Aviation - K. Tokunaga.

RAFALE INTERNATIONAL

GIE - Rafale International
78, quai Marcel Dassault 92552 Saint-Cloud cedex 300 - France
www.dassault-aviation.com
www.snecma.com
www.thalesgroup.com

FOX THREE
N°5

p.2/3

Significant *Milestones*

p.4

A truly *Passive Radar*

THE FIRST PRODUCTION *SINGLE-SEAT AIR FORCE RAFALE FLIES*

On 16 April 2003, Rafale C101, the first production single-seater for the French Air Force, made its maiden flight from Mérignac with test pilot Frédéric Lascourreges at the controls. During the 1 h 15 min flight, the fighter performed aggressive combat manoeuvres and flew at high supersonic speed.
Rafale C101 is the first aircraft to be equipped with the new avionics core of the omni-role F2 Standard which encompasses major improvements over the F1 Standard currently in service. The main features of the F2 Standard include the Front Sector Optronics (although it is not yet fitted to C101), the MIDS-LVT (Multifunction Information Distribution System - Low Volume Terminal) Link 16 datalink, specific air-to-ground modes for the RBE2 electronic scanning radar, additional modes for the Spectra self-defence/electronic warfare suite, and a wide range of weapons: Scalp EG cruise missiles, the AASM (Armement Air-Sol Modulaire) air-to-surface modular armament with INS / GPS reference and imagery guidance, plus long-range infrared-guided Mica IR missiles which supplant the long-serving Magic 2. Moreover, a high-resolution 3D digital database permits automatic terrain-following at low-level. Finally, an in-flight refuelling pod will be adopted for naval aircraft.
At the core of the F2 Standard increased capabilities is the Modular Data Processing Unit (MDPU) composed of line-replaceable modules, including commercial off-the-shelf elements. The MDPU enhances avionics/armament integration thanks to its redundant, open and modular architecture. The system is highly flexible, allowing the integration of new avionics and future weapons. It has been conceived with growth in mind to facilitate the incorporation of new capabilities from one standard to another. C101 is the first Rafale equipped with the MDPU straight from the production line, although both M02 and B302 have been retrofitted with the system.
The first Rafale B/Cs will be delivered to the French Air Force test and evaluation unit (CEAM squadron) which will deploy to Saint-Dizier Air Base in 2005. Escadron de Chasse 1/7 'Provence' will then become the second Rafale front-line unit after French Navy Flottille 12F which stood up in May 2001.

SIGNIFICANT MILESTONES

In the last few months, the Rafale has passed numerous and significant milestones in its development programme. The trials of the air-defence Standard F1 have been completed, and various new configurations have been tested with Standard F2 and F3 external loads. New internal and external systems are also under active development and testing.

"At the moment, we are concentrating on the trials of the F2 omni-role standard, says Pierre-Cyril Delanglade, Engineer in Charge of Rafale Flight Tests at Istres. We are busy expanding the flight envelope with new external stores in heavy configurations. We are also performing weapons releases to make sure there are no adverse effects on the stores or on the aircraft during the release."
Internal systems trials have followed a similar path, and progress has been quick: Dassault Aviation test pilots and flight test engineers have been very active developing and testing the Front Sector Optronics (FSO), the Link 16 Multifunction Information Distribution System-Low Volume Terminal (MIDS-LVT) datalink, the Modular Data Processing Unit (MDPU), and the Direct Voice Input system.

New external loads

The range of missions which can be performed by the Rafale is constantly being expanded, and the integration and trials of the Intertechnique buddy-buddy refuelling pod have now been completed. This pod is due to be used by the French Navy from its aircraft-carrier to provide an organic in-flight refuelling capability to the carrier battle group. "To date, Rafale M1, the first production naval Rafale, has successfully refuelled other Rafale and Super Etendard fighters, clearly demonstrating the inherent flexibility of the design, explains Pierre-Cyril Delanglade. The pod itself has been cleared up to Mach 0.9 / 580 knots IAS, and in-flight refuellings have been conducted - with transfer rates of 530 litres/minute - at 280-350 knots at altitudes up to 20,000 feet, but this could be expanded to 30,000 feet without any problem." Even for countries with no naval air arms, a Rafale equipped with this refuelling pod could increase the combat capabilities of a strike package as it boasts a significant self-escort capability with its Mica air-to-air missiles, allowing a raid to penetrate deep into hostile territory while still having an embedded tanker force.
Similarly, the Rafale has successfully flown with a New Generation Reconnaissance Pod (NG Recce Pod), a new configuration which is representative of the Standard F3 fighter. The NG Recce Pod will significantly boost the capabilities of reconnaissance units. It will be fielded by Rafale units from 2007, and will progressively supplant Mirage F1CR and Super Etendard reconnaissance aircraft currently in service with the French Air Force and Navy. The NG Recce Pod has been flown at Mach 0.9 / 580 knots IAS with two 2,000 litre external fuel tanks and four Mica missiles. Supersonic speeds have been demonstrated too, the fighter reaching Mach 1.4 with the NG Recce Pod on the centreline pylon and two Mica air-to-air missiles at the wingtips. It has been determined that the NG Recce Pod has negligible impact on aircraft handling.

New weapon configurations

The improved Standard F2 for the French Armed Forces will allow air-to-ground attacks to be performed with advanced weapons such as the powerful and stealthy MBDA Scalp EG cruise missile and the low-cost Sagem AASM (Armement Air-Sol Modulaire, Modular air-to-surface armament). "The new weapons are already being tested at Istres and Cazaux, and Scalps were recently dropped from the wing pylons of the Rafale, a more demanding scenario than releases from the fuselage centreline hardpoint, says Pierre-Cyril Delanglade.

Full-scale guided firings are expected to be carried out in late 2003."
A new triple ejector rack for staggered carriage of GBU-12 laser-guided bombs has now been tested, allowing six GBU-12s to be carried, along with three 2,000 litre drop tanks and four Mica missiles. Taking advantage of what had been done with the GBU-12s, the first flights of a Rafale fitted with six AASM GPS/INS/Imagery-guided bombs have been performed too.
The first separation firings of the infrared-guided, long-range, multi-target MBDA Mica IR air-to-air missile have also been conducted with the firing envelope now opened at supersonic speeds. Fully guided missiles are planned to be fired in late 2003.
Flight test engineers have taken advantage of the ongoing programmes to clear the normally subsonic 2,000 litre drop tank up to Mach 1.6 when two fuel tanks are fitted to the aircraft. The obvious advantage of this flight envelope expansion is that a Rafale in an air-to-ground fit could accelerate to high-supersonic speed after weapon delivery, either to escape a threat or to carry out an interception without dropping its fuel tanks.

Carrier trials

In late 2002, the fighter participated in a three-week trial campaign on board the Charles de Gaulle to validate various weapon/external load configurations at heavy weights. For instance, Rafale M1 was catapulted at a weight of 21,4 tonnes (47,137 lb.) with a Scalp on the centreline pylon, two 2,000 litre drop tanks on the inboard wing pylons, and four Mica missiles at the wingtips and under the fuselage. During another test, it was recovered at a weight of 15,7 tonnes (34,581 lb.) with six AASM 300 kg bombs (plus empty 1,250 litre drop tanks), clearly demonstrating its huge 'bring back' capability.
Perhaps even more significant is the flight testing of the NG Recce Pod in an aircraft-carrier environment to make sure that the pod/Rafale airframe combination could withstand the shocks and vibrations associated with carrier operations.
The Rafale flight test programme is continuing at an unabated rate and it is expected that, in 2003, more than 450 Rafale sorties will have been carried out from Istres and Cazaux by the Air Force / Test Centre / Dassault integrated test team. In 2004, other important events will be recorded, such as the first firing of a Scalp pre-strategic cruise missile from a Rafale launched from the Charles de Gaulle carrier.

RAFALE INTERNATIONAL

FOX THREE

N°6

p.2 / 3  Data*Fusion*

p.4 / 5  *AASM*

p.6 / 7  *Meteor*

p.8  Eric *Gerard*

Bucking the trend : *the lower, the better*

Recent conflicts have shown that most fight/bomber strike raids are now conducted with precision-guided weapons from medium or high altitude.
A variety of strike aircraft of diverse age, technology and performance level are generally involved in coalition operations. Capabilities vary widely between these platforms, and manportable air defences are rightfully considered a formidable threat for all of them below 15,000 feet. Stand-off jamming is required, at the expense of tasking flexibility. However this is not always enough to avoid "blue" losses in the face of opponents operating SAMs with high altitude coverage and counter-stealth airspace surveillance…
At this point, theatre air commanders would probably dream of an aircraft with a hefty payload capability for smart weapons, immune to air defence systems. The aircraft must be survivable and operate on a "reasonable" budget…
Enters the Rafale. It is fully interoperable with coalition assets and procedures, and it is therefore totally capable of participating in strike operations, as required for political and diplomatic flexibility. Taking a closer look at the bird, we find an aircraft very close to the commander's dream.
The Rafale is fitted with a multi-sensor terrain-following system operating at the pilot's choice from the radar or from a digital terrain database : the RBE2 radar can detect even unreported obstruction and the digital terrain database does away with telltale emissions where total covertness is required. There is also a radar altimeter available in nap-of-the-earth flight over water or flat land. Data fusion is part of the system to cross-check the sensors before feeding their data to a flight path computation module whose development has been carried out per the exacting standards of safety-critical engineering. The relevant expertise does not come overnight and actually builds on the lessons learned of the Mirage 2000N and D in service with the French Air Force.
The terrain-following function integrated with the Rafale's flight control system actually flies the aircraft closer to the ground or the sea than would be reasonable for the crew flying in manual mode - and it does so with a demonstrated safety level even in blind weather. It remains a valuable help to the crew even when flying higher above ground level, allowing them to concentrate on other mission tasks without the burden -and energy-consuming anxiety - of maintaining terrain clearance during hi-speed/low-altitude legs. With its high thrust and low wing-loading, the Rafale is equally at ease flying at treetop height: its aerodynamics - delta wing and canards - is ideal for low-level agility and ride quality, and its canard foreplanes do not block downward visibility.
Flying low and fast in the clouds then becomes a real option : high altitude SAMs are no longer an issue since you fly under the radar coverage, and short range optically-guided air defences are powerless against a foe they cannot see. Other short range air defence systems can be dealt with by the Spectra EW suite capable of jamming and decoying. Speed is part of the game too, since air defence engagement zones are dramatically reduced against transonic targets, even in clear weather.

Advice to commander : next time, think twice before choosing your altitude option. Higher might not necessarily be better. The Rafale offers high AND low altitude options.

Data *fusion:*
seeing through the fog of war

In order to cope with the multifaceted threats of the 21st Century, Rafale aircrews rely on three essential systems to survive and achieve total battlespace dominance: a state-of-the-art multisensor suite, a smart data fusion management system and an advanced Man-Machine Interface (MMI).

Advanced MMI

Good situational awareness begins with a big and clear picture displayed on large, colour screens. For the Rafale omnirole fighter, Dassault engineers have designed the most modern Man-Machine Interface in service anywhere, introducing 21st Century technology to considerably reduce aircrew workload and to substantially improve situational awareness. The Hands On Throttle and Stick technology has been adopted to make function selections easier, and a Helmet-Mounted Sight and Display is on offer. To accelerate and facilitate information assimilation, the instrument panel of the Rafale cockpit is divided into one large Head-Up Display (HUD) and three colour multifunction screens: two touch-sensitive lateral displays, and a wide-angle, high-resolution head-level display collimated to infinity to enable the pilot to shift instantly from head-up flying to head-down mission monitoring without a need to refocus. In the two-seat Rafale variant, the front and rear cockpit displays can be operated in a tandem mode, which presents the pilot and the back-seater with the same information, or de-coupled so that crew members can carry out different tasks simultaneously, an obvious advantage during complex missions.

Multisensor technology

To carry out all its missions, the omnirole Rafale is equipped with a multisensor suite that comprises the Thales RBE2 multimode electronic scanning radar, the Thales Front Sector Optronics (FSO) passive IR/TV/laser system and the Thales Spectra multi-spectral electronic warfare system, plus the infrared seekers of the Mica IR missiles. This combination of multiple sensors considerably enhances the probability of detecting hostile targets, including stealth aircraft. It also lowers the risk of fratricides.
The Rafale's weapon system can also simultaneously deal with airborne and ground threats, a crucial advantage over the nearest competitors because pilots are now able to attack targets on the ground while engaging the enemy fighters presenting the greatest threat. For example, even with the radar in an air-to-surface mode, the FSO is fully capable of detecting and tracking hostile interceptors, and the pilot can instantly engage an emerging threat.
Silent intercepts can be conducted with the radar switched off, the FSO and the Spectra system then becoming the main sensors. It is worth noting that the FSO's laser supplies an accurate range-measurement, to provide the pilot with the 3D positions of the targets.

Smart data fusion

On the Rafale, there is no preferred sensor: the radar, the FSO, and the Spectra electronic warfare suite all contribute to situational awareness, and the data obtained from the different sources is fused into a single tactical picture shown on the central, head-level display, offering the pilot a clear image of the evolving tactical situation. Until now, pilots only had their brains to process the information obtained by their radars/eyes and to build a mental image of the evolving situation. With the Rafale, the system has taken over the processing role, considerably reducing workload, and allowing aircrews to devote more time to tactics management. The pilot now concentrates on the fight, not on the flight.

Sensors have inherent advantages and drawbacks: the passive FSO has excellent countermeasure resistance, and its angular resolution is better than that of the radar. On the other side, the radar is able to determine the target's position and velocity vector in all weather conditions. The Spectra suite can analyse enemy radar emissions to precisely identify an emitter. The powerful data fusion algorithms combine and compare the data gathered by all Rafale sensors, and accurately position and identify targets. It's much more than simple correlation as it gives the pilot an accurate and unambiguous tactical picture.

One of the key advantages of the system is its ability to identify and classify the type of target/threat, by using either the Spectra suite or the TV sensor of the FSO. When all tracks are positively identified, the system automatically creates a synthetic image with all enemy and friendly tracks shown in a clear and explicit way.
Off-board sensor can also contribute data to the integrated tactical air picture, via the datalink. Wingmen or AEW aircraft can feed their data to the leader's system, thus helping target-sorting and co-operation within the formation.
Multichannel target acquisition/tracking associated with smart sensor fusion is a key-enabler which will radically change the face of air warfare. This combination of multisensor technology and smart data fusion significantly increases mission success rates through enhanced crew awareness and improved aircraft survivability. With its multi-sensor technology, its advanced data fusion management system, and its remarkable Man-Machine Interface (MMI), the Rafale clearly stands in a category of its own and no other fighter in the world has such a wide array of systems at its disposal.

Right on the Spots !

The revolutionary AASM (Armement Air-Surface Modulaire, Modular Air-to-Surface Armament) was selected by the French Air Force and the French Navy in September 2000 to supplement their current inventory of laser-guided bombs and missiles, more than 3,000 AASMs being acquired for the Mirage 2000 and Rafale fighters. This unique weapon designed to destroy an adversary's best-defended target is already undergoing a comprehensive test programme for both the Rafale and the Mirage 2000. The first flights of a Rafale fitted with six AASMs were performed in 2003, and the weapon was subsequently tested on board French aircraft-carrier Charles de Gaulle when a Rafale was recovered at a weight of 15,7 tonnes (34,581 lb.) with six AASM bombs (plus empty 1,250 litre drop tanks), clearly demonstrating its huge 'bring back' capability. The first firings are now due to be conducted at the Cazaux Flight Test Centre in 2004.

A modular weapon

Designed and produced by Sagem, the AASM is a low-cost, all-weather, fire-and-forget weapon optimised for high-accuracy stand-off attacks.

Thanks to its fully modular architecture, the AASM can be utilised for a wide range of strike missions, offering unmatched destructive capabilities against soft or hardened targets. The weapon is divided into three major subsystems:
- the guidance kit at the front
- the warhead and fuse in the middle
- the range extension kit at the rear.

Recent advances in the fields of navigation and optronics technologies have allowed Sagem engineers to design a highly accurate weapon, a crucial advantage when collateral damages must be avoided. Depending on the tactical situation, the required precision, and the importance of the target, the Air Force commanders can choose between two types of state-of-the-art guidance kits :
- a combined Inertial Measuring Unit / GPS receiver navigation system for all-weather attacks with a 10 m class accuracy
- a combined Infrared Imaging seeker / Inertial Measuring Unit / GPS receiver for day and night attacks with metric precision.

The low-cost IMU / GPS receiver would be the main guidance system in most cases. In the event the AASM is unable to receive GPS signals after launch for any reason, the IMU will provide rate and acceleration measurements which the weapon will develop into a navigation solution.
For even greater accuracy, the affordable infrared imaging seeker is a key subsystem. It uses autonomous target recognition algorithms to locate its target, no operator intervention being required. This seeker also ensures exceptional resistance to GPS signals unavailability or jamming, and target coordinates errors can be compensated.

Stand-off engagement capability

For very long distance engagements, the AASM is equipped with a bolt-on tail unit / range extension kit which comprises a solid rocket motor and flip-out wings. Ranges exceed 50 km for a high-altitude release or 15 km for a low-level firing, and even more significant is the capability to engage targets at high off-boresight angles: the Rafale does not have to overfly the target to carry out its attack with deadly accuracy, and it can safely remain out of reach.
The 250 kg warhead can be either a general purpose unitary munition (Mk 82, or any other similar types) or a hardened penetrator (BLU-111, or MBDA Bang/CBEMS series optimised for storage on board aircraft-carriers). It is worth noting that other variants with heavier, more powerful warheads weighing up to 1000 kg such as the Mk 84 multi-purpose bomb or the BLU-109 penetrator are planned to engage targets requiring more destructive power or deeper penetration.
The AASM is a 3 m long weapon that weighs 340 kg. Up to six can be carried by a Rafale on two triple stores adaptors. Six widely separated targets to be attacked in a single pass, with a full 90 degrees off-boresight capability. For maximum terminal efficiency, the AASM angle of impact can be adjusted to match the target's characteristics.
The mission planning module can be used on a stand-alone basis or can be embedded into the Rafale mission planning system. The mission parameters comprise release envelope, the target co-ordinates and weapon terminal settings. Prior to bomb release, the guidance kit will be fed with aircraft position, velocity and altitude data through the store-station interface.
For the AASM, Sagem has chosen the "Wooden-round" concept, and the weapon can be left unattended for many years until it is used.
The AASM fulfils the warfighter's most stringent requirements in terms of attack accuracy, destructive power and cost effectiveness.

Rafale pushes
BVR fight at extreme !

In order to quickly achieve total air-dominance, a concept of multi-layer offensive/defensive air-to-air weapons has been chosen for the Rafale omnirole fighter, allowing all known and future air-threats to be engaged from extreme long range to extreme short range. To carry out its air-defence/air-superiority missions, the Rafale relies on a wide range of advanced air-to-air weapons: Meteor missiles for very long-range engagements, Mica RF and Mica IR multirole missiles for long-range to short-range scenarios, and a powerful 30 mm gun for close-in dogfights. With such a wide array of weaponry, hostile fighters, strike bombers, cruise missiles, unmanned aerial vehicles and helicopters will all be easily defeated.

Integrating the Meteor to the Rafale

Thanks to the involvement of the Rafale integration team in support of missile development from the very beginning, Meteor qualification on the Rafale is definitely a low-risk undertaking. Preliminary aeromechanical integration work has already been completed, and a series of wind tunnel tests have now been conducted.
This first stage of the comprehensive trial programme was a total success. Functional integration (fire control) is not expected to be a major hurdle either: the Mica and the Meteor both operate in the same way, and the Rafale's fighter-to-missile datalink is already fully capable of accepting the new missile.
Up to four Meteors can be carried by a single Rafale, two under the aft lateral fuselage pylons and two under wing store stations. Obviously, the capability to carry Mica missiles will remain unchanged, especially for the infrared-guided Mica IR variant mounted at the wingtips and under the outboard wing rails.

Ramjet propulsion

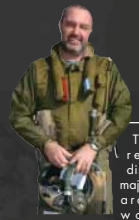
The Meteor is a Pan-European multinational programme officially launched in December 2002 when MBDA was awarded a development and production contract by the British Defence Procurement Agency on behalf of the governments of six European countries.
The Meteor is a highly flexible, long-range, agile air-to-air missile which provides a comprehensive operational capability in the most complex combat scenarios. The weapon can engage air targets autonomously by using its state-of-the-art active radar seeker by day and night, in all weathers and in dense electronic warfare environments.
The rear section of the missile comprises the Bayern Chemie / Protac boron-filled, solid propellant, throttleable, ducted ramjet motor which is one of the principal elements of the missile's success. Thanks to the ramjet propulsion, high-speed is maintained throughout the engagement and the motor offers

variable thrust levels to match the target's hard manoeuvres. The Meteor's ramjet motor system offers ranges in excess of 100 km and speeds of more than Mach 4. Even when launched from extreme stand-off ranges, the missile has enough kinetic energy in the end-game to defeat fast and hard manoeuvring targets such as highly-agile, fifth generation fighters. Its vastly expanded no-escape zone significantly enhances the Rafale's lethality at long ranges. Moreover, high-value assets such as tankers and early warning aircraft can be engaged at very long ranges too, boosting even further the fighter's overall combat efficiency.

Advanced active radar seeker

Terminal guidance is provided by an active radar seeker design based on proven technologies borrowed from the MBDA Aster

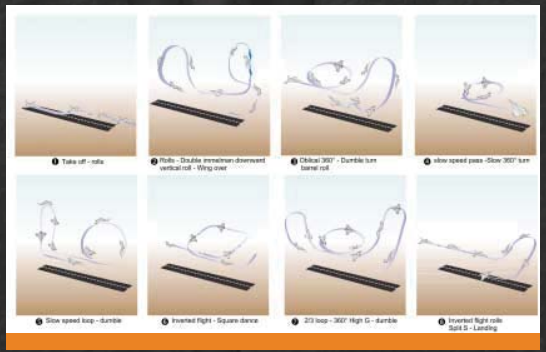
surface-to-air and Mica air-to-air missile programmes. In June 2003, Thales and MBDA signed an agreement to jointly develop an improved derivative of the AD4A seeker already in service on the Mica and Aster missiles. Mid-course guidance will be provided by a fighter-to-missile datalink until the active seeker acquires the target, the missile then becoming autonomous. Alternatively, the Meteor can be fired without using mid-course update, allowing the Rafale to immediately turn away to deny the enemy aircraft any firing possibility.
Following extensive wind tunnel testing, a wingless aerodynamic configuration has been chosen for the Meteor: MBDA has concluded that the selected airframe configuration is the optimum solution to fulfil the required performance characteristics. The controls and aerodynamics principle incorporated by MBDA will result in a missile which has a very high turn rate and which, at the same time, maintains the performance of its ramjet propulsion system thanks to a constant ram air supply. The Meteor missile will therefore have the level of manoeuvrability and speed needed to achieve the demanding end-game performance to intercept even the most agile air targets.
To ensure total target destruction, the missile is equipped with both proximity and impact fuses and with a powerful blast fragmentation warhead that is detonated at the optimum point to maximise lethality.
With the acclaimed Mica IR and RF missiles, the Rafale is already equipped with superior weapons, but the advent of the Meteor will further improve the fighter's outstanding combat efficiency: the Meteor offers enhanced all-round kinematics performance and a higher kill probability to ensure unequalled combat efficiency, even against the most modern hostile fighters.



ERIC GERARD

The Rafale is regularly displayed at major airshows around the world by Dassault Aviation test pilot Eric Gérard.
After high school, Eric joined the French Navy in 1975 and was awarded his Naval Aviation Fighter Pilot Wings in 1978. The following year, he gained his carrier-qualification.
From 1979 to 1987, he flew Super Etendard strike fighters from Hyères and Landivisiau naval air stations, and from the *Foch* and *Clemenceau* carriers, successively flying with Flottilles 17F and 14F.
He was then selected to become a test pilot and graduated from the EPNER, the prestigious French Test Pilot School, in 1988. While serving with the French Flight Test Centre, Eric was involved in various projects, including the Super Etendard Modernisé, the Mirage 2000 and the Rafale flight test programmes.
In 1991, he was recruited by Dassault Aviation to take part in the Mirage 2000-5 development effort and in the Rafale carrier trials. In July 1999, he became the first pilot to trap a fixed-winged aircraft on the nuclear aircraft-carrier *Charles de Gaulle*.
During his career, he was successively awarded the French National Defence Medal, the Lebanon Campaign Medal and the French Aeronautical Medal. Eric is now credited with over 5,200 flying hours.

IN FLIGHT DISPLAY



PEMA 2.0 - Photos F. Robineau - Dassault Aviation - K. Tokunaga.

RAFALE INTERNATIONAL

GIE - Rafale International
78, quai Marcel Dassault 92552 Saint-Cloud cedex 300 - France
www.dassault-aviation.com
www.snecma.com
www.thalesgroup.com

RAFALE INTERNATIONAL

FOX THREE

N°7

p.1/2

Flottille **12F**

p.3/4

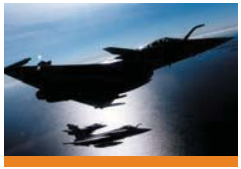
AESA

THE FIRST RAFALE UNIT
IS NOW FULLY OPERATIONAL

In a ceremony headed by Admiral Jean-Louis Battet, the French Chief of the Naval Staff, Flottille 12F - the first Rafale unit - was officially declared combat ready, a major step forward for the Rafale programme.

After months of intense operational testing, the Rafale has now reached full operational capability. On Friday 25 June 2004, Flottille 12F was officially granted approval to conduct offensive and defensive missions with its Standard F1 Rafales. From then on, the French Navy Rafales became fully capable of carrying out the whole spectrum of air-superiority and air-defence missions, either from the *Charles de Gaulle* nuclear carrier or from any land base. In fact, the Rafale could have been engaged in combat two years ago. In 2002, at the peak of Operation Enduring Freedom - the international effort against terrorism - in the Indian Ocean, Flottille 12F flew operationally and could have fired air-to-air missiles to protect the French carrier battle group if needed. To this day, nearly 5,000 flying hours and 2,000 carrier landings have been recorded by the unit.

A successful process



Flottille 12F, previously flying the F-8E(FN) Crusader, was recommissioned in May 2001, and has been a key asset and player for the tactical evaluation of the new fighter. This evaluation phase is now completed, and, from now on, the pilots will be able to devote their time to tactical training. Thanks to a remarkable collaboration between the French Navy, the DGA and all the companies involved in the programme, the Rafale's entry into service was undoubtedly a major success. The fighter has been operationally tested in severe environments - extreme temperatures and high ambient humidity levels - in the Indian Ocean and the Red Sea, and it is fully compliant with the extremely stringent French Navy requirements. According to Flottille 12F pilots, the Rafale has already demonstrated its exceptional qualities during numerous engagements against other fighters such as US Navy F/A-18 Hornets and F-14 Tomcats, Royal Saudi Air Force F-15 Eagles, and Belgian Air Force F-16 Fighting Falcons. The required level of reliability has been demonstrated and the Thales RBE2 radar and the Thales/MBDA Spectra electronic warfare suite have proved extremely successful, allowing the fighter to efficiently perform all the missions it was envisioned for. The Snecma M88-2 turbofan is also highly praised by pilots and maintainers alike. Its thrust, responsiveness, reliability and maintainability have set new standards: the excess power available and the immediate power response give the aircraft exceptional wave-off characteristics, a decisive factor for demanding carrier operations.

A new configuration tested operationally

During the tactical evaluation phase, Dassault Aviation and the Marine Nationale have gone even further than initially planned, and the Rafale Standard F1 can now be used for buddy-buddy in-flight refuelling, a capability not envisioned until the delivery of the Standard F2 Rafales. What is even more significant is the fact that the first three aircraft adapted for the in-flight refuelling mission were all modified, at sea, onboard the *Charles de Gaulle* in the Indian Ocean with minimal assistance from France. Only three Dassault personnel and three Navy specialists had to be flown to the area. The first aircraft, Rafale M6, was modified in only eight days by this dedicated team. The other two fighters, M4 and M9, were both directly retrofitted by Flottille 12F specialists and their validation flights were conducted by two pilots of the unit. A batch of five 2,000 litre drop tanks was lent by Dassault to supplant the 1,250 litre variant in use with Flottille 12F, considerably boosting the off-load capability of the aircraft. It is worth noting that switching from an air-defence configuration to a tanker fit takes only about 1 h 30 min. The modified Rafales were engaged operationally over Afghanistan to support the effort against terrorism, co-operating with reconnaissance Super Etendard Modernisés from Flottille 17F. Two Rafales fitted with in-flight refuelling pods were capable of significantly increasing Super Etendard Modernisés radius of action. Although there was no real airborne threat in the theatre of operations, the Rafales were also utilised to escort the reconnaissance jets with their long-range, active radar Mica missiles. The ability to carry out missions as a refuelling tanker is a welcome boost to operational flexibility: the Rafale can keep up with any strike package since it can match the speed and altitude performance of other fighters, providing great flexibility in planning and executing long-range missions.

The comprehensive operational test programme set up by the French Navy has resulted in the Rafale being a mature programme. Indeed, the omnirole fighter was successfully flown in complex air-defence missions as part of a coalition, the latest operations over Afghanistan clearly marking the beginning of the Rafale's operational career.

The future is definitively on track :
Rafale Standard F3 development contract signed

In February 2004, the Délégation Générale pour l'Armement (the French Procurement Agency) announced that the contract to develop the F3 Omnirole Standard for the Rafale had been signed. Due to enter service in 2008, the Standard F3 will offer new, expanded capabilities for both French Air Force and French Navy units. New functionalities for the radar include a high-resolution synthetic aperture radar (SAR) mode. With its high-quality digital images, the New Generation Reconnaissance Pod will offer unmatched capabilities for real-time stand-off reconnaissance. The new Gerfaut Helmet-Mounted Sight/Display produced by Sagem will also be adopted for Standard F3 Rafales, remarkably enhancing the lethality of the agile Mica IR missile. With the advent of Standard F3 Rafales, new weapons such as the ASMP-A nuclear missile and the latest variant of the acclaimed Exocet anti-ship missile will find their way into the Rafale's already impressive armament inventory, thus enhancing the firepower of the new omnirole fighter.

AESA RADAR
TEST FLOWN ON RAFALE

In April 2002, the DGA, the French defence procurement agency, appointed Thales to develop an active array radar demonstrator optimised for the Rafale omnirole fighter. Called DRAA (Démonstrateur Radar à Antenne Active, or Active Array Radar Demonstrator), the programme culminated in a series of demanding flight tests to validate its detection performance. Although the development schedule was extremely tight, the DRAA met all programme milestones on time. This Active Electronically Scanned Array (AESA) demonstrator will pave the way to a production equipment for the Rafale.

An extremely fast programme

Today, the Rafale is the only European fighter fitted with an electronic scanning radar. Its remarkable RBE2 radar is already in full operational service with the French Navy and will soon enter service with the French Air Force. It is far more advanced than legacy mechanically-steered radars used by most of the Rafale's competitors. Their flexibility and performance are clearly limited by the complex hydraulic drives associated with moving their radar dish around.

With the adoption of an active antenna, RBE2 radar performance will be even further increased : detection and tracking ranges will be significantly improved, angular coverage will be considerably expanded and reliability will be boosted to unprecedented levels. The state-of-the-art DRAA active array is composed of numerous solid-state transmit and receive GaAs modules. They are used to point and move the radar beam at an extremely high speed. Aircrews will also benefit from improved situational awareness while observability of the aircraft will be reduced. Additionally, the introduction of the active array paves the way for the development of new radar functions in such areas as counter-countermeasures.

The numerous T/R modules also virtually eliminate mechanical breakdowns and reliability has been dramatically improved thanks to an increased redundancy: a number of modules can fail without affecting overall radar performance. Antenna status can be established in real-time, and maintenance operations programmed accordingly, leading to considerably lower operating costs for operators. As a result, active array technology offers significantly greater operational readiness than previous antenna technologies.

To develop the DRAA, Thales has taken advantage of its long experience in solid-state technology which dates back to the early 90s when the Cobra battlefield radar was conceived. Since then, other radar applications have benefited from solid-state advances, and numerous surface warships and ground-based defence systems are equipped with such radar systems. *"The first development studies for the airborne AESA array for the Rafale had been carried out in 1999*, explains Philippe Ramstein, Thales Director for the Rafale Programme. *The RBE2 variant currently in front-line service is already an electronic scanning radar, and changes to adapt the new AESA array are kept to a strict minimum. The DRAA fully complies with the plug-and-play concept, and the passive and active arrays are thus totally interchangeable. This clearly facilitates upgrades, so all French Rafales will have the capability to be equipped with an AESA."*

Test-flying the DRAA

In December 2002, the first flight of the AESA system was carried out in a Mystere XX flying test bed belonging to the French MoD located in the Flight Test Centre at Cazaux (South-West of France). Subsequently, the DRAA demonstrator was fitted to two-seat production Rafale B301. *"For us, it was essential to prove to our customers that we could easily fit a new array to the existing RBE2 hardware,* stresses Jean-Marc Goujon, Rafale Radar Programme Manager. *As such, one of the main goals of the DRAA programme was to demonstrate that the new array could easily be fitted to the B301's current RBE2 electronic scanning radar without any modifications of the whole radar architecture. This modification was a total success, Thales and Dassault engineers being able to complete the task in less than three hours! This is a considerable achievement that proves impossible for our competitors who would have to completely redesign and rebuild their radar sets to accommodate an AESA."*

The first flight in Rafale B301 was recorded from Istres in May 2003. During the comprehensive flight test programme, the fully integrated Band X DRAA radar successfully transmitted, received and collected radar data, confirming all Thales prediction, a clear indication that the company totally masters AESA technology.

DRAAMA towards the serial production AESA RBE2

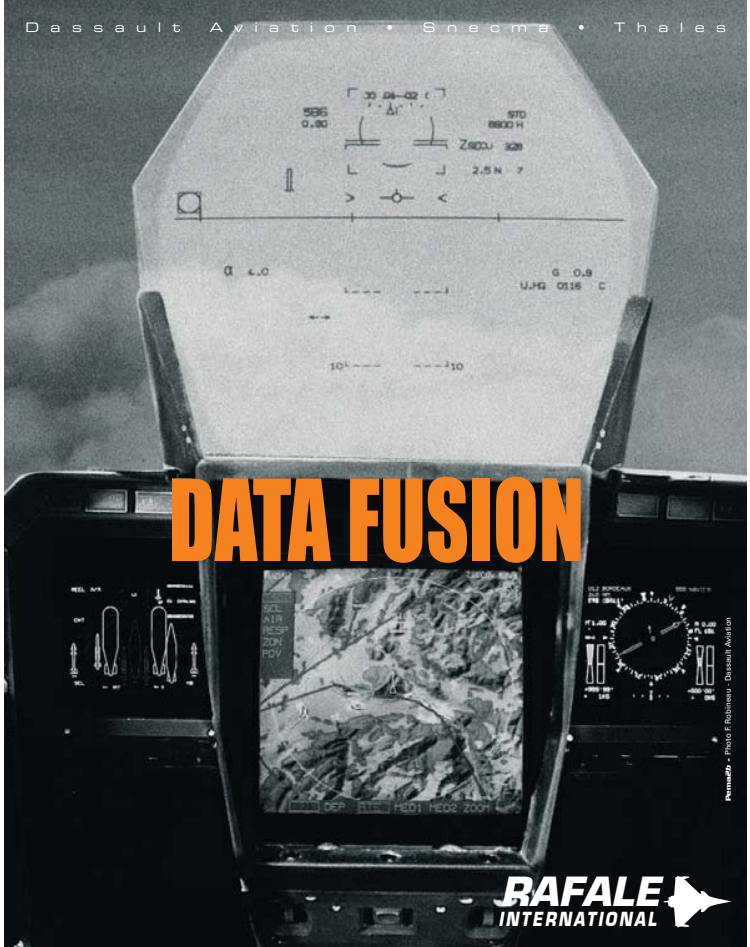
For Thales, the next stage of the ongoing development process for the Rafale fighter is the DRAAMA (Démonstrateur Radar à Antenne Active Modes Avancés, or Advanced Modes Active Array Radar Demonstrator) programme which was officially launched by the DGA in July 2004. Optimised to prepare full-scale production, the DRAAMA array will be entirely new and will benefit from the latest developments in radar/solid-state technology. It is worth noting that all components of the DRAAMA antenna will be built in Europe, a key factor for total autonomy and independence. By the end of 2007/early 2008, DRAAMA development and test flying programme will have been completed, and qualification should have been granted by the DGA.

The advent of the DRAA and DRAAMA programmes will allow engineers to shortly equip production Rafales with cutting edge radar technology. Developed in a record time, the DRAA radar already proved that Thales is fully capable of meeting stringent requirements with state-of-the-art solutions. With the AESA, the Rafale Omnirole fighter will undoubtedly become more lethal, more survivable, more reliable and more affordable, key advantages for operators in search of the ultimate fighter.

RAFALE INTERNATIONAL

GIE - Rafale International
78, quai Marcel Dassault 92552 Saint-Cloud cedex 300 - France
www.dassault-aviation.com
www.snecma.com
www.thalesgroup.com

PEMA29 - Photos F. Robineau - Dassault Aviation - Marine Nationale



DATA FUSION

Photo F Robineau - Dassault Aviation

RAFALE INTERNATIONAL

While rival late-generation fighters build pilot ergonomics around inherited technologies, Rafale offers a revolutionary man/machine interface designed around the plane's most vital component: the pilot. The result is the most advanced modular integration of data, communication and control ever engineered into a combat aircraft. *Rafale*. The *OMNIROLE* fighter ■

FRENCH MINISTRY OF DEFENCE ORDERS A FURTHER *59 RAFALE FIGHTERS*

The French MoD has recently announced an order for 59 Rafale omnirole fighters, bringing total orders so far to 120 aircraft - 82 Rafale B/Cs for the Armée de l'Air and 38 Rafale Ms for the Marine Nationale - out of 294 required. Deliveries of these 59 Rafales will stretch from June 2008 to January 2012, with 47 fighters for the French Air Force (11 Rafale B two-seaters and 36 Rafale C single-seaters) plus 12 Rafale M carrier-borne fighters for the French Navy. The order also encompasses 138 Snecma M88-2 turbofan engines.

The 59 fighters will be produced in the latest, fully omnirole F3 Standard capable of undertaking an extremely wide range of roles: air-defence/air-superiority missions with Mica IR and EM air-to-air missiles, precision attacks with Scalp cruise missiles and AASM modular air-to-surface armaments, anti-ship strikes with the acclaimed AM39 Exocet sea-skimmer, reconnaissance with the Thales new generation reconnaissance pod, and nuclear deterrence with ASMP-A missiles. Among other improvements, Standard F3 Rafales will be fitted with the Sagem Gerfaut Helmet-Mounted Sight and with an enhanced Thales Spectra self-defence suite. Their Thales RBE2 radar will offer high-resolution cartographic modes plus a radar terrain-following capability on top of the high-resolution 3D digital database introduced in the F2 Standard variant.

FRENCH AIR FORCE RAFALE

OMNIROLE FIGHTERS ENTER SERVICE

In December 2004, the first three Rafale fighters arrived at Mont-de-Marsan Air Base, in the south-west of France, where they are utilised for initial conversion training and for the Rafale operational evaluation.

CEAM

The whole evaluation phase will be conducted at Mont-de-Marsan by the CEAM (Centre d'Expériences Aériennes Militaires), the French Air Force Evaluation Centre. «The CEAM has now begun a rigorous series of tests to assess the Rafale's performance in all mission areas, explains General Eric Rouzaud, CEAM Commander. Whereas development testing conducted by the integrated test team mainly involves demonstrating that the aircraft meets or exceeds the specifications laid out by the Ministry of Defence, operational testing is geared towards using the aircraft in its role as a fighter. As a result, the Rafale will be flown in a wide variety of scenarios against various threats. Here, we also handle initial Rafale pilot conversion and we develop new tactics and procedures adapted to the aircraft.» The number of French Air Force Rafale pilots is currently rapidly expanding, with a steady flow of newcomers arriving at Mont-de-Marsan from various Armée de l'Air bases. The first five pilots and five navigators were all experienced aviators drawn from a wide range of backgrounds, and some of them had previous Rafale experience with the French Navy. They started flying the Air Force Rafales at Mont-de-Marsan in December 2004 and became the first cadre of instructors in order to train the following waves of front-line aircrews.

In-depth evaluation

The evaluation of the Rafale's robust air-to-air and air-to-surface capabilities will impose a major effort to the CEAM. «The advent of the Rafale with its modern RBE2 electronic-scanning radar, its Front Sector Optronics, its advanced electronic warfare suite and its Multifunction Information Distribution System link 16 datalink has forced us to devise a comprehensive evaluation programme, says Lieutenant-Colonel François Moussez, the Officer in Charge of the Rafale evaluation at Mont-de-Marsan. It is anticipated that, by mid-2006, more than 600 Rafale evaluation sorties will have been logged by CEAM specialists. Numerous firings will be conducted in the coming year, with Mica IR air-to-air missiles, Scalp cruise missiles and AASM air-to-surface armament, all to be tested in realistic conditions, including jamming. When operational testing is complete, the aircraft will be declared fully combat-ready in the air-to-air and air-to-surface arenas, and the operating manuals will be ready for the first front-line squadron.»

French Minister of Defence Flies in a Rafale fighter

On 24 February 2005, Mrs Michèle Alliot-Marie, the French Minister of Defence, undertook a sortie in two-seat Rafale B304 from Mont-de-Marsan Air Base. The pilot who flew the Minister of Defence, Lieutenant-Colonel François Moussez, said Mrs Alliot-Marie was 'totally at ease' during the 1 h 30 min sortie. The mission included long-range and short-range air-to-air engagements, an in-flight refuelling by a French Air Force C-135FR tanker and some low-level flying during a simulated attack profile with Scalp cruise missiles.

A fully omnirole squadron

By early June 2005, six Rafales will have been delivered to the CEAM and this number will grow to fourteen by the end of the year. «In July 2005, the first Rafale squadron, Escadron de Chasse 1/7 'Provence', will officially reform at Saint-Dizier, in eastern France, reveals Lieutenant-Colonel Louis Pena, EC 1/7's future Deputy Commander. However, the aircraft and aircrews will remain at Mont-de-Marsan until early 2006, when the first Rafale fighters will relocate to Saint-Dizier. Currently, the squadron and the operational evaluation unit share the aircraft.»
When the first squadron is declared operational, in September 2006, the aircrews will be cleared to carry out a wide range of missions with their radar-guided (Mica EM) and infrared-guided (Mica IR) missiles, their AASM powered bombs and their Scalp missiles. EC 1/7 will eventually be equipped with 20 Rafales, fifteen two-seaters and five single-seaters. It has already been announced that the second Rafale squadron will be stationed in Saint-Dizier too, whereas the third will be based in Mont-de-Marsan.

A superb fighter

The aircrews at Mont-de-Marsan are all enthusiastic about their new aircraft. «So far, we are extremely pleased with the first results of the evaluation, stresses General Rouzaud. Obviously, we have taken advantage of the Navy's experience: thanks to the expertise they have passed on to us, the Rafale's introduction is all but a step into the unknown for the French Air Force. Dassault's technical support is outstanding, and our strong partnership will allow us to fully exploit the capabilities of the fighter very soon.»
All aircrews agree that the Rafale is a big improvement on existing jets. «Early assessment has been satisfactory, explains Louis Pena. The man-machine interface is very intuitive and easy to use. The reclined seat proves extremely comfortable and g-tolerance is massively ameliorated. Endurance is excellent, even at low-level where we can fly at 450 knots for 1 h 30 min in a clean configuration.» The airframe, engines and avionics suite are also highly praised. «The fighter proves extremely agile and the Snecma M88-2 turbofans are very powerful, confirms François Moussez. Engine response is instantaneous, a crucial advantage in a dogfight. The Front Sector Optronics will allow new, innovative tactics to be devised. Finally, the RBE2 radar can track multiple targets, even when enemy fighters split.»

Rafale squadron facility construction begins

Construction of a new high-tech facility for the first Rafale squadron officially began at Saint-Dizier Air Base on 03 February 2005 when General Wolsztynski, the French Chief of the Air Staff, laid the building's foundation stone. When fully operational, in December 2005, the 12,000 square meter building will be divided into four areas: a hangar large enough to accommodate five fighters, a maintenance / servicing facility, a storage area and an office / mission planning block.

AIR-DEFENCE MISSION *FOR FLOTTILLE 12F*

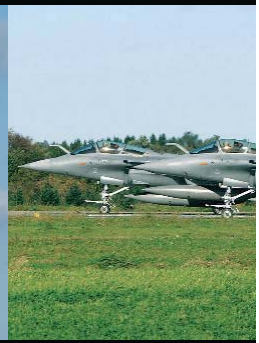
In early 2005, Flottille 12F, the first naval Rafale unit, was tasked to participate in the air-defence of the French airspace. Two Rafales were detached to Lann-Bihoué Naval Air Station, in western France, to replace a pair of French Air Force Mirage 2000-5 fighters. It is highly unusual for Navy aircraft to take part in a traditional Air Force mission, but Armée de l'Air Commanders had requested help from their Navy counterparts to share the burden for a week, as an experiment.

At Lann-Bihoué

The detachment was composed of two pilots and seven maintainers/armourers. The two Rafales were each armed with two Magic 2 heat-seeking missiles at the wingtips, and one of them also had two Mica EM fire-and-forget radar-guided missiles under the wings. Both were equipped with a 1,250 litre fuel tank on the centreline pylon and with an array of flare and chaff decoys. During the whole week, the two fighters were cocked and ready to go in just seven minutes, ready to be vectored off to intercept any threat. At the end of each sortie, the engineers had 30 minutes to turn around the fighter, including ten minutes to fill up the tanks. However, the aircraft was usually operational again in 15 minutes, and no major technical problem arose during the deployment.

A very well-suited fighter

«The Rafale is ideal for the job, stresses one of the two duty pilots. It can climb to 40,000 feet in under two minutes and accelerate very rapidly to supersonic speed. More significantly, it can supercruise in dry power, even with four missiles and a belly drop tank. Endurance is excellent too, and we can stay airborne up to two hours with one tank.» The pilots also praise the Rafale's advanced man-machine interface which considerably reduces their workload. On average, the fighters were launched once a day for training, but two live intercepts were also carried out. The participation of Flottille 12F to the French air-defence effort has been so successful that it is expected that the experiment will be re-conducted in the fall, between two training deployments of the Charles de Gaulle's carrier air group.



First Rafale participation in the Tactical Leadership Programme

To further increase its tactical capabilities and ameliorate aircrew effectiveness, the French Navy decided to send three Rafale fighters to Florennes, in Belgium, to take part in the prestigious Tactical Leadership Programme. During the exercise, the three aircraft (including one spare) flew 50.6 flying hours in 28 sorties, recording a remarkable 100% mission availability rate. The Rafales were mainly used in the escort role, and they usually took off first and landed last after two hours airborne without in-flight refuelling, a testimony of their outstanding endurance. Their weapon system and their self-defence suite proved extremely reliable and impressed all participants.

THE RBE2 AESA: *a major asset for the Rafale and a critical component of operational superiority*

Designed from the outset to deploy an electronically scanned radar, the Rafale is equipped with the RBE2 radar from Thales. In production since 1997, the RBE2 is the first multi-function electronic scanning radar developed for a combat aircraft. With its advanced electronic scanning technologies, the RBE2 offers new capabilities, particularly in air-to-air, air-to-ground and air-to-surface functions, terrain following and terrain avoidance. Most of these new capabilities are beyond the reach of conventional radars. Electronic scanning in both planes makes it possible to authorise simultaneous designation of multiple targets to different air-to-air missiles, while at the same time performing searches in directions completely independent of the targets tracked. In this respect, the RBE2 marks a radical break with all previous-generation radars. This level of tactical situation awareness gives the Rafale the ability to counter enemy tactics with remarkable effectiveness.

For very low-altitude penetration missions, the RBE2 uses electronic scanning technologies to generate a three-dimensional ground map covering a wide area forward of the aircraft, supporting terrain following and manoeuvres in the horizontal plane within the area scanned by the radar.
In addition, the RBE2 on the Rafale F3 standard will offer high-resolution ground mapping modes that are also unique in Europe.
To date, the RBE2 is the only European electronic scanning radar equipping a new-generation combat aircraft in operational service. It has successfully completed various assessments and out-of-area campaigns.

The active electronic scanning antenna (AESA)

Certain radar functions were designed from the outset to be performed by an electronically scanned antenna, and the RBE2 is thus inherently suited to the AESA active antenna. The transition to electronic scanning technology, which in the case of the RBE2 concerns transmit and receive technologies only, will provide new capabilities and enhance performance, while at the same time improving reliability and reducing maintenance costs. The radar therefore offers a unique opportunity to capitalise on the know-how gained through the development of its various functions, which are based, from the start, on electronic scanning technologies.
Thanks to the RBE2's scalable architecture, the upgrade to the active antenna simply involves replacing the tube transmitter and passive electronic scanning antenna with around 1,000 active modules. This operation is independent of other functional developments underway. An active module is a transmitter/receiver based on solid-state technologies (gallium arsenide semiconductors).

Enhanced operational effectiveness

In July 2004, the French defence procurement agency (DGA) awarded Thales a contract to develop the second-generation active electronic scanning antenna (AESA), specially adapted to the RBE2. Development is underway. The first demonstrator met all performance objectives and has been flying on the Rafale since April 2003.

The AESA active antenna will increase the RBE2's range and the quality of its angular coverage.
In air-to-air mode, longer range makes it possible to detect new threats with low radar reflectivity (new-generation fighters, stealth targets, etc.) at an earlier stage, allowing more time to process them, and ensures coherence with the arrival of future missiles (Meteor, etc.).
In air-to-ground mode, the higher power budget translates into better contrast on synthetic aperture radar (SAR) images.
In addition, due to the antenna's large number of active modules and the phenomenon of progressive degradation, failure of some of these modules will have no noticeable effect on performance. Real-time analysis of antenna status can be performed at any time for maintenance scheduling.
As a result, the active antenna is much more reliable from an operational point of view, thereby guaranteeing higher operational availability of the Rafale. Its simplified maintenance concept will also contribute to reduced cost of ownership.
Lastly, the use of active antennas opens up new possibilities for further development of radar functions, particularly in areas such as resistance to countermeasures.

Radarology: an antenna is said to be "active" when its radiating surface comprises several tens or hundreds of elementary modules, each performing both transmit and receive functions. These modules are based on solid-state technologies. In other words, they use monolithic microwave integrated circuits (MMICs) and not tubes.

FOCUS ON THE M88

A state-of-the-art fighter engine

The M88-2 engine powers the new-generation Rafale multi-role fighter. Featuring a redundant fully digital control system for exceptional ease of handling, the M88-2 also offers a modular design for enhanced maintainability, new-generation materials and other advanced technologies. The outstanding performance of the M88-2 is largely due to its state-of-the-art control system, designed to optimize engine operation throughout the flight envelope. The engine is particularly well suited to low-altitude penetration and high-altitude interception missions. Powering both the carrier-borne and land-based versions of Rafale, the M88-2 has already proven its excellent performance and dispatch reliability in service.

Snecma has developed a new version of the M88-2, the M88-2E4, that offers lower fuel consumption and cost of ownership, with longer service life for the engine's critical parts. A new demonstrator engine, dubbed "ECO", has also been developed as part of an advanced R&D program. It aims to demonstrate the feasibility of reducing the life cycle cost (LCC) of the M88-2 at its current thrust level. A secondary aim is to use the technologies developed through the ECO program to pave the way for a higher thrust engine. The possibility of developing an engine developing 90 kN (20,200 lb) of thrust with reheat has been demonstrated.

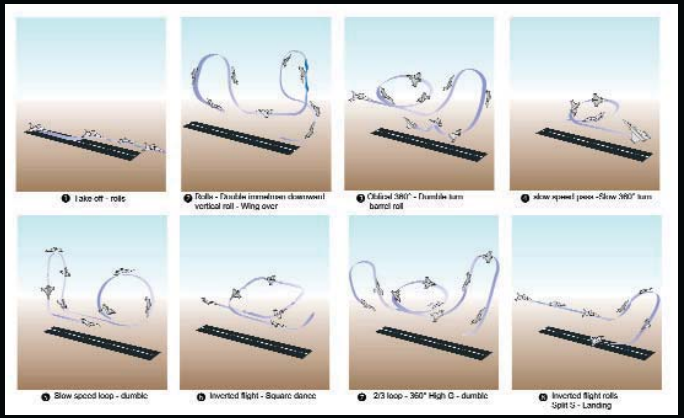
Snecma has delivered 90 M88-2 engines to date, with the fleet logging over 22,000 hours in flight. The M88-2E4 engines deployed by the French naval air arm and air force have posted outstanding dispatch reliability.

A recent flight evaluation with a foreign Air Force spotlighted the excellent performance of the engine, along with the advantages of its innovative maintenance concept.

At the end of 2004, the French Ministry of Defense placed an order for 59 additional Rafale combat aircraft. For Snecma, this means the production of 118 M88-2 engines as well as the associated spares, for delivery starting in 2007.

RAFALE FLYING DISPLAY

The Rafale omnirole fighter is regularly displayed at major airshows around the world by Eric Gérard, a Dassault Aviation test pilot credited with over 5,300 flying hours, including 600 in Rafales. «During the tight display routine, I push the aircraft to its limits to demonstrate both its outstanding agility and the fly-by-wire's 'carefree handling' feature that won't let the pilot stall the aircraft or pull too much g, he says. The highlight of the display is the Square Dance, a 360 flat turn with four rolls, a very violent manoeuvre only performed by the Rafale.» During the six-minute show, speed will vary from 100 knots for the slow pass to 500 knots, roll rate will reach 270 degrees per second, and g-load will peak at - 2.5 / + 9 g. Airfield performance is impressive too, with a 500 metre takeoff distance and a 400 metre landing run, even without a brake chute.



RAFALE INTERNATIONAL

FOX THREE

DASSAULT AVIATION - SNECMA - THALES N°9

Exocet punch for the Rafale.
Rafale : built to last.

FIRST EXOCET TRIALS

The first stage of the integration trials of the combat-proven AM39 Exocet antiship missile has successfully been completed by a production Rafale from the Dassault facility in Istres, the fighter carrying a single AM39 on the centreline pylon.

To this date, more than 3300 Exocet sea-skimming missiles have been sold to 34 customers. For increased commonality, the Exocet is available in three variants : surface-to-surface (MM38 and MM40), air-to-surface (AM39), or submarine-to-surface (SM39).

The 1,475 lb (670 kg) air-launched missile has a range of between 27 and 38 nautical miles (50 and 70 km) depending on launch speed and altitude, and its 363 lb (165 kg) blast fragmentation warhead is powerful enough to disable a frigate or a destroyer. Over the years, the AM 39 Exocet has progressively been updated, with the successive improvement programmes concentrating on radar seeker counter-countermeasure capabilities, thus limiting vulnerability to jamming and decoying while increasing lethality.

Flight envelope expansion was carried out by Rafale M1, with three sorties only being required to validate the normal operating envelope: 600 knots / Mach 0.9 maximum speed, 5.5 g maximum g-load and 4 m/s vertical sink rate for carrier landings. The aircraft and missile combination will be tested at sea onboard the *Charles de Gaulle* carrier in December 2005. During these trials, the vertical sink rate will be cleared up to 5 m/s. The first separation tests are planned for early 2006.

FRENCH AIR FORCE RAFALES:
FAST FORWARD

Today, Mont-de-Marsan Air Base is a hub of activity as the CEAM (Centre d'Expériences Aériennes Militaires), the French Air Force Evaluation Centre, conducts a rigorous operational evaluation of the Standard F2 Rafale omnirole fighter. The CEAM is currently evaluating the performance of the Rafale and of its weapon system, including the RBE2 electronic scanning radar, the Spectra electronic warfare suite, the Front Sector Optronics, the data fusion system and all the various missiles and precision weapons.

Link 16 and Mica IR missiles

«In the last few months, the Rafale evaluation and the Rafale aircrews conversion training have been carried out concurrently, explains General Rouzaud, CEAM Commander. So far, thirteen crews - each composed of one pilot and one weapon system operator - have completed their conversion process, nine of them belonging to EC 1/7 'Provence', the first Rafale fighter squadron. The Rafale is planned to enter operational service around Summer 2006 and, for us, the timetable is extremely tight. That means that our experts don't have time to conduct the two phases one after the other as it is usually the case. However, the Rafale is a very flexible aircraft and we have no difficulties mixing the two missions.»

All French Air Force Rafales are fitted with the Link 16 datalink system and new tactics are already being developed to take advantage of this revolutionary system. «We regularly work with E-3 AWACSs to test information exchanges and to validate new tactics, says Colonel Rondel, the CEAM Evaluations Manager. With the Link 16, we now have a 360 degree vision around the Rafale and we can clearly see 'hostile' fighters attacking us from the sides or from the rear. The operational evaluation of the infrared-guided Mica IR missile has also begun, and the first results are nothing short of astounding. The Mica IR missile can be utilised either for a dogfight or for a long-range interception. When used in conjunction with the Link 16, we can conduct silent interceptions at extreme range, and we can even shoot Micas off-boresight for self-defence with an external target designation, either from another Rafale or from an AWACS.»

Maintenance training

As part of the wider conversion effort, French Air Force engineers have been busy learning how to maintain and repair the Rafale. «We have already trained about 100 Rafale engineers, which is quite good considering that we have no spare airframe just for maintainers, stresses General Rouzaud. Thanks to our exchange programme with the French Navy, we have been capable of fielding the new type without major problems. The French Air Force has set up here the Rafale Formation Centre which handles all Rafale training courses, including those of the Air Force, the Navy, the French Flight Test Centre, and the industrial partners. We are also ready to accommodate any potential export customers.»

The operational evaluation of the omnirole Standard F2 Rafales is expected to be thorough enough to allow the operational release of the type at Saint-Dizier Air Base next summer. From 2008 onwards, the CEAM will switch its attention to the improved Standard F3 Rafales which will offer expanded capabilities in the fields of reconnaissance, nuclear deterrence and anti-ship strikes

VIRTUAL REALITY

A new, state-of-the-art Rafale Simulation Centre is being put together by Dassault and Thales to train future Rafale aircrews. Taking advantage of their respective fields of excellence, the two companies have created a new concept of a fully integrated training simulator network. Dassault Aviation and Sogitec are in charge of the global system architecture, the visual system, the network environment, the high-fidelity flight model and the building. Thales Airborne Systems and Thales Services develop the cockpits, the simulator architecture and the weapon system modelisation (RBE2 electronic scanning radar, Front Sector Optronics, Spectra electronic warfare suite). Through its Military Customer Support Division, Dassault Aviation ensures the global management of the programme.

Three Instructor Operating Stations (IOS) manage the four Cockpits

High-fidelity

The first two Rafale bases, Saint-Dizier Air Base and Landivisiau Naval Air Station, will each be equipped with a complete Rafale simulation facility, with four cabins at Saint-Dizier and two at Landivisiau. If needed, the two facilities can be coupled in order to simulate complex missions with up to six Rafales 'flown' simultaneously. The two facilities can even be interconnected with off-site simulators in order to conduct real time cooperative training mission with other assets: aircrews at different locations will then be able to train together in the same threat environment via a high-level architecture protocol (HLA) which ensures that the simulators can talk to each other and share data over the network.

The new full-mission Rafale simulators will be extremely high-fidelity devices using the real Modular Data Processing Unit borrowed from the fighter. As such, they will accurately replicate the performance of the Standard F2 Rafale omnirole fighter. Pilots will be able to practise demanding scenarios, including interceptions, dog-fights, precision attacks and even carrier landings at night. To augment the value of the training, more than 200 friendly or hostile virtual entities (50 aircraft, 40 missiles, 20 warships, 20 moving surface targets and 100 SAM sites) can be simulated during each session, allowing extremely complex missions to be rehearsed. Other innovative capabilities such as the voice control of the virtual friendly aircraft or the use of Night Vision Goggles will be implemented.

For increased flexibility, each cockpit can be easily reconfigured from one version to another in less than an hour, for example from the Air Force to the Naval variant, or from the single-seat to the two-seat version (four cabins can be utilised to simulate two two-seaters). Additionally, the two Rafale Simulation Centres will be equipped with dedicated debriefing facilities, allowing missions to be replayed to increase experience and enhance training value.
With their new, full-mission, reconfigurable, networked simulators, the French Armed Forces will soon get the tool they need to train Rafale aircrews for the future. The simulator centres will be declared operational at Saint-Dizier in April 2007, and at Landivisiau in May 2008.

RAFALE PRODUCTION IS
NOW IN FULL SWING

With the Rafale fighter, Dassault Aviation has pioneered new design and production methods which are progressively being adopted by the rest of the world, from famous automotive companies to most major aircraft manufacturers. The sweeping changes introduced for the Rafale programme have helped streamline manufacturing techniques in order to reduce both fabrication costs and delays from order to delivery.

Digital revolution

From the early stages of the Rafale programme, the widespread use of digital technology for the development considerably facilitated the elaboration of digital blueprints that were later transferred to production plants. For production engineers, the advent of the automated conception with the Catia 3D tool meant that new production methods could be adopted. Huge investments in new tooling were made to reduce costs and increase flexibility, the staff undergoing specific training to adapt to the new techniques. Traditionally, fitters and riggers were key employees in a Dassault plant. Now, everything fits perfectly and complex rigs are not required anymore. This is a real cultural revolution. New, large, automated production machines have been introduced in the last few years and, for maximum flexibility and adaptability, they are utilised to fabricate parts for both the fighters and the Falcon business jets. With these machines, the level of production accuracy has been boosted to unprecedented levels. This means that parts taken from one aircraft will fit another, without any adjustment or modification as was common practice on previous aircraft. «With the Rafale, there is no adjustment required, such is the quality of the construction, explains Etienne Prévost, Rafale Programme Manager. Everybody - from the design office to the production engineers working in our factories - utilises a common, unique digital reference that considerably facilitates production. For the time being, all assembly instructions are still printed on paper fact sheets but we will eventually switch to computer instructions with 3D graphics.» Today, all major Dassault Aviation production plants are already heavily involved in the Rafale programme. For instance, Seclin, in Northern France, specialises in the fabrication of large primary parts. The Rafale's fuselage is assembled at Argenteuil, near Paris, from components delivered from Biarritz (in the south-west of France) and from various partners' facilities. The Biarritz plant also specialises in composite materials. At Martignas, close to Bordeaux, the wings are assembled from elements coming from Seclin. Rafale final assembly and acceptance testing is carried out at Bordeaux-Mérignac. It should be noted that, from the production people's point of view, only two Rafale versions exist, the Air Force single-seater being produced by mating up the forward fuselage of the Naval single-seater to the rear fuselage of the Air Force two-seater.

MIDS/LINK 16 **ON THE RAFALE**

The Rafale new-generation multi-mission combat aircraft now has MIDS/Link 16 capability to ensure full interoperability with the major NATO and allied platforms for joint and/or allied operations.

Link 16 is NATO's most recent interoperable datalink standard and is defined in STANAG 5516. It is a real-time tactical link for the exchange of digital multi-service data across multi-user networks that can comprise several hundred platforms.
L16 is a tri-service datalink (air, land, naval) and supports a broad range of operational services, including tactical situation awareness, command, control, electronic warfare, mission execution, anti-surface warfare and anti-submarine warfare.
L16 enables real-time exchange (in the order of seconds) at tactical level. In other words, the information it carries is considered valid at the moment it is sent and the moment it is received via the communication network. The information itself is fully standardised. Messages are structured into fields to avoid any possible misinterpretation. Exchange procedures and protocols are also strictly defined in the NATO standard.
MIDS (Multifunctional Information Distribution System) is the waveform that supports Link 16 and is itself defined in STANAG 4175. Located in L band, the MIDS waveform is highly protected (TRANSEC and COMSEC) against jamming and intrusion, and enables basic bit rates up to around 100 kilobits per second.
Until recently, the relatively big and heavy MIDS terminals could only be integrated with large platforms: special-mission aircraft, surface ships, ground centres, etc. However, the latest generation of the terminal, called MIDS-LVT (low-volume terminal) is smaller and lighter, so MIDS/L16 capabilities can be implemented on smaller aircraft, including combat aircraft and helicopters. These new terminals are now in production.

MIDS = Multifonctional Information Distribution System
NCW = Network Centric Warfare

On the Rafale, the MIDS-LVT is fully integrated with weapon systems via the aircraft's databus (1553 and BHV high-speed bus). The L16 management function is performed by the aircraft's mission computer, and the human-machine interfaces are incorporated with the existing cockpit displays.
The Rafale will use Link 16 for air-to-air and air-to-ground/surface missions for all mission phases, from alert to landing, and for two main classes of services: external cooperation (with other participants in the engagement) and internal cooperation (within the aircraft's own patrol).
For external cooperation, the Rafale will automatically receive tactical situation information, i.e. the representation of its operational environment with the positions of other players (friendlies, hostiles, neutrals, etc.) in the theatre of operations. It will also have a direct connection with its control centre (ground, surface or air) for the exchange of mission-specific information such as flight plans, navigation and refuelling waypoints, guidance to target, engagement orders, acknowledgements and reports.
For internal cooperation, MIDS/L16 will be used to exchange data on the relative positions of aircraft within the patrol, their statuses, detection data (e.g. one aircraft using its radar to provide tracks for other aircraft), coordination data and target distribution data.

...

Link 16 capability gives the Rafale multiple operational advantages:

- First, it enables the aircraft and its crew to receive real-time information automatically:

  o broad spectrum of data on the operational environment, mission, etc.
  o data is extremely reliable and accurate (e.g. on targets — absolute or relative position, route, speed, altitude, etc.)
  o no crew saturation (data is stored, then displayed on request or automatically, according to the phase of the mission)
  o updates (instant or periodic).

- Second, it gives the aircraft full interoperability:

  o with French forces:

  - as part of the SCCOA* air command and control system, with its fixed and deployable components, SDCA** airborne detection and command system (equivalent of AWACS) and (in the near future) tanker aircraft, Mirage 2000 combat aircraft and SAR helicopters operated by the French Air Force

  - the French Navy's air arm, with the *Charles de Gaulle* aircraft carrier, anti-air frigates, carrier-based airborne early warning aircraft (French Hawkeyes) and (in the near future) multi-mission frigates

  - the Martha system (ground-based air and area defence) and helicopters operated by the French Army

  o with NATO forces, particularly the Air Command & Control System (ACCS) with its fixed and deployable components, airborne early warning (AEW) assets, other allied command systems (including combat aircraft) and (in the near future) the Alliance Ground Surveillance (AGS) system.

The Rafale is one of the first combat aircraft to be equipped with an advanced real-time and fully interoperable tactical datalink. This new capability will enhance the aircraft's operational effectiveness as part of broader force structures and will enable it to play a critical role in future network-centric warfare operations.

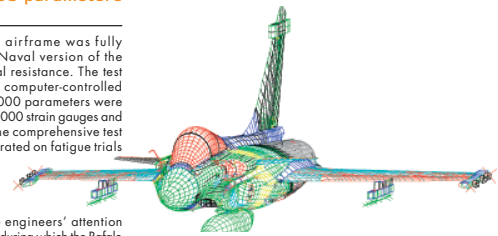
* SCCOA: Système de Commandement et de Contrôle des Opérations Aériennes
** SDCA: Système de Détection et de Commandement Aéroporté

RAFALE : "AN EXTREMELY STRONG" AIRFRAME

Between 1992 and 1999, a test airframe was used to validate the Rafale's design structural service life. The fatigue and static tests were based on a demanding flight spectrum representing expected flight usage, with data drawn from Mirage 2000 service experience.

No fewer than 3,000 parameters recorded

The Rafale static/fatigue airframe was fully representative of the real Naval version of the aircraft in terms of structural resistance. The test installation comprised 110 computer-controlled actuators and more than 3,000 parameters were recorded simultaneously by 3,000 strain gauges and 50 displacement sensors. The comprehensive test programme initially concentrated on fatigue trials and two aircraft lives - equivalent to 2 x 5,000 flying hours and 2 x 3,500 flights - were 'flown' without sustaining major damage. The engineers' attention then switched to the static trials during which the Rafale was tested up to 185 percent of design limit load before the airframe broke.



Additionally, the static and fatigue strength of some crucial components was tested separately: windshield, canopy, wing attachments, fuselage main fittings, landing gear, canard foreplanes, engine mounts... Additional Finite Elements Computations have beeen performed whenever needed to demonstrate the strength of components that have not been tested.

«Having completed all this substantiation process, we are fully confident that the airframe will prove problem-free for well over the planned service life, stresses Philippe Delaage, an aircraft engineer of the Rafale Management Team. Moreover, in-service aircraft are entirely monitored in real-time by a Health and Usage Monitoring System integrated into the mission computer, thus allowing the operator to precisely follow up the actual use of each aircraft through fatigue indexes.»

French MoD initial design specifications for the Rafale are 5,000 flying hours/3,000 landings with a severe usage spectrum, but studies have shown that the expected economical life (that is without any major structure component replacement) is 7,000 hours and 5,300 landings.

Editorial

In the 10th issue of FOX THREE,

the Rafale Team is proud to report on the

French Air Force first operational Rafale

squadron at Saint-Dizier Air Base, on the

final evaluation of the Standard F2 and on

the first flight of a Standard F3 Rafale.

We will conclude with a thrilling look at

Flottille 12F's international Air Defence

Week, at Landivisiau Naval Air Station.

Enjoy the reading!

The "FOX THREE" Team

Summary

p.3/5

Saint Dizier Air Base

p.9/11

Final evaluation

p.12/15

Landivisiau Naval Air Station

FIRST FRENCH AIR FORCE RAFALE SQUADRON OPERATIONAL

Escadron de Chasse 1/7 "Provence", the first French Air Force squadron to operate the Dassault Aviation Rafale omnirole fighter, attained full operational capability at Saint-Dizier Air Base on 27 June 2006, during a ceremony attended by French Prime Minister Dominique de Villepin, Defence Minister Michèle Alliot-Marie and other senior government and Air Force officials. This largely symbolic event took place the day after two of the squadron's aircraft handled their first Quick Reaction Alert air-defence mission from Mont-de-Marsan air base, in southern France, where they had deployed.

Escadron de Chasse 1/7 "Provence" operated the Jaguar from Saint-Dizier in the ground-attack role until June 2005 when it started its conversion process. By the end of 2006, it will be equipped with a total of 20 Standard F2 Rafales. A second Rafale squadron, this time tasked with the nuclear deterrence / strike role, will stand up at Saint-Dizier in 2008 with a further 20 aircraft, bringing the Air Wing there to full complement. It has now been announced that the third Rafale squadron will form at Mont-de-Marsan. In all, the French Air Force will receive 234 Rafales, split between Rafale B two-seat and Rafale C single-seat versions. To date, 120 Rafales have been ordered for both services, and 35 have been delivered to both the Air Force and the Navy. The Air Force order covers a total of 82 aircraft (44 single-seaters and 38 two-seaters) with an additional 38 Rafale Ms – all single-seaters - for the Navy. Under current plans, production is to continue until 2023.

In the meantime, the French Navy has taken delivery of its first Standard F2 Rafale, with a second one to leave the Dassault production line before the end of the year. Another fourteen will enter service in 2007 / 2008. They will bolster the first batch of ten Standard F1 Rafale M fighters that specialise in air-to-air operations with *Flottille 12F*, the first French Navy Rafale unit which became fully operational at Landivisiau Naval Air Station in June 2004. Standard F2 aircraft are equipped with an improved radar offering air-to-surface modes, with a Link 16 datalink for network-centric operations with other French and foreign assets, with infrared-guided Mica IR and radar-guided Mica EM air-to-air missiles, and with Scalp long-range cruise missiles as well as AASM fire-and-forget modular precision weapons. Eventually, the French Navy will operate 60 Rafale M single-seaters.

NEW MILESTONES FOR THE RAFALE TRIALS

With the final evaluation of the Standard F2 by the French Flight Test Centre, the first flight of the Standard F3 variant from the Dassault Aviation premises and the recent firing of the first guided AASM missile, the Rafale test programme is moving forward at unprecedented rate.

Rigorous evaluation

From mid-May to early June 2006, the French Flight Test Centre successfully conducted the final evaluation of the Standard F2 Rafale. Prior to the qualification of the Standard F2 and its official acceptance by the Defence Procurement Agency, French Air Force and French Navy test pilots and engineers flew the variant in a demanding environment to make sure that it could enter service without any restrictions. Two aircraft were involved in a series of complex sorties, simulating various mission profiles: deep strikes with Scalp cruise missiles, close air support attacks with AASM precision weapons, battlefield air interdiction bombings (also with AASMs), and air-to-air engagements with radar and infrared-guided Mica missiles. Severe electronic warfare environments were replicated, and the Rafales were pitted against a wide range of opponents: Mirage 2000-5F fighters, Crotale surface-to-air missiles and the threat generators / simulators of the multinational electronic warfare training range, in Eastern France. The French AWACS fleet actively participated in the trial campaign, and the Rafale aircrews routinely utilised their Link 16 datalink to exchange data with both the AWACS and their wingmen.

Standard F3

In May 2006, two-seater B302, the second production Rafale, was rolled out from the Dassault Aviation facility, at Istres, after a short conversion programme that brought it to full Standard F3 configuration. Under current plans, Standard F3 Rafales will enter service with the French Air Force and the French Navy in 2008. They will offer expanded combat capabilities thanks to the introduction of the Exocet anti-ship missile, of the ASMP-A nuclear missile, of the Pod Reco NG reconnaissance pod and of various improvements to the Thales RBE electronic-scanning radar and to the Thales Spectra self-defence suite.

Flight testing of the improved standard started in May 2006, and initially focused on the radar / digital terrain following modes. By October 2006, the in-flight testing of the new Pod Reco NG will have begun, and trials with Exocet missiles will follow soon afterwards. Four Rafales, B301, B302, C101 and M02, will take part in the Standard F3 development programme, with 400 test sorties to be logged between May 2006 and early 2008.

AASM

The Rafale programme reached a significant milestone on Wednesday 26 July 2006 when single-seat Rafale C101 fired an AASM stand-off weapon off the French Missile Test Centre, in the South-West of France. The revolutionary AASM (Armement Air-Sol Modulaire, or Modular Air-to-Surface Armament) is a low-cost, all-weather, fire-and-forget weapon optimised for high-accuracy attacks at long ranges. Designed and produced by Sagem, the AASM can be utilised for an extremely large range of strike missions. Thanks to its modular architecture, it offers unmatched destructive capabilities against soft and hard targets. Depending on the tactical situation, the required precision to avoid collateral damage, and the importance of the target, the Air Force and Naval commanders can choose between two types of state-of-the-art guidance kits:
- a combined Inertial Measuring Unit / GPS receiver navigation system for all-weather attacks with a 10 m class accuracy
- a combined Infrared Imager seeker / Inertial Measuring Unit / GPS receiver for day and night attacks with metric precision.

For long distance engagements, the AASM is equipped with a bolt-on tail unit / range extension kit which comprises a solid rocket motor and flip-out wings. Range exceeds 50 km for a high-altitude release, or 15 km for a low-level firing. Even more significant is the capability to engage targets at high off-boresight angles: with the AASM, the Rafale does not have to overfly the target to carry out its attack with deadly accuracy, and it can safely remain out of reach.

Test firing

The firing was completed off the French Atlantic Coast and the overall trial was under the responsibility of the *Centre d'Essais en Vol*, the French Flight Test Centre of the *Délégation Générale de L'Armement*, the Defence Procurement Agency. The weapon was of the INU / GPS variant that offers 10 m-class precision. Commandant Sylvain Guiraud, a test pilot from the French Air Force Evaluation Centre, flew the 26 July sortie and carried out the firing. *"We wanted to test the AASM in an operational environment, with representative delivery profiles that will be used by French Air Force and French Navy front-line Rafale squadrons,* he said. *Our main goal was to test a fully functioning instrumented round to make sure that the armament and the aircraft could share targeting data in a satisfactory way."*
Rafale C101 took off from Cazaux Air Base at 11 h 00 local. *"The AASM was fired at low-level over the sea, at 1500 feet and 450 knots in level flight,* explained Sylvain Guiraud. *The weapon hit the target with chirurgical precision. Prior to the attack, the coordinates of the target had been transferred to the Rafale via the Link 16 datalink. I used the Rafale's Front Sector Optronics system to watch the impact in real time. In a combat scenario, the FSO could be used for battle damage assessment."*

INTERNATIONAL
AIR DEFENCE WEEK

From 03 to 07 July 2006, Flottille 12F, the first French Navy Rafale unit, organised for the first time a week-long intensive air defence exercise from its Landivisiau Naval Air Station home-base, in Brittany, Western France. *« From Landivisiau, we routinely train with the Super Etendard strike fighters of the French Carrier Air Wing, but in order to be fully proficient, air-defence pilots need to regularly train against other air defence assets such as F/A-18 Hornet, F-16 Fighting Falcon, Mirage 2000 and Typhoon fighters, stresses* Commander Jérôme Puech, Officer Commanding Flottille 12F.
But we are rather isolated in Brittany. For instance, for a two-hour sortie, we only have 20 to 25 minutes of 'playtime' in the TSA 43 area, in Central France, due to the distance involved. It is not a very effective way to train. There are only two solutions to this problem: either travel to outside bases, or invite other squadrons here and fight in our superb training areas. »

Encouraging results

For the 2006 edition of the *Flottille 12F* Air Defence Week, three units and a total of eight aircraft deployed to Landivisiau:
- two French Air Force Mirage 2000Cs *from Escadron de Chasse 1/5 'Vendée'*
- four Belgian F-16 MLUs belonging to 349 Fighter Squadron
- two Royal Navy Sea King ASaC Mk 7s from 849 Naval Air Squadron.

Additionally, Super Etendards from *Flottilles 11F and 17F* took part in the exercise on a daily basis, while Flottille 4F E-2C Hawkeyes and French Air Force E-3F AWACS were also heavily involved.
« Flottille 12F Air Defence Week seeks to familiarise aircrews with the employment of advanced air-defence tactics, explains Jérôme Puech. *We knew we could host a fair number of aircraft at Landivisiau. This is why we invited quite a large number of French and foreign units: French Mirage 2000s, Spanish and Swiss F/A-18s, Belgian, Italian, Dutch and Portuguese F-16s, British Typhoons and Hungarian MiG-29s. We wanted to make sure that every participant would get the best training opportunity: our goal was not to set up a bilateral squadron exchange, but to organise a large-scale multinational exercise with complex scenarios. This year, only three units responded positively, but this is really encouraging and we will do better next year. »*
With its numerous training areas, Landivisiau Naval Air Station is perfectly positioned to accommodate such an exercise. *« Our D12, D14 / D15, and D5 / D7 areas are just a few minutes flying time away,* continues Commander Puech. *We can fly at supersonic speeds without any risk of damaging private properties with our 'bangs', and we can use our flares and chaffs without any restriction. Moreover, our training areas are large enough to simulate long-range engagements, and we can split to accurately replicate tactics we use with our radar-guided, fire-and-forget Mica missiles. »*

Obvious advantage

During their stay, each pilot flew several missions every day and, for all Mirage 2000 and F-16 aircrews involved, the exercise was their first encounter with the Rafale. Needless to say, they were all impressed by the latest Dassault fighter.

« In a dogfight, using only our guns and short range missiles, it is indeed very difficult for a Mirage 2000 pilot to win the day against a Rafale, admits Commandant Jean-Roch Piselli, the 'Boss' of EC 1/5 Detachment. *Considering the imposed rules of engagement during the first phase of the exercise, our only real opportunity was to fire first, just after the crossover. Even though the Mirage 2000 is equipped with notoriously effective fly-by-wire controls, it does not offer the same level of performance in terms of manoeuvrability and engine thrust and response. We have to select full afterburner as soon as the fight begins while the Rafale pilot can throttle back and even remain in full dry, military power: we burn more fuel and our infrared signature is significantly higher whereas he can reaccelerate very rapidly if needed. »*

Flottille 12F was declared fully operational in June 2004, and the Rafale pilots now perfectly know how to handle their aircraft to quickly win the fight: *« we always devise a 'game plan' to exploit both the Rafale's fantastic acceleration and its outstanding agility,* explains Lieutenant-Commander Pascal Cassan. *Against a F-16, the Rafale is more powerful in the whole flight envelope, and is considerably more manoeuvrable below 300 knots. Ideally, after the crossover, I will climb into the sun to force him to slow down. I will constantly threaten him by pointing the Rafale's nose in his direction. That will force him to tighten his turn even more, and his speed will wash out very rapidly. On the contrary, the F-16 pilots will do what they can to keep their speed and energy up. »*

Numerous 'beyond visual range' (BVR) engagements were simulated during the week, and the Rafale proved as deadly in the long-range arena as in a dogfight: *« I think that our RBE2 electronic scanning radar is very good,* indicates Lieutenant Le Bars. *Against a F-15 or a F-16, two aircraft types that have enormous radar cross-sections because of their massive air-intakes, our detection ranges are excellent. In a BVR scenario, we always try to engage at high level and fire our lethal Mica missiles at high altitude to give them the longest possible range. Ideally, we will 'loft' the radar-guided Micas to boost their range before diving down to low level while simultaneously opening left or right. In doing so, we deny the opponent any opportunity to fire back. When in the 'merge', we quickly gain the upper hand against a F-16: with our large delta wing and our canard foreplanes, we have considerably more authority in pitch and we can turn more tightly, the Rafale offering better sustained turn rates than the F-16 at low, medium and high levels. Our Snecma M88-2 turbofans are so powerful that we often have to reduce power to avoid overtaking our prey.»*

All participants agreed that this first edition of the *Flottille 12F* Air Defence Week was a total success. *Flottille 12F* specialists are already busy preparing the 2007 event which should attract a larger foreign contingent. By July 2007, the first four Standard F2 omnirole Rafale fighters will be in service with the unit, and they are likely to participate in the exercise too.

Interception and Combat

Produced by MBDA, the extremely advanced MICA is capable of both beyond visual range interceptions and close-up dogfights, a crucial advantage for air-to-air combat. Thanks to its thrust vectoring vanes and long-cord wings, this lightweight (246 lb, 112 kg) weapon has excellent range and manoeuvrability, even at high angle of attack. This translates into a very high kill probability against hard turning targets at very long ranges. During the development programme, the MICA has been tested in very demanding environment, and the trial programme culminated in the engagement by two MICAs fired from one fighter of two widely separated targets using countermeasures.

Two variants of the MICA are now in service with French Air Force and Navy Rafales: the radar-guided MICA RF (Radio-Frequency) and infrared-guided MICA IR. The interchangeable seekers ensure a massive reduction in direct operating and maintenance costs as the airframes, warheads and motors are the same for both variants, the only difference being the seeker. More significantly, the availability of two guidance systems offers enhanced tactical flexibility, and hampers enemy countermeasure selection, both MICA seekers also having excellent counter-countermeasure capabilities. When under a Rafale's MICA threat, a target would have difficulties choosing between two very different types of defensive tactics.

On the Rafale, the MICA missiles are fitted to two hardpoints under the sides of the rear fuselage, and to wing pylons and wing-tip points. The fuselage-mounted MICAs can be ejected at up to 4 g whereas the wing-mounted missiles can be rail-launched at up to 9 g.

MICA RF

With its Thales AD4A active radar homing head, the MICA RF is fully autonomous after launch so that a pilot can either engage several targets simultaneously or immediately turn away after a shot, reducing the time spent in a potentially dangerous area or denying the enemy aircraft any firing possibility. Its high impulse Protac motor ensures very long range, and the short propulsion time considerably reduces the likelihood of visual detection. The fighter/missile datalink permits beyond-visual range interceptions with a remarkable probability kill percentage. After launch, the MICA climbs to very high level where its aerodynamic configuration minimises drag and significantly increases range.

In the Rafale, interception and firing data are calculated for numerous priority targets which can be engaged with MICA BVR / air combat active radar seeker missiles shot in quick succession. With its electronic scanning antenna, the Thales RBE2 radar is fully capable of tracking another great number

of targets while updating the MICAs via the dedicated, mid-course, secure, radar-to-missile links which enable very long-range multiple firings with an exceptionally high probability kill rate, even against hard manoeuvring enemy fighters. This gives the Rafale a unique combined situational awareness and combat capability/efficiency while considerably reducing aircrew workload, especially in complex tactical situations.

MICA IR

The extremely manoeuvrable MICA IR missile has now become the Rafale's standard short-range IR-guided air-to-air missile. Over the years, the successive development of various generations of infrared sensors for the Matra 530, Magic 1 and Magic 2 missiles has allowed French specialists to design a highly-effective passive, dual-band imagery IR seeker for the MICA

IR. Compared with the other IR-guided missiles, the MICA IR has been fitted with a seeker that is fully autonomous for cooling.

In hard manoeuvring combat, the MICA IR allows both lock before launch or lock after launch attacks to be performed. In the lock after launch mode, off-axis shots and even 'over-the-shoulder' interceptions can be undertaken if required to defeat an aircraft approaching from behind. The IR seeker has many advantages for such a long range missile. It has excellent angular resolution and countermeasure resistance - thanks to dual band imagery - and is totally stealthy: when used in conjunction with the Rafale's revolutionary Front Sector Optronics system, the passive homing head enables 'silent' interceptions without tell-tale radar emissions to betray the fighter's position; a clear illustration of the Rafale's multiple covert interception tactics.

A vertically launched naval/land variant of the MICA, the VL MICA, is on offer for both naval and land applications. The naval configuration comprises a varying number of missiles housed in vertically-mounted containers for ship defence against saturation attacks. The land version is adapted to a truck, and could prove highly efficient to defend high-value static targets such as air bases or refineries. Using either IR or active RF seekers, the VL MICA system is claimed to be capable of engaging up to eight different targets spread over a 360 degree arc in less than 12 seconds. The VL MICA and the airborne MICA are fully interchangeable, helping reduce costs of ownership when both variants are purchased by a single country.

RAFALE COMBAT PROVEN

The Rafale omnirole fighter was engaged in combat for the first time in March 2007 by French Air Force and French Navy aviators.

In early October 2006, the French Ministry of Defence announced an urgent operational requirement for the adoption of laser-guided weapons on French Air Force Rafales. The anticipated rise of Taliban activity in Afghanistan in the spring had led to the decision to fit the Rafale with the 500 lbs-class GBU-12 / 22 laser-guided bombs. Standard F2 Rafales then in service with the Air Force and the Navy were capable of firing Scalp cruise missiles, AASM modular stand-off precision weapons and Mica air-to-air missiles, but it was felt that a GBU-12-class weapon would prove ideal in Afghanistan where laser designation was adapted due to stringent rules of engagement. Accordingly, a feasibility study was launched by the Defence Procurement Agency and Dassault Aviation. In less than a month, Dassault Aviation engineers developed a technical solution to integrate the GBU-12 and GBU-22 bombs on the Rafale. The technical proposal was accepted and the 'Echo' project was officially launched on 17 November 2006, the contract signed with Dassault calling for an entry into service as soon as possible with both the Armée de l'Air and the Marine Nationale. To cut development time, it had been decided not to equip the Rafale with a laser designation pod. Instead, the aircrews rely on buddy-lasing, the cooperative technique where another fighter holds a laser spot on a target so that it can be struck by weapons dropped from the Rafale. Alternatively, a forward air controller on the ground - or a suitably trained special forces commando - could designate targets for the Rafales. It should be noted, however, that, from early 2009, the Standard F3 Rafales will be fitted with a Damoclès laser designation pod under the right forward fuselage hardpoint. The introduction of the Damoclès targeting pod will allow Rafale aircrews to self-designate targets at extended ranges, both in daytime and at night.

Flight testing

Capitalising on a series of trials already carried out by Dassault in 2001, the 'Echo' development and test programme moved forward very rapidly to comply with the expected release dates. The project was a total success, only 15 sorties being required for the flight envelope expansion and the weapons-separation test/firing trials which culminated with the qualification live firings, at Cazaux, in mid-February 2007. Trials were carried out with a combat load of six GBU-12s, three 2000-litre fuel tanks, and four Mica air-to-air missiles for interception, combat and self-defence. It took Dassault less than four months to deliver the complete LGB package to the armed forces, including aircraft modifications and armourers training. The Rafale was declared operational with the laser-guided bombs in early March 2007 after some 15 GBU-12s had been dropped by Navy and Air Force aircrews for evaluation and training purposes.

A total of six Navy and Air Force Standard F2 Rafales deployed to Afghanistan, the three Armée de l'Air two-seat fighters flying into Dushanbe, in Tadzhikistan, on the 12th of March 2007 while the three Marine Nationale single-seat aircraft had joined the Charles de Gaulle's carrier air group at Djibouti a few days earlier, bringing the overall number of Rafales in the area to fifteen, including the nine Standard F1 aircraft used for air-defence and buddy-buddy refuelling missions from the French Navy flagship.

Into combat

At Dushanbe, Air Force Rafales were usually equipped with four GBU-12s and two 2000-litre drop tanks only. With no perceived air threat, Mica missiles were not fitted. From early May 2007, the 30 mm cannon was declared operational and, from then on, Rafales flew with 125 rounds, ready to respond to any call for strafing. *"The Rafales always operate with the Mirage 2000Ds as a mixed force, each pair comprising a Rafale and a Mirage, explains Colonel François Moussez, French Air Force Rafale Project Officer. We usually launch two waves per day, one in the morning, and one in the afternoon, with mission duration varying from 4 h 30 min to 6 h 30 min. Overall availability has been excellent since the beginning of the deployment, and we have not cancelled any single mission due to mechanical problems. On average, about 50 sorties are flown each month, with each aircraft logging about 80 flying hours per month. The initial maintenance team was composed of 50 engineers, but experience shows that we will be able to significantly cut down that number soon. All maintenance data is transmitted back to France via a military satellite link for storage and analysis."*

A giant leap forward

For the French Air Force, the introduction of the Rafale over Afghanistan represents a major capability boost. *"Compared with the Mirage 2000, the Rafale offers a much longer range and a much higher payload, with up to six GBUs available per aircraft instead of two for the Mirage, stresses Colonel Moussez. With its L16 datalink, the Rafale easily plugs into command and control networks and tactical data is routinely exchanged via datalink with USAF F-15E Eagles and US Navy F/A-18 Hornets. Situational awareness is significantly improved by the L16, a crucial advantage for flight safety in a country where the number of air-traffic control radars is rather low. The Rafale's electronic scanning radar is also an essential tool for combat effectiveness, allowing tankers and other fighters to be detected at very long ranges."*

The Rafale aircrews did not have to wait long to become combat proven. The first GBU-12 firings were carried out by a Navy Rafale on Wednesday 28 March 2007 when two bombs were delivered in support of Dutch troops on the ground. The laser illumination was provided by a Super Etendard Modernisé. Two days later, an Air Force Rafale working in conjunction with a Mirage 2000D dropped for the first time a GBU-12 to provide fire support to NATO ground forces. Since then, the Rafales have delivered a large number of weapons in combat with outstanding precision.

The Rafale omnirole fighter was engaged into combat eight months only after being declared operational by the French Air Force, an achievement which has attracted a lot of interest from foreign observers. Since the beginning of the deployment, the Rafale's availability rate has continuously been better than 90% and the aircrews did not experience any difficulty integrating into a complex command network thanks to the fighter's advanced systems and state-of-the-art man-machine interface.

INTO COMBAT
WITH THE NAVY

In May 2006, the first Standard F2 Rafale M omnirole fighter was delivered to the French Navy Operational Evaluation Unit, at Mont-de-Marsan, in the South of France. Compared with earlier Standard F1 Rafales in service with Flottille 12F (the first Navy Rafale squadron), the improved Standard F2 offers expanded capabilities thanks to the introduction of the L16 datalink, the Front Sector Optronics, the MICA IR air-to-air missile, the AASM modular air-to-surface armament and the Scalp cruise missile.

Short notice deployment

In December 2006, the Navy Operational Evaluation Unit was ordered to get ready for a deployment to the Afghan theatre of operation. At the time, the unit was busy devising new tactics and operational procedures to prepare the new version's entry into front-line service. The OEU's efforts immediately switched to the introduction of the GBU-12 laser-guided bomb as part of the urgent operational requirement. By early March 2007, the Navy Rafales had been modified and the fully trained detachment was ready to deploy to Afghanistan with three aircraft and five pilots. At the time, the Charles de Gaulle nuclear aircraft carrier was already off Djibouti, and the three Standard F2 Rafales had to trap aboard after a seven-hour high-altitude transit with the help of French Air Force C-135FR tankers.

Single-seaters

The French Navy Rafale operations over Afghanistan were a total success, and thirty missions were flown with a 100% dispatch rate, the first GBU-12 firing being recorded on Wednesday 28 March 2007. "On average, mission duration was just over five hours, with tanker support provided by French Navy Standard F1 Rafales, Royal Air Force Tristars, and US Air Force KC-10s and KC-135s, explains the Commanding Officer of the French Navy Operational Evaluation Unit. We normally flew with four GBU-12s and two 1250-litre drop tanks. With no air threats, no air-to-air missile was required. Missions were flown in conjunction with Super Etendard strike fighters. Thanks to the Rafale's advanced man-machine interface, we did not experience any difficulty operating in such a complex operational environment in a single-seater. With the L16, we automatically exchanged data with other assets in the area, and our RBE2 electronic scanning radar and our Front Sector Optronics proved invaluable for flight safety. The FSO was also very useful to identify at standoff distances which aircraft in a box was our allocated tanker. The Rafale's excellent bring-back capability was a real bonus, and we could trap aboard the carrier with four GBU-12s and 1700 kg of fuel, which gave us a much improved safety margin compared with that of our Super Etendard colleagues."
The Rafale is now firmly in service with Flottille 12F and the unit recently passed a significant milestone when the 10000 flying hour mark was reached. In 2008, the first Standard F3 Rafale M will be delivered to the French Navy and, under current plans, the second Naval Rafale squadron will be created in 2009.

A BRIGHT **FUTURE**

In late 2006, it was announced that a contract had been signed for the development of an improved variant of the Rafale omnirole fighter.

Damoclès and AESA

As part of the Rafale 'road map', French Air Force and French Navy Standard F3 Rafales will be equipped from early 2009 with the Damoclès laser designation pod. At the same time, the current inventory of 250 kg-class GBU-12 and GBU-22 LGBs will be expanded with the entry into front line service of the much more powerful, 1000 kg-class GBU-24.

Produced by Thales, the Damoclès is a state-of-the-art targeting pod fitted with a 3rd generation staring array infrared detector. The introduction of the Damoclès will allow Rafale pilots to self-designate targets at substantially greater ranges and higher altitudes than earlier systems. Its excellent resolution means it can also be used for battle damage assessment and stand-off reconnaissance.

From 2012, the Rafale's current electronic scanning RBE2 radar will be fitted with a new generation Active Electronic Scanning Array which will offer increased detection range and better angular coverage in azimuth. The Thales AESA will prove ideal for operations with the Meteor, a long-range interception missile now being tested by MBDA. The AESA radar array will be made up of more than 1,000 transmitter/receiver modules so that several can fail with no significant degradation in acuity. It will further contribute to the Rafale's excellent reliability. The RBE2's open architecture will facilitate upgrading, and the new AESA array is totally 'plug and play', switching from the passive to the active array configuration taking less than two weeks.

FSO-IT and MWS-NG

Improvements will not be limited to the radar, however, and new variants of the Front Sector Optronics and of the Missile Warning System will be introduced in 2012.

FSO-IT (Front Sector Optronics-Improved Technolgies) is a further step of the current FSO with which pilots are able to covertly detect targets at very long ranges and to identify them at stand-off distances. The FSO has already proved its worth during numerous NATO exercises (Tiger Meet and Tactical Leadership Programme) and recent combat operations over Afghanistan, providing Rafale aircrews with unprecedented situational awareness. The new variant will offer outstanding performance levels and will contribute to an even better understanding of the tactical situation.

The MWS-NG (Missile Warning System-New Generation) will benefit from the introduction of new technologies which will significantly ameliorate its detection and warning capabilities thanks to a lower false alarm rate and to an increased detection range. As a result, the survivability of the Rafale will be further boosted.

With the adoption of cutting edge technology, the Rafale will become more lethal, more survivable, more reliable and more affordable, and French Air Force and French Navy aviators will be well armed and prepared to face future threats.

Editorial

In the 12th issue of Fox Free,

The Rafale Team is proud to announce that, Rafale omnirole fighters have participated in two major exercises in the USA. French Navy and French Air Forces Rafales successfully took part in Joint Task Force EXercise and in Red Flag, attracting a lot of favourable comments from users, foreign participants and outsiders.

The "FOX THREE" Team

Summary

p.3/5

Omnirol Squadron

p.4/5

Full scale deployment

p.8-11

Fully interoperable

OMNIROLE **SQUADRON**

Now equipped with its full complement of 15 Standard F2 Rafale omnirole fighters, Flottille 12F can carry out an extremely large range of combat missions, from land or from the deck of an aircraft-carrier: air-defence, sweep, escort, close-air-support, battlefield air interdiction, anti-ship attacks with precision weapons... On top of their internal 30M791 30 mm cannon, Standard F2 Rafales can be armed with radar and infrared-guided Mica EM/IR air-to-air missiles, Scalp cruise missiles, GBU-12 laser-guided bombs and AASM (Air-to-Surface Modular Armament) low-cost, all-weather, fire-and-forget weapons. In 2007, five French Navy Standard F2 Rafales were engaged in combat operations over Afghanistan with GBU-12s. They successfully supported troops in contact and fired their bombs with deadly accuracy.

Towards Standard F3

From late 2008, the unit will start using operationally improved Standard F3 Rafales which will offer expanded capabilities thanks to the introduction of the ASMP-A nuclear missile, of the Pod Reco NG stand-off reconnaissance pod, of the Damocles laser-designation pod and of the acclaimed AM39 Exocet missile. With Standard F3 Rafales, Flottille 12F will be capable of carrying out the full spectrum of aero-maritime fighter missions, from anti-ship attacks in coastal and blue waters to power projection over land, and from air superiority/air-defence to nuclear deterrence. Under current plans, a second naval squadron, Flottille 11F, will start converting from the Super Etendard to the Standard F3 Rafale in 2012.

FULL SCALE **DEPLOYMENT**

As part of its continuation training programme, the French Navy sent six Rafale omnirole fighters and two E-2C early warning aircraft to the USA to participate in Joint Task Force EXercise (JTFEX) 2008-4, a major training effort involving more than 30 warships and 15,000 military personnel from four countries.

Keeping skills sharp

With the *Charles de Gaulle* in refit for a nuclear reactor refuelling and complex overhaul, it was decided by the French Navy to deploy the Rafales and the Hawkeyes to the USA to maintain skills in carrier operations.
Traditionally, the French and US Navies have always closely cooperated, and French and US decision makers were keen to bolster this cooperation even further. Cross deck operations had been carried out before on numerous occasions, but not on a large scale, and both navies were willing to test their interoperability and validate common operating procedures. *"The purpose of the deployment was to demonstrate our ability to integrate with US Forces,* explained Captain Patrick Zimmermann, the French Carrier Air Group Commander. *We had not been idle while the* Charles de Gaulle *was in dry-dock, however, and we have used that timeframe to regenerate our carrier air group and to train new pilots. In mid-2007, and again in May 2008, Rafales and French Hawkeyes trapped onboard USS* Enterprise *and USS* Harry Truman, *further demonstrating interoperability. In February 2008, we were given the green light by US authorities for the deployment onboard USS* Theodore Roosevelt, *and we started planning the exercise. The Aéronavale contingent was composed of six Rafales, two Hawkeyes and officers, NCOs and sailors from Flottilles 4F and 12F, the* Charles de Gaulle*'s carrier deck crew and the French Carrier Air Group mission planning cell."*

Across the Atlantic

On 26 June 2008, six Flottille 12F Standard F2 Rafales left their homebase in Landivisiau to cross the Atlantic via Lajes, in the Azores archipelago. The Rafales were accompanied by two French Air Force C-135FR tankers and all ground personnel, spares and ground support equipment were carried by an Armée de l'Air transport aircraft and a hired civilian airliner.
During the first two weeks of the deployment, the Rafales were accommodated at Naval Air Station (NAS) Oceana, in Virginia. Numerous training missions were flown from there with, or against, locally-based US jets. For the whole duration of the exercise, at Oceana and onboard USS *Roosevelt*, VFA-31 'Tomcatters', a F/A-18E Super Hornet squadron, was the hosting unit for Flottille 12F. For the French fighter pilots, training with their US counterparts was an excellent opportunity to test new tactics and to verify interoperability.

FULLY INTEROPERABLE

During their deployment in the USA, French Navy Rafales seamlessly integrated with US and foreign forces involved in Joint Task Force EXercise (JTFEX) 2008-4. They participated in demanding combat training missions, simulating attacks of ground targets with precision weapons, and performing mock air-to-air engagements at long and close ranges.

Onboard USS *Roosevelt*

For the French contingent, the exercise culminated with the deployment of five Rafales for five days onboard USS *Theodore Roosevelt* (CVN-71). Prior to embarking on the carrier, Flottille 12F pilots performed four simulated field deck landings each (two in daytime and two at night) at NAS Oceana or at nearby Naval Auxiliary Landing Field Fentress. Experienced US Landing Signal Officers (LSOs) were assessing the performance and safety levels of the French Navy aviators before allowing them to trap onboard the carrier. On 19 July 2008, the first Rafale carrier landing was recorded onboard USS *Roosevelt*. The first two days onboard the US vessel were dedicated to Carrier Qualifications and every pilot had to log ten 'traps', six in daytime and four at night, in order to become fully qualified again. On the very first day, four pilots gained their day and night carrier qualifications, with the other four the following day, an achievement made possible by both the superb handling qualities of the Rafale in the circuit, and the size of the US carrier which allowed simultaneous launch and recovery of fighters.

Once fully qualified, French pilots switched to complex, multinational combat training scenarios. They operated as part of the *Roosevelt*'s Carrier Air Wing (CVW-8), and flew combined missions with US Navy F/A-18C Hornets, F/A-18E/F Super Hornets and EA-6B Prowlers. For mission planning, briefings and debriefings, they shared a ready-room with VFA-31 aircrews.

During the tactical training phase of JTFEX 2008-4, French and US naval aviators took part in operations spanning the US east coast, from Virginia to Florida. Most sorties were flown in the W-12/W-122 training areas off the east coast, and over the BT-11 and Navy Dare County training ranges, in North Carolina. Other strike missions were flown as far as Florida, with tanker support from US Forces. Both low-level and medium/high-level profiles were flown by Flottille 12F aircrews. *"We took advantage of our deployment to the USA to train section and division leads,* explained Commander 'Tom' Valette, Flottille 12F Commanding Officer. *The whole spectrum of combat missions was simulated, from self-escort strike to close air support, and from basic fighter manoeuvring to air-defence. For strike or close air support scenarios, we simulated attacks with loads of six AASM stand-off, fire-and-forget modular air-to-surface armaments, or six GBU-12 laser-guided bombs, plus a full-up air-to-air load of Mica radar and infrared-guided missiles. On most missions, we had US Navy adversary units in Oceana or US Air Force fighters trying to oppose our ingress. That was very realistic training in a different environment for us."*

All-round compatibility

Interoperability extended to secure communications network as the Rafale is equipped with NATO-standard radios. In-flight refuellings did not pose any problem either, and French Rafales took fuel from US Air Force KC-135 and KC-10 tankers, Omega Boeing 707s and US Navy Hornets and Super Hornet fighters equipped with buddy-buddy refuelling pods. The *Charles de Gaulle* is fitted with catapults and arresting gears which are very similar to those of US carriers. The design of the catapult shuttle used to attach the French fighter's launch-bar is slightly different from that in service with US aircraft, however, which meant that US shuttles had to give way to French ones whenever a Rafale was due to be catapulted, the operation taking less than one minute to complete. All Rafales were usually launched by the same catapult in order not to disrupt the launch-cycle of USN aircraft. 'Hot refuellings' with the Snecma M88-2 turbofans running were carried out during the deployment too, further demonstrating the Rafale's interoperability with US support equipment.

Total success

In five days, Flottille 12F Rafales logged 153 carrier landings, including 57 at night. The last Rafale was catapulted from the *Roosevelt* on 23 July, and the squadron continued the exercise from NAS Oceana. In early August, the six Rafales flew across the Atlantic back to Landivisiau, again with tanker support from the French Air Force. For Flottille 12F, JTFEX 2008-4 was an outstanding success and the unit demonstrated, on a large scale, that it could routinely and safely operate from a US carrier, far from its traditional support infrastructure. French and US pilots are looking forward to other, intensive cross deck exercises in the near future. In all, the six aircraft logged 480 flying hours in just over a month with very good availability and reliability rates. This exercise has proved, once again, that the Rafale is a fully mature fighter which has no difficulty blending into a US-led coalition type force and, with the *Charles de Gaulle* due to be fully operational again from early 2009, the Flottille will find itself back into action soon.

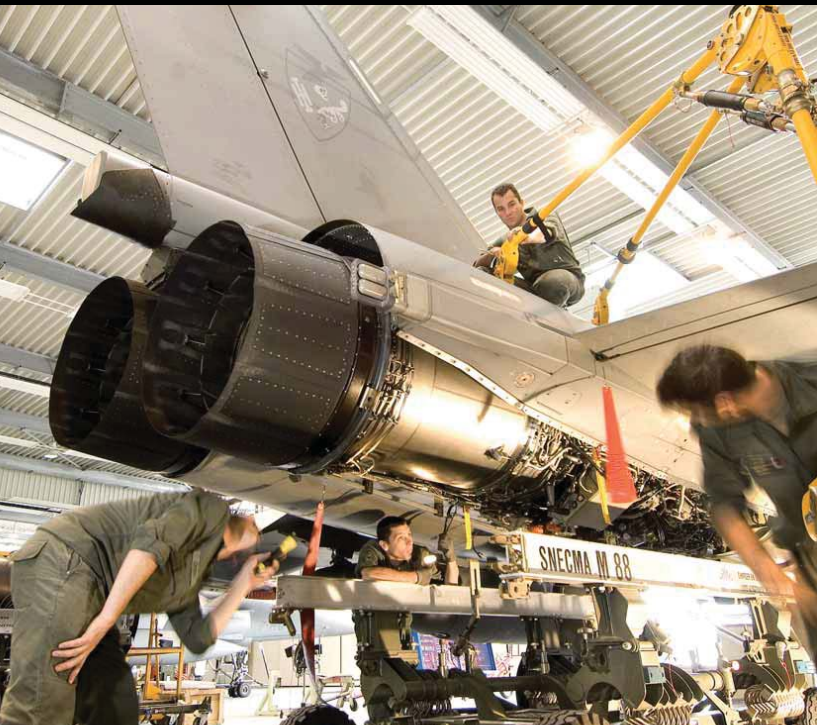
Link 16

For the French Navy, one of the main goals of JTFEX was to demonstrate that its Rafales were fully interoperable with US fighters. Aéronavale Rafales have already participated in combat operations over Afghanistan and they are more than likely to deploy to the Indian Ocean again in the next few months, so every opportunity to train with US assets proves invaluable. For each JTFEX training mission, the Rafales 'plugged' into the US Navy Link 16 datalink network prior to taking off. Once airborne, they shared tactical data with US fighters and with French, US, and British AWACs, Hawkeyes and Sea Kings. As a result, the situational awareness of all Rafale pilots was massively ameliorated, and overall combat efficiency was significantly increased: Flottille 12F aircrews rose above the 'fog of war' and all hostiles and friendlies were clearly identified, allowing French pilots to either dodge or engage the threat, depending on the tactical situation. Thanks to the L16 datalink, tactical control was both easier and quicker, and the Rafales were able to prosecute their time-critical targets more effectively and more rapidly.

M88: MORE THRUST THAN ENOUGH

Snecma (a SAFRAN Group company) is currently working on a more powerful variant of the acclaimed M88-2 turbofan, a state-of-the-art engine which powers the Rafale omnirole fighter.

The Rafale was conceived as a swing-role fighter capable of carrying out an extremely wide range of missions. As a result, the M88 engine had to comply with stringent requirements: it had to be compact and was designed to excel at low and high levels. Moreover, engine response to pilot throttle movements had to be instantaneous. *"The M88 is an innovative powerplant with a very high thrust to weight ratio, an extremely low fuel consumption in all flight regimes, and a very long life,* explains Michel Caunes, Snecma M88 programme Director. *As of October 2009, 75 production Rafales powered by M88 engines had been delivered and development and production engines had logged more than 100,000 functioning hours."*



High level of performance

To provide the required amount of thrust while keeping fuel consumption within given limits, Snecma engineers had to come up with innovative solutions to ensure that performance levels complied with the extremely demanding French power and durability requirements. Consequently, the M88-2 incorporates advanced technologies such as integrally-bladed compressor disks, called '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, and its non-polluting, smoke-free emissions make the aircraft more difficult to detect visually than older designs.

The M88-2 powerplant is rated at 10,971 lb dry and 16,620 lb with afterburner. It is equipped with a fully-redundant Snecma FADEC (Full Authority Digital Engine Control) which allows it to accelerate from idle to full afterburner in less than three seconds. Thanks to the FADEC, the M88-2 engines give the Rafale stunning performance: carefree engine handling allows the throttle to be slammed from combat power to idle and back to combat power again anywhere in the flight envelope. The compressor utilises a three stage low pressure fan, and a six stage high pressure compressor. Peak engine temperature is 1,850 K (1,577 °C) with a pressure ratio of 24.5:1, and, at maximum dry power, specific fuel consumption is in the order of 0.8 kg/daN.h, increasing to 1.7 kg/daN.h with afterburner.

Modular engine

Reducing the costs of ownership and improving performance have always been obvious targets for Snecma and the M88 has been designed to achieve the optimum combination of operational readiness and reliability. To facilitate rapid repair and maintenance in harsh conditions and minimise spares holdings, the engine is divided into 21 modules, interchangeable without a need for balancing and re-calibration. Some of these modules can even be changed without taking the engine out of the Rafale airframe, and a M88 can be removed and replaced in under an hour. Even more significant is the fact that, after maintenance, there is no need to check the turbofan in a test bench before it is installed back on the aircraft. The M88 is the only engine of its kind that can be returned to service after changing modules without requiring a new ground acceptance test – all what it needs is a simple leak test. As a direct consequence, the French Air Force has decided not to procure any dedicated test bench for the M88. Since entering service, the M88-2 has undergone a number of improvements and M88-2 Stage 4 engines are currently being delivered.

M88 ECO and TCO technology programs

The M88 was designed as a totally modular engine with a lot of built-in growth potential. In the last couple of years, Snecma has been extremely active, testing new hardware to increase engine life, reduce costs and demonstrate that higher thrust levels could be achieved.
From 2003 to 2007, during the M88 ECO programme, Snecma engineers tested new technologies to demonstrate that they could increase even further the life of some components to diminish operating costs. In all, more than 4,000 Total Accumulated Cycles (TACs) were logged by the test engine during endurance trials. The engine was also rated up to 20,000 pounds of thrust to demonstrate that this level of power could be achieved with a limited amount of modifications.
Launched in 2008, the M88 TCO (Total Cost of Ownership) programme was initiated to further improve engine durability and bring support costs down. Capitalising on the ECO project, Snecma was able to upgrade the high-pressure compressor and the high-pressure turbine of the M88-2: cooling is ameliorated and stronger components have been introduced, boosting durability by up to 50%. Life expectancy between overhaul has been considerably expanded for a number of modules, helping further minimise the impact of planned maintenance on engine availability. The First Engine To Test (FETT) ran for the first time in September 2009 and the first TCO pack for M88 engines will be delivered to the French Armed Forces in 2011.

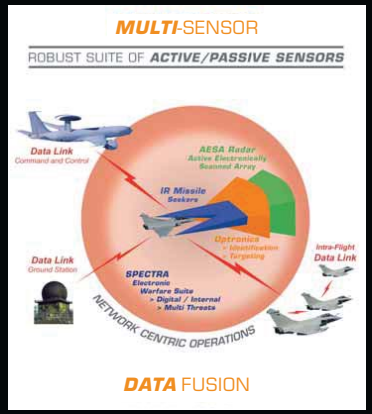
Uprated engine

For Air Arms requiring more power for enhanced combat agility and improved performance in very hot weather, Snecma is considering the development of a variant of the M88 which will be rated at 20,000 lb with afterburner. The staged approach has had a very good impact on commonality between variants: *"since the M88 programme was launched, one of our objectives was to regularly introduce new technologies that could reduce the engine's operating costs, increase its dispatch reliability and increase its thrust,* explains Michel Caunes. *The successive M88 ECO and TCO technology programs allow us to progressively reduce risks and limit associated costs. We have managed to retain a very high degree of commonality between the M88-2 TCO and the uprated engine. Compared with the M88-2 TCO, the uprated turbofan will require less than 20% new parts, including a redesigned low-pressure compressor for a higher airflow. In fact, we will have to alter only two of the 21 modules. This is quite an achievement which will enable us to keep costs within acceptable limits. The M88-2 and the new engine will remain fully interchangeable, but the introduction of the new type will impose the adoption of slightly enlarged air-intakes to allow for the higher airflow."*
With the new uprated engine, the Rafale omnirole fighter will prove even more competitive in terms of thrust-to-weight ratio at combat weight. The fighter will be able to take off at maximum weight in a very short distance, even in the most demanding weather conditions, at high altitude, in the heat of the desert. Climb rate, acceleration, sustained turn rate will all be massively improved, bringing the Rafale's combat effectiveness to unprecedented levels.

NOWHERE TO HIDE

For the Rafale omnirole fighter, Thales has provided the most advanced sensors and integrated avionics suite ever designed for a combat aircraft. It comprises the RBE2 electronic scanning radar, the Front Sector Optronics, the Spectra electronic warfare suite, the Damocles targeting pod and the AREOS[1] reconnaissance system, all supplied by Thales.

All the Rafale's sensors are closely integrated and all data is automatically fused to massively reduce pilot workload and significantly increase tactical effectiveness. *"Our goal was to avoid saturating the pilot,* explains Jean-Noël Stock, Thales Rafale Programme Director. *This smart data fusion significantly increases mission success rates through enhanced crew awareness and improved aircraft survivability. This is a crucial advantage over our competitors."*



AESA[2]

From the outset, the French Armed Forces have adopted an innovative electronic scanning radar for the Rafale fighter. Electronic scanning radars have numerous advantages over legacy mechanically steered types: they scan the sky much more quickly, they allow targets to be tracked outside the selected search volume and their radar modes can be interleaved.

The first Rafales were all fitted with a passive antenna and Thales and the French Military are now switching to active electronic scanning array technology. *"In the late nineties, we thought there were some risks involved going straight to the AESA and this is why we chose the PESA[3] for the first Rafale standards,* stresses Jean-Noël Stock. *The active array is made up of solid-state GaAs transmit/receive modules which can steer and reposition the radar beam at very high speed in any direction. The new radar variant also incorporates a new data processing unit and a strengthened structure to cope with the higher weight of the AESA. In terms of performance, detection range is increased by considerably more than 50% and the radar can look in many directions at the same time, offering significantly enhanced tracking capabilities. Angular coverage in azimuth is improved and very small targets with lower radar cross section such as cruise missiles could also be detected. Furthermore, AESA radars are inherently more reliable and cheaper to maintain."*

The AESA demonstrator first flew in 2002 and, since then, hundreds of flight hours have been logged to support the development effort. On top of that, the AESA has been successfully evaluated by a number of potential customers. A European production line for T/R modules has been set up and, at the time of writing, six development AESAs had been delivered and three pre-series AESAs were in production, with first deliveries to Dassault Aviation planned for 2011.

Passive interception

The Rafale is the only fighter equipped with an integrated system optimised for target identification and battle damage assessment at stand-off distances. The Front Sector Optronics is composed of a powerful TV sensor to identify targets and to determine the number of hostile aircraft within an incoming raid, and of an eyesafe laser rangefinder for telemetry. When used in conjunction with the long range Mica IR missile, the FSO allows entirely passive interceptions to be carried out without radar emissions. In the air-to-ground mode, the FSO is used to accurately determine target coordinates before attacking with precision weapons such as the AASM (Air-to-Surface Modular Armament) or LGBs (Laser Guided Bombs). A new generation infrared sensor for passive search and track of airborne targets and for night identification could be integrated into the FSO at a later stage. Such an infrared sensor operating in the 8 to 12 µm band has been fielded in the French Air Force F2 Standard Rafales, and an updated variant working in the 3 to 5 µm band is being studied for the future growth of the FSO. The FSO has been in service since 2005 and is now combat proven.






SPECTRA

The Spectra[4] multi-spectral, totally integrated electronic warfare suite is designed to ensure efficient electromagnetic detection, laser warning, missile approach warning using passive IR detection technology, jamming and chaff/flare dispensing. Three-dimension direction-finding accuracy is excellent, and the time taken for signal identification is extremely short. Its very high processing power gives outstanding detection and omni-directional jamming performance through active antennas, optimising the response to match the threat, even in a multi-threat environment. The location and types of systems detected by Spectra can be recorded for later analysis, giving Rafale operators a substantial built-in ELINT capability.

AREOS

For both strategic and tactical reconnaissance missions, the French Armed Forces have adopted the Thales System Reco NG (new generation tactical reconnaissance system) for the Rafale. *"This high-tech, day and night equipment can be used in a wide range of scenarios, from stand-off distances at very high altitude down to very high speed and extremely low-level,* enthuses Jean-Noël Stock. *To shorten the intelligence gathering cycle and accelerate the tempo of operation, the pod is fitted with a datalink which allows high resolution images to be transmitted back to the military deciders in real time."* Since July 2009, the System Reco NG has been undergoing qualification testing / operational evaluation at Mont-de-Marsan Air Base, with entry into service planned for early 2010. This very advanced system is now offered on the export market under the AREOS designation.

Damocles

In modern warfare, the ability to detect, localise, identify and engage ground targets at stand-off distances is a real necessity. This is why the Rafale is now being fitted with the Thales Damocles targeting pod. The new infrared (3rd generation staring array detector) and laser technologies chosen for the Damocles provide extended detection and recognition ranges, permitting laser-guided armament to be delivered at substantially greater ranges from higher altitudes, considerably reducing the aircraft's vulnerability to short/medium-range air-defence systems.
In mid-2009, the French MoD issued a contract for the Mastrid (Multi-context Airborne System for Target Recognition and IDentification) demonstrator to ensure that new capabilities will be available for the Damocles XF (eXtended Features) from 2012. With the Mastrid project, a new high-definition TV sensor optimised for short-range engagement and a new software to boost the resolution of the IR sensor will be developed and test flown.

With such a large suite of advanced sensors and a direct access to datalink networks, the Rafale is a key contributor to the common tactical air picture. The ongoing improvements to its sensor suite will further increase the combat effectiveness of an already revolutionary aircraft

[1] AREOS: Airborne REconnaissance and Observation System
[2] AESA: Active Electronically Scanned Array Radar
[3] PESA: Passive Electronically Scanned Array Radar
[4] SPECTRA: Self-Protection Equipment Countering Threats of Rafale Aircraft

GLOBAL **REACH**

With its outstanding endurance, its in-flight refuelling capability and its very long-range stand-off weapons, the Rafale omnirole fighter is extremely well equipped to strike distant, well-defended, deeply buried hardened targets.

The Rafale has been designed as a very compact, high-tech fighter capable of carrying a huge external load of fuel tanks and missiles. In fact, it can carry more than 15,000 kg of kerosene and weapons, quite an accomplishmentor an aircraft weighing less than 10 tonnes empty.

Scalp

For long-range attacks of high-value, heavily defended targets, the French Armed Forces have selected the Scalp cruise missile of the MBDA Scalp / Apache / Storm Shadow / Black Shaheen family. The Rafale's normal combat load is composed of two Scalps, four Mica air-to-air missiles and three 2,000-litre drop tanks. The Scalp can be released at very low level, with the Rafale flying in terrain-following mode to avoid detection. With its fuel-efficient Microturbo engine, this 'intelligent', stealth weapon can navigate autonomously at high subsonic speed towards the target which will be clearly identified by its onboard infrared sensor: automatic target recognition algorithms compare the actual scene with the memorised scene, identify the designated target, and accurately select the impact point in order to hit with very high precision. To maximise its military effect, the Scalp is fitted with a remarkably powerful Broach tandem warhead which can defeat heavily protected bunkers.

Buddy-buddy tankers

With their 4,700 kg of internal fuel, single-seat Rafales boast an impressive range which can be massively extended by up to five external drop tanks (three 2,000-litre and two 1,250-litre fuel tanks) under five wet hardpoints, four under the wings and one under the fuselage. Range can be further increased thanks to air-to-air refuelling and the Rafale can refuel from a wide range of tankers: A330 MRTT, Boeing 707, Il-78 Midas, KC-135, KC-130, VC-10... It can also be fitted with a buddy-buddy refuelling pod under the centreline pylon, and French Navy Rafales routinely refill the tanks of other Rafales and

of Super Etendard fighters, extending their reach from the *Charles de Gaulle* carrier. Buddy-buddy tankers could also prove really useful in a high threat environment, their six Mica air-to-air missiles giving them considerable firepower for self-defence (and even to escort a strike package).

Combat-proven AASM

For simultaneous attacks of multiple targets, the Rafale can ripple fire up to six AASM (Armement Air-Sol Modulaire, Modular, Air-to-Surface Armament) stand-off precision weapons in one pass to strike six different impact points with clinical precision. Designed by Sagem, the AASM is composed of a GPS / INS / IR imager guidance kit at the front, a bomb body (general purpose or penetration) in the centre, and a rocket motor at the rear. The extremely advanced AASM can be released from very high or very low levels, and its powerful controls allow it to manoeuvre aggressively to engage distant, off-boresight targets. Up to six AASMs can be carried by a single Rafale, plus four Mica air-to-air missiles and three 2,000-litre drop tanks.

Météor

For air-defence / air-superiority missions, the Rafale is already equipped with the outstanding Mica air-to-air missile capable of performing both short-range dogfight combats and long-range interceptions. For engagements at even longer distances, the Rafale will soon be armed with the MBDA Meteor air-to-air missile. The new, ramjet-propelled Meteor will offer a no-escape zone several times greater than that of today's missiles. This extremely fast missile - Mach 4+ - is designed to retain sufficient energy at end game to defeat hard manoeuvring targets. When fitted to the Rafale, the new Meteor missile will create a formidable combination of weapon/sensor/airframe. The French Ministry of Defence has recently reaffirmed its support to the programme, and it has been officially announced that a first batch of 200 Meteors will be ordered for the Rafale as part of 2010 defence procurement budget.

On top of the Scalp, the AASM, the Mica IR/RF, the Meteor and its internal 30 mm gun, the Rafale is cleared to carry the AM39 Exocet antiship missile and the GBU-12/22/24 laser guided bombs, and the French Armed Forces are seriously considering the adoption of rockets in the near future. With such a wide range of weapons, the Rafale has now become the most powerful strike fighter ever designed, a tool that will deter aggression.

RAFALE KICKS THE DOOR DOWN

The Rafale has proved, in action, that it is the best all-round fighter in service anywhere. Operating from air bases in Corsica and Sicily and from the *Charles de Gaulle* nuclear-powered aircraft-carrier, the omnirole fighter has managed to bring down enemy air-defences and, more importantly, protect civilian populations.

On 19 March 2011, French Air Force Rafales carried out the very first strike missions against forces loyal to Libyan Leader Colonel Gaddafi. With tanker support, the fighters flew extremely long-range sorties from their base in Saint-Dizier, in the North-East of France. The daring, seven to eight hour-long raids against heavily defended targets were entirely successful: the Rafales quickly achieved uncontested air-supremacy and used their Armements Air-Sol Modulaires (AASMs, or Air-to-Surface Modular Armaments, also known as SBU-38 Hammer under the new NATO designation) to bring down air defences and destroy units that posed a direct and immediate threat to the besieged city of Bengazi and to civilian lives. Simultaneously, other Armée de l'Air Rafales flew the first reconnaissance missions to start gathering up-to-date intelligence with the Pod Reco NG (New Generation Reconnaissance Pod, also known on the export market as AREOS, for Airborne REconnaissance Observation System). They undertook reconnaissance missions over points of interest, using their pod to photograph numerous tactical and strategic targets at stand-off distances.

Destroying enemy air-defences

Such was the confidence of the French aircrews in their new mount that all missions were conducted without any support from dedicated electronic warfare and SEAD (Suppression of Enemy Air Defences) assets: thanks to its Spectra state-of-the-art electronic warfare/self-defence suite, the Rafale was able to operate at operating base on the island of Corsica. The Rafale's low logistical footprint was a decisive advantage for the move from Saint-Dizier to Solenzara, the large number of Transall and Hercules airlifters being mainly needed to transport the huge amount of ammunition required for the combat operations. For air-to-ground missions, the Rafales are equipped with either four to six GBU-12 Paveway 2 laser-guided bombs or four to six AASM precision weapons, plus a full load of flares and chaffs and of MICA (Missile d'Interception, de Combat et d'Autodéfense, Interception, Combat and Self-Defence Missile) air-to-air missiles. The GBU-12 is mainly used for 'dynamic targeting', a kind of close air support, but without any forward air controller on the ground. The AASM has so far mostly been fired against high-value and well-defended military targets, such as ammunition dumps, air-defence systems and hardened shelters. Operation Harmattan is the first time the Rafale has used the Damoclès laser designation pod 'in anger'. The pod is indifferently fitted to aircraft armed with the GBU-12 or the AASM and is used for target identification at long distances, for the guidance of GBU-12s or to determine the precise coordinates of a target before engaging it with an AASM. The Damoclès is a valuable addition to the Front Sector Optronics, an internal system mounted above the nose of the Rafale. The FSO is composed of a powerful TV sensor, a laser rangefinder and an infrared search and track system. ■

will in a dangerous environment, against a dense network of deadly surface-to-air missile systems. Even more significant is the fact that the Rafale was able to accurately locate enemy air-defence systems and engage them.

As early as 20 March 2011, Armée de l'Air Rafales started operating from Solenzara, a forward

Enter the Navy

The Rafale was designed from the start to operate from the pitching deck of an aircraft-carrier and, from 23 March 2011, French Navy Rafales flying out of the *Charles de Gaulle* joined the fight. For over four months, French Navy Flottille 12F Rafale aircrews performed the whole spectrum of conventional offensive combat operations from the carrier (except anti-ship attacks with Exocet missiles, even though surface combatants were destroyed by Rafales in Libyan harbours using laser-guided bombs).

From the Gulf of Sirte, the *Charles de Gaulle* launched waves after waves of fighters which dropped hundreds of precision weapons (GBU-12s, AASMs and Scalps) against a wide variety of targets. Flottille 12F Rafales mainly operated in three types of configurations: reconnaissance, attack and buddy-buddy tanker. Although the air-threat was considered very low and the surface-to-air threat had been significantly reduced by air strikes, the Navy Rafales usually flew with a full load of flares and chaffs and of MICA air-to-air missiles on top of their air-to-surface weapons or of their recce pod. For air-to-ground missions, they usually carried four GBU-12 laser-guided bombs or four AASM precision weapons, these loads being increased to six weapons when required. About half of all missions conducted by Navy Rafales were flown at night.

Scalp attack

Although all numbers were still classified at the time of writing, it can already be revealed that Navy and Air Force Rafales have destroyed hundreds of targets, ranging from armoured personal carriers to main battle tanks, from artillery positions to long-range missiles, from parked aircraft to air-defence radars, from hardened ammunition storage facilities to deeply buried command posts…

Among the Rafale's weapons, the Scalp stealth cruise missile was singled out for long-range strike missions against hardened targets very deep inside Libyan territory. Strikes were conducted by a combination of French Navy Rafales and Armée de l'Air Rafales and Mirage 2000Ds. It is understood that the first target for the Scalps was a heavily-defended high-value target deep inside Libya, where a strike with close range weapons would have proved unnecessarily dangerous.

Extreme range

A key advantage of the Rafale compared to the other French and foreign fighters is its very long range. *«French Air Force Rafales initially flew with two 2,000-litre external fuel tanks under the wings on top of their MICA air-to-air missiles and of their air-to-surface ordnance,* reveals the Armée de l'Air Rafale detachment commander. *When the availability of tankers became an issue, a third 2,000-litre drop tank was added to the Rafale based in Solenzara, thus helping minimise the pressure on the Allied tanker force.»* The Rafale then carried 6,000 litres of external fuel on top of the 4,700 kg of internal fuel for the single-seat Rafale C, and 4,400 kg for the two-seat Rafale B, giving an outstanding range and an extended time on station.

Endurance was a crucial parameter for Rafales operating from the *Charles de Gaulle* too: *«we typically flew missions lasting over two hours without tanker support,* stresses the Commanding Officer of French Navy Flottille 12F. *With tanker support, either from a Rafale configured for buddy-buddy tanking, a C-135FR, a KC-135R or from any other coalition tanker, we flew 4-hour long sorties with two refuellings. Our 'playtime' was excellent, with relatively short transits to and from Libya. In fact, out of 4 hours airborne, we remained 2 h 20 min on station, ready to strike any target of opportunity.»* Usually, two of the ten Rafales onboard the carrier were configured as buddy-buddy tankers, each with an in-flight refuelling pod under the centreline pylon and two to four drop tanks under the wings. One of them was systematically launched prior to any recovery cycle, ready to give away fuel to any fighter which might have encountered difficulties when attempting to trap back onboard the carrier. Another one was ready to be catapulted away, should the situation have got worse. ■

Datalink

The Rafale is the first French fighter equipped with the L16 datalink which is fully integrated into the fighter's weapon system. Through the L16, pilots share surveillance and targeting data, and give and receive orders. *«To boost flight safety, we use our L16 for deconfliction, without speaking on the radio,* explains the Armée de l'Air Rafale detachment commander. *We are assigned block levels by the NATO Air Tasking Order and, by just looking at a screen, we know what the flow looks like. The Rafale's man-machine interface has been cleverly designed. For example, there are some modes that declutter the displays, allowing the pilot to concentrate on the target. You prioritise things: tasks, Desired Mean Points of Impact, air targets… If the AWACS decides that there is something more important happening, the system will just show it to you. Pretty neat… Nearly everything can be done without any radio coms. The Rafale has got a very silent cockpit and I like silence in my cockpit during combat missions. I tend to have Damoclès imagery on the right lateral display, with a fuel page on the left display and the tactical situation on the centre screen. If needed, Damoclès imagery can be expanded on the head-level display for better quality.»*

The Rafale's participation in the NATO operation is an uncontested success. It has confirmed, in action, that all the choices made a few years ago by French Air Force and Navy decision makers were the right ones. The fully omnirole fighter once envisioned has now come of age and is fully operational, as demonstrated by the current operations in Libya. ■

Outstanding reliability

At the time of writing, French Rafales had logged over 6,000 combat flying hours in close to 2,000 sorties in support of the Harmattan operation with outstanding reliability. Flying out from forward operating bases, Solenzara, on the island of Corsica, and Sigonella, in Sicily, and from the *Charles de Gaulle* carrier, the omnirole fighter has demonstrated, in action, that the maintenance and support concept designed by Dassault Aviation fully fulfils the stringent requirements decided by the French Armed Forces when the programme was launched. The Rafale's inherent reliability and its ease of maintenance have significantly contributed to a very high dispatch rate that has helped bring down operational costs while maximising military efficiency.

Recce

Very early into the mission, the Armée de l'Air started using the AREOS pod for pre-strike reconnaissance, battle damage assessment and video reconnaissance. The French Navy soon started doing recce missions too, from the *Charles de Gaulle*, and Air Force and Navy Rafales then became one of the main providers of airborne imagery for the whole coalition. *«We broadcast all the recorded imagery on the way back to base,* explains the Armée de l'Air Rafale detachment commander at Solenzara Air Base. *We have also transmitted French Air Force AREOS imagery to the* Charles de Gaulle *while on our way back to base so that all data can be processed more quickly to shorten the OODA (Observation Orientation, Decision, Action) loop. The system is highly flexible, with remarkably sharp images. We have mainly used the AREOS in high level mission profiles, but we could also have chosen low-level high-speed runs, with a 'pop up' to take imagery.»* ■

Air superiority

On the first few days of the Allied air operations, Rafales in air-to-air configurations flew Offensive Counter Air (OCA) missions to achieve air-superiority over Libya, preventing Libyan loyalist fighters from taking off from their own bases. They also escorted strike fighters and were ready to protect them against any airborne threat.

Rafales flying their recce or strike missions over Libya remain fully capable of providing air-to-air support with their MICA missiles. On several occasions, they have been re-tasked in flight to investigate and identify air targets detected in the vicinity of their working areas. The air-to-air threat is assessed by NATO as very low or negligible, but Rafale pilots could still have found themselves engaged against a last ditch attempt to regain air supremacy. *«Rafale strike and recce missions are always conducted without any dedicated escort, our RBE2 radar, our Link 16, our FSO and our Spectra electronic warfare suite helping us maintain a very good all-round situational awareness,* explains the Armée de l'Air Rafale detachment commander. *Nevertheless, we stand ready to strike back and engage enemy fighters at all times. If intercepted, we could have destroyed any airborne threat with our MICAs during the very same missions.»*

RAFALE TACTICAL NODE AND ISTAR TOOL

The conflict in Libya has clearly demonstrated that the Rafale, with its state-of-the-art sensor suite, has become a key tool for ISTAR (Intelligence, Surveillance, Target Acquisition and Reconnaissance) missions.

Without any forces on the ground to provide them with up-to-date intelligence, NATO commanders have to rely on airborne assets to build up an unambiguous tactical picture. Ongoing operations have shown that, thanks to an unmatched combination of powerful sensors, Link 16 datalink and intuitive man-machine interface, the Rafale is a decisive airborne asset in the ISTAR role and key provider of vital intelligence.

Comprehensive sensor suite

French Air Force and French Navy Rafales fly over Libya with a fully operational sensor suite that includes the RBE2 electronic scanning radar, the Spectra internal electronic warfare suite, the Front Sector Optronics, the Pod Reco NG (New Generation Reconnaissance Pod, also known on the export market as AREOS, for Airborne REconnaissance Observation System), and the Damoclès laser designation pod. Among all the allied aircraft engaged over Libya on a daily basis, the Rafale is the only one to boast such a large array of internal and external sensors. As a result, the pilots have at their disposal all the systems required to detect and locate hostile activity. For instance, they can use their radar high-resolution mode to look at an area of interest from extreme distances before cueing their Damoclès pod to precisely identify a target and find its coordinates. Alternatively, the radar high-resolution mode can be utilised to keep a sharp eye on enemy activity through a thick cloud layer.
With its Link 16 datalink, the Rafale omnirole fighter readily plugs into the complex NATO command and control networks. All collected intelligence is easily transmitted back to the C² assets, the Rafale thus becoming a node within a much larger C² structure. *"With the Rafale, we are part of the network centric warfare loop and we can easily engage time sensitive targets,* explains the Armée de l'Air Rafale detachment commander at Solenzara Air Base. *The Rafale has become a gathering platform for information and we are continuously fed with data. We also scatter information to our wingmen and to other assets."*
It should be noted here that the Rover system, fully operational on the Rafale, has not been utilised in Libya due to lack of forward air controller on the ground.

Sharp-eyed Rafale

Reconnaissance is one of the Rafale's main missions. With the advent of the AREOS, which entered service in late 2010, the French Navy and Air Force are equipped with one of the best recce systems in the world. Thanks to the AREOS's powerful dual band infrared/visible sensor mounted in a swiveling turret at the front end of the pod, the Rafale can remain outside the range of enemy air defences while taking incredibly sharp pictures from stand-off distances, day and night. Similarly impressive is the capability to transmit back in real time all imagery taken during the mission via a broadband datalink system that offers a 360-degree coverage. The highly directive data beam would prove very difficult to intercept, and all data can be encrypted for additional security. *"The AREOS is a superb system for both day and night operations, and the High Command is extremely happy with all the imagery we provide,* explains French Navy Flottille 12F Commanding Officer. *Onboard the* Charles de Gaulle *aircraft-carrier, naval photo interpreters process all data which is sent back to the French and Allied headquarters in near real-time. Everything is done to cut down the time required to process the information in order to shorten the intelligence gathering cycle and accelerate the tempo of operation, and the AREOS, with its high-speed datalink, is a key enabler. The new reconnaissance mode of the Damoclès pod has also proved tremendously useful, helping us gather imagery during a larger number of sorties."* ■

Ease of use

Like all the Rafale systems, the AREOS has been optimised to reduce aircrew workload: *"reconnaissance missions are conducted day or night by two aircraft equipped with one AREOS pod, four MICA air-to-air missiles and two 2,000-litre drop tanks, and dozens of targets are photographed in the course of the flight,* reveals the Flottille 12F Commanding Officer. *The pod is highly automated and our state-of-the-art mission planning tools allow us to precisely program the system prior to the flight. During the sortie, all is done to minimize the pilot's workload and the pod automatically points its main sensors at areas of interest. As a consequence, we can cover huge areas in a very limited amount of time while concentrating on the tactical situation and on the surface-to-air and air-to-air threats. We also have at our disposal a user-friendly target of opportunity mode that proves ideal in some circumstances. The pod is equipped with large data recording systems and we have never experienced any capacity issues, even when the AREOS is 'on' during the whole sortie."*

Neither the Air Force nor the Navy would give any precise details on the tactics being used but we can ascertain that the main advantage of flying as a two-ship is that each aircraft can photograph the same target from different angles or directions and/or from different altitudes. Alternatively, the route of the aircraft can be adjusted so that each fighter within the patrol will photograph widely separated targets on each side. ■

Dynamic targeting

The Damoclès laser designation pod has also proved highly successful over Libya. The ongoing NATO operation is the first time the pod has been used in anger against real targets by Rafale aircrews. The pod provides the Rafale with extremely valuable ISTAR capabilities, especially for dynamic targeting, i.e. the engagement of moving forces without any guidance from a Forward Air Controller. *"The lack of FACs on the ground has forced us to use new tactics and we rely on our onboard sensors to locate and positively identify our target,* says Commanding Officer of Flottille 12F. *This is why the Damoclès proved essential to sort out targets and accurately determine their coordinates. We also have excellent all weather capabilities and we use our radar high-resolution mode to find and designate targets, even in the worst conditions, when the wind is blowing sand for instance. The Damoclès arrived at a crucial moment, and we can now autonomously 'spike' without resorting to buddy-lasing. The Damoclès now incorporates a number of ameliorations which have benefited both the Super Etendard Modernisé and the Rafale communities: laser pointer, laser spot tracker and recce mode. The Damoclès is optimised for the air-to-surface role and the FSO for the air-to-air mission: we constantly switch from one to the other depending on the conditions, day, night, sand storm… In very bad weather, when we can't see the ground at all, we can still 'paint' radar images of the target areas thanks to the RBE2 high-resolution mode."* ■

DESTROYING ENEMY AIR DEFENCES

For the French Armed Forces, the operation in Libya offered a unique opportunity to improve new tactics and to prove in action that the Rafale omnirole fighter could perform an extremely wide range of missions, including the Destruction of Enemy Air Defences, which eventually led to the collapse of the Libyan Air Force air-defence network.

Inherent flexibility

With its intuitive and easy to use man-machine interface and its wide array of systems and weapons, the Rafale can perform an incredibly large number of missions. «*The Rafale's sensor and armament suite has proved extremely effective and remarkably flexible,* explains the Commanding Officer of French Navy Flottille 12F. *I will take one example: the Rafale's weapon system has not been specifically designed for the DEAD role, the Destruction of Enemy Air Defences. With all our sensors - the radar high-resolution mode, the Spectra suite and the Damoclès and Front Sector Optronics systems - we were, however, fully capable of detecting, localising and engaging enemy surface-to-air missile sites and we destroyed SA-3 and SA-6 SAM systems with our AASMs, including some mobile, time sensitive systems. This was a significant achievement. I would like to insist on the fact that Flottille 12F is one of the very few units in the world which can carry out such a large array of missions from a carrier deck, from reconnaissance to nuclear deterrence, from DEAD to anti-ship attacks, from close air support to air-defence.*»

Jamming the enemy

Such is the quality of the Spectra electronic warfare suite that the Rafale literally disappeared from the radar screens of the Libyan Air Force while performing 'soft kills' on the enemy radar systems. Spectra relies on advanced jamming modes and jamming techniques to defeat hostile weapon systems and to hide the progression and whereabouts of the fighter. With its state-of-the-art antennas and sub-systems using the latest technology, Spectra is also incredibly precise, with an amazing angular accuracy. This proves essential to accurately locate a threat and significantly enhance aircrew situational awareness. Rafale pilots and weapon system operators can also rely on fine-tuned data-fusion to 'rise above the fog of war', all electronic warfare data being fused with radar, L16 and Front Sector Optronics information to produce a single, unambiguous tactical picture. Finally, the Rafales always fly with a full-up load of decoys, chaffs and flares, and are thus ready to instantly react should they be engaged by a Libyan surface-to-air system. ■

Stand-off accuracy

The Armement Air-Sol Modulaire (AASM, or Modular Air-to-Surface Armament), also known as the SBU-38 Hammer (standing for Highly agile and manoeuvrable munition extended range), has proved to be one of the most effective stand-off precision weapons in service anywhere.

Thanks to the advanced technologies chosen by Sagem during the development programme, the AASM offers a large number of operational advantages over more traditional precision weapons. The AASM's main advantage is its range, and targets have been struck in Libya at distances more than 50 km away from the release point. The second advantage is the multiple target release mode, when up to six widely separated DMPIs (Desired Mean Points of Impact) can be hit with deadly accuracy in one run. The third advantage is the weapon's ability to strike a target at a precise angle (from the horizontal to the vertical) to achieve the largest amount of destruction for the largest military effect or, on the contrary, to minimise the risk of collateral damages. The AASM's final advantage is its modularity, with numerous warheads available. For example, the Armée de l'Air relies on standard Mk 82 bomb bodies whereas the French Navy fielded insensitive BANG-series (Bombe Aéronavale Nouvelle Génération, or new generation naval aviation bomb) warheads as prescribed for use on the French aircraft-carrier. In the future, heavier and lighter bomb bodies could be adopted for the AASM.

Hammering the enemy

The AASM has been used by the Rafale throughout the campaign, the weapon proving totally successful in a large number of scenarios, including strikes against highly defended targets such as air-bases. In fact, such was the accuracy of the new munition that the AASM is now considered as the Rafale's main offensive weapon for conventional strikes and DEAD missions. *«During the conflict, we flew air-to-surface missions with AASMs to bring down the Libyan air-defence / command and control network,* reveals the Armée de l'Air Rafale detachment commander at Solenzara Air Base. *The obvious advantage of the weapon is that we can hit six distant or widely separated targets with only one trigger press. This means that a Rafale two-ship can destroy twelve targets in one pass, at stand-off ranges. This is a really impressive fire power that clearly minimises the required number of sorties to disable a given target. Later in the campaign, we opted to have one aircraft of a two-ship fitted with AASMs while the second one carried up to six laser-guided GBU-12s, giving enhanced tactical flexibility. The AASM is user-friendly and targets coordinates can be fed into the weapons in three different ways: manually, from the Damoclès targeting pod, or from data sent from the AWACS via datalink.»*

GPS/INS and IR versions

The GPS/INS-guided variant of the AASM bore the brunt of the French Air Force and French Navy effort and was fired in massive numbers. The infrared variant of the AASM (known as the SBU-64) has also been utilised operationally by both Navy and Air Force Rafales, scoring hits with clinical surgery too. This variant is fitted, in addition to the INS/GPS guidance kit, with an advanced passive infrared IR imagery homing head that is activated during the final target approach. Automatic target recognition algorithms compare the actual scene with the memorised scene, identify the designated target, and select the impact point in order to hit with outstanding precision. The AASM IR has proved essential in some demanding conditions. For instance, the weapon was fired at military buildings that required hits with extreme accuracy to obtain a significant military effect. A laser-guided variant of the AASM is planned to enter service in 2013, thus bringing another useful capability to the Rafale.

Editorial

In the 16th issue of Fox Three,

The Rafale Team is proud to explain how the Rafale is being extensively modernised to defeat all future surface, naval and airborne threats. With the successive introduction of the Active Electronically Scanned Array for the RBE2 radar, of the Meteor ramjet-propelled missile, of the new generation missile detector, of the acclaimed AM39 Exocet anti-ship missile and of new variants of the battle-proven AASM air-to-surface modular armament, the omnirole fighter will become even more efficient, lethal, survivable, reliable and maintainable. With such a powerful offensive and defensive tool, decisions makers will have at their disposal the required asset to handle all crises: in an ever changing world, the Rafale will stand ready to instantly react to a new geopolitical situation and to prevail on the battlefield.

The 'FOX THREE' Team

Summary

p.3/7


ENTER THE AESA AND THE METEOR

p.8/11


EXPANDING THE AASM FAMILY

PEMA ZM - Photos : DASSAULT AVIATION - V. Almansa / MBDA - Th.Wurtz / DGA / SIRPA AIR / SAGEM – Ph.Wodka-Gallien / THALES - This document is not contractual and cannot engage the responsability of the industrial partners in any matter. Dassault Aviation and the industrial partners reserve the right to modify any herein indicated characteristics without prior notice.

ENTER THE AESA AND THE METEOR

The AESA (Active Electronically Scanned Array) for the RBE2 electronic scanning radar is in final stages of trials.

Extended detection and tracking ranges, enlarged angular coverage, improved resistance to jamming, considerably ameliorated reliability. These are the main advantages offered to the Rafale by the new AESA now being tested by the Direction Générale de l'Armement (DGA), the French Defence Procurement Agency. *«The DGA is taking an active role in the development and qualification of the new front end antenna supplied by Thales,* explains General Stéphane Reb, the DGA Rafale Programme Director. *Under the latest plans, qualification of the new radar is expected by the DGA in early 2013 as part of a rolling programme of continuous improvements for the Rafale. We work in close loop with the armed forces and the contractor to minimise risks and keep costs down and we ensure that all sensors reach maturity levels before they enter service. The adoption of a very reactive loop is, in my view, the best way to keep the Rafale updated.»* ■

Performance confirmed

A major milestone was passed in 2011 when an AESA performance evaluation test campaign was conducted by the DGA at Cazaux Air Base using Mirage 2000 and Falcon 20 flying test benches. The new radar was pitted against a range of lightly instrumented and fully characterised targets (in terms of radar cross section) to make sure that performance levels matched predictions. In all, 25 flights totalising around 140 test runs were performed by DGA engineers and flight test specialists. The results have shown that detection and tracking ranges in air-to-air modes exceeded expectations. This means that Rafale aircrews' situational awareness will be brought up to unprecedented levels using the radar alone. The AESA, when utilised in conjunction with the Rafale's Front Sector Optronics, Spectra electronic warfare/self-defence suite and L16 datalink, will transform the fighter into a lethal opponent in the unforgiving air-to-air arena.

Air-to-surface radar modes have also been checked to make sure that the Rafale will remain a deadly performer when attacking surface targets or when hugging the ground at very high speed. For instance, the terrain-following modes of the AESA have also been thoroughly tested in various conditions, over a wide range of backgrounds, when overflying flat terrain, mountains or industrial buildings, and when facing vertical cliffs. This mode is crucial for low-level high-speed penetrations against a dense network of surface-to-air missile systems. ■

AESA series production

Such is the confidence of Thales and Dassault in their new product, that pre-series AESA radars have already been demonstrated to potential export costumers during demanding and realistic combat scenarios. Series production of AESA systems for the Rafale omnirole fighter has begun at the various Thales plants and series AESA sets will be used for the qualification programme to be conducted by the DGA.

The first production Rafale to be delivered with the AESA will be an Air Force single-seat Rafale C which will make its maiden flight in 2012. It is anticipated that the first five Armée de l'Air aircraft with the AESA will be operational by the end of 2013. By early 2014, the first Air Force front-line squadron will start flying Rafales equipped with the new radar. In an effort to standardise the French Ministry of Defence Rafale fleet, the French Navy is also slated to receive Rafales fitted with the AESA from 2013 for service onboard the *Charles de Gaulle* nuclear aircraft-carrier.

Meteor

In the air-defence / air-superiority role, the AESA will allow Rafale aircrews to fire their new Meteor air-to-air missile at extreme ranges, further expanding the Rafale's already impressive lethality against airborne threats. Designed and produced by MBDA, the Meteor is a new generation air-to-air missile conceived to supplement the MICA (Missile d'Interception, de Combat et d'Autodéfense, or Interception, Combat and Self-Defence Missile) already in service on the Rafale.

With its advanced aerodynamic configuration, its powerful active radar seeker, its eye-watering terminal manoeuvrability, its innovative datalink and its state-of-the-art ramjet propulsion, the Meteor will be capable of defeating in a matter of seconds and at extreme ranges all known airborne threats: agile combat aircraft, stealthy cruise missiles, combat and transport helicopters, early warning and electronic warfare aircraft, tankers, unmanned airborne vehicles... The Meteor offers enhanced all-round kinematics performance and a higher kill probability to guarantee unequalled combat efficiency, even against the most modern hostile fighters.

Flight trials and integration work of the Meteor on the Rafale is in progress, and some of the flight envelope expansion has already been carried out, including carrier landings and catapult shots. In early 2011, the French Ministry of Defence announced an order for an initial batch of 200 Meteor missiles to equip both French Air Force and French Navy Rafales, with the new missile to enter operational service in 2016.

With the acclaimed Mica missiles, the Rafale is already equipped with superior weapons, but the advent of the AESA and of the Meteor will further improve the fighter's outstanding combat efficiency. ■

AM39 Exocet

The Rafale has been designed from the start to excel in all air-to-air and air-to-surface missions, including anti-ship strikes. As a result, the omnirole fighter can carry the acclaimed AM39 Exocet, an anti-ship missile that has now become the benchmark for all Navies and Naval Aviations. The integration of the AM39 Exocet anti-ship missile on the Rafale has now been completed and the aircraft's modular data processing unit can handle all the missile's firing modes. A final operational evaluation firing will be conducted from a Rafale launched from the *Charles de Gaulle* nuclear aircraft-carrier in early 2012 before the missile is declared fully operational on French Navy Rafales in mid-2012. It is worth noting that, although the French Navy will take the lead in the anti-ship role, Air Force two-seat and single-seat Rafale variants will be fully capable of firing the Exocet too.

French Navy pilots from Flottilles 11F and 12F have already begun training with the Exocet missile. New advanced tactics are being actively devised to take advantage of the Rafale's L16 datalink in the demanding anti-ship role. This means that attack profiles will be performed without any radar emission from the fighters, targeting data being provided by external means, an Atlantique 2 maritime patrol aircraft or an E-2C Hawkeye early warning aircraft for example.

DDM NG

For enhanced survival on the battlefield, the Rafale is equipped with the fully integrated and highly-automated Spectra self-defence / electronic warfare suite. It ensures efficient electromagnetic detection, laser warning, missile approach warning using passive IR detection technology, jamming and chaff/flare dispensing, even in the most demanding multi-threat environment.

As part of the Spectra performance enhancement programme, a Détecteur De Missile Nouvelle Génération (DDM NG, or New Generation Missile Detector) has been adopted. Thanks to the use of the latest infrared imagery technology, the new system will offer greatly improved field of view, detection ranges and a lower false alarm rate compared to the earlier system now flying on the Rafale (DDM) and to other technologies. With the DDM NG, the exhaust plume of an incoming missile can be detected at very long-range without any telltale emission that would betray the presence of the Rafale. The discreet missile approach warner ensures high probability of detection and low false alarm rates, even against recent and totally passive IR-guided weapons. When a missile launch is detected, the DDM NG can trigger a decoying sequence to dodge the threat. Four upward-firing launcher modules for various advanced types of flares are built into the airframe, and the Rafale is equipped with internal chaff dispensers.

Flight testing of the DDM NG is currently in progress and, in early 2011, the second environmental data gathering campaign was completed. The system overflew various scenes and backgrounds to make sure it could 'understand' its operating environment and detect simulated missile launches in this environment. ■

EXPANDING THE AASM FAMILY

Sagem is busy working on new variants of the Armement Air-Sol Modulaire (AASM, or Modular Air-to-Surface Armament), also known as the SBU-38 Hammer (standing for Highly agile and manoeuvrable munition extended range).

The AASM is regarded as the best air-to-surface precision weapon in service anywhere and was first used in anger in Afghanistan by French Rafales. This affordable, modular and highly effective weapon has been massively utilised in Libya by both French Air Force and French Navy Rafale omnirole fighters, helping destroy an extremely large array of targets with deadly accuracy.

Combat proven

Two variants are already operational and they have both been fired in Libya with a success rate very close to 100%: the first one is fitted with a GPS/INS guidance kit whereas the second one is equipped with a GPS/INS/Infrared Imaging guidance head, allowing challenging targets to be destroyed even when the GPS signal is not available, or when there is a target location error. Both are powered by a rocket motor and can be fired at distances exceeding 50 km. Their impact angle can be selected and adjusted to match the target's characteristics and ensure the highest level of destruction.

At the time of writing, the French armed forces had expressed a need for 3,400 AASMs with a 250 kg-class warhead, 800 of which had now been delivered to the French Air Force and to the French Navy.

Laser-guided variant

A new variant of the AASM, fitted with a laser/GPS/INS-guidance kit, is now being developed for use on the Rafale, with operational service entry planned for 2013 . It will outperform both the GBU-12 Paveway II and GBU-22 Paveway III thanks to its long range, its 360-degree engagement capability and its agility, allowing time-sensitive fast moving targets to be destroyed at will. Alternatively, it will still be able to strike with clinical accuracy targets the coordinates of which are known. This new variant is externally similar to the IR imaging version. Development flight and firing testing of the Laser AASM is now almost completed. In all, three test firings were performed in difficult conditions to push the munition to its limits. The first one was a basic trial during which the AASM impacted vertically. The second one was an air interdiction scenario: a building was attacked from very long range (more than 40 km away) with a delayed fuse to simulate a penetration warhead. The aim of the test was to make sure that the AASM could still hit the intended target when the laser energy levels finding their mark were low, thus mimicking the divergence of the laser spot from long distances. There again, the precision was outstanding.

Complex scenario

The third test firing was, by far, the most impressive and the most challenging as it was completed against a moving target simulating a speeding car. *«The scenario was extremely precise,* explains a DGA Flight Test Engineer at Cazaux. *A Rafale was circling a compound at medium altitude at a distance of 15 kilometres, unheard, out of view and well outside the range of anti-aircraft artillery and man-portable air-defence systems. Suddenly, a car fled from the compound and the Rafale was asked to take it out. Without leaving its orbit, the omnirole fighter fired a Laser AASM 90 degrees off-axis, with laser illumination provided by a DHY-307 laser designator on the ground simulating a deployed team of Special Forces. The calibrated target was speeding on a rail at 80 km/h. The target's albedo was known as we wanted to assess the behaviour of the seeker and check its ability to perfectly track a very fast object. The test was entirely successful and the AASM impacted within one metre of the laser spot. With such accuracy, it would have totally wrecked a real car or a real armoured vehicle.»*

In 2012, the Laser AASM will enter qualification phase and the DGA engineers and weapons specialists will perform a further three firing trials before the new variant is cleared for use by both French Air Force and French Navy Rafales.

Future developments

Sagem is looking at a variety of new developments to further expand the AASM family and augment the Rafale's operational capabilities. Among the various options being considered, both heavier and lighter versions with larger or smaller warheads and a new guidance kit for anti-ship attacks are being discussed. A firing trial with a 125-kg class bomb body has already been conducted, and a 80-km range has been demonstrated. The development of a very heavy AASM, with a 908 kg (2,000 lbs) warhead (for example a Mk 84 general purpose bomb body or a BLU-109 penetrator) could be launched very rapidly. In the not too distant future, a version with an anti-ship capability may appear: *«we are seriously considering fitting the AASM with a datalink which will allow moving targets to be engaged*, explains General (Ret) Jean-Pierre Rayssac, Sagem Director of AASM Business Development. *This datalink would prove particularly useful against ships that can move at 30 knots and change position really rapidly.»* With its adjustable attack angle, the AASM will prove ideal for the engagement of surface combatants because current naval air-defences, such as search and fire control radars, short-range surface-to-air missiles and close-in weapons systems are all optimised to primarily counter sea-skimming anti-ship missiles. They are not universally capable of defeating a vertically diving target which may take advantage of the ship's configuration and layout to hit with devastating military effects.

ROVER on Rafale

The ongoing operations in Afghanistan have clearly shown the need for a way to exchange imagery between troops on the ground and pilots flying combat aircraft. The solution was the ROVER (Remotely Operated Video Enhanced Receiver) system universally adopted by NATO air arms operating over Afghanistan and by forward air controllers.

The ROVER system is now fully operational on French Air Force and French Navy Rafales. It allows Rafale aircrews and forward air controllers on the ground to easily and swiftly exchange videos or images to confirm that the selected target is the right one before carrying out an attack. The adoption of the ROVER allows Rafale aircrews to rise above 'the fog of war'. The added advantage of the configuration chosen for the Rafale is that the ROVER terminal is not fitted to the pod, but rather to the airframe itself. This means that any type of imagery, including radar high-resolution maps and Front Sector Optronics images, can be downloaded in real time to the FAC and the local commander, thus clearly augmenting the military value of the omnirole fighter while increasing its tactical flexibility.