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F4 Standard Rafale
and the future



French Air Force at
Mont-de-Marsan



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Rafale





Low and fast – a single-seat Rafale C races into action armed with a mixed air-to-air and air-to-ground load-out of infrared-guided Mica AAMs and Scalp stealth cruise missiles.

Dassault Aviation/Alexandre Paringaux

Front and back cover: A Dassault Rafale C breaks for the camera during Exercise Atlantic Trident in April.
Jamie Hunter

Omni-role advances

Designed as a state-of-the-art warplane capable of carrying out the entire spectrum of combat missions, the Dassault Aviation Rafale omni-role fighter has matured into a successful combat tool that has pushed the French Air Force (Armée de l'Air) and French Navy (Marine Nationale) into the digital age.

While the aircraft has notched up important export orders from Egypt, Qatar and India, development of the aircraft has continued, as underlined by the latest Standard F4 variant scheduled to enter service in 2025. Standard F4 will bring a host of new capabilities. A new tactical datalink, and new GaN technology for the active electronically scanned array (AESA) radar and jammers are just some of the promised advances.

The Rafale has also proven itself in combat with both the French Air Force

and Navy. Most recently, Rafale Ms flying from the deck of the aircraft carrier *Charles de Gaulle* have contributed to the global fight against terrorism in the Arromanches III mission.

The final part of *AFM's* exclusive Dassault Rafale supplement brings a report on the work of the 30e Escadre at Mont-de-Marsan. This unit provides a range of capabilities for the French Air Force, including operational evaluation, air defence/air superiority, conventional strike and pre-strategic and tactical reconnaissance.



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A pair of Rafales at high altitude. The wingman is fitted with a TALIOS targeting pod under the right forward fuselage hardpoint while the lead carries the Damocles pod in the same position. All photos DGA

FUTURE RAFALE

Dassault Aviation and the French Defence Procurement Agency have launched development of Standard F4, the next variant of the Rafale omni-role fighter that will enter service in 2025.

Henri-Pierre Grolleau has the story.



ALL ARMÉE de l'Air (French Air Force) and Marine Nationale (French Navy) Rafale B, C and M variants in the inventory have now been brought up to increment F3.4+ standard. Dassault Aviation, its industrial partners and the French Armed Forces are now busy preparing for entry into service of the Standard F3R. This encompasses a range of new systems, including the Thales TALIOS (Targeting Long-range Identification Optronic System) targeting pod, the MBDA Meteor beyond-visual-range air-to-air missile (BVRAAM), a Mode 5 IFF interrogator, a Mode S transponder, and numerous improvements to existing systems such as the RBE2 active electronically scanned array (AESA) radar, the Spectra electronic warfare/self-defence suite and the Link 16 tactical data link. Qualification of F3R is expected in late

2018, with service entry in early 2019. "F3R trials have proved completely successful," explained the general (name withheld by request) in charge of the Rafale programme within the Direction Générale de l'Armement (DGA, Defence Procurement Agency). "Testing is progressing at an extremely fast pace and the new standard will be delivered on time and on budget."

Meteor missile

The introduction of the Meteor ramjet-propelled BVRAAM will be one of the key features of the Standard F3R, a major step forward that will enable Rafale aircrews to prevail over the battlefield, especially when used in conjunction with the fighter's AESA radar. This new ramjet-propelled missile has been ordered to supplement the current Mica EM/IR missile. It is designed to engage targets at extended ranges and to defeat a

range of threats, including fast jets, airborne early warning and control aircraft, tankers, helicopters, unmanned aerial vehicles, and even cruise missiles. As specified by the French Ministry of Defence (MoD), Rafales will carry two Meteors under their rear fuselage hardpoints, although export customers will have the option of doubling that number to four, using existing wing pylons. Meteors will be used alongside Micas, and upgraded Mica NG missiles, for the foreseeable future.

In all, five Meteor integration test firings were performed to evaluate the Rafale's fire-control system and the missile itself in realistic conditions. "The last test firing was completed on April 6, 2017 out of Cazaux air base, in the southwest of France," continued the programme director.

"The scenario of the test was particularly demanding and technically challenging: the Meteor was fired at an extremely distant target but, during its time of flight, it was re-targeted at a pop-up threat, scoring a direct hit. This unique capability has been made possible by the superb detection range of the AESA radar and by the Meteor itself, with its huge interception volumes. "The ability to re-target the Meteor using ►

the Rafale's fighter-to-missile data link was successfully demonstrated and the target was destroyed by a direct hit even though the missile's warhead had been replaced by telemetry equipment: undisputable proof of the quality of the guidance provided by the fighter and of the precision of the missile."

The next Meteor test firing will be part of the F3R operational evaluation to be conducted in early 2019 by a joint air force/navy team.

New targeting pod

The operational limitations of the Damocles targeting pod currently in service on Rafale and Mirage 2000D strike fighters have long been identified. This is the reason why, in 2012, the DGA and Thales signed a contract for the development of the TALIOS new-generation targeting pod.

Compared with the current Damocles, the TALIOS is fitted with a TV channel and with a new infrared sensor, addressing a number of shortfalls highlighted during combat operations in Afghanistan, Mali and the Middle East. Initial development trials were conducted using a DGA Essais en Vol (DGA EV, Flight Test Centre) Mirage 2000D at Cazaux.

According to the programme director: "Flight testing of the TALIOS has so far proven highly successful. Development of the TALIOS and of its subsystems by the industry ran on time, strictly adhering to the terms of the contract, and initial testing carried out by the DGA proved entirely satisfactory. The TV and IR sensors both work superbly well, offering unmatched image quality. I believe that we have exceeded the performance of foreign pods in terms of resolution and image sharpness. We have also demonstrated that extraction of co-ordinates was particularly accurate. Since early 2017, flight-testing has begun on the Rafale and development is expected to be completed in mid-2017.

"In all, 20 TALIOS pods have been ordered, and approval for an additional batch of 25 has been granted, including a number for the French Navy to



A Meteor missile is launched from the rear right fuselage hardpoint of Rafale B301 during the qualification trial held in April 2017.

replace Atlantis pods that were withdrawn from use in July 2016 when the last Super Étendard Modernisé was sent to the boneyard.

Upgrades to the image processing unit have been implemented to increase the range and the resolution of the older Damocles, but I have to admit that the introduction of the TALIOS comes at a very relevant time."

Like the Damocles, the TALIOS will be mounted under the Rafale's right forward-fuselage hardpoint, offering an excellent field of regard, even when weapons and external fuel tanks are carried beneath the wing pylons.

Deliveries

The French MoD has ordered 180 Rafales, divided into four tranches of 13, 48, 59 and 60 airframes. Exports amount to a further 84 aircraft for Egypt (24), Qatar (24) and India (36), bringing total firm orders to 264 fighters.

At the time of writing the French Armed Forces had accepted into service a total of 148 Rafales, including 48 Rafale C single-seaters and 54 Rafale B two-seaters for the Armée de l'Air and 46 Rafale M naval single-seaters for the Marine Nationale. Another four aircraft will be delivered to the French Air Force in 2017 (one) and 2018 (three), leaving all other production slots for export customers. There will then be a three-year gap in deliveries to France and, between 2021 and 2023, the last 28 Rafales from the fourth production tranche will be produced for the French Air Force and Navy.

"All in-service aircraft will be upgraded to F3R Standard within a short

timeframe," explained the programme director. "The retrofit is simple and quick because it mainly involves uploading new software. The French MoD is currently looking at various options for a fifth production tranche, which could be ordered in 2020 for an as-yet decided number of aircraft."

F4 Standard

As part of a spiral development, the MoD and Dassault Aviation recently announced the launch of Standard F4, the next major step for the Rafale programme. The Rafale was conceived from the outset with 'evolutivity' in mind, and its weapon system is designed in such a way as to facilitate upgrades. The Standard F4 development strategy is based on four pillars that cover interconnectivity, combat engagement/sensors, armament upgrades, and support/availability.

Formal development of the new Standard F4 will begin in 2018, but risk-reduction studies will be launched this year.

"Standard F4 will be even more ambitious than F3R," explained the programme director. "While F3R is mainly restricted to software upgrades, new hardware will be required for the far-reaching F4, even though the airframe will remain unchanged. In practice, F4 will be split into F4.1, for older, in-service aircraft, and F4.2, for new-build airframes. F4.1 will be limited to a number of improvements only in order to avoid complex hardware changes, but F4.1 will accept the new Rafale weapons now being developed. F4.2 will include the whole package of upgrades for the radar, the electronic warfare suite, the Front Sector



Optronics and the cockpit to accommodate a helmet-mounted display (HMD).

"All Tranche 4 aircraft – the 28 airframes to be delivered in 2021-23, and all Tranche 5 Rafales will be delivered as F4.2 aircraft. Standard F4 development will take about six years, with service entry due in 2025, but some systems will find their way into the inventory earlier, as soon as they are ready, using a building-block approach thanks to software upgrades."

Communications advances

With the advent of the F4 Standard, the Rafale will be equipped with the new Thales Contact software radios that will be widely fielded across the French Armed Forces in the next couple of years. These new-generation radios will remain fully compatible with legacy radio waves and should be tested on the Rafale as early as 2020.

The Rafale will also be fitted with a new point-to-point, directional, discreet, high-speed fighter data link to be used exclusively for communications and data exchange within a Rafale patrol. This will use a new three-dimensional waveform (FO3D, or *Forme d'Onde 3 Dimensions*) generated by digital signal processing using dedicated antennas for the required bandwidths and the expected data flow.

This new fighter data link will supplement – and not replace – the current Link 16. Accordingly, the Rafale's core avionics system will have to be modified to accommodate the two data link systems that will operate alongside each other (although they will not be linked).

The architecture of the internal network will have to be modified for it to become even more resistant to cyber attack. The CAPOEIRA (Connectivité Améliorée Pour les Evolutions du Rafale, or improved connectivity for the Rafale's future variants) research programme has recently been launched to help determine what sort of architecture will be required for a future, totally secure navigation and attack system.

In 2015, as part of an urgent operational requirement, the French Air Warfare Centre integrated a satellite communication

Two-seat Rafale B301 taxis out with a TALIOS targeting pod under the right air intake. B301 is an instrumented test aircraft only used for trials.



Above: The quality of the image provided by the TALIOS pod is said to be exceptional, much better than that of the Damocles, especially in daylight thanks to the adoption of a powerful TV sensor. Mounting the pod on the right forward-fuselage hardpoint ensures an excellent field of regard.

(satcom) system into the Rafale. "This system will not be kept on the Rafale," the programme director added. "The future military satcom will be encrypted, fully secure and impossible to intercept thanks to a military-grade antenna and a hardened modem. It will enable the Rafale to activate a communication relay mode between fighters and troops on the ground on one side, and higher echelons on the other."

Radar and Spectra upgrades

The current Thales RBE2 AESA radar will be further improved. It will benefit from the introduction of two new air-to-surface modes: a ground moving target indicator (GMTI), to detect and track moving targets over land, and a UHR (ultra high resolution) mode, to replace the current HR functionality for synthetic aperture radar (SAR) imagery, offering superior radar image quality at very long distances. The ability to interleave radar modes will be enhanced, thus helping provide aircrews with even better situational awareness.

The Spectra electronic warfare/self-protection suite produced by Thales and MBDA is fully integrated. It is composed of a wide range of systems: a Détecteur d'Alerte Radar (DAR, or radar warning receiver), a Détecteur d'Alerte Laser (DAL, or laser warner), a Détecteur de Départ Missile (DDM or DDM NG, or missile launch detector), a high-power radar

jammer, and decoy dispensers that can launch a range of flares and chaff.

Over the coming months, Spectra will be improved, with bandwidth extensions for the detectors and jammers to cover lower and higher frequency bands, thus providing an instantaneous reaction against any type of pop-up threat.

"Our objective here is to obtain extremely accurate RF emitter geolocation and 3D tracking, including of airborne radars," said the programme director. "The capabilities of a single Rafale to locate and track a threat without resorting to traditional, but time-consuming, methods of triangulation or of bearing measurements along the aircraft's flight path will be significantly improved. It is a very important step forward, and the recent progresses made by Spectra will boost the capabilities of the Rafale in that field."

Advanced weaponry

New variants of current weapons will be modernised for the updated Rafale, including the Scalp cruise missile, the Mica air-to-air missile and the Hammer (Highly Agile Modular Munition Extended Range) precision weapon. The new weapons will be introduced incrementally, through software upgrades.

In February 2017 it was announced that the British and the French defence ministries had signed contracts with MBDA to upgrade the remaining Scalp/Storm Shadow stealth cruise missiles in service ▶

Research programmes

The DGA oversees a number of research programmes aimed at promoting advanced technologies for the Rafale in the field of sensors, especially for the RBE2 radar, as the Rafale Programme Director explained.

"We will soon launch the AESA NG programme, which will supplement the MFA [Multi-Function Array], CARAA [Capacités Accrues pour le Radar RBE2 à Antenne Active, enhanced capabilities for the active RBE2 radar] and MELBAA [Modes et Exploitation Large Bande pour l'Antenne Active, wide-band operating modes for the active array] projects in order to help mature technologies to be produced from 2025 for Standard F4.2.

"The CARAA demonstrator first flew in late 2015. It is composed of numerous receptors, enabling the creation of radar lobes optimised by advanced calculation techniques to cancel jamming in many directions simultaneously.

"The first flight of the MELBAA demonstrator is expected in late 2017. The trials will focus on dedicated types of targets: slow-movers, helicopters, fighters hiding in the Doppler beam, stealth targets etc. Further developments will include interleaved modes that will be further refined thanks to the appearance of a new generation of calculators powerful enough to provide the processing power required to exploit these modes fully."



Rafale B301 takes off from Cazaux. It is fitted with a single Meteor test round under the fuselage and a Mica EM missile under the wing. The difference in size between the Mica and the Meteor is noteworthy.



on both sides of the Channel. Under the deal, MBDA will refurbish the missiles and carry out a limited upgrade to sustain the weapon until its planned out-of-service date in the early 2030s. The first refurbished Scalp missile is due to be delivered back to the French Armed Forces in 2020. Scalp cruise missiles were first fired in combat from Rafales during the conflict in Libya, in 2011. The missile has also been successfully used operationally in Iraq and Syria.

The Mica family of AAMs, which includes the infrared-guided Mica IR and the radar-guided Mica EM, will be updated to Mica NG (New Generation) standard with, among other undisclosed systems, new seekers. The MBDA Mica, which equips the Mirage 2000-5, the Mirage 2000-9, the Rafale and upgraded Mirage F1s, has met with considerable success. Moreover, a surface-to-air version, the Vertical Launch Mica (VL Mica), has been ordered by several foreign nations.

Expanded Hammer family

The Hammer family will be expanded, minimising the need to procure Paveway II/III and Enhanced Paveway precision-guided bombs from the United States. Three variants of the Safran Electronics & Defense Hammer precision weapon are in service: the SBU-38, with inertial/GPS guidance; the SBU-64, with a dual-mode inertial/GPS and infrared seeker; and the SBU-54, with laser guidance as well as the inertial/GPS kit.

"We need to increase our stocks of precision weapons and we are committed to helping promote and support a national weapons industry," the programme director stated. "A new, simplified Hammer variant is already being developed. This Block 4 variant will be fitted with a revised rear kit, without the rocket motor. The wings will be retained, and its aerodynamic shape and its weight and balance will remain unchanged to ease aeromechanical integration onto the Rafale. Recent operational experience has proved that the rocket motor is not always required, and not always switched on in combat by French aircrews, especially for short-range

engagements during close air support missions. In any case, we will retain the capability to produce both variants of the Hammer, the powered variant remaining available for stand-off attacks in high-threat environments.

"Other improvements are high on the agenda, including a data link between the weapon and the Rafale, and new seekers to engage other types of targets, including fast-moving, highly mobile vehicles. We have launched preliminary studies to develop heavier variants of the Hammer to eventually replace the current inventory of 500kg-class GBU-16 Paveway II and 1,000kg-class GBU-24 Paveway III laser-guided bombs.

"Priority is likely to be given to the 1,000kg variant. A new rear kit will probably have to be designed, but every effort will be made to keep changes to an absolute minimum, most current components being reused, including the seekers and guidance systems."

A new, dual-mode seeker was exhibited by Safran at the Paris Air Show in June 2015.

GaN technology

Thales and the DGA are actively preparing the future radar developments that will be introduced on Standard F4.2, incorporating cutting-edge Gallium Nitride (GaN) technology for the radar and jammer antennas. Thanks to additional radar apertures, detection capabilities will be unmatched and electronic

attack capabilities will become a reality. The programme director explained: "Even though we are entirely satisfied with the current RBE2 AESA radar, we are already working on the next generation scheduled

to appear on new-build aircraft in 2025.

"For the same volume, GaN technology will offer an expanded bandwidth, more radiated power and an even easier ability to switch from one mode to another, or from one functionality to another. With the same antenna, we will be capable of generating combined, interleaved radar, jamming and electronic warfare modes as part of an electronic attack mission.

"GaN emitters will not be restricted to the radar and they will also equip the Spectra suite. For example, for the antennas in the wing apexes, ahead of the canard foreplanes, we could obtain a very quick emission/reception cycle, either saving some volume or augmenting radiated power. On Tranche 5 Rafales, we will have at our disposal twice the amount of transmitted power for the radar and jamming antennas. Thales has already produced and tested in laboratories a series of GaN module prototypes for the new radar and initial testing results look extremely promising.

"Following the entry into service of the AESA in 2013, the deliveries of the Meteor in 2018 will push the Rafale into a class of

DGA support for export customers

The DGA is actively supporting Egypt, Qatar and India, the Rafale's first three export customers.

"We provide support on a case-by-case basis, depending on the terms of each specific contract," explained the Rafale Programme Director. "Our customers seem to appreciate a genuine, independent governmental guarantee. They request complete visibility in all areas, for example in the field of airworthiness, and we assist them and support them for their programmes.

"The development of specific variants for our partners goes according to the plan. The air force is in charge of the training of a number of foreign students and the DGA supports the Armée de l'Air. I'll give you an example: to handle a growing number of students and of Rafale training sorties and to satisfy increased training requirements, the number of mission planning aids and of simulation tools had to be increased and the DGA purchased the additional systems to address the needs."



Above: With its AESA radar, Meteor and Mica missiles, powerful engines, remarkable agility and an advanced data-fusion system, the Standard F3R Rafale will prove to be a lethal foe in the air-to-air arena for years to come.

its own – we will be the only ones in the world operating a fighter equipped with an AESA and a ramjet-propelled missile – but we have to keep investing to maintain our leadership. This is the reason why this GaN technological path is so important, especially for the development of additional emitting panels and apertures that will offer extended radar angular coverage.

“It is not just an improvement; it is a real technological breakthrough in the field of detection. Jamming modes will not be left untouched and will push the Rafale’s electronic warfare capabilities to unprecedented levels thanks to the introduction of what we call ‘smart jamming’, with a wider band coverage and GaN emitters from 2025. These capabilities will be further expanded thanks to the adoption of MFAs [Multi-Function Arrays].”

The Rafale’s Front Sector Optronics (FSO) will be fitted with a new-generation infrared search and track (IRST) sensor optimised for the tracking of air targets, either alone, or in conjunction with the RBE2 radar.

Changes in the cockpit

Although the Rafale’s man-machine interface is lauded by pilots, its cockpit will not be left untouched, with new, larger, lateral touchscreens to be adopted. Because the existing working environment is well balanced, with ergonomics that have proved to be highly successful, the DGA and the industry will introduce only minor adjustments in the cockpit’s design, as part of an evolutionary process.

More importantly, a Helmet-Mounted Display (HMD) will find its way onto the Rafale, filling an operational gap: “The DGA has formally expressed a need in order for the industry to study our requirements. Our specifications are fully compatible with various systems from different providers. We have taken steps to ensure that all Mk16F ejection seats produced under licence in

France by SEMMB [Société d’Exploitation des Matériels Martin-Baker, a 50/50 joint venture between Safran and Martin-Baker] since 2015 are capable of accommodating an HMD.”

Long-term future

Safran Military Engines constantly innovates and further develops the M88 turbofan. The programme director admitted: “Contrary to popular views, we are not going to create a new M88 variant rated at 9 tonnes/20,000lb of thrust, nor a new high-pressure core. Nevertheless, modifications to the engine calculator will help further improve component durability and engine availability. M88 technology will gradually evolve in order to propel UCAVs [unmanned combat aerial vehicles], and the Rafale will eventually benefit from these technological advances, but not until the advent of the MLU [midlife upgrade] variant.”

Future Rafale variants will benefit from the multiple research programmes

launched by the DGA. These include the extremely secretive DEDIRA (Démonstrateur de Discrétion du Rafale, Rafale discretion demonstrator), which focuses on new and innovative processes to improve the airframe’s low-observable qualities against air-defence radars and fighter air-intercept radars.

“We are currently having discussions with the Armée de l’Air and the Marine Nationale regarding their future operational needs and requirements,” the programme director confirmed. “Many options are being scrutinised, from the development of a UCAV to an increase in the number of Rafales. Nothing has been decided yet. What I can tell you is that we will not alter the Rafale’s airframe if we do not need to and that we will keep its proven aerodynamic shape.

“The Rafale retains a huge growth potential, especially regarding the size of the radar antennas and the dimensions and weights of its weapons. We might adopt radar cross-section reduction kits, but without radically modifying the airframe. We will keep all options open. For example, we are considering the possibility of increasing the number of decoys carried by the fighter. In this respect, a DIRCM [directional infrared countermeasures] turret used to generate a laser jamming signal to defeat an incoming missile could well find its way onto the Rafale.”

With such a clear roadmap ahead and with the recent successes on the export market, the Rafale’s long-term future is assured. Dassault Aviation and its partners are constantly investing to make sure their fighter remains at the forefront of technology. The future upgrades to be implemented on the Rafale are ambitious and far-reaching. They represent a clear technological breakthrough in several fields, utilising a fully mature, combat-proven airframe that offers a considerable growth potential.



Above: A close-up of the new TALIOS targeting pod. The external shape of the TALIOS is similar to that of the older Damocles, helping cut integration costs thanks to a significant reduction in the number of sorties needed for flight envelope expansion.

Rafale French Navy combat

A pair of Rafale M fighters overflies the French flagship. The 'Charles de Gaulle' has proved particularly reliable after teething problems were solved, spending more time at sea than any other 'flat top' in the world. Dassault Aviation/Katsuhiko Tokunaga



Arromanches III



In late 2016 the French nuclear carrier *Charles de Gaulle* deployed off the Syrian coast for combat operations against so-called Islamic State as part of the global fight against terrorism. For the first time, her carrier air group was mainly composed of Rafale Ms. **Henri-Pierre Grolleau** tells the story.

THE ARROMANCHES III mission was the last for the *Charles de Gaulle* before her entry into dry dock for a major refit and a nuclear refuelling, which will keep her out of action until mid-2018.

The deployment kept the French carrier air group extremely busy. According to open source data from the French parliament, the air group completed 484 offensive sorties, including 108 attacks, and delivered 177 bombs and cruise missiles.

"Without taking into account the buddy-buddy refuelling missions, we logged nearly 500 sorties with remarkable regularity and with excellent reliability," explained Capt 'Jean' (all surnames withheld on request), the commander of the Groupe Aérien Embarqué (GAé, embarked air group).

"Our tasks included reconnaissance and intelligence-gathering flights, air interdiction missions and planned raids against previously and positively identified targets – with French assets only or as part of a multinational effort – and close air support missions, protecting friendlies on the ground, in Iraq and in Syria.

"Standardisation, forged by regular participation in various NATO exercises all year long, especially in the Tactical Leadership Programme in Albacete, undoubtedly facilitates combat operations in these types of conflicts as part of a coalition.

"We know each other very well, and we all work in a similar way, using common procedures."

Flottilles 11F and 12F

During Arromanches III, Flottilles 11F and 12F each deployed 12 Rafale Ms aboard the French flagship. The GAé also included two Flottille 4F E-2C Hawkeyes from Lann-Bihoué, two SA365F Dauphins and an SA319 Alouette III from Flottille 35F at Hyères and an NH90 Caïman of Flottille 31F, also from Hyères, bringing the complement to 30 aircraft.

Commander 'Alban', the CO of Flottille 11F, explained: "The carrier's senior aeronautical engineering officer was in charge of overseeing all Rafale maintenance. His mission was to ensure that enough assets were available at all times to



Above: The 'shooter' touches the deck with his green flag, giving the signal for a cat shot for the awaiting Rafale M31. *Marine Nationale*

carry out every single tasked mission.

"Each Flottille maintained its own aircraft, but with some flexibility, allowing one unit to reinforce its sister squadron with a dedicated team of engineers, should the need arise."

Alban added: "For combat missions, pilots flew aircraft from one or the other unit, and every day we provided numerous waves of bomber-configured Rafales. Our goal was to have all the aircraft in the required configuration, with the correct fit for a given mission.

"Equipment would include the active electronically scanned array [AESA radar]; the Rover [Remotely Operated Video Enhanced Receiver] system to share a video stream with troops on the ground; the Fightacs digital kneepad to have quick and direct access to digital imagery and

digitally annotated maps that showed points of interest; and the Damocles targeting pod for target surveillance, extraction of co-ordinates and laser spiking.

"A further three, and sometimes four, Rafales were fitted with an in-flight refuelling pod under the centreline station for buddy-buddy refuelling. We also provided Rafales for intelligence-gathering missions with the Pod Reco NG reconnaissance pod.

"Typically, our working day spanned 14-plus hours between the first and the last mission launches. All the missions were flown as part of a wide, multinational coalition, tasking being provided by an allied CAOC [Combined Air Operations Centre], which was under the operational control of the Combined Joint Task Force in charge of co-ordinating all air and land combat operations against Daesh [so-called Islamic State] in the whole theatre.

"Missions and taskings were shared and deconfliction between combat patrols was carried out at CAOC level to maximise combat efficiency and reduce risks."

Robust tanking plan

Because of the long transit distances, *Charles de Gaulle's* Rafales depended on tanker support. Late last year the tanker fleet in the Middle East was extremely varied and French Navy Rafales were refuelled by an array of assets drawn from multiple air arms.

They included French Air Force (Armée de l'Air) C-135FR Stratotankers, US Air Force KC-10 Extenders and KC-135R Stratotankers, Royal Australian Air Force (RAAF) KC-30s, Italian Aeronautica Militare KC-767s and Luftwaffe A310s.

"I never took fuel from a Royal Air Force A330 Voyager, although they were there too," noted Flottille 11F's CO. "About 80% of the tankers ►



Above: Rafale M pilots strapping in prior to another mission. The Rafale's Mk16F ejection seat is reclined at 29°. *Dassault Aviation/Katsuhiko Tokunaga*

Rafale French Navy combat



Hooks down, a pair of Rafales carrying unexpended ordnance enters the circuit at precisely 657ft (600ft above the deck, and another 57ft above the water). The leader is armed with four Hammers and the wingman, four GBU-12s. Marine Nationale

we refuelled from belonged to the ever present C-135FR/KC-135R family, either US or French.

"Each time, we requested a 'fill to full', expressing our fuel requirement over the radio in pounds. Various diversion options had been prepared, but all had their own logistical drawbacks.

"Thankfully diversions for tanking/tanker issues were extremely rare. The in-flight refuelling plan produced by the CAOC was always remarkably robust.

"Nevertheless, the tasking was often modified in response to changes in the mission or to use available extra fuel from the given tankers. The end result was that we often had to refuel from the tanker of the previous slot, which had additional kerosene to transfer, before heading back to base."

Into combat

As soon as the Rafales reached their allocated operating area, their pilots would first call the fighter controller on the ground or on board an AWACS. Then the Joint Terminal Attack Controller (JTAC) would allocate them a combat air patrol orbit and an altitude block to ensure deconfliction would be guaranteed horizontally and vertically with the multiple assets – bombers, fast jets and unmanned aerial vehicles (UAVs) – waiting to be relieved.

"We were there when the battle for Mosul began," said Commander Alban, "and each time we approached the city we could see on our screen all the aircraft holding, waiting their turn to be allowed to proceed towards the area where the fighting was taking place.

"Seen from our position [it was a] rather small area, the size of a large town. As soon as a patrol was returning to base the JTAC would call in the next one to ensure there was always enough firepower available.

"There were always a lot of friendlies in the vicinity, all around, above or below us: US Air Force B-52 Stratofortresses, F-15E Strike Eagles, A-10C Thunderbolt IIs and Reaper drones, RAAF F/A-18F Super Hornets, British Tornados and Typhoons, and F-16 Fighting Falcons drawn from various countries...

"Thanks to the Link 16 data link, we knew at the flick of a switch what weapons and what remaining fuel the other aircraft in the network had. Pretty neat and very useful.

Sharing airspace with the Russians

Russian fast jets and combat helicopters were operating in force in Syrian airspace during Arromanches III, but every effort was taken to avoid close encounters.

"The GAÉ's mission was definitely not to establish a contact with our Russian opposite numbers," pointed out Captain Jean. "In Syria, a kind of cohabitation was established between allied and Russian aircraft, with deconfliction ensured at command level between our respective headquarters.

"Our pilots followed very strict guidelines to avoid potentially hazardous situations. The idea was quite simple: avoid contact at all costs so as not to find ourselves in a situation that could easily deteriorate and rapidly escalate.

"This is where the RBE2 electronic scanning radar and its AESA antenna prove their immense value. Thanks to their extraordinary detection ranges, the pilot can see what's going on far ahead, giving them time to anticipate and stay clear of Russian fighters.

"The Rafales flying in Syria were predominantly fitted with the ASEA antenna. I noticed myself that use of the AESA is addictive and, once you've tried it, it's difficult to come back to the older PESA [passive electronically scanned array] system."



Above: Concentration etched on the face of a Rafale M pilot. French Navy aircrews are trained to a very high standard, a typical fighter pilot logging 220 flying hours each year. Jean-Philippe Pons/Marine Nationale

"After we checked in and completed the authentication procedure, the JTAC provided us with a sitrep [situation report], an accurate description of the tactical situation in the area.

"When we weren't too busy, in the rare periods of relative calm when fighting abated, we performed armed overwatch, trying to determine where fires were coming from in an effort to locate Daesh firing positions. Easier said than done."

Each offensive patrol comprised two bomber-configured Rafales, the first fitted with four or six 500lb (227kg) GBU-12 Paveway II laser-guided bombs (LGBs) and the second with four to six Hammer (Highly Agile Modular Munition Extended Range) precision weapons. One of the pair also carried a Damocles targeting pod under the right forward fuselage hardpoint.

Pilots could therefore handle all sorts of situations, achieving a variety of military effects thanks to different types of bomb bodies and multiple fusing options.

Three types of bomb body were used by the French Navy during Arromanches III: the 500lb BLU-111, the 250kg (551lb) Corps de Bombe à Effets Multiples Sécurisé (CBEMS, multiple effects insensitive bomb body) and the 500lb BLU-126, which contains less explosive mass than a regular BLU-111 or CBEMS to reduce the risk of collateral damage.

"The mission leader routinely flew the aircraft equipped with the Damocles," said Alban.

"Before each engagement during a fire support mission, we received via the radio a 'nine-line' – a standardised briefing with attack data, including target co-ordinates, the attack heading and the type of weapon approved by the Red Card Holder, a French officer in the CAOC who can veto the engagement if he thinks conditions for a safe fire are not met, especially if friendlies are too close to the target area.

"Having an officer able to step back and think about safety issues is clearly an advantage in some conditions. It's very efficient and the Red Card Holder remains a major asset to minimise the risk of friendly fire."

Multiple targets

Many targets were destroyed by French Navy Rafales before the start of the battle for Mosul, including improvised explosive device (IED) and vehicle-borne IED (VBIED) factories. During the battle itself, targets were mainly mortar emplacements, sniper positions and VBIEDs on the move.

"I clearly recall a very intense mission during the battle for Mosul," said Commander 'Marc', commanding officer of Flottille 12F. "I was flying as the wingman of a two-ship. The weather was marginal at best, with numerous thunder cells.

"Communications with troops on the ground were difficult. The JTAC wanted a PID [positive identification] of the target. It took a while to do so, because my leader had to wait for a hole to appear in the cloud base to lock on the target and identify it with his Damocles pod and extract accurate co-ordinates.



*Main photo: Armourers, invariably called 'bombs' in the French Navy, prepare to load a Scalp cruise missile under the belly of a Rafale. Marine Nationale
Below: The French Rafale M uses a launch bar similar to that in service with the US Navy, ensuring interoperability. Marine Nationale*

"The hole quickly disappeared, however, and I had to fire a Hammer precision weapon at those co-ordinates through the clouds.

"Shortly afterwards, the weather started to improve again and my leader dropped a GBU-12 at a second target. It was a very dynamic mission, with two successive engagements."

Flottille 12F's CO recalled another mission: "At dusk we were asked to destroy a heavy mortar emplacement carefully hidden in the middle of a palm grove. Accurate mortar firing had stopped the progression of friendlies and quick action was required.

"This time I was the leader and my aircraft was fitted with a Damocles. The weather was good and infrared imagery proved decisive in accurately locating the target: the pod's infrared sensor clearly showed a hotspot that marked the location of the mortar's hot barrel below the palm trees.

"I immediately started spiking the target for a GBU-12 bomb. On the multifunction screen displaying Damocles imagery I clearly saw the impact of the bomb and a huge secondary explosion betraying the destruction of the ammo stored nearby.

"The friendlies were soon able to move forward again."

Scalp firing

Both the Armée de l'Air and the Marine Nationale (French Navy) fired large numbers of MBDA Scalp EG (Emploi Général, general purpose) stealth cruise missiles in the Middle East.

Used against hardened targets of strategic value, Scalps deprive IS terrorists of any prior warning of an incoming strike: fighters operating at medium level to remain outside the range of light weapons and shoulder-launched missiles could be detected audibly before an attack with laser-guided bombs – but the Scalp, which can be fired from hundreds of kilometres away, follows a very low-level attack profile.

Commander Marc fired a Scalp at an

undisclosed target in the Middle East: "I barely noticed the firing itself. It's quite surprising for a weapon weighing about a tonne, but you can hardly feel the actual release; all unwanted attitude changes in pitch, roll and yaw are eliminated.

"I shot the Scalp at night. I couldn't see the horizon and I had no external references at all. It may be the reason why I did not notice any movement of the platform. For operations from the *Charles de Gaulle*, the Scalp is mounted under the centreline pylon, along the airframe's longitudinal axis, which is probably the reason why there are no movements in roll.

"In any case, the Rafale's sophisticated fly-by-wire controls are very efficient at erasing the airframe's secondary effects, all induced aerodynamic effects being cancelled."

Surveillance duties

During the two-and-a-half months of the deployment, weather had an impact on the Rafales for fewer than ten days.

"The RBE2 radar's high-resolution mapping mode [also known as synthetic aperture radar, SAR] is highly useful when the weather starts deteriorating," explained Commander Marc.

"It allows us to identify points of interest using radar imagery and to confirm that what we're looking at is really what the JTAC wants us to look at, to avoid errors linked to the use of wrong co-ordinates.

"For example, in Mosul, major roads and the bridges over the Euphrates River can clearly be seen on the radar screen."

The French carrier air group launched numerous reconnaissance missions as part of the coalition effort to gather intelligence: "The Rafale's Pod Reco NG works remarkably well," explained the GAé commander.

"Thanks to its ability to photograph and map a huge area while providing extremely high-resolution imagery, it's truly in a class of its own. This capability was praised by



French Navy Rafale in detail

Although commonality remains high between Armée de l'Air and Marine Nationale variants of the jet, the Rafale M differs in several ways from its French Air Force B and C counterparts. The most obvious modification is the massive, extremely robust landing gear designed to absorb the loads associated with catapult shots and carrier landings. The nosewheel is fitted with a launch bar compatible with the launch shuttles used by US-built Mk13 catapults.

Under the rear of its fuselage the Rafale M is equipped with a power-operated, automatically retractable arresting hook; in the cockpit, the hook handle is slightly different from that on the Rafale B/C.

The Rafale M also features a fuel dump valve on the right side of the rear fuselage for the pilot to jettison fuel and reduce weight should they need to trap back aboard the carrier earlier than expected.

In all other respects, the Rafale M retains the same airframe and same systems (including the avionics, sensors, engines, auxiliary power unit and Mk16F ejection seat) as the French Air Force's single-seat and two-seat versions, helping reduce procurement and support costs and easing logistics and maintenance. All variants have also benefited from the Rafale M's corrosion protection.

BAN Landivisiau

On May 2, 1967, a naval fighter landed for the first time at the new Base Aéronavale (BAN, naval air base) at Landivisiau, in Brittany, signalling the start of a very successful operational story. Today, three naval squadrons – Flottilles 11F, 12F and 17F, all stationed at Landivisiau – are equipped with the Rafale M fighter.

Flottille 17F, the last Super Étendard Modernisé operator, is in the midst of conversion and should be fully operational on the Rafale M in mid-2018, in time for carrier qualification aboard *Charles de Gaulle* when the vessel comes out of refit.

When 17F is operational, all the units will be capable of conducting the whole spectrum of combat operations: air defence of the task force, air superiority in a contested environment, pre-strategic and tactical reconnaissance, non-traditional intelligence and surveillance, nuclear deterrence, anti-ship strikes, interdiction, precision attacks deep inside enemy territory, close air support and buddy-buddy refuelling.

Escadrille 57S meanwhile operates the Falcon 10MER (Marine Entrainement Radar) from Landivisiau in the training and light transport roles.



Flottille 11F



Flottille 12F



Flottille 17F

the upper echelons and our annotated imagery was always in high demand.”

It was during Arromanches III that the first laser-guided variant of the Hammer family (known as the SBU-54) was fired in combat by the French Navy – although an opportunity to fire the powerful internal 30M791 30mm cannon did not arise during the deployment.

Capt Jean explained: “Firing on co-ordinates is extremely efficient, but against targets on the move the Laser Hammer gives us formidable offensive capabilities to overcome the tactics developed by Daesh.

“After each attack, [their] warfighters move very rapidly to try to avoid destruction and we have to be very fast to engage them: in this type of situation the Laser Hammer proves invaluable.

“Daesh personnel have been constantly bombed for over two years now, forcing them to modify their tactics. As a result we also had to adapt our own tactics, exploiting to the full the capabilities of our fast jets to prevail on the battlefield.

“The Laser Hammer variant also has the advantage of retaining the capability to hit recorded initial co-ordinates accurately should the laser guidance be interrupted by clouds, smoke or obstructions – something that’s clearly impossible with the GBU-12.”

After-action review

Mission Arromanches III, the first of its kind without any Super Étendard Modernisé (SEM) aircraft aboard the French flagship, revealed how useful the interaction between Flottilles 11 and 12F can be, resulting in excellent reactivity and operational flexibility.

“With a single type on board it’s easier to obtain a good availability rate and generate

a large amount of sorties,” said Capt Jean.

“For the past 12 years we’d been preparing ourselves for the withdrawal of the Super Étendard Modernisé and the conversion of Flottille 17F, the last of the three naval fighter squadrons, to the Rafale.

“Mission Arromanches III has given us unparalleled insight into our future operational capabilities. We now have at our disposal a superb combat tool perfectly adapted to our needs and missions.

“After the terror attacks that have struck our country, our fellow citizens clearly feel the pressure of terrorism but the Armée de l’Air and the Marine Nationale are taking an active part in the fight against terror groups.”

For the crew of the French carrier and the air group personnel, Arromanches III proved especially intense: “The fact that the GAÉ was able to be back up to speed so rapidly for an additional deployment was a source of satisfaction for all of us,” reflected Capt Jean.

“Weapon consumption was high, but I want to stress that the *Charles de Gaulle*’s load carrying capabilities are excellent in terms of ammunition, kerosene, spare parts and food. This helps reduce the pressure on fleet replenishers and the whole logistic chain.”

Resilience at sea

“Since the Bois Belleau mission in 2013, we’ve taken part in four successive deployments, including two back-to-back deployments in 2016,” added Capt Jean. “We were in theatre on January 1 last year and were again at sea, off Syria, on December 15.

“This is quite an achievement. True, we spent nearly six months in France, but with time at sea in the Mediterranean in the summer





Left: Rafale M36 just after trapping back on board 'Charles de Gaulle'. It is carrying a Damocles targeting pod. L Bernardin/Marine Nationale

to prepare for the next deployment, conducting carrier qualifications for recently arrived young aircrews.

"As I speak, we don't have a single pilot within the carrier air group who's not been engaged in combat in one theatre or another. It used to be unheard of to have 100% combat-proven, battle-hardened pilots, but this is the case today – which gives you a good idea of the experience level among GAé aircrews in strike and close air support missions."

Although the *Charles de Gaulle* will be unavailable until mid-2018, French Navy Rafales are not staying idle. Between March 16 and March 30 this year, a pair of Rafale Ms deployed to Lann-Bihoué, south Brittany, for the homeland air defence mission.

The two quick reaction alert (QRA) Rafales were held at short-notice readiness, ready to take off and intercept any aircraft that might enter French airspace without prior consent or radio contact, or needing assistance. Navy Rafales will handle the northwest QRA at Lann-Bihoué again later this year.

Flying out of Jordan

In late March, four French Navy Rafales deployed to the Middle East for combat operations from Jordan against so-called Islamic State at a time when the threat to French interests remained extremely high.

They replaced a quartet of Armée de l'Air Rafales at the base, enabling the air force units to temporarily reduce their sustained operational tempo. The concept of a so-called 'land-based carrier air group' had already been successfully tested in 2008 when SEMs deployed to Kandahar in the fight against the Taliban.

The withdrawal of the SEM and the switch to the 'all-Rafale GAé' has led both to a considerable increase in firepower and the survivability of offensive and defensive combat air patrols, helping missions to be planned and executed in non-permissive or denied environments.

Moreover, the carrier can launch a much higher number of sorties with 24 Rafales than with a mix of Rafales and SEMs, as was the case until July 2016, the transition representing a major step forward for the Marine Nationale.



E-2C Hawkeyes in action

Flottille 4F's two E-2C Hawkeyes played a decisive role during the Arramanches III deployment, using their powerful AN/APS-145 radar to detect all air and surface activity for hundreds of miles around.

"Once more, the Hawkeye provided us with the ability to fully understand what was going on around the *Charles de Gaulle* and around our fighters," said Capt Jean. "The Hawkeye's radar range is outstanding, and it can see everything through 360° while a fighter pilot's focused on his mission."

"All French and allied assets used their Link 16 data link to co-operate and share tactical data, significantly increasing our combat capabilities. The Hawkeyes flew every day, either 'feet wet' over the eastern Mediterranean or 'feet dry' over the theatre. On some given days, two sorties were flown, one 'feet dry' and one 'feet wet'."

"In Iraq there's a traffic control authority, because airliners are routinely flown within the country and to and from foreign destinations. But in Syria the coalition did not have access to any air traffic control service, and in those conditions our Hawkeyes proved invaluable."

"Until the Rafale is equipped with a satcom system, the E-2C will remain a useful communication relay. Thanks to its advanced communication suite, it can maintain contact between the fighters and the carrier. Finally, its comprehensive electronic intelligence systems are priceless in helping update our radar database."



Above: A Rafale M comes in to land under the watchful eye of two flight deck personnel. All external weapons have been expended. A Pugnet/Marine Nationale

Left: A heavily armed Rafale taxis from the forward edge of the deck to the lateral catapult. It is loaded with a 2,000lb GBU-24 Paveway III laser-guided bomb under the centreline pylon, two 2,000-litre drop tanks and four Mica EM/IR air-to-air missiles. A Pugnet/Marine Nationale



AIR FORCE RAFALES

The 'Lorraine' squadron's transfer from Al Dhafra to Mont-de-Marsan in September 2016 made the 30^e Escadre (30th Wing) fully operational. **Henri-Pierre Grolleau** visited Base Aérienne 118 for AFM.

Main photo: A pair of 30^e Escadre Rafales cruises high above southwest France. All photos Henri-Pierre Grolleau unless otherwise stated

A FLEET OF 47 Rafale B/C and four Mirage 2000D fighters, three Alpha Jet trainers and two TBM700 light transports equips the 30^e Escadre for its role as the Armée de l'Air's (French Air Force's) spearhead in the fields of operational evaluation, air defence/air superiority, conventional strike and pre-strategic and tactical reconnaissance.

Over the last couple of years, the Armée de l'Air has recreated wings (escadres) at all its major air bases. "All the activity of the squadrons is managed at escadre level," said Lt Col Nicolas (all surnames withheld on request), the 30^e Escadre Operations Officer. "On Tuesdays, three successive meetings are organised at three different levels – air base, operations officers of the squadrons, and duty flight commanders – to oversee the activity of the following week. Everything is planned in close co-operation with the other escadres, especially the 31^e Escadre

at Istres for the allocation of tanker slots."

The 30^e Escadre is divided into six units, served by 900 personnel:

- Escadron de Chasse et d'Expérimentation (ECE, Fighter and Evaluation Squadron) 1/30 'Côte d'Argent';
- Régiment de Chasse (RC, Fighter Regiment) 2/30 'Normandie-Niemen';
- Escadron de Chasse (EC, Fighter Squadron) 3/30 'Lorraine';
- Escadron de Soutien Technique Aéronautique (ESTA, Aeronautical Technical Support Squadron) 15/30 'Chalosse';
- Centre de Formation Rafale (CFR, Rafale Training Centre) 23/30;
- Equipe Technique Interarmées Rafale (ETIAR, Joint Rafale Technical Team) 61/30.

The three 30^e Escadre combat squadrons belong to two separate commands. The Centre d'Expertise Aérienne Militaire (CEAM, Air Warfare Centre) is responsible for ECE



NACTION

1/30, and the Commandement des Forces Aériennes (CFA, Air Forces Command) for EC 2/30 and EC 3/30. A similar organisation exists at Saint-Dizier, where squadrons are split between the CFA and the FAS (Forces Aériennes Stratégiques, Strategic Air Forces).

'Côte d'Argent' – Opeval

ECE 1/30 is heavily involved in operational testing of new Rafale and Mirage 2000 systems. Commandant (Major) Vincent, the squadron's operations officer, explained: "'Côte d'Argent' is the unit that prepares for the future. We are in charge of conducting the operational evaluation [Opeval] of new systems, of innovating and of refining the new tactics and operational doctrine to be used by Armée de l'Air combat units. Our mission is to deliver to the front line a fully operational system with a clear and concise operating manual.

"Fully developed weapon systems that have passed their development tests and met their design specifications are put through their paces here, performing missions in realistic combat conditions. We are extremely busy supporting the Rafale programme. We regularly update its flight manual and its tactical manual. The first of these focuses on the aircraft's systems and the second on the tactics and use of sensors and weapons. These manuals are updated every time a new item of equipment or new standard is introduced."

ECE 1/30 actively supports the development of new Rafale variants. For example, its personnel are heavily involved in the introduction into service of Standard F3R. "We are currently focusing on the Rafale's Front Sector Optronics [FSO] that will be substantially improved, with a better video image and enhanced target tracking

precision," continued Commandant Vincent. "Refinements will be brought to the Spectra electronic suite to increase its detection capabilities and improve the precision of the jamming. Our specialists have flight-tested the TALIOS targeting pod and we are already working on the Meteor [beyond-visual range air-to-air missile, BVRAAM] operational trial scenarios. To fulfil our missions, we are often required to modify our Rafales, these modifications being usually applied to two-seaters. These aircraft remain fully capable of undertaking combat missions, but aircrews have to be aware of the changes introduced to the aircraft."

Snipe targets

ECE 1/30 aircrews and specialists carry out multiple operational evaluation campaigns each year. Commandant Vincent provided some examples: "Over the last few months, ►



Homeland defence

At the time of writing, 'Normandie-Niemen' and 'Lorraine' were both providing assets for the southwest and northeast quick reaction alerts (QRAs), at Mont-de-Marsan and Saint-Dizier respectively. Each QRA site is provided with two armed Rafales that can be scrambled within minutes to intercept, identify and, if required, use force against an aircraft, civil or military, that refuses to obey an order. "A young pilot like me spends about a week every month in the QRA facility," explained 2nd Lt Sébastien.

"Every operational pilot in the squadron is cleared to undertake the QRA mission, including those of the Forces Aériennes Stratégiques. We follow a very strict training programme, with stressful and combat-realistic scenarios: interception at very high altitude of a business jet that has lost radio contact with air traffic controllers, in-flight assistance of a lost light piston aircraft close to a no-fly zone, interception of a foreign fighter that has entered French airspace without diplomatic clearance.

"We also simulate situations that rapidly degenerate, allowing us to perform both QRA and dogfight training during the same sortie. The Rafale proves ideal for the QRA mission: it is very powerful, with excellent acceleration and climb rate, a high ceiling and a remarkable endurance.

All QRA Rafales are armed with four Mica EM/IR missiles and they carry a full allocation of decoys and of 30mm ammunition. Usually, aircraft selected for the QRA mission are all equipped with the FSO to identify targets at stand-off distances."



A CEAM Rafale photographed between sorties during Exercise Serpentex 2016 at Solenzara, Corsica. It is fitted with a Damocles targeting pod.



Above: A 'Lorraine' pilot photographed in front of one of the unit's aircraft. Noteworthy is the Tiger scarf, reflecting affiliation with NATO's Tiger Association.



A two-seat 'Normandie-Niemen' Rafale B prepares to depart for a night air defence/in-flight refuelling training mission.



I was involved in air-to-air gunnery trials against the new Snipe targets currently being evaluated. These very small targets – with a wingspan of less than two metres – will be used operationally to allow frontline pilots to train in realistic conditions against very small slow-movers. The goal of the evaluation was to develop valid tactics. The challenge for the pilot is to stabilise the firing run long enough in order to press the trigger at the correct time. Easier said than done when engaging such a small object that proves incredibly difficult to acquire visually. During the trials I was involved in, the Snipe was flying at 70 knots [130km/h] at 3,000 feet. I fired a 0.5-second burst and the Rafale's 30M791 revolver cannon fired 21 30mm rounds. It's a very difficult exercise because the delay between the visual acquisition and beginning of the firing pass is extremely short, with a very, very small firing window.

"Another example of the type of work we perform here: prior to each deployment or multinational exercise, we test on the ground and in flight the Link 16 networks that will be used in the field. We recently tested a Norwegian network prior to the deployment of Rafales to Finland for the Arctic Challenge 2017 multinational exercise. Finally, as part of our support to export programmes, we recently dropped unguided, slick Mk82 bombs."

'Normandie-Niemen' – air-to-surface leader

RC 2/30 'Normandie-Niemen' is unquestionably one of the best-known French Air Force units. This fully omni-role squadron can undertake the complete range of air-to-air and air-to-surface missions assigned to the Rafale, except the nuclear deterrence role allocated to the Saint-

Dizier wing. RC 2/30 is the unit dedicated to lead the supervision of all tactics related to reconnaissance and conventional attack missions and co-operation with special forces. In close concert with the experts of the CEAM, its subject matter experts (SMEs) constantly refine operational concepts and procedures when new weapons or new variants of in-service weapons are introduced. The SMEs focus on all the tactics used to deliver guided weapons, including the GBU-12/22/24 Paveway II/III laser-guided bombs, the Hammer (Highly Agile, Modular Munition Extended Range) family of precision weapons and the Scalp cruise missile, or to execute a recce pass with the Pod Reco NG (New-Generation Reconnaissance Pod, known on the export market as AREOS, for Airborne Recce Observation System). The squadron flies the single-seat Rafale C.

EC 2/30 is also the dedicated Rafale squadron in charge of supporting French special forces: "We are the special forces' primary point of contact within the Armée de l'Air fighter community," explained 2nd Lt Sébastien, one of the 'Normandie-Niemen' pilots/forward air controllers. "We co-operate closely with the commandos of the 1^{er} Régiment Parachutiste d'Infanterie de Marine, the 13^e Régiment de Dragons Parachutistes and the Commando Parachutiste de l'Air N° 10 for all aspects of fire support missions. We rely on procedures that are common to everybody and we routinely support their exercises."

Pod Reco NG

The training syllabus to master the use of the Pod Reco NG is remarkably short. Only two training sessions in simulators and three medium-altitude and four low-level/very-low-level training sorties are required. The Pod Reco NG is equipped with a powerful long-range optical photography (LOROP) sensor in a rotating turret at the tip of the pod, and an infrared line-scanner (IRLS) at its rear.

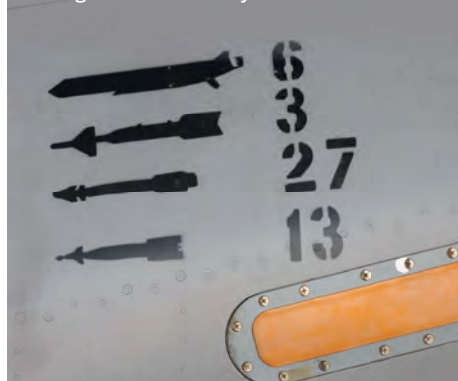
During each training sortie, the trainee pilot will have to photograph targets during



Former Free French squadrons in action: Rafale Cs from 'Lorraine' (nearest) and 'Normandie-Niemen' taxi to the runway at Mont-de-Marsan.

Hammer ARC

Alongside their colleagues of ECE 1/30, the specialists of EC 2/30 are busy preparing the entry into service of a new variant of the Hammer precision weapon. Known as Hammer ARC (Agile Release Capabilities), this new variant will soon be introduced for close air support missions. It will offer an expanded firing envelope thanks to new control laws optimised for off-boresight firings. With the previous control laws, the weapon could not be dropped from an orbit when the Rafale was wheeling around a target, observing the combat area from a short distance away with its targeting pod. This meant that the fighter had to leave its orbit pattern and fly away for a few nautical miles before coming back for the attack run and weapon release, a time-consuming process when the lives of troops in contact are at stake. With the ARC firing mode, a pilot will be able to drop the weapon while still wheeling around the target, thus considerably reducing the time needed to engage a time-sensitive objective. "In addition, the new ARC version is cleared for firing from very low level, in automatic terrain following, and in a turn," said General Richard Reboul, the Deputy Commander of the Commandement des Forces Aériennes. "This is a major advantage for entry operations, in contested or heavily defended airspace, during the first few days of a conflict."



planned recce runs and targets of opportunity assigned by the instructor during the sortie.

As was the case with the Reims-based Mirage F1CR strike fighters that previously handled the Plan d'Imagerie France (PIF, Imagery Plan for France), civilian authorities can ask for specific photos to be taken for later use. For example, when a new railway line is constructed, all major structures such as bridges and tunnel entrances are systematically photographed to create files that could be used at a later stage by rescue services – firefighters, ambulances, police or Gendarmerie – should an accident happen.

"The Pod Reco NG is extremely simple to use, with very intuitive symbology and 'switchology,'" continued 2nd Lt Sébastien. "Consequently, we do not need to train that frequently in the recce role. During a planned reconnaissance mission against known targets, the Rafale handles everything by itself, the pilot limiting himself to a system surveillance role. Various types of target designation can be utilised for targets of opportunity: via the high-resolution radar mode, the FSO's TV sensor, or a selection on the digital map display, or just

by overflying the target, performing a 'mark' to register its co-ordinates before initiating a quick manoeuvre to return and take vertical or oblique images." Despite this apparent simplicity, a thorough mission planning process is always required to ensure success.

'Lorraine' returns

In summer 2016, the Armée de l'Air undertook a major reshuffle of its Rafale units and of its inventory of the fighters. In summary, the higher echelons had decided to regroup most B-model two-seaters at Saint-Dizier for conversion training and nuclear deterrence missions, and most C-model single-seaters at Mont-de-Marsan and Al Dhafra in the United Arab Emirates (UAE). However, a small number of single-seaters are still based at Base Aérienne 113 Saint-Dizier supporting the operational conversion activities of Escadron de Transformation Rafale (ETR, Rafale Conversion Squadron) 3/4 'Aquitaine'. Similarly, a handful of two-seaters are allocated to Base Aérienne 118 in Mont-de-Marsan for various missions. To realise



'Lorraine' Rafale C120 comes into land at the end of another training sortie. It carries the markings of Escadrille (flight) SPA 38 on the fin.



Main photo: Two Rafale C single-seaters break away from the camera ship. The nearest aircraft is equipped with two Mica IR missiles on the wingtips, two 2,000-litre external fuel tanks and a Scalp stealth cruise missile under the centerline pylon. **Left:** A 'Normandie-Niemen' pilot busy preparing his next sortie. Even in the digital age, maps are still useful.

this plan, EC 1/7 'Provence' left Saint-Dizier for Al Dhafra while 'Lorraine' was relocated from Al Dhafra to Mont-de-Marsan.

The changeover saw aircraft numbers revised among the units. While at Al Dhafra, 'Lorraine' had six Rafales and now 'Provence' also has six. While at Saint-Dizier, EC 1/7 had 20 aircraft, and now 'Lorraine' has the same number at Mont-de-Marsan. This meant that a number of single-seaters transferred directly from Saint-Dizier to Mont-de-Marsan, without ever visiting the UAE. "The transfer of the single-seaters of EC 1/7 from Saint-Dizier to Mont-de-Marsan provided us with the opportunity to organise a superb training mission," recalled Capitaine Olivier, the 'Lorraine' tradition/public affairs officer. "An appeal had been launched to all Armée de l'Air and Marine Nationale [French Navy] squadrons so that they could provide 'Red Air' assets and, when the 12 Rafales took off on their way to Mont-de-Marsan, they had to forcibly make their way through. This was incredibly realistic training... and a good way to optimise the use of precious resources."

EC 3/30 'Lorraine', formerly No 342 Free French Squadron in the UK Royal Air Force, is one of the most prestigious Armée de l'Air units. This former Mirage F1 operator was re-established at Al Dhafra in 2010 after it had been selected to become the forward-deployed unit in the UAE, flying Mirage 2000-5F interceptors. It began re-equipping with Rafales in 2011.

Confronted with a sharp reduction in the number of frontline units, the French Air Force decided to preserve its most historically important escadrons (squadrons) and escadrilles (flights). This is the reason why flights SAL 56 'Scarabée', SPA 38 'Chardon de Lorraine' and SPA 162 'Tigre' have been allocated to EC 3/30 'Lorraine' while escadrilles 'Metz', 'Nancy' and 'Thionville' have disbanded. Thanks to the allocation of SPA 62, EC 3/30 'Lorraine' is now part of the famous NATO Tiger Association.

Air-to-air expertise

EC 3/30 operates single-seat Rafales in air-to-air and air-to-surface roles, with a strong emphasis on air-defence/air superiority missions. "We have here a high ratio of aircrews with an air-defence background," explained Commandant Damien, an experienced EC 3/30 pilot. "About 60% of all our flying hours are devoted to air-to-air combat training, except when we are involved in laser designation training which brings the ratio between air-to-air and air-to-surface to around 50/50."

"What you have to understand, and I must insist on this point, is that it takes longer to train a pilot in the air-to-air role than in the air-to-surface role. For a Scalp strike or an air interdiction mission, most of the job is done on the ground, on the mission planning workstation and in the briefing room, leaving no room for improvisation. In the air-to-air arena, the challenge is to identify and understand the enemy's behaviour. You need to be mentally quick to ensure that the developing situation fully complies with the rules of engagement edited by the higher echelons. In order to do so – and to be good at it – you need to train and train again."

Complex air-combat training missions are organised daily. Capt Olivier described a typical mission: "A Sweep 2/Strike 2, that is four Rafale C single-seaters – in fact two 'Normandie-Niemen' strikers escorted by two 'Lorraine' Rafales – would take off from Mont-de-Marsan to fictitiously attack a target in the TSA 43 training area. A CAP 2 [two-ship combat air patrol] composed of either two EC 1/4 Rafale B two-seaters from Saint-Dizier or two EC 1/2 Mirage 2000-5F interceptors from Luxeuil would try to defend that target and intercept the incoming four-ship raid."

'Lorraine' in combat

'Lorraine' was the first French squadron to be involved in the fight against so-called Islamic State (Daesh). EC 3/30 aircrews

ESTA: a hub of activity

ESTA 15/30 'Chalosse' is the focus of all activity at Mont-de-Marsan. Within the Armée de l'Air, most engineers are now part of ESTAs, leaving only aircrews, administrative and intelligence specialists within frontline units. With its 630 personnel, ESTA 15/30 is by far the largest unit within the 30^e Escadre. It oversees servicing, maintenance and repair for all 56 aircraft stationed at Mont-de-Marsan, including the Rafales and their M88-2 turbofans. ESTA engineers are also frequently required to adjust the jet's configurations to match the training requirements of the three squadrons. For instance, during AFM's visit to Mont-de-Marsan, a team of engineers was busy installing a Pod Reco NG under the centreline pylon of a Rafale so that pilots could train with that advanced system.



Armourers equip a Rafale with a Laser-Guided Training Round (LGTR) during Exercise Serpentex 2016 at Solenzara.

Rafale 30^e Escadre



Two Rafale C single-seaters up from their Mont-de-Marsan home. Even with two Micas, two 2,000-litre drop tanks and a Scalp missile, the Rafale remains extremely agile.

still regularly deploy to the Middle East for combat operations, either to Al Dhafra to reinforce EC 1/7 'Provence', or to the French Air Force forward operating base in Jordan.

Capt Olivier took part in a two-month operational deployment in Jordan in early 2017. He spoke of his combat experience in Iraq and Syria. "Missions typically lasted about five hours, with pilots logging about 100 hours over the course of two

months," he said. This represented a sortie every three days, on average. The main advantage of Jordan compared to Al Dhafra lies in the drastic reduction in transit times to and from our operating areas.

"A return trip takes about three hours less than from Al Dhafra, with a corresponding reduction in airframe usage which leads to savings in operating costs and considerably less aircrew fatigue.

"The other advantage is the reduction of pressure on the tanker fleet. When I was in Jordan, Mosul East had been liberated from Daesh terrorists and most of the fighting focused on Mosul West. Weapon configurations are adjusted depending on the operational constraints, the requirements of the troops on the ground, and the anticipated weather conditions.

"For instance, if the weatherman tells us that it is more than likely that a cloud layer will prevent us from seeing targets on the ground, we will ask armourers to equip our Rafales with Hammer precision weapons that can be fired on GPS co-ordinates instead of GBU-12s that require laser guidance down to impact.

"We had enough Damocles targeting pods to equip all our Rafales and we usually took off with four bombs, Hammers or GBU-12s, three 2,000-litre fuel tanks, a varying number of Mica missiles and a full allocation of decoys and of 30mm ammo. We were sometimes asked to destroy hardened targets with a GBU-24 bomb fitted with a 2,000lb penetrator. Most of the time we flew as two-ships, even though planned air interdiction missions were occasionally flown as four-ships to attack specific targets spread over a wide area. Usually, we stayed three hours on station before heading back to base."

Hammer V1 and V4

The Hammer has become the preferred air-to-ground weapon within the Rafale community. It is now available in three variants each weighing a total of 340kg (750lb): SBU-38, with inertial/GPS guidance; SBU-64, with dual-mode inertial/GPS and infrared seeker; and SBU-54, with laser guidance added to the inertial/GPS kit. All these variants are collectively known as V1s when fitted with a standard-yield 500lb (227kg) class Mk82 bomb body, or V4s when equipped with a BLU-126 bomb body/low collateral damage weapon that can be used safely near friendly forces in urban areas. Capt Olivier said: "The Hammer has proven incredibly flexible in operational use. We can fire the Hammer from very low to very high level, from very short to very long stand-off distances, while remaining well clear of enemy air defences. In Iraq, we mostly fired

Unit badges



ECE 1/30 'Côte d'Argent'



EC 3/30 'Lorraine'



RC 2/30 'Normandie-Niemen'



Escadrille BR 128 (ECE 1/30 'Côte d'Argent')



Apart from the Rafale B/C and the Mirage 2000D (seen here), 'Côte d'Argent' has relinquished all other types and variants of combat aircraft. Last to go was the Mirage 2000-5F.

CFR, ETIAR & QRS

CFR 23/30 plays a central role within the Rafale community. The CFR, a pool of expertise in the field of technical training, has been created to provide theoretical education to French and foreign students. The ground-school syllabi focus on all the Rafale's systems, using state-of-the-art training aids.

Tuition is provided in French or in English language in purpose-built facilities.

ETIAR 61/30 brings together all the Rafale technical experts within a single entity to create a link between the French Air Force and the French Navy on one side, and the DGA and the industry on the other.

As part of a wider effort to support export contracts, Base Aérienne 118 at Mont-de-Marsan will soon accommodate the Qatari Rafale Squadron (QRS) that will train future Qatar Emiri Air Force (QEAF) pilots and maintainers. Training of the first Qatari engineers has already begun with the CFR and ESTA 15/30 'Chalosse'.

By the end of the year, the first QEAF pilots for the type will start flying from Mont-de-Marsan. It should be noted that, at the time of writing, the QRS had not yet received any official name or any traditional Armée de l'Air 'mcanographic' number.

them with the rocket motor off to reduce their time of flight and hit their targets within the shortest amount of time. Various types of delay or impact fuses are in service, allowing us to obtain different military effects.

"I clearly remember a combat situation in Syria. Daesh combatants were hiding in an abandoned house, in a small hamlet. They were surrounded, but their intensive and accurate fires had blocked the progress of friendlies. Under guidance of a US UAV [unmanned aerial vehicle] and after clearance by the French Red Card Holder who had quickly performed a CDE [collateral damage estimation], I released a SBU-54 Hammer V4 which hit its intended target with devastating precision, without any damage to the other houses in the village or to friendly forces only 60 metres away."

Armée de l'Air Rafale pilots deployed in Jordan fly about 15% of all sorties in darkness using night-vision goggles (NVGs). "At night, combat on the ground looks more impressive: you can clearly see the explosions if you are looking in the right direction because the NVGs' field of view is rather narrow. By contrast, gunfire and firing positions are still difficult to accurately localise."

Meteor on the horizon

The Direction Générale de l'Armement (DGA, Defence Procurement Agency), the

CEAM and the 30^e Escadre are actively preparing the entry into service of the F3R Standard and of the associated Meteor ramjet-propelled BVRAAM that will revolutionise the Rafale's air-to-air capabilities. Tactics used by fighter pilots will have to be adapted to take into account the Meteor's extreme engagement range.

Commandant Damien said: "Our tactics had already been modified after the introduction of the AESA [active electronically scanned array] radar but we are still tied by the range of the Mica missile. Thanks to the Meteor, we will be able to fire from very far away while keeping a high PK [probability of kill] to degrade the enemy's offensive and defensive capabilities without endangering ourselves. It's a totally new approach to air combat tactics. One problem will remain, however: targets will still have to be positively identified, but the Rafale's FSO will often allow us to address this problem. The firing mode symbology of BVR missiles will also change slightly and a modest training programme will have to be put in place for all aircrews."

The Meteor's engagement range is so great that it will pose new challenges to Rafale pilots. "We have launched a new study into the use of training ranges," stressed Lt Col Nicolas. "TSA43, the main training airspace in central France, is already too small for effective air-to-air training with the Mica missile, so you can easily imagine the problem with the Meteor. We are pushing hard to unite distinct and fragmented areas off Cazaux to create a single area that would prove ideal for long-range air-to-air training with the Meteor missile. It will not be that easy because a lot of operators, including the test pilots of the DGA EV [DGA Essais en Vol, Flight Test Centre] and the Alpha Jets of the 8^e Escadre are flying intensively in these areas."

After the transfer of EC 3/30 'Lorraine' from Al Dhafra to Mont-de-Marsan, the 30^e Escadre is now fully operational. The wing actively participates in homeland defence duties and in the global fight against terrorism while maintaining a remarkably high level of readiness, thanks to regular participation in exercises in France and abroad.



The Rafale can carry Hammer precision munitions on a triple launcher under each wing. Rafales are expending huge quantities of weapons in combat. Dassault Aviation

