

# RAFALE

## THE OMNIROLE FIGHTER

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## INTRODUCTION

Over the last decades, air forces have always been the first military components engaged in all crises or conflicts, from the Falklands to the Gulf, from Bosnia to Kosovo, from Afghanistan to Libya, and more recently Mali, the Central African Republic, Iraq and Syria.

Military aviation is undoubtedly the most strategic weapon today, both in terms of combat effectiveness and of critical technologies implemented.

In modern warfare, air dominance from day one is a must, so that air-to-ground and air-to-sea operations can be conducted safely and efficiently.

In the course of asymmetrical and counter-insurgency conflicts, the air arm also remains at the forefront of the military effort, its flexibility and firing power helping ensure that allied forces prevail.

The September 11 events have shown that, in peacetime, it is essential to secure the national airspace with easily deployable control and air defence assets.

The decisive place of the air component in modern warfare is demonstrated by the defence strategies decided by those nations who want to keep a leading role on the world stage.

**The *RAFALE*, with its “OMNIROLE” capabilities, is the right answer to the capability approach selected by an increasing number of governments.**

**It fully complies with the requirement to carry out the widest range of roles with the smallest number of aircraft.**

**The *RAFALE* participates in permanent “Quick Reaction Alert” (QRA) / air-defence / air sovereignty missions, power projection and deployments for external missions, deep strike missions, air support for ground forces, reconnaissance missions, pilot training sorties and nuclear deterrence duties.**

The Air Force single-seat *RAFALE C*, the Air Force two-seat *RAFALE B*, and the Navy single-seat *RAFALE M* feature maximum airframe and equipment commonality, and very similar mission capabilities.

**Lessons learned from the latest conflicts where air power was used, can be summarized into four overarching expectations about weapon systems by political decision makers:**

- **"Versatility"**, that is the capability, with the same system, to perform different missions,
- **"Interoperability"**, or the ability to fight in coalition with the allies, using common procedures and standards agreements, and collaborating and communicating in real-time with other systems,
- **"Flexibility"**, which can be illustrated by the ability to conduct several different missions in the course of the same sortie (**"OMNIROLE" capability**). With this capability, it is possible to switch instantly on the demand of a political decision maker, from a coercion mission ("strike force") to a preventive mission (a dissuasive low-altitude, high-speed "show of force"), or to a protection mission (Air Superiority) or even to cancel a mission until the last second (reversibility),
- **"Survivability"**, that is the capability to survive in a dense threat environment thanks to stealthiness and / or to advanced electronic warfare systems.

**The "OMNIROLE" RAFALE combines all these advantages: it is relevant against both traditional and asymmetrical threats, it addresses the emerging needs of the armed forces in a changing geopolitical context, and it remains at the forefront of technical innovation.**

Thanks to its versatility, its adaptability and its ability to meet all air mission requirements, the *RAFALE* is the "poster child" transformational fighter which provides a way forward to air forces confronted to the requirement of doing "more" with "less", in an ever-changing strategic and economic environment.

**Of a moderate size, yet extremely powerful, superbly agile and very discrete, the latest type of combat aircraft from *DASSAULT AVIATION* does not only integrate the largest and most modern range of sensors, it also multiplies their efficiency with the particularly performing "multi-sensor data fusion".**

## I. - “OMNIROLE” BY DESIGN

When the *RAFALE* programme was launched, the French Air Force and French Navy published a joint requirement for an omnirole aircraft that would have to replace the seven types of combat aircraft then in operation.

The new aircraft would have to be able to carry out a very wide range of missions:

- Air-defence / air-superiority/air policing,
- Anti-Access/Aera Denial,
- Reconnaissance,
- Close air support,
- Dynamic Targeting,
- Air-to-ground precision strike / interdiction,
- Anti-ship attacks,
- Nuclear deterrence,
- buddy-buddy refuelling.

These requirements were taken into account from the start of the *RAFALE*'s development, leading engineers to invent an aircraft which goes beyond the needs of each type of mission.

**Versatile and best in all categories of missions, the *RAFALE* is a true “Force Multiplier”.**

The *RAFALE* has exhibited a remarkable survivability rate during the latest French Air Force and Navy operations, thanks to an optimized airframe and to a wide range of smart and discrete sensors. It is slated to be the French armed forces prime combat aircraft until 2050 at least.

## II. - A FULLY OPTIMIZED AIRFRAME

**The *RAFALE*, a fully “OMNIROLE” fighter, is available in three variants:**

- the ***RAFALE C*** single-seater operated from land bases,
- the ***RAFALE M*** single-seater for carrier operations,
- the ***RAFALE B*** two-seater flown from land bases.

All three variants share a common airframe and a common mission system, the differences between naval and land versions being mainly limited to the undercarriage and to the arresting hook.

## **II-1 - Airframe - Materials - Flight control system**

The *RAFALE* features a delta wing with close-coupled canards. In-house research in computational fluid dynamics has shown the specific benefits of close coupling between the wings and the canards: it ensures a wide range of centre of gravity positions for all flight conditions, as well as excellent handling throughout the whole flight envelope.

The close-coupled canards / delta wing configuration is key to the combat performance of the *RAFALE*: even at high angle-of-attack, it remains fully agile, and its range performance in strike missions with heavy weapon loads is unmatched for such a compact design.

An advanced digital "Fly-by-Wire" (FBW) Flight Control System (FCS) provides for longitudinal stability and superior handling performance. The FCS is quadruple redundant with three digital channels and one separately designed analogue channel, with no mechanical back-up: design independence between channels is key to avoiding simultaneous anomalies on all channels.

The Flight Control System of the *RAFALE* attains the highest level of flight safety by leveraging on the extensive experience of *DASSAULT AVIATION* in Fly-by-Wire technology: **over one million flight hours without a single accident caused by the FCS.**

The *RAFALE* is safe and easy to fly in all flight regimes, featuring the same precise, yet benign handling performance in all load-out configurations throughout the flight envelope, allowing the pilot to focus on its mission.

The flight control system of the *RAFALE* offers auto flight in terrain following mode in all weather conditions, allowing the *RAFALE* to fly unobserved in the opponent's airspace: an important survivability factor in a high threat environment.

The radar cross section of the airframe has been kept to the lowest possible value by selecting the most adequate outer mould line and materials. Most of the stealth design features are classified, but some of them are clearly visible, such as the serrated patterns on the trailing edge of the wings and canards.

***DASSAULT AVIATION* has long been recognised for designing sturdy airframes that sustain over 30 years of operation without heavy structural upgrades.**

Thanks to the *DASSAULT AVIATION* unique know-how in finite element modelisation, the *RAFALE* airframe fatigue is monitored with the same gauge-free concept which has proved its worth on the *MIRAGE 2000* fleet.

Composite materials are extensively used in the *RAFALE* and they account for 70% of the wetted area. They also account for the 40% increase in the max take-off weight to empty weight ratio compared with traditional airframes built of aluminium and titanium.

## **II-2 - The M88 - a new generation engine**

**The M88-2 is a new-generation turbofan engine offering a high thrust-to-weight ratio with easy maintainability, high despatch reliability and lower operating costs.**

The M88-2 incorporates advanced technologies such as integrally bladed compressor disks ("blisks"), a low-pollution combustor with smoke-free emissions, single-crystal high-pressure turbine blades, ceramic coatings, and composite materials.

The M88-2 powerplant is rated at 10,971 lbs dry and 16,620 lbs with afterburner. It is equipped with redundant "Full Authority Digital Engine Control" (FADEC), which provides for carefree engine handling anywhere in the flight envelope: the throttle can be slammed from combat power to idle and back to combat power again, with less than three seconds from idle to full afterburner.

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, *SAFRAN AIRCRAFT ENGINE* 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 M88 is the subject of a constant improvement effort by *SAFRAN AIRCRAFT ENGINE*, leading to the latest M88-4E version, which builds on the TCO programme. This version, which offers a longer engine life, is now fully operational. Production deliveries began in 2012, and *RAFALE* aircraft now comes out of the production line fitted with M88-4Es.

### III. . - A WIDE RANGE OF SMART AND DISCRETE SENSORS

#### III-1 - RBE2 / AESA - “Active Electronically Scanned Array” radar

**The *RAFALE* is the first operational - and so far, the only - European combat aircraft to use an electronic scanning radar.** Developed by *THALES*, the *RBE2* radar has benefited from a massive research effort and from *THALES*' unmatched know-how based on past experience. Compared to radars with conventional antennas, unprecedented levels of situational awareness are attained with earlier detection and tracking of multiple targets.

**With its superior beam agility and its enormous computing power, the *RBE2* offers outstanding performance that cannot be replicated by mechanical scanning radars.**

In October 2012, the first *RAFALE* fighter equipped with an “Active Electronically Scanned Array” (AESA) *RBE2* radar was delivered to the French MoD. The AESA provides a wide range of functions:

- All-aspect look-up and look-down detection and tracking of multiple air targets for close combat and long-range interception, in all weather and in severe jamming environments,
- Ability to track targets in, or out of the search domain, bringing the ultimate advantage in air combat,
- Real time generation of three-dimensional maps for terrain-following above uncharted terrain in blind conditions. The *RAFALE* is the sole new generation combat aircraft to currently propose such a function,
- Real time generation of high resolution 2D ground maps for navigation updates and detection, identification and designation of ground targets,
- Detection and tracking of multiple naval targets.

**The *RBE2*-AESA is fully compatible in terms of detection range with the long range *METEOR* air-to-air missile. The AESA offers an unprecedented growth-potential for the future.**

**In those situations where discretion becomes the single most important tactical factor, the *RAFALE* can rely on several other sensor systems:**

### **III-2 - “Front Sector Optronics” - FSO**

Developed by *THALES*, the “Front Sector Optronics” (FSO) system is fully integrated into the aircraft. Operating in the optronic wavelengths, it is immune to radar jamming and it provides covert long-range detection and identification, high resolution angular tracking and laser range-finding for air, sea and ground targets.

**The FSO’s powerful TV sensor (cued by the *RAFALE*’s active and passive sensors) is truly valuable to positively identify targets in situations where a visual contact is required by the rules of engagement.**

### **III-3 - *SPECTRA* - internal Electronic Warfare suite**

**Jointly developed by *THALES* and *MBDA*, the *SPECTRA* internal “Electronic Warfare” (EW) system is the cornerstone of the *RAFALE*’s outstanding survivability against the latest airborne and ground threats.**

It is fully integrated with other systems in the aircraft, and it provides a multi-spectral threat warning capability against hostile radars, missiles and lasers.

The *SPECTRA* system carries out reliable long-range detection, identification and localisation of threats, allowing the pilot to instantly select the most effective defensive measures based on combinations of radar jamming, infrared or radar decoying and evasive manoeuvres.

The angular localisation performance of the *SPECTRA* sensors makes it possible to accurately locate ground threats in order to avoid them, or to target them for destruction with precision guided munitions.

The outstanding capability of *SPECTRA* regarding airborne threat localisation, is one of the keys of the *RAFALE*’s superior situational awareness.

Also instrumental in *SPECTRA*’s performance is a threat library that can be easily defined, integrated and updated on short notice by users in their own country, and in full autonomy.

*SPECTRA* includes a new generation missile warning system that offers increased detection performance against the latest threats.



### **III-4 - Net-centric capability**

The net-centric capability of the *RAFALE* hinges on its open architecture, its data fusion software and its compatibility with a variety of data links, which “plug” the *RAFALE* into the integrated battlespace.

A secure high-rate data link is provided to share data in combined air operations in real time with other aircraft in the formation, airborne and surface command and control centres, tactical air controllers or other friendly assets. The Link 16 data link is also available to those customers cleared to operate it.

As a net-centric capable asset, the *RAFALE* can exchange images. The *Rover* (“Remotely Operated Video Enhanced Receiver”) is an element of this capability which allows aircrews and forward air controllers on the ground to share videos or images of the target. It helps prevent blue-on-blue incidents and collateral damage, a decisive advantage in peacekeeping operations.

**The *RAFALE*'s interoperability, as part of a multinational operation, has been demonstrated on countless occasions, and Link 16 as well as non-NATO solutions is provided to meet various customers' requirements.**

### **III-5 - TALIOS- Targeting and Laser designation pod**

**The new *TALIOS* targeting and laser designator pod designed by *THALES*, brings full day and night surveillance and laser designation capability to the *RAFALE*, with metric precision. It permits laser-guided weapons to be delivered at stand-off range and altitude.**

The IR sensor of the *TALIOS* pod operates in the mid-wave infrared band and is coupled to a high-resolution new generation TV sensor.

***TALIOS* is interoperable with all existing laser-guided weapons.**

**III-6 - AREOS - Recce pod with Quick Analysis Capability**

For both strategic and tactical reconnaissance missions, the French Armed Forces have adopted the new generation *THALES AREOS* reconnaissance system for the *RAFALE*.

**As demonstrated in Libya, Mali, the Central African Republic, Iraq and Syria, this high-tech, day and night equipment can be used in a wide range of scenarios, at stand-off distances, from high to low altitudes.**

To shorten the intelligence gathering cycle and accelerate the tempo of operations, the *AREOS* pod is fitted with a data link which allows high resolution images to be transmitted back to military decision makers in real time.

**The outstanding performance of *AREOS* in stand-off reconnaissance makes it a sensor with a true strategic value.**

## IV. - THE SHEER POWER OF MULTISENSOR DATA FUSION

What makes the essential difference is the *RAFALE*'s "multi-sensor data fusion" process running on data provided by all the sensors of the aircraft.

In essence, the "multi-sensor data fusion" concept implemented into the *RAFALE* allows the pilot to act as a true "tactical decision maker", rather than being only a sensor operator.

The core of these enhanced capabilities of the *RAFALE* lies in a "Modular Data Processing Unit" (*MDPU*) incorporating "commercial off the shelf" (COTS) elements. It is composed of up to 19 flight "line-replaceable units" (LRUs), with 18 of them individually providing 50 times the processing power of a typical mission computer employed in previous generation fighters.

The *MDPU* is the cornerstone of the upgradeability of the *RAFALE*. It allows a seamless integration of new weapons and new capabilities to maintain the warfighting relevance of the *RAFALE* over the years as tactical requirements evolve, and as the computer industry keeps rolling out new generations of processors and software.

The "multi-sensor data fusion" provides a link between the battlespace surrounding the aircraft and the pilot's brain with its unique ability to grasp the outcome of tactical situations and make sensible decisions.

It hinges on the computing power of the *MDPU* to process data from the *RBE2-AESA* radar, the "Front Sector Optronics" (*FSO*) system, the *SPECTRA* EW system, the IFF, the *MICA* infrared seekers, and the data link.

### IV-1 – "Multi-sensor data fusion"

Implementation of the "multi-sensor data fusion" into the *RAFALE* translates into accurate, reliable and strong tracks, uncluttered displays, reduced pilot workload, quicker pilot response, and eventually into increased situational awareness.

It is a full automated process carried out in three steps:

1. Establishing consolidated track files and refining primary information provided by the sensors,
2. Overcoming individual sensor limitations related to wavelength / frequency, field of regard, angular and distance resolution, etc., by sharing track information received from all the sensors,
3. Assessing the confidence level of consolidated tracks, suppressing redundant track symbols and decluttering the displays.

#### **IV-2 - A unique “Man-Machine Interface” (MMI)**

DASSAULT AVIATION has developed a very easy to use pilot interface (MMI), combining the "Hands on Throttle and Stick" (HOTAS) control concept with touch screens.

It relies on a highly integrated suite of equipment with the following capabilities:

- **For short-term actions**, head-up flying using a wide-field-of-view “Head-up Display” (HUD),
- **For medium and long-term actions**, analysis of the tactical situation as a whole (the "big picture"), using a multi-image color “Head-Level Display” (HLD). The HLD picture is focused at the same distance as the HUD picture to allow for fast eye transitions between head-up and head-down displays and the external world's view,
- **Management of system resources** via the left and right colour touch screens.

The comprehensive design of the cockpit provides for everything that aircrews can expect from an “OMNIROLE” fighter: a wide field of view at the front, on both sides, and at the rear, a superior agility, an increased G-protection with 29° tilted seats, and an efficient air conditioning system demonstrated under all climates.

## V. - A FULL RANGE OF ADVANCED WEAPONS

The mission system of the **RAFALE** has the potential to integrate a variety of current and future armaments.

The **RAFALE** has been cleared to operate the following weapons:

- The **MICA** air-to-air “Beyond Visual Range” (BVR) interception, combat and self-defence missiles, in their IR (heat-seeking) and EM (active radar homing) versions. The **MICA** can be used within visual range (WVR) and beyond visual range (BVR).
- The **METEOR** very long-range air-to-air missile, The **METEOR** very long-range rocket and ram-jet powered air-to-air EM missile. Its combination with the Rafale weapon system is a real paradigm change in air to air affairs.
- The **HAMMER** (standing for Highly Agile and Manoeuvrable Munition Extended Range) modular, rocket-boosted air-to-ground precision guided weapon series, fitted with INS/GPS or INS/GPS/IIR (imaging infra-red) guidance kits, or with the upcoming INS/GPS/laser guidance kit.
- The **SCALP** long-range stand-off missile,
- The **AM39 EXOCET** anti-ship missile,
- **Laser-guided bombs** with different warheads from 500 lbs to 2,000 lbs
- **Classic bombs non guided**
- The 2500 rounds/min **NEXTER 30M791** 30 mm **internal cannon**, available on both single and two-seaters
- **Specifics armaments** selected by some clients.

The **RAFALE's** stores management system is Mil-Std-1760 compliant, which provides for easy integration of customer-selected weapons.

With its 10-tonne empty weight, the **RAFALE** is fitted with 14 hard points (13 on the **RAFALE M**). Five of them are capable of drop tanks and heavy ordnance. Total external load capacity is more than nine tonnes (20,000 lbs.). Hence, **RAFALE** can lift the equivalent of its own empty weight in payloads.

“Buddy-buddy” refuelling missions can be carried out in portions of the airspace out of reach of dedicated and vulnerable tanker aircraft.

With its outstanding load-carrying capability and its advanced mission system, the **RAFALE** can carry out both air-to-ground strikes, as well as air-to-air attacks and interceptions during the same sortie.

It is capable of performing several actions at the same time, such as firing air-to-air missiles during a very low altitude penetration phase: a clear demonstration of the true “**OMNIROLE**” capability and outstanding survivability of the **RAFALE**.

## VI. – MISSION READY WITH LOW OPERATING COSTS

### VI-1 - Built-in supportability

The *RAFALE* supportability and mission readiness claims are supported by the undisputed track record of the earlier generation of French fighters, such as the combat-proven *MIRAGE 2000*.

From the early beginning of the development phase, the French MoD assigned very stringent “integrated logistic support” (ILS) requirements to the *RAFALE* programme. “Computer aided design” (CAD) with the *Dassault Systèmes CATIA* software suite, concurrent engineering and bold technological choices ultimately produced an ILS system that exceeds the original supportability requirements.

**The following examples, selected from a range of unique and innovative features, demonstrate the advance in reliability, accessibility and maintainability brought by the *RAFALE*:**

- Based on 20 years plus of experience gained on the *MIRAGE 2000*, integrated testability of the Weapon Delivery and Navigation System (WDNS) has proven itself. Accordingly, it has been decided on the *RAFALE* to extend it to all aircraft systems. **Thanks to accurate and comprehensive testability features, it allows targeted replacements to be made on the flight line**, down to electronic circuit boards and specific components.
- **Human factors engineering work has been conducted with *CATIA*** in order to ensure the accessibility of the components within aircraft bays, so that all flight line operations can be carried out by a single technician. Special attention has been paid to minimizing the duration of these operations and the occurrence of errors.
- **The centralised armament safety system** makes all safety pins and last chance / end-of-runway actions unnecessary, minimising the risk of errors and accidents, and contributing to achieve an unbeatable “turn-around time” (TAT).
- **Precision manufacturing techniques together with the use of *CATIA*** eliminate time-consuming boresighting procedures following cannon, head-up display (HUD) or radar exchanges.
- With the *M88* engine, **it is no longer necessary to perform checks on an engine test bench** before reinstalling an engine on an aircraft. The *M88*'s groundbreaking design means that the engine can be changed and the aircraft can take off again within an hour.
- To allow the *RAFALE* the greatest possible autonomy during deployments, it requires only **minimum ground support equipment**:

- The *RAFALE* is fitted with an on-board oxygen generation system (OBOGS) which suppresses the need for liquid oxygen re-filling. Ground support equipment for the production and transportation of oxygen is no longer required
- Optronics are cooled by a closed-loop nitrogen circuit, which negates the need for a dedicated nitrogen supply chain.
- The built-in auxiliary power unit (APU) makes engine start-up possible even when no ground power cart is available.
- All ground support equipment is compact and foldable in order to be easily transportable by air. It can be used without external power. And only two types of carriages and cradles are necessary to perform all armament loading / unloading.

All of these maintainability features were validated from the development phase by French Navy and Air Force support specialists, and have demonstrated their reliability in combat during various operations. This ease of maintenance means that technicians can be trained quickly: Rafale conversion training and aircraft support was organized for an export client within a matter of weeks, **providing the client with the operating autonomy it needed to successfully deploy its fleet.**

## **VI-2 - An affordable high-tech fighter**

**Thanks to its outstanding reliability, the *RAFALE* has lower maintenance costs.**

- Its unique maintenance concept results in a **lighter scheduled maintenance plan** with less man-hours and a smaller number of maintenance technicians.
- **The *RAFALE* does not have to leave its operational base for maintenance purposes.** Unlike on other types of fighter aircraft, the *RAFALE* airframe and engine no longer require time-consuming and costly periodic depot-level inspections.
- **With more than 3,300 flight hours logged by *RAFALE* “fleet leaders”, no structural parts have been changed**, proving the robustness of the airframe and the maintenance concept.
- A case in point is the **modular *M88* engine**, made up of 21 modules: all maintenance and repair can be done by returning nothing more than modules or discrete parts to the depot or to the manufacturer. No balancing procedure and **no run-up check are necessary** before returning the engine to service.
- Failure-prone systems have been eliminated early on in the design process:
  - there is no airbrake
  - the air intakes have no moving parts
  - the ac generators do not have any constant speed drive (CSD)
  - and the refuelling probe is fixed in order to avoid any deployment or retraction problem.



This results in **reduced spares inventory, less man-hours and less ground support equipment.**

RAFALE deployments have confirmed that specialized infrastructures are unnecessary, even in cases of intensive use: maintenance can be performed outdoors or in a temporary shelter.

- Another source of reduction of the required spares inventory comes from the **constant standardisation approach during the design phase**,
  - The same part number is used at various locations on the airframe: this is made possible with precision airframe manufacturing which allows to suppress fitting and boresighting operations when installing airframe components.
  - Left-hand and right-hand parts are identical wherever applicable (i.e. foreplanes, FCS actuators).
  - Miscellaneous parts such as screws and electronic modules have also been included into the standardisation effort.
- The required spares inventory is further reduced by adapting the troubleshooting procedures to allow the **exchange of electronic circuit boards within “line replaceable units” (LRUs), rather than exchanging the LRUs**: this applies to the *RBE2* radar, the *SPECTRA* EW suite, the *MDPU* mission computer and to other equipment as well.
- **Special attention has been paid to accessibility issues**: for instance, the side-opening canopy facilitates the replacement of the ejection seat, so that two technicians can perform its removal in 10 minutes only.
- **No heavy test equipment is needed around the RAFALE on the flight line**: All checks at this level can be run by maintenance technicians on the aircraft itself.
- **No test bench is needed for the M88 engine**, a remarkable first in fighter aircraft maintenance.
- Based on significant experience in corrosion protection for carrier-based aircraft (*SUPER ETENDARD*) and maritime patrol aircraft (*ATLANTIC 1/ ATLANTIQUE 2*), *DASSAULT AVIATION* has developed new **advanced corrosion protection processes** which help drive down the cost of maintenance of the *RAFALE*: corrosion issues discovered during maintenance being the perfect “show stopper” which exceeds spending targets and delays the return of aircraft to service in the most unpredictable way.

## VII. “COMBAT PROVEN”

From 2007 to 2011, French Air Force and Navy *RAFALE* fighters were engaged in countless combat missions in Afghanistan where they demonstrated a very high proficiency and a tangible military value. The *AASM/HAMMER* precision-guided modular air-to-surface armament, *PAVEWAY* laser-guided bombs, and the 30 mm cannon were employed on many occasions, scoring direct hits with remarkable precision.

In 2011, French Air Force and French Navy *RAFALE* fighters were successfully engaged in coalition operations over Libya. They were the first fighters to operate over Benghazi and Tripoli, and they carried out the whole spectrum of missions the *RAFALE* was designed for: air-superiority, precision strikes with *HAMMERS* and laser-guided bombs, deep strike with *SCALP* cruise missiles, Intelligence, Surveillance, Tactical Acquisition and Reconnaissance (ISTAR) and Strike Coordination And Reconnaissance (SCAR). During the Libyan conflict, hundreds of targets – tanks, armoured vehicles, artillery emplacements, storage dumps, command centres and air-defence systems (SA-3 Goa and SA-8 Gecko fixed and mobile SAM launchers) – were hit with tremendous accuracy by *RAFALE* aircrews.

Since early 2013, French Air Force *RAFALES* have taken a leading role in Mali, helping destroy enemy infrastructure and support friendly troops in contact. Four *RAFALES* undertook the longest raid in French Air Force history, taking off from Saint-Dizier, in eastern France, and landing in N'Djamena, in Chad, after hitting 21 targets and spending no less than 9 h 35 min airborne. The French Air Force quickly set up a forward operating base in Chad, and the *RAFALE* detachment later grew to eight aircraft for operations in the Sahelo-Saharan strip and in the Central African Republic. This represented the first time the *RAFALE* had operated from a FOB in Africa. The type now routinely operates in Africa.

More recently, *RAFALES* were engaged in support of peace-keeping operations in the Central African Republic and in Iraq and Syria as part of a wide international coalition. In Iraq and Syria, *RAFALES* operate in difficult conditions, far from their bases, taking advantage of their huge operational range to strike distant targets with extreme accuracy. Air Force *RAFALES* now operate out of two countries in the area while their naval colleagues flew from the deck of nuclear carrier *Charles de Gaulle*, thus significantly increasing the number of combat aircraft in theatre.

## VIII. - THE WAY AHEAD

**RAFALE** capabilities are regularly updated in order to keep its combat relevance at the highest level with respect to its operational environment and return of experience from the French armed forces.

Since 2013, all **RAFALE** “*OMNIROLE*” fighters have been delivered with the “Active Electronically Scanned Array” (AESA) *RBE2* radar. They are also fitted with a new missile launch detector and the “Front Sector Optronics” updated unit (FSO-IT), offering improved target detection and identification performance.

Meanwhile, engineering work is already being done to further extend the air-to-air and air-to-ground capabilities and the connectivity of the **RAFALE** well into the next decade.

The on-going effort will ensure more robust detection, tracking and identification of emerging air-to-air threats, and increase the **RAFALE**’s survivability with new low observable modes and with the latest advances in electronic warfare systems.

Air-to-surface capabilities could benefit from assisted target recognition and enhanced sensor resolution, enabling the **RAFALE** to attack ever more elusive targets.

New materials could extend the life of engine components.

In October 2018, the qualification of the F3R standard was announced. The F3R standard is an evolution of the **RAFALE** “F3” standard. It is part of the on-going process to continuously improve the aircraft in line with operational requirements. It enabled Dassault Aviation to integrate the following equipment and weapons onto the **RAFALE**:

- The European *METEOR* long-range air-to-air missile produced by MBDA. This high-performance missile achieves maximum effectiveness thanks to the AESA radar which has equipped all production **RAFALE** aircraft delivered since mid-2013. The first guided firing of a *METEOR* was conducted from a **RAFALE** in April 2015. Qualification firing was performed in April 2017, paving the way to service entry in 2019.

- The Thales *TALIOS* new-generation targeting and laser designator pod. Primarily used for air-to-ground strikes, in daylight or darkness, this pod will further enhance the high degree of precision that the **RAFALE** has achieved since its first engagements.

F3R also includes upgrades to **RAFALE** sensors and to systems ensuring total interoperability.

In early 2019, the French Ministry of Defense announced the signature of the development contract of the new **RAFALE** F4 standard.

The policy underpinning the *RAFALE* program is continuous development to adapt the aircraft to changing needs, through a succession of standards. As early as 2023, a first version of the F4 standard will follow the F3R standard.

The F4 standard will incorporate operational experience feedback and enable continuous improvement of the *RAFALE* to be maintained.

Looking further ahead, the connectivity of the *RAFALE* will be further extended to keep it “plugged” into tomorrow’s integrated battlespace. New systems will be introduced to increase the fighter’s lethality against the latest air-defences and facilitate communication with higher echelons, other air assets, tactical units in the fields and surface combatants at sea.

**IX. - SPECIFICATIONS AND PERFORMANCE DATA****Dimensions**

Wing span.....10.90 m  
Length.....15.30 m  
Height..... 5.30 m

**Weight**

Overall empty weight .....10 t (22,000 lbs) class  
Max. take-off weight .....24.5 t (54,000 lbs)  
Fuel (internal).....4.7 t (10,300 lbs)  
Fuel (external).....up to 6.7 t (14,700 lbs)  
External load .....9.5 t (21,000 lbs)

**Store stations**

Total.....14  
Heavy - wet.....5

**Performance**

Max. thrust .....2 x 7.5 t  
Limit load factors .....- 3.2 g / + 9 g  
Max. speed .....M = 1.8 / 750 knots  
Approach speed .....less than 120 knots  
Landing ground run .....450 m (1,500 ft)  
Service ceiling .....50,000 ft

## BACKGROUND: *RAFALE* deployment history

Four batches of 13, 48, 59 and 60 aircraft have been ordered by the French MoD, totalling 132 aircraft for the French Air Force (63 *RAFALE* B two-seaters and 69 *RAFALE* C single-seaters) and 48 *RAFALE* M naval single-seaters for the French Navy. Egypt, Qatar and India have signed contracts for respectively 24, 36 and 36 *RAFALES*, bringing firm orders to 276 aircraft. By the end of December 2018, no less than 175 *RAFALES* had been delivered to the Armée de l'Air, the French Navy and Egypt.

Capabilities are developed incrementally, and released in packages ("standards"). The first release (standard F1) featured only air-to-air capabilities. It became operational in 2004 with the French Navy on *RAFALES* launched from the *Charles de Gaulle* nuclear aircraft-carrier during operation "Enduring Freedom".

The second capability release (standard F2) entered service in the French Air Force and in the French Navy in 2006. It provided the *RAFALE* with true "OMNIOLE" capabilities for air-to-air and air-to-ground missions.

Standard F3 is the current release. It has been qualified by the French MoD in 2008. It adds air reconnaissance with the *AREOS* recce pod, anti-ship with the *AM39 EXOCET* (implemented in *RAFALE* B, C, and M), and the nuclear capability with the *ASMPA*. The first *RAFALE* F3 was delivered to the Air Warfare Centre and Operational Test & Evaluation Centre (CEAM) of the French Air Force in mid-2008 at Mont-de-Marsan Air Base, in full accordance with the contracted delivery schedule.

Three French Navy and seven French Air Force units are equipped with the Rafale:

- Flottilles 11F, 12F et 17F at Landivisiau and on board carrier *Charles de Gaulle*;
- Escadron de Chasse 1/4 "Gascogne", at Saint-Dizier;
- Escadron de Chasse 2/4 "La Fayette", at Saint-Dizier;
- Escadron de Transformation Rafale 3/4 "Aquitaine", at Saint-Dizier;
- Escadron de Chasse et d'Expérimentation 1/30 "Côte d'Argent", at Mont-de-Marsan;
- Escadron de Chasse 2/30 "Normandie-Niemen", in Mont-de-Marsan;
- Escadron de Chasse 3/30 "Lorraine", at Mont-de-Marsan;
- Escadron de Chasse 1/7 "Provence" at Al Dhafra, in the United Arab Emirates.

The *RAFALE* regularly participates in numerous multinational exercises: Red Flag, ATLC, Tiger Meet, Maple Flag, Arctic Challenge, Pitch Black, Bold Quest.... The *RAFALE* M is the only non-US type of fighter cleared to operate from the decks of US carriers, using their catapults and their arresting gear.