Paris Air Show, June 2023

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, its reactivity and its precise firing power helping ensure that allied forces prevail.

The September 11 events have shown that, in peacetime and in times of crisis and war, it is essential to secure the national airspace with air-defence assets that can take off extremely rapidly to carry out air policing missions.

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 policing missions, nuclear deterrence duties, power projection and deployments for external missions, deep strike missions, air support for ground forces, reconnaissance missions, and pilot training sorties.

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.

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

- **"Versatility"**, that is the capability, with the same system, to perform different types of missions,

- **"Interoperability"**, or the ability to fight in coalition with allies, using common procedures and standards agreements, collaborating and communicating in real-time with other systems, and even sharing support systems and equipment,

- **"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"), to intelligence gathering 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 reduced signatures, to advanced electronic warfare systems, to the efficiency of its weapon system, to the reliability of its systems and to active security.

The *"OMNIROLE" RAFALE* combines all these advantages: its design makes its relevant against both traditional and asymmetrical threats, it addresses the emerging needs of the armed forces in a changing geopolitical and security context, and, with its endless growth potential, it constantly remains at the forefront of the technical innovation.

Thanks to its versatility, its adaptability and its ability to meet all air mission requirements, including for high intensity warfare, 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.

Compact, 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".

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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,**
- **Reconnaissance,**
- **Nuclear deterrence**,
- **Air-to-ground precision strike / interdiction,**
- **Close air support,**
- **Anti-ship attacks,**
- **buddy-buddy refuelling.**

These requirements were taken into account from the start of the *RAFALE's* development, leading engineers to invent an evolutive 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 an impressive combat efficiency and a remarkable survivability rate during the latest French Air and Space Force and French Navy operations, thanks to an optimised airframe and to a wide range of smart and discrete sensors. It is slated to remain a key combat aircraft asset for the French armed forces beyond 2050.

II. - A FULLY OPTIMISED 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.

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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 a key factor for the combat performance of the *RAFALE*: even at high angle-of-attack, it remains fully agile, and its range performance in strike missions even in the heaviest weapon configurations 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*'s advanced flight control system allows automatic flight in terrain following mode to be undertaken in all weather conditions, even with zero visibility, allowing the fighter to fly unobserved in the opponent's airspace, a decisive survivability factor in a high threat environment.

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. Building on *DASSAULT AVIATION*'s massive experience in the fields of flight controls and automatic terrain following, the AGCAS (Automatic Ground Collision Avoidance System) protects the aircraft and the crew in the most challenging situations, allowing the pilot to focus entirely on his mission.

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.

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II-2 - The *M88* - a compact and powerful 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 overhauls 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 AICRAFT 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 come out of the production line fitted with *M88-4Es*.

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

III-1 - *RBE2* / AESA - "Active Electronically Scanned Array" radar

The *RAFALE* is the first 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 the entire detection and tracking volume, 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,
- Presentation in real time to the crew of high resolution 2D ground maps for the detection, identification and designation of ground targets and for navigation updates,
- 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.

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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 and its weapon system. Operating in the optronic (visible and infrared) 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 allows stealthy targets to be detected and tracked, placing the *RAFALE* and its combat sphere at the centre of future engagements, while visually identifying targets at stand-off distances, as 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 has benefited from the introduction of a new generation missile warning system that offers increased detection performance against the latest threats.

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III-4 - Net-centric capability for collaborative combat

Thanks to its net-centric ability to share data, the *RAFALE* is totally connected to the other battlespace assets. This capability hinges on its open architecture that allows the simultaneous use of multiple broadband datalinks. The *RAFALE* can share tactical data in real time with other aircraft in the formation, and with airborne and surface command and control centres, tactical air controllers or other friendly assets.

As a net-centric capable asset, the *RAFALE* can exchange images. Thanks to the *Rover* ("Remotely Operated Video Enhanced Receiver") system, *RAFALE* aircrews can share videos or images of the target with forward air controllers on the ground, thus helping prevent blue-on-blue incidents and collateral damage, a decisive advantage in peacekeeping operations.

The *RAFALE* is equipped with a Link 16 or with a non-NATO customer-specific solution depending on the customers' requirements. Its interoperability, as part of a multinational operation, has been demonstrated on countless occasions.

The *RAFALE* will soon be equipped with a trans-horizon connectivity capability via a satellite link.

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

The *TALIOS* targeting and laser designator pod designed by *THALES* brings full day and night surveillance, identification 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. It also allows reconnaissance tasks to be undertaken, and will soon allow pre-planned recce missions to be conducted.

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III-6 – ***Helmet-mounted display***

The French Air and Space Force and the French Navy have chosen the *THALES SCORPION*® helmet-mounted display for their *RAFALE* fighters.

The *SCORPION*® is a high-tech system used to facilitate and accelerate target acquisition and designation.

It projects right in front of the eyes of the pilot and of the weapon system operator a symbology that considerably ameliorates the perception of the situation, especially outside the limits of the cockpit.

This helmet allows the simultaneous use of the helmet-mounted display and of night vision goggles.

Other types of helmet-mounted displays have been integrated into the *RAFALE* to meet the specific requirements of a number of export customers.

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IV. - THE SHEER POWER OF MULTISENSOR DATA FUSION

IV-1 – "Multi-sensor data fusion"

The process of fusion of all data provided by all onboard and offboard (wingmen, C²…) sensors is what makes the *RAFALE* pretty unique.

Implementation of the "multi-sensor data fusion" into the *RAFALE* translates into accurate, reliable and strong tracks and into an unambiguous perception of the evolving tactical situation. It helps reduce pilot workload, speed up pilot reactivity, and eventually increase situational awareness within and outside the boundaries of the combat sphere.

It is a fully 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.

The core of these enhanced capabilities of the *RAFALE* lies in a new "Modular Data Processing Unit" (*MDPU*) that handles the data fusion.

The *MDPU* is the cornerstone of the *RAFALE*'s upgradeability. 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.

It hinges on the computing power of the *MDPU* to process data from the *RBE2*-AESA electronic scanning radar, the "Front Sector Optronic" (*FSO*) system, the *SPECTRA* electronic warfare system, the IFF, the *MICA* infrared seekers, and the data broadcast by the other battlefield players via the data link.

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

DASSAULT AVIATION has developed a very easy to use and extremely ergonomic pilot interface (MMI) that includes the "Hands on Throttle and Stick" (HOTAS) concept.

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) and the helmet-mounted display,
- **For medium and long-term actions**, analysis of the tactical situation as a whole (the "big picture"), using a multi-image “Head-Level Display” (HLD). The HLD picture is focused at the same distance as the helmet-mounted display symbology to allow for fast eye transitions between the tactical displays in the cockpit and the external world,
- **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-tolerance with 29° tilted seats, and an efficient air conditioning system demonstrated under all climates.

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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 ***METEOR*** very long-range air-to-air missile,
- 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 ***HAMMER*** (standing for Highly Agile and Manoeuvrable Munition Extended Range) modular, rocket-boosted air-to-ground precision guided weapon series now available in 250 and 1000 kg variants. It is fitted with INS/GPS, INS/GPS/IIR (imaging infra-red) or INS/GPS/laser guidance kits at the front, and with a range augmentation kit at the rear.
- The ***SCALP*** long-range stand-off missile,
- The ***AM39 EXOCET*** anti-ship missile,
- **Laser-guided bombs** with different warheads and seekers
- **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 interoperability in the field of weapons is guaranteed by the Mil-Std-1760 compliance of the stores management system, 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 carrying heavy ordnance or drop tanks. Total external load capacity is more than nine tonnes (20,000 lbs.).

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

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With its outstanding load-carrying capability and its advanced mission system, the *RAFALE* can carry out 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*.

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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 ground-breaking 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**:

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- 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. Until recently, only two types of carriages and cradles were required to perform all armament loading / unloading. Now, only the Sefiam 1602^{e} is required for all the external stores, weapons, pods and pylons. Moreover, this advanced remotely-operated weapon loader is battery-powered and proves more accurate to position and operate, with fewer personnel.

All of these maintainability features were validated from the development phase by French Navy and Air and Space 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 can be organised for export clients, **providing them with the operating autonomy they need until the successful deployment of their 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 4,500 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

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- 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 specialised 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 engineers 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.

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VI-3 A strong commitment to increase availability

DASSAULT AVIATION is in charge of the support and maintenance contracts for all *DASSAULT AVIATION* aircraft in service in France and abroad (PBL = Performance Based Logistics).

- The founding principles of this process are that a single contractor is accountable for the contract and that the package of services and supplies are contracted over a long duration to guarantee long-term stability.
  These principles allow the State to obtain from the Industry a strong commitment for the long-term availability of its fleets and of its support systems and give *DASSAULT AVIATION* a long term vision to predict future needs and allocate sufficient resources to the various programmes.

- In the face of the successive crises we have recently gone through (Covid, war in Ukraine, raw material crisis and supply chain crisis), these contracts demonstrate their effectiveness every day. They allow the French State and the Industry to share a common global view and bring in a true capability to predict, anticipate and act thanks to a centralised analysis by the industrial prime contractor of all critical needs for the availability of the fleets. It also helps ensure the long term future of the defence industrial technological base.

- Through a reinforced technical and logistics support, including at the various air bases, close to the final users, *DASSAULT AVIATION* strives to increase combat fleets availability thanks to a centralised State-Industry technical platform, end-to-end logistics, availability/technical/logistics advisers, etc.

- As the company is the single contractor, *DASSAULT AVIATION* can meet new engagement scenarios, as demonstrated during high intensity warfare exercises. They are specifically adapted to each client, in France and abroad.

DASSAULT AVIATION's primary objective it to integrate, manage, anticipate and innovate in the field of operational support in order to, day after day, improve availability rates.

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VII. *"COMBAT PROVEN"*

From 2006 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 and Space 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 (fixed and mobile SAM launchers) – were hit with controlled 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.

***RAFALES* have actively been engaged in support of operations in Iraq and Syria as part of a wide international coalition, conducting long distance raid to fire *SCALP* cruise missiles.**
In Syria, *RAFALES* operate in difficult conditions, far from their bases, taking advantage of their huge operational range to strike distant targets with clinical accuracy. French Navy *RAFALES* flying from the deck of nuclear carrier *Charles de Gaulle* have allowed a significant increase in the number of combat aircraft in theatre.

The *RAFALE* takes an active role securing the NATO airspace (Enhanced Air Policing) in the Eastern part of Europe: after the Russian aggression in Ukraine, French Air and Space Force *RAFALE* fighters later supported by their French Navy counterparts conducted combat air patrol and were kept at short-notice readiness during the whole 2022/2023 winter in the Baltic States. The *RAFALE* was the only combat aircraft to demonstrate a capability to deploy without delay to two other neighbouring countries while still conducting its QRA mission.

The *RAFALE* has also demonstrated its ability to undertake long-duration missions (over 10 hours) and to deploy to overseas territories in the Pacific in less than 48 hours.

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VIII. - THE WAY AHEAD

The *RAFALE* is slated to become the sole type of combat aircraft operated by the French Air and Space Force and French Navy. Everything that is necessary to maintain its combat relevance will be undertaken.

The policy underpinning the *RAFALE* program is continuous development to adapt the aircraft to changing needs, through a succession of standards. In early 2019, the French Ministry of Defence announced the signature of the development contract of the new *RAFALE* F4 standard. It is part of the on-going process to continuously improve the aircraft in line with operational requirements.

In March 2023, the F4.1 Standard was qualified by the DGA, the French defence procurement agency. It encompasses the adoption of the following equipment and weapons onto the *RAFALE*:

- for the Front Sector Optronics, a new IRST that will advantageously supplement the *RAFALE*'s existing sensor suite, providing improved day/night passive target detection and identification capabilities against low signature aircraft through the infrared spectrum.

- for the RBE2 AESA radar, new Synthetic Aperture Radar (SAR) and Ground Mobile Target Indication and Tracking (GMTI/T) modes. These improvements significantly enhance the *RAFALE*'s ability to produce, in all weathers, high resolution radar imagery at very long range and to detect and track ground targets.

- new collaborative modes to increase the *RAFALE*'s detection, tracking and firing capabilities, thus significantly increasing again the lethality of the fighter.

- the *THALES SCORPION*® helmet-mounted display to accelerate the designation and acquisition of targets, and new, larger side cockpit displays that offer improved resolution.

- the *HAMMER* family now includes the 1000 kg variants that retain the modularity of the 250 kg variants thanks to various guidance kits affixed to various types of bomb bodies. The *HAMMER* 1000 kg brings new multitarget stand-off capabilities against larger or more hardened targets. The *RAFALE* can carry three *HAMMER* 1000 weapons while still offering a very long range.

The introduction of the F4.1 Standard has begun and new functionalities and equipment will be introduced over the course of the decade:

- the *MICA NG* (New Generation) air-to-air missile.

- major improvements in the field of connectivity, with a communication server, a Satcom satellite link and new software radios of the *CONTACT* (Communications numériques tactiques et de théâtre, digital tactical and theater-wide radio communications) family.

- a new digital jammer for the *SPECTRA* self-defence / electronic warfare suite.

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New developments have been launched to provide the *RAFALE* with new capabilities in the next decade. These developments will allow new, emerging threats to be defeated while improving the *RAFALE*'s survivability thanks to the adoption of new, low probability of interception modes and of a state-of-the-art electronic warfare suite. The integration of more and more powerful artificial intelligence algorithms will help the pilot manage the collaborative combat sphere during increasingly complex missions, when facing more and more elusive threats.

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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) without drag-chute

Service ceiling ..... ….50,000 ft

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BACKGROUND: *RAFALE* deployment history

Numerous batches of *RAFALE* fighters have been ordered by the French Armed Forces, covering a total of 192 aircraft for the French Air and Space Force and for the French Navy. Several export contracts have been signed with:
- Egypt, for a total of 55 *RAFALES*,
- India, for 36 *RAFALES,*
- Qatar, for 36 *RAFALES*,
- Greece, for 12 ex-French aircraft and 12 new-built *RAFALES*,
- Croatia, for 12 ex-French *RAFALES*,
- the United Arab Emirates, for 80 Standard F4 *RAFALES*,
- Indonesia, for 42 *RAFALES*.

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 French Navy *RAFALES* launching 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 *"OMNIROLE"* capabilities for air-to-air and air-to-ground missions.

Standard F3 is the current release. It was 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 French Air Force Operational Evaluation Centre (CEAM) in mid-2008 at Mont-de-Marsan Air Base, in full accordance with the contracted delivery schedule.

The first Standard F4 *RAFALE* fighters were delivered to both the French Air and Space Force and to the French Navy in early 2023. The entire French *RAFALE* fleet is now being brought up to the F4 Standard.

Seven French Air Force and three French Navy units are equipped with the *RAFALE*:
- 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,
- Flottilles 11F, 12F and 17F at Landivisiau and on board carrier *Charles de Gaulle*.

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.

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