

# AN UPDATE ON EUROFIGHTER MODERNIZATION



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Second Line of Defense

# An Update on Eurofighter Modernization

## SECOND LINE OF DEFENSE

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## INTRODUCTION

Both the UK and Italy will operate a mixed Eurofighter and F-35 fleet. Both have operated the Tornado, which is reaching the end of its service life. Both will sort through evolutions of the Eurofighter to encompass some of the mission sets for Tornado as the Tornado is retired and as the F-35 comes into the two fleets and provides the next surge for the re-working of air-led combat concepts of operations.

A key element of this transformation will be reworking the connectivity among air, sea and ground systems as well as shaping the weaponization approaches of joint and coalition forces.

In part, this is a Eurofighter transition whereby the radars are upgraded, and weapons added; in part this is the coming of the F-35 and its impact on reshaping air enabled combat operations.

And associated with this will be fundamental changes over time in C2, and the approach to strike operations.

The UK and Italy already fly together in operations through their use of Tornados and Eurofighters and have clearly shared combat learning with regard to the use of these platforms; as the F-35 comes on line this combat learning cycle will continue into the next generation of aircraft, and shaping ways to approach fifth generation warfare.

In effect, the dynamics of change for Italy and the UK will be a function of the intersection of four variables: the evolution of the Eurofighter; the impact of the F-35 and the global fleet of F-35s; changes in weaponization, and evolving C2 for strike and combat operations.

This report highlights a number of the dynamics of change in these two European combat forces associated with Eurofighter modernization. Much as the USN carrier air wing will alter its approach as F-35s come to the carrier deck, but modernize their Super Hornets to compliment and add lethality to the entire air wing, the RAF and the IAF will work interactive modernization of the two air platforms.

Continuing with the case of the USN carrier air wing, the dynamics of co-modernization can be better understood.

*The new carriers – the USS Ford or the British Carrier the Queen Elizabeth – bring new command capabilities and operational infrastructure which enhance their contributions to other combat capabilities in the battlespace.*

*The coming of the F-35 puts on the carrier deck a core capability to operate at the edge of the carrier's battlespace and can reach deep into the operational networks which support each cell of a honeycombed force.*

*The legacy assets will be modernized under the influence of synergy opportunities as well as fifth generation warfare dynamics to work more effectively in expanding the capabilities of a synergistic joint or coalition force.*

*Currently, the Super Hornets operating with the new Hawkeye are beginning to demonstrate the expanded reach of the carrier by delivering off boarding weapons capabilities, whereby one asset can direct the fire of another.*

<http://www.sldinfo.com/a-dominant-21st-century-fighting-force-the-role-of-the-large-deck-carrier/>

There is a clear analogy to what the British and Italians are in the process of doing as well, but this time with the Eurofighter instead of the Super Hornet. The excellent thrust to weight ratio of the aircraft makes it a solid platform going forward to expanding the payload/utility equation of the aircraft and its contribution to the performance of an air combat force.

According to Group Captain Paul Godfrey, the air boss of RAF Lossiemouth:

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“The modernization of Typhoon is underway and we have seen real progress in terms of electronic warfare, sensors and integration, and improvements in the human machine interface which is going to the cockpit more effective to operate the aircraft in the expanded battlespace with 5th gen assets.”

This report looks at the process of modernization highlighted by Group Captain Godfrey.

## RESHAPING CONCEPTS OF OPERATIONS: EUROFIGHTER, THE F-35, THE UK AND ITALY

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# Reshaping Con-Ops: Eurofighter and the F-35

UK and Italian Collaborative Opportunities



There is an inherent possibility that the UK and Italy could provide an important force for synergy in shaping concurrent approaches to evolving concepts of operations. Of course, this depends upon how effective their working relationship is and how effective cross-MOD, and cross-industrial relationships are in leveraging their working relationship.

And the two countries can play an important role as well with the European Air Group (EAG), the only multinational organization that focuses solely on airpower and its evolution. Recently, the EAG which has been a fundamental element of shaping the European Air Transport Command and the creation of the European Personnel Recovery Centre, has started to look for the Air Chiefs of the seven European Air Forces for whom they work at the integration of 4th and 5th generation aircraft. And the EAG has a Typhoon integration group as well.

Clearly, Italy and the UK can play an important role working through the challenges and the opportunities based on the evolution of Eurofighter while the F-35 is introduced.

And both will be operating F-35Bs from sea bases so can lead in shaping an understanding of how sea-based and land-based air can work together to great a significant operational effect as well.

## The Reconfiguration of Eurofighter

The twin dynamics of the retirement of the Tornado and the arrival of the F-35 pose a significant challenge as well as opportunity for both the UK and Italy. And shaping effective responses to this challenge can open prospects of innovation for other Eurofighter users as well.

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Although operational needs have kept moving the Tornado retirement date to the right, the scheduled date is 2019 for the RAF. Italy will be a bit further down the road and retire their Tornados with 5 years after the intended RAF retirement date.

As one UK Typhoon pilot put it: “There is a clear need to expand the effects of Typhoon operations and here the enhancement of its weapons package will be an important improvement.”

To take up some of this role the Eurofighter is being reconfigured to provide an enhanced capability for the ground attack role, over and above the austere level of Enhanced Paveway II integration that was used by the RAF during the Libya campaign. Paveway 4 is being integrated in PIE and then further weapon capability, primarily from MBDA, is being integrated, some of which are currently carried by Tornado.

The Tornado carries both Storm Shadow and Brimstone and both are being shaped for integration onboard the Eurofighter. The integration of the Storm Shadow on Typhoon is being driven in part by funding from the Middle East, notably Saudi Arabia that wants its Typhoons to have a cruise missile carrying capability, and when married with its new air tanking capability can enhance the strike range of its Typhoon force.

Brimstone 2 is designed to operate against maneuvering surface targets on land or sea. It is a low collateral, close air support weapon and has been combat proven by the RAF in both Afghanistan and Libya. It will greatly enhance the effect of the Eurofighter as well.

And the modernization package for the Eurofighter radar will allow the integration of Storm Shadow and Brimstone 2 to be more effective as well.

As Alan Tovey in the Daily Telegraph highlighted the synergy between weapons modernization and radar upgrades:

*The new radar will increase the range at which Typhoon pilots can identify potential targets, as well as allowing them to scan a 200-degree field of vision, greater than rival fighters, giving them a tactical advantage.*

*The addition of the radar will take Typhoon's capabilities ahead of other fourth-generation fighters such as France's Rafale and Sweden's Gripen, making it more attractive to export clients looking to upgrade their air forces.*

<http://www.telegraph.co.uk/finance/newsbysector/industry/11241622/Typhoon-jets-export-potential-lifted-by-new-E-Scan-radar.html>

The RAF has already caught a glimpse of what 5th generation aircraft can do for its Typhoons in training with the F-22s. The experience of training at Langley AFB was quite clear: and to quote the Typhoon pilot: “The situational awareness of the F-22 enhanced our survivability and lethality.”

And this pilot saw a future where the hard points on the Typhoon can evolve over time in terms of what it carries to support an initial fifth generation insertion fleet.

## The Impact of the F-35 Fleet

The F-35 is built from the ground up to be a 21st century multi-tasking aircraft.

In the words, of Rear Admiral Manazir, the head of USN Air Warfare:

*The F-35 is not an A (Attack) or an E (Electronic Warfare) or an F (Fighter); it is all of those. Earlier we had an F-14, an A-6 and an EA-6B and needed all three to do our job; now one airplane blends those capabilities and we can leverage that as we look at the integration of the other capabilities of the air wing we are developing.*

*Fifth generation is opening up so many possibilities that how we used to think about our capabilities is changing; how do we wring out the full capabilities of the air wing with the fifth generation as a catalyst for change?*

*Where it used to be platform-to-platform, we now have inherent in a single weapon system, the capability to fold in all those things that we used to think were single missions, like the fighter mission, like the attack mission, like the electronic warfare mission.*

*Those missions were given to separate platforms because we didn't have the way to fold them into a single platform. Now we have that capability to do that. So that fundamentally causes us to look at the way in which we do business in the future.*

<http://www.sldinfo.com/expanding-the-reach-of-the-integrated-strike-group-leveraging-fifth-generation-capabilities/>

The F-35 will function as a forward scout, a passive sensor strike force, a forward battle management fleet, and generally operate in ways, which will enable the rest of the strike forces to operate much more effectively.

As the head of the Italian Air Force, Lt. General Preziosa, has put it with regard to the impact of the F-35 on his legacy fleet in an earlier interview:

*One way to think about the way ahead is to continue to use 4th generation aircraft in surging mass to more classic airpower situations. One would use the F-35 as the key asset up against the distributed operational settings or for operations in denied air space. Another way to look at it will be to find ways to gain more synergy between the F-35 and the legacy fleet. How can we better utilize our older assets during the process where the F-35 fleet becomes a reality?*

*Shaping combinations of 4th generation with the F-35s will be a mix and match opportunity in tailoring airpower to the missions ahead.*

*This is a challenge; but it is a key task within which the F-35s will make the legacy aircraft more effective; and the 4th generation aircraft will add support and strike capabilities to an F-35 enabled air power force.*

<http://www.sldinfo.com/a-21st-century-approach-to-airpower-the-italian-air-force-and-the-f-35/>

He then added that when he was speaking of airpower, he was not simply speaking to the question of an air force.

*All of the services are enabled by airpower.*

*“The Navy is not defined by its ships but by its operational reach and this comes with airpower.*

*The Army tends to think of airpower in terms of their helicopters, but Afghanistan teaches a different lesson.*

*Continents are working together; why not the services?”*

## Working New Concepts of Operations

This puts an innovative challenge in front of the UK and Italian Air Forces – how best to work the relationships with a Eurofighter undergoing multi-mission modernization while the F-35 enables air and sea bases to operate with greater reach by linking up with the global fleet of F-35s?

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USMC and USN airpower leaders have both highlighted the importance of the F-35 fleet aspects in enhancing the range of the sea base, and its ability to work more effectively with land-based air assets. With the F-35Bs coming off of the amphibious fleet, the reach of the F-35Bs is enhanced by its integration with allied and joint F-35s sharing data, and decision-making. This is a key enabler for the tiltrotor enabled assault force, which comes off of today's amphibious ships.

For the British and Italians, the ability of the F-35 to tie in the sea base with land-based operations is an important consideration, as F-35Bs will fly off of the new Queen Elizabeth class carriers, as well as off of the smaller Italian carriers, more akin to the USN amphibious ships. Indeed, British strategic planners are already trying to think through the cross cutting of a new large aircraft carrier with a fifth generation strike capability which can allow aircraft on the seabase to integrate other at sea assets with land based ones.

Eurofighters forward deployed on land bases and operationally integrated with the F-35s can provide a lethal expansion of the strike capability of the overall force as the F-35 prioritizes targets and identifies strike support which the Eurofighters can provide as weapons carriers and launchers.

Shaping such integrated concepts of operations will require technological changes as well as cultural changes. The technical changes will be easier than the cultural ones, for sure. The technical dynamic is already under way in working F-22 relationships with the legacy fleet for the USAF.

As then head of the ACC, General Mike Hostage put it:

*I have got the command embarked on a full-court press to get a fourth to fifth, fifth to fourth capability that will need a combat cloud to be fully empowered, but it will then allow us to fundamentally change how the fourth generation platforms fight in addition to the fifth gen.*

*Without that back and forth communication, machine-to-machine, the fourth gen's going to have to do what they already do, they'll just leverage some of the capability that fifth gen — the SA the fifth gen can provide.*

*If I can get that machine-to-machine, now the fourth gen platform will begin to realize some of the benefits inherently at the tactical level that the fusion engines of the fifth generation aircraft provide.*

<http://www.sldinfo.com/training-for-air-combat-general-hostage-focuses-on-the-challenge-of-training-for-the-21st-century-fight/>

But there is a cultural shift as well which was highlighted in a dialogue between Secretary Wynne and Lt. Col. "Chip" Berke, the only operational F-22 and F-35 pilot in the world.

*The fifth generation pilots are going to have to be trained that firing first is not their core con-ops.*

*Giving validated targets to other shooters is the 'to be' condition.*

*This is reversing decades of training and experience where the instinct is to fire first and ask questions later.*

*With 5th generation aircraft you are setting up the air space for air dominance, and weapons are delivered from assets throughout the managed airspace.*

*Without the 5th generation aircraft you have to fight your way in and expend significant effort just trying to survive.*

*With the 5th generation aircraft you are setting up the grid to shape the offensive and defensive force to achieve the results which you seek.*

<http://www.sldinfo.com/shaping-a-new-pilot-culture-wynne-and-berke-discuss-the-way-ahead-for-airpower/>

## Evolving Weapons at the Vortex of the Change

Weapons have largely been considered as organic assets in terms of the weapon on which they have been integrated. They are integrated to a particular class of airplanes, or variant of that class, or to a particular type and class of subsurface or surface naval platforms.

Now one is looking at the effect being delivered kinetically and non-kinetically by a strike fleet. Fifth generation aircraft will accelerate an off-boarding shift where weapons can be on very different platforms as long as a target identified, and communicated to the strike asset. Over time, unmanned and manned assets will work the target acquisition and delivery dynamic.

But for now, a core challenge for the British and Italians is how to weaponize effectively their “integrated” Eurofighter and F-35 fleet?

Clearly missiles such as Storm Shadow, Brimstone and Meteor are part of the solution set but as solutions are found, a new phase in the evolution of weapons can be opened up whereby an aircraft like Eurofighter could carry much longer range strike weapons (such as SPEAR 3 destined for F-35), rather than focusing on the air-to-air battle as its primary mission.

In other words, the challenge and opportunity for Eurofighter will be to make a real transition to a more flexible strike role through the missiles it carries and can be directed organically or by the command center, which in the emergence of the F-35 will be distributed, not directed by a hub and spoke system as currently is done with the AWACS as the hub of the combat air operation.

For the F-35, the challenge will be to work through its role as a fleet, in operating forward to not only acquire targets, but to strike first passively, or by other means, and to be able to operate within innovative new C2 arrangements.

As USAF Colonel (Retired) Rob Evans put the challenge:

*If warfighters were to apply the same C2 approach used for traditional airpower to the F-35 they would really be missing the point of what the F-35 fleet can bring to the future fight.*

*In the future, they might task the F-35 fleet to operate in the battlespace and affect targets that they believe are important to support the commander’s strategy, but while those advanced fighters are out there, they can collaborate with other forces in the battlespace to support broader objectives.*

*The F-35 pilot could be given much broader authorities and wields much greater capabilities, so the tasks could be less specific and more broadly defined by mission type orders, based on the commander’s intent. He will have the ability to influence the battlespace not just within his specific package, but working with others in the battlespace against broader objectives.*

*Collaboration is greatly enhanced, and mutual support is driven to entirely new heights.*

*The F-35 pilot in the future becomes in some ways, an air battle manager, or a Peyton Manning-style quarterback who is really participating in a much more advanced offense, if you will, than did the aircrews of the legacy generation.*

*And going back to my comment about the convergence of planning and execution, and a warfighter’s ability to see and sense in the battlespace ... that’s only relevant if you take advantage of it, and the F-35 certainly allows warfighters to take advantage of it.*

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*You don't want to have a fifth-generation Air Force, shackled by a third-generation system of command and control.*

<http://www.sldinfo.com/thinking-airpower-leaders-and-preparing-the-way-for-the-f-35/>

### Leveraging Weapons Commonalities: The Case of the Meteor Missile

A good example of the potential cross benefit between legacy and fifth generation aircraft involves the impact of the Meteor missile upon those European forces operating both Eurofighter and F-35. With Meteor enabled for Eurofighter and F-35A/Bs, the opportunity for joint stockpiling, joint development and common training for a missile, which can be used on both platforms, is significant.

Working through how Eurofighters will work with F-35s is an important operational challenge for the Italian forces, but clearly having a common weapon in the form of Meteor can provide cost savings and amortization of support and training costs as well.

And the F-35 will be able to find targets for the Eurofighter, much like the USMC F-35s are already doing for the F-18s at Yuma or Beaufort Air Stations. This increases the survivability of both platforms, and gives increased utility and becomes a force-multiplier for Eurofighter in an air operation.

Italy is buying a mixed F-35B and F-35A fleet and it would make a great deal of sense for Italy to work with its partners in Alenia and MBDA to shape a common F-35 approach whereby Meteor can be used on both the A and the B.

Italy has invested significantly in Meteor development and currently manufactures the seeker near Naples. It is clear that cost savings can be obtained from pooling resources for buying, stockpiling and maintaining a common weapons capability for the F-35A, F-35B and Eurofighter.

A key element of any rethink about the future of 21st century airpower is clearly working coalition investments and experiences more effectively in building out common capabilities and shaping greater interoperability for operations. The F-35 provides a unique integrated air combat capability whereby coalitions of joint or allied F-35s can be supported in common.

And linking F-35s with evolving overall joint and coalition combat force will be a key opportunity as well. For Italy and the UK, as both F-35B operators, and Meteor partners, there is a clear opportunity to leverage joint experience and investments as well.

The UK is in a similar position with Italy (Eurofighter and F-35B operators), there is a natural partnership between the two in shaping a common policy with regard to Meteor integration on the F-35 and the residual ability to leverage the advantages from commonality.

Furthermore, this gives both the UK and Italy an increased operational edge and grants both nations a significant capability for coalition operations, which could be leverage to enhance their political influence in those coalition operations.

UK and Italian leadership on Meteor would also act as a catalyst towards other JSF users interested in this capability. It is a case of each country's natural alliances reinforcing the others.

There are also broader industrial benefits worth considering as well. It is clear that the global F-35 enterprise draws upon a global supply chain; what is not fully realized is that next generation weaponization can both benefit from the F-35 global enterprise and empower legacy aircraft at the same time.

With regard to Italy, Meteor's integration on both F-35 and Eurofighter offers the opportunity to improve the overall Italian industrial return across the F-35 program and reinforces the investment plan for the Final Assembly and Check Out (FACO) facility; expanding the FACO's role to include the weapon aspects of sustainment is fully in keeping with the vision for a Regional Support Center as clearly articulated by the Italian Government.

In short, developing new weapons for combat aircraft is clearly a core necessity moving forward. The Eurofighter and F-35 sharing the benefits of a next generation missile like the Meteor can enhance as well ways to ensure that these two aircraft work seamlessly across the battlespace for 21st century operations.

## THE ITALIAN AIR FORCE SHAPES A WAY AHEAD: THE PERSPECTIVE OF THE ITALIAN CHIEF OF STAFF

Excerpts from the Full Interview:

At the beginning of the 20<sup>th</sup> Century, Italy was a pioneer in combat aviation. Although different at the beginning of the 21<sup>st</sup> century, Italy has again emerged as an important player in military aviation. They are key players in the two key 21<sup>st</sup> century multinational military aviation industrial coalitions, Eurofighter and F-35, as well as establishing a center of excellence for pilot training along with introducing one of the best 21<sup>st</sup> century trainers, the Aermacchi M-346.

In late September, in the famous Italian Air Ministry building in the center of Rome, *Second Line of Defense* conducted its third interview with Lt. General Preziosa, the Chief of Staff of the Italian Air Force. Italy is the only NATO Air Force to have performed all NATO Interim Air Policing (IAP) missions in Slovenia, Albania, Iceland and the Baltic.

According to Lt. General Preziosa, with regard to the Italian role in the NATO air policing mission earlier this year:

"We had four aircraft operational 24/7 for the Baltic Air Policing mission, but that meant we had to have other aircraft available, more than 100 personnel operating locally and reachback to Italy for logistical support. This also required us to pay attention to air defense and provide modern air defense support to our Eurofighters.

We use a messaging system to support our Eurofighters and not radio communication from the ground; the Lithuanians did not have such a system, so we needed to install it and operate during our time in the Baltic Air Policing mission."

This put the Italians up on a regular basis against Russian aircraft, where the Russians test and probe Western defenses and various capabilities, including electronic warfare systems.

Italy has also recently announced a successful negotiation with Kuwait to buy 28 Eurofighters (22 single seaters and 6 double seaters), which was negotiated directly by the Italian state with Kuwait.

With regard to the Kuwait sale, Preziosa noted that the Kuwaitis were clearly aware of the work, which the RAF and Italy were doing to ensure that F-35 and Eurofighter would be able to work together. They also focused upon the training infrastructure in Italy and the maturity of the Eurofighter support structure as important elements of down selecting the Eurofighter for the Kuwaiti Air Force. And, of course, the Saudi use of Eurofighter and their own positive views of the Saudi experience in current Middle Eastern operations played a part as well.....

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He also discussed the key relationship with the Royal Air Force, for both Air Forces are working a similar transition. For Lt. General Preziosa, the close relationship with the RAF was important in working through the way ahead with regard both to Eurofighter modernization and working with the F-35.

“There is no point in having to repeat lessons which have been learned by one Air Force or the other.”

For Lt. General Preziosa, the Eurofighter is an excellent aircraft but will be modified to work more effectively with the F-35 in operating in the 21<sup>st</sup> century battlespace. The payload evolution of the Eurofighter is significant, and weapons modernization will support both the F-35 and the Eurofighter in providing new tools for the tool kit for air operations.

In effect, the two planes will work together in shaping along with other allied assets a 21<sup>st</sup> century air combat choreography within which weapons modernization and other assets will be woven in over time for the U.S. and its allies to remain ahead in the inevitable competition with adversaries.....

## ITALIAN AIRPOWER MODERNIZATION: A DISCUSSION WITH THE EDITOR OF RIVISTA ITALIANA DIFESA

Recently *Rivista Italiana Difesa* (RID) published one of the most comprehensive looks at the F-35 as a combat capability published in any language; but this was published in Italian as a Special Supplement. In an interview with the editor of RID and the author of the report, he provided an overview of the synergy of the F-35 with the Eurofighter and the evolution of Italian airpower.

**Question: You are the editor of RID.**

**Could you describe the focus of your magazine and your background as well?**

Pietro Batacchi: *Rivista Italiana Difesa* is the leading Defense magazine in Italy and one of the most important in Europe. It deals with the full spectrum of Defense issues and is well established in Italian Defense community after 33 years of editorial activity.

Regarding myself, I have a degree in political science. After the University I attended a Strategic Study Advanced Course at the Defense High Studies Center in Rome and then I got a PHD in International Relations.

**Question: From your vantage point, you are in a good position to describe Italian, European and global military aerospace trends.**

**What are the major findings and conclusions of your Special Report?**

Pietro Batacchi: The main finding of my study on the F-35 was very simple. The F-35 provides the Italian military with a strategic instrument/aircraft able to penetrate not only permissive but disputed airspace thanks to its low observability or to ensure greater operational flexibility allowed by its “net-centric” and open architecture.

In addition we can talk about the great internal fuel capability that offers to the aircraft an enormous autonomy and operation persistence, much greater than the ones normally experienced by a fighter aircraft.

Due to all these reasons the aircraft manufactured by Lockheed Martin gives to the political leaders the opportunity to join a conflict from the very early stages, with a clear political and strategic return, and to increase their diplomatic options.

**Question: For both the UK and Italy, the shaping of a 21st century air combat force is being built around the introduction of the F-35 twined with the modernization of the Eurofighter and both the RAF and the IAF are working with each other to shape a path forward.**

**How would you describe the role of Eurofighter modernization and its interaction with the coming of the F-35 fleet?**

Pietro Batacchi: The modernization of the Eurofighter can be considered incremental. The aircraft was born as a pure air superiority fighter designed to deal with the threats of the Russian aircraft during the Cold War.

Over the years the requirements have been changed and today, thanks, for example, to the Phase 1 Enhancement Program (P1E), the Eurofighter Typhoon has evolved in a modern swing role aircraft able to find and attack ground targets.

This evolution process will continue with P2E, including the integration of the Meteor and Storm Shadow missiles, and with the integration of the CAPTOR-E AESA radar in the next years that will definitively complete the growth of the aircraft.

Ultimately, the two aircraft can be considered highly complementary and perfectly tailored to a military more and more expeditionary and projection oriented as the Italian one.

After all, when the Italian Defence White Paper talks about a "Regional Full Spectrum" military, it means a military able to intervene in all the Mediterranean scenario also in high intensity conflicts under which both F-35 and Eurofighter Typhoon are best suited if employed together.

**Question: And the Eurofighter recently has seen a success in the sale of aircraft to Kuwait. The agreement was negotiated by the Italian government.**

**The Italian Air Force has operated frequently from Kuwait.**

**What role do you see the IAF's impact on Kuwait might have had on the Kuwaiti decision?**

Pietro Batacchi: The Italian Air Force and Ministry of Defense in general had a great role during the bargaining bringing to the successful outcome of the Kuwait's campaign. As Italian Defense industry can confirm the Italian Defense was very important in providing it with a great support and exploiting the channels with Kuwait opened since the first Gulf War in 1991 joined also by the Italian military and Air Force.

**Question: From an industrial point of view, the modernization of a legacy asset like Eurofighter along with the innovations driven by shaping a fifth generation warfare capability associated with the F-35 fleet will provide a rich area to shape new approaches to capabilities going forward.**

**How do you see this interactive combat modernization space shaping up going forward?**

Pietro Batacchi: Also regarding the industrial point of view, the two aircraft can be considered fully complementary. The Eurofighter provided the Italian and the European industry more in general with a high quality involvement as the program allowed Italy to develop new technologies that before were not available in Europe.

At the same time, the industrial participation in the F-35 program brought in Italy an advanced industrial process in which all the components and parts have to be perfectly produced and in which the tolerances must be more than narrow. This aspect was fundamental for the Italian industry which now can replicate this process

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in the future aeronautical programs starting, for example, from a new fighter aircraft that could be manned or unmanned.

**Notably this is true with regard to missiles. Indeed, the first new fifth generation missile is Meteor which is clearly the first of several new missiles to follow drawing off the fifth generation warfare transition.**

**How do you see the future of the evolution of missiles driven by the evolving concepts of operations?**

Pietro Batacchi: The Meteor missile will provide Eurofighter with Beyond Visual Range capability that is crucial in the modern air-to-air combat scenarios where the probability of the so called dog fight are more and more lower. In addition we have to consider the importance of the advanced data link that together with new open architecture of an air-to-air missile can allow to change mission and target during the flight and get in this way greater flexibility in the engagement.

**Question: Finally, Italy is well positioned in terms of building and supporting 21st century combat forces.**

**At Cameri you are building the new generation aircraft. Italy is also building some additional Eurofighters but over the next decade the effort will focus on MRO or sustainment and modernization of the Eurofighter fleet.**

**And Italy has a 21st century fighter, the Aeromachi M-346.**

**How do you see the Italian industrial position and its advantages moving forward?**

Pietro Batacchi: The Italian aerospace industry is well positioned for the future challenges. It gained a great experience during the past with important program such as the Tornado, the Eurofighter and now with the F-35. In addition the Italian defense industry has a long standing tradition in some excellence sectors as, for example, in the trainer sector as you mentioned or in the missile sector or in the electronic warfare systems field. So the Italian industry has all the competencies needed to see to the future with optimism and to continue to play a key role in Europe.

## ROYAL AIR FORCE OPERATIONS AND EVOLVING CONCEPTS OF OPERATIONS

Excerpts from full interview follow:

During a visit to Europe in October 2015, there was a chance to visit with senior RAF officers and to discuss RAF operations as well as the double transition with Typhoon modernization as well as the introduction of the F-35. For the RAF, it is really a triple transition as the new Queen Elizabeth carriers will be the complimentary platform to the F-35B.

Coningsby is also one of two Quick Reaction Alert locations to deal with all threats to British air space whether they are potential terrorists or resurgent Russians.

And indeed, this activity has ramped up significantly in the past few years, consuming resources and focusing the attention of the RAF on this core task.

XI Squadron will be involved in an exercise at Langley Air Force Base later this year with Rafales and F-22s, which is a further step in the direction of working the evolving concept of operations for fifth generation enabled air combat operations.

And Group Captain Godfrey is the first F-35 transition officer commanding an RAF Typhoon base and clearly will be looking at ways to shape the transitional dynamics.

**Question: The RAF has had to focus more on British airspace protection with both the terrorist threat and the upsurge in Russian airspace activity impacting on the UK.**

**What role has the Quick Reaction Alert force played in this process?**

Answer: At RAF Coningsby, we are more focused on the terrorist threat whereas at RAF Lossiemouth we focus more on the Russian activities.

But the demand on resources is significant. Everything at each base, from equipment, to logistics to training is focused on maintaining the alert posture and ensuring we are ready 24/7.

**Question: With regard to the Russians, what have they been doing in terms of flying into areas surrounding the UK?**

Answer: Russian aircraft haven't entered UK airspace, but have been escorted by RAF aircraft in international airspace within the UK's area of interest.

We've seen a wide range of Long Range Aviation aircraft, including Tu-95 Bears, Tu-22 Backfires and Tu-165 Blackjacks, with the different variants of Bear being most common.

In the past couple of years, Russian activity has increased and we have therefore adapted our operating procedures to ensure that we can deal with the various Russian aircraft and their activities once inside the UK's area of interest.

**Question: There is a level of activity we have not seen since the Cold War; but the pilots who flew those missions are not doing them now.**

**Do you think the Russian pilots today actually understand the rules of the old game or are they pushing the envelope?**

Answer: That is a good question.

We do have some residual Cold War experience in the Typhoon force from a UK perspective and, although LRA activity dropped off in the early 2000s, they have been visiting sporadically over the years, so we have always kept up the knowledge and procedures; I don't know what it's like in Russian LRA force, but they have been through a modernization program and are clearly getting more proficient at what they do.

However, you are still not entirely sure what is going on in the minds of their pilots, when you intercept them.....

**Question: Godders, you have been involved with preparing the F-35 transition and now will return to Typhoons, with your posting to RAF Lossiemouth. You are the first Typhoon station commander with in-depth F-35-knowledge and are well placed to work the transition with Typhoon.**

**What is your sense of the way ahead?**

Group Captain Paul Godfrey: The penny dropped for me three years ago when I flew Typhoon with USAF F-22s on Exercise Western Zephyr at Langley AFB.

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This was the first time I'd seen and operated within a 4th/5th gen fighter mix and I saw exactly how powerful it could be.

The F-22s in the formation demonstrably made the Typhoons more lethal and, more importantly, more survivable.

**I then brought this experience into the UK F-35 entry into service program, meaning that we could concentrate on strengths that a fifth gen platform brings to everything else that you've got, whether that is the fighter, tanker aircraft, AWACs, or UAVs.**

The F-35 has had a troubled history in terms of the press, but for us, it is a revolutionary capability that perfectly suits the current and planned UK capabilities.

It has also been very interesting working closely with the USMC who have also seen the F-35 for what it can do and have disregarded the negative press and just got on with it.

At the same time, the modernization of Typhoon is underway and we have seen real progress in terms of electronic warfare, sensors and integration, and improvements in the human machine interface which is going to the cockpit more effective to operate the aircraft in the expanded battlespace with 5th gen assets.....

**Question: How important is the shift from Tornado to Typhoon in terms of Typhoon subsuming the missions of the former?**

Wing Commander Matt Peterson: The key is to understand the shift from an air-to-air focused platform to a true swing-role capability.

We must expand our horizons and think about them as a system rather than individual parts.

The combination of Typhoon and 5th generation capabilities is undeniably an example of the sum being greater than the parts.

Fifth generation systems are unique, and Typhoon is a different type of aircraft, but working through how to leverage both is a key to the evolution of our approach.

Combined together, we will see significant force multiplication. We must expand our horizon, and think about them as a system as a whole, which might have one or two different platforms in operation and then using those capabilities of each for a greater effect.

We also need to shape a different mindset as we work the new combat approach.

The F-35 is the newer platform and revolutionary in many respects.

The Eurofighter is a high-end 4th gen capability undergoing significant modernization, but when they fly together they fly as a team, and it is important for pilots to understand this in order to get the combat choreography right.

**Question: The Italian Air Force along with the RAF is working through the Typhoon and F-35 double transition.**

**What is the impact of that dynamic?**

Group Captain Paul Godfrey: In effect, the emergence of the F-35 global fleet provides a significant means to expand our reach, with the emergence in some ways of what you might call and Euro-Med capability. We

are working new relationships in the region and forging even closer working relationships to sharpen new ways to plan and execute coalition missions. The Italians are a very important partner in these efforts.

Wing Commander Matt Peterson: It is clearly important to exercise with a variety of potential coalition partners.

The invaluable lessons learned during exercises, like the forthcoming one in Langley, are a huge force multiplier and enable coalition capabilities to integrate and assimilate before they are employed on operations in the fluid contemporary strategic environment....

## AN UPDATE ON EUROFIGHTER MODERNIZATION: THE PERSPECTIVE OF A FORMER ITALIAN AIR FORCE PILOT

During a visit to Europe in the early Fall of 2015, one of the subjects of interest was the cross cutting modernization of the Eurofighter with the introduction of the F-35. Clearly, the Royal Air Force and the Italian Air Force are key players in this process, but during a visit Munich there was an opportunity to talk with some key Eurofighter personnel as well.

One of those personnel was Raffaele Beltrame who is the Eurofighter Project Test Pilot for Airbus Defence and Space in Germany. Previously, he was a Tornado pilot in the Italian Air Force and clearly understands a key element of the Eurofighter transition, namely, the subsuming of Tornado missions within the Eurofighter for the RAF and the IAF. He has been involved with Eurofighter since the introduction of the plane to the Italian Air Force in 2004.

He highlighted that with the Tornado they could load 2 Paveway GBUs but with Eurofighter they can load 6, and clearly from this standpoint, the aircraft represents an upgrade.

The upgrade process and the evolution of the Eurofighter was discussed by Beltrame, in part, through the demonstration of developments in the cockpit simulator. And the cockpit simulator is tied in with the situation room at the Eurofighter facility in Munich, where scenarios are worked through by the pilot in a virtual operational environment.

Beltrame provided a number of key takeaways from our discussion.

First, the inclusion of the air to ground mission sets in the Eurofighter are progressing well. This was not part of the original 1990s design but modifications of the Eurofighter are allowing for this evolution. The program has implemented a number of aerodynamic improvements to the aircraft which allow for a better execution of both the air to air and air to ground mission sets.

<http://www.sldinfo.com/upgrading-and-modernizing-the-eurofighter-aerodynamic-upgrades/>

Second, given the ability to hold six air to air missiles along with the air to ground missiles, the pilot can be focused on the air to ground but have available systems to protect himself in the air against intruders.

Third, the organic capabilities of the aircraft are expanding, and with the expansion of capabilities, the effort is to improve the capability of the pilot to manage those expanded tasks. This is being done by enhanced automation, the use of voice commands, and an improved helmet and pilot interface to manage the information more effectively for the targeting task.

Fourth, the Eurofighter is designed to work in a network. The further evolution of the Eurofighter is focused on improving its ability to work in a network,, notably one being reshaped by the introduction of the F-35.

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For Beltrame, a major change in air combat was underway, whereby the classical C2 structure makes no sense with the coming of the F-35 and the expanded capability of the Eurofighter to execute tasks. As he put it: “A hierarchy certainly remains; but he who has the best situational awareness should be directing the execution of the missions.”

He also saw a clear trend to enhance the ability of the ability to leverage automated systems to can better domain knowledge to make better decisions, and this was clearly part of the evolving air combat capabilities of 21<sup>st</sup> century forces, which in turn drove demand for a different kind of C2 system as well.

He focused as well on the challenge for air power leaders to command a fleet of F-35s and Eurofighters, which would be capable of mixed mission operations over the spectrum of warfare.

The shift from limited and sequential targeting to dynamic targeting of an interactive fleet would be a major challenge moving forward. In other words, shaping an effective C2 system for a dynamic fleet operating in a fluid battlespace has little in common with the slow motion war which we have experienced over the past 20 years.

## THE WAY AHEAD FOR EUROFIGHTER MODERNIZATION: A DISCUSSION WITH PAUL SMITH

The Eurofighter is a clear player in shaping European and global air forces. It has reached critical mass and will be modernized through its operational life to work with new air assets and to deal with the evolving threat environment.

The program currently has seven customers, 599 committed aircraft orders, 446 deliveries to date, more than 300,000 flying hours with 100,000 employees and more than 400 companies involved in the program. This kind of critical mass provides a solid foundation for the evolution of the program.

The Eurofighter consortium has launched a series of capability enhancements as part of a Capability Roadmap, which is designed to increase the combat effectiveness of the fighter. It has evolved from an air defense aircraft to a multi-mission aircraft, notably with the addition of new weapons to subsume Tornado functions and to incorporate a new AESA radar as well as cockpit and linkage improvements as well. And the Maintenance, Repair and Overhaul (MRO) business also ensures that Eurofighter will continue to be a solid program for the next few decades.

Paul Smith, formerly of the Royal Air Force and now with Eurofighter provided an RAF derived perspective on how to think about the transition. Smith is an experienced pilot with more than 3,000 fast jet flight hours with 600 of those hours flying Typhoon. He worked during his time with the RAF for four years working the Operational Test and Evaluation Program for the RAF. And in the period prior to his retirement he worked for Air Vice Marshal Gary Waterfall when he was at the Typhoon Force Headquarters.

At Eurofighter, Paul Smith works on the modernization program, notably with regard coordinating customer input into cockpit design.

**Question: Clearly, as you are looking at Eurofighter modernization, notably for the British and Italian customers, there is a clear focus on working Eurofighter with F-35.**

**How are you approaching that dynamic?**

Paul Smith: If you look at both of their future planned force structures, then their combat mass both in terms of number of aircraft platforms and individual aircraft weapon loadout will be Typhoon. Three-quarters of the

RAF will be Typhoon going forward into the 30s and 40s and, and somewhere between, around 100 or 50 or so F-35s.

They will be complimentary, with the aircraft contributing related but different capabilities. And it's important that they are absolutely networked.

When considering modernization, one can start with the basic character of the aircraft, with a strong, light airframe with significant thrust to weight ratio. This allows the aircraft to carry a significant weapons load out at Mach 1.5. The kinematics, and the sensor integration in the aircraft have allowed the aircraft to evolve from its initial air defense and air dominance role to a multi-mission role. The aircraft delivers a good integrated picture to the pilot in an effective and simple manner to guide his actions.

It is a different type of sensor integration from the F-35, but we are upgrading our sensors over time, and are clearly doing so with direct relevance to working changes in the cockpit and are also upgrading our helmet mounted display to further enhance pilot decision making.

**Question: How would you describe the approach to enhanced air-to-ground attack in the aircraft which is important to the RAF and IAF in subsuming Tornado functions?**

Paul Smith: With new sensors and new weapons, we are expanding the weapons envelope to support a broader variety of missions. We are carrying flexible weapon loads to enable us to maintain our air-to-air functions while adding ground attack weapons. We have 6 dedicated AAM stations and currently can simultaneously carry up to 6 PGMs of 500, 1000 or 2000lb class.

The weapons load-out for such an integrated mission by 2018 will include 4 Paveway IVs, 6 Brimstone 2s, 6 AAMs, with a 27 mm Mauser and two 1000L fuel tanks and one Laser Designator Pod or LDP. This will be further augmented by the integration of SDB II and the introduction of the SPEAR next generation precision surface attack missile.

And with the ability to carry Storm Shadow or Taurus, the Eurofighter can provide for a deep strike capability as well with 2 stand-off missiles and 8 air-to air missiles along with a 27 mm Mauser and 3000L conformal fuel tanks and one Laser Designator Pod or LDP.

With a heavy strike load, your primary focus is not air-to-air but of course you need to be prepared to fight your way out if needed. It is not unknown that the air sweep, which precedes a ground attack, may not have removed the entire threat, so having the ability and weapons to fight your way out when needed is useful.

And the broad notion is really air-to-surface not just air to ground, for we are shaping a modernization strategy for maritime attack as well with both SPEAR and Marte-ER missiles integration work in progress.

**Question: The engine for the aircraft is well known to be one of its key capabilities. How does engine performance play into the modernization strategy?**

Paul Smith: The engine-airframe combination underpins every aspect of fighter weapon system performance. In my experience of flying Tornado operationally, we struggled for aircraft performance when carrying a full weapon load; the excess thrust means this is never an issue with Typhoon and the engine is virtually indestructible!

There are no scheduled maintenance intervals for the engine; it has a sophisticated Engine Health Monitoring System (EHMS) that uses sensors to inform maintainers of when and what tasks need to be performed. Experience across the whole in-service engine fleet is that the average engine time 'on wing' before initial

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maintenance is over 1100 hours – indeed, some of the RAF's aircraft have flown more than 1500 hrs without the EHMS flagging up the need for maintenance.

As I noted before, the plane has a very good thrust to weight ratio. For the engine only, it is over 9:1, giving an aircraft thrust:weight ratio of approximately 1.15:1. This is enhanced as well by the low weight and large wings of the aircraft, with a resultant low wing loading. It is a very strong wing with about 70% carbon fiber composites as the baseline material.

**Question: With regard to the sensors, a major shift is from your current radar which is maximized for its air to air role to an AESA radar designed to give you a different range and variety of threats and targets.**

**How would you describe the change?**

Paul Smith: The new Captor-E radar allows for greater capability to see and operate within the battlespace. It provides for flexible task management with multifunctional performance and simultaneous modes for air to air and air to surface. It provides an electronic attack capability, which complements our current EW capability on the aircraft as well as ESM, or electronic support measures as well.

The new radar will be able to leverage very effectively the new Meteor missile with its two-way data link to expand the capability of the aircraft to operate against adversary aircraft at a distance and in complex combat situations. The situational awareness delivered by the fusion of Captor and other sensors in combination with the larger no escape zone of the Meteor should give Typhoon a significant combat advantage.

**Question: Part of the modernization program is the enhancement of the infrared airborne tracking equipment as well.**

**How will this program integrate with the aircraft as a combat system?**

Paul Smith: PIRATE or passive infrared airborne tracking equipment is designed to enhance our situational awareness and to provide for a passive multi-function track-while scan sensor. It is designed to provide for longer-range detection and enhanced capability to track multiple threats, particularly those with a low RCS.

It will allow us to reshape our combat tactics as well in dealing with adversaries, notably when we add the Meteor missile to the aircraft as well.

**Question: In effect, you are addressing Typhoon modernization, missile modernization and evolving sensor integration, including the pods, which you will add, to provide for evolving multi-mission capability.**

**Is it fair to say then that you are focused then on cross-cutting modernization efforts to enhance its role in the 21<sup>st</sup> century combat space?**

Paul Smith: That is a good way to put it. And the way we are modernizing the aircraft in a way that will make it a very good asset to work the F-35s going forward. And as we go forward we are looking at various data link enhancements, which further enable the air, combat force.

It is a journey but one going in the right way for our customers. It is about gaining and maintaining information superiority and then leveraging that with the appropriate weapons and means to provide for combat superiority.

The way I would put it is that Eurofighter is an inherently living fighter. The platform has longevity in terms of its airframe, power plant, cockpit, avionics and autopilot. It is well positioned for weapons integration and

leveraging externally mounted sensors. The airplane is capable of mature sensor fusion and we are focused on evolving the sensor management capability of the airplane as well.

Put in other terms, we are focused on obsolescence management and sustainment adaptation.

And looking forward we are looking to enhance data link bandwidth, ways to further reduce the pilot's workload through expanded automation of functions, where we become more of a "hybrid" air platform.

And in your interview with Air Marshal (retired) Geoff Brown, he highlighted the potential role of the Super Hornet as a UAV/UCAV wingman. We certainly are looking at this role as well.

<http://www.sldinfo.com/looking-back-and-looking-forward-in-21st-century-warfare-air-marshal-retired-geoff-brown-looks-at-the-evolution-of-airpower/>

## EUROFIGHTER MODERNIZATION: LARS JOERGENSEN EXPLAINS THE APPROACH

During my visit to Eurofighter in Munich, Paul Smith explained the thrust of modernization of Eurofighter and the approach highlighted by Italian test pilot, Major Raffaele Beltrame. In this interview, Lars Joergensen explains the underlying approach to modernization.

The *Second Line of Defense* team first met Lars at a seminar in Copenhagen on airpower. This was not surprising for not only is Lars Danish but he is currently running the Eurofighter campaign in the Danish competition for its replacement combat jet. The team was impressed not only with the knowledge of combat aviation evidenced by Lars but his ability to explain how Eurofighter fit into the evolution of 21<sup>st</sup> combat aviation and the evolving choreography of air combat operations.

Lars has an impressive background with Eurofighter, having worked on a wide range of issues within the company. He worked as a sensor flight test-/system engineer on the Eurofighter for 8 years, then in the Business Development world and now doing sales in Denmark. Although I have been to Munich many times, Lars invited me to have a chance to talk with the team and to see the Eurofighter cockpit modernization and related facilities.

With the Royal Air Force and the Italian Air Force focused on retiring Tornado and having Eurofighter subsume Tornado ground attack functions, the shift from air defense to a broader multi-mission role is obvious and important for the Eurofighter nations.

But our discussion goes beyond this to shape a broader understanding of the intersection between the radar modernization and the evolution of the crucial triad of plane, pods/sensors and weapons in shaping the way ahead. And underlying the modernization of the plane is a shift from the classic federated computer system in the aircraft to a more flexible sensor integration approach.

**Question: The airplane was born in the last period of the cold war and was designed for air defense.**

**How would you describe its evolution since its origins?**

Lars Joergensen: The plane was conceived in the 1980s, designed in the 1990s and built in the 2000s. It was produced and used in the first decade of the 21<sup>st</sup> century as an air defense or air superiority fighter. Its combat systems were optimized for those missions.

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It was designed to fight and win the air-to-air battle and assist in clearing the skies to enable the ground attack mission then to succeed against the Soviet Union and the Warsaw Pact. It could always carry ground strike weapons, but that was in the context of a second phase after performing the mission it was optimized for.

Now with the incorporation of the Tornado missions by Eurofighter, the multi-mission capabilities are being shaped and implemented for the aircraft. And for the RAF and the IAF, there has been a plan for some time to fly both the F-35 and the Eurofighter together and in so doing the Eurofighter is being modified and modernized as part of their approach to air combat operations.

They are planning for the cross-use of these airplanes and sharing many of the same weapons. And even if they fly many of the same weapons, they are planning to use the planes and those weapons differently in shaping their approach to 21<sup>st</sup> century air operations.

**Question: You were showing me earlier, the nature of the core computer system in the aircraft and the evolving dynamics of change.**

**Could you explain the baseline concept as well as the approach to change?**

Lars Joergensen: The systems architecture is built around a federated system where each computer communicate with each other via high-speed data busses. Each of the combat sub-systems was housed in separate physical computers as part of the avionic system running the aircraft. And each of these sub-systems, such as communications, display & control, attack, flight control, etc. was tasked to one of the four core Eurofighter companies.

But technology has changed, computer processing speed has increased dramatically, and now we are looking at the computers in the aircraft less as blocks of capabilities, than as cluster of slots housing GigaHertz clock speed processors, which can add, enhanced capabilities and provide some key data fusing functionalities.

We have learned that too much integration can actually be a disadvantage as it removes the flexibility to quickly add on new functionality.

One could say that our way of now clustering processors with high communication needs to “slots” which then exchange data via a lower bandwidth bus is an optimized compromise of an integrated architecture.

So in my view we found the optimum compromise, which also provides for significant redundancy, which is a good thing in the evolving era of what your team has called Tron Warfare.

Obviously, integration is necessary to ensure flight integrity, but because integration occurs through the avionics bus this clearly is a key focus of attention as we modernized the airplane.

And of course, some classic capabilities can be modernized but the basic system works so well that it is modernization more for security purposes than anything else. Here I have in mind the flight control system which is central to managing an aircraft which is designed inherently to be unstable but stabilized by the flight control system. The plane is balanced and stabilized by the computer flight system.

And as we move forward, we will look at the slots in the computer systems as places where we can build in additional data links, or fuse data in conjunction with the pods and weapons on the aircraft as well.

Notably with regard to the communications ports and the attack identification ports we are looking at adding in more interactive capabilities for the aircraft.

**Question: Let us focus on some additional modifications as well. Eurofighter has recently announced an upgrade of the aerodynamic system, which enables an expansion of the payloads to be delivered by the aircraft.**

**Could you discuss those innovations?**

Lars Joergensen: By the addition of fuselage strakes and wing root extensions, we have increased the maximum lift created by the wing by 25% and increased increased yaw stability significantly at high AOA. The immediate benefit is increased turn rate, tighter turning radius, and enhanced nose-pointing ability at low-speed, which are essential fighter capabilities in air-to-air combat.

In addition, the kit provides extra growth potential, enabling easier integration of future air-to-surface configurations and flexible applications, enhancing the aircraft's mission effectiveness in the air-to-surface role.

You can really now create some fancy weapon configurations on the airplane and still have a good aerodynamic robustness of the airplane, which helps you a lot when you're clearing and certifying weapon loads because the certifier knows that this airplane is now very robust and able to deliver those weapons with a broader AOA.

**Question: Earlier we discussed the F-16 and its analogy to how you see the Eurofighter evolving.**

**Could you return to that discussion and lay out how you see the significance of the F-16 analogy?**

Lars Joergensen: Because the F-16 had a robust airframe, a very good thrust to weight ratio and a federated avionic architecture, it has been able to evolve way beyond the original concept of the airplane. By the constant addition of capabilities, it has grown significantly in weight over time, roughly a pound a day since 1974 through the late 1990s. It was able to do so successfully because of its robust airframe, its good thrust to weight ratio and miniaturization of computers and of electronics.

Its federated avionic architecture made it possible to upgrade the weapon system stepwise and in competition – one of the “secrets” of its affordability. Just look at the multitude of EW systems and targeting pods available for the F-16.

And with the weapons development, notably the AMRAAM, suddenly even the F-16 could become an air superiority fighter and provide impacts similar to an F-15, something not envisaged when the F16 was designed.

**Question: Let us return to the question of flying and fighting with 5<sup>th</sup> generation fighters. The British have flown with F-22s at Nellis and the Germans in the Alaska Red Flag.**

**What feedback have you had from those experiences?**

Lars Joergensen: At a Farnborough Air Show a couple of years ago, we had discussions with some members of the Air Force Research Lab who were focused on how the F-22 and the Eurofighter made a powerful team in carrying out air strikes. Given the speed and high altitude both airplanes can fly at, they were interested in discussing how to weaponize such an air combat force.

As they put it, “We are firing third generation weapons from fifth generation aircraft and this makes no sense.” And clearly they were interested in looking at the interaction between weapons in the internal bay of an F-22 allowing it to operate as a low observable aircraft and Eurofighter with its evolving payloads as an interesting way to shape a way forward.

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With regard to Eurofighter we have own variation of flying older weapons as you saw in the cockpit simulator where we receive voice-warnings with regard to some weapons not being designed to operate at the speed which Eurofighter can operate and deliver weapons.

There are two other problems as well, namely data sharing and linking and IFF challenges. How do we ensure friend and foe identification with a mixed combat force involving the F-22?

**Question: With regard to weapons, obviously the coming of your AESA radar will facilitate change in interaction with weapons as well?**

**How would describe this change?**

Lars Joergensen: Our current mechanically scanned radar has proven very good for the air to air mission. With the AESA you have much more flexibility, and part of that flexibility will be to work with weapons differently in particular as a data facilitator.

The first new weapon were this will become very clear is Meteor where the airplane will interact with the data link on the missile to identify and destroy targets in a fluid air combat space. Other weapons will follow.

Thanks to the Eurofighter's large nose aperture, combined with the ability to move the AESA antenna, we will be able to fire, guide and communicate with weapons "over the shoulder" so to speak while flying away from the threat, thus significantly enlarging our attack envelope with missiles.

**Question: There is a clear interaction among changes in the aircraft, the weapons onboard the aircraft, and with upgrades in the sensor pods.**

**In a sense you are have a triangular approach to modernization?**

Lars Joergensen: It is clear that a variety of Air Forces are using their sensor pods, including targeting pods, to provide a variety of information and quickly increase capabilities. By combing those innovations with weapons innovation and tying them back to the aircraft you can get enhanced combat effect. And given that the process of tranche upgrades inevitable will be slower than pod upgrades, this expands the ability to modernize at a more rapid pace than we could do simply through tranche upgrades on the aircraft itself.

Put another way, the "intelligence" of the weapon system can be described as the sum of the capabilities of the platform, the pod, the weapons and of course the other data link participants. And it is the sum of all these elements that turns you into an effective operational asset.

It is often easier to upgrade the pod instead of the platform. For example during the Swiss flight evaluations, we turned the Tranche 1 Eurofighter platform into a really good recce-asset overnight by adding a pod and leave all the processing in the pod – there were no changes to the platform's avionic system or software. One can also use the intelligent weapons as sensors. For example, the Norwegian F-16 uses the IRIS-T seeker as very capable IRST.

And with the coming of Litening 5 to the Eurofighter, which then allows Eurofighter partners to determine how to use the slots in the pod to augment desired and relevant combat potential. The press release concerning Litening 5 highlighted this point:

"Meanwhile, the miniaturization of some of the components used in the pod has left two empty spaces, which Oren says will allow customers to incorporate dedicated, and in many cases classified, features."

Since we have a high capacity connection to the pod, these empty spaces can often be used as a quick fix to urgently needed Weapon System features. Features you then might pack into the platform upgrades at a later time, when it fit with the general upgrade cycle.

## NEXT GENERATION MISSILES AND AIRPOWER MODERNIZATION: THE CASE OF EUROFIGHTER AND THE METEOR MISSILE

Shaping 21<sup>st</sup> century U.S. and allied air combat capabilities is a function of the intersection of a number cross-cutting dynamics:

- The reshaping function of fifth generation warfare,
- Selective and appropriate modernization of the most capable of non-fifth generation aircraft,
- The introduction of longer range kinetic and non-kinetic strike platforms,
- The reshaping of a dynamically integrated combat force and of C2 systems,
- And the evolution of the weapons/robotic systems enterprise.

Dynamic and interactive change is how the air combat system will be transformed over time to enhance the lethality and range of effects which airpower can deliver in a multi-mission, multi-tasking environment.

Shaping a new weapons revolution where weapons are enabled throughout the attack and defense enterprise and not simply resident for organic platform operations is a key element of the way ahead.

For example, the new software enabled Meteor missile can be fired by one aircraft and delivered to target by that aircraft or the inflight data link can be used via another asset – air or ground based – to guide it to target.

One key dynamic clearly is the interaction between the evolution of the manned aircraft and of missile systems, whereby the aircraft is modified to make better use of the expanded capabilities and range of “smart weapons” and the weapons change themselves to more effectively interact with the modifications of the aircraft as well.

A case in point is the modernization of the Eurofighter intersecting with the introduction of the next generation air combat missile, the Meteor.

The upgrades underway for the Eurofighter will see the introduction of a new radar, which has built into it a much better way to work with missiles which themselves can “think” and “operate” more effectively in a fluid, high speed battlespace.

It is the intersection of the two which creates the new combat effect – a combat air system in which the aircraft can work the relationship with the missile to enhance the probably of the kill of adversary systems and at greater distance.

The intersection of co-modernizations is the core dynamic; which makes it difficult to describe if only one side of the modernization process is considered in terms of the overall combat capability.

### From the Missile Modernization Perspective: The Meteor Missile

The new Meteor missile developed by MBDA is now in production.

It is representative of a new generation of air combat missiles for a wide gamut of new air systems.

## Second Line of Defense

It is planned for the F-35, the Eurofighter Typhoon, the Rafale, the Gripen and other 21st century aircraft.

Some of the baseline capabilities of the missile are as follows:

*METEOR is being developed to meet the requirements of six European nations (UK, Italy, Spain, Germany, Sweden and France) for a superior Beyond Visual Range (BVR) missile system with the operational capability to excel in all current and future combat scenarios;*

*This collaboration of six European nations provides access to technology and expertise from across Europe.*

*The range and performance of the Meteor and its ability to enable both old and new air systems moves air-to-air weapons into the next generation.*

*What is METEOR and what are its benefits?*

*A fast and highly maneuverable Beyond Visual Range air-to-air weapon*

*Very large No Escape Zone owing to the air-breathing ramjet – several times that of current MRAAMs - resulting in a long stand-off range and high kill probability to ensure air superiority and pilot survivability;*

*Networked capability through data-link*

*Guidance is provided by an active radar seeker benefiting from enhanced technologies drawn from MBDA's advanced seeker programmes;*

*Capable of engaging air targets autonomously by night or day, in all weather and in severe electronic warfare environments;*

*Equipped with both a proximity and impact fuse to ensure total target destruction in all circumstances.*

At the heart of the Meteor program is an integrated development team led by the prime contractor, MBDA.

The missile was developed to meet the operational requirements of 6 partner nations and for 3 very different combat aircraft, the Eurofighter Typhoon, the Rafale and the Gripen.

It is also compatible with the F-35 weapon bay and is planned for inclusion in the Block 4 upgrade package.

Frequently, a multi-national program is more of a problem than a solution.

In this case, the challenge of building for multiple aircraft and partners at the same time, has given the MBDA team a leg up on the 21st century.

To design and build the missile, a comprehensive model was developed; this incorporated the various aspects of a successful missile, ranging from aircraft characteristics, to radar system performances, and the various operational scenarios and operational approaches of the different aircraft and air forces.

This has meant that MBDA has forged a very robust model for development, which is then at the heart of the production of the missile itself. The missile is software upgradeable so that changes over time will be written into the code in the model and directly incorporated into production runs.

Software upgradeability is a game changer for 21st century systems not well understood or highlighted by analysts.

In the past, new products would be developed to replace older ones in a progressive but linear dynamic. But now, one builds a core product with software upgradeability built in, and as operational experience is gained, the code is rewritten to shape new capabilities over time.

Eventually, one runs out of processor power and BUS performance and needs to consider a new product, but with software upgradeability, the time when one needs to do this is moved significantly forward in time.

It also allows more rapid response to evolving threats.

As threats evolve, re-programming the missiles can shape new capabilities, in this case the Meteor missile. The current production missile is believed to be using well below the maximum processing power and bus capacity of the missile.

Significant upgradeability is built in from the beginning.

Another key aspect of the missile is it is designed from the beginning to be employed on and off-board. It can be fired by one aircraft and delivered to target by that aircraft or the inflight data link can be used via another asset – air or ground based – to guide it to target.

The enhanced range of Meteor over legacy AMRAAM is important; but even more so are its systems which create the no-escape zone targeting capability.

Here the speed of the missile upon moving in on the target and the capability of the missile with its onboard sensors and reach back to sensors on the combat fleet allow it to “think” its way to a maneuvering and EW protected target.

The missile is designed to be able to operate via a three-phase speed control system.

First, it accelerates to cruise speed, which is dependent on launch condition and target altitude. This initial speed is selected to optimize range and maximize interception with the life of the missile even when the target turns to tail.

The second phase is mid-course guidance speed control. In this phase, the missile can accelerate and maximize intercept speed.

And in the third phase, at the extreme of its range, final acceleration to the target is generated to overcome any last-ditch evasive maneuver. Non-air breathing missiles are unable to achieve this.

The aim is to maximize fuel into speed at target intercept but not before. This is necessary because the range to intercept is unknown for long-range shots at launch, which is really determined by future target maneuver behavior so that the missile needs to adjust to that target behavior.

There are a number of integrated systems aboard the Meteor missile, which allows the missile to operate in the manner described.

But the secure data link system is an element, which enhances the ability of the missile as an organic asset to move from fire and forget, to fire and think through how best to hit the target, and to do so with onboard systems enhanced by an ability to leverage the sensors in the surrounding blue battlespace.

In this sense, it can operate either autonomously or leverage assets in the battlespace to destroy high-speed, maneuvering, targets, which are using electronic warfare and other systems to try to protect themselves.

## From the Aircraft Modernization Perspective: The Eurofighter Case

The Eurofighter is a clear player in shaping European and global air forces.

It has reached critical mass and will be modernized through its operational life to work with new air assets and to deal with the evolving threat environment.

The program currently has seven customers, 599 committed aircraft orders, 446 deliveries to date, more than 300,000 flying hours with 100,000 employees and more than 400 companies involved in the program.

This kind of critical mass provides a solid foundation for the evolution of the program.

The Eurofighter consortium has launched a series of capability enhancements as part of a Capability Roadmap, which is designed to increase the combat effectiveness of the fighter.

It has evolved from an air defense aircraft to a multi-mission aircraft, notably with the addition of new weapons to subsume Tornado functions and to incorporate a new AESA radar as well as cockpit and linkage improvements as well.

It is the modernization effort associated with the new AESA radar and cockpit integration issues, which interests us most here with regard to intersecting modernization.

Paul Smith, an experienced RAF Typhoon pilot, now with Eurofighter put it this way:

*The new Captor-E radar allows for greater capability to see and operate within the battlespace.*

*It provides for flexible task management with multifunctional performance and simultaneous modes for air to air and air to surface.*

*It provides an electronic attack capability, which complements our current EW capability on the aircraft as well as ES, or electronic support measures as well.*

*The new radar will be able to leverage very effectively the new Meteor missile with its two-way data link to expand the capability of the aircraft to operate against adversary aircraft at a distance and in complex combat situations.*

*The situational awareness delivered by the fusion of Captor and other sensors in combination with the larger no escape zone of the Meteor should give Typhoon a significant combat advantage.*

Lars Joergensen of Eurofighter provided his perspective as well on the cross-cutting modernization impact of radar with missile modernization:

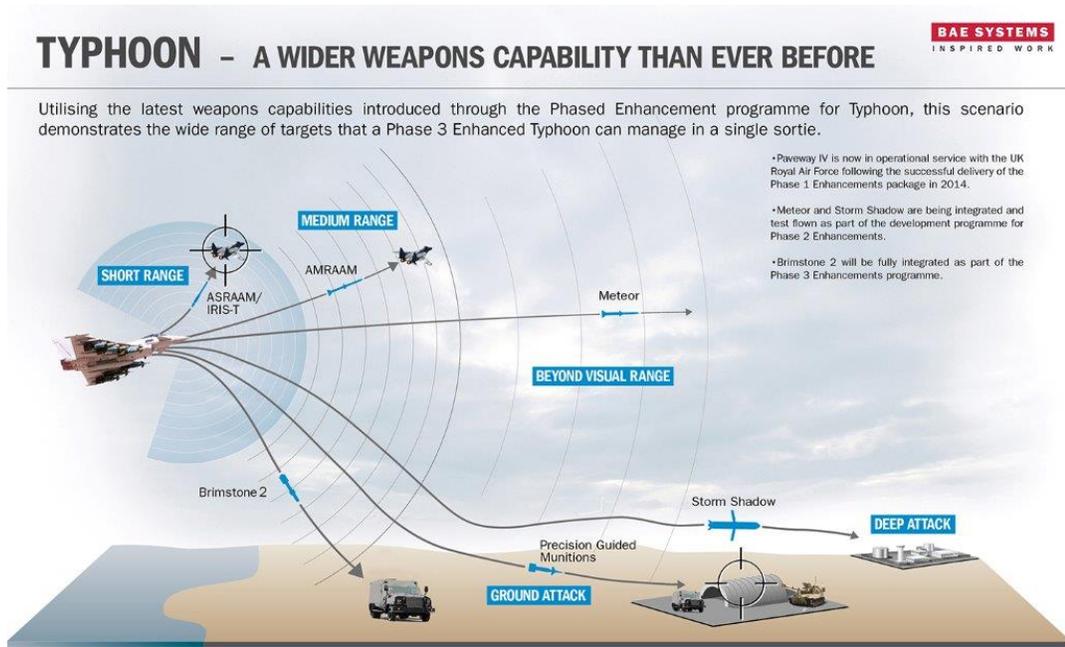
*Our current mechanically scanned radar has proven very good for the air to air mission.*

*With the AESA you have much more flexibility, and part of that flexibility will be to work with weapons differently in particular as a data facilitator.*

*The first new weapon we will become very clear is Meteor where the airplane will interact with the data link on the missile to identify and destroy targets in a fluid air combat space. Other weapons will follow.*

*Thanks to the Eurofighter's large nose aperture, combined with the ability to move the AESA antenna, we will be able to fire, guide and communicate with weapons "over the shoulder" so to speak while flying away from the threat, thus significantly enlarging our attack envelope with missiles.*

One of the key companies in the Eurofighter consortium BAES, has highlighted the missile upgrades to Eurofighter in the following graphic.



But what this graphic does not convey is how the Meteor missile/AESA combination lays a new foundation for the way ahead in terms of how the Eurofighter works with its missiles.

With the intersection of the new AESA radar on Eurofighter with the Meteor missile, a foundation has been laid to work a more interactive strike capability within the battlespace.

The radar with its independent modules and ability to track and see at distance interconnecting with the missile's guidance system and data links can interactively "chase" the target until it is destroyed, a target at greater distance and operating with high maneuverability.

And moving from this foundation, the weapons enterprise intersecting with manned aircraft can operate quite differently as the missile can be fired from one platform and then "commanded" by another, which enhances not only the probability of kill but enhanced survivability of the air combat fleet.

It is part of moving from organic launch and "fire and forget" from a particular air platform, to launch from one platform and interactively hunting down the target but able to operate independently or tap into the "fleet" assets operating against the adversary.

## Conclusion

The evolving air combat enterprise is undergoing significant change as interactive elements operating in combat packages enhance the effects which these force packages can provide.

This provides for a resilient package of honeycombed air assets which can operate by themselves but can be linked like lego blocks into a more expansive set of force capabilities.

This allows for shaping an enterprise, which can deliver the desired effects, but on the evolving electronic warfare battlefield.

## Second Line of Defense

Intersection among missiles, robotic systems (RPAs) and manned combat assets will form the core infrastructure moving forward.

Meteor being operated from F-35 as well as Eurofighter will allow better tactics for blue forces, with more efficient weapon deployment (fewer missiles fired = more targets engaged) against evolving air threats.

## THE RE-NORMING OF AIRPOWER: THE EUROFIGHTER CONTRIBUTION

Airpower has become a ubiquitous enabler of combat operations.

Indeed, air enablement is a key element of virtually every aspect of the US and its allies in operating worldwide against a variety of threats.

Airpower has evolved throughout the “land wars” to become an enabler for intelligence, strike, lift, and generally shaping more agile ground forces.

As the focus shifts from the “land wars” to challenges shaped by a variety of competitors and adversaries mixing advanced with more traditional technologies, airpower is undergoing a fundamental transformation.

Fifth generation aircraft are a major change agent in the evolving airpower dynamic.

We have argued for some time that the introduction of fifth generation aircraft into legacy fleets was part of a process we have called the “re-norming” of airpower.

We have even published a book with that title.

But we have emphasized that it is the overall air combat enterprise, which will change, not simply the introduction of a new production fighter aircraft.

This means in part that some legacy systems will simply be jettisoned, but some will be modernized as the air enterprise evolves.

All legacy aircraft are not created equal; a premium will be placed on those, which are inherently upgradeable and provide core capabilities for the evolving air enterprise.

The Royal Air Force is relying on a twin transformation of the Typhoon with the F-35 to provide for its core strike capability.

This means that the modernization of the Typhoon coupled with the reshaping function, which the F-35 will bring to the reshaping of the air operations effort, are both part of the British and Italian approaches to re-norming airpower.

And with the UK and Italy both re-norming under the impact of the introduction of the F-35 and the modernization of Eurofighter, cross cutting operational lessons certainly will be learned and shared in shaping an overlapping re-norming approach.

Both the UK and Italy will operate a mixed Eurofighter and F-35 fleet. Both have operated the Tornado, which is reaching the end of its service life. Both will sort through evolutions of the Eurofighter to encompass some of the mission sets for Tornado as the Tornado is retired and as the F-35 comes into the two fleets and provides the next surge for the re-working of air-led combat concepts of operations.

A key element of this transformation will be reworking the connectivity among air, sea and ground systems as well as shaping the weaponization approaches of joint and coalition forces.

In part, this is a Eurofighter transition whereby the radars are upgraded, and weapons added; in part this is the coming of the F-35 and its impact on reshaping air enabled combat operations.

And associated with this will be fundamental changes over time in C2, and the approach to strike operations.

The UK and Italy already fly together in operations through their use of Tornados and Eurofighters and have clearly shared combat learning with regard to the use of these platforms; as the F-35 comes on line this combat learning cycle will continue into the next generation of aircraft, and shaping ways to approach fifth generation warfare.

In effect, the dynamics of change for Italy and the UK will be a function of the intersection of four variables: the evolution of the Eurofighter; the impact of the F-35 and the global fleet of F-35s; changes in weaponization, and evolving C2 for strike and combat operations.

There is an inherent possibility that the UK and Italy could provide an important force for synergy in shaping concurrent approaches to evolving concepts of operations. Of course, this depends upon how effective their working relationship is and how effective cross-MOD, and cross-industrial relationships are in leveraging their working relationship.

A recent report by Justin Bronk of RUSI provides an important look at the Eurofighter modernization part of the re-norming equation. <sup>1</sup>

The report is based on discussions with Typhoon pilots and others, and provides a look at various ways ahead with the Eurofighter as part of the European approach to re-norming airpower over the next two decades.

The numbers of operational Eurofighters and their evolving capabilities make them important elements of the defense modernization effort. A recent press release from Eurofighter highlighted the baseline achievements of the enterprise in providing for a core European capability.

*Eurofighter Typhoon has now achieved more than 300,000 flying hours since the entry-into-service of its worldwide fleet. Eurofighter Jagdflugzeug GmbH confirmed the milestone today (July 17, 2015) adding that, with 571 aircraft ordered and 438 delivered, the programme has "delivered unprecedented levels of reliability".*

*The first 5,000 flying hours were achieved in November 2005. 10,000 hours came in August 2006 and 20,000 in May 2007. By August 2008, the Eurofighter Typhoon fleet had surpassed 50,000 hours and 100,000 flying hours was reached in January 2011. In July 2014 the consortia announced that the 250,000 flying hour milestone had been reached while, at the same time, Eurojet, the makers of the Typhoon's EJ200 engines, celebrated half a million flying hours on the aircraft.....*

*The global Eurofighter fleet now comprises 22 operating units with locations in Europe, the South Atlantic and the Middle East.*

The RUSI reports highlights some core modernization requirements and opportunities for the Eurofighter.

*In order to complement, and eventually take over from, Tornado in the strike and interdiction role in the RAF, Aeronautica Militare and later Luftwaffe service, the Eurofighter requires not only fleet-wide software upgrades to P1Eb standard (or equivalent), but also integration of the Storm Shadow stand-off air-launched cruise missile and the dual-mode Brimstone or Brimstone II anti-armour missile which has proved so successful in Libya and more recently over Iraq. The integration of these weapons is planned and early test flights are underway on instrumented production (test) aircraft in the UK (page 20).*

## Second Line of Defense

*Another aspect of the modernization challenge is to more effectively integrate Eurofighter into the evolving air enterprise being reshaped by distributed air operations.*

*To ensure that the Eurofighter can maintain the capabilities which the*

*Tornado, F-18 and Harrier currently provide to European air forces once the latter types are retired is only part of the challenge.*

*Whilst armament, software and sensor-payload upgrades required to accomplish this are known quantities, the longer-term challenge is to ensure maximum interoperability with the F-35 as it enters front-line service in the 2020s.*

*This challenge comprises issues including datalink security and bandwidth, communications, and sensor fusion. During Red Flag, F-22s and Eurofighters could only communicate through a Battlefield Airborne Communications Node (BACN) due to the unique communications equipment on the F-22.*

*Through Link 16, the Eurofighter can receive information in real time from networked ground and air assets. Whilst it does not employ the sort of centralised sensor-fusion architecture found on the F-35, and to a lesser extent the F-22, the Eurofighter's attack and identification system (AIS) presents a combined picture to the pilot via the multifunction information distribution system (MIDS).*

*AIS also integrates data from the Eurofighter's own radar, PIRATE, DASS and navigational aids to present the pilot with the best possible situational awareness from an otherwise federated sensor architecture. However, this still requires a significant amount of data management on the part of the pilot and could be significantly streamlined (pages 21-22).*

*In our interview with Sqn Leader Hugh Nichols, he highlighted what he saw as important modernization priority for Eurofighter:*

*Question: Secretary Wynne made the point that modernization of legacy aircraft should be taken going forward from the perspective of working with the F-35.*

*How do you view that approach?*

*Sqn Ldr Hugh Nichols: It makes sense.*

*Each aircraft brings different strengths to the fight and we will fly them both, with the tactics will evolving over time.*

*Software modifications will undoubtedly be required in order to get the most out of each aircraft and ensure full interoperability; take Link 16 for example, where the F-35 could put out a huge amount of information.*

*We need to ensure that Typhoon is able to receive and display the information without overloading the pilot.*

*Question: Typhoons have flown for some time with F-22s and now with F-35s.*

*What is the impact on the Typhoon?*

*Sqn Ldr Hugh Nichols: It makes the Typhoon more lethal and survivable.*

*Today, every legacy aircraft that can fly with a Raptor clearly wishes to do so.*

*But there is going to come a point where they will prefer to fly with the F-35 due to the data linking capability of the F-35 and how that capability enhances the situational awareness of all aircraft in that fight.*

*For example, we can push information out to the legacy fleet so they know where the threats from integrated air defense platforms are and therefore they have a better understanding of where they are safe from those systems.*

Modernization to enhance the range of the Eurofighter to play a wider role in a sustained air operation is underway.

*A variety of airframe and engine upgrades have been suggested such as thrust-vectoring engines and leading-edge root extensions (LERX) to improve the aircraft's already formidable WVR performance, and conformal fuel tanks (CFTs) to increase range without significant drag penalties.*

*The CFTs can theoretically be mounted on all Tranche 3 aircraft if certified and would certainly give a boost to the aircraft's ability to mount long-range interdiction missions.*

*However, the RAF has a very capable tanker fleet in the A330 MRTT and extensive experience operating with other NATO-member tankers. This means that the Typhoon's range is more than adequate without CFTs, except in situations where aerial tanking is in critically short supply. Even without aerial refuelling, a large wing and fuselage and the ability to carry up to three supersonic external fuel tanks give the Eurofighter an impressive range (page 22).*

Its ability to carry significant ordinance externally is an important contributor to the overall ability of the air combat enterprise to deliver effects in the battlespace.

And modernization to enhance this capability is important as well.

Indeed, the combination of fifth generation aircraft operating forward with significant weapons loads of a variety of types with a modernized Eurofighter would clearly enhance European combat power.

Based on discussions with pilots, the author highlighted a core point that the big ticket upgrades are important but significant change could come from a more comprehensive effort to fill operational gaps.

*Instead, pilots across the RAF, Luftwaffe and Aeronautica Militare want the small-scale problems with subsystems fixed as a priority. Whilst huge progress has been made in eradicating the majority of software and equipment bugs since the aircraft first entered service in 2003, there are still noticeable deficiencies with some subsystems such as the radios. Fixing these issues should not be nearly as capital-intensive as major modifications such as CFTs or the CAPTOR-E radar. However, they offer very significant performance gains through removing performance bottlenecks in both system architecture and pilot workload.*

The report also offers an important warning about the future for multinational programs.

Real capabilities emerge from a program like the A400M by keeping the aircraft common and having modernization proceed across the fleet. This has not been the case with Eurofighter and has slowed down the modernization process.

*Part of the problem surrounding the Eurofighter's development following its introduction into service in 2004–06 has been the substantially differing mission priorities of the four development nations. Under the original consortium arrangements, upgrades were supposed to be jointly funded and developed. This has proved a predominantly unworkable model given the significantly different operational imperatives and doctrinal role for the Eurofighter in British, German, Italian and Spanish service (page 19).*

The author concludes with the importance of modernizing the Eurofighter fleet as the F-35 enters service and, in effect, reshapes or re-norms airpower.

## Second Line of Defense

*Developing maximum network, systems and tactical interoperability between the Eurofighter and the initially small numbers of F-35s, which will enter service throughout the 2020s, offers significantly increased combat effectiveness for both types. Each is capable of offering strengths where the other is comparatively weak.*

*The Eurofighter offers exceptional performance, heavy- and diverse-ordnance capacity, long-range and combat mass, whilst the F-35 will bring unmatched situational awareness, low-observable survivability in defended airspace and powerful electronic warfare capabilities. (page x).*

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