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Scalp EG / Storm Shadow : Lessons from a successful cooperation

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INTRODUCTION

In the early 2000s, the Scalp EG¹ missile and its British counterpart, Storm Shadow, provided the United Kingdom and France with advanced and highly effective independent, deep strike weapons. These weapons put their respective air forces into the top tier of military operators, allowing them “Day One” entry into any theatre of operation, with capabilities equivalent to those of the United States.²

A unique example of multi-lateral European cooperation, the Scalp EG / Storm Shadow programme achieved significant objectives for the two countries:

- ▶ Achieving operational advantage in a field traditionally dominated by the US;
- ▶ Delivering capabilities to time and to budget;³
- ▶ Developing and maintaining a strong, autonomous capability in complex weapons, allowing France and the UK to deliver a wide range of operational capabilities and boosting the export of European combat aircraft;
- ▶ Promoting industrial and technological rationalisation, enabling skills to be maintained while allowing a world-class European missile champion to emerge.

As preparations are made to renew these capabilities, it is important to know whether or not this model can be re-used in future programmes, or whether it was merely the product of very specific circumstances that cannot be reproduced.

¹ “*Système de Croisière conventionnel Autonome à Longue Portée et d'Emploi Général* (General Purpose Long-Range Standoff Cruise Missile)”. The term “general purpose” distinguishes it from the specifically anti-runway Apache.

² i.e. a cruise missile fired from a combat aircraft such as a Rafale or a Typhoon, the equivalent of an American F16 / JASSM-ER combination.

³ The programme involved missile development as well as the integration of the missiles onto the different launch aircraft, although platform integration was not part of the original ITTs: they were contracted later and separately, with the aircraft requirements taking precedence. The French missile development programme remained within budget. The same appears to have been true on the British side for the missile development programme. It is more difficult, however, to determine whether the integration work remained in budget as this expenditure was spread across various aircraft capability increments over a long period of time. Also, not all of the planned integration work was completed on the British side due to the abandonment of the Harrier platform.

Developing a world-beating capability

The Genesis

The evident effectiveness of American cruise missile strikes during the first Gulf War (1991) – their ability to attack heavily defended hardened targets at long range with metric precision⁴ – led the French and Royal Air Forces to seek equivalent capabilities. In the UK’s case, the Royal Navy had already procured American Tomahawk missiles for its nuclear attack submarines in 1998.

The two nations produced statements of requirement independently, but with concepts that were, in practice, quite similar. The statements of requirement gradually began to converge as the British tendering process advanced with one key area of common ground between the two countries being the desire for a weapon system that could be used without the risk of third-party interference.

To meet their respective needs, France and the UK launched separate competitions that reflected their different national contexts:

- ➔ The French APTGD⁵ competition was launched in 1994 for the acquisition of a small quantity (100) of high end missiles.⁶ This resulted, later that year, in the selection of a Matra Défense solution derived from the Franco-German “Apache” missile; this was in preference to a solution proposed by Aérospatiale, based on the ASMP.⁷ However, no announcement was made following the competition because the solution was unaffordable.
- ➔ In contrast, the British competition was for a low cost, “off-the-shelf” cruise missile, to be acquired in large numbers; an approach that resulted from the abandonment of NATO’s MSOW⁸ programme after the Americans pulled out. The CASOM⁹ ITT was also issued in 1994, and in 1996 the solution from the Matra BAe Dynamics (MBD) consortium was selected in preference to more than 6 rival bids. The £700m contract was awarded in February 1997 for the development and delivery of almost a thousand missiles. The main competitors had been the KEPD¹⁰ (later to become the Taurus¹¹) from

⁴ The objective is to destroy shelters or concrete installations at distances of several hundred kilometres with sufficient precision to hit the weak points of the target structure.

⁵ *Arme de Précision Tirée à Grande Distance* (long distance precision weapon).

⁶ A lower-cost version would be derived later.

⁷ *Air Sol Moyenne Portée* (medium range air to surface): the missile of the airborne component of the French nuclear deterrent – a “high-end” cruise missile.

⁸ *Modular Stand-off Weapon*: the programme aimed to develop a weapon that could be fired from a safe standoff distance but with a range well below the specifications of a cruise missile. D. Evrard: *Storm Shadow/Scalp EG: a kind of European cooperation led by industry*. Air&Space Europe Vol 1, n°3, 1999.

⁹ Conventional Armed Stand-Off Missile.

¹⁰ KEPD: Kinetic Energy Penetrator and Destroyer.

¹¹ TAURUS: Target Adaptive Unitary and dispenser Robotic Ubiquity System.

LFK/Saab and the JSOW¹² from the US firm Texas Instruments. The latter company quickly withdrew because of insufficient technical maturity, leading the Americans to launch the JASSM¹³ programme immediately afterwards.

The launch of the UK competition offered the French a convenient get-out: following the British competition, the French reviewed their contract, their industrial structure (Aérospatiale was no longer a partner of Matra Défense) and their requirements, and chose to align themselves with the British approach. This included reviewing the missile's performance, both reducing its complexity and its unit production cost (UPC). The UPC was reduced sufficiently that it made the programme affordable despite increasing the number of missiles procured from 100 to 500. In addition to these gains from the British programme, a final price reduction was negotiated on the French contract in 1997.¹⁴ A final global contract for 6 billion francs, (about €974m) was awarded in December 1997, one year after the British decision.¹⁵

In the end, Matra BAe Dynamics signed two totally independent contracts: one through its British subsidiary with the MoD, the other through its French subsidiary, with the DGA, with each contract bearing 50% of the development costs. The programme was therefore launched without any inter-governmental commitment, with the manufacturer on its own, bearing the strategic risk of the merger along with the contractual and financial risks resulting from any potential lack of intergovernmental cooperation.¹⁶

An ambitious military capability

The Scalp EG / Storm Shadow missile that emerged from these two ITTs equips the RAF's Tornados and Typhoons,¹⁷ and the French Air Force and Naval Aviation's Mirage 2000s and Rafales. It also equips the Tornados of the Italian and Saudi Arabian Air Forces, the Mirage 2000s of the Greek and UAE Air Forces, the Qatari, Indian and Egyptian Rafales, and the Saudi and Qatari Typhoons.

¹² Joint Stand-off Weapon.

¹³ Joint Air-to-Surface Standoff Missile.

¹⁴ This late round of negotiation took place in the context of a 30% cut in weapons programmes advocated by Jean-Yves Helmer when he took over the helm of the DGA. It was especially difficult, as this was a programme that stemmed from a call for tenders and was subject to time constraints.

¹⁵ *Flight International*, "France takes Scalp", 14 January 1998 – The notion of global contracts was consistent with the British contract structure, but at the time it was revolutionary in France. On either side of the Channel, the contract excluded integration onto the aircraft; the integration contracts were awarded as part of the development of the aircraft standards.

¹⁶ That said, it would probably have been unthinkable for France or the UK to put firms like Matra Défense or BAe Dynamics in existential peril; this offered the industry some level of assurance.

¹⁷ It was also supposed to equip the Harrier, but was ultimately never integrated onto that aircraft.

The missile, with an official range of “greater than 250km”,¹⁸ is designed for day/night, all-weather precision attacks on high-value, heavily-defended, hardened fixed targets, using a tandem shaped charge (“BROACH”) warhead. It is launched from a combat aircraft far from the air defence systems – a key requirement that emerged from the First Gulf War. The missile’s pinpoint terminal guidance is achieved by a combination of GPS guidance and an imaging infra-red seeker. The seeker identifies the target by constantly correlating between the real-time infra-red image and a target model stored onboard the missile which designates the desired point of impact. JASSM uses the same targeting principle but until it was introduced, the American Tomahawk used a lower-quality system that compared optical images against a digital terrain map.¹⁹

The missile’s inherent stealth and low-level flight capability give it high survivability. It is equipped with GPS-based TERPROM²⁰ navigation, but it also has autonomous capabilities (inertial units, terrain-aided navigation) which allows it to dispense with GPS altogether. GPS-based guidance can provide additional navigation accuracy but is a weak point in terms of operational autonomy. This external dependence was meant to be eliminated by using the Galileo satellite navigation system, but that system’s entry into service has been delayed and the system is not yet effective.

In total, more than 2,500 Scalp EG/Storm Shadow missiles have been produced.²¹

There are only minor differences between the French and British systems:

- ➔ The aircraft interfaces are different, i.e. Tornado/Typhoon vs Mirage 2000/Rafale;
- ➔ The mission planning systems are different for each nation, though they share many common building blocks.

A mid-life refurbishment programme for the missile has been under way since 2016.

The competition

The current competitors to the Scalp/Storm Shadow are the American cruise missiles. When the programme was initially launched, the Taurus was a direct competitor, but its status changed when its manufacturer, LFK, was acquired by MBDA.

The American equivalent of the Scalp EG/Storm Shadow, the JASSM, was announced in 1995, started development in February 1997 but arrived on the

¹⁸ The range clearly depends on the scenario.

¹⁹ Digital Scene-Mapping Area Correlator or DSMAC.

²⁰ TERrain PROfile Matching: one of the British contributions to the programme, also used by American missiles

²¹ Order figures published by MBDA.

market very late compared to the European weapon, in 2010. The JASSM initially had a stated range of 400 km but was succeeded in 2014 by an Extended Range version with a stated range of 900 km. Its warhead is very similar to that of the Scalp / Storm Shadow BROACH concept. Its development cost was far higher, due mainly to a long series of failed test launches and it is integrated onto a larger number of platforms²² which now offer good export prospects, even if the Americans only sell it to key allies (Australia, Poland, Finland).²³ The number of missiles produced in 2017 roughly matches the number of Scalp/Storm Shadow missiles.

The European rival to the Scalp EG / Storm Shadow at the time of the British ITT – the Taurus KEPD 350 – was initially designed by LFK. It entered service at the end of 2005, reflecting the determination of the Germans to equip the Luftwaffe with a national weapon of this type. With an equivalent range and a slightly heavier warhead, the missile uses the same navigation technologies as its counterparts, such as DSMAC terminal guidance. Its development took longer, only coming into service after the acquisition of LFK by MBDA. Unlike the Franco-British missile it has not been used in any operations but has, nevertheless, managed to win export contracts with the Spanish and South Korean Air Forces. The total number of missiles produced remains below 1,000 and like its Franco-British equivalents, is currently undergoing a mid-life upgrade contracted in 2014.

Now taken over by MBDA following the acquisition of LFK, the Taurus continues independently, without any real commonality or read-across with the Scalp EG/Storm Shadow.²⁴

There are equivalent Russian and Chinese missiles, but they are rarely exported. The Indians have also developed an equivalent solution for their own needs.

²² The JASSM is integrated onto the F15, F16 and FA 18 as well as the B1 and B52. The JASSM-ER is integrated onto the B1 and should shortly be integrated onto the B52, B2 and F16. It can only be integrated onto the F-35 by using external mounts (source: *Jane's*).

²³ Poland received a complement of JASSM-ERs in 2016 (“70 JASSM-ER Missiles for the Polish F-16 Fighters. US State Department Issues a Consent” – *Defence 24.com* – 29 November 2016).

²⁴ “Europe’s cruise missile conundrum” – *Interavia* – June 1998.

The emergence of an industry leader

Tectonic shifts in the industrial base

When the programme began, there was a capable European industrial base in the missile sector, with five major industrial players mastering some or all of the relevant technologies:

France:

- ➔ Aérospatiale, produced high-end, strategic missiles with high subsonic velocities such as ASMP and Exocet;
- ➔ Matra Défense had developed the stealthy, low speed Apache missile as part of the Apache MAW consortium (Matra Défense and MBB) within a Franco-German cooperation. Constrained by the concept of use at the time, the specification of the Apache missile was based primarily around stealth and had a relatively limited performance.

United Kingdom:

- ➔ BAe Dynamics: although the company did not have a product in this range it was a major player, having developed expertise through NATO projects.
- ➔ GEC Marconi, created by the merger of the two rival British companies, had expertise in long-range strike capability but none in cruise missiles. It specialised in remote standoff weapons before considering a merger with Hughes on a reduced Tomahawk for the CASOM competition.²⁵ These two British competitors made an abortive attempt to join forces at the start of the CASOM competitive process.²⁶

Germany:

- ➔ MBB (now LFK, part of MBDA) had developed the Apache missile with Matra Défense (in association with Aérospatiale). The company put forward the Taurus missile, based largely on its experience with the Apache.

Only the French players had the full suite of technical capabilities to be able to offer a complete capability. The other players, however, were not far behind and had some advanced technologies that could offer significant advantages compared to their competitors.

Only the two French firms were consulted for the French competition. The involvement of other European players was not prohibited but was made more

²⁵ *Les Echos*, 28 May 1996 – “Missile de croisière britannique : GEC s’allie avec Hughes”.

²⁶ Think Defence – UK Complex (Guided) Weapons – CASOM / Storm Shadow.

difficult when the requirement was made more demanding; a step taken partly to sustain the skills necessary for the airborne component of the French deterrent.²⁷

On the British side, the competition was open to international players from the outset as there was no national off-the-shelf capability. The key drivers in the competition were cost and the ability to field a solution quickly. Bids were put together by bespoke consortia created for the competition. Given that some form of industrial return for the UK was a factor in any competition, an alliance with a British firm was at least desirable, if not essential, for any competitor.

With this in mind, Matra Défense – which had initially planned to submit a CASOM bid with its Apache partner LFK – quickly took on board the lessons learned from losing the ASRAAM contract and decided to ally with the dominant British player, BAe Dynamics. This brought its alliance with LFK to an end; its alliance with Aérospatiale/DASA suffering the same fate later on.²⁸ LFK subsequently decided to submit a Taurus proposal, based on the DWS39 developed with Sweden.

For both Matra Défense and BAe Dynamics, it soon became clear that the alliance could and should become a merger; a proposal supported by both governments. The two national programmes, combined into a single industrial programme, became the catalyst for the merger. Given what was at stake, the managers of the two companies linked the two procurement programmes directly to the merger: the more or less simultaneous signature of the French and British contracts became the *sine qua non* condition for the definitive merger of Matra Défense and BAe Dynamics into the new firm Matra-Bae dynamics, or MBD.

The alignment of missile specifications between France and the United Kingdom resulted from industry's desire for a competitive product tailored to the British ITT.²⁹

In some ways, it seems likely that the launch of the Taurus by LFK and the bitter financial battle that LFK waged, were designed to prevent the merger between Matra Defence and BAE Dynamics; a merger that threatened to sideline Aérospatiale/DASA and the German missile industry. However, once the contracts were awarded, the merger succeeded and MBD became a fixture in the industrial landscape; a global player with a full spectrum of weapon products had been created.

Subsequently, in 1999, Italy also selected Scalp/Storm Shadow – again in competition with the Taurus – based principally on the missile's performance. The

²⁷ This was confirmed in Matra Défense's announcement after winning the initial French competition: it coincided with the launch of studies on the future naval missile and a production-sharing arrangement in line with the Matra Défense/Aérospatiale agreements on the Apache (*Les Echos* – J-P. Neu – 16 December 1994).

²⁸ Following the French competition, Aérospatiale was supposed to undertake part of the production of the chosen missile. The commitment was reciprocal.

²⁹ "Can European Co-operation Deliver Competitive, Cutting-edge Defence Equipment?" Laurent Giovachini – RUSI Acquisition: International Collaboration – RUSI Defence Systems, June 2007.

scale effect on costs and the lower risk inherent in an already well-developed solution were also important factors in the decision. It also led Italian industry to ally with the new company, with Alenia Marconi Systems merging with MBD in 2001.

Ultimately, Aérospatiale also merged with MBD, creating MBDA. It was facilitated by the earlier merger, in 1998, of the Aérospatiale Group with Matra Hautes Technologies. This merger, agreed between the French Government and the Lagardère Group, was based on the selection of Aérospatiale's Aster missile for the PAAMS and SAMP/T programmes. The subsequent Meteor programme was the first major programme taken on by the newly merged MBDA. The Scalp/Storm Shadow programme was nonetheless the first step and the main catalyst for the creation of the European missile-maker MBDA.³⁰

Effective programme management

The Scalp EG and Storm Shadow contracts, once launched, ran in parallel without any inter-governmental coordination body; the industrial programme team assured co-ordination between the two contracts so that they converged towards a common product.

France and the United Kingdom had each bought into a co-development approach. Each nation's contract was untenable without the other nation's contribution and each contract specified 50% self-financing of the development phase, corresponding to the other nation's financial contribution. Each contract could, theoretically, have continued if the other were abandoned. However, even if the self-financing requirement could be met, the overall contract value would have been greatly reduced due to the lower overall quantity of missiles ordered. It was obvious to all involved that any unilateral questioning of the cooperation would have immediate bilateral consequences³¹ and would have had a serious impact on the construction of the future European missile systems champion.

Despite this symmetry, there was an appearance of asymmetry between the two contracts: the British ITT framed the purchase as an off-the-shelf procurement with minimal changes hence requiring little development; the French contract, by contrast, was focused more on the technical development requirements. This apparent asymmetry created the illusion that France was taking greater technical risks on the development, or even that the British were getting a better deal; a view that has emerged in French parliamentary reports.³²

³⁰ Interview with Fabrice Brégier: "MBD vise le leadership mondial dans les missiles" – *Les Echos* – 25 October 1999.

³¹ MBDA presentation of the Scalp / Storm Shadow programme to the Conseil Economique de la Défense (CED) – February 2010.

³² On this point, see the views of the French National Assembly and the Cour des Comptes (French equivalent of the UK's NAO) in the Finance Commission report concluding the work of the Evaluation and Control Mission on the conduct of cooperative weapons programmes (François Cornut-Gentille, Jean Launay and Jean-Jacques Bridey), in particular page 128: "*The picture in relation to Storm Shadow is more mixed, as it is a derivative of the SCALP-EG and France shouldered most of the development costs for the British version.*"

In reality, the contracts incentivised industry to maximise commonality in their solution even if each nation retained flexibility in its choices. Without *juste retour* constraints and limited government interference, the selection of subcontractors was based on a “best athlete” principle.³³ The preference for autonomy and the desire to export the missile meant that European solutions were preferred to avoid ITAR constraints, something that was possible because of the increased openness of the French technology base.

Although the solution remained close in its fundamentals to the architecture of the Apache missile, the specificities of the Scalp/Storm Shadow requirements led MBD to select the terminal guidance imaging infrared seeker proposed by France which, at the time, out-performed its American counterpart. The French motor was also selected³⁴ in order to retain sovereignty and exportability.³⁵

The British performance requirements led to the selection of British solutions for the warhead (BROACH)³⁶ and the terrain matching system (TERPROM). The satellite guidance, although non-critical, remained a weak link in terms of autonomy, mainly because of delays in the Galileo programme which could have provided a completely autonomous European guidance and navigation solution.

Despite the absence of an inter-governmental agreement, the division of work was clear and sufficiently adaptable to incorporate second-tier partners, as demonstrated when the Italians joined the programme. Although the programmes were distinct in terms of their stated requirements and contracting route, the broad convergence of military need and MBDA’s decision to offer the same product to both customers meant that a single programme directorate could be set up within MBD.

Separate, national organisations in each country

The single industrial programme directorate found itself facing two independent national organisations with no joint structure to facilitate communication or coordination between them, with the risk of uncoordinated national decisions persisting throughout the life of the programme. On the government side, the programme was dependent on information exchange agreements. There were no major crises during development and key decisions, such as the warhead choice, were made in a spirit of mutual understanding. This meant there was no appetite for additional co-operation structures. However, the absence of an intergovern-

³³ This means selecting the most efficient players in the supply chain, those with the necessary skills to develop those technologies required to achieve the goals of the programme. This stands in contrast to the method often adopted in cooperations between multiple industrial groups, in which firms use these programmes as an opportunity to obtain and develop new skills.

³⁴ The only alternative was an American motor, which could have jeopardised the product’s autonomy.

³⁵ The motor is one of the critical technologies cited in the non-proliferation treaties: having a European engine limited export problems. The Taurus, with its US-made engine, is far more restricted in this respect.

³⁶ The French and British did not have the same needs at the outset, and therefore had different warheads. However, the performance of the British warhead against hardened targets soon won over the French, who integrated it into their own specifications.

mental body was probably a factor in the lack of convergence on support. Because of differences in launch aircraft and targeting chains, the mission preparation functions remained national, based on a shared industrial concept.³⁷

The concept of avoiding a joint government team continued when the two countries embarked on consideration of the missile's mid-life upgrade programme. After a joint design phase, the mid-life upgrade was again split into two separate contracts, one placed by the British in October 2016, the other by the French in December 2016. In any event, it would have been costly to create a common structure at that stage.

The countries benefited fully from each other's test and evaluation resources, and government expertise in this domain. The French, for example, were able to access the results of tests conducted by the British in the United States. The unified industrial programme structure, the synergy between the teams' skills and the strong downward pressure on costs allowed significant efficiencies to be achieved during missile qualification.

In addition to the other benefits it brought to the programme, the UK also brought a sense of urgency; wishing to make the weapon available to the armed forces as quickly as possible to meet pressing operational needs. This led to the acceleration of the development process, via the UK's Urgent Operational Requirement process, in order to make the missile available for use in the Second Gulf War. The British determination to field the weapon early resulted in the only inter-governmental agreement of the programme; an MoU covering sharing of operational information between the two air forces.

Incentives to control costs

The various tendering processes and final negotiations created significant negative financial margins for the programme and put it under severe budgetary pressure from the outset. MBD's immediate priority was to drive costs down by exploiting their freedom to manage the programme in an optimal way. A permanent cost-cutting campaign was instigated across MBD and its supply chain,³⁸ that ran all the way through to qualification. MBD systematically reviewed the suppliers from both countries and selected the best offer in terms of a mix of skills, autonomy and cost. This approach ultimately kept the programme on budget.

The contractual structure incentivised the nations to avoid unilateral changes of requirements. There were very few changes in the course of the programme, barring one significant change to the warhead. This change led to a simplification of the programme, was put in place very quickly and did not affect the programme

³⁷ This approach also reflected both countries' desire to keep their targeting procedures completely separate.

³⁸ Including industrial subcontractors and partners.

price estimate, as the change in cost was covered by the contractual contingency reserves.³⁹

In addition to direct cost control measures, the economies of scale – including exports – played a large part in reducing overall costs and enabled industry to generate a profit. This scale of production was something of a “one-off” for a European complex airborne missile; the number of missiles produced was of an order more typical of American missile production runs rather than European ones which are typically about a tenth of the size.

³⁹ In the presentation to the CED, MBDA stated that 85% of the French contract contingency funding (capped at 25m francs) was used, less than 5% of the total French contract value. The increased cost was also due in part to the acceleration of the Storm Shadow programme, under the Urgent Operational Requirement.

What lessons can we learn?

When analysing the key success/failure factors behind cooperative programmes it needs to be recalled that every co-operation is different and Scalp EG/Storm Shadow had unique characteristics. For instance, from a formal government perspective, it was not a cooperative programme in the sense that it was not covered by any agreement between the French and British Governments. It was, however, a tremendous bilateral cooperative success story that has interesting lessons to offer.

A product designed for export

Exporting cruise missiles is not a straightforward undertaking given their strategic nature and the necessary measures put in place to limit technological proliferation. However, with a strong demand for such weapons on the export market, the missile's architecture was designed from the outset around the option of exporting the missile to non-NATO countries. This approach made it possible, albeit after some lengthy wrangling, to comply with the requirements of the existing non-proliferation agreements (Wassenaar⁴⁰ and MTCR⁴¹).

The chaotic development of the JASSM and its delayed development, provided a window of opportunity for European cruise missiles on the export market. With Stormshadow/Scalp becoming available in the very early 2000s, it offered its various launch platforms a significant competitive advantage in terms of precision air-to-ground strike capability. Combined with other exceptional weapon systems such as the Meteor, it provides European combat aircraft with an edge when competing with American solutions that are not scalable and are often tightly controlled.

Scalp/Storm Shadow exports are supported by both the French and the British governments, who can leverage the missile's strike capability and operational record with their existing and prospective combat aviation customers. The missile remains affordable for a world-class technology and the missile's supply chain resides almost exclusively within the two countries, limiting the risk third-party constraint on exports.⁴²

⁴⁰ The Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies is a multilateral export control regime set up by 41 countries to coordinate policy in this area. It came into effect on 12 May 1996, replacing the Coordinating Committee for Multilateral Export Controls.

⁴¹ The Missile Technology Control Regime (MTCR) is a multilateral export control regime set up in 1987 with the aim of limiting the proliferation of weapons of mass destruction by controlling transfers of potential delivery systems. The related Hague Code of Conduct (HCOC) of 2002 currently has 138 signatory states. Not all nations with ballistic capabilities have yet signed up: the subscription process remains open.

⁴² There were temporary difficulties over the part of the missile made in Italy and the recent difficulties with exporting Scalp to Egypt illustrate a degree of dependence on certain American components.

Once developed, success in exporting the missile was immediate: Scalp for the UAE, was sold almost immediately after the main contracts (1997); the Greek Scalp order in 2000 came hard on the heels of the Italian Storm Shadow order in 1999; an order for Saudi Arabia (Storm Shadow) followed later in 2006, with the most recent order from Egypt (Scalp) in 2016. These exports demonstrate how well the weapon addressed the needs of the market and continues to do so.

The need to export missiles led the two governments to work together closely on the question of licensing. These multi-level, inter-governmental contacts, that included the French President and British Prime Minister, along with the defence, diplomatic and economic departments of the two governments, enabled inter-governmental problems to be ironed out quickly despite competition between aircraft platforms. In doing so, it prefigured the subsequent Lancaster House Treaty arrangements.

Because of the separation of the national programmes, each government collects royalties on its own export sales in proportion to its development expenditure. Since the Scalp/Storm Shadow programme drew heavily on the development of the Apache missile, financed by France, France obtained an export licensing formula on more advantageous terms than the standard formula used by the British customer. However, the formulae apply only to the contracts signed by each nation; France receives no royalties on British sales and vice versa.

Maintaining genuine operational autonomy

The maintenance of operational autonomy was important on both sides of the Channel; a traditionally critical requirement for the French, it was somewhat less so for the British. The UK realised, however, that with an autonomous capability it carried greater weight in any coalition with the Americans, a point enforced by Storm Shadow's excellent results during the strikes on Iraq. These astonished the Americans, particularly the incident where two Storm Shadows targeting a single bunker followed each other through the same 50-cm hole, comprehensively destroying it.⁴³ The weapon helped give the British credibility in American eyes during the second Gulf conflict in 2003, particularly as the corresponding American system, JASSM, was not available. The Americans mainly used their Tomahawk capability (also used by the British) and airborne weapons (e.g. the AGM-84H SLAM-ER) leaving their aircraft more vulnerable.

The autonomy of the Scalp/Storm Shadow capability was confirmed during the Libyan crisis, and later during the Syrian crisis. Used by both countries, the weapon confirmed its capability to support a "first entry" capability (Libya) and deliver precision retaliatory strikes (Syria). It gave Europe a very effective precision deep strike capability that was almost entirely independent from the US at all levels in the targeting chain, including the targeting and mission preparation systems. These were, by choice, even more independent on the French side.

⁴³ It took a detailed, post-war analysis of the debris to confirm what had happened as it was initially assumed the second weapon had missed. See *Flight International* – May 2003.

This autonomous capability greatly enhanced the value of European combat aircraft in comparison to their American competitors. While the recent arrival of the JASSM to equip the F/A18 and F16 in Poland and Finland has been crucial in boosting the credibility of these American capabilities in those countries, the degree of independence the Americans allow in its use is more difficult to determine.

The renewal of the Scalp/Storm Shadow capabilities will necessarily have to consider the needs for operational and industrial autonomy, given the advantages they give the nations in coalition/non-coalition operations and in the export of such weapons. It is clear, however, that the precise requirements will not be simple to harmonise, given the different weight given to the need for independence by the two countries' policies and cultures.

The art of converging requirements around the solution

The French selection of a stealthy missile over a high-speed one was implicit in their acceptance of the British ITT's requirements.⁴⁴ This made it possible to obtain a reasonably complex and effective missile for a unit cost compatible with the needs of mass production and export.⁴⁵ The use of a proven architecture for the critical missile elements, based on mature technologies from each side of the Channel, clearly helped to converge the requirements.

The absence of an inter-governmental structure overseeing the two contracts did not appear to be a handicap during the original programme for the reasons discussed. However, such an approach could create difficulties when it becomes necessary to renew the capability in the 2030 timeframe. For this to continue as a cooperation, with its attendant benefits, there need to be suitable mechanisms in place to share performance data and emerging needs between the two governments.

The original programme benefited from the very special circumstances that surrounded the creation of MBD, with a manufacturer making a strategic choice to accept a very high risk by embarking on the development of a missile with two independent but complementary contracts. However, the risk taken by industry was commensurate with the reward: becoming the undisputed leader of Europe's missile sector. It is not clear what industrial incentive there would be to justify taking such a risk in the future.

⁴⁴ The expert debate sought to decide between the two cruise missile solutions developed by France: the ASMP family emphasised speed, by developing a supersonic solution, while the Scalp family developed a stealthier solution, allowing a subsonic solution. Due to a lack of expertise in the field of supersonic ramjets, the British could not really envisage the first solution, thus provisionally settling the debate in France, which was already heading in that direction because of the costs of the French tender proposals.

⁴⁵ The ASMP solutions cost several million euros per unit, compared to a price tag of under a million euros for the Scalp. The cost of the equivalent US missile is higher, but still in the order of a million euros.

The challenge of controlling programme performance, cost and time

The programme delivered without any critical derogations against performance, cost and time, partly because the solution was largely based on the Apache missile. Although many of the technologies chosen were innovative, they were sufficiently mature to limit the technical risk and the sharing of the remaining development costs greatly facilitated the launch of the programme.

Since the selection of subcontractors was primarily a matter for industry, the absence of formal workshare constraints meant that MBD could operate with considerable freedom. The programme suffered from almost none of the usual top-heavy decision-making and additional costs that typically beset cooperative programmes. Any decisions made by each nation were made quickly, without going through an international organisation for review, and the absence of workshare constraints limited the industrial-level discussions to a few key cases. In general terms, industry had a free hand to optimise the profitability of the programme.

The increase in production numbers reduced the unit cost, enabling a larger number of units to be purchased on the French side, and creating a competitive advantage for the Italian ITT and other exports; competitors did not have the advantage of scale or the range of launch platforms. Obviously, now that JASSM has reached maturity with JASSM-ER, the nature of the market is beginning to change.

The performance of the Scalp / Storm Shadow remains what it was at the outset and is still world-leading even if the range of the JASSM-ER is impressive. This level of performance was not, however, a lucky accident but rather the result of significant upstream research and development investment, and several years spent developing the corresponding skills in the two nations.

The missile was ready for the Second Gulf War, barely six years after it went into development; a remarkable result, especially when compared to the far less flattering results of its competitors. Two favourable events acted to accelerate the programme: the fact that the French contract was awarded one year later than the first contract, which put pressure on industry,⁴⁶ and the fact that it dovetailed into an (UK) urgent operational requirement programme which also drove all the players to deliver an operational product as soon as possible (even if the French had to accept a slight delay in their programme).

Industrial consolidation: the cornerstone of the programme

The Scalp EG / Storm Shadow programme is evidence of how important it is to base strategic industrial restructuring in the defence sector around a key programme. Both companies had to adapt their structures, processes and supply chains to achieve the highly challenging programme goals. One industrialist

⁴⁶ MBDA would have had to assume – on their own – the consequences of France pulling out or not giving the green light, as the UK contract was already under way. But, given the crisis that would have ensued, the probability of such a situation occurring was low.

involved in the programme noted that *“The merger between two traditionally competing companies led – as it often does in the first few years – to significant tensions within MBD; except on the Scalp / Storm Shadow programme, where the success of the programme depended above all on the success of the teams' work. For the sake of the programme, the management of the time had to do all they could to avoid internal ructions.”*

The cooperative programme lifted the national programmes of Matra Défense and BAe Dynamics out of their purely national logic by opening up new perspectives and getting each entity to share the best it had to offer. The subsequent success of the programme validated the industrial strategy adopted, providing the basis for other multi-national ventures such as Meteor. It also exemplified the principles for a successful merger between peers: creating value by optimising the use of capital, increasing competitiveness by enhancing the skills set (requiring strong complementarity between the two companies for the goal to be achieved), increasing production volumes, and achieving this without disrupting customer relationships under the guidance of leadership that kept its eye on the main objective.⁴⁷

⁴⁷ *Fusions-acquisitions: la seule chose que vous devez savoir* (Mergers and Acquisitions: The only thing you need to know) – Roger L. Martin – September 2017 – Harvard Business Review France.

CONCLUSIONS

The success of Scalp EG / Storm Shadow programme was built around a highly challenging schedule and an unshakable faith in the success of a programme that was essential both for the operational independence it would bring and for the industrial consolidation that underpinned it.

Similar drivers were evident in the flagship MBDA programmes that followed; Meteor was driven by a desire for further rationalisation within the industry. The need for strategic autonomy remained a key factor: a desire to remain at the level of the Americans without depending too heavily on them continued to be a strong incentive for investing in these strategic programmes, at least for France and the UK,⁴⁸ but also, increasingly, for Germany. It is, to a large extent, MBDA that guarantees that this ambition remains feasible.

The Scalp EG / Storm Shadow programme was a unique form of bilateral European cooperation – not a “classical” cooperation, managed by governments, but one founded on a common industrial product selected through competition by the two countries – and that is potentially a reason for its success. Some further success factors are worth noting:

- ▶ It was a response to high-level, strategic requirements that were important to both countries, with strong symbolism in terms of the top-level, autonomous capability it provided, both in military and industrial terms.
- ▶ Avoiding national variations allowed the programme to focus on the fundamental requirements and reducing the unit cost of the missiles.
- ▶ It was a European industrial solution designed to satisfy demanding NATO customers while remaining exportable outside NATO. Ultimately, this was quite similar to the American benchmark system that would arrive on the market much later but it was a competitive solution because it reached the market earlier.
- ▶ Industry’s desire to win this contract was part of a clear industrial strategy to rationalise the missile sector; the cooperative development of Scalp EG / Storm Shadow enabled the first step in that process, with the creation of MBD. Industry took a gamble on a competition that it had to win in both countries in order to develop the weapon, but it deliberately based its solution on the synergies that would be generated by merging the Matra Défense and BAe Dynamics teams and their supply chains. The same logic

⁴⁸ The UK sought to be as independent as possible from the Americans when it came to equipping the Typhoon, perhaps for reasons of autonomy, but also to preserve the Typhoon’s export prospects. The UK developed the ASRAAM independently (in competition with the German IRIS-T, derived from the Sidewinder) and, jointly with France, developed the Storm Shadow – in competition with the German Taurus, which contains many ITAR components (engine, seeker assemblies, etc.) – and the Meteor (which Germany joined).

would later be followed for the merger with Alenia Marconi and Aérospatiale, which centred on the Meteor and Aster systems respectively. While this approach is effective for complex missiles, the strategy is more difficult to apply to MBDA's other products, which are more often driven by unique national considerations.

- ▶ There were separate national programme structures at state level, with very light coordination between them. This was a programme without MoUs (there were merely agreements to facilitate information exchanges), that was principally held together by industry. With both countries seeing the programme as a strategic priority, it wasn't subjected to any major requirement changes. The mid-life refurbishment programme maintains the model of separate national contracts; only the preparatory phase for the refurbishment was done jointly, in order to limit design divergence and to maximise commonality.
- ▶ The product was built on the mature technologies and established experience acquired by the two countries, and able to satisfy the requirements of two separate competitions. In just six years, the development provided both countries with a mission-ready weapon system that neither could have dreamed of before.
- ▶ Something of an outlier in the landscape of European co-operation, this programme proved very effective in both its genesis and in its implementation. It obeyed all the fundamental principles of successful cooperation, namely: aligned performance and schedule requirements, a shared political will to maintain military and industrial rationalisation, an industrial solution based on skills, industrial management provided by a strong prime contractor with no workshare obligations, and clear cost-sharing arrangements.
- ▶ The programme was also successful in that it benefited from a favourable 'alignment of planets', the right conditions coming together at the right time and in the right place.

Despite the element of happenstance, it is worth asking whether this model can be re-used for other capabilities. This "cooperative" programme raises a number of interesting questions:

- ▶ First of all, to be successful, should cooperation be left to industry? Governments are unavoidably involved in the financing of technology development, in awarding contracts to industry, in implementing agreements to exchange documents and information, in defining the military needs and in overseeing the qualification phases. In this particular case, the two governments managed – thanks to two separate competitions and two independent contracts awarded to a single industrial entity – to avoid many of the usual pitfalls of cooperation: workshare allocation, alignment of funding, and compromises over requirements. This programme remains a special case and it is clear that most future cooperations will not be amenable to this type of organisation; nonetheless, the method could be

tried more often, and there could be more programmes driven by cooperation centred around a defence industry offering.

- ▶ Secondly, when should nations cooperate on technologies? If the project was such a success, it is partly because it built on considerable prior technological investment by each of the nations. It was able to rely both on proven technologies (TRL 7⁴⁹ and above) and maturing technologies (TRL greater than 4), none of which had been developed in cooperation between the two countries. Had the countries attempted technological cooperation earlier in these phases, it is possible that the project would have failed, for lack of a strong decision-making integrator in the critical technology selection phases.⁵⁰ To some degree, the procedure adopted – and MBD's determination to use this programme as a flagship for its merger – placed the technology selection process entirely in the hands of industry, with little state intervention. This effectively optimized the process. Efforts since then, including the Materials and Components for Missiles Innovation & Technology Partnership (MCM ITP) programme, show that collaboration at the lower technological readiness levels (TRL 1-4) can bring results for later programs. However, the effectiveness of cooperation at the higher TRLs (4 to 6) – with their greater cost, complexity and strategic implications for the industrial base – remains to be demonstrated.

- ▶ Thirdly, could competition generate a higher success rate in cooperative programs? The impact of competition on the success of the programme should not be overlooked and a competitive model could be used more widely in bilateral and multilateral cooperation than it is today. Though cooperation undeniably brings additional costs, there are grounds to suspect that the industry exploits the root-N rule⁵¹ to obtain a form of additional margin in directly awarded contracts. The efficiency of the Scalp/Storm Shadow programme is also due, in large part, to the need for the industry to come up with competitive bids in the face of determined and insistent competition. The proposals therefore precluded the usual additional costs and duplications from the outset, particularly as some of the competitors

⁴⁹ The TRL (Technology Readiness Level) scale is a technological maturity metric adopted by the US Department of Defense and recognised as a standard tool for technological comparison: TRLs 1 to 3 correspond to laboratory research work. In TRLs 4 to 6, the focus is more on industrial readiness. In TRLs 6 to 8, the technology is in the development, integration and system qualification phases. TRL 9 corresponds to actual operational use.

⁵⁰ In terms of minimising duplicate investments, one school of thought holds that concerted action is most effective at the basic research level (TRLs 1-3) or at the prototyping / developing level (TRL6+, as was the case here), but not in the middle, the “Valley of Death”, (TRLs 4-6). It is in this latter zone that we find the point of maximum uncertainty: efficient choices are made in this phase on the basis of industrial strategy alone – rarely an area for easy inter-governmental cooperation.

⁵¹ This widely quoted rule of thumb that suggests that the total cost of a cooperative development programme is proportional to the square root of the number of cooperative partners. In the case of a bilateral cooperation, with two partners, this suggests a total cost 40% higher, meaning each nation saves 30% compared to doing a purely national development (140% divided by two nations gives 70% of relative cost).

were not hampered by such considerations. Any competitive process may be limited by the need to maintain sovereignty, at least at the European level.

- ▶ Finally, it is instructive to study the motivations of the different actors within this cooperation. The industrial players had to find effective solutions to meet, among other things, difficult financial targets. This motivation, added to a determination to make a success of the industrial merger – a visionary motivation for the time – emerges clearly from all of the interviews with those who worked on the original Scalp EG / Storm Shadow programme. There was a sense that there was “something special” about this programme. The recent Nobel Prize winner in economics, Richard Thaler, who developed behavioural economics has sought to better understand the motivations of individuals beyond a purely rational economic perspective. The tools of behavioural economics are likely to offer valuable insights to help manage future cooperations more effectively, and increase their chance of success.

With the British and French deep strike capabilities coming up for renewal by 2030, this cooperation and the reasons for its success, as well as the limitations of its model, merit careful reflection.