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Air Power and New Technologies



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Design and layout :

Emmanuel Batisse

Philippe Bucher

SGT (OR-5) Nadir Bouras

Distribution :

Claude Donavin

CLC (OR-4) Mathieu Cornu

Correspondence address :

CESA

1 place Joffre – 75700 Paris SP 07 – BP 43

Phone : +33 1 44 42 83 96

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vortexlarevue@gmail.com

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Overflight

Jean-Christophe Noël

Dear readers,

We thought it was all over, maybe it had even completely disappeared, or was at the very least pushed out of the borders of Europe. And yet, on February 24, 2022, war suddenly broke out, setting Ukraine ablaze. The South of the “Bloodlands”, the nickname given by T. D. Snyder to these regions where Nazism and Stalinism reigned, interacted and then fought each other between 1933 and 1945, causing the death of 14 million civilians, is once again the scene of violence and destruction.

Obviously, everyone is trying to understand the stakes of this war and the way it unfolded. If the flow of history teaches us one thing, it is modesty and it is advisable to remain cautious in our analyses. Our understanding of the war between the Soviet Union and Nazi Germany between 1941 and 1945 has, for example, been obscured by the publication of mainly German sources during the Cold War, resulting in a biased view of events. The opening of the Soviet archives from 1991 onwards has made it possible to correct certain interpretations to a large extent and to make sense of events that were puzzling, such as Stalin’s inaction before the outbreak of Barbarossa. Let’s keep in mind that our ignorance largely exceeds our knowledge for the moment.

However, the vocation of military analysts and other strategists is to try to understand what is happening in order to anticipate future events and improve the preparation of armed forces. Certain trends are nevertheless emerging on the battlefield. The Russians, suffering from their completely failed entry into the war, are returning to basic principles and are seeking to conquer ground by consuming large quantities of ammunition, equipment and men. The Ukrainians, whose initial resistance surprised and impressed, are trying to modernize their arsenal and westernize it in an accelerated manner. A war of attrition seems to be taking place, where maneuver has disappeared and the outcome will depend on the stocks, production capacities and logistical performance of each side.

Caught between the desire not to deliver easy, superfluous and quickly invalidated comments and the will to inform our readers, we finally made the choice to publish three articles devoted to Russia seen from slightly differing points of view.

The *Varia* section begins with an interpretation of the events of the first month of the war written by G. Coulombel, M. Pinel, X. Rival. Going beyond the simple narration of the fighting, they evoke the industrial aspects of the conflict and insist on the outdated doctrinal framework of the Russian aerospace forces. This will probably be one of the enigmas to be solved in the future. Why were Russian airmen, who were not ignorant of Western conceptual texts, not able to have a greater impact on the conflict?

A. Maurin completes with P. Grasser this *Varia* section by two texts. The first author offers a beautiful synthesis on the Russian space strategy. She insists on the fact that Russia tries to maintain its status as a “space power” despite its very limited means and is developing “nuisance” capabilities to show that it still counts. The war in Ukraine could stimulate investments and start a new phase... if resources so allow. The second author returns to Russian Anti-Area, Anti-Denial (A2/AD) capabilities, an aspect that has not been commented on much since February 2022, when discussions concerning the actual performance of Russian ground-to-air capabilities multiplied prior to the launch of the “special operation” against Kiev. The author reminds us that the vastness of Russian territory forced Moscow to make choices to protect its skies.

The way the war is being waged in the Donbass area heralds, for some, the appearance of a new cycle in the art of war and the return of high-intensity air-land warfare. Perhaps, although we must not forget that war is a chameleon, as Clausewitz wrote nearly two centuries ago. As an act of organized violence, it changes form according to the circumstances, the actors, their political goals... and the technologies employed, we would add. Confrontations similar to those in the Donbass could be conducted in a very different way if the capacities of the two adversaries were different. The Ukrainians have understood this and they are targeting force buildup. The relationship between new advanced technologies and the future of air power is the theme of the main feature in this third issue.

Three articles introduce this feature. The first, written by L. Henninger, serves as a reminder to all those who think that technology is the only decisive factor in modern warfare. He shows that technological capabilities are only one factor in a much more complex set that plays a role in the adaptation and evolution of military organizations. He calls for a better understanding of this phenomenon by taking into account the human sciences. N. Nelson and A. Stiles take stock of the American experience in the deployment and industrial integration of new disruptive technologies to draw lessons that could benefit Europeans. Some may regret that this article does not take sufficient account of political choices of sovereignty, but it has the great merit of showing that changes must also take place upstream of the battlefield for combatants to be effective. The third article, written by C. Talon, tells you everything you ever wanted to know about how new technologies work (hypersonic, quantum and artificial intelligence (AI)), yet never dared to ask. So, the reader will be better armed to understand what is at stake with the development of these technologies.

Readers who wish to deepen their knowledge will benefit from consulting the following three articles which develop several other themes related to these three technologies. D. Pappalardo analyzes and compares the different options chosen by the major powers for the development of hypersonic technologies. He underlines the new strategic dilemmas that are emerging, recalling that they are often more related to doctrines than to the technology itself. P. Vallée explores the different applications in the aeronautical world that could be generated by advances in quantum science. Some potential projects are unexpected and will undoubtedly stimulate the reader's imagination. However, the author is careful to quash any excessive ardor by estimating that these applications will not necessarily be game changers in the future. Finally, G. A. Boy focuses on the man-machine relationship and reflects on the issues of trust and collaboration that will be brought to the forefront with the development of AI. The author favors the empirical way of solving emerging problems and making progress in this field.

Far from these disruptive technologies, the general public probably considers that the symbol of novelty in aeronautics is the drone. Two articles are proposed to reflect on their introduction and use in the armed forces. As a sociologist, V. Karioty investigates in general the way new technologies are integrated in military organizations, and more specifically how the French Air and Space Force personnel experienced the arrival of drones. Taken from her thesis, this article shows that things went rather well, even if she does not obfuscate some tension. R. Desjars de Keranrouë develops a reflection on the operational use of drones. He believes that the complementarity between traditional weapon systems such as fighter aircraft or MALE, which are very efficient but expensive, and cheaper categories of UAVs that produce substantial military effects on the battlefield, deserves to be explored. One of the underlying ideas is to massify our aircraft fleets.

The last text that concludes this study is a mixture of the use of new technologies, operational feedback, the constraints of urban warfare, and the rise in military capabilities of armed and terrorist movements. L. Antebi provides us with an article that can serve as a summary, as it deals with the use of new technologies during the operation "Guardian of the Walls" in the Gaza Strip in May 2021. Does this operation herald, like the 1973 Yom Kippur War with its proliferation of tactical missiles, the appearance of new technologies that will spread to the battlefield in the future? Only time will tell, but reading this article already offers some food for thought that contrasts with the lessons that can be learned from the conflict in Ukraine.

The historical article takes us back to a time when jet engine technology had just appeared. However, this is not the most important factor that was to fuel the development of French air defense in the post-war period, as revealed by L. Paoletti. The question of French sovereignty weighed heavily in a context of both American presence in Europe through NATO and fears of Soviet invasion.

For the first time, the personality who takes the floor in the “interview” section is of French nationality. But his intervention is very special and, in a sense, unique, because he is the first of the French military aviators. General Mille, Chief of Staff of the French Air and Space Force (FASF), was kind enough to receive us for a very enriching interview, during which the man, the pilot and the military leader were revealed to us. He also speaks in detail about his vision for FASF. Among the many topics discussed, we emphasize his desire to place the use of air power in a joint framework, thus enabling the assets of FASF reveal their full potential.

The book review section closes this issue. Anticipating General Mille’s remarks, we broaden the spectrum of topics covered by focusing on books dealing with joint military issues and not only air power ones. The books reviewed in this issue offer critical analyses of the performance of armed forces engaged in various operations in recent decades. The first three books that caught our attention review recent operations of the French and British Armies. But we do not abandon the field of air warfare since we also present a must-have book to better understand the last 30 years of air warfare. The reader will be able to judge in what way the Ukrainian conflict is part of the continuity of these conflicts or is distinct from them.

If you wish to react to the content of this issue, or should you require further information or to make suggestions or proposals, we remain at your disposal via email at vortexlarevue@gmail.com.

We wish you an excellent read!

***Air Power
and New Technologies***

Human Sciences: Helping us to Think Better about Technology?

Laurent Henninger

Laurent Henninger is a military historian. He works on the concept of “military revolution” and its various occurrences throughout the ages. He is also a member of the editorial board of the magazine Guerres & Histoire.

For the past thirty years, the expression “military revolution” has been constantly used to characterize anything and everything.¹ Beyond the marketing effect of such semantic inflation, let us look at one of the rare “revolutions” that could legitimately deserve this title: the “military revolution” of Early Modern period (from the XV^e to the XVIII^e century). This little journey through time should allow us to better define the problem we intend to address: do the various human sciences provide relevant intellectual tools for thinking about technology?

Is technology the only thing that is changing the art of war? The military revolution of modern times

It is usual to place at the center of this historical phenomenon the appearance and the distribution of firearms – both collective (artillery) and individual (arquebuses, then muskets and finally rifles) – to explain all the events and processes that structured the art of war at that time. However, it appears that this

1. In reality, this expression is used in two contexts, and in two debates. On the one hand, it is used by historians of Early Modern period to designate all of the upheavals in the art of warfare that occurred from the XV^e to the XVIII^e century and that were largely rooted in the appearance and spread of firearms. On the other hand, it refers to a debate launched at the Pentagon in the 1990s around the upheavals observed since the first Gulf War and focused on the computerization of the battlefield. See the various articles devoted to this notion in T. de Montbrial and J. Klein (eds.), *Dictionnaire de stratégie* (Paris: PUF, 2000).

vision is very reductive, and even ideological, because it considerably limits the scope and depth of the art of war and thus bridles our comprehension. As soon as we look seriously at this matter, we see that the revolution actually began two centuries earlier, in the last centuries of the Middle Ages, with the rise to power in Western and Central Europe of popular infantry (rural or urban). These foot soldiers were generally engaged as a result of social or political struggles involving peasant or “bourgeois” populations (in the medieval sense of the term, *i.e.*, city dwellers) against the feudal aristocracy and its socio-tactical system of arms: chivalry. This is a change that owes nothing to new technologies, but everything to new tactics in the context of new social, political and economic conditions. In this respect, this situation is comparable to those which saw the birth of the Greek hoplitic phalanx or the Roman legion.²

The only technical – and not technological – aspect of this development in infantry lies in the search for weapons to keep heavy chivalry at a distance, with considerable frontal impact power. Long staff weapons or mechanical “throwing weapons” became widespread. On the other hand, when combat was inevitable, weapons appeared facilitating the combat of foot soldiers against horsemen. The halberd was exemplary in this respect since it combines a spear (for stabbing), an axe (for chopping), a hook (for unhorsing mounted adversaries), all mounted on a staff long enough to reach the opponent.

Note that nothing here is a “technological breakthrough”: no new metal or new mechanisms, only the widespread implementation of weapons known for centuries. A few decades later, we will see the appearance of individual firearms, which eventually supplanted the bow and crossbow. However, from a strictly technical point of view, these new weapons were inferior in every way to these mechanical throwing weapons: they were less precise, expensive to produce and purchase, did not work in wet weather, had a shorter range, and were dangerous for the user. If the “technological” logic of today’s world had been applied, individual firearms would never have won out over bows and crossbows.

They eventually did so, for one reason: they required a much simpler and faster learning process (a few weeks, at the most), allowing a powerful and rich prince to quickly have a plethora of infantry, where an archer needed five years of daily training to become effective. Technological progress would not be made until later.

The continuation of this military revolution of modern times was to see science and technology lead the way in all fields, starting with naval warfare. The basic sciences themselves (mathematics, physics, etc.) were at the forefront of this development. But the problem was then transformed, because we realized that this military revolution was in reality “only” the military aspect of a glob-

2. The appearance of these two tactical formations can only be explained from the rise of the “middle classes” of small landowners, both in Greece and in Rome, and their participation in the war as the main military force, reflecting their political and social position.

al upheaval affecting Western civilization – and consequently the rest of the world – since the West was embarking on a vast enterprise of domination. It is therefore appropriate to think of this historical movement as a whole, including religious reformation, social changes (the rise of a new class: the bourgeoisie; and the progressive decline of another: the landed aristocracy), political (the birth and deployment of the modern State with its bureaucratic apparatus), economic (the birth and rise of capitalism), geographical (the Great Discoveries and colonization, mentioned above), artistic and above all, philosophical, all of which played leading roles.

This was proof that technology could not be considered as separate from these phenomena. Indeed, it was precisely from the meeting and constant exchanges – between soldiers, master craftsmen, inventors, entrepreneurs, bankers, navigators, mathematicians, philosophers, artists and architects – that modern *engineering* was born; whereas in Asia, where such intellectual melding was prohibited, developments remained confined to *ingenuity*,³ with all the limits that one can imagine... By the way, let's not forget that the broad dissemination and the continuous improvement of firearms of all kinds between the XV^e and XX^e centuries was to modify the very definition of what courage was, passing from a heroic, demonstrative and theatrical courage, to a sober, more stoic kind of courage, made of acceptance of fate.

We can also approach this problem of the interaction between techniques and societies by taking it in a way “in reverse” through three examples.

It was believed for a long time that the pre-Columbian societies had not discovered the use of the wheel, until archaeologists discovered children's toys mounted on small wheels. The principle was thus known, but the reasons for the refusal to implement the use of the wheel is still the subject of conjecture.⁴

The Chinese in the fourteenth century mastered many of the techniques and technologies necessary for transoceanic navigation, as evidenced by Admiral Zheng, whose famous expeditions reached the eastern coast of Africa. However, shortly after his return, an imperial decree ordered the destruction of the ships and their blueprints, as well as the formal prohibition to embark on such ventures again. The imperial court and the mandarin caste believed that a wide opening to the rest of the world and foreign influences would create chaos. As it turned out, this was to lead to the rise of the merchant class to their detriment. This would inevitably upset the ruling oligarchy, and even the entire social order, which in this civilization is assimilated to the celestial order.

3. Unlike what we call “ingenuity” here, engineering is not just about making artifacts or machines, or even gadgets, but about putting them at the service of a broader and deeper transformation. It expresses the difference between an inventor and an entrepreneur. Starting from the analysis of a need, it leaves the strict domain of technology to touch other domains that it involves in a systemic and global process.

4. See R. Metz, *Histoire politique de la roue* (Paris: Vuibert, 2020).

Let us return briefly to the New World with the Indian tribes of the Great Plains of North America. When they discovered the horse with the herds formed by animals escaped from Spanish corrals in Mexico and returned to the wild, the Indians, who had the opportunity to observe the way the Spaniards used their mounts, chose not to adopt the heavy saddle with stirrups and to ride bareback. Anthropologists have now understood that this decision came from their cosmology in which animals are the equals of humans. It was therefore not necessary to ride them by means of constraining artefacts, but rather to try to be one with the beast by leading it with the thighs.

These three examples are not given to praise these civilizations and their refusal of certain innovations. It is a way of showing that the systematic quest for technical progress is not an absolute goal that runs through all of humanity and its history, that there is no determinism of technique, but only technical determinants.⁵ Moreover, it is also necessary to understand that certain civilizational and social configurations can block all or part of the innovation process. The interest is then for the researcher to understand precisely which configurations and in what way innovations were blocked.

The importance of the humanities in understanding and controlling technological development

For a long time now, political decision-makers, strategists and policymakers have been taking into consideration not only military factors, especially tactical factors, but also economic, financial and geographical factors. But all that is the subject of research and thought in the disciplines of the “human sciences” (anthropology, sociology, history, philosophy, to mention only the main ones and without excluding the others)⁶ and is still too often underestimated, even though these subjects constitute formidable intellectual tools to explore aspects of strategy that have almost always been ignored.⁷ However, we are already used to the fact that technological advances in the fields of information technology and communication are changing the way of life and the essence of the human condition.

5. These social changes – in the broadest sense of the term, *i.e.* including political, economic, cultural and technical factors –, are indeed systemic and composed of factors, none of which is sufficient on its own to drive the others.

6. Psychology is part of this, of course, and it is already widely used in the armed forces, which is a very good thing. But it is limited to the study of man as an individual, including his relationship with the machine, whereas the other human sciences study him as a collective being, a member of a group, a community, a class, a sex, a nation, or even an organization or an institution.

7. History is a special case. Overused – unfortunately! – by all military authors and warlords since Antiquity and constituting one of the foundations of the intellectual training of officers everywhere in the world, it showed its limits with the two world wars in the XX^e century to be almost totally rejected from the 1950s onwards under the pretext that the strategies of the nuclear age would render it obsolete. Such a discourse – of American origin – was part of a real scientific ideology aiming at the mathematization of war and strategy. Of course, this is not the case, provided that history is used with discernment and good sense, avoiding the deadly pitfalls of ideology and the frantic search for hypothetical “lessons” that would allow to build recipes at will with little intellectual effort.

Not a week goes by without reading articles in the mainstream press about the consequences of the omnipresence of screens in the daily lives of young generations, about their cognitive dependency on screens with the gradual disappearance of reading. This is only the acceleration of a trend that has been observable since the 19th century, with revolutions in transportation, medicine, leisure, arts and communication. In this last field, it is interesting to note that the telephone initially had difficulty in being accepted by social elites, because only the servants were supposed to answer when they were rung! If sociological or anthropological analyses of the effects of these technologies on daily life, the economy, politics or even collective mentalities are now commonly accepted, why should it not be the same for weapons technologies in military societies, and to ask oneself what changes they might entail?

Technology is deserving of thought: this is an absolute necessity. Since Aristotle, techniques have been one of the great subjects of study for philosophers, and this was neither a coincidence, nor a fad: the use of tools is one of the main markers of the human species that differentiates it from animals. These tools were extensions of Man, of his arms, his legs, his brain. With the current technological explosion, which could accelerate to the point where it may soon border on the uncontrollable, this relationship is likely to be turned upside down. And humanity is in danger of losing its grip – in every sense of the term. This is why, more than ever, it is necessary to design and implement tools and devices that will allow us to control our destiny. The human sciences are part of this process. They delve into the conditions governing the emergence and disappearance of technologies, their positive and adverse effects, as well as the risks they pose.

The humanities help explain the transition from invention to innovation, *i.e.* the dissemination of an invention throughout society and its subsequent adoption. This approach helps identify the conditions that make it easy – or not – to adopt a technology in a social or professional category of the population, or the persistence of technologies that may nonetheless seem obsolete.

The first of these disciplines, the philosophy of techniques, asks as a first question: what really is technical? Then, what is the role of the machine? And what is humanity's role?

But the questions need not stop there; we could for example add one about the nature of the sites for deployment. Within the framework of our problem, this would be the equivalent of fundamental research in mathematics or physics. Even if the flights of fancy of these supposed absent-minded researchers in fundamental mathematics may seem totally disconnected from reality and perfectly irrelevant to us, we will need to think twice. Without such research, the engineering sciences would not be what they are today. There would be no GPS, no hypersonics, no datalinks, no ballistic missiles, and the list goes on... The sociology of technology studies the insertion of the technology into a civilizational, social, and political system, while Anthropology studies technology in the relationship that men, as collective beings, have with their bodies, their physical existence.

And lastly, History studies all of this in relation to time. All of these approaches aim at countering, at hindering the *fetishization* of technology, at mastering it, at dominating it to contribute to its control, because the technology that self-justifies winds up chasing its own tail and is as likely as not to run amok.

Last but not least, most of the techniques today are intended to be thought of within the framework of “technical macro-systems”,⁸ as is currently the case for transport, road systems, pipelines and power grids. But these macro-systems are not only technical. They are also economic and political, and even social. In such systemic and dynamic environments, all the elements must be thought out, both in themselves and in their mutual interactions, if only to understand the place and role assigned to each of them. The reflection on the interactions between several macro-systems is also facilitated.

It is ultimately a question of avoiding men becoming mere appendages of their machines, appendages that will sooner or later become superfluous. Now, war being an eminently political phenomenon – if not the most political of all –, we risk ending up with the emergence of the absolute monster: its ultimate depoliticization, by the absence of men in war. Weapons (and even many other artifacts) are not used in the same way depending on the men, the armies, the cultures (tactical, strategic or political), and even according to the weapons. By freeing ourselves from the study of technology by the human sciences, we are forbidden to think about the hybridization of man and machine, each according to its own nature, and we transform man into a machine like any other. We then fall into the dangerous and slippery slope of the age-old quest of the “super-warrior”.

This fantasy is part of an even larger utopia, which has also brought about catastrophes, *i.e.* the search for the “ultimate weapon”, which itself derived, at the time of the XIX^e century industrial revolution, in the age-old frantic search for the “decisive battle”. Let us not forget either that the errors committed by machines are infinitely more devastating than human errors – which we originally sought to avoid by developing these machines.

Let us add that the temptation to hide behind the machine are numerous in order to escape from political, strategic or tactical responsibilities. If it differs from it, or even opposes it in many respects, our era can to some extent be compared to that great turning point in the history of humanity that was the Renaissance. The upheavals in all fields are even more far-reaching. The shocks and ruptures will be of a scale that we can hardly imagine. Philosophy and human sciences must help us – in all humility – to survive in the chaos and singularities that are beginning to unfold. For the aviators, it is not a question of putting an end to the love affair between them and their machines, but to transcend it.

It is a question, in a way, of going beyond the stage of adolescent love to engage in adult love.

8. A. Gras, *Les macro-systèmes techniques* (Paris: PUF, coll. “Que sais-je ?”, 1997).

Introduction to New Technologies

Colonel Christophe Talon

Christophe Talon is Deputy-director for Non-Proliferation, Science and Technologies at the General Secretariat for Defence and National Security (Secrétariat Général pour la Défense et la Sécurité Nationale, SGDSN), an inter-ministerial organ under France's Prime Minister.

This article, intended for the general public, is a piece taken from the French General Secretariat for Defence and National Security (SGDSN)'s 2030 prospective study, entitled "Chocs futurs" (Future Shocks). The opinions expressed in this article are not representative of an official position but rather, express the researchers' views and frame of thinking in 2022 in regard to the technological issues most likely to culminate into strategic breakthroughs in the years to come.

Beyond the strategic ruptures which, either conspicuously or not, underpin the foundational fabric of our world today, there are leaps in technological advances likely to disrupt the future, along with the existing traditional security and defence equations established thus far. For educational purposes, this article aims to direct the reader's attention to a series of technological pursuits, whose dissemination could have a long-lasting impact on current strategic balances if left under-analysed without the necessary foresight.

The turn of this century has been punctuated by the end of the U.S. unipolar hegemony, the relative decline of the West's economic and military superiority, the reassertion of Russia on the international stage, and finally, the inexorable rise of China. This new geopolitical environment, most often described as apolar, heralds the affirmation of novel power strategies, implementing new modes of action in unprecedented strategic spaces of confrontation (*i.e.* cyberspace, exo-atmospheric space, or the deep seabed). All of which bestow upon technology a unique identity that is simultaneously a challenger, an arbitrator, and a disruptor of strategic equilibrium.

Indeed, addressing the entire gamut of technological "breakthroughs" would surpass the limits of this article. Hence only three have been selected. Importantly, should a total command of these three breakthroughs be acquired, they could grant their wielders a considerable military advantage and entry into a restricted club of states. This is the case for hypervelocity, quantum physics, and artificial intelligence, even though their fields of application remain yet to be fully uncovered.

Hypervelocity

For nearly ten years, gliders and hypersonic cruise missiles were synonymous with the new height of military power. Today, they are at the centre of strategic competition between states as it makes its return to the international stage. Owing to their abilities to bypass anti-missile defence systems, they are able to reach their targets – even fleeting ones – located both far behind enemy lines and out at sea. This has profoundly altered the nature of military operations due to their impact on today's decision cycles. Yet, the challenge that remains unsolved for all actors willing to acquire them is their heavy burden on development budgets.

1. Defining Hypervelocity and Its Functioning

A weapon is considered as hypersonic the moment it travels at a speed greater than Mach 5, or in other words, five times the speed of sound.¹ Yet, these extremely high evolution speeds subject hypersonic weapons to numerous thermal and aerodynamic constraints. This is in relation to their friction with the atmosphere, consequently putting much strain on their structures, materials, and electric components. Indeed, just as the aero- and thermo-dynamics of hypersonic equipment present substantial scientific challenges, their development and production also require a thorough command of new technological features, particularly in terms of thermal protection and propulsion.

To be specific, hypersonic weapons fall into two categories. The first are Hypersonic Glide Vehicles (HGV), which are gliders accelerated by a ballistic missile. The second are Hypersonic Cruise Missiles (HCM), which are cruise missiles with not only aerobic propulsion,² but are also equipped with a ramjet³ as well as a super-ramjet.⁴

Hypersonic gliders lack active propulsion. They are carried by a ballistic missile at speeds that can go up to Mach 20. At the end of their propelled trajectory, the gliders detach from their missile to be launched beyond the range of ground-to-air systems into the upper atmosphere where they then continue towards their target. Overall, their trajectory cannot be predicted due to the consecutive relaying from its ballistic launch to their subsequent rebound into the atmosphere, including overall glide manoeuvres.

Hypersonic cruise missiles have their own propulsion. Flying at an altitude of about thirty kilometres and capable of manoeuvring at very high speeds, HCMs can reach the hypersonic threshold thanks to their attached ramjets. However, in order to sustain its trajectory at hypersonic speeds, they would require a super ramjet.

1. The Mach number does not correspond to a fixed speed but depends on the local conditions of temperature and pressure.

2. Aerobic propulsion requires oxygen to function.

3. This is a type of reactor, adapted to and has reached very high speeds. While they have no moving parts, they still require oxygen in order to function.

4. There is a ramjet within, whose combustion occurs at supersonic speeds.

2. Hypervelocity as a Strategic Rupture

At the military level, manoeuvring hypersonic weapons undeniably constitute a game-changer for states with such technology. Borne out of the enduring logic behind the sword-versus-shield duality, these weapons represent a dramatic upgrade in capabilities, compared to so-called “classic” weaponry, such as ballistic or cruise missiles. This is due to several reasons.

Firstly, if intercontinental ballistic missiles were to reach very high speeds at the order of 8 km/s during their re-entry into the atmosphere, then their kinematics in the ballistic phase could be relatively calculated in relation to gravity. However, by applying specific constraints to its engines, their trajectories could be significantly modified and thereby thwart the adversary’s defences. Nevertheless, this can only be done at their re-entry phase back into the atmosphere. Additionally, conventional cruise missiles are limited by their range at the order of 1,000 km to 3,000 km. Their subsonic or supersonic speeds also do not permit them to counter anti-aircraft and anti-missile defences, whose operational capabilities have only continued to evolve in these recent years.

Conversely, the combination of both speed⁵ and trajectory unpredictability for hypersonic weapons considerably not only reduces their vulnerability to current interception systems, but also “disqualifies” them. These weapons also offer an extremely reactive strike capability at ranges much greater than those of existing systems. The obvious exception to this are ballistic missiles. Although, on the contrary, the latter cannot be flexibly put into use⁶ and possess trajectories that can be estimated with relative ease. Hypersonic systems thus provide a solution for maintaining the capacity to penetrate enemy anti-aircraft and anti-missile defences.

A priori, hypersonic vectors can carry both conventional and nuclear payloads, as well as deliver damages at any time and from any distance, provided that the current targeting processes are adapted to these new capabilities. As a result, they do not only represent a threat but also an instantaneous one to high value-added targets, whether they are fixed or mobile on land or at sea.

3. The State of Play vs. Ambitious Endeavours

Geopolitics is the most favourable catalyst to the development of hypersonic weapons. Indeed, the growing strategic antagonisms between great powers have only “fueled” the race to develop even more superior capabilities. In this context, hypersonic weapons are undeniably invaluable as they permit their bearers to immediately outclass their rivals through velocity and manoeuvres against increasingly efficient anti-aircraft and anti-missile defences. Consequently, hypersonic systems could be privileged vectors for a wide range of missions, from nuclear deterrence to conventional strategic strikes, including anti-access and

5. A machine moving at Mach 6, for example, would take just over 4 minutes to reach a target located 500 km away.

6. This refers to the HCM in particular.

area denial (A2/AD). Under the logic of whoever enters an air space first is whoever will acquire air superiority, hypersonic weapons should be wholly taken advantage of to gain such a competitive edge.

The proliferation of “hypersonic”⁷ weapons testing (*i.e.* those by Pyongyang at the end of 2021, as well as Russian President Vladimir Putin’s highly orchestrated statements regarding the successful firing tests of a salvo of TSIRKON hypersonic missiles on 24 December 2021) denotes not only an emblem of power but also of the modernisation of a state’s capabilities. However, hypersonic systems are still quite premature for the time being. The first operational commissioning would mostly not take place for another several years, likely due to limitations in terms of payload, navigation autonomy, and terminal accuracy.

From a technical point of view, hypersonic development continues to face many difficulties, including but not limited to, the resistance of materials to very high temperatures, combustion control under supersonic conditions, or even the resistance to vibrations. Hence, the navigation quality of these weapons regarding their precision upon impact are essential elements from an operational point of view. Yet, they remain uncertain at this stage as hypersonic vectors continue to be impacted by thermal and acceleration constraints.

Moreover, in order to overcome these difficulties and achieve the expected operational efficiency, countries wishing to acquire such capabilities will have to make substantial financial investments to develop a new set of *savoir-faire*,⁸ while accepting the risk that these efforts would not bear fruit in the near future to contribute to operational capability.

By 2030-2035, however, there is little doubt that hypersonic weapons will be in the arsenals of several powers. France, itself, endeavours to acquire them for its nuclear deterrent’s airborne component by 2035. In this respect, considering the strategic rupture that the advent of these weapons would bring about, the risks pertaining to the very likely misunderstanding that may arise upon firing due to its mode of use as either a conventional weapon or as a part of a nuclear deterrent system. Similarly, the question on the evolution of current means of defence (DAMB, detection) and that of doctrines and postures will have to be prepared for in advance.

Quantum

The development of a universal quantum computer brings hope for major breakthroughs in many strategic sectors, such as the medical and pharmaceuticals field, food production, energy, and of course, defence. The downside is that

7. Pyongyang has deliberately, in a vague manner, claimed these missile tests to be hypersonic. North Korea plays on ambiguities to hide its real capabilities in hopes that states, who are confirmed to possess hypersonics, would reveal their own capabilities.

8. This pertains to the development of testing and qualification means, *i.e.* hypervelocity wind tunnels.

even scientists cannot fully grasp the extent these breakthroughs would disrupt existing power balance between states nor which sectors would be the first to feel its impact. Without a doubt for national security, quantum technology's inherently binary nature could alter the confidentiality of strategic exchanges. The world also would veer towards a pursuit for new weapon system designs or the improvement of old ones.

1. The Principles of Physics Behind Quantum Computing

The theory behind the so-called “quantum” computing was first conceived by physicists in the 1970s, based on principles that were oftentimes incoherent. Traditional computers today, from the simple desktop to a supercomputer, involve transistors and processors, as well as a binary basis for encoding information (whose well-known bits include values of either 0 or 1). Namely, a quantum computer manipulates elementary particles, such as photons, to represent information.

These infinitesimal particles at the order of 10^{-22} metres possess, so to speak, “quantum” properties. Amongst them includes the phenomenon of “superposition” (when a single particle exists in several different states at the same time) and of “entanglement” (when two or more particles in a quantum state are linked to the other despite being separated by distance), whose properties serve as supporting pillars of quantum physics. Concomitantly, these two principles are also the most complex of components that warrant much apprehension, given the current macroscopic and deterministic approach employed *vis-à-vis* the physical phenomena surrounding the world.

The superposition principle is often illustrated by the thought experiment, Schrödinger's cat. This paradox illustrates a cat locked in a box with a radioactive substance and a sealed vial of poisons. Upon the disintegration of the radioactive substance (in accordance with laws governed by quantum physics), the vial will shatter, releasing the poison and killing the cat. However, as long as the box remains unopened and one cannot look inside the box with the naked eye, the cat is simultaneously both alive *and* dead, as the radioactive substance cannot be said to still be intact or disintegrated. A concept entirely counterintuitive, it remains as a purely mathematical consequence of quantum theory without its equivalent at a macroscopic scale in the physical reality. Thus, using the vocabulary from “classical” physics to describe subatomic physics is hardly compatible.

The phenomenon of entanglement can also be understood through a thought experiment. This one consists of tossing two identical coins. Indeed, at the macroscopic level, the probability for both coins to land on the same face is one-out-of-four. However, in the subatomic context of entanglement, the two individual coins integrate to become inseparable as a whole. They would now *systematically* always land on the *same* faces together (resulting in either both heads or both tails), thus bringing the probability up to one-out-of-two.

These two principles, amongst others, differentiate quantum physics from “classical” physics. Notably, a quantum system can only be measured by probabilities, while physical phenomena can be modelled continuously over time. Such specification allows for a technological development in both defence and national security that involves a high potential interest and varying maturity levels in accordance to their respective fields.

2. Examples of Concrete Applications of Quantum Technology in Security and Defence

By applying the superposition principle, the founding fathers of quantum computing sought to take advantage of the ability for a particle to be in multiple states at once, to build a system that could perform multiple calculations at the same time, and not simply in parallel, which is what computers currently do. This transition from classical to quantum physics is epitomised notably by the use of the quantum equivalent of classical computer bits, or qubits. As such, the values are no longer restricted to either 0 or 1 in a deterministic manner, but rather, as a superposition of these two values, and thus with different probabilities. Very concretely, this approach allows quantum computing systems to exponentially increase their computing power as their qubits number increases. Again, this differs from classical machines, which are “limited” to a linear growth. As such, quantum technology brings forth remarkably interesting opportunities and developments that can be applied to numerous fields, such as cryptography.

Indeed, the security of current cryptographic mechanisms relies, to a large extent, on “hard” mathematics. Those who know the exact algorithm key of a cryptographic signature or decryption simply need to apply the appropriate mathematical equations using today’s computing power. The issue lies in those without this key, who are then faced with a complex impracticality. However, a universal quantum computer – an advancement unlikely to be achieved in the next twenty years – could fundamentally call into question the “difficulty” of certain mathematical problems and thereby the security of crucial cryptographic constructs. This is due to its significantly higher computing power. Thus, theoretically, the operations today that require perhaps billions of years to solve could now be done within a reasonable time.

However, “quantum cryptography”⁹ – based on theories by academia in the mid-eighties – is not formulated by a quantum computer. Rather, it solely relies on superposition and entanglement principles to establish new mechanisms of secure information transmission. Namely, it presents the possibility of transmitting information without, at first glance, any confidentiality protection and only guarantees *a posteriori* the detection of any third-party interceptions. As such, quantum cryptography does not, in itself, constitute a major conceptual break-

9. Otherwise known as “quantum communications”.

through, insofar as it does not call into question the security of classical cryptography and is only of significant interest for specific cases.

Nevertheless, beyond cryptography, quantum physics yields major strategic advances in quantum computing, quantum simulation, and high-precision sensors. In the latter field, the extreme sensitivity of quantum subatomic particles and the entanglement principle, when exploited can, in fact, enable quantum sensors to carry out measurements of unparalleled precision in various fields, such as electromagnetics (the measurement of time and frequency) or even geopositioning and navigation by associating, in particular, gravity measurements with dating. It is not difficult to imagine the added operational value provided by such a capability. For one, it ensures its user not only a total autonomy *vis-à-vis* satellite positioning systems from being easily “scrambled”, but also an advanced capability in detecting submarines based on the variations in their movements on a gravitational field.

In this regards, France may soon possess the first navy in the world to be equipped with operational quantum sensors through its acquisition of the *Girafe* system¹⁰ developed by *ONERA*. The finalised sophistication of such a sensor is yet to come to fruition and will not be so until at least 2028, as engineers are still striving to “miniaturise” them to facilitate their transport.

3. *Quantum: Revolution or Utopia?*

Considering how the finite potential of algorithms and today’s supercomputer capacities are progressing on an asymptote, numerous initiatives in both research and the industrial world have been propelled to look towards quantum computers for an alternative. However, their development and production continue to be a scientific, technological, and industrial enigma. Today’s capabilities are only able to manipulate these infinitely small entities under very specific and limited conditions in a laboratory: namely, at extremely low temperatures and pressures, and only with “small handfuls” at a time. Beyond the machine itself, the entire spectrum of algorithms also needs to be explored to establish calculation methods that can fully take advantage of all the possibilities offered by quanta.

Finally, several technological avenues for the development of quantum computers are being explored today, albeit none stand out in particular. So far, qubits can be created from a wide variety of quantum mechanics: a single atom whose electrons are manipulated by lasers (atomic qubits), single photons, and certain semiconductors. This is done by sculpting matter on a nanometric scale or by simulating the behaviour of single atoms, using electrical circuits developed with certain superconducting materials. All in all, each has as many advantages as disadvantages, so much so that it remains impossible today to decipher with certainty which amongst them is the most promising.

10. *Girafe*: a gravity gradiometer based on cold atom research interferometric.

Artificial intelligence

The past ten years has witnessed an unprecedented acceleration in the development of artificial intelligence (AI),¹¹ thanks to the leaps of progress made in computing power, mass data processing, storage capacities, and algorithm methods. Notably in this field, GAFAM,¹² by assuming such colossal financial risks, have made significant contributions. In terms of sovereignty and national security, AI may present new opportunities but also new potential threats, of which many countries are only starting to become more aware. The road towards acquiring total command of all AI-related technology is inevitably also issuing the world into a new era where data will be just as prized as energy.

1. Defining Artificial Intelligence and Its Functionings

In its report of 21 March 2017, France defined AI as “a set of concepts inspired by human cognition or the biological brain, intended to assist or supplement the individual in the mass information”.¹³ In other words, the principle of AI is to allow computers – or machines – to think and act like human beings by imitating human thought, albeit much easier said than done!

Human thinking applies different mechanisms and cognitive functions derived from neural connections in order to interact with the surrounding environment, in particular to perceive, speak, move, memorise, reason, as well as exercise abstraction or creativity.

Indeed, researchers have endeavoured to reproduce these functions of human intelligence since the late 1950s by following two complementary approaches inspired by human learning. The first – much favoured in the 80s – is based on the transmission of knowledge, and has in particular, made it possible to develop expert machines. The second approach is based on an iterative principle of trial and error, borne out of both an observation of the world and of experimentation. Thanks to the increase of available data, computing powers, and algorithm optimisation, this approach has formed the founding blocks of today’s main AI achievements. These are the ones currently used the most in everyday life without necessarily having the consciousness of doing so. A notable example is the function on social networks that recommends new content based on one’s consumption behaviour. Other examples are search engine suggestions or automatic foreign language translations. Unsurprisingly, today, both researchers and industrialists alike have invested in this ability of AI development the most out of them all.

11. This expression was used for the first time in 1956 during a Dartmouth College conference in the United States. It was a scientific workshop, considered as the birthplace of AI as an autonomous research field.

12. GAFAM: Google, Amazon, Facebook, Apple, Microsoft.

13. Editor translation from France IA “[Rapport de synthèse france intelligence artificielle](#),” *Ministère de l’Économie, des finances et de la relance*, 21 March 2017.

In an attempt to reproduce biological intelligence, researchers now use statistical learning algorithms, whose design is inspired by the functioning of the human brain. For the brain, the connections of neurons are created, reinforced, or even disappear according to different stimuli. Likewise, these computer programs, called “artificial neural networks”, use specific equations and variable settings to adjust themselves according to the data they manipulate. This is so they may produce the best results possible. It is then by interconnecting these equations with each other that artificial intellectual stimulation can occur, enabling machines to learn autonomously. This is the principle behind “machine learning”.

Specifically, machine learning can take various forms, one of which is “deep learning”. Here, the idea is to let the machines learn on its own by providing it with as many examples as possible. AI is then able to analyse and cross-check millions of pieces of information (“big data”) to extract what human labour would overlook and miss. The end-product developed from this is the equivalent of what the biological world understands as intuition.

Another computation of machine learning is “reinforcement learning”. This, on the other hand, consists of stimulating the AI by having it train against itself to enrich its database and its ability to analyse. This is akin to the idea of two chess players competing against each other to develop their individual skills.

Interestingly, “active training”, unlike the two concepts above, humans would intervene in the AI learning process. This is done by offering it data to analyse, while expecting and knowing in advance the result that is to be obtained. This method not only reinforces the algorithms, verifies the accuracy of their analytical capabilities, but also creates a solid knowledge foundation for the AI. This stage of preparation is particularly long and tedious due to the large volumes of data needed to be implemented, often requiring manual operations and specialised business expertise to do so. It nevertheless remains essential for the optimisation and securing the operational reliability of high-performing programs, such as self-driving vehicles or image recognition applications. In the long term, machine learning will be able to provide its expected support and awaited services more rapidly and accurately.

2. Artificial Intelligence: A Source of Innovation in All Its Forms but with Many Limitations

Indeed, the recent years are testament to how much progress has been achieved in AI development. This is most notably observed in the advancements of self-driving vehicles that are now capable of identifying and differentiating the objects on a road, and of facial recognition programs that can now nearly rival human performance. Importantly, the fruits born of such ventures can also be translated to other sectors. For instance, when the movement of data to be analysed is saturated with a large volume, the use of AI is essential as it helps its users to “find a needle in a haystack”.

In the medical field, for example, AI assists doctors in determining the causes of certain diseases, such as cancer, by sifting through blood test data from a large number of patients. Notably, this has led to the discovery of certain genetic mutations that now make it possible to predict the severity of prostate cancer in men. Likewise, AI helps operators of video surveillance systems in large cities by identifying, in a mass number of video streams, potentially dangerous situations that would require law enforcement interventions or emergency response personnel.

In terms of defence and national security, artificial intelligence also represents a key asset in many areas, including intelligence and protecting information systems. In addition to human expertise, AI allows intelligence services to analyse more quickly mass heterogeneous data (comprising spatial images, drone videos, electromagnetic data, texts, etc.) stored from intelligence-gathering. Additionally, it can also detect from the data patterns that may result in crises or conflicts. In order to ensure the security of information systems, AI is used to detect security breaches, data leaks, and even certain automated tasks of incident response.

While these high-impact examples, often popularised by the media, unquestionably underpin the spectacular progress made in AI, they not only remain very technical and specific, but also often require immense volumes of “training” data to obtain a satisfactory result. Indeed, the day when an ultimate, high-functioning AI, capable of taking into account the surrounding context and learning from only a few examples, is still quite far. Perhaps even farther away is the feat of recreating true biological intelligence, which would know not just to find the “best” result, but rather the result that corresponds the most to a given situation. This would require combining logical deductions with applicable emotions, intentions, and creativity. It would therefore be more accurate today to speak of artificial intelligence in the plural, as opposed to *the* artificial intelligence.

3. AI: The Origin of New Challenges and Potential Threats

The rise of AI depends directly on the accessibility of data and the availability of digital infrastructures that allow them to be disseminated, stored, and processed. Both constitute in this respect the heart of a new issue of sovereignty.

Inevitably, obtaining reliable predictive models requires executing algorithms on preprocessed datasets, which is currently a scarce resource. Data is the major “fuel” of AI and is more often the product accumulated from the knowledge capitalised in the digital space of various forms. Again, such is not always directly accessible, but this time, it is due to them being located in the “Deep Web” and the “Dark Web”¹⁴ or because of their innate nature, the confidentiality of certain technical data, their language, etc. The major international digital households, GA-

14. The “Deep Web” is a part of the web that is accessible but not by generic search engines. The “Dark Web” is a part of the web that is only accessible using specific software, configurations, and authentications, *i.e.* TOR.

FAM, have fully integrated the issue of controlling access to this mass data and are investing colossal sums to capture, capitalise, and analyse this raw material.

Another challenge is the availability of digital infrastructure to route and process data. The growing complexity of machine learning algorithms, in particular, deep learning, makes it essential to use powerful and energy-intensive computing infrastructures to route the data to servers, where it will then be processed and stored. The physical infrastructures, which are now being developed on land (servers), at sea (submarine cables), in the air, and in the exo-atmospheric space, represent so many vulnerabilities. Moreover, to fully secure state sovereignty, only possessing autonomy in the critical sectors of data and applications is not enough. It is also necessary to ensure that the digital infrastructures as well are properly controlled and secured. The seabed management strategy presented by the French Minister for the Armed Forces, Florence Parly, is part of this perspective.

Beyond these national security issues, AI's rapid progress and its dissemination in everyday lives also raise many questions and legitimate concerns within societies. The ones that are the most frequently noted are, but not limited to, the restriction of individual freedoms, stock market crashes, jobs being replaced by machines, the lack of transparency of algorithms, and the risks of abuse in the field of marketing. Aware that it needs the support of the masses in order to advance further, AI experts are now moving towards the development of a "responsible" AI. The ultimate objective is to collectively benefit from all the opportunities that AI can bring forth for, most notably, the improvement of overall living conditions and security.

The history of military innovation shows that the added capability value offered by an innovative technology based on its potential at maturation and its final level of profitability is not always self-evident. Unsurprisingly, decision-makers tend to prefer improving existing technology to investing in a radically unprecedented innovation. Indeed, the latter requires acquiescing to significantly high initial investments that may not necessarily translate immediately into an operational advantage.

However, hypervelocity, quantum technology, and artificial intelligence escape this rule as these technologies bring about strategic breakthroughs. Aware of the stakes, France has also adopted several acceleration strategies in terms of artificial intelligence and quantum technology with the aim to secure its position as a lead competitor on the world stage in these two domains.

Creating a Modern and Responsive Defense Industrial Base in Europe

Nicholas Nelson
Andrew Stiles

Nicholas Nelson is an experienced leader in the aerospace, defense, and security sectors. He currently serves as a Principal at the Georgia Tech Research Institute and is the Senior Fellow for Emerging Tech & Policy at the Center for European Policy Analysis (CEPA).

Andrew Stiles is currently a Senior Consultant focused on EDTs at Deloitte Consulting. His work is focused on space technologies and unmanned systems.

Europe has a fleeting opportunity to build its defense tech playbook: what lessons can the U.S. offer?

The modernization of defense is now more than ever a race for technological superiority between near-peer competitors. The successful development, deployment, and integration of emerging and disruptive technologies (EDTs) is already having a profound impact on theaters of conflict. Beyond the kinetic and cyber threat of Russia, China is no less a threat to European Alliances across all of the EDT technology verticals, and many more. The trend is clear, and the future of global security increasingly demands a robust European industrial base. This industrial base must be capable of effectively developing and producing EDTs that can not only match, but also outperform authoritarian rival powers. This competition was once viewed as the purview of the U.S., Russia, and China, but the invasion of Ukraine shows that Europe needs indigenous innovation capabilities, independent of allies and supply chains that may or may not be available when needed.

Despite the emerging need for defense innovation, Europe has historically shown limited interest in re-igniting a structured approach to defense technology innovation, “Responsive Defense”. This must change.

Responsive Defense is less about the specific technologies (which are grouped broadly by the term EDT), but rather the specific enterprise-wide practices needed to efficiently and effectively develop, deliver, and deploy these EDTs. This spans across multiple aspects of defense industry enterprises and across both the private and public sector. This ranges from contract award structuring, to human capital and compensation planning, including strategic investments (in assets such as research and development infrastructure, new agencies, start-up infrastructure, etc.), and other areas upon which will be expanded below. Hence, Responsive Defense is a methodology through which actors can build a playbook to modernize defense industrial bases that are more capable of – and more efficient in – technology innovation.

The term is intended to provide a more concrete direction for the industry, given that despite the many discussions conceptualizing a future European defense industrial base, few solutions have been proposed for achieving one. By examining lessons learned from the U.S.'s path to building a defense innovation ecosystem, Europe can establish a more tangible approach to developing EDTs. This article thus offers five key recommendations that may serve as a building block towards a European playbook.

From the Global War on Terror to Great Power Competition

In charting a path forward for Responsive Defense, it is key to first understand the current state of the European defense industrial base. From the end of the Cold War, the U.S. and its NATO Allies have enjoyed a capability gap over both state and non-state adversaries. However, this gap has drastically shrunk in recent years. This is due to several factors: the transatlantic Alliance's two-decade "strategic pause" on near-peer defense innovation during the Global War on Terror; the accelerating pace of technological change; the shift of research and development (R&D) spending from governments to the private sector; and growing defense innovation efforts by Russia and China. Simply put, NATO is no longer the main driver of new defense technologies and has even fallen behind its competitors in key emerging technology areas. As techno-strategic competition with Russia and China captivates the West, there is an urgent need for transatlantic leaders to develop key technological priorities and a common policy framework to elevate its edge.

After the Cold War, the U.S. and Europe shifted their focus to combating terrorism and capacity-building in fragile states. As a result, the urgency to develop and field new systems to combat potential near-peer competitors eroded. Without this motivation, NATO and its members – especially its larger members – continued to develop and acquire complex, bespoke platforms, which assumed permissive operating domains, such as billion-dollar satellites, multi-billion-dollar aircraft carriers, and GPS-dependent ground and air assets. This approach yielded incrementally better capabilities, but no truly game-changing technolo-

gies. Concurrently, several of Europe's largest states drastically cut funding to their militaries and defense sectors, leading to a severe degradation of previously robust capabilities. While this approach was sufficient for fighting technologically inferior non-state actors in the Global War on Terror, it has left Europe vulnerable in today's renewed era of Great Power Competition with China and Russia.

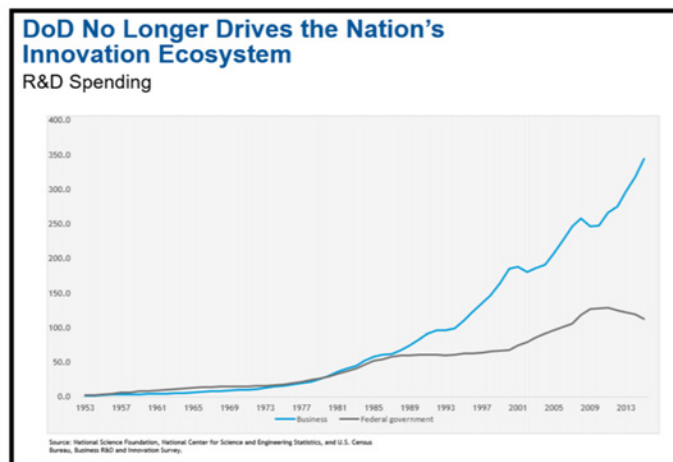
A Widening Capability Gap is Tilting the Geopolitical Balance

In the meantime, Russia and China have taken advantage of the West's pause in defense innovation to develop differentiated and comparatively more cost-effective area denial-capabilities designed to mitigate the U.S. and Europe's traditional strengths. Over the last decade, China has risen as a scientific and technological powerhouse, while Russia has more creatively and assertively pursued asymmetric advantages. Both the Kremlin and the Chinese Communist Party (CCP) have invested in innovation programs and EDTs that are beginning to change the character and nature of modern warfare to their benefit.

After multiple decades of complacency, the gradual erosion of the West's technological edge has become front-and-center on the global geopolitical stage, with the Russian invasion of Ukraine, alongside developments in both Russian and Chinese hypersonic capabilities.

Addressing the New Challenge

To address this, the U.S. began rapidly accelerating its efforts to better engage non-traditional actors (such as tech startups) and expand its own consolidating defense industrial base. This began with the launch of the Defense Innovation Unit Experimental (DIUx, now DIU) in 2016, followed by efforts such as AFWERX, the U.S. Air Force's innovation arm in 2018. The most significant shift in the U.S. Government strategy is focused around courting private sector and corporate venture capital (VC) to expand the scope and improve the speed of funding for non-traditional businesses and startups in the defense sector. The U.S. now provides initial grant funding and contract opportunities for startups, but also matches venture funding with additional, non-dilutive government funding.



The U.S. has realized that the government, namely defense R&D, is no longer the primary driver of the development of new tech. As can be seen in the associated figure, into the late 1980s, there was relative parity between U.S. government R&D and commercial R&D spending. This began diverging significantly as the Cold War ended, while a number of successive new tech industry booms drove the market forward. By 2005, commercial R&D was double that of the government. By 2015, it was three times greater and today, it is five times higher. This effectively means the majority of new technologies and innovations are coming from sources not tied to government funding or institutions. Further, it has resulted in commercial capabilities matching and even surpassing government capabilities, even in areas which were/are considered innately government functions.

These startups and non-traditional actors complement rather than replace large defense companies. Indeed, a number of large incumbents have recognized the value of the different capabilities and skill-sets these new entrants provide and have, as a result, not only nurtured a range of strategic partnerships with these companies, but also directly invested in several via their own respective corporate VC arms.

In the eighteen months between early 2019 and the end of 2020, the U.S. Air Force, and now the Space Force, have deployed well over \$300 million (as well as attracting an estimated \$350 million from private investors). This has resulted in over 1,800 companies being added to the industrial base. They range from advanced artificial intelligence/machine-learning and unmanned aircraft firms to key domestic suppliers of critical components for major platforms. The Air Force, via its AFWERX innovation hub, aims to help cultivate a handful of new defense “unicorns” – venture-backed startups with valuations above \$1 billion – in the next five years. To this end, they plan on deploying over \$600m to startups, as well as to small- and medium-sized businesses. The end result of all this has been a marked improvement in the time it takes to field cutting-edge solutions.

Looking toward the EU’s Future: Lessons from the U.S.

Europe has only begun to respond to these shifting global power dynamics as recently as 2021, with the much-welcomed announcement of the NATO Innovation Fund, the Alliance’s new €1 billion EDT investment vehicle, as well as adjacent efforts, such as the EU’s CASSINI fund. Yet, successfully executing Responsive Defense in Europe will require more than new agencies, €1 billion, and a dream – as the U.S. has learned over the last decade. However, the trials and errors in the U.S. offer valuable lessons learned and a potential development roadmap for Europe.

The U.S. has already spent more of a decade painfully transitioning from a federal acquisition system – that once only offered a valley of death for EDT startups – toward a Responsive Defense operating model. The need to re-ignite

U.S. defense innovation emerged from the threats posed by the return to Great Power Competition across growing international threats in EDT technology domains, including cyber capabilities, nuclear capabilities, autonomous vehicles, and most recently hypersonic missiles. Along with the growing realization that the latest key technologies were arriving in commercial consumers hands years before soldiers had access on the battlefield.

The U.S. responded to this necessity to create new opportunities for nascent EDT startups, and has increasingly encouraged the use of private and public funds to drive Responsive Defense. Much work remains, but the trajectory is moving in a direction conducive to success, and to date, these efforts have given rise to a handful of defense unicorns, including Anduril (last post-money \$4.6 billion), ShieldAI (last post-money \$1.21 billion), Palantir (NYSE: PLTR; \$23.29 billion), Space Exploration Technologies (SpaceX) (last post-money \$100.3 billion), Eprius (last post-money \$1.35 billion), and Rebellion Defense (last post-money \$1.15 billion).

While NATO Allies are beginning to accelerate sovereign EDT industrial bases, a handful of startups are wasting no time. They have taken a page out of the U.S. playbook to gain noteworthy momentum in the defense and dual-use spaces, with the presumptive goal of ascending to unicorn status. Core-defense players taking center stage include burgeoning names, such as Helsing (Munich, Est. 2021) and Prelogens (Paris, Est. 2016), who are developing software that can assist intelligence and warfighting domain operatives by synthesizing geospatial satellite data or seamlessly integrating historically siloed battlefield data pools into actionable information. Both organizations have Series A post-money valuations that are trending in the direction of future financing rounds, propelling post-money valuations above \$1 billion USD.

While limited in scope, European startups have demonstrated the ability to produce high valuations both in the defense sector, as well as for dual-use technologies broadly. For Europe, the next step is to begin honing government and industry-led efforts to support and sustain the nascent ecosystem into the long-term.

To do so, three particularly impactful lessons learned from the U.S. experience in EDT innovation are identified, which can be leveraged by European nations to help evolve their own defense industrial bases. These are 1) Hyper-Scale Contracting, 2) Differentiated Talent Investing, 3) Enduring Budgets and Transition Pathways.

Hyper-Scale Contracting is Critical for Building Sustainable Programs and Complementary Investment

First, Hyper-Scale Contracting revolves around making large bets on market leaders so that companies rapidly reach scales without succumbing to the historically multi-decade, incremental growth dynamics of the defense industry (*i.e.* the industry's "valley of death"). In the U.S., hyper-scale investing has – under limited circumstances – enabled U.S.-based startups to scale over the valley of death.

NASA, for example, invested heavily in SpaceX in the 2000's, providing over \$1 billion contracts for the Commercial Resupply Services program. Further, Anduril generated its initial revenue and "centaur-level" valuations through obtaining contracts of over \$100 million with North American border-states. This is a way for government agencies to maximize the return on their investment (investments being contract awards), because once startups win large defense contract awards, investors become far more willing to inject large sums of capital for the startups to build out more advanced capabilities. The result is a compound effect on not only share-price performance, but also on the defense industry's infrastructure, workforce, and product quality, which directly serves the geopolitical objectives of European governments and alliances.

Differentiated Talent Investing Demands that the Industry Re-Evaluate Economic Priorities

Second, Investing in Differentiated Talent emphasizes the need for the industry to pay more and expect more from the workforce. One critical lesson learned in the U.S. has been the need to modernize how both government and industry compensate defense industry talent. The U.S. defense industry failed to adapt its approach to attract and retain top-tier tech talent in the late twentieth century, stemming from a failure to evolve human capital models across private and public entities during this period.

Following the Second World War, talent and compensation in the U.S. defense industry thrived on offering below-market compensation to employees, who, in return, committed entire careers to a single organization in exchange for generous pension plans upon retirement. This system thrived when many other domestic industries utilized it as well. However, companies in adjacent industries, namely tech, pivoted toward the 401(k) retirement planning model in the late twentieth century. The defense industry ignored this trend and continued the increasingly archaic approach of offering below-market compensation, failing – well into the early twenty-first century – to adjust compensation to be competitive with rapidly rising tech industry salaries. Today, starting salaries among prime defense contractors for engineers are astonishingly lower than engineering salaries among the FAANGs (referring to the big tech companies, Facebook, Amazon, Apple, Netflix, and Google). Many primes offer starting salaries ranging from \$40,000-\$70,000 annually, while FAANGs offer upwards of \$170,000-180,000, in addition to stock options. Prime contractors are also continuing to ignore rising costs of living and the emergence of hyperinflation in the U.S. economy, further accelerating recruiting deficits and workforce attrition.

The talent recruitment approaches that worked in 1965 do not work in 2022, and as a result, many incumbent prime contractors in the U.S. today fail to attract talent out of top-tier engineering universities and companies. They are thus left with either a talent shortage or a workforce skewed toward the bottom 50%

of performers in the labor market. This has, in part, contributed to an array of systemic issues over the past two decades, ranging from significant delays in critical defense technology programs to major operations scandals at some of the leading prime defense contractors in North America.

At the same time, the emergence of the new companies driving EDT development, such as SpaceX and Anduril, have been able to attract technical and business talent that ordinarily would not have considered legacy aerospace and defense contractors due to culture, salary, or progression concerns. They do this by paying more competitive salaries, and also by providing a non-traditional tech startup work environment, which values taking risks, flat hierarchies, and opportunities to develop new skill-sets.

A final note on Differentiated Talent Investing: private industry's role in modernizing this talent model is not sufficient alone to solve the underlying issue. Government entities funding major defense programs must recognize that low-margin requirements on hardware and software contracts are often the source of the problem, cascading down the industry value chain and resulting in a host of long-term deficiencies. Hence, both the private and public sector need to adopt the modern tech industry approach: buy, expect, and most importantly, deliver high quality across the board.

Enduring Budgets and Transition Pathways

Allocating funding seems obvious, but too often, there is limited forethought given to this issue. To ensure success, organizational funding must be significant, multi-year, and consistent or include inbuilt annual growth. A number of high-potential initiatives have either been announced with no dedicated funding or have had sizable funding gaps in subsequent years, damaging their brand and relationships with defense companies and startups alike. New efforts from the NATO Innovation Fund to CASSINI and national efforts will likely rely on the willingness of Alliance members to make contributions beyond other NATO and EU defense and space obligations. If so, multi-year commitments are crucial, as are success metrics, such as return on investment, which are rarely used within NATO, the EU, or national government departments.

In a similar vein, much has been written about the so-called “valley of death” in defense industries. While it can often be relatively easy to win small initial rewards, rarely is there ever a clear path to production contracts. Production contracts are necessary for both business health and growth, but are also critical in attracting external investors, and creating reliable progression pathways from small awards to large scale contracts.

Challenges in the European Ecosystem

This success story has not been mirrored in Europe. Four key elements are holding back the European defense ecosystem.

First, protectionism is still a problem in many European countries. National governments retaining large stakes in European defense companies disincentivize potential European-wide efforts at developing new solutions. Where funding is available, it usually goes to bolstering these legacy defense companies rather than non-traditional actors or potential defense startups.

Second, where there are European-wide needs, Europe's national legacy defense companies tend to favor high-cost, multi-mission platforms. Developing these platforms, however, often leads to significant duplication of effort. A case in point: the Tempest Future Fighter Aircraft and the Future Combat Air System are two programs costing billions of euros each that are developing platforms with very similar capabilities.

Third, VC in Europe, unlike in the U.S., has not been incentivized to enter the defense sector. Contracts rarely flow to smaller companies directly, and instead are passed through to them as subcontractors on more niche and/or low-margin work, resulting in lower margins and decreasing potential attractiveness for investors. Additionally, there have been few attempts at the European or national level to provide rapid revenue opportunities or innovative, complementary levers, such as governments matching private venture funding.

Fourth, Europe's entrenched defense players continue to struggle to compete with technology companies and startups for best in class technical and non-technical employees, due to their heavy bureaucracy, comparatively low salaries, lack of innovation culture, and slow promotion timelines.

Further, in the U.S., many of the same issues remain challenges for the U.S. defense sector. This should give hope to Europe: its situation is not far removed, and adopting U.S. best practices should yield similar benefits. EU defense entities and, most critically, national governments need to provide much greater access to contracts to smaller entities and startups, even if it seems to come at the expense of so-called national champions. At the same time, entrepreneurs and non-traditional businesses must be found and incentivized to pursue the aforementioned contracts and grants. Europe has a robust and growing VC community that should be tapped into. Similarly, university incubators and accelerators are key potential partners and sources of talent.

Final Recommendations

As the West considers more actionable approaches to re-building its defense innovation capabilities, Responsive Defense offers foundational principles from which companies and national actors alike can use to more tactically plan their

adaptation strategies. Across the EU, UK, and U.S., many of the same high-impact challenges can be observed, along with their respective solutions, which are summarized below:

- **Hyper-Scale Investing:** Adjust risk equations to allow for ambitious bets on ambitious players. Startups often have the highest degree of both organizational drive and nimbleness in the private sector to solve the defense industry's greatest technological challenges. Governments need to assess which nascent players have the potential to scale, and then make prime contract-sized bets on them to do exactly that.
- **Differentiated Talent Investing:** Invest heavily in human capital and expect a lot in return. For Governments and militaries, this means re-evaluating which variables are prioritized on assessments for contract awards and recognizing that pricing correlates with quality – not just competition. Investing more and demanding more from the private sector up-front gives industry players the ability to hire the right talent, while reducing development and budget risks during delivery.
- **Enduring Budgets and Transition Pathway Creation:** Fostering a more predictable business environment by reducing sporadic contracting and increasing opportunities for businesses to pursue predictable and progressively larger programs will allow for the private investment community to take more risk on startups seeking investment. Venture Capital responds best to speed and predictability in business cycles. This is key in unlocking private sector investment, which will enable the European defense industrial base to thrive.
- **For Europe specifically:**
 - Prioritize the problem at hand rather than political goals. Though geopolitics and capability gaps are highly interrelated, they are not the same. Budgeting for defense programs needs to be focused on the latter in order to ensure long-term commitment to critical programs, and as a result, successful outcomes.
 - NATO Alliance members cannot afford a protectionist attitude for defense technology. Flow of IP, talent, development programs, and funding opportunities needs a cross-border approach to allow new market entrants to find the right opportunities to build businesses.

Europe has the population, defense spending, research, and talent capabilities to develop a flourishing defense innovation ecosystem in order to develop key new defense capabilities and secure itself. While structural changes like these do not come easily, the current approach pioneered by the U.S. provides a way to accelerate this process. With a new set of leading defense companies and EDT capabilities on both continents, NATO and its member states stand to significant-

ly benefit in the geopolitical arena with stronger threat-deterrence that address existing and emerging capability gaps.

Reaching this future state through Responsive Defense; however, is a long-term game. Europe will need to create sustained funding opportunities through both government and hybrid programs, while re-evaluating orthodox operating models for armament acquisition and contract awarding. This will require increased focus and consistent effort if European nations and their allies are to develop a competitive edge in Great Power Competition, while catalyzing economic growth and technological innovation for domestic economies in the twenty-first century.

Hypersonics: Between Rhetoric and Reality

Colonel David Pappalardo

David Pappalardo is an officer of the French Air and Space Force and is currently serving in the Directorate General of International Relations and Strategy of the French Ministry of Armed Forces.

From “new lethal weapons” and “spectacular and revolutionary” to “*Sputnik moment*”, there is no shortage of hyperboles to describe current developments in hypersonic technology. It is so much so that on 4 January 2022, an investigation by the French newspaper, *Les Echos*, headlined that this new arms race was likely to “reshuffle the cards of global security”.¹ Indeed, the year 2021 was filled with various new cases. In August, the United States accused China of testing a new disruptive weapon that was capable of circling the earth at low orbit before striking its target. Although Beijing denied this, arguing that it was a test for a reusable space vehicle, General Mark Milley (US chairman of the Joint Chief of Staff) compared the test to the 1957 launch of the Soviet’s *Sputnik* satellite, which had overtaken the United States in its space conquest by surprise.

In addition, on 11 October 2021, North Korea unveiled a range of weapons at the Defence Development Exhibition “Self-Defence-2021”, including a hypersonic glider and a Manoeuvrable Re-entry Vehicle (MaRV) coupled with a new booster named *Hwasong-8*.² Although the glider, flight-tested a few days earlier, generated much doubts about the speed achieved and the actual success of the test, Pyongyang’s statements focused solely on the “hypersonic” feature, thereby generating a viral buzz. They used this same declaratory strategy during the two tests for a manoeuvring re-entry warhead on January 6th and 11th. Yet, this was not only similar to what the US had developed in the 1980s with the *Pershing-II* missile, but it had also heavily referenced China’s *DF-21D* and *DF-26* missiles.

1. A. Bauer, “[La course aux armes hypersoniques rebat les cartes de la sécurité mondiale](#),” *Les Echos*, 4 January 2022.

2. C. Zwirko, “[New missiles and Kim Jong Un idolatry dominate ‘Self-Defense-2021’ expo](#),” *NKPRO*, 12 October 2021.

During its first test, the warhead accurately hit a target at a distance of 700 km while demonstrating a capacity to move laterally over 120 km once in position, according to the Korean Central News Agency.

Finally, Russia claimed on 19 March 2022 that it had used its *Kh-47M2 Kinzhal* air-launched ballistic missile fired from a modernized *MiG-31* to destroy an underground ammunition storage in Ukraine³. While it was a first in combat operations, the strategic messaging mainly focused on the hypersonic nature of this weapon to intimidate NATO. However, the *Kinzhal* neither is a disruptive weapon nor offers Russia a significant operational advantage in the war in Ukraine. *Kinzhal* is rather a modified ground-launched *Iskander-M* short-range ballistic missile, the latter having been used many times since the beginning of the conflict to create similar military effects.

To focus blindly on the word “hypersonic” is to forget that a large proportion of “ordinary” ballistic missiles are already hypersonic, insofar as, depending on their range, they often reach speeds well over five times the speed of sound. In contrast, current technological developments demonstrate the search for manoeuvrability at very high speeds and under very high aerodynamic constraints in either the upper layers of the atmosphere (gliders, cruise missiles) or during the re-entry of a warhead into the atmosphere (MaRV). Such efforts must be deciphered in light of the classic dialectic between attack and defence. In such cases, it must aim to increase penetration capabilities in the face of ever more elaborate and integrated missile defences. Hypersonics thus serve four strategic ambitions. The first is to ensure the credibility of nuclear deterrence for nuclear states. Secondly, hypersonics aim to increase conventional deep precision strike capabilities, which can either support an anti-access posture (Russia and China) or, on the contrary, seek to bypass them through a combination of energy-manoevrability (United States). Finally, they are vectors of strategic signalling that can serve an intimidation posture (Russia, China, and North Korea). These four strategic ambitions are already supported by more classical missile technologies. In this regard, hypersonics are therefore less of a revolution than an incremental progress in established functions.

Nonetheless, the strategic signalling of various competitors intertwines rhetoric with reality. Hence, the effects on strategic stability should not be overestimated in comparison with other missile technologies already in use. On the one hand, the proliferation of these technologies remains relative to date, given their high level of sophistication; on the other hand, hypersonic weapons do not significantly alter the logic of nuclear deterrence, insofar as the current arsenals already guarantee – and will continue to guarantee for the foreseeable future – the mutual vulnerability of nuclear states. In this sense, claiming that the United States and its Allies are facing a “*Sputnik* moment” is exaggerated. However,

3. This weapon was unveiled in 2018. It has been in operational experimentation on *MiG-31 K* since 2020.

even if these hypersonic weapons do not create new problems, they can certainly amplify existing ones in terms of escalation management, expansion of battle-field space,⁴ and the reduction of reaction times, especially when they are serving opaque and ambiguous doctrines.

A Redefinition of the Dialectic between Attack and Defence

High Speeds for the Energy-Manoeuvre Ratio

Weapons capable of reaching speeds above Mach 5 already exist as ballistic missiles, whose maximum speed increases with range (up to more than 20 times the speed of sound for ICBMs).⁵ However, their trajectory is predictable: as soon as they are detected, it is relatively easy to determine the point of origin (and therefore to assign responsibility for the attack) and to estimate the ballistic missile's impact point. This is also the case for any space-orbiting vehicle moving at hypersonic speeds along a predictable trajectory. In fact, in order to penetrate elaborate defences, current developments of weapons capable of speeds above Mach 5 focus rather on using energy to manoeuvre at very high speeds within the upper atmosphere.

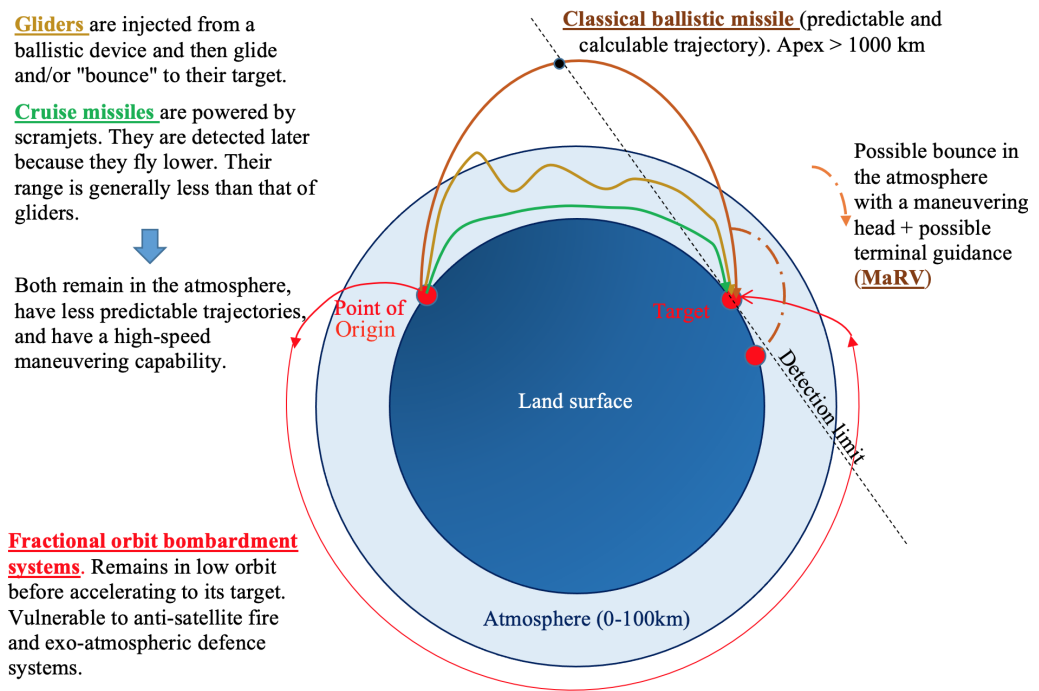
There are two main types of hypersonic weapons. The first is the Hypersonic Glide Vehicle (HGV), which is combined with a ground- or air-launched ballistic missile. Once separated from their booster, they can fly at speeds of around 3 to 5 km/s and altitudes between 50 and 70 km. They rebound off of the atmosphere to increase range and convert their speed into energy for manoeuvring. The absence of propulsion, on the other hand, creates a range-penetration dilemma: should the range obtained from the first rebound allow it to maintain a sufficient speed, subsequent manoeuvres would then slow it down, exposing the vehicle to the risk of interception at the terminal flight phase.

The second major category is the Hypersonic Cruise Missile (HCM), which is usually powered by a scramjet throughout the flight (supersonic combustion ramjet). These missiles are slower than gliders (around 2 to 2.5 km/s) with generally shorter ranges. Yet, because they fly at lower altitudes (between 30 and 40 km), their detection is even more complicated. They can also manoeuvre very effectively, especially during its final phase, and can be air-, sea- or ground-launched. On the down side, the development of scramjet technology is not a walk in the park: operating them is akin to "keeping a match lit in the middle of a hurricane", leading certain competitors to initially favour gliders instead in their development of hypersonic weapons. However, significant progress has been made since then. Today, scramjets have become a key priority for the United States Air Force (USAF) in achieving their large-scale hypersonic strike capabi-

4. The expansion of the battlefield is more significantly related to the increased range of precision weaponry, hypersonic or otherwise.

5. Intercontinental Ballistic Missiles with a range of over 5 500 km.

lity. At the end of 2021, Russia also actively engaged in a testing campaign for their *3M22 Tsirkon* hypersonic cruise missile, launched from the *Admiral Gorshkov* frigate and the *Severodvinsk* submarine. Moscow is thus on the verge of fielding the first scramjet missile, capable of reaching speeds of around Mach 8, several months ahead of its initially scheduled deadline.⁶ Finally, France aims to bring its future *ASN-4G* missile into service by 2035 for its nuclear deterrent.



Please note that the diagram is not up to scale.

Figure 1: This figure summarises the different flight profiles and the main characteristics of the hypersonic weapons under consideration (ballistic missiles, manoeuvring warheads, HGV, HCM, and FOBS).

Beyond HGV and HCM, two other “hybrid” categories can be identified. The first are ballistic missiles attached to Manoeuvrable Re-entry Vehicles (MaRVs), which can increase the accuracy of terminal guidance and possibly hit slow-moving targets. Iran, China, and North Korea are developing this technology, which is a serious point of concern, particularly in the context of anti-ship warfare. The second is the Fractional Orbital Bombardment System (FOBS), which has returned to the spotlight with China’s testing in the summer of 2021 (although the exact nature of these tests remains unconfirmed). Unlike gliders that “fly” in the atmosphere, FOBSs circulate in low orbit before performing a re-entry manoeuvre and heading towards its target. The Soviets introduced the first FOBS in 1968 before abandoning them in the 1980s. While they did not contravene the

6. “[3M22 Zircon](#),” *Missile Defense Advocacy Alliance*, 20 July 2022.

letter of the Outer Space Treaty *per se*, they evidently contradicted its intended purpose.⁷ FOBSs, moreover, have limited operational value. Admittedly, they can “navigate via the South Pole” to evade the northbound-oriented US missile defences. Yet, the extension of an ICBM’s range can also achieve the same capabilities, like Russia’s new *SARMAT* due to enter into service by 2025. FOBSs also suffer from payload limitations, with re-entry into the atmosphere being more difficult to manage. Finally, the use of a low orbit makes their trajectory more predictable than that of gliders or hypersonic cruise missiles.⁸ However, coupling a FOBS to a manoeuvring re-entry body would increase the uncertainty on the final trajectory, as well as on the point of impact.

Increasing Penetration Capacity as an Operational Objective

Beyond the different technologies used, the operational objective remains the same: guaranteeing and increasing the penetration capabilities of offensive systems by thwarting adversary defences (bypassing) and/or destroying them (suppression). The principles remain the same: converting speed into manoeuvrability; adopting a flight profile in the higher layers of the atmosphere that are ill-suited to current detection and interception systems; crippling the adversary to the point of paralysis (undermining decision loops); increasing the unpredictability of trajectories (thus posing an interpretive dilemma).

Four Main Strategic Purposes

Ultimately, the development of hypersonic weapons supports four main purposes, epitomised by the choices of the main hypersonic players today.

1 – Guaranteeing the Credibility of Nuclear Deterrence

The first is ensuring the credibility of exercising nuclear deterrence in the face of an increase in adversary missile defences. For example, Russia particularly insisted on this rationale as it presented its *Avangard* system as a response to both US and NATO missile defences – despite the latter being neither directed at Russia, nor designed to counter a large-scale ballistic attack. As an HGV previously known as *Project 4202*, the *Avangard* is equipped with a nuclear warhead and can reach speeds of around Mach 20 for manoeuvring, thus granting its high penetration capacities. The *Avangard* is currently carried by the SS-19 *Stiletto*, pending the entry into service of Russia’s new RS-28 *Sarmat* ICBM by the end of 2025.

7. The 1967 Outer Space Treaty explicitly prohibits the placing in orbit of weapons of mass destruction (WMD). Just like ballistic missiles that only pass through space, FOBSs are not legally considered as space objects as they do not complete a full orbit around the earth. As such, they do not fall within the scope of space law.

8. E. Maitre, “[Système de bombardement orbital fractionné \(FOBS\): une nouvelle capacité chinoise?](#),” *Observatoire de la Dissuasion*, Bulletin no. 91 (2021): 6-9.

The United States believes that China is also using these technologies in a more obscure way as part of an overall modernisation effort – both quantitative and qualitative – for its nuclear deterrent. For example, the test conducted in the summer of 2021 may well have been a glider deployed from an ICBM. Albeit unconfirmed, this hypothesis is more credible today than that of the FOBS due to its few operational advantages, as mentioned above.

France is also moving towards hypersonics, developing a fourth generation air-to-ground nuclear missile (*ASN-4G*) to be put into service in 2035.⁹ This new manoeuvring HCM will guarantee the credibility of the French deterrent's airborne component beyond 2040, while respecting the principle of strict sufficiency.

The United States, on the contrary, seems to not be using hypersonic technology to modernise their nuclear triad,¹⁰ for which Washington has already provisioned more than 27 billion USD by 2022. In particular, it is worth noting that the United States has maintained its focus on stealth and numbers, rather than hypervelocity in regard to its nuclear deterrent's airborne component.

2 – Increasing Conventional Deep Precision Strike Capabilities

The second strategic objective consists in improving conventional Deep Precision Strike capabilities (DPS) as coercive tools. This logic was inherited from the United States's Conventional Prompt Global Strike programme, envisioned in 2003 but never realised.¹¹ The initial objective of this programme was to precisely strike any position on the globe in less than an hour with conventionally-armed submarine-launched intercontinental ballistic missiles. This program was put to a halt for two reasons: not only was the cost-effectiveness ratio too detrimental, but the misinterpretation risk for an adversary on the warhead's nature (conventional or nuclear) was also too high, potentially leading to an uncontrollable nuclear escalation.

With the end of the Treaty on Intermediate-Range Nuclear Forces (INF) and the hardening of Russia and China's A2/AD postures,¹² the United States is now revisiting this concept in light of hypersonic developments in all three services. The US Army is developing the Long Range Hypersonic Weapon (LRHW) "*Dark Eagle*", which is set to enter into service by 2023. With a range of over 2 000 km, LRHW uses a ground-launched glider co-developed with the

9. In parallel, the *V-MAX* experimental project aimed at developing a hypersonic glider was granted to the Ariane Group by the French Directorate General of Armaments in 2019. This innovative project aims to develop technological building blocks related to the hypersonic glider, whose future use has yet to be decided (conventional or nuclear).

10. *Columbia*-class nuclear-powered ballistic missile submarine; Ground Based Strategic Deterrent programme; B-21 bombers and AGM-181 Long Range Stand-Off Weapon.

11. Congressional Research Service, "[Conventional Prompt Global Strike and Long-Range Ballistic Missiles: Background and Issues](#)," *Congress.gov*, Updated 16 July 2021.

12. Anti-Access/Area Denial.

US Navy.¹³ The latter has initiated the Intermediate-Range Conventional Prompt Strike (IRCPS) programme, which will integrate the same hypersonic system on *Zumwalt*-class destroyers from 2023, and on future *Virginia*-class nuclear attack submarines from 2028.

The USAF is still exploring two complementary avenues. The first concerns the development of the *AGM-183A* Air-launched Rapid Response Weapon (ARRW, dubbed “Arrow”). Due to be deployed this year on the *B-52*, the program is currently experiencing many technical difficulties: the United States suffered a third consecutive failure during the propulsion system’s testing on 15 December 2021 from a *B-52*.¹⁴ While the *AGM-183A* was planned to be the first operational hypersonic weapon to enter service in the United States, the fiscal 2023 budget has clouded the horizon of the programme, canceling procurement in 2023 and reinvesting funds in research and development.¹⁵ Concomitantly, the USAF has accelerated its scramjet-powered hypersonic cruise missile programme, following the successful flight tests of its Hypersonic Air-breathing Weapon Concept (HAWC) demonstrator on 27 September 2021 and on March 2022. The objective is to finalise the design for its future missile, the Hypersonic Attack Cruise Missile (HACM), by 2023. The HACM is set to constitute as the USAF’s main airborne hypersonic system by the end of the decade.¹⁶

In short, at this stage, the US is considering a purely conventional application of hypersonic weapons, for which they are not currently considering reaching intercontinental ranges (to avoid ambiguity with their nuclear deterrent). Nevertheless, hypersonics embody the current strategic competition with Russia and China. Washington is thus investing massively to catch up with Moscow and Beijing, as shown by the budget allocated for the 2022 fiscal year in the National Defense Authorization Act (2.7 billion USD provisioned, accounting for a 750% increase in investments between 2015 and 2020).¹⁷ For the United States, hypersonic systems have become essential pillars of operational superiority in response to Russia’s A2/AD posture in Europe and China’s in Asia. Hypersonics can help re-establish access by neutralising enemy defences and, more specifically, the key elements of these postures (detection and command centres, surface-to-air systems, launch sites for the main offensive systems, etc.).¹⁸

13. *Common-Hypersonic Glide Body* (C-HGB).

14. This is a further setback for an already backlogged program, and one for which the USAF had set aside 161 million USD to buy twelve units in FY22 (<https://breakingdefense.com/2021/12/air-force-hypersonic-weapon-runs-into-trouble-after-a-third-failed-test/>).

15. Insinna, “[Air Force ditches plans to buy first hypersonic ARRW missile in FY23](#),” *Breaking Defense*, 29 March 2022.

16. The contract for the first missile design of the HAWC program was awarded in June 2021 to Lockheed and Raytheon (for a period of 15 months). In addition, there is a strong linkage with Australia’s Southern Cross Integrated Flight Research Experiment (SCIFIRE) program.

17. Congressional Research Service, “[Hypersonic Weapons: Background and Issues for Congress](#),” *Congress.gov*, 5 May 2022.

18. With the risk of escalation that this entails, given the entanglement of conventional and nuclear elements in the Command, Control and Intelligence architectures.

3 – Toughen Up Anti-Access Postures

In contrast, the third strategic ambition of hypersonic weapons relates to the strengthening of anti-access postures, as evidenced by Russia and China. Seeking to stun the adversary and strike targets in depth at short notice, the hypersonic systems developed by Moscow and Beijing not only threaten key Allied infrastructures but are also likely to prohibit manoeuvring and/or reduce freedom of action.

Anti-access aims to counter the adversary's ability to project power from all domains. By targeting airpower-enabling infrastructures, hypersonic systems can challenge air superiority. They can also contribute to A2/AD in the maritime domain to keep carrier strike groups' air components – symbolic of US naval supremacy – at bay. Russia's *Tsirkon* missile is presented primarily as being anti-ship with characteristics that could reach its target despite a fleet's layered defence architecture. China's case is even more striking for maritime anti-access. Taking advantage of geography, Beijing has sought to extend its maritime interdiction zone up to the second island chain, including the Bonin Island and the Marshall Islands. China has specifically developed MaRV-equipped ballistic missiles: those being the 1,400 km-ranged *DF-21D* and the 4,000 km-ranged *DF-26*, respectively also known as the “Carrier killer” and the “Guam killer”. In addition, Beijing has officially commissioned in 2019 the 2500 km-ranged *DF-17* ballistic missile, equipped with a hypersonic glider capable of reaching Mach 10,¹⁹ suggesting an anti-ship function. In parallel, China is developing a two-stage, anti-ship, air-launched ballistic missile on its *H6-N* bomber. Known as the *CH-AS-X-13*, it is believed to have been developed from the *DF-21D* surface-to-surface missile, thereby posing an additional threat to opposing naval forces.

Finally, regional powers like North Korea and Iran are also seeking to develop similar capabilities, although they are mainly focused on manoeuvring warheads.

4 – A Vector for Strategic Signalling

Beyond posture strengthening, hypersonic weapons are also undoubtedly a tool for strategic signalling. They not only serve as a broader intimidation posture in the context of renewed great power competition, but may also embolden regional powers (Iran and North Korea in particular). Beyond the operational purposes mentioned above, hypersonic weapons also contribute to the prestige of a nation. The current escalation of verbal volleys must also be interpreted from this angle in order to untangle the skein where rhetoric and reality intertwine. This is all the more necessary since a hypersonic strike capability – especially on a moving target – does not only depend on an effector and a technological building block. It also requires a highly integrated intelligence, targeting, and command architecture, in which space assets are of paramount importance.

19. CSIS Missile Defense Project, “[DF-17](#),” *Center for Strategic and International Studies*, 2 August 2021.

Between Rhetoric and Reality: What Are the Effects on Strategic Stability?

Either a source of concern or hope, the tensions caused by hypersonic vectors in regard to strategic stability are widely discussed in the light of the four previous strategic purposes. They must be analysed even more carefully because the frenzy over hypersonic technology can be used to endorse both aggressive rhetorics and bureaucratic rationales to secure budgets.

Today, strategic stability can be defined as a situation in which actors are not structurally inclined to choose escalation over restraint. The question is therefore to understand to what extent hypersonic weapons are likely to undermine strategic stability according to its three commonly defined pillars: nuclear stability, crisis stability, and arms race stability.²⁰

Perhaps Overestimating the Threat to Nuclear Stability

Following the US disclosure of China's FOBS-like tests carried out in the summer of 2021, General John Hyten (then vice chairman of the Joint Chiefs of Staff) accused China of seeking a disarming first strike capability to prevent the United States from retaliating.²¹ Tempered a few days later by Secretary of Defence Lloyd Austin, this single statement shows how rhetoric can exaggerate the reality when it comes to hypersonics. Contrary to Hyten's assertions, the threat of hypersonics to nuclear stability should not be blown out of proportion. The principle of mutual vulnerability, which lies at the heart of deterrence, is already assured by existing means. Indeed, there is already no defence against a complex intercontinental ballistic missile attack, and this situation is unlikely to change. With only 44 exo-atmospheric interceptors located in Alaska and California, the US homeland missile defence is not suited to counter a saturated attack. In fact, such a composition is only geared towards regional powers, such as North Korea or Iran, with whom the US refuses to concede mutual vulnerability. The same applies to NATO's missile defence as it is only capable of intercepting medium-range ballistic missiles.²² Furthermore, the second-strike capability of nuclear-powered ballistic-missile submarines is not directly threatened by such developments. In other words, there is most likely not a "Sputnik moment" in today's nuclear stability.

Conversely, one could argue that advances in hypersonic technology are, in fact, beneficial to nuclear stability since they increase the effectiveness of penetrating defences (qualitative improvements) without oversaturating attacks (quantitative moderation). This is, for example, the path taken by France with its *ASN-4G* programme, which concurs, as mentioned above, with the strict sufficiency principle.

20. B. Hautecouverture, E. Maitre, B. Tertrais, "[The future of strategic stability](#)," *Recherches & Documents*, Bulletin, no. 7 (2021).

21. D. Martin, "[Exclusive: No. 2 in U.S. military reveals new details about China's hypersonic weapons test](#)," *CBS News*, Updated 16 November 2021.

22. Embodied by four *Aegis* ships and two *Aegis Ashore* sites, the first of which has been operational in Romania since 2016 and the second of which is due to be in service in 2023.

A Risk to Crisis Stability and Escalation Management

Hypersonic systems, by their intrinsic nature, alter the relationship between time and space by reducing the former (shortened reaction time) and expanding the latter with less trajectory predictability (“destination uncertainty”), and could therefore complicate escalation management during a crisis. In addition to ambiguous doctrines, hypersonics further exacerbate pre-existing risks, forcing the adversary to blindly decide in a two-tiered security dilemma.²³ The first level is an interpretive dilemma due to a double ambiguity. For one, the attack destination remains unclear as it is impossible to determine with certainty the intended target. In the case of two nuclear powers, this ambiguity only raises the adversary’s suspicions that a conventional decapitation strike may be meant for its nuclear forces. On the other hand, ambiguity also lies in the warhead’s nature, which can be either conventional or nuclear.²⁴

Even once this dilemma has been resolved, it gives way to another in which the decision-maker has to tailor his response in an extremely short timeframe. The use of hypersonic weapons can aggravate the response dilemma by aggressively escalating the situation. In order to not lose the strategic advantage conferred by their own offensive systems, the defending belligerent might resort to hypersonics before knowing the outcome of the enemy’s strike (the “use-it-or-lose-it” scenario). In this context, there is a high risk of misinterpreting the adversary’s intentions, which sets the path towards uncontrollable escalation. This is especially the issue if the defender relies on a high alert posture (“launch upon warning”) and/or grants strong transfers of authority for utilisation (including preventive strikes). On the contrary, one may argue that these risks could also incentivise states into maintaining strong political control over the deployment and use of these capabilities in order to prevent undesired escalations.

In sum, the ambiguity at the source of instability lies rather in doctrines than in technologies. For example, China and Russia remain nebulous about the nature of their warheads (hypersonic or otherwise) deployed from their delivery systems, as well as strong obscurity on nuclear or non-nuclear forces. Moreover, the entanglement of conventional and nuclear use in command, control, and intelligence structures already increases the risk of unintended escalation in the event of a conventional strike against one of these dual-use components.²⁵ Therefore, even if hypersonics do not create new problems in escalation management, it could significantly amplify them should there be a tense strategic competition.

23. C.-P. David, O. Schmitt, *La guerre et la paix. Approches et enjeux de la sécurité et de la stratégie* (Paris: Presses de Sciences Po, 2020): 564.

24. W. Heather, “Asymmetric arms control and strategic stability: Scenarios for limiting hypersonic glide vehicles,” *Journal of Strategic Studies*, no. 6 (2019): 789-813.

25. J. Acton, “Escalation through Entanglement: How the Vulnerability of Command-and-Control Systems Raises the Risks of an Inadvertent Nuclear War,” *International Security*, no.1 (2018): 56-99.

Speeding Towards a Hypersonic Arms Race?

Undoubtedly at the onset of a hypersonic arms race, it is still too early to say with certainty that the cards to global security will be significantly “reshuffled” to the point of disrupting strategic stability. To speak of uncontrollable proliferation seems excessive when the technology needed to operationally field gliders and even more scramjets remains only within the realm of major powers for the time being. Yet, it is true that a growing number of countries’ interests have been piqued, independently or in cooperation, as evidenced by the acquisition of MaRVs by regional powers, such as Iran and North Korea.

Moreover, the commotion surrounding hypersonics cannot be a distraction from the development of other more accessible missile technologies. The latter are, in fact, at a higher risk of proliferation, for which there still remains little or no tangible operational response (loitering munitions, drones, conventional cruise missiles, etc.). The label “hypersonic” must not become the “bullfighter’s muleta” used to lure and exhaust the opponent into the arena of strategic competition. Nevertheless, France must continue to explore such technology to avoid being caught strategically off-guard. The changes that the deployment of these weapons could introduce into the French national defence strategy must continue to be assessed – in both their offensive and defensive dimensions, nuclear as well as conventional, and within all armed services.

Quantum under the Service of the Third Dimension

Sous-lieutenant Pierre Vallée

Pierre Vallée is a French Air Force and Space Force Officer working at the Centre d'études stratégiques aérospatiales and a PhD candidate in Political Science.

“Those who are not shocked when they first come across quantum theory cannot possibly have understood it.”

– Niels Bohr, Nobel Prize in Physics (1922)

In June of 2002, the field of physicists was quite taken aback when a daringly challenging title of a co-authored study by two Anglo-Saxon physicists had been published.¹ According to the assertion of Jonathan Dowling and Gerard Milburn, the world was at the brink of a new era under the auspices of “the second quantum revolution”. Such an analysis, ever audacious for its time, has since been favourably endorsed by much of the scientific community.

A successor to the twentieth century’s first revolution that mothered the transistor, the laser, computer circuits, and medical resonance imaging (MRI), this new quantum age was to come to fruition through the refining of knowledge at the subatomic level and “counterintuitive” principles coming into force on yet another scale. These advances would open the gates to new technological possibilities of a previously unimaginable nature.

The commercial sector has already begun tinkling with some of these new means, with the armed forces not far behind. Drummed on by the innovations of a string of strategic competitors, military research had also fallen into full

1. J. Dowling and G. Milburn, “[Quantum technology: the second quantum revolution](#),” *Philosophical Transactions of the Royal Society A* 361, no. 1809 (2003): 1655-1674.

swing. The swirl of forces resolutely engaged in this race towards quantum were entranced with its promises of new capability achievements and operational perspectives, particularly in the aerospace field. Indeed, the third dimension is the preferred medium to cultivate technological advances. Hence, the upgrades that quantum can induce in sensors, communications, and computing segments gave rise to hopes of an unprecedented qualitative leap in aerospace technology.

This article therefore proposes to also pilot aerospace power into the horizons of “the second quantum revolution”. Even without being overly exhaustive, this overview of specific concrete capabilities may still render readers “shocked”, in light of their respective prospects.

Section I opens with a study of three groups of applications in particular – sensors, communications, and computing, which all play a predominant role in the implementation of air power. While the successive review of these three areas is intended to bring about added clarity, such a methodology is not to suggest the existence of an exclusive imperviousness between the three. Similarly, this article employs a strictly explanatory approach to simply outline certain hoped-for technological concretions. For the other “roads untaken,” these will not be dwelt upon further. In essence, should the second quantum revolution transform the way the world is looked at – or rather in this case, the way war is waged, it is still contingent on the dissolution of many challenges and uncharted terrain of which the author hopes to make aware. Concurrently, these tactical considerations cannot be divorced from a strategic level of analysis. This is all but a reminder not to be enthralled by the hubris of the game changer, a term that can easily be applied to future quantum technologies – the focus of Section II.

Quantum Sensing

Quantum physics when applied to the field of sensors may issue impressive improvements in precision and reliability in measurement. Such a qualitative benefit is seemingly evident in the context of aerospace power, since sensors (for navigation, detection, positioning and guidance, etc.) are essentials when traveling and taking action in the third dimension.

For such means, inertial units can therefore pinpoint the position of an aircraft on a three-dimensional plane of x , y , z (longitude, latitude, altitude). However, the measurements of its sensors (gyroscopes and accelerometers) hold a margin of error that increases exponentially in function with the factor of time. Although it is possible to filter out and reduce the noise that disturbs the operations of such instruments, it is not possible to completely correct the drift of these units.

Deviations of Inertial Units Produced by Safran Electronics & Defense

Unit Model	GADIRU	SIGMA 95L	SIGMA 95N
French Aircraft in Question	A400M	NH90	Rafale
Position Drift (approx.)	3,700 m/h of flight time	2,900 m/h of flight time	1,850 m/h of flight time

Source: Safran (2018)

A case in point is the *Marathon-Monfreid* exercise flight in 2019 (Saint-Dizier/Réunion in 12 hours). A pure inertial navigation would result in a difference of about twenty kilometers between the actual position and that which is displayed on the *Rafale* console. To compensate for this discrepancy, the information from the units is coupled with satellite positioning data (GNSS²) during recalibration operations.

In the quantum era, this hybrid mechanism would no longer be necessary. The units would function with atomic gyros and accelerometers. Cooled to a temperature close to absolute zero (-273.15°C), these atoms would act as a wave of matter with an ultra-sensitivity to variations in speed and rotation. Keen on exploring this prospect, Thales estimates the possibility of attaining navigation with up to a hundred times more precision than that of calculations by “conventional” inertial units.

Indeed, any vector using inertial navigation could benefit from this breakthrough: helicopters, drones, aircrafts, but also space rockets and missiles. For example, the navigation of the *Ariane VI* launcher is based solely on its *Space-Naute* unit and without GNSS correction. Its drift could be reduced with a transition into quantum sensors. In the case of missiles, not only would the Keplerian trajectory of ballistic missiles benefit with higher precision, but also the cruise period’s quality of standoff models would also witness a drastic improvement, making it easier for radars to lock onto targets upon its terminal approach.

Beyond the advantage of accuracy, quantum inertial navigation may also cure the over-dependency that military platforms have on space. Indeed, there is always a risk of losing GNSS signals due to either natural phenomena (*i.e.* unfavourable topographical, geomagnetic, or meteorological parameters), or from a deliberate hindering of an adversary’s freedom of action. In this context, quantum inertial units present the opportunity for navigation to remain autonomous despite being in semi- or non-permissive aerial environments.

2. Global navigation satellite system.

Moreover, the nature of certain missions may also demand a need to graduate from GNSS. Accordingly, the French Ministry of Defence maintains that Strategic Air Force (SAF) must possess the capacity to deliver armament “with neither data links nor satellite positioning.”³ The SAF is in the midst of applying this into practice. Notably, *Rafale* aircrafts turned off their GNSS receivers for the duration of a 12-hour exercise during a firing force assessment in March 2019.

In accordance with this dual advantage, the Pentagon has well identified precision and autonomy as a veritable edge to possess. In its 2019 report on *Applications of Quantum Technologies*, the United States Department of Defense (DoD) expressed its intentions to develop quantum inertial units, citing two cases for implementation: “navigation in a GPS-denied environment” and “the guiding of strategic sea-to-ground ballistic missiles.”⁴

Likewise, the United Kingdom also concurs with these ventures. As part of its 2014 ten-year plan on quantum technology (revised in 2020), the National Quantum Technologies Programme is running the High-BIAS² project, aimed to transform quantum navigation research into reality.⁵ Although civilian airlines would be the first beneficiaries of such advancements, they will undoubtedly pool into the military dimension as well. Subsequently, BAE System has stepped forwards to supply the demonstrator that would carry the unit. Finally, in France, the 2021 *Stratégie française sur les technologies quantiques* (“French Strategy on Quantum Technologies”) clearly exhibits the authorities’ interest on the issue – despite there being yet a budget or public programme made public.⁶

Regardless of these developments, quantum is not a polar opposite to the use of GNSS; in fact, the situation is quite the contrary. A case in point are atomic clocks, which were born from the “first quantum revolution”. Specifically, they process energy changes of an atom’s electrons – otherwise known as “oscillations” – under the effect of light microwaves. These are emitted by macroscopic quartz or laser oscillators that generate a frequency modelled on the natural resonance frequency within an atom. Every time this occurs, a signal is generated to determine each second. Since 1967, this has been equivalent to 9,192,631,700 oscillations of a caesium atom’s electrons, thereby producing a precision where a second is of the order of a ten-millionth of a billionth (10^{-16}).

For GNSS, the central issue lies rather in limiting these approximations. Satellite geolocation is the result of calculating the time it takes for a signal to travel from a transmitter (aircraft) to its receiver (satellite), relative to the speed of light. To contextualise this order of magnitude, the inaccuracy of a single second is equivalent to a positioning difference of about 300,000 km.

3. Ministère de la Défense, “[Télécommunications](#),” by J. Bompard, Question N° 9447, Assemblée nationale: JORF, 25 March 2014.

4. Defense Science Board, “[Applications of Quantum Technologies: Executive Summary](#),” *Department of Defense*, 2019: 17.

5. High Bandwidth Inertial Atom Source.

6. E. Macron, “[Présentation de la stratégie nationale sur les technologies quantiques](#),” transcript of speech delivered at Saclay, 21 January 2021, 9.

Today, GNSS constellations offer decimetric or even centimetric accuracy. With *Galileo*, each satellite carries four clocks (two rubidium and two hydrogen). They operate without any correction for 12 hours – this is the time needed for a satellite to return to a ground station to receive an update from the ground-based clock. During this period, the desynchronization of the clocks (1.8 nanoseconds for the rubidium clocks and 0.45 for the hydrogen clocks) results in a theoretical average approximation of 0.3225 metre. However, this is an optimal quality that can be obtained only if the setting are ideal, where the clocks have complete stability, without any device or satellite link malfunctioning. Therefore, this may not be sufficient in certain cases, such as ground-to-air or air-to-ground suppression of high-value moving targets, missile defence, or the guidance of manoeuvring hypersonic systems.⁷

With the dawn of the second quantum revolution came new clocks as well. The functioning of microwaves is being replaced by an optical mechanism that uses atoms that are ultra-sensitive even to basic visible lights (aluminium, ytterbium, or strontium). Their variation frequency – much greater than that of caesium – would make it possible to incorporate additional data into the measurement of the second.⁸

In addition, rather than observing oscillations independently in isolation, the phenomenon of quantum entanglement would make it possible to examine collectives of united atoms. The average taken from these would then be equal to the individual vibration of each atom, rendering measurements significantly more precise. Furthermore, quantum entanglement could take place between clocks to allow a perfect synchronisation of their systems.⁹ The satellites would then share a fundamentally identical unit of time, allowing ultra-precision in positioning calculations.

To summarise in concrete terms,¹⁰ an optical clock would push the precision of the second to 10^{-19} . In a theoretical comparison over the span of 24 hours, the accuracy achieved by optical quantum models could reach a factor of 1,000 over their classic atomic predecessors.¹¹

Another area where quantum sensing could represent a substantial breakthroughs is radar and lidar¹² detection capabilities. Their development is based on

7. While the importance of precision against a moving target is evident, the finesse of guidance and the flight envelope for hypersonic weapons also represent an essential issue “in judging the fulfilment of strategic expectations and the relevance of investment in this area. See J. Henrotin, “[Armes hypersoniques: quels enjeux pour les armées?](#),” *IFRI Briefings*, June 2021: 8-9.

8. For example, it takes 518,295,836,590,864 oscillations of ytterbium to sound one second.

9. The Einstein-Poincaré and Eddington algorithms (classic clock) or the Jozsa algorithm (quantum clock) offer theoretical ways of achieving this synchronisation.

10. This performance was achieved in 2018 over a few seconds by a team from the Joint Institute for Laboratory Astrophysics with a strontium clock.

11. It is possible to calculate this gap theoretically: classic atomic models offer an accuracy of the order of 0.002592 metres, whereas optical quantum clocks would reach 0.002592 millimetres.

12. Radio detection and ranging; light detection and ranging.

one of the counterintuitive principles of physics: the phenomenon of entanglement, more commonly known as “quantum entanglement”. To explain, a particle at the subatomic scale, such as a photon, can be simultaneously in several places at once, regardless of distance. Contrary to the visible world’s principle of unity, these parts remain connected and ultimately form a single system. In other words, a disturbance in one part of this system would affect the entire quantum structure.

As a result, this quantum state is extremely sensitive to the smallest of changes, such as variations in temperature, gravity, or even time. Much like the echo of a radar, any interference felt by the transmitted photon will be reflected in the retained photon. The analysis of the latter therefore provides information of unparalleled precision which, for detection purposes, would make it possible to be alerted of an object’s presence.

In theory, the sensitivity of quantum radar/lidar could allow the detection of any type of platform, regardless of their radar- or laser-equivalent surfaces. Such a hypothesis would inevitably redefine the power balance between states, as the quest for “stealth” has become akin to attaining a certain capability standard. Indeed, much like the generations of fighter aircrafts, each qualitative leap in military equipment since the end of the Cold War has mostly resulted in improved stealth.¹³

Nevertheless, the international scientific (and military) community remains divided on the subject. China, for one, has high hopes for this technology. In 2016, it was the first to announce that it had developed a quantum radar based on photon entanglement with the capacity to detect a target within an envelope of 100 km. This would correspond perfectly within the Integrated Air Defense System located on China’s coasts. While a similar logic could be applied to Kaliningrad, Crimea, and the Kuril Islands, Moscow maintains absolute secrecy in this regard.

On the other side of the earth, Washington is positioning itself at opposite ends of Beijing’s gamble. In 2019, the DoD’s Science Committee expressed scepticism on the subject, stating that “quantum radar would not provide enhanced capabilities”¹⁴ – without declassifying its analysis any further. This undeniably comes with quite a surprise, especially since the United States’ northern neighbour, Canada, shares the same enthusiasm as China. Ottawa, in particular, envisions quantum illumination as a means to optimise detection capabilities of the two countries’ North American Aerospace Defense (NORAD) Command against Arctic electromagnetic interferences and stealth vectors.

Indeed, this is a puzzling case of differences in opinions. As China continues to insist on approaching the subject with much circumspection, any implemen-

13. “Enhanced stealth” (4th generation++), then “extreme stealth” (5th generation), and finally, “total stealth” (6th generation); based on a table by O. Zajec, “[Faut-il encore penser en termes de ‘générations’ d’avions de combat ?](#),” *Stratégie*, no. 102 (2013): 315-328.

14. Defense Science Board, “[Applications of Quantum Technologies...](#),” *op. cit.*

tation of the fruits of its research could represent an immense challenge for any U.S. aerial architectures largely based on stealth. Already undermined by the proliferation and improvement of high and low frequency radars, the ordering principle of the U.S. Air Force's means may become definitively obsolete. Paris, for its part, refuses to "put all its eggs" on stealth, while building the framework of its Future Combat Air System. Accordingly, the French Defence Innovation Agency is in charge of "envisaging technology yet to exist, such as quantum radars," in order to predict an aerial environment's level of permissiveness that its systems might confront.¹⁵

Quantum Communications

Like quantum sensors, the main contribution of quantum communications is qualitative, as it would considerably increase the security level of exchanges. In theory, they would allow data to be transmitted without the risk of any eavesdropping taking place or of any interception of the data.

For this, having a "key" is of the essence. Originally, in order to protect their exchanges from prying eyes, the infamous Alice and Bob¹⁶ referred to a code (or a "key") known to both parties so as to encrypt and decrypt their messages. Although "symmetrical cryptography" is still used by some algorithms,¹⁷ this process requires the two correspondents to not only learn of the key in advance, but also to prepare beforehand of their exchange procedures, as well.

Over time, "asymmetric cryptography" was developed to add an extra layer of transmission security. This method relies on both a "public" key that can be exchanged and a "private" one that remains unshared. In this model, Alice transmits her public key to Bob. Bob then encrypts his message with the key and sends it back to Alice. Once received, she decrypts it using her private key. This process gradually became the standard for classic security protocols on the Internet and for other confidential exchanges. This is notably the case for the *ACiD Cryptofiler* algorithm, used by the French Ministry of Armed Forces to protect the exchange of *Diffusion Restreinte* ("Restricted Distribution") or DR-level information.

Regardless, none of the keys in either system are unbreakable, as they are simply based on complex factorisations of prime numbers, which can always be broken. Indeed, certain petaflop supercomputers have already developed the

15. R. Le Gleut and H. Conway-Mouret, "Sénat, 2040, l'odyssée du SCAF – Le système de combat aérien du futur," *Information Report*, no. 642, Paris: Présidence du Sénat, 2020. This difference can also be explained by the divergence in U.S. and French genetic strategies on where to place stealth in weapons systems.

16. In cryptography, "Alice" and "Bob" are two interlocutors while "Eve" (passive attack) and "Mallory" (active attack) are their opponents.

17. Akin to AES (Advanced Encryption Standard). Approved in 2005 by the NSA, it was one of the most sought-after encryption algorithms for U.S. government exchanges. It has now been superseded by asymmetric models, such as RSA (Rivest-Shamir-Adleman, the three inventors).

capacity to process billions of these combinations in all but a few seconds.¹⁸ The emergence of quantum computers will only increase this risk and, according to some simulations, could even render all conventional security protocols obsolete. To make matters worse, quantum algorithms designed to optimise factoring speeds already exist today. Notably, Shor's algorithm – named after its inventor, the U.S. mathematician Peter Shor – is said to be capable of factoring integers in polynomial time. In short, while it is impossible today for the most efficient computers and classic algorithms to factor a 300-digit number, Shor's algorithm would achieve this in less than ten seconds.

Faced with these risks, communication in the quantum age proposes another "cryptosystem". Although it takes up the baton from the operating principle of symmetrical cryptography, it is no longer based on mathematical models, but rather on the properties of quantum physics. According to the best-known protocols (BB84 and BBM92), the distribution of the "key" between Alice and Bob takes place through a quantum channel, made possible by a mediator particle being transmitted via open air, satellite link, or optical fibre.

In this model, upon receiving Alice's key, Bob will study the property of the received photon in order to reconstruct it. Once this is completed, the two can then continue their exchange via a classic channel by encrypting their messages using this quantum key. Such a model therefore provides the possibility to generate a key – known as "quantum key distribution" (QKD) – between the involved parties that is entirely unpredictable and theoretically unbreakable. To emphasise, the security of such a key is no longer vulnerable to computing power or an attacker's mathematical ingenuity because it is based on quantum properties. Moreover, owing to Heisenberg's uncertainty principle,¹⁹ any attempt by a third party to intercept or spy on an exchange will generate the decoherence phenomenon. This disturbance will immediately alert its correspondents. Quantum attacks, as well, are no exceptions to this rule.

Quantum communications can therefore thwart both active (disclosure and interception) and passive (modification and availability) cyber threats. As a result, all would then depend on the time needed for the communicating parties to regenerate the quantum key. When this is cut short, a decoherence signal would immediately put an end to the exchange, providing interlocutors the opportunity to set up a new communication channel via key distribution. Indeed, for a state without sufficient regeneration capacities, quantum communications can be seen as a simple means of ensuring the integrity of the information exchanged.

The applications of quantum communications extend much farther than aerospace power alone: robust communications between effectors and sen-

18. The *Jean Zay* supercomputer at the CNRS can perform 28 million billion operations per second (28 petaflops), which is ideal for "brute force" attacks. This power enables them to carry out what is known as "high-performance computing".

19. Also known as the "no-cloning theorem", it is impossible to spy on a quantum system without disturbing it.

sors underpins military effectiveness in the multi-domain operational context. Moreover, considering the increasing commitments of coalition-based military engagements, the ability to transmit/receive data securely with other actors is an undeniable asset to possess.

The quality of QKD not only depends on the vector (optical fibre, open air, or satellite) chosen to transmit the polarised photons, but also on the quantum practice itself – that being either entanglement (BBM92) or superposition (BB84). Additionally, the quality also varies in function with the distribution distance: the value of the photon decreases as the elongation increases. As a result, fibre amplifiers used for long-distance cable transmissions are inoperable for polarised photons.

In 2013, scientists succeeded in achieving a QKD with the process of entanglement between two terrestrial points 300 km apart. Subsequently, in 2018, the record of 421 km using superposition was attained. Indeed, the terrestrial wire network is at the forefront of quantum communications within the commercial domain. However, it remains only applicable to a limited geographical area and is therefore of limited military interest. The exception lies in cases of short distances or over a mesh of terrestrial relays.

Nevertheless, these limitations are mitigated in the case of transmission via open air or satellite.²⁰ For this reason, the third dimension appears to be a privileged domain for quantum communication projects. Its inherent transparency could, in time, counterbalance the central role that undersea cables currently have in communications.²¹ An example of interest took place in 2017, when Chinese satellite *Mozi* tested a QKD (BB84 protocol) with a ground station over a distance of 1,200 km. Three years later, *Mozi* began providing quantum communications between Beijing and Vienna, as well as over a distance of 7,000 km.

Despite the traction that quantum communications has gained, the enthusiasm is not unanimously shared across the board. When asked about the use of QKD by state agencies, the United States National Security Agency expressed its aversion, citing reasons of cost issues and the technology's alleged inefficiency. Joining the United States in this analysis are the United Kingdom's National Cyber Security Centre, and the French *Agence nationale de la sécurité des systèmes d'informations* ("National Agency of Information Systems Security" or ANSSI). Although the ANSSI's views are more nuanced, it maintains that the QKD is a "complementary measure to traditional cryptographic means in the logic of defence-in-depth," and not at all a complete replacement of said traditional means.²²

China is again observed as a leader in this field, owing in particular to the experiments conducted by its *Mozi* satellite.²³ These endeavours subsequently sent

20. However, the phenomenon of atmospheric diffraction alters the exchange of photons by laser.

21. 98% of internet data and international communications pass through it.

22. "L'avenir des communications sécurisées passe-t-il par la distribution quantique de clés ?," Avis scientifique et technique : la QKD, ANSSI, 4 May 2020.

23. It has also took over the Space-Quantum Experiment at Space Test project started by the Eu-

a wave of similar projects being launched across Asia, particularly in Japan and Singapore.²⁴ For Beijing, it seeks to deploy a veritable quantum constellation, comprising more or less twenty satellites altogether.

This new divergence of approaches only raises more questions; this is even the case within the Western camp itself. Washington, Paris, and London seem to be reluctant (for the time being) to adapt their means of exchange to QKD devices. However, this may result in an incompatibility of communication systems between the “endowed states” and all others. Further, all three capitals are participants in supranational discussions in favour of the adoption of quantum communications, rendering it even more untenable to uphold such viewpoints. The European multi-orbital connectivity constellation project, promoted by French commissioner Thierry Breton with the support of Paris endeavours “to project Europe onto quantum encryption with civil and military applications.” Similarly, the NATO Science & Technology Organization’s report for the projected years of 2020 to 2040 deemed “the development of a large quantum communication satellite architecture” essential in guaranteeing a secure exchange capacity for the Alliance.²⁵ Indeed, in the face of a supranational dynamic favourable to the development of quantum communications, states with contradictory positions would undoubtedly have their viability shaken.

Quantum Computing

Quantum computing is a paradox in itself: while its research is the least developed, the opportunities it represents could completely revolutionise the way societies operate. In short, quantum computing will evoke a heightened acceleration as encapsulated by the spirit of Moore’s Law.²⁶ Notably, it will allow an exponential increase in the speed of calculations, processing, and the exploitation of collected information.

In computing, the unit of measurement is expressed as an information “bit” (or “binary digit”), whose binary value is either 1 or 0. In the case of a quantum information unit, the “qubit” (or “quantum binary digit”) represents a linear value, which can be 1, 0, or both. Implemented in superconducting or photonic

ropean Space Agency and the Viennese Institute for Quantum Optics and Quantum Information, which was abandoned in the early 2000s.

24. See S. Abe, “宇宙開発戦略本部 [Space Development Strategy Headquarters],” speech, 総理大臣 [Prime Minister’s Official Residence], Tokyo, 29 June 2020. For its part, in June 2020, Singapore carried out quantum entanglement of photons from its SpooQy-1 CubSat to validate the concept. In cooperation with the Rutherford Appleton Laboratory (United Kingdom), the City State has since embarked on building a nano-satellite that is expected to perform a QKD with a ground station by 2022.

25. NATO Science and Technology Organization, *Science & Technology Trends 2020-2040: Exploring the S&T Edge* (Brussels: NATO Sciences & Technology Organization, 2020): 24.

26. It was formulated in 1985 by Dr Gordon E. Moore and characterises the exponential increase in the computing power of computers. This is expressed in “flops” (floating-point operations per second) and begins from megaflops (10^6) in 1964 to petaflops (10^{15}) in 2008. Exaflops (10^{18}) are in the process of being standardised.

processors,²⁷ the qubit not only makes it possible to combine information units linearly, but also to execute a number of operations that exceed the capacities of “classic” computers. To contextualise, Beijing, upon using a photonic quantum processor in 2020, managed to carry out a “boson sampling”²⁸ in only 200 seconds. The same operation in that same year would have taken Fujitsu’s best conventional supercomputer, *Fugaku*, 2.5 billion years to complete.

As mentioned previously, the development of quantum supercomputers calls into question the durability of symmetric and asymmetric exchange certificates. Given current computing capacities, a 2020 diagnosis regarding the security of encryption algorithms by ANSSI recommended that symmetric modules should have a key of at least 112 bits, while asymmetric modules should have 2,048 (private) and 65,536 (public) bits.²⁹ According to the audit, it is specifically with such sizes that factoring attempts can be discouraged – but only within a reasonable time frame with the former up until 2026 and the latter until 2030. After these deadlines, ANSSI advises to switch to 128-bit, 3072-bit, and 65,536-bit keys, respectively, for guaranteed security. In this respect, the advent of quantum computers would turn such “recommendations” into “rules” much sooner than expected. For example, in 2019, a study published in the journal *Quantum*, estimated that a quantum computer applying Shor’s algorithm (the factorisation of prime numbers at an exponential rate) could, in theory, break a 2,048 key in under 8 hours.

For the military, the value of quantum supercomputers lies beyond their decryption power. Because of the “datafication” phenomenon in the military ecosystem,³⁰ their field of applicability is much broader. Faced with the exponential influx of data, these computers would allow for an optimal management of data – from the point of its creation to its processing (data mining), and then to its exploitation.³¹ This ability to perform billions of billions of operations per second will be fundamental in overcoming the technical challenges of mosaic warfare.³²

The vast sensor diversity of an aerospace weapon grants it a special position in the organisation of future C4ISR architectures.³³ Similarly, the current capability

27. Even though both technologies use the principle of quantum entanglement, photonic processors work with single photons, while superconductors use ultra-cold atoms (usually Rydberg).

28. H. Zhong and al., “[Quantum computational advantage using photons](#),” *Science* 370, issue 623 (2020): 1460-1463. In complexity theory, this experiment and its “Gaussian boson” variant are frequently used to test the advantages of quantum computers over their classic counterparts.

29. ANSSI, [Règles et recommandations concernant le choix et le dimensionnement des mécanismes cryptographiques](#), Version 2.03 (21 February 2014): 50.

30. The author prefers the term “digitisation” over the term “digitalisation”, which places greater emphasis on the central role of data.

31. Grover’s quantum algorithm (named after its inventor, the Indian-American computer scientist Lov Grover) offers in theory a quadratic acceleration of exhaustive search. It is said to be the best tool for processing a massive unstructured database.

32. Regarding the importance of new technology (including quantum ones) in the multi-domain operational concept carried by DARPA, see S. Walker, “[Opening Remarks – Dr. Steven Walker, DARPA Director](#),” *Youtube video*, DARPA tv, 24 September 2018.

33. Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance.

dynamic in favour of “systems-of-systems”, the development of swarm flight practices, as well as the implementation of combat “clouds” reinforce the importance of having a tool capable of collecting and merging information. Indeed, as noted by the *EAF Strategic Vision* of April 2022, “the massive exploitation of data, which must be structured, stored, disseminated, and processed will play a central role during operations.”³⁴ Thus, quantum computers may well be one of the most suitable solutions to overcome the military’s “primacy of data” challenge.

For aerospace power, this obstacle manifests particularly when rendering 3D tools autonomous. In this respect, quantum processing capabilities would optimise the performance of artificial intelligence algorithms.³⁵ The speed and quality of calculations offered by quantum power would then have repercussions on the “Observe-Orient-Decide-Act” loop at each of its stages. Specifically, feedback will be shortened and as a result, it can ultimately lead to gaining an advantage over the adversary.

Going so far as upstreaming operations, quantum computers would be an undeniable support to planning, targeting, and wargaming processes. Indeed, quantum computing may allow the optimisation of certain support procedures. A key example is predictive maintenance of military vehicles. For aircrafts in particular, quantum computers could detect the first signs of a technical failure with much higher accuracy. Similarly, it could review millions of lines of code in on-board software systems – 2 million for an *F-22*, 3.5 for the *Reaper*, 8 for the *F-35* (24 with ALIS) – in record time, while accelerating update sequences. This would subsequently improve overall operational readiness and, in turn, the aircraft’s technical availability as well.

Finally, the simulation power of quantum computers would also bring about contributions to industrial developments for complex capabilities, namely aerospace systems. The United States Air Force is fully committed to digital engineering in order to ensure better control of the costs and delays in its programmes. This quantum simulation is also being extended to nuclear systems. The *Commissariat à l’Énergie Atomique et aux Énergies Alternatives* (“Alternative Energies and Atomic Energy Commission” or CEA) has initiated a series of collaborations with several French enterprise (*i.e.* *Atos* in May 2021, *C12* in March 2022) to drive its simulation programme into the quantum era, while guaranteeing operational credibility of its oceanic and airborne nuclear warheads.

Nonetheless, these are all but a few examples that hardly encapsulate the military expectations enshrouding quantum computers – even the field itself is greater than immense. The French Ministry of Armed Forces has come to terms with this fact. On 4 January 2022, it launched the *Plateforme nationale de calcul quantique* (“National Quantum Computing Platform”) in Saclay, aimed at obtaining the first computer by 2023.³⁶

34. Ministère des Armées, *Décourager – Défendre – Défaire : Vaincre par la 3D* (Paris: Service d’information et de relations publiques de l’armée de l’Air et de l’Espace, 2022).

35. Here, the Harrow-Hassidim-Lloyd quantum algorithm opens up innovative perspectives for improving deep learning and neural network mechanisms.

36. On this occasion, the “60 seconds Defence” podcast of the Ministry’s spokesperson listed

Unlike quantum communications and quantum sensing, there is an international consensus on the value of quantum computers. Expectations on the military side are unanimously shared in the field of “datafication”. This is ever more reflected in the fierce competition brewing amongst the private sector – with the support of public stakeholders – to be the first to achieve “quantum supremacy”.³⁷ News of releases and announcements are following one after the other: Google first broke the news of its *Sycamore* computer in 2019; China’s Institute of Science and Technology then presented its *Zuchongzhi2* in 2020; not long after, IBM entered the race in 2021 with its *Eagle*. Military Staff around the world are keeping a close eye on such headlines in hopes of jumping on board commercial developments and capitalising on the dual-use advantage this technology provides.

At Long Last, A Game Changer for the Twenty-First Century?

By categorising quantum technology into sensing, communications, and computing, its analysis becomes more digestible overall. However, such framing is not meant to imprint any notions of compartmentalisation. On the contrary, these fields are interdependent and reinforce one another. Indeed, true “quantum warfare” is intrinsically holistic.

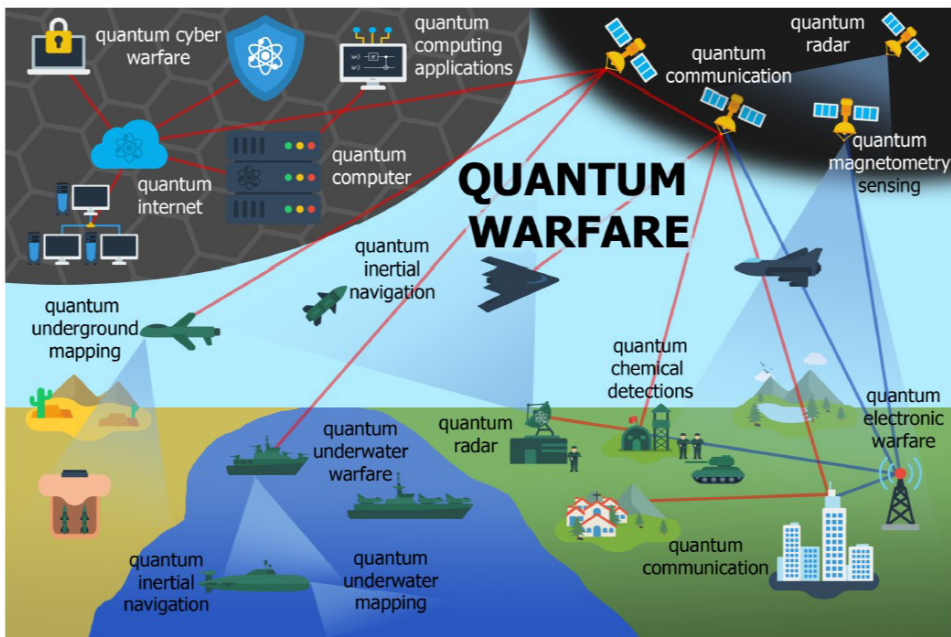


Figure 1: Sketch of quantum warfare utilising various quantum technology systems.

three areas of immediate interest: intelligence (“quantum computer would make it possible to collect and process billions of data in record time”), coordination (“possibility to finely coordinate the trajectory of thousands of satellites in space or thousands of armoured vehicles in a theatre of operations”) and the defence industry (“it would make it possible to rapidly design complicated objects such as radar antennas or ship hulls”).

37. In other words, the tipping point where a problem is no longer solvable by a classic computer and requires a quantum answer.

From examining military applications of quantum technology, there is an impression of an imminent fracturing between the world “before” and the world “after” – or rather, between the first and the second quantum revolution. For certain states, this transition from the “old” world into the “new” will be inevitably strenuous. Indeed, even acceptance itself is far from instantaneous. Moreover, the transition highly depends on possessing a scientific, technological, and financial “entry ticket”, which for the time being, remains an exclusive privilege to only a limited number of countries. From there on, a caste of “quantum aristocracy” is born, where a “nobility” of states would have a clear edge over any opponents still trapped in the “first” world. In hindsight, this balance of power would be reminiscent of the space dimension at the time of the two Gulf Wars, where “endowed states” such as the United States clashed against an impoverished adversary like Iraq.

This review of how the military applies quantum technology offers a bit of foreshadowing for the upcoming paradigm shift in aerospace power. This being the case, the possibilities that this “second revolution” may present should be thoroughly questioned as a whole. On the one hand, the hopes that quantum has enchanted in its onlookers must be confronted with the reality of cold facts. On the other hand, the reality of this impending transition must be questioned in a manner that wholly considers the phenomenon of war.

Indeed, the million dollar question is whether quantum is only a hype or truly a game changer. This was precisely the question asked by an Australian DoD official at the 48th Annual Collaborative EW Symposium in 2019, rekindling the old myth of “the decisive weapon”. Yet, this time, states are erring on the side of caution for this debate. The Pentagon’s framework documents quantum technology as having a remarkable potential and a significant impact, but does not make any references to the game changer notion. The French *Stratégie nationale*, on the contrary, is perhaps more cunning, encouraging the military instead to monitor, anticipate, detect, and appropriate “any breakthroughs that could constitute a game changer for military operations.” The prize for ambiguity, however, goes to said Australian official in 2019, who concluded that “quantum technology will certainly provide game-changing capabilities, even if there is quite a bit of hype surrounding it.”

Hence, subsequent questions follow: how can its impact be analysed and will it truly create miracle tactics? Before embarking to answer them, there must first be an agreement on what the notion of game changer constitutes. Undoubtedly, this versatile term can be understood in many different ways, be it at the strategic, operational, or tactical level.

The first interpretation of this concept mirrors that of the frenzy surrounding the early envisionings of nuclear weapons. At the time, “nuclear” had been synonymous with “absolute weapon”, whose characteristics were so unprecedented

that they would modify the very nature of warfare.³⁸ Yet, to duplicate this discourse onto quantum technology would be to overlook the elementary principles of the phenomenon of war.

To begin, no tangible parallel can be drawn between quantum technology and nuclear weapons. While there is a “nuclear aristocracy” based on the 1967 non-proliferation treaty,³⁹ quantum is not regulated by any legal regime. As a result, the logic of technological levelling (either by development or dissemination) is inevitable in the medium/long term. Therefore, should a “quantum aristocracy” emerge over time, it will only be temporary: sooner or later, quantum will impose itself as one of the predominant topics in international relations.

More broadly, the hypothesis of quantum as a “miracle weapon” is unfounded. Such thinking only evokes the rhetoric from the Revolution in Military Affairs (RMA) of the 1990s. While some weapons and technology indeed changed the way war is fought, none disqualifies war itself. Nuclear and quantum are of no exception: both are part of the historical trajectory stemming from the sword and shield that Fuller’s law of constant tactical factor encapsulates.

Further, the second quantum revolution is not an unending horizon. On the contrary, many states are already anticipating the next game changer, so to speak. The prudence practised by Western countries regarding the alleged “Q-Day” – whose arrival would call into question all existing exchange protocols – is explained by the existence of countermeasures, such as the post-quantum cryptography, which is based on new, emerging mathematical concepts. Notably, prior to a scientific and technical analysis published on 14 April 2022, the ANSSI published a brief on 4 January 2022 that considered such measures as “the most promising way to counter the quantum threat.”⁴⁰

To again dispute claims of the “ultimate weapon”, there exists in quantum communications weaknesses as well. The implementation of QKD in the commercial domain has highlighted these vulnerabilities.⁴¹ Specifically, QKD protocols will only increase the importance of Alice and Bob’s physical infrastructure: attacks will subsequently shift to hardware corruption rather than software. In the field of sensors, specifically, quantum interferometry is not a panacea. Other technological approaches that are less costly and more stable do exist. For in-

38. For nuclear weapons, this myth appears as early as 1946 in the book by one of the first thinkers of the apocalypse, B. Brodie (ed), *The Absolute Weapon: Atomic Power and World Order* (New Haven, CT: Yale Institute of International Studies, 1946).

39. Taking its roots from the concept of “conventional aristocracy” by Dean R.-J. Dupuy on the Antarctic Treaty (1959).

40. ANSSI, “[Avis scientifique et technique de l’ANSSI sur la migration vers la cryptographie post-quantique](#),” *Avis scientifique et technique*, 11 April 2022.

41. For example, the *Clavis*² QKD platform marketed by the company ID Quantique was unable to withstand a “blinding attack”. The latter managed to take control of Bob’s photon receiver without even alerting him. See A. Huang and al., “Testing Random-Detector-Efficiency Countermeasure in a Commercial System Reveals a Breakable Unrealistic Assumption,” *IEEE Journal of Quantum Electronics* 52, no. 11 (2016): 1-11.

stance, the quantum operation of inertial units could be replaced (with the same advantages) by stellar aiming mechanisms. While this process is already in use for the guidance of the *M51* submarine-launched ballistic missiles, the adaptation of this device onto an aircraft is currently being studied and could lead to a standardisation of the system in the coming years.⁴²

From another angle, the anticipated “revolution” remains suspended in limbo due to scientific difficulties (*i.e.* obtaining a sufficient number of qubits, maintaining absolute zero for cold atoms, etc.), as illustrated by the disparity in Technology Readiness Levels. More importantly, reaching technological maturity does not equate to an immediate military availability. Once it does reach this stage, the tool in question must then undergo adaptation, miniaturisation, hardening, and then qualification procedures before it can be fully integrated into a platform. It is therefore reasonable to argue that the aerospace tool will not benefit from this “second revolution” for at least several more years to come. It is more likely that a “hybrid” transition phase that combines classic technology with quantum bricks will intercede before the arrival of the “second revolution”.

Technology	TRL	Horizon
Quantum computer (annealer)	4-5 (5-6)	2030
QKD (satellite)	7-8 (6-7)	2025 (2030)
Post-quantum cryptography	7-8	2025
Quantum communication network	1-3	2030-2035
Quantum inertial navigation	4-5	2025-2030
Quantum clocks	4-6	2030
Quantum radar	1-2	none
Quantum RF antenna	4	2025-2030
Quantum magnetic and gravity sensing	5-6	2025
Quantum imaging	5	2025-2030

Table 1: TRL and time horizon expectations. These expectation reflect general TRL rather than just military TRL. Note that various quantum technologies are at different TRL within the same application.

Source: M. Krelina, *Quantum Technology for Military Applications*, 11/2021

There exists, however, another definition of game changer that is much more relevant to quantum technology. It emerges as a reaction to the “absolute weapons” rhetoric, and urges to replace this notion with the reality of the existing laws of war. Here, while quantum technology does not embody a “strategic level” game changer, they do transform the way operations are planned and conducted. In simpler terms, while the new quantum technology does not break the intangible laws of war, they do nonetheless revolutionise the principles of war.⁴³ The

42. Called *Vision* and jointly developed by Safran Electronics & Defense and Sodern, this system would join hemispheric resonant gyroscopes with a star sight.

43. On this distinction between timeless principles (principles of strategy) and contextual principles (principles of war), see O. Zajec, “Principes de la stratégie, principes de la guerre,” in M. Motte (ed.), *La mesure de la force: Traité de stratégie de l'École de guerre* (Paris: Tallandier, 2018): 107-130.

paradigm shift is therefore more so at the operational and tactical level, rather than at the strategic level.

An appropriate representative of this concept is quantum sensors as they fulfil the age-old dream of any strategist: “discovering what lies on the other side of the hill.”⁴⁴ Anything from silos, land and sea mines, to networks of tunnels could appear. If this prospect concerns enough Military Staff,⁴⁵ it should be made to never again obscure the transcendence of the laws of conflict. The fog of war will be eventually cleared away by the adversary’s capacity to adapt, bringing transparency back to the oceans and the land.

In short, it would be rather perilous to endeavour to understand the phenomenon of war through the prism of quantum at all costs. Such ventures would come with the risk of confusing procedures with principles, and operational with strategic, where, finally, the desired end state remains far out of reach. Forcing this quantum leap forward may ultimately bestow the tools of war (means) greater importance than the objectives they are supposed to serve (ends).

What can be drawn concretely from the comparison between the second quantum revolution and the RMA is a wariness of being too optimistic. Despite technological dogmatism being so deeply embedded into military ecosystems, RMA has not systematically resulted in “state parties” winning over an adversary that has not transitioned out of the “first era”. On the contrary, it has always been the culprit behind cognitive biases that led to general underestimations of enemy capabilities.

This desire to understand the world through “revolution” be it in military or quantum matters – they are not mutually exclusive – involves a dangerous compulsion to rip away the two’s foundational fabric. No matter if it is today’s RMA or tomorrow’s quantum, other alternative paths do exist and will also endure. Doctrinally, at the limit of technological omniscience is asymmetric resilience. In force, the quantitative imperative will find its answers in the qualitative focus.

Nevertheless, at both levels, quantum systems will only aggravate these discrepancies and risk programming the decision-maker to repeat their mistakes of the past. Both the outcomes of the Iraq-Afghanistan operational sequences and the analyses made by the West during the early days of the conflict in Ukraine are all but bleak reminders that it is meaningless to dictate one’s vision of war onto an adversary. Indeed, doing so makes one forget that war remains, first and foremost, a game of reciprocal actions (*Wechselwirkungen*).

44. Duke Arthur Wellesley of Wellington is credited with this remark.

45. Regarding the risk of “ocean transparency”, see K. Kubiak, “[Quantum Technology and Submarine Near-Invulnerability](#),” in *European Leadership Network, Global Security Policy Brief, December 2020* (Fondation pour la recherche stratégique): 12-13.

The Machine as a Partner

The Issue of Human Autonomy Teaming

Guy André Boy¹

Guy André Boy is Flex Tech Chair at CentraleSupélec (Université Paris Saclay) and Chairman of the Scientific Council of the ESTIA Institute of Technology. He is a Fellow of the International Council on Systems Engineering and of the Académie de l'Air et de l'Espace, corresponding member of the International Academy of Astronautics. He was Chief Scientist at the NASA Kennedy Space Center and Dean at the Florida Institute of Technology.

For more than three million years, human beings have been building tools to extend their capabilities. These tools were first manually manipulated instruments. They have progressively been extended to other human effectors and sensors. They were extensions before becoming prostheses, like the airplane, which allows humans to fly – flight being a physical capacity that humans do not have a priori. Today, it is a question of extending the capacities of the human being at the cognitive level. The computer has become an extension of mental capacities, and computer networks – the Internet in particular – make it possible to go even further in increasing both individual and collective human intelligence. We are developing and using machines that go beyond the capacity of simple tools to become true partners. This evolution is also verified in the aeronautics industry, with airplanes that have never stopped being automated. After the first autopilots were installed on airliners in the 1930s, increasingly sophisticated automatic systems were developed, such as flight management systems (FMS), traffic alert and collision avoidance systems (TCAS) and data link systems (datalink). Today, artificial intelligence, or what we might better call augmented intelligence, is making its way into the systems of future aircraft and will increasingly be considered as partners. This article analyses the challenges posed by these developments.

1. guy-andre.boy@centralesupelec.fr

(1a) The system of systems (SoS) and the multi-agent system ...

What do we mean by system? Several precise definitions² have been proposed, but the common image of a system is that of a machine. However, when doctors talk about the cardiovascular system, they are referring to the representation of a human organ that allows blood to circulate throughout the body, not a machine in the mechanical sense of the term. Social scientists speak of socio-cultural systems. It is important to note that a system can be qualified as an agent, in the sense of an entity capable of acting, *i.e.* “something that does something (that possesses a function capable of creating an activity) and that has a structure, that evolves in time, in something (environment) for something (purpose)”³. Therefore, the terms “system” and “agent” will be used here indifferently to designate “a set of elements (human or machine), in dynamic interaction, organized according to the objectives”⁴.

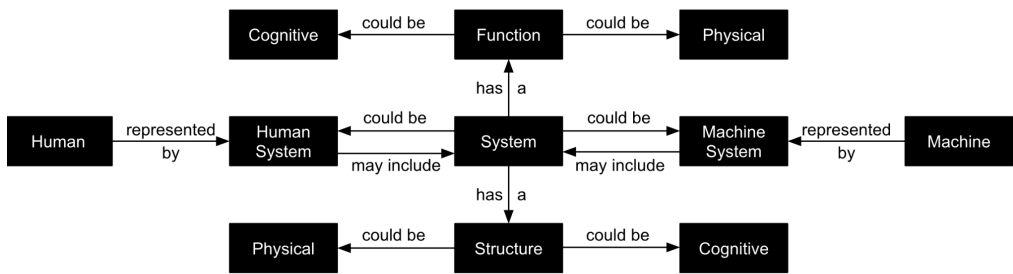


Figure 1: Flowchart representation of a system

More generally, we will speak of “natural systems” and “artificial systems”, and more precisely of human systems and machine systems, which can include other systems, defining in a recursive way the broader concept of system of systems (*i.e.* a multi-agent system). For example, the human body (*i.e.* a natural system) can include a pacemaker (*i.e.* an artificial system); conversely, a car (*i.e.* an artificial system) can include a human being (*i.e.* a natural system).

A system is finally defined by its structure and function, which can be physical and/or cognitive. For example, the human heart has a specific structure that allows it to pump blood (its main function). Automation engineers speak of Cyber-Physical Systems (CPS), combining cognitive capabilities with physical systems, while computer scientists have developed the Internet of Things (IoT), where some soft-

2. A system is generally defined as “a combination of interacting systemic elements, organised to achieve one or more stated objectives”. Editor’s translation from ISO/IEC JTC 1/SC 7 Software and systems engineering, “[Systems and software engineering – System life cycle processes](#),” ISO/IEC 15288 (2015).

3. Editor’s translation: J. L. Le Moigne, *La modélisation des systèmes complexes* (Paris: Dunod, 1990).

4. Editor’s translation: J. de Rosnay, *Le Macroscopie, vers une vision globale* (Paris: Seuil – Points Essais, 1977).

ware is complemented by physical capabilities (e.g., sensors).⁵ It should be noted that the concepts of CPS and IoT can lead to very similar systems in practice.

(1b) ... contain important automation and autonomy functions.

To better understand sociotechnical systems,⁶ we need to define⁷ the concept of “cognitive function”.⁸ It should be noted that humans have cognitive functions that are described as natural, just as digitized machines can also have artificial cognitive functions. Cognitive functions can be categorized in relation to Rasmussen’s model of human behavior⁹ to better interpret the emergence of engineering disciplines that contribute to machine automation (Figure 2). We started using this model when the piloting of airliners changed from three to two crew members in the cockpits in the early 1980’s. At that time, the aim was to replace the flight engineer with new, more automated on-board systems, which the captain and his co-pilot could easily manage. We were already in the presence of cognitive functions of control of physical objects evolving towards cognitive functions of management of increasingly automated systems.

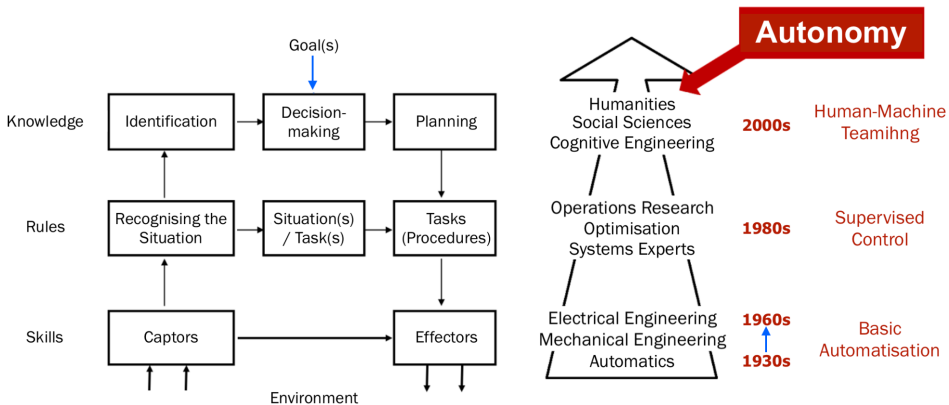


Figure 2: The evolution from automation to autonomy, according to the Rasmussen model

5. With a primary focus on software that is either integrated into hardware or not, AI was conceived from the field of computer sciences. On the contrary, information systems (IS), borne from the engineering field, have focused for quite some time on material and physical elements.

6. A “sociotechnical system” is defined as a system of smaller human and machine systems. It interacts with complex societal infrastructures and human behaviours in various fields, such as healthcare, transport, defence, issues with environmental systems, etc.

7. G. A. Boy, *Cognitive Function Analysis – Volume 2 in the Series: Contemporary Studies in Cognitive Science and Technology Series* (Norwood, NJ: Ablex/Praeger Press, 1998).

8. The representation of cognitive functions is generally defined in two ways: (1) logically, where a cognitive function is considered as an application used by a human agent or machine to transform a task (that which is prescribed to be performed) into an activity (what is actually performed); or (2) purposively, by providing a cognitive function with attributes such as a role, a context of validity, and resources.

9. J. Rasmussen, *Information Processing and Human-Machine Interaction* (Amsterdam: Elsevier, 1986).

In the field of aeronautics, skill-based cognitive functions (*i.e.*, direct sensing-action or stimulus-response inference) were transferred to machines as early as the 1930s in the form of autopilots on commercial airplanes using the electrical and mechanical engineering and control theories that gave rise to automation. This transfer of subconscious sensory-motor cognitive functions is generally referred to as basic automation (*e.g.*, cruise control in today's automobiles). Rule-based cognitive functions were transferred to machines in the 1980s using operations research, optimization, and expert systems. This transfer of conscious cognitive functions is generally called supervisory control (*e.g.*, the flight management system or FMS). Knowledge-based cognitive functions are currently studied in the fields of cognitive engineering, human-centered design, human systems integration, as well as humanities and social sciences. These cognitive problem-solving functions require autonomy capabilities from the agents involved. We speak of a human-automaton team in which humans must deal with highly automated machines offering certain types of autonomy (for example, certain technologies that support problem solving).

Both people and machines can be “automated”. On the one hand, human cognitive functions can be automated either by intensive training and long experience, or by following a procedure (*e.g.*, the pilot's checklist). On the other hand, from an engineering point of view, machine automation consists of developing appropriate algorithms that replace human (*i.e.*, natural) cognitive functions with machine (*i.e.*, software and thus artificial) cognitive functions.

However, these two types of automation can only be operated and used in very specific contexts (*i.e.*, expected situations). Outside these contexts (*i.e.*, in unexpected situations), their rigidity can be the cause of incidents or accidents.^{10 11} Therefore, in these unexpected situations, the people at the helm must solve the problems by themselves, using the physical and/or cognitive resources available, whether they are humans or machines.¹² These actors therefore need flexibility, as well as appropriate knowledge and skills to solve unexpected problems, requiring autonomy, as opposed to following procedures or monitoring the automation of machines based on initial planning.

Let us give here three main classes of cognitive functions that contribute to autonomy: situational awareness (perception, monitoring, mental model and knowledge construction, identification of trends and detection of abnormalities); reasoning and action (mission planning, activity and resource scheduling, task

10. G. A. Boy, “[Dealing with the Unexpected in our Complex Socio-Technical World](#),” *IFAC Proceedings* 46, n°15 (2013): 402-409; and G. A. Boy, “Dealing with the Unexpected,” in P. Milot (ed), *Risk Management in Life-Critical Systems* (London: ISTE Ltd., 2014 and Hoboken, NJ: John Wiley & Sons, Inc., 2014).

11. M. R. Endsley, “Situation Awareness in Future Autonomous Vehicles: Beware of the Unexpected,” in *Proceedings of the 20th Congress of the International Ergonomics Association (IEA 2018), 26-30 August 2018*, (Florence: Springer International Publishing, 2019): DOI: 10.1007/978-3-319-96071-5_32.

12. G. A. Boy, [Design for Flexibility: A Human Systems Integration Approach](#) (Cham: Springer, 2021).

execution and control, fault diagnosis, crisis management, learning and adaptation); interaction and collaboration (shared knowledge and understanding, prediction of behavior and intentions, task and goal negotiation, construction of operational trust). When it comes to machine agents, these cognitive functions must be built, verified, and validated by a series of tests based on “humans-in-the-loop” simulations, which gives rise to systemic issues of designing specific architectures.

Resources that are useful and usable for problem solving, especially in unexpected situations, are called “FlexTech”. FlexTech resources are used to help human operators become more autonomous and allow them to move easily from rigid automation to flexible autonomy. Operational flexibility is achieved when each agent in a problem-solving situation, such as an unexpected event, finds effective help from one or more of its human and/or machine partners. For example, a FlexTech resource is the “undo” function used in word processing to delete a misspelled word, thus providing some flexibility to writers in their typing tasks. This function is very different from that of an automated lexical and/or syntactic text checker, which automatically changes sentences as you type. Automation replaces, while FlexTech supports, human activity.¹³ In practice, human operators using automated machines tend to become complacent, especially when the automation works perfectly, in the contexts in which it has been validated.

In the case of the mailman, the cognitive function, “delivering letters,” can be automated to different levels of automation. For example, the mailman’s bicycle can be replaced by an automobile – note that we see here how physical and cognitive functions can be articulated. e-mail represents a much higher level of automation, where postal workers are radically replaced by computers, software, and information networks. e-mail uses also assume that the different human agents involved have appropriate tools equipped with appropriate physical and cognitive functions, defined in specific contexts of validity (*e.g.*, a power supply and well-functioning servers, together with an appropriate user interface).

Autonomy is a property that gives a human or a machine sufficient robustness to function without external intervention or supervision. In the case of a human being, certain automated machines allow us to be more autonomous and, more generally, endow us with functions that we do not naturally have. Two examples can be cited: exoskeleton systems can offer more autonomy to handicapped people; and as already mentioned in the introduction, the airplane allows us to fly, whereas the human being is not naturally capable of flying. In the case of a machine, their autonomy is necessary when a system must make a critical decision, in terms of time and/or life, that cannot wait for external support. This is especially true in the management of a remote system; the

13. M. R. Endsley, “Autonomous Horizons: System Autonomy in the Air Force – A Path to the Future,” *Human-Autonomy Teaming*, Technical Report AF/ST TR 15-01 (2015); DOI: 10.13140/RG.2.1.1164.2003.

system must then be equipped with rich on-board data and decision-making systems.¹⁴ For example, NASA's Curiosity and Perseverance rovers can move autonomously from one point to another on the planet Mars using stereo vision and on-board path planning. This type of autonomy is limited, leaving NASA teams with the ability to modify the robot's trajectory, perform context-sensitive activities, and other unexpected problem-solving activities, for example. In both cases, autonomy requires a clear systemic definition of what we mean by a human or a machine (Figure 1).

(2) The development of AI puts the place of these functions in a new light and raises the question of trust and collaboration.

The combination of artificial intelligence (AI)^{15 16} and systems engineering (SE)^{17 18} has developed recently because digital engineering has been growing rapidly since the beginning of the 21st century, immersing engineering design in software and promoting Industry 4.0 (mainly based on 3D printing). In the last decade, AI has grown even faster.

The development of AI-based defense systems contributes to the generation of new and emerging human roles and functions that need to be more precisely identified. More specifically, safer, more efficient, and more comfortable Human Autonomy Teaming (HAT) integration requires a better understanding of emerging human factors such as situation awareness, decision making and risk taking. In addition, the trust-collaboration-performance triptych needs to be better articulated and measurable.

Trust

Trust is a very rich subject that has been explored in many fields, such as psychology, sociology, human factors, philosophy, economics, and political science. Trust is intimately related to cooperation and collaboration. In this paper, we focus on a systemic and organizational (*i.e.*, multi-agent)¹⁹ view of trust and

14. T. Fong, "[Autonomous Systems](#)," *NASA Capability Overview*, 24 August 2018.

15. AI refers to systems that exhibit intelligent behaviour that analyse and respond to their environment with some degree of autonomy to achieve specific goals. AI-based systems can be purely software and function in the virtual world (*e.g.* voice assistants, image analysis software, search engines, speech and face recognition systems) or embedded in hardware devices (*e.g.* advanced robots, semi-autonomous cars, drones, or Internet of Things applications).

16. The European Commission's High-Level Expert Group on Artificial Intelligence, [A Definition of AI: Main Capabilities and Scientific Disciplines](#) (Brussels: European Commission, 18 December 2018).

17. INCOSE – International Council on Systems Engineering, "[Systems Engineering](#)," *INCOSE – International Council on Systems Engineering*, Accessed on 26 January 2022.

18. INCOSE and Vision 35, "[Engineering Solutions for a Better World](#)," in *Systems Engineering Vision 2035* (San Diego, CA: INCOSE, 2021). Systems are expected to be more socially acceptable, considering their impact on society and the environment. They are thus more self-sufficient, ultimately allowing them to seamlessly interact, understand, and respond to requests.

19. R. C. Mayer and al., "[An Integrative Model of Organizational Trust](#)," *The Academy of Management Review* 20, no. 3 (1995): 709-734.

collaboration.²⁰ According to French and his colleagues,²¹ the interest in trust most often appears in situations of uncertainty and vulnerability. Trust is necessary when there is a risk that one may not be able to accomplish the task at hand.²² It is therefore essential in the partnership between humans and machines with autonomous capabilities. This need is even more acute in systems that are constantly evolving. Therefore, the explainability of the output data provided by AI systems deserves special attention.

David Atkinson²³ has postulated that “the trust we place in automation today is based on trust gained over many years of developing highly reliable and complex systems”.²⁴ This means that trust in complex systems is based on familiarity. Familiarity can take time. The more familiar one becomes with a complex socio-technical system, the more one knows how to use it, the more one can trust or distrust it.²⁵ Human-in-the-loop simulations²⁶ are very effective in speeding up this process.^{27 28} The people involved in these simulations are the ones who are most likely to have the most trust in the system. Individuals participating in these simulations are likely to develop appropriate strategies in response to events.

Trust depends on stable interaction between agents, minimal conflict resolution between them, and predictability of interactions. Trust is a matter of control. Operators trust a system when they understand who (*e.g.*, the pilot) or what (*e.g.*, the virtual assistant) is in control.

Finally, trust is a question of system reliability. Operators tend to distrust a system when they experience too many inconveniences while using it, and con-

20. C. Castelfranchi and R. Falcone, “[Trust Is Much More than Subjective Probability: Mental Components and Sources of Trust](#),” in *Proceedings of the 33rd Hawaii International Conference on System Sciences, Maui, HI, 4-7 January 2000*, 1-10, (Washington, DC: Institute of Electrical and Electronics Engineers, Inc.): DOI: 10.1109/HICSS.2000.926815.

21. B. French and al., “[Trust in Automation – A Literature Review](#),” *CSIRO Report EP184082*, 2018.

22. R. Hardin, *Trust* (Cambridge: Polity Press, 2006).

23. D. Atkinson, a former research director at JPL-Caltech, is one of the leading scientists who have worked on trust in human-machine systems, where machines are increasingly autonomous.

24. D. Atkinson, “[Human-Machine Trust](#),” in *Workshop on Human-Machine Trust for Robust Autonomous Systems, Ocala, FL, 31 January-2 February 2012* (Pensacola, FL: Florida Institute for Human and Machine Cognition, 2012).

25. E. Salas and al., “[On Teams, Teamwork, and Team Performance: Discoveries and Developments](#),” *Human Factors* 50, no. 3 (June 2008): 540-547.

26. Human-in-the-loop modelling and simulation tools lead to digital twin concepts and tools enabling a virtual representation of the span of an object or system’s life cycle (from its conception to obsolescence). This concept of digital twin is currently being developed in several fields, including the operational maintenance of helicopter engines and remote oil rig operations. In these two cases of applications, simulations are implemented, while machine learning and reasoning systems are used to facilitate decision-making.

27. Q. Lorente and al., “[Development of a digital twin for collaborative decision-making, based on a multi-agent system: application to prescriptive maintenance](#),” *INCOSE International Symposium* 32, (2022): 109-117.

28. S. C. D. Pinto and al., “[From Requirements to Prototyping: Application of Human-System Integration Methodology to Digital Twin Design](#),” in *International Conference On Engineering Design (ICED21), Gothenburg, 16-20 August 2021* (HAL-Inria) 1617-1626.

versely, to trust it when it very often offers satisfactory results. This is a general rule that confirms or refutes reputation (systems can be rated on their successes and failures – in the same way that many web systems are rated by communities of people). When people make too many (identical) mistakes, they tend to get frustrated with the system. This may be due to their level of mastery of the system, or to the quality of the system itself.

This relationship between trust and trustworthiness encourages research efforts on issues of tangibility.²⁹ physical tangibility (*i.e.*, the ability to grasp physical objects); and figurative tangibility (*i.e.*, the ability to grasp abstractions and concepts). Specifically, the US Air Force studied trust in a human-robot team and emphasized the need for both independent and interdependent decision making in dynamic, high-risk environments.³⁰ In short, trust is about: the ability of a team to make decisions; the ability of a team to make decisions; and the ability of a team to make decisions. In short, trust is about: competence (including perception, understanding, and projection for decision making/action); predictability and transparency; reputation (stable signals and behaviors); and reliability (anticipating, guiding, enabling teamwork).

Cooperation and collaboration

In the multi-agent context of a future air combat system, cooperation and collaboration are equally important parameters to consider. In cooperation, the objective of each agent is the same, but their interests are individual. In collaboration, on the other hand, the operators come together around a common interest and goal. In an orchestra, for example, the musicians collaborate to play a symphony. They are coordinated by scores, which have been previously written by a composer.³¹ Collaboration between humans and increasingly autonomous systems, as teammates, in uncertain dynamic environments, consists of highly interdependent activities. On both the human and machine sides, training for collaboration is a key issue.³²

29. G. A. Boy, *Tangible Interactive Systems: Grasping the Real World with Computers* (Cham: Springer, 2016): DOI: 10.1007/978-3-319-30270-6.

30. K. Schaefer and al., “Trust in Human-Autonomy Teaming: A Review of Trust Research from the US Army Research Laboratory Robotics Collaborative Technology Alliance,” in Chen J. (ed), *Advances in Human Factors in Robots and Unmanned Systems* (Cham: Springer International Publishing, 2019): 102–114, DOI: 10.1007/978-3-319-94346-6_10.

31. G. A. Boy, *Orchestrating Human-Centered Design* (London: Springer-Verlag, 2013).

32. J. E. Driskell and E. Salas, “[Collective Behavior and Team Performance](#),” *Human Factors* 34, no. 3 (June 1992): 277-288. The experiments conducted by these authors showed that members of a collectively-oriented team are more likely to pay attention to the inputs of other team members and improve their performance during team interaction than egocentric members. This can also be applied to the collaboration between pilots and virtual assistants. In this case, the question arises as to the type of training that should be developed to adapt to these new “employees”. Moreover, one may question whether the virtual assistant is an egocentric one or not? In this case, the type of machine learning that should be implemented must also be determined.

Salas, Cooke, and Rosen³³ have worked on this point and emphasized the importance of certain processes. These include the need for measurement of shared cognition, advances in team building, the use of synthetic task environments for research, the need for a multidisciplinary perspective, and technological training or interventions to improve team effectiveness.³⁴ It is also critical to identify appropriate FlexTech resources that can enhance shared cognition.

Some principles can also be suggested. Rephrasing what Klein and his colleagues³⁵ have already produced in the field of human-robot interaction, here are some very relevant concepts for Human Autonomy Teaming: the more adaptable, the less predictable; collaboration should be based on the SADMAT model (*i.e.*, Situation Awareness [SA]-Decision Making [DM]-Action Taking [AT], developed in the MOHICAN project (DGAPEA-MMT-2020); attention management should be context-dependent, based on a shared understanding.

Finally, to better understand and control the machine as a partner, it will be useful to consider three types of systemic interaction models (SIMs):³⁶ (SIM 1) supervision; (SIM 2) mediation; and (SIM 3) cooperation through mutual understanding³⁷. SIM 3 is about intersubjectivity, where an agent can build a model of its environment to interact with it in a safe, efficient, and comfortable way. Such a model includes a learning function, which consists of working together sufficiently to ensure that the teamwork considers the identity of the other partner. Intersubjectivity is indeed a question of human maturity (maturity of the practices involved) defined by Human Readiness Levels (HRLs),^{38 39} of technological maturity measured by Technology Readiness Levels (TRLs), and of organizational (or societal) maturity characterized by organizational readiness levels (ORL or Organizational Readiness Levels),⁴⁰ which will be integrated into a TOP [Technologies, Organizations and People] model).⁴¹

33. E. Salas and al., "On Teams, Teamwork, and Team Performance," *art. cit.*

34. Some challenges for the next few decades include the increased emphasis on team cognition, reconfigurable and adaptive teams, multicultural influences, and the need for naturalistic study and better means of measurement.

35. G. Klien and al., "Ten challenges for making automation a 'team player' in joint human-agent activity," *IEEE Intelligent Systems* 19, no. 6 (Nov.-Dec. 2004): 91-95, DOI: 10.1109/MIS.2004.74.

36. G. A. Boy, *Human Systems Integration: From Virtual to Tangible* (Boca Raton, FL: Taylor & Francis Press, 2020).

37. SIM models have often been used in the deployment of cognitive function analysis (CFA), particularly in civil aeronautics and space.

38. M. R. Endsley, "[Human Readiness Levels: Linking S&T to Acquisition...and beyond](#)," in *National Defense Industrial Association Human Systems Conference, Alexandria, VA, 10-11 February 2015* (Arlington, VA: National Defense Industrial Association, 2015).

39. G. Salazar and al., "[Understanding Human Readiness Levels](#)," *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* 64, no. 1 (December 2020): 1765-1769.

40. G. A. Boy, "[Socioergonomics: A few clarifications on the Technology-Organizations-People Tryptic](#)," in *Proceedings of INCOSE Human Systems Integration Conference 2021, San Diego, CA, 17-19 November 2021* (HAL-Inria).

41. G. A. Boy, *Orchestrating Human-Centered Design* (Berlin: Springer, 2013).

(3a) Faced with new challenges, ...

Many research challenges await researchers to achieve satisfactory forms of human-machine partnership. Here are some of them in the field of Human Autonomy⁴² Teaming in particular:

- what kind of conceptual models of human-machine teams should be developed and validated; how can collective trust be appropriately built, calibrated, and exploited to establish the roles of each agent and the proper sharing of authority (who is in charge?); in aerial combat, for example, collaboration between humans and machines should be based on the same principles as in the field of human-machine interaction. In aerial combat, for example, collaboration between humans and machines should be done at the right level of granularity⁴³ and move away from the idea that a machine endowed with artificial intelligence could be autonomous;⁴⁴ from an ethical point of view, can a machine be left to decide alone on certain lethal actions?
- How can a system of systems maintain continuity of operations in unexpected, uncertain, unforeseen, and unpredictable situations-continuity is intimately linked to resilience;⁴⁵ if, for example, the overall socio-technical system is partially or totally destroyed, how can its constituents remain able to carry out their own mission autonomously, when each system in the overall system has its own *raison d'être* and may be dependent, independent, or interdependent on the others;⁴⁶
- how to measure and leverage the performance of the human-machine team to continuously improve system performance; and how to certify human-machine concepts and systems in partnership?

These challenges are incentives for ongoing and future research. Human systems integration (HSI) of an air combat system can be viewed from two coordi-

42. J. B. Holbrook and al., "[Enabling Urban Air Mobility: Human-Autonomy Teaming Research Challenges and Recommendations](#)," in *ALAA Aviation Forum, Virtual, 15-19 June 2020* (Mountain View, CA: NASA AMES Research Center, 2020). A NASA Civil Aviation Committee recently reviewed the existing research on Human Autonomy Teaming (HAT), identified stakeholder community objectives, reviewed relevant operating concepts, and defined a framework for establishing a coordinated, comprehensive, and prioritised research plan that would enable future market applications of aviation. This review effort is intended to provide policy makers, engineers, and researchers with useful guidelines for directing and coordinating HAT research efforts.

43. The right level of granularity can only be determined by a team of experts faced with the current situation. This is the reason why this requires human-in-the-loop simulations.

44. J. M. Bradshaw and al., "[Teamwork-Centered Autonomy for Extended Human-Agent Interaction in Space Applications](#)," in *2004 AAAI Spring Symposium, Palo Alto, CA, 22-24 March 2004* (Palo Alto, CA: Association for the Advancement of Artificial Intelligence, 2004).

45. Once again, it is through modelling and human-in-the-loop simulations that the construction of SoS can be done, especially the attention paid towards the separability of systems. Separability is a fundamental property of complex (living) systems.

46. D. D. Woods and D. L. Alderson, "Progress toward Resilient Infrastructures: Are we falling behind the pace of events and changing threats?," *Journal of Critical Infrastructure Policy* 2, no. 2 (Fall/Winter 2021): 5-18, DOI: 10.18278/jcip.2.2.2.

nated perspectives to ensure overall consistency, interoperability, and appropriate sharing of authority. The first is to focus on the fighter pilot to improve his or her working environment (*e.g.*, cockpit design for UAV or remote-carrier management). The second is to focus on the C2 to improve the operation of the combat cloud. Such an approach can only be properly implemented by developing human-in-the-loop scenarios and simulations that allow for the step-by-step discovery of emergent functions and structures of the systems involved. Although there are solid theoretical leads, everything remains to be built in practice in this field.

On the notion of emergence, we have worked on the navigation system of the NASA piloted lunar rover. This system, called “Virtual Camera,”⁴⁷ allows us not only to orient ourselves on sectors that have already been catalogued, as we are used to doing by following the instructions of a GPS in our vehicle, but also to discover unknown sectors. They are progressively filled in using sensors and incorporating new geographical and geological data into the initial database.⁴⁸ This system has been extended to the onboard weather awareness system for civil transport aircraft, the OWSAS.⁴⁹

We are currently working on advanced visualization techniques and tools to increase physical and representational tangibility.⁵⁰ Human-in-the-loop simulations require the development of digital systems representing the sociotechnical system under consideration, which are now called digital twins. Several versions of the future combat cloud could be designed, compared virtually and progressively “tangibilized” to promote the distribution of the right information that is easily understood, at the right time, and in the right place.

Finally, we need to continue to analyze and better understand the issues of trust and collaboration, never forgetting that any socio-technical system evolves over time. Its functions and structures can be modified, removed and/or added as experience is gained, needs change and operational risks arise. For this reason, the flexibility of the corresponding system of systems must be a constant concern.

(3b) ... an empirical approach is essential to succeed.

Future AI-based systems must be developed with the appropriate HSI metrics, methods, and evaluation tools. HSI favors Scenario-Based Design (SBD) to ground proposed solutions. This type of design requires the participation of

47. G. A. Boy and al., “[The Virtual Camera Concept: A Third Person View](#),” in Salvendy, G. and W. Karwowski (eds), *Advances in Cognitive Ergonomics – First Edition* (Boca Raton, FL: CRC Press, 2010).

48. D. Platt and al., “[Design and Evaluation of an Exploration Assistant for Human Deep Space Risk Mitigation](#),” *IFAC Proceedings Volumes* 46, issue 15 (2013): 373-380.

49. G. A. Boy and S. Boulnois, “[Onboard Weather Situation Awareness System: A human-systems integration approach](#),” in *HCI-Aero '16: International Conference on Human-Computer Interaction in Aerospace 2016, Paris 14-16 September 2016* (New York, NY: Association for Computing Machinery, 2016).

50. G. A. Boy, *Design for Flexibility* (London: Springer, 2021).

business experts, such as fighter pilots or air traffic controllers. The PRODEC method⁵¹ has been developed to promote the acquisition of knowledge by subject matter experts, the design of scenarios and human-in-the-loop simulations, and the discovery of certain emergent properties of the socio-technical system from the interactions between the different agents. PRODEC has been used in the framework of the DGA MOHICAN project.^{52 53}

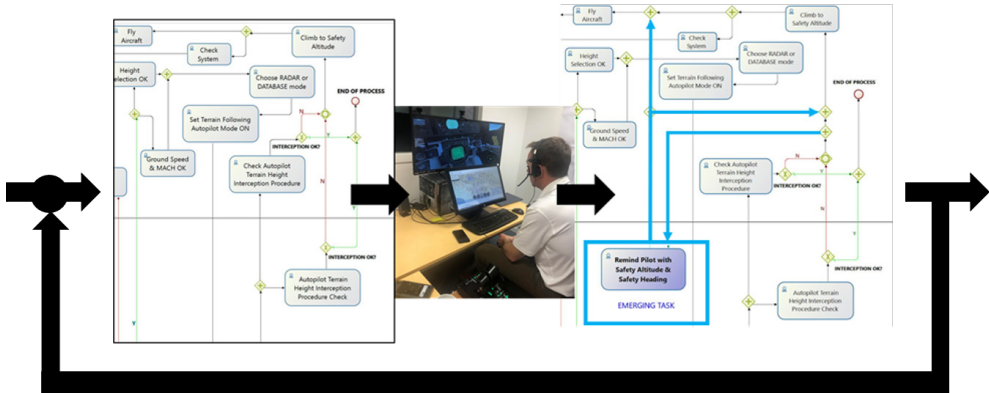


Figure 3: An example of a task (left) and its activity (right) analysed using BPMN graphs,⁵⁴ including the identification of their emergent properties (in blue on the activity side)

The PRODEC cycle (Figure 3) can be described as follows: (Step-1) initial task analysis; (Step-2) clarification of emergent functions and structures; (Step-3) implementation of the prototype using the declarative representation presented in Figure 4; (Step-4) human-in-the-loop simulation; (Step-5) observation and analysis of activity for clarification of emergent properties; (Step-6) modification of the previous task analysis; and (Step-7) for further refinement, return to Step-2. The task analysis (*i.e.*, the development of procedural scenarios in Steps 1 and 6) allows for the implementation of scenarios that guide the development of prototypes to test new system configurations, but also progressively make explicit emergent properties and the step-by-step modification of the task analysis.

This approach of human-systems integration with increasing autonomy, as well as the PRODEC method, are developed within the FlexTech Chair (located at CentraleSupélec-University of Paris Saclay and ESTIA) to which the Air and Space Force is associated.

51. The PRODEC method can facilitate the analysis, design, and evaluation of complex sociotechnical systems. The knowledge obtained from experts in the field is translated into procedural scenarios (the “PRO” part of the PRODEC method is short for “procedural”), which can then be represented as directed graphs (*e.g.* tasks involved in the description of a mission or of a job to be done).

52. To be released in G. A. Boy and al., “[Human Systems Integration of Increasingly Autonomous Systems using PRODEC Methodology](#),” *FlexTech Chair*.

53. Immense gratitude is expressed to the team at Synapse Defense, which has greatly contributed to the PRODEC method’s applicability during the MOHICAN project.

54. L. Fischer (ed), *BPMN 2.0 Handbook – Second Edition: Methods, Concepts, Case Studies and Standards in Business Process Modeling Notation (BPMN)* (Lighthouse Point, FL: Future Strategies Inc., 2012).

Drones and Their Pilots

Technology and Social Hierarchies within the French Air and Space Force

Vicky Karyoti

Karyoti is the Transatlantic SFP Scholar research fellow at the Swedish Institute of International Affairs. She holds a PhD in Political Science from the University of Southern Denmark (SDU), a MSc in International Security & Law from SDU and a BA in International and European Studies from Panteion University in Athens. Her research interests include emerging and new technologies, military professionalism, security, sociology, and alliances.

Technological developments have always been an integral part of warfare.¹ Either to solve problems of a military nature or to achieve and maximize military effectiveness by adopting a civilian artifact, warfare has walked a parallel path with technology. Each stage of its development has reflected the available technology at the time, human inventiveness, and the societal context of the respective time period.² Indeed, technological developments change not only the conduct of warfare, but society itself. Here lies a question of primacy, and whether technology is the primary factor behind social change. The latter idea is known as technological determinism – a position regarding the ontological precedence of technology and science over social change – that presupposes technology as

1. A. Krishnan, "Automating War: The Need for Regulation," *Contemporary Security Policy* 30, no. 1 (2009): 172-193, DOI: 10.1080/13523260902760397; Hew Strachan, *The Direction of War: Contemporary Strategy in Historical Perspective* (Cambridge: Cambridge University Press, 2013), DOI: 10.1017/CBO9781107256514; C. Coker, "Post-modern war," *The RUSI Journal* 143, no. 3 (1998): 7-14, DOI: 10.1080/03071849808446260; C. Coker, "[Artificial Intelligence and the Future of War](#)," *Scandinavian Journal of Military Studies* 2, no. 1 (2019): 55-60; A. Bousquet, "A revolution in military affairs? Changing technologies and changing practices of warfare," in McCarthy, Daniel R. (ed) *Technology and World Politics: An Introduction* (Abingdon, OX: Routledge, 2017), DOI: 10.4324/9781317353836-9; M. van Creveld, *Technology and War: From 2000 B.C. to the Present* (New York, NY: The Free Press, 1989).

2. P. E. Fontenoy, *Submarines: An Illustrated History of Their Impact* (Santa Barbara, CA: ABC-CLIO, 2007).

being a greater determinant of social change than other factors.³ In this view, new and emerging technologies would replace old ones, driving social change forward with an improved efficacy.

This article discusses the significance of the French Air and Space Force (FASF)'s acceptance of drones. It examines in particular the process in which drones were incorporated by the Forces' military professionals. The focus is therefore a cultural and organizational one that aims to discern how newly introduced technology impacts a professional entity, namely a military organization. Specifically, this article will question how the introduction of drones has impacted the internal social structure, cohesion, and culture of FASF. Indeed, much can be learned from the possible aftermath of such processes on airpower's effectiveness and future. Moreover, the French 2022 presidency of the European Union (EU) Council is shaping new developments in Europe. As a result, the future of European airpower security has been brought to the forefront of strategic and academic discussions. Hence, today's timely circumstances render it imperative to discuss, more than ever, how emerging – and potentially disruptive – technologies can impact airpower.

The History and Significance of Drones

Scientifically speaking, drones are not considered as a new technology, even for twentieth century standards. Having first appeared in 1918, drones are hailed as one of the first efforts towards airpower autonomy.⁴ Yet, surprisingly, they did not factor into airpower and operations as they are understood today until the century's end. Instead, drones were presented – scientific and technological progress aside – as a solution to the information and reconnaissance area of operations, which had become central to warfare during the 1990s.⁵ They were used in ways to support other operational platforms by providing more precise, detailed, and up-to-speed data without the need to expend soldiers and expensive equipment. In short, drones provided speed, accuracy, agility, and protection, while being relatively cost-effective.

Furthermore, drones reduced the risk of casualties as fewer soldiers were needed to be present in areas of operations. This contribution became invaluable when the world heralded a “post-heroic” society – a term used by several writers to describe mostly Western societies, especially those of states involved in operations overseas.⁶ According to said authors, the absence of the existential-threat

3. M. Roe Smith and L. Marx (eds) *Does Technology Drive History? The Dilemma of Technological Determinism* (Cambridge, MA: The MIT Press, 1994).

4. T. P. Schultz, *The Problem with Pilots: How Physicians, Engineers, and Airpower Enthusiasts Redefined Flight* (Baltimore, MD: Johns Hopkins University Press, 2018).

5. W. Phelps, *On Killing Remotely: The Psychology of Killing with Drones* (New York, NY: Little, Brown, 2021).

6. M. Hasian Jr., *Drone Warfare and Lawfare in a Post-Heroic Age* (Tuscaloosa, AL: University of Alabama Press, 2016).

element of operations (such as the ones in Afghanistan, Iraq, Syria and others), paired with the prevalence of social media in providing images of soldiers killed or injured in such operations, have shifted the public opinion towards a significantly lower tolerance for human casualties and suffering.

A great milestone in the history of drones is the use of the armed drones, including its subsequent deployment for lethal engagement with targets. Indeed, such a characteristic was technically and theoretically possible well before this point; however, the practice of using armed drones is only attributed to the 9/11 attacks and their proceeding responses by the United States and its Allies.⁷ This gave rise to countless ethical, legal, operational, and political debates, which nonetheless did not effectively stop the use of armed drones.⁸ On the contrary, it was the catalyst for a completely new market dedicated to surveillance experts, new recruitments, training, and facilities. It also gave birth, of course, to a completely new body of military professionals, assigned to operate drones in various roles. It is precisely regarding these new roles and individuals that this article explores the cultural and organizational challenges evoked.

The French Air and Space Force

Such challenges occur because of existing rules, practices, and underlying assumptions within FASF's culture. Due to where it stands in the context of European airpower, the case of the French Air Force (FAF) cannot be avoided in a discussion on an air forces' integration of drone use. Despite being a key NATO ally today, France has historically been known to develop its own military capabilities instead of relying on alliances and partners. However it developed its own drones much later than others, ascribing the delay to the reluctance of its domestic aircraft industry in expending resources towards this new technology, preferring instead to continue with its "big, legacy platforms".⁹

Additionally, France was also late to arm their drones. It was only in 2017 when the French government announced that some French surveillance drones were to be armed. According to the French Minister of the Armed Forces, Florence Parly, the first drone to be armed would be the MQ-9 *Reaper* drone of

7. V. Karyoti, "[9/11's legacy of drone warfare has changed how we view the military](#)," *The Conversation*, 7 September 2021.

8. C. Kennedy and J. I. Rogers, "Virtuous drones?," *The International Journal of Human Rights* 19, no. 2 (2015): 211-227, DOI: 10.1080/13642987.2014.991217; W. Chappelle and al., "Combat and Operational Risk Factors for Post-Traumatic Stress Disorder Symptom Criteria Among United States Air Force Remotely Piloted Aircraft "Drone" Warfighters," *Journal of Anxiety Disorders* 62 (2019), DOI: 10.1016/j.janxdis.2019.01.003; A. M. Johnson and S. Axinn, "The Morality of Autonomous Robots," *Journal of Military Ethics* 12, no. 2 (2013): 129-141, DOI: 10.1080/15027570.2013.818399; D. Whetham, "Drones to protect," *The International Journal of Human Rights* 19, no. 2 (2015): 199-210, DOI: 10.1080/13642987.2014.991215; D. R. Brunstetter, "[Can We Wage a Just Drone War?](#)," *The Atlantic*, 19 July 2012.

9. Cour des comptes, "[Les Drones Militaires Aériens : Une Rupture Stratégique Mal Conduite](#)," *Rapport public annuel 2020* (February 2020); J.-B. Jeangène Vilmer, "[The French Turn to Armed Drones](#)," *War on the Rocks*, 22 September 2017.

the medium-altitude, long-endurance (MALE) categorization for the *Escadron de drones*¹⁰ (ED) 1/33 Belfort. Neither the type of ammunition nor a timeframe for the arming process had been specified, but it was nonetheless completed by 2019, as evident by the first French armed drone strike carried out in Mali of that year.¹¹ In 2021, the French government signed for the acquisition of an additional *Reaper* drone of the high-altitude, long-endurance (HALE) variety.

Today, FAF has two operational drone squadrons: the ED 1/33 Belfort based in Cognac, France (originally named *Escadron d'expérimentation drone*¹² 1/33 Adour), and the *Escadron de reconnaissance*¹³ 2/33 Savoie, (traditionally a *Mirage* F1 squadron). For this article, pilots from various squadrons and types of aircraft, including fighter pilots, drone pilots, and helicopter pilots were interviewed. Such diversity is the reason for which this article is able to study FAF and its culture holistically with a rich and nuanced understanding of the said culture and individuals within it. The choice to focus on FAF's culture becomes obvious when one considers that throughout the world, the air force branch of each nation's armed forces has been the branch primarily responsible for the utilization of aircraft and the achievement of superior airpower. That does not mean that services within other branches, such as the Navy, do not have a history of utilizing the aircraft. Rather, it is because this separately dedicated tradition towards air force primacy has carried a different significance on the creation, development, and life of FAF's culture.

Indeed, the impact on the history and nature of military aviation is clear. When a branch's entire purpose and objective is the utilization of aircraft, the identity and culture of the branch itself becomes built upon the function of flying the aircraft.¹⁴ For many decades, this was translated into the physical presence of the pilot who controls the aircraft. Even in cases of an entire crew manning an aircraft – as it is the case for bomber aircraft, it is nevertheless the individual piloting the aircraft, who remains as the key professional element of an aviation enterprise.¹⁵ In addition, many pilots understand the main function of FAF is combat. This, in turn, further narrows down FAF's central identity to the specific branch that performs air combat operations. Other tasks, such as transportation, ISR, and general support, are therefore seen as auxiliary to the primary task of combat.

10. Editor's translation: 1/33 Belfort Drone Squadron.

11. "[France Carries out First Armed Drone Strike in Mali](#)," *France 24*, 24 December 2019.

12. Editor's translation: Drone Experimentation Squadron.

13. Editor's translation: Reconnaissance Squadron.

14. T. P. Schultz, *The Problem with Pilots* (Baltimore: Johns Hopkins University Press, 2018); W. Phelps, *On Killing Remotely: The Psychology of Killing with Drones* (Boston: Little, Brown and Company, 2021); Carl H. Builder, *The Icarus Syndrome: The Role of Air Power Theory in the Evolution and Fate of the U.S. Air Force* (New York: NY Routledge, 1994).

15. L. Calhoun, "The End of Military Virtue," *Peace Review* 23, no. 3 (2011): 377-386, DOI: 10.1080/10402659.2011.596085.

This primacy of certain technology – and the tasks which are dedicated to its functioning – creates a type of internal social hierarchy within the air force branch as a professional group. That social hierarchy reflects the internal configuration of said professional group, which is then divided into smaller subgroups. Each of these consist of various tasks (*i.e.* pilots, engineers, members of administration etc.), attributes of tasks (*i.e.* fighter pilot, helicopter pilot, drone pilot etc.), as well as the various units within FAF (such as the various squadrons). Essentially, these different tasks and formations have their own subculture and identity, which are formed through history, tradition, and evolution, and constantly driven by FAF's mission and the individuals' sense of duty and professionalism.

The Status of Professions

A service's social hierarchy is created through the distribution of status among the tasks and units in a professional group. Indeed, some tasks hold more weight in status than others, as they are seen as primary and others as auxiliary or supportive.¹⁶ "Primary" tasks are thus the ones that embody or closely approximate the most "ideal" or "iconic" duties of the professional group – in other words, the responsibilities for which the professional group is most known. The individuals responsible for these primary, "iconic" tasks enjoy higher status both within the professional group and beyond in the encircling society. As a result, they become the most sought-after tasks that individuals aspire to perform when they enter a professional military group.

According to the "Sociology of Professions", the prestigious position of certain professionals is due to the historical primacy of professions over other occupations. The military profession belongs in the same occupational category as medicine, clergy, and law, which are given more significance within a society than others.¹⁷ According to certain scholars, the various reasons are due to expertise, specialized knowledge, unique mandates, social responsibility, and relationship with the state.¹⁸ Regarding expertise and specialized knowledge, individuals within these professions are obligated to acquire training and education at the highest level in order to perform their tasks. Such expertise is esoteric in a sense as it is not only a prerequisite for the entry and membership into the profession, but also its performance at the highest standards. These expectations are hence imposed by the profession's structure itself, and remain vital for the performance of specific tasks.

Such is directly connected to the second-most important characteristic of professions: they have a unique mandate to perform tasks, which are forbidden to non-members of the profession. Military professionals are required to kill and

16. E. C. Hughes, *Men and Their Work* (Glencoe, IL: The Free Press, 1958).

17. A. Cribb and S. Gewirtz, *Professionalism* (Cambridge: Polity Press, 2015).

18. S. P. Huntington, *The Soldier and the State: The Theory and Politics of Civil-Military Relations* (Cambridge: Harvard University Press, 1957); M. Janowitz, *The Professional Soldier: A Social and Political Portrait* (Glencoe, IL: The Free Press, 1960).

be killed as a baseline for their duties. Likewise, lawyers are the sole individuals who can defend others in a court of law, while only judges may adjudicate in these courts; doctors are the sole individuals who can operate on others and make medical decisions, while only priests may perform clerical duties on the masses. Indeed, professionals have a special relationship both with the society within which they operate, and the state which has mandated their duties. Professions have a relationship of responsibility and accountability to society, their mandate is both a freedom and a check. Additionally, professions operate with a very strict relationship with the state, especially the military profession, which in modern societies is an integral part of the state structure. The state regulates the extent of the military mandate and enforces the limits of that expertise.

All these reasons contribute to the high status which military professionals enjoy in their societies, as well as the possibility of being subjected to strict scrutiny by said societies. This high status is mirrored at a micro-level within the military profession as well as its internal configurations, depending on the aforementioned tasks and their respective perceived primacy. In an air force, this primacy belongs to the fighter pilot. Yet, this is not deterministic: it is not an implication that this is the only career desired by individuals or that other tasks are not prestigious. During the interview process with FASF pilots, while several mentioned that flying the fighter aircraft had been an age-old dream, many others mentioned that it was their own choice to pursue other tasks. Regardless, all talked about the necessity of every individual and their contribution, as well as the indispensable value of each of their colleagues. This multiplicity of personal desires, career choices, of history and tradition, however, does nevertheless create a social hierarchy, which is admitted by all.

New technology can therefore disrupt this social hierarchy and the distribution of status amongst subgroups and individuals. When a new technology is introduced, it can leave resounding effects, depending on certain factors. Unsurprisingly, it will mostly impact subgroups and individuals, whose tasks rely on technology, especially “old” technology. New individuals and new tasks will enter the group, and new subgroups with their own, new cultures will be created. While existing subgroups might resist these new tasks and individuals, they might also accept the new reality as it is: the new does not have to replace the old.

Drone Pilots: Myths and Reality

Indeed, why should drones pose such a problem of cultural and organizational change? What makes drones any different from other new technologies? Finally, why do they have a sociological dimension? This is partly due to the societal ideas and mythology surrounding drones, many of which are often mirrored by professional military groups. For example, a prevalent comparison is likening

the operation of drones to “playing video games”, which is deeply entrenched not just in society but also within the military, specifically in services which employ drones.¹⁹

According to Wayne Phelps, this comparison is very popular for four reasons: the visual make-up of drones – both interior and exterior; the way they are flown; the length and level of training required by the crew; and lastly, the remoteness characteristic of drones. In terms of their appearance, some of the smaller, unarmed drones closely resemble hobby drones and gadgets, available for the public to purchase. On the outside, the ground control station resembles video game controls, with its knobs, dials, and, of course, the famous “joystick”. They were designed precisely as such because military professionals were already acquainted with them from playing video games themselves at their own leisure. Regarding the way they are flown and their remoteness, this is similar to the interior of the ground control station, where crews remain while operating drones. As drone crews do not need to be physically inside the drones, they undergo and control the drone through a live video feed, presented on a computer screen.²⁰ Again, the combination of controls with the computer screen draws a more than expected parallel with video games.

Such a comparison is impactful in the way military professionals view drone pilots, which tends to take on a negative and oftentimes dismissive hue. Of the professionals interviewed, one recounted how his colleague from a manned aircraft squadron was transferred to a drone squadron, where he stayed for two years before returning to his original squadron. The pilot admitted that after experiencing drone operations from the inside and having seen what it is to fly a drone, his opinion of them changed with a higher respect for the drone pilots and crews, changing how this experience was retold:

“... [H]e said there’s a lot of nice things about [drones]. It kind of pushed me a little bit in my reflection when I was saying that I had to choose at the end of my second year of flight commander, and I think it helped me make the right decision because I understood from someone who had the same training as me, with the same background, and the same way we see things. If he told me that it was not that bad and that there were a lot of good sides, then that is what it is.”

Nevertheless, the widespread view of drone pilots is a negative one, which not only perpetuates the differentiated treatment of drone pilots, but also the reigning primacy of pilots of manned aircraft.²¹

Another myth misconceives drone pilots and crews as sitting in their air-conditioned offices of their native territories, able to return home to their fa-

19. J. Campo, “Distance in War: The Experience of MQ-1 and MQ-9 Aircrew,” *Air & Space Power Journal-Spanish* 29, no. 3 (2015): 3-10.

20. W. Phelps, *On Killing Remotely...*, *op. cit.*

21. *Ibidem*; M. W. Byrnes, “[Airpower Revolution on a Razor’s Edge – Part Two of the ‘Nightfall’ Series](#),” *Air and Space Power Journal* 29 (2015): 31-56.

milies at the end of their 9-5: this is only half true and only for certain states and services.²² For instance, the US Air Force does in fact deploy in garrison – the term for deployment “at home” and not overseas – but the US Navy does not.²³ FASF, however, deploys drones forward, which means that drones are being stationed overseas, often in the same facilities as other aircrafts. This presents both advantages and disadvantages.

On the one hand, forward deployment allows for greater connection of drone pilots to their missions, colleagues, and the organization as a whole. It allows for a mental separation and transition between being deployed and being at home, as well as between war and peace.²⁴ It also allows for the development of the mentality within the larger professional group that drone pilots and their crews are contributing to the combat function as much as everyone else.²⁵ Forward deployment can contribute to the creation and perpetuation of common cultures between members of a professional group, but also between subgroups, due to the close interactions carried out under an intense environment. On the other hand, forward deployment places drone pilots and crews in harm’s way as they are deployed in close proximity to the area of operations. While still not in immediate danger compared to pilots and crews of manned aircrafts, drone pilots are still not back on domestic soil. They miss their families and normal life and can experience feelings of isolation and separation.

A significant problem in drone pilots’ recognition as equals among others is that not only do they not resemble the iconic heroes that pilots have always been presented to, but they also stand in opposition to that image as they themselves are not physically present in the aircraft. Indeed, there are two different “benchmarks” that embody the ideal or iconic duties of an air force member, both in the eyes of the public and members of this professional group.

The first “benchmark” criteria that encompasses the “pilot” status is being physically present inside the aircraft. Such a qualification not only applies to fighter pilots, but also transport pilots, helicopter pilots, and bomber pilots. On the contrary, drone pilots do not “make the cut”. Nevertheless, air forces still refer to them as “pilots” because a pilot is defined as the person who is in control of the aircraft, regardless of whether they are physically present onboard.²⁶ This is also why within drone crews, the person responsible for the control of the aircraft – whether as a part of the Launch Recovery Element (LRE) or the Mission Control Element (MCE) – is a pilot, while the sensor operators and the intelligence network are

22. H. Gusterson, “[An American Suicide Bomber?](#),” *Bulletin of the Atomic Scientists*, 20 January 2010.

23. W. Phelps, *On Killing Remotely...*, *op. cit.*

24. G. Chamayou, *Théorie du drone* (Paris: La Fabrique, 2013); Byrnes, “Dark Horizon: Airpower Revolution on a Razor’s Edge,” *Air & Space Power Journal* 29, no. 5 (2015): 31-56.

25. W. Phelps, *On Killing Remotely...*, *op. cit.*; Chaitra M. Hardison and al., *Stress and Dissatisfaction in the Air Force’s Remotely Piloted Aircraft Community: Focus Group Findings* (Santa Monica, CA: RAND Corporation, 2017).

26. W. Phelps, *On Killing Remotely...*, *op. cit.*; T. P. Schultz, *The Problem with Pilots* (Baltimore: Johns Hopkins University Press, 2018).

not. Likewise for manned aircrafts and their crews, despite some being physically present and a part of the operating crew, these navigators are still not awarded the “wings” of the pilot as they do not directly control the aircraft.

Nonetheless, this insistence on physical presence persists, because of the significance placed on the risks and dangers a “physically-present” pilot faces, along with the courage and bravery this requires. Indeed, how can drone pilots claim to display bravery if they are out of harm’s way? Why should they be considered – and awarded – bravery medals, along with personnel that have largely seen live action? This argument has been discussed by many authors already, and it narrows down to the definition and understanding of courage and bravery. For some parts of society, including military professionals, courage and bravery can only be shown in the face of immediate adversity with a considerable danger to physical safety.²⁷

In contrast, Kirkpatrick offers a different understanding of courage, one which is built on three criteria: just cause, right intention, and to be facing real risks of which they have the ability to understand.²⁸ Under this model, drone pilots do indeed face real risks, psychological effects, including ethical and moral dilemmas with which they are burdened. According to one interviewee (an ex-fighter pilot and now a MQ-9 *Reaper* drone pilot):

“[I]t’s kind of [a] psychological risk because when [your attack fails] and ... there is a house that might be damaged because of what you did, it’s something [that is] very traumatizing and that’s why we train so much, because that’s [the] worst thing that could happen to a fighter pilot as well as [to remotely piloted aircraft] pilots.”

Hence, even though drone crews may not be physically present in the cockpit, one could argue that due to the nature of operating a drone, they witness the outcome of their attacks much more vividly through their video feeds. This would contrast to, for instance, bomber pilots, who would release their ordnance but would not have a clear view of the area after their bombardment, or any military professional, launching a missile from thousands of miles away.²⁹ As such, the argument that drone pilots do not deserve the same prestige as conventional pilots due to a lack of physical presence facing a certain threshold of risks is a strawman one.

The second “benchmark” qualifying drone pilots with the same primacy as other pilots – or even “pilots” at all – involve those who insist on the issue of “combat”. Interviewees claimed that the main function of the air force is combat. That is a historical and organizational fact, even in the presence of other types of a force’s

27. W. Phelps, *On Killing Remotely...*, *op. cit.*; J. Kirkpatrick, “Drones and the Martial Virtue Courage,” *Journal of Military Ethics* 14, no. 3-4 (2015): 202-219, DOI: 10.1080/15027570.2015.1106744

28. J. Kirkpatrick, “Drones and the Martial Virtue Courage,” *op. cit.*

29. D. A. Mindell, *Our Robots, Ourselves: Robotics and the Myths of Autonomy* (New York, NY: Penguin Publishing Group, 2015).

operations. Transport, search and rescue, and ISR,³⁰ are all functions of an air force but they mainly exist to support and complement its main function of combat.³¹ This explains not only the primacy of fighter pilots in air forces around the world, but also in other services that have a robust aviation branch.³² It is thus wrong to assume that drones do not partake in combat operations, as confirmed by the interviewees of this article. While it is true that drones are mostly being used for ISR, they are also armed and have been used in combat functions for several years, especially in the United States. The French doctrine of drone use also dedicates a considerable portion towards dictating the proper deployment and use of armed drones, including the guiding principles for their use.³³ Finally, unarmed drones participate in combat, by providing close air support or laser-guided munitions.

Consequently, both rationales behind the two “benchmark” criteria are incoherent as they overlook many other subgroups within the military profession, which are neither physically in danger nor experience combat. Beyond drone pilots, there are many other subspecialties and subgroups within the professional military group that hold various non-combat-related roles, such as medics, air traffic controllers, those in logistics and administration, mechanics and engineers, communications officers, and more. All of which are unlikely to see combat action, with the exception of medics. Considering how far these duties are to having a combat function, they, on the other hand, do not receive the same scrutiny and disparaging comments for their professional ethos and identity as drone pilots do.

The Impact of Technology

A Lesson from the Horse

Historically, new technological developments as well as societal and strategic-political changes have impacted the conduct of warfare through – among others – the increase or decrease in centrality and importance of certain branches, tasks, and individuals. An example can be drawn from the history of the cavalry. For centuries, horses have been the foundation for the creation of not just armies, but also of societies and cultures. Horses have served as the epicenter of warfare, either as a standalone for riders or by pulling a chariot. The centrality of the horse, documented and immortalized in countless depictions of warriors in all major cultures, was such an integral part of warfare that it led to the creation of one of the most famous war tactics in history – the charge.³⁴

30. Intelligence, surveillance, and reconnaissance.

31. W. Phelps, *On Killing Remotely...*, *op. cit.*

32. T. P. Schultz, *The Problem with...*, *op. cit.*

33. Centre interarmées de concepts, de doctrines, et d'expérimentations, “[Emploi des systèmes de drones aériens](#),” *Réflexion doctrinale interarmées RDIA-2012/010_ESDA*, no. 136 DEF/CICDE/NP (6 June 2012).

34. J. Robinson and al., *The Last Great Cavalry Charge: The Battle of the Silver Helmets Halen 12 August 1914* (United Kingdom: Fonthill Media, 2017); M. Favereau, *The Horde: How the Mongols Changed the World* (Cambridge, MA: The Belknap Press of Harvard University Press, 2021).

In a way, this can be compared with the fighter aircraft. The culture of fighting in the air was primarily built on and around dogfights. Pilots were dubbed “knights of the air”,³⁵ an allusion to the iconography of cavalry officers. Popular media especially had a hand in the creation of this revered “pilot” image by publishing thrilling stories of brave fighter pilots and their adventures in the air. Subsequently, the branches created for the utilization of the aircraft as a tool of warfare were born out of the fighter aircraft culture, both by and for fighter pilots. Indeed, the air force professional group is epitomized by the fighter pilot and its associations (such as pilot overalls, masks and headpieces, scarves), which have all become a status symbol.³⁶ Fighter pilots, like cavalry officers, enjoyed – and to a certain extent, still enjoy – a high status not just within the military profession, but also within society. They embody the “iconic” image of the professional group, because they are responsible for the tasks with which the group is associated.

By contrast, new technology can have the power to disrupt this established hierarchy and distribution of status within a profession. In the case of the cavalry, the introduction of mechanized and armored vehicles is presented as the reason for the horse’s eventual obsolescence from warfare.³⁷ Most importantly, it is also heralded as the reason for the disbanding of cavalry regiments, and the relatively delayed – and largely unorganized – process of introduction and adoption of mechanized warfare. Research for this article revealed that the intervening factor was how new technology was viewed from within the cavalry, rather than the technology itself.

In the first initial decades, it was proposed to either create separate regiments based on mechanized vehicles or mixed regiments of both horse and vehicle. This idea found many supporters but also opposition, especially from within the cavalry regiments. These officers felt that their positions and regimental homes might be threatened with obsolescence. Others with more pragmatism emphasized the shortcomings of the nascent technology, pointing out its deficiencies and inadequacies.³⁸ Eventually, certain cavalry regiments were disbanded – especially those which resisted the new mixed configuration – while others survived by accepting the new configuration. Beyond them was, of course, the introduction of new tasks, as well as the new individuals responsible for them. Horses slowly – but not in a linear fashion – disappeared from warfare, except for some cases of guerilla warfare and official ceremonies.

35. S. A. Fino, *Tiger Check: Automating the US Air Force Fighter Pilot in Air-to-Air Combat, 1950–1980* (Baltimore, MD: Johns Hopkins University Press, 2017).

36. T. P. Schultz, *The Problem with...*, *op. cit.*

37. G. F. Hofmann, *Through Mobility We Conquer: The Mechanization of U.S. Cavalry* (Lexington, KY: The University Press of Kentucky, 2006).

38. D. French, “[The Mechanization of the British Cavalry between the World Wars](#),” *War in History* 10, no. 3 (July 2003): 296–320.

New Technology and the Future of Services

The story of the horses teaches that the introduction of a new technology into a professional military group can have negative effects on the internal cohesion and the future of the group, but this is also dependent on how the group reacts to it. Bringing back the theories from sociology discussed above, such a fate can be avoided with a clearer understanding of what a group's culture and structure is, as well as how it can be adapted to the new reality without significantly impacting it. If the core task of a professional group stays the same, and the new technology is not threatening it, there is no reason for the process to have disruptive or even catastrophic effects.

So far, the core tasks of FASF is combat with an internal hierarchy reflecting the primacy of combat/fighter pilots. That does not mean that drone pilots are being isolated from the rest: a new, purely drone squadron has been created, and an old Mirage squadron has been transformed into a drone squadron. Drones are deployed with the rest of the forces, further escaping criticisms of isolation. FASF is also characterized by mobility; officers know that they might be assigned to a new squadron or a new type of aircraft, considering this as even an integral part of military duties. According to an interviewee:

“...[If the Force] says, ‘Hey, you are going to be here because you cannot be a fighter pilot.’ Sometimes it’s just [that] you take a fighter pilot or transport pilot and you say to them that they have to fly drones but it will be three years tops, and then [they can do] what [they] want. ‘Do you want a Rafale? Do you want to go overseas? Do you want to go spend [a] year [with] drones?’ And people say, ‘OK’”.

Moreover, drone pilots and their subculture is recognized, according to the conducted research, as part of a larger culture, common to all FASF officers. As noted by one interviewee, a veteran fighter pilot and now within FASF administration:

“[I]f you have a new aircraft and you bring [in] young people, you have more young than old and the culture will be more dynamic. But I guess that’s pretty much the same case in every human group, but also cultures evolve and I think you can map them according to the age of the system on which they operate and the overall time people will spend in the same unit. But with time, new cultures will mix into this big pot”.

As such, the existing hierarchy has not experienced a shock from the introduction of drones, but rather a flexible reorganization to also include drones and their crews. That is not to say that this has been without hiccups, as proven by the long period it took before drones were used by the French armed forces, and the subsequent longer period it took to arm them. Additionally, research reveals that, while drone pilots may be considered as much a professional as any other pilot, some individuals do not wish to be “downgraded” into becoming a drone pilot,

either by being reassigned from a previous position or being directly assigned as one upon graduation from the *École de l'air et de l'espace*.³⁹

A trend of the post-9/11 decades seems to have been distant warfare and the effort to avoid casualties. However, this seems to be changing as Western states reorient towards high-intensity warfare.⁴⁰ One can observe heavy investments in technologically driven platforms and a return to more traditional, legacy platforms (such as nuclear-powered submarines), as well as an inclination for bilateral deals outside of alliance contexts.⁴¹ This could mean that, post-heroic society ideas notwithstanding, the focus might return to military professionals and their groups, as well as the importance of early and successful adoption of new technology. In the high-intensity conflict of the future, early developers and adopters of new technology might win a significant advantage over their adversaries.⁴²

As this article has demonstrated, the nature of a new military technology and how it is perceived can have significant consequences for its chances to be early or properly adopted and integrated. Military necessity has been one of the driving forces behind technological developments, but whether they are successful or not depends on how they are implemented and used. For future technologies, this remains to be seen.

39. A military school and *grande école*, training line officers in the French Air and Space Force.

40. R. S. Cohen and al., *The Future of Warfare in 2030: Project Overview and Conclusions* (Santa Monica, CA: RAND Corporation, 2020); O. Schmitt, "France: Between Autonomy and Allies," in G. J. Schmitt (ed), *A Hard Look at Hard Power: Assessing the Defense Capabilities of Key US Allies and Security Partners* (Carlisle: US Army War College Press, 2020).

41. K. Liptak and M. Vazquez, "[Biden and UK to Help Australia Acquire Nuclear-Powered Submarines in New Pushback on China](#)," *CNN*, 16 September 2021.

42. M. C. Horowitz, "[Artificial Intelligence, International Competition, and the Balance of Power](#)," *Texas National Security Review* 1, no. 3 (May 2018): 36-57.

The Use of Drones: an Underestimated Asset for Air Power?

Lieutenant-colonel Romain Desjars de Keranrouë

Romain Desjars de Keranrouë is posted at the Analysis and Anticipation Office, within the General Staff of the French Air and Space Force.

In just a few years, aerial drones have taken over the skies. As a recent report reminds us, the number of commercial drones in France has grown “from 400,000 in 2017 to 2.5 million today.”¹ From a military perspective, “drones [...] have [...] become near-standard military equipment, with a global fleet reportedly far exceeding 20,000 devices, while it remains difficult to accurately assess the state of the fleet in countries like China or Iran.”²

From Libya to Ethiopia and Yemen, from Nagorno-Karabakh to Ukraine, drones, whatever their category,³ are making strategists, soldiers, industrialists and politicians react and debate.⁴ Embodying a revolution in military affairs, or even a breakthrough for some, not meeting the challenges of high-intensity conflicts and only adapted to asymmetric engagements for others, they leave no one indifferent.

These questions are not new. In a study and prospective book published in 2013, IFRI researchers already mentioned the probable appearance of “an adversary that has massively integrated drones into its fleet [which] could lead to a reconsideration of the trade-off that has been made between the refinement of platforms, their types, and their numbers.”⁵ Observation of current conflicts tends to confirm these statements and should lead airmen to better understand how drones could change the contours of air power.

1. C. Perrin, G. Roger, B. Sido and F. Bonneau, “Les drones dans les forces armées,” *Rapport d’information de la commission des Affaires étrangères, de la défense et des forces armées*, no. 711 (June 2021): 32.

2. S. Baudu and J. Lassalle, “La guerre des drones,” *Rapport d’information de la commission de la défense nationale et des forces armées*, no. 4320 (July 2021): 9.

3. NATO identifies three categories of UAVs based on their mass. Cat. I: light UAVs, under 150 kg, which include micro, mini and small UAVs, with a range limited to the Line of Sight; Cat. II: tactical UAVs between 150 and 600 kg without a satellite link (range of about 200 km); Cat. III: UAVs over 600 kg, which include theater, attack and strategic UAVs, with a satellite link, thus freeing themselves from the distance constraint.

4. No less than four parliamentary reports are scheduled between 2020 and 2021 on the subject of drones in the military.

5. C. Brustlein, E. de Durand and E. Tenenbaum, *La suprématie aérienne en péril, menaces et contre-stratégies à l’horizon 2030* (Paris: La Documentation française, 2014): 62.

This raises several questions, now. For example, what lessons should we draw from recent engagements, the most emblematic of which are those in Nagorno-Karabakh,⁶ Libya, described as “the world’s largest drone war”,⁷ or Yemen, where the Houthis proclaimed that 2019 was “the year of the drones”?⁸ By favoring only the MQ-9 *Reaper* today, the EuroMALE tomorrow or the future remote effectors of the Loyal Wingman type, aren’t the Western air forces depriving themselves of additional options?

To answer these questions, we will first highlight how drones offer the possibility for sometimes modest military organizations to acquire real air power (I). We will then develop the idea that drones are now necessary to maintain initiative and freedom of action, “the essence of strategy”⁹ (II). Finally, it will be suggested that a complementary development of means to the *Reaper*, EuroMALE, and other *loyal wingmen* could be seriously considered to meet the challenges of future conflicts (III).

Reinventing air power by regional actors

In France and in Europe, the use of UAVs, and particularly the *Reaper*, is focused on counterterrorism, in a context of air supremacy. As Senators O. Cigolotti and M.-A. Carlotti remind us, “France continues [...] to have a ‘strategic’ use of its armed drones (the *Reaper* drone and tomorrow, the Eurodrone) which are intended to be used for high value-added operations.”¹⁰

Yet, in other parts of the world, drones are proliferating as the “poor man’s solution”.¹¹ They make it possible to combine resources and to maneuver at acceptable costs in the face of air powers that implement a strategy of resources, costly and with a very high technological level.

The operational capabilities of UAVs

Traditionally, air weapons have four roles: air control, which allows for fire support and interdiction, mobility, strategic attack, and intelligence. UAVs naturally contribute to these major functions, firstly by enhancing their observation capabilities, whatever their size. Their persistence, thanks to their endurance (more than 24 hours for some types), or their permanent presence over an area thanks to their quantity and regular relays, reinforces this intelligence capability. It is now possible to map the enemy’s position in detail, for example by identifying its ground equipment, its units and their tactics, its defense systems, etc.

6. The war in Ukraine has just started at the time of writing. The author evaluated it was too early to draw lessons from the engagement. The use of TB2 drones, however, is similar to that in the Nagorno-Karabakh conflict.

7. Interview with UN Special Representative for Libya Ghassan Salamé,” *United Nations Political and Peacebuilding Affairs*, 25 September 2019.

8. I. Williams and S. Shaikh, “[The missile War in Yemen](#),” *Center for Strategic and International Studies*, (9 June 2022): 50.

9. A. Beaufre, *Introduction à la stratégie* (Paris: Hachette Littératures, 1998): 184.

10. O. Cigolotti and M.-A. Carlotti, “Haut-Karabagh: dix enseignements d’un conflit qui nous concerne,” *Rapport d’information de la commission des Affaires étrangères, de la défense et des forces armées*, no. 754 (7 July 2021): 61.

11. C. Brustlein, E. de Durand and E. Tenenbaum, *op. cit.*, 92.

Moreover, most drones have been armed within 20 years.¹² The sensor/shooter pair placed on the same platform has significantly accelerated targeting and striking operations. Remotely operated ammunition,¹³ sometimes called prowlers, which could be categorised between the missile and the drone, have led to the multiplication of Strike, Coordination and Reconnaissance (SCAR)¹⁴ missions over the battlefield. These missions caused the destruction of many Armenian ground-air systems, unable to detect the shootings,¹⁵ during the Nagorno-Karabakh war. The targets of the attacks can be of various nature, ranging from military objectives (such as armored ground equipment, or air bases as in Latakia) to individuals essential in the functioning of enemy organizations... (High Value Target),¹⁶ including the destruction of installations contributing to the blow of enemy's economic potential (attack on the Aramco site in Saudi Arabia, which slowed down the world's gross oil production by 5%).¹⁷

This rapid evolution is reminiscent in some respects of the emergence of airplanes on the battlefields at the beginning of the 20th century, initially confined to observation before being used for fire support and bombing.

*Air occupation*¹⁸

Thanks to their persistence, drones produce military and psychological effects, sometimes even societal, as was the case for the populations overflowed in the tribal areas of Pakistan during the war in Afghanistan.¹⁹

The war between Azerbaijan and Armenia highlighted the use of drones when they can operate without being threatened. The Bayraktar TB2²⁰ drone contributed to a very significant reduction of the enemy's firepower on the ground. The ground troops, although relatively well trained, were disarmed and suffered heavy losses without being able to retaliate effectively.²¹

This air occupation, easier to implement when associated with air supremacy, can also be envisaged against adversaries using interceptors or technologically advanced means. The Turks thus supported the Tripoli government in Libya, against the forces of General Haftar, which had *Wing Loongs* drones²² from the United

12. The first Hellfire firings on MQ-1 *Predators* date back to 2001 for the United States and 2004 for Israel.

13. Remotely operated munitions are automated and durable aerial munitions. They are of variable size and have the capacity to fly over an area in search of a target, to locate and identify it and finally to attack it by shooting at it at the right moment. This type of ammunition is used like a drone but is not intended to be recovered.

14. Search and dynamic attack mission of target of opportunity. Participates in interdiction missions.

15. O. Cigolotti and M.-A. Carlotti, *op. cit.*, 59.

16. Strike against the Iranian general Soleimani for example.

17. J.-V. Brisset, "[Le drone s'impose comme la version pas chère du missile](#)," *L'Usine Nouvelle*, 17 September 2019.

18. J.-C. Noël, "Occuper sans envahir: drones aériens et stratégie," *Politique étrangère*, n°3 (2013): 105-117.

19. "[Drones in Pakistan traumatize civilians, US report says](#)," *BBC.com*, 25 September 2012.

20. Drone without satellite link, limited to 150 km range, equipped with ISR sensors and can be armed with up to 4 rockets or light anti-tank missiles of local manufacture Roketsan. Its endurance can go up to 24 hours. It is quite similar to the Patroller UAV that the Army is to receive.

21. O. Cigolotti and M.-A. Carlotti, *op. cit.*, 84.

22. MALE drone available in several versions, with an endurance of more than 20 hours and a

Arab Emirates. As pointed out by Senators O. Cigolotti and M-A. Carlotti, “the entry of the TB2s into the Libyan conflict has created a break in the dynamic, which until then had been favorable to the ANL/Emirates. Their strikes have called into question the air superiority of the NLA in the theater of operations, which it had enjoyed until then, thanks to the support of the Emirates”.²³

The war in Ukraine seems to confirm this trend. The TB2 drones used by the Ukrainians inflicted definite losses on Russian troops at the beginning of the campaign,²⁴ despite the size of the Russian air arsenal.

The rise of ISR

The spread of UAVs and their increasingly systematic use by regional powers such as Ethiopia²⁵ and Morocco, for example, are raising the general level of understanding and anticipation of belligerents on the battlefield, while maintaining a form of rusticity. Thanks to the multiplication of sensors, these powers benefit from better command and control (C2) capabilities and can prepare actions where their means will be combined. Their professional level will probably improve as a result.²⁶ Of course, C2 capabilities often remain rustic, so there is no question of planning complex maneuvers. However, the use of UAVs in a maneuver combined with electromagnetic and information fields can produce strategic effects, as proved by the arrival of the Bayraktar TB2 in Lybia.

Hybridity

Hybrid strategy blurs the limits between the types and levels of conflict, allowing those who know how to use it to achieve their goals without resorting to the full mobilization of their traditional military means. The drone can play a role in this type of strategy.²⁷ If drone attacks are more easily attributable than in cyberspace, the designation of the sponsor is not automatic. While the drones or missiles that hit the Aramco oil site²⁸ are of Iranian origin, the attack was claimed by the Houthis, seemingly absolving the leadership in Tehran of any responsibility. The CIA conducted strikes outside the recognized theaters of operation using drones, where the use of fighter jets, which are more visible, would have been less appropriate and would certainly have led to even more outraged reactions.

The loss of a drone also elicits fewer reactions than of an aircraft and its crew. No sensitive escalation began in June 2019, for example, after a U.S. Global Hawk drone was shot down south of Iran. Lastly, some categories of civilian-purchased drones can be militarized, complicating the attribution of the strike.

range of over 1,000 km. It can carry more than 500 kg of cargo, including air-to-ground weapons (missiles and bombs).

23. A. Thomas, “[Confrontation turco-émiratienne en Libye : le drone, nouvel atout stratégique](#),” *Fondation pour la Recherche Stratégique*, no. 12/2021, (June 2021): 15.

24. D. Malyasov, “[Ukrainian Bayraktar TB2 drones successfully attack Russian convoys](#),” *defence-blog.com*, 28 February 2022.

25. AFP, “[Éthiopie: les drones, arme clé dans l'évolution récente de la guerre](#),” *L'Express*, 14 January 2022.

26. J.-J. Patry, “La ‘salve manœuvrante’: une avancée décisive dans les combats des 20 prochaines années en attendant l’ère des essais autonomes,” *Defense & Industries*, no.15 (April 2021).

27. W. Lacher, “[Drones, deniability, and disinformation: warfare in Libya and the new international disorder](#),” *War on the Rocks*, 3 March 2020.

28. J.-V. Brisset, “[Le drone s'impose comme la version pas chère du missile](#),” *L'Usine Nouvelle*, 17 September 2019.

The drone can thus contribute to winning the war before the war, which is now acknowledged by the highest French authorities. The Chief of Staff of the Armed Forces thus affirms that “drone strikes constitute a gradual offensive action that minimizes the geopolitical implications” in his strategic vision,²⁹ while the deputies S. Baudu and J. Lassalle confirm that “drones are at the heart of hybrid strategies, as defined by the Strategic Update 2021”.³⁰

The poor man's weapon to challenge the rich man

In January 2022, three combined drone and Houthi missile attacks forced the United Arab Emirates to put its THAAD missile defense³¹ and fighter aircraft on alert. Batteries and aircraft were to neutralize these cheaply developed drones. However, the missile of a Patriot battery can cost more than 1M USD when the price of the drone used for attacking does not exceed a few hundred dollars.³² UAVs can thus partially reduce the balance of power between the belligerents, by immobilizing equipment and imposing high costs on the forces with the most advanced equipment, which must protect themselves from strikes by non-state organizations.

In a complementary way, in Iraq, after the Islamic State resorted to commercial drones – Phantom-III quadcopters and Skywalker X-8 flying wings – armed with grenades,³³ the United States recently acknowledged a form of inability to repel this type of threat. General McKenzie, commander Central Command, declared, following an internal Pentagon report which evaluated the detection and interception capacity of this type of drone at less than 40%, that “using very expensive weapons on a cheap drone is neither profitable nor effective. And if you are not able to shoot down a craft that flies over a base, you do not have air superiority”.³⁴

Lessons to be learned from these new uses

These examples highlight the emergence of new courses of action that show the offensive potential of drones. Of course, we must avoid the trap in overly novelty fascination. The limits of UAVs are also poorly understood and will undoubtedly depend on the operational context in which they are used. But it would be regrettable not to draw inspiration from what our potential adversaries are doing to improve our courses of action. Especially since the consequences are significant in terms of the art of war.

29. A. Thomas, *op. cit.*, 4.

30. S. Baudu and J. Lassalle, “La guerre des drones,” *Rapport d'information de la commission de la défense nationale et des forces armées*, no. 4320 (July 2021): 15.

31. G. Powis, “[Les Émirats arabes unis interceptent missiles et drones houthis](#),” *Air & Cosmos*, 25 January 2022.

32. S. G. Jones, J. Thompson, D. Ngo, B. McSorley, J. S. Bermudez Jr, “The Iranian and Houthi War against Saudi Arabia,” *Center for Strategic International Studies*, no. 12 (2021): 11.

33. P. Grasser, “Conquérir et sanctuariser le ciel syrien,” *Vortex* 2 (2021).

34. P. Samama, “[L'armée américaine reconnaît sa difficulté à lutter contre les drones 'Costco'](#),” *BFM Éco*, 9 January 2022.

The impact of the aerial drone in military strategy

*Saturation, as a “maneuver through weariness”*³⁵

One of the first consequences of the development of UAVs in the art of war is the return of the principle of saturation. The use of a significant number of drones on a battlefield highlights the limits of strategies based on technological excellence, with equipment that is both numerous and costly. This is the “maneuver by lassitude” described by General Beaufre. Thus, for S. Baudu and J. Lassalle, “the use of drones makes it possible (...) to pose a disproportionate threat to the means invested, requiring, for those who must defend themselves, strong resources to counter it”.³⁶ If the Israeli *Iron Dome* is effective against Hezbollah attacks (90% interception for a unit price of about 50,000 US\$,³⁷ compared to drones costing sometimes a few hundred dollars), the bill increases steadily when the batteries have to deal with about 400 Palestinian rocket and drone attacks per day. And S. Baudu and J. Lassalle add: “Faced with swarms of drones costing a thousand euros, is it clever to use missiles that cost between one and two million € each?”³⁸ The terms of “quality or quantity” debate applied to equipment could therefore evolve in the future with the development of drones.

Come back of the maneuver of the maneuver

One of the fundamental aspects of strategy is to seek to increase one’s freedom of action thanks to the “maneuver factor, which combines rational mechanics and combinations”.³⁹ Thus, the sensor/shooter pairing augurs a come back of this maneuver to the heart of air power, with the triptych of fire/physical maneuver/information operations.⁴⁰

UAVs are particularly well-suited to developing and exploiting these combinations, as demonstrated using TB-2s in Syria, then in Upper Karabakh. Thus, in 2020, the Turkish operation Spring Shield combined a hundred Anka and Bayraktar TB2 drones with the jamming of Syrian ground-air defense systems. The results are indisputable. At the cost of half a dozen downed drones, more than a hundred vehicles and heavy platforms were destroyed. *Bis repetita* in Upper Karabakh, where the addition and integration of loitering ammunition to the above-mentioned system gives the Azerbaijani forces the opportunity to master a coherent set of drones, ammunitions and electronic warfare in support of air-land maneuvers.⁴¹

35. A. Beaufre, *op. cit.*, 155.

36. S. Baudu and J. Lassalle, *op. cit.*, 19.

37. T. Fournol, “Défense antimissile: débats et actualités,” *Fondation pour la Recherche Stratégique*, Observatoire de la défense antimissile, no. 12 (2021): 51-52.

38. P. Mirallès and J.-L. Thiériot, “La préparation à la haute intensité,” *Rapport d’information parlementaire par la commission de la défense nationale et des forces armées*, no. 5054 (February 2022): 92.

39. A. Beaufre, *op. cit.*, 185. Rational mechanics is here related to the logical choices made according to the forces available, that is to say the choice of means. The combinations include the acquisition of initiative and surprise, when the rational mechanics are no longer sufficient, because of the inferiority of the means or for other reasons.

40. G. Bouthérin and C. Grand, *Envol vers 2025, réflexions prospectives sur la puissance aérospatiale* (Paris: La Documentation française, 2011): 35-47.

41. J.-J. Patry, *op. cit.*

Furthermore, “the use of maneuver warfare requires superior intelligence and understanding of the adversary’s.”⁴² William Lind identifies three principles of maneuver that flow from these two preconditions. These are the importance of decentralizing initiatives, the need to accept, generate, and use confusion and disorder, and the need to be unpredictable by acting without necessarily following the usual doctrinal precepts. The example of the Ukrainian *Aerorozvidka* UAV battalion⁴³ illustrates the value of combining intelligence gathering (creation of an intelligence system within the unit) and decentralized tactical initiatives (remote operators on quad bikes, equipped with night vision goggles and modified and armed octocopter UAVs) to create disorder and surprise based on a high degree of mobility.

The extension of the use of UAVs from the competition phase to open warfare, in a defensive or offensive mode, has the additional consequence of proportionally reducing the margin of maneuver of the opposing competitor, even if he holds air supremacy. The case of the Houtis is also emblematic. Their inventiveness in manufacturing drones, their ability to generate confusion by attacks coming from different directions, combining various means that are sometimes difficult to attribute, has created formidable problems to the Saudi military. Thus, “attacks on Saudi infrastructure, particularly with drones, represent an effective means of imposing very significant reputational or economic costs on the Saudi government at relatively low cost”.⁴⁴ A significant number of resources are being held back, that cannot be mobilized in offensive operations, resulting in a tension between the traditional strategy of means and defensively limited operational and tactical options.

In this dialectic of the shield and the sword, it is therefore not certain that the strategy of means alone always prevails, because the adversary does not necessarily look for the complete defeat of his opponent as war goals. He will rather try to obtain quick gains through limited operating modes. The objective is then to wear down the adversary, by imposing our tempo and by taking initiatives, to prevent any triumphalist discourse from the enemy and to eventually lead to a relative political paralysis. By diversifying the use of drones, by resorting to remote warfare at a controlled cost, today’s competitors are thus provoking ruptures from which Western nations, turned towards a direct strategy of means, based on material superiority, could draw inspiration.

A prefiguration of MDO integration

Finally, UAVs can be the ideal vectors for accelerating Multi Domain Operation (MDO) integration in the armed forces. Their combined use with ground weapons (targeting for artillery or in dynamic mode), with jammers (offensive jamming and intelligence gathering, or denial of access by jamming drone links, in Syria in particular),⁴⁵ as an anti-ship system (on July 29th 2021, a multiple drone strike hit an oil tanker North-East of the port of Duqm, outside the territorial waters of Oman)⁴⁶ or supported by artificial intelligence (for the first time, Tsahal employed

42. C. Brustlein, E. de Durand, E. Tenenbaum, *op. cit.*, 204.

43. J. R. Miquel, “[Ukraine: comment une unité d'élite de pilotes de drones met en échec l'armée russe à Kiev](#),” *L'Express*, 28 March 2022.

44. S. G. Jones, J. Thompson, D. Ngo, B. McSorley, J. S. Bermudez Jr, *op. cit.*, 11.

45. P. Grasser, *op. cit.*, 167.

46. S. G. Jones, J. Thompson, D. Ngo, B. McSorley, J. S. Bermudez Jr, *op. cit.*, 6.

swarm drones using artificial intelligence against Hamas)⁴⁷ are as many examples that foreshadow the integration of effects and the MDO operations of tomorrow.

An armed drone provides the assurance of “a junction between the world of intelligence and that of kinetic operations”.⁴⁸ While UAVs already combine an effective sensor-effector loop, accelerating the reconnaissance-fire complex, their use will eventually offer the possibility of setting up a real laboratory for collaborative combat and connectivity, through LOS (Line of Sight), BLOS (Beyond the Line of Sight), satellite and tactical links, which retransmit video or intelligence to C2s in real time.

The substantial role of UAVs in the traditional functions of the air force (ISR, coordination, fire support, strikes) must therefore be considered when considering joint integration, “which will depend on air power”.⁴⁹ It encourages us to think of them as precursors to future MDO operations.

What future for drones, or the indispensable evolution of mentalities

In “the new era of techno-capacity imagination”,⁵⁰ drones offer very promising prospects, provided that certain rules of the game are accepted.

Combining strategy of means and integral maneuver

The courses of action observed in recent conflicts raise the classic question of the implementation of specialized means to ensure both maneuver support missions and strategic strikes.

This question arises, for example, for Israelis.⁵¹ As early as 2013, they contemplated the incoming divide of their air force between a piloted component for long-range strike missions and a remote piloted component of equivalent volume by 2030. At that time, however, the analysis was supplemented by a distinction between permissive and non-permissive environments.

The Israeli example proves that UAVs make it possible to consider new options, by pushing “the choice of the complementarity of fighter armed MALE UAVs, which appears to be the best operational compromise at the present time”.⁵² In this context, it is essential to play on the saturation of the adversary by producing “consumable” and “disposable” equipment while integrating them, in an MDO logic, “to a robust and multi-layered system including electronic warfare systems, radars and intelligence capabilities.”⁵³ Ground-to-air defense could even support them by preventing potential aircraft from approaching the drones to destroy them.

47. “Israël a utilisé le premier essaim de drones guidés par IA au monde lors des attaques contre Gaza,” *Trust my Science*, 02 July 2021.

48. R. Desjars, “La guerre à distance, 20 ans d’engagement des équipages de drones MALE,” *Revue Historique des Armées*, no. 301 (2020).

49. G. Bouterin and C. Grand, *Envol vers 2025, réflexions prospectives sur la puissance aérospatiale* (Paris: La documentation française, 2011): 229-238.

50. J. Henrotin, “Aviation de combat 2021,” *DSI*, Hors-série, no. 78 (2021).

51. P. Gros, “Les drones armés israéliens: capacités, bilan de leur emploi et perspectives,” *Fondation pour la Recherche Stratégique*, Recherches & Documents, no. 9 (2013).

52. R. Briant, J.-B. Florant et M. Pesqueur, *op. cit.*, 34.

53. A. Thomas, *op. cit.*, 12.

The false problem of connectivity

It can be argued that, in a high-intensity conflict, the vulnerability of UAVs, due to their dependence on the electromagnetic spectrum (massive jamming, weak links), is increased. Their performance could thus suffer from it. The increasing dependence on data (immoderate use of ISR streams, giving rise to the expression *Predator Crack* in reference to the drug of the same name) can sometimes lead to the temporary halting of a mission due to an excessive need for video stream.

But this dependence also concerns collaborative combat systems. Connectivity and the network-centric approach present the same fragility in the field of links: “it seems judicious to evaluate the feasibility and relevance of contemporary operational concepts in a non-permissive or degraded electromagnetic environment, characterized by incomplete or intermittent coverage.”⁵⁴

Innovations will undoubtedly emerge to address these limitations and vulnerabilities. The company ‘La Poste’ is able to deliver parcels in Beyond Visual Line of Sight (BVLOS) by exploiting the mobile network connection. Israel has just authorized commercial drones to fly without GPS.⁵⁵ Although tactical or theater drones are not affected by these steps forward, they indicate that concepts of drone use should not be frozen at today’s technological level. “The conflict in Nagorno-Karabakh is symptomatic of an intermediate stage between the ‘dronisation of forces’, which has become established over the last 30 years, and ‘collaborative combat in swarms’, which could become a reality in 30 years’ time.”⁵⁶ Conceptual or capability adaptations (rusticity and disposability, or reinforcement of protection) are perfectly feasible.

Capability strategy

Generally speaking, UAVs, thanks to their very varied range of use, offer complementary means to those at the top of the spectrum. Our capability strategy could therefore evolve by enriching our range of UAVs, which today consists solely of the Reaper, a sort of “Rolls-Royce» of the MALEs.”

As for the case of Turks and Israelis, the development of new classes of UAVs would probably require an evolution in the structuring of our force system. The beneficial effects would be significant in the economic and diplomatic domains. The Turkish example is demonstrative: “the military industry has become, for Erdoğan, the centerpiece of a project of economic, social and cultural domination that extends from Central Asia to Africa, passing through Northern and Eastern Europe.”⁵⁷ There is even talk of *Bayraktar Diplomacy!*⁵⁸

But the main consequences of this new strategy would obviously be military and industrial. It would then be necessary to “invest in a ‘high-low mix’, that is

54. C. Brustlein, E. de Durand, E. Tenenbaum, *op. cit.*, 184.

55. “Synthèse de l’étude sur le marché des drones civils,” *Agence de l’innovation de défense*, 05 July 2021.

56. O. Cigolotti and M.-A. Carlotti, *op. cit.*, 60.

57. C. Mann, “Ukraine, Haut-Karabakh, Balkans, Asie centrale... La guerre des drones d’Erdoğan,” *Revue des deux mondes*, 17 February 2022.

58. S. Mitzer, “The Fight For Nagorno-Karabakh: Documenting Losses On The Sides Of Armenia And Azerbaijan,” *Oryx Blog*, 27 September 2020.

to say, to mix high-tech capabilities with more rustic and less costly solutions.”⁵⁹ Between expensive models such as the MQ-9 Reaper, which costs \$12 million, and the TB2, nicknamed the “AK47 of the air”, at \$5 million,⁶⁰ or also the Chinese Wing Loongs drone at \$1 million, many avenues can be explored to develop a capability model that favours the combination of means and manoeuvre. The best option would be to produce consumable UAVs, satisfying both the notion of mass and the supply of real industrial series.

These consumable UAVs could provide feedback for future project developments, perhaps even the FCAS and Loyal Wingman. Thus, “in the long term, we are in line with the concerns surrounding the FCAS, which must be both the definition of a system and of new practices. We need to think about what tomorrow’s fighter aircraft will be, what tomorrow’s use of drones will be in their diversity – accompanying drones, disposable drones, projectable drones, ‘warrior’ drones. We need to define this in the context of the use of the FCAS, which will not happen tomorrow, but also in the context of the ‘pre-FCAS’, which would allow us to see how drones and their different variations could be used, like ‘remotely operated’ munitions”.⁶¹ However, it will be important not to copy the industrial and technological processes used for major equipment programmes. For example, the capabilities required for deep penetration will not need to be mobilized. In short, “technical advance is an essential factor of power”. But this lead can be useless if it is used for the benefit of a bad strategy. However, the choice of tactics is the strategy.”⁶²

Options exist today to adapt our force system, ranging from the Reaper today to the EuroMALE at the end of the decade and the Loyal Wingman in the years 2040-2050. They would allow us to develop a high/low capability mix capable of resolving the extension of conflict areas. The close air support and air interdiction missions would be accomplished through a combination of rustic effectors saturating the adversary, mainly drones, protected by a multi-layered ground-to-air defence.

Without triggering new and unnecessary quarrels between the two schools of air power, that of the “Integral Air” and that of cooperation,⁶³ this division of work would optimise, on the contrary, the employment of air power, offering the Rafale and then the FCAS the opportunity to be fully employed to act in strategic depth after having conquered air superiority.

In short, as stated by the former Air Force Chief of Staff, General Mercier, “tactical missions of support, reconnaissance, [...] ground attack missions, which are less strategic depending on the level of control of the airspace, will be able to accommodate rustic platforms”.⁶⁴

59. P. Mirallès and J.-L. Thiériot, *op. cit.*, 137.

60. C. Deluzarche, “Comment les drones low cost pourraient redessiner la guerre du futur,” *Wall Street Journal*, 21 June 2021.

61. S. Baudu and J. Lassalle, *op. cit.*, 112.

62. A. Beaufre, *op. cit.*, 69-70.

63. J. de Léspinois, “La stratégie aérienne cartographiée,” *DSI*, Hors-série, no. 78 (2021). The author highlights the native tendencies of air power, between the proponents of Air Integral, followers of Douhet, where strategic bombing, alone, achieves victory; and the proponents of cooperation, where air power cooperates and works in support of land and sea forces.

64. G. Bouterin and C. Grand, *op. cit.*, 234.

Has Artificial Intelligence Triumphed over Terrorism?

Lessons learned from the IDF's use of advanced technology in Operation Guardian of the Walls

Dr. Liran Antebi

Dr. Liran Antebi is the director of the Advanced Technologies and National Security Program at the Institute for National Security Studies (INSS), a lecturer in the Israeli Air Force Academia, and a Major (in reserve service) of the Israeli Air Force.¹

Introduction

Operation Guardian of the Walls (GW) took place during May 2021 as another ongoing round of the armed conflict between the Israel Defense Forces (IDF) and the Hamas terrorist organization in the Gaza Strip.² The operation was characterized by Hamas' heavy fire on Israeli civilians and territory. Nevertheless, the IDF's air defense system was able to defend Israel during the operation, intercepting 90% of the rockets launched at its populated areas. The IDF also succeeded in foiling further attempts by Hamas to strike Israel, including the use of explosive unmanned aerial vehicles (UAVs) and strikes from both the land and sea.

During the operation, Israel took action to inflict considerable damage on Hamas and to restore peace to the country. The IDF attacked more than 1,500 targets in the Gaza Strip and achieved exceptional results by hitting complex targets, including Hamas' offensive tunnels, all while maintaining a low rate of

1. Dr. Antebi would like to thank Miss Yuval Knafo, a student in the Diplomacy and Security Studies M.A. program, at Tel Aviv University and an intern at INSS, for her great assistance in producing this article.

2. Other organizations that took part in the operation are the Palestinian Islamic Jihad, the Popular Front for the Liberation of Palestine, as well as other terrorist organizations in Judea and Samaria, Gaza and Lebanon.

harm to civilians in Gaza. This operation – which mostly combined advanced technology in the fields of air defense systems, standoff weapons, and many other intelligence systems – earned itself the nickname of “the first artificial intelligence war”. In light of the high-intensity use of such a large number of innovative technology, the question arises as to what their impact was on the IDF’s success during the operation.

This article will thus define the operation from a technological perspective. It will open with a general description on the course of the operation and its outcomes, including a comparison with the IDF’s previous operations in the Gaza Strip. It will then outline how advanced technology was incorporated into the operation by both the terrorist organizations involved and the IDF. Among them notably are artificial intelligence (AI), air defense systems, UAVs, and various digital technology put into service by ground forces. Finally, prominent cases of success and failure will be examined in an effort to decipher their impact on the level of success achieved by the IDF against Hamas.

General Background on the Operation

Operation GW lasted twelve days (from May 10 to May 21) and was extremely powerful in the indices of rocket fire towards Israel and the IDF’s operational response.³ In contrast to previous operations, this one began without any security escalation in Gaza and was initiated and planned by Hamas. Increasing tensions in the preceding weeks, centered on Jerusalem between the city’s Arab and Jewish population, was what led to this operation.⁴ Following ongoing clashes, Hamas announced that “Jerusalem Day” was an important milestone in the history of Israel and Hamas’ confrontation. With that, it launched the first rocket attack on Israel the same evening on May 10, 2021.⁵

During the entire operation, Hamas fired more than 4,360 rockets and mortar shells at Israel. The highest firing intensity was measured on the second day of the operation, with 480 rockets directed to Israeli territory. The missile range was extensive reaching as far as Jerusalem.⁶ The “Iron Dome” air defense system successfully intercepted 90% of launches towards populated areas. Despite its relative success, 11 people were killed by rocket fire with hundreds wounded, an IDF soldier killed by anti-tank fire, as well as much property in various cities destroyed.

Besides heavy rocket fire, the Palestinians also fired anti-tank missiles. Additionally, at least one attempt was made to penetrate Israeli territory via un-

3. U. Rubin, “[Israel’s Air Defense in Test During Operation Guardian of the Walls](#),” *The Jerusalem Institute for Strategy and Security*, 8 July 2021.

4. M. Milstein, “[The Guardian of the Walls: A Strategic Balance, A Look to the Future and Policy Recommendations](#),” *Reichman University Institute for Policy and Strategy*, 27 May 2021.

5. *Ibidem*.

6. U. Rubin, *art. cit.*

derground tunnels. A number of suicide UAVs and explosive drones were also launched at Israel. There was also an attempt made to operate an unmanned underwater vehicle, along with attempts to attack from the sea, land, and the underground dimension. All these were also all thwarted by the IDF. Furthermore, several rockets were fired from Lebanon and Syria, of which one was intercepted by the Iron Dome. An Iranian UAV that came from the direction of Syria, close to the Jordanian border, was also intercepted by the Israeli Air Force (IAF).

In order to restore peace, Israel took action to neutralize Hamas and their capabilities. The IDF has hit over 1,500 targets in Gaza,⁷ all while foiling attacks from the ground, air, and sea. It also destroyed over 100 km of tunnels that Hamas was using as hideouts, attack bases, and command-and-control centers. More than 200 people were killed in Gaza during the operation, including dozens of terrorists in which five were at senior levels within the Hamas organization. Unfortunately, among these fatal casualties were also civilians. Greatly damaging Hamas' strategic and tactical capabilities, the IDF's unprecedented use of advanced technology greatly contributed to their operational success – namely those of the IAF, who worked in close cooperation with the IDF's Military Intelligence Directorate (Aman).⁸

Comparison with Previous Operations Against Hamas

Though this operation is similar to previous operations in Gaza, there was a significant change in the pattern of Hamas rocket launches. As a result, the Israeli air defense system faced its most rigorous test yet. Palestinian terrorist groups – especially Hamas – made significant breakthroughs to breach Israel's air defenses in this operation. They used three primary methods:

- A high firing rate born of rocket production systems designed to meet this requirement and prolong combat duration.
- More powerful rockets compared to previous attacks.
- Launching rockets at a greater distance than previously.⁹

These patterns demonstrated Hamas' evolved learning process.

Out of the rockets that were fired, 1,660 were intercepted and 176 of them managed to penetrate the defense of the Iron Dome and hit populated areas. The terrorist organizations fired an average of 400 rockets a day, compared to the 140 fired during the most trying days of Operation Protective Edge in 2014. Heavy barrages of 100-150 rockets within minutes to the same area posed one of the

7. The Meir Amit Intelligence and Terrorism Information Center, "[Escalation from the Gaza Strip – Operation Guardian of the Walls – Summary](#)," *The Israeli Palestinian Conflict* (23 May 2021).

8. A. Kalo, "[AI-Enhanced Military Intelligence Warfare Precedent: Lessons from IDF's Operation 'Guardian of the Walls'](#)," *Frost & Sullivan*, 9 June 2021.

9. U. Rubin, *art. cit.*

most difficult challenges. Despite this, an impressive feat of maintaining a 90% success rate in interceptions is quite the achievement.¹⁰

Below is a summary of Operation GW in comparison to previous operations in Gaza:¹¹

Operation	Endurance	Rockets and mortar shells fired	Average firing rate per day	Attempts to launch UAVs / Drones	Success rate of interceptions by Iron Dome	IDF ground maneuver in Gaza?	Civilians killed in Israel	IDF soldiers killed	Killed in Gaza (fighters and civilians)
Cast Lead (Gaza War), 2008-2009	22 days	640	29		Before operational Iron Dome	V	3	10	1166 (at least 709 of them were terrorists)
Pillar of Defense, 2012	8 days	1667	151		84%	–	4	2	163 (at least 80 of them were terrorist)
Protective Edge, 2014	50 days	4300	81	1-3 'Ababil' UAVs (one was intercepted by the IAF)	90%	V	6	68	1768 (750-1000 estimated to be terrorists)
Guardian of the Walls, 2021	12 days	4360	400	Apparently 7 armed UAVs and several drones	90% *Intercepted mortar shells since 2016	–	11	1	256 (at least 67 of them were terrorists)

The Role of Innovative Technology in Operation GW

Israel is known as a world leader in several fields: defensive systems, technological intelligence, advanced air force, defensive and offensive cyber capabilities, and military AI. During this operation, the IDF mainly demonstrated an increase in the use of AI technology for military intelligence purposes, rapid, accurate target attacks, as well as an advanced use by its air force. The operation emphasized the preeminence of the Israeli air defense technology, especially improvements in the Iron Dome's capabilities, such as intercepting even UAVs.

10. A. Levin and Y. Bustan, "[The stick and the laser: the IDF's impressive technological capabilities will not suffice in the next round](#)," *Forbes Israel*, 21 June 2021.

11. The data was collected from a number of sources. Indeed, there were sometimes gaps in the numbers due to counting methodological differences or because of those who were responsible for publishing the data. Nevertheless, these gaps were not strikingly significant. Hence, this article has simply chosen one set of numbers over the other in order to give the readers a general impression of change over the years. Here are the sources: U. Rubin, *art. cit.*; The Meir Amit Intelligence and Terrorism Information Center, "[Examination of the number of Palestinians killed during Operation Cast Lead indicates that most were armed terror operatives and members of Hamas's security forces involved in fighting against the IDF](#)," *Terrorism Information – General Information*, 7 April 2009; "[An analysis of the names of Gazans killed during Operation Guardian of the Walls indicates that about half of them were terror operatives](#)," *The Israeli Palestinian Conflict*, 22 June 2021; Y. Ziton, "['Protective Edge' in numbers](#)," *Ynet*, 8 August 2014.

The technological aspect of the operation received widespread coverage in international media and was sometimes coined as the “First AI War”. Indeed, the operation demonstrated extensive use of AI-based systems and Big Data analytics, supporting many areas of warfare aimed at enhancing and accelerating the entire operational process from raw data gathering, research, and analysis to strategic planning, identifying potential targets, and carrying out actual strikes.¹² AI has also been used in “swarm” technology, as well as in systems already considered to be more “traditional”, such as the Iron Dome; the latter has taken on a central role in shaping this operation’s outcome.

However, the adoption of new technology is not a conception of the IDF alone. The “other side” has also demonstrated the ability to use innovative technology, including those made by the local military industry, the Iranian industry, as well as off-the-shelf products and improvised technology.

Most of Hamas’ attacks were through an array of rockets and mortar shells designed to execute a high rate of firing over many days. Yet, Hamas has also used other technology, namely fixed-wing UAVs equipped with explosives, aimed to crush and explode in Israel. At least four of these UAVs were intercepted by the IAF’s defensive system, including the first interception of its kind by the Iron Dome. Importantly, one of the UAVs was intercepted by a *Python* air-to-air missile, which was originally intended to intercept fighter jets from a F-16. Many other UAV types were also intercepted, but its means remains classified. Attempts to launch *Shahad*, fix-winged Iranian UAVs armed with explosives, were neutralized by a pre-emptive strike on the launch squad.¹³ Finally, rotary drones carrying explosives were also deactivated by the IDF.¹⁴

Notably, Hamas has attempted to carry out a naval attack using an unmanned underwater vehicle on the eighth day of the operation (May 18). The IDF successfully neutralized both the vehicle and the terrorists who deployed it.¹⁵

On the ninth day of the operation, a UAV entered Israel and was shot down in the ‘Springs Valley’ area. This intrusion was largely reminiscent of an earlier event that occurred in February 2018. After GW, it was revealed that the aircraft, which had originated from Iran as a part of its UAV program, had been a significant air threat to Israel.¹⁶ Indeed, this recent conflict reflects an increase in the unmanned danger posed by the “other side” as well as the ability of terrorist organizations to use unmanned technology that, until a few years ago, were only at the service of advanced countries.

12. A. Kalo, *art. cit.*

13. L. Antebi, “[The ‘Other Side’s’ Unmanned Systems: After Operation Guardian of the Walls](#),” *INSS Insight*, no. 1477 (June 2021).

14. *Ibidem.*

15. *Ibidem.*

16. Y. Kubovich, “[Gantz: Iran Tried to Smuggle Explosives from Syria to West Bank With Drones](#),” *Haaretz*, 23 November 2021.

In addition, Hamas had a cyber unit with intentions to inflict damage on Israel via cyberspace. Nevertheless, preliminary intelligence gathering has enabled the IAF to strike the positions, command rooms, servers, computers, and senior operatives at the outset of the operation to subsequently incapacitate it.¹⁷

Overall, Operation GW, along with the recent changes occurring throughout the Middle East, only demonstrate that the threats to Israel, especially in the air realm, are changing. Varied technology is becoming more accessible to non-state organizations, allowing them to operate in a more technologically advanced manner than ever before. Previous years had been characterized by the use of primitive weapons by terrorist organizations (kites and balloons) in contrast to the Israeli difficulty in providing a counter-technological solution. 2021 particularly portrayed the significant impact of how certain advanced technology were now easily accessible, simple to operate, and available at low prices (sometimes off-the-shelf), allowing different countries and terrorist organizations to employ armed UAVs for intelligence-gathering and fine-tuning the accuracy of their attacks. In the case of Hamas, these are in addition to the proven success of rocket and mortar shells strikes.

A posteriori, these air challenges from Hamas (such as the changes in the northern theatre of Hezbollah and Iran's influence in the Middle East) were, in fact, not the most extreme adversary that Israel must contend with in the future. This all but demonstrates the ongoing "learning curve" of the "other side", which continues to recognize and exploit the weaknesses in the defense of the state actor – a phenomenon that threatens a variety of countries.

Innovative Technology Used by the IDF in Operation GW

With the IDF's extensive use of innovative technology during Operation GW, new standards and outputs have been achieved as a result. The following summarizes the most notable ones.

The technological aspects of airstrikes

Unlike previous operations, the IAF launched a powerful attack at the onset of this operation in response to Hamas' unprecedented heavy rocket fire launched, particularly on Tel Aviv and Jerusalem. In the first three days of the operation, the IAF fired nearly 1,000 munitions on about 750 different targets, of which 33 were offensive tunnels and another 160 were hidden rocket launchers. 60 terrorist operatives, including senior members of the Hamas, were targeted from the air, destroying four tower buildings. Most notably, in one of these attacks, 170 bombs were dropped in just 18 minutes without any civilian casualties.¹⁸ This achievement is extraordinary as

17. A. Bohbot, "[Plan Executed: Air Force Hit Infrastructure and Senior Members of Hamas Cyber Unit](#)," *Walla*, 19 May 2021.

18. Y. Ziton, "[170 Bombs in 18 Minutes and UAVs Interception: Documentation of Air Force Strikes](#)," *Ynet*, 13 May 2021.

these strikes were carried out on a small but densely populated area.¹⁹ This demonstrates highly advanced skills that require both intelligence capabilities, command and control, as well as precision-guided weapons and the expertise to operate them.

Although most of the attacks in the operation were carried out by fighter jets, the role of UAVs cannot be overlooked. They were crucial to the IDF's intelligence-gathering capabilities, especially within an asymmetrical conflict. Among other advantages, they enabled real-time intelligence-gathering with real-time decision-making in regard to the execution or cancellation of an air strike that would endanger civilians – namely, the “roof knocking” missions; these allowed non-combatants to leave an area before a larger attack was to be carried out to further prevent civilian casualties.²⁰

According to the IAF data, 70-75% of its operational flight hours were performed by UAVs. During the operation, about 20 UAVs were in the air at any given time. UAVs carried out 643 sorties for various missions for a total of 6,132 hours.²¹ This is a very large amount of flight hours considering such a short operation. For comparison, during the Second Lebanon War, about 16,000 hours of UAVs were flown over 34 days and about 21 UAVs were used at any given time, but in a much larger area than that of the Gaza Strip.²²

Nevertheless, since the Second Lebanon War, the IAF's UAV fleet has evolved greatly and now includes the Israel Aerospace Industries' (IAI) *Heron*, IAI *Heron TP (Eitan)*, Elbit *Hermes 900* and Elbit *Hermes 450* UAVs. These advanced systems allowed both cooperation between UAVs and between them and other air or land systems. For example, UAVs played an important role in missions to locate rocket launcher squads, which made their extermination possible.²³ By using UAVs, the IAF gained the ability to close a rapid ‘fire circle’²⁴ on those squads.²⁵ In fact, the IAF claims that it has managed to shorten the time needed to close a fire circle by 30-40%, including the time needed to receive information from a variety of sources and sensors, to make legal decisions, and then to process and disseminate that information.²⁶

19. The area of the Gaza Strip is 360 square kilometers and it is estimated that as of 2021 almost 2 million people live there, while in the area of the city of Gaza itself which is about 76 square kilometers more than half a million people live. See: Central Intelligence Agency, “[Gaza Strip – The World Factbook](#),” *Central Intelligence Agency*, 20 January 2022.

20. R. Yishai, “[‘The First Artificial Intelligence War’: The New Intelligence Methods in ‘The Guardian of the Walls’](#),” *Ynet*, 27 May 2021.

21. T. Lev-Ram, “[‘First of its kind in the world’: An ‘UAV exercise’ with the participation of 5 countries was held in Israel](#),” *Maariv*, 22 July 2021.

22. L. Antebi, “[Unmanned Aerial Vehicles in Asymmetric Warfare: Maintaining the Advantage of the State Actor](#),” in U. Dekel and al. (eds.), *The Quiet Decade: In the Aftermath of the Second Lebanon War, 2006-2016* (Tel Aviv: Institute for National Security Studies, 2017).

23. Capability that has been operational since the Second Lebanon War in 2006.

24. Also known as “sensor to shooter” – the time between identifying the target and its location until it is attacked.

25. S. Levi, “[They got a lot of assignments and each time they prove themselves more](#),” *MAKO*, 21 January 2021.

26. T. Eshel, “[Information Technology Drives Massive Growth in Israel's Combat Capability](#),” *Defense Update*, 21 May 2021.

AI technology

Israel is considered as a world leader in developing and implementing AI-based military applications, which had a tremendous impact on expediting the progress of closing fire circles. A senior IDF officer said that “for the first time, AI was a key component and force multiplier in fighting the enemy”.²⁷ It was considered as a first-of-its-kind campaign for the IDF, due to the implementation of new methods of operation and technological developments that constituted a power multiplier for the entire IDF.²⁸ AI was also used prominently in air defense systems (to be reviewed separately in this article), as well as in swarm technology, which will be addressed with relation to ground forces.

AI has improved and accelerated the scope, capacity, and lethality of real-time targeting processes. Based on these AI outputs, IAF pilots could then fire at targets on the ground. This ensured better efficiency of firepower, including accurate attacks that minimized collateral damage. Moreover, this technology – particularly machine-learning ones – were used to track, locate, and detect various targets, starting from launch squads to commanders and senior members of the terrorist organizations in Gaza.²⁹

One of the main challenges for advanced militaries around the world today is dealing with the vast amount of information pooling in from multiple sources, including a variety of sensors. The IDF has such extensive data collection capabilities – from the field of signal intelligence (SIGINT), visual intelligence (VISINT), and human intelligence (HUMINT) to geographic intelligence (GEOINT) – that the gross amount of information collected has caused a bottleneck due to difficulties in processing, synthesizing (including cross-referencing from various sources), and distributing the information to relevant parties in real time as usable intelligence.

The IDF revealed that during the operation, three new self-developed AI programs were put to use: “The Alchemist”, “The Gospel”, and “The Depth of Wisdom”.

“The Alchemist” software is a system that provides a dynamic visual image directly to the commander in the field. This system enabled real-time target detection and border protection. This helped counter strikes on the Israeli home front.

“The Gospel” is an intelligence system that generates recommendations based on AI capabilities for services determining what to target and the division command. These “target researchers” would confirm the various recommendations for targeting and work with the system to identify the high-value ones.³⁰ The implication of this software can be understood by comparative examination

27. A. Bohbot, [“The destruction of the metro and the thwarting of launches: the technological means that the IDF first operated in Gaza,”](#) *Walla*, 27 May 2021.

28. A. Bohbot, *art. cit.*

29. A. Kalo, *art. cit.*

30. S. Cohen, [“This is what hundreds of kilometers of Hamas ‘metro’ tunnels revealed by the Military Intelligence Directorate,”](#) *Israel Defense Forces*, 27 May 2021.

of the rhythm of target production before and during the operation. Throughout the 12 days of the operation, the IDF disclosed 200 high-value targets. According to the IDF, up until several years ago, this would have required an entire year to accomplish. The IAF then subsequently attacked 50% of these targets, which allowed the IDF to reduce the number of multi-barreled launchers and about half of the Kornet³¹ launchers.³² Those AI programs were developed by Unit 8200 of the Intelligence Corps.³³

In addition, Unit 9900 used AI to enable visual intelligence analysis through sensors, ISR sorties, and drones to create “dual maps” that modeled both the ground and the underground of the Gaza Strip.³⁴ These maps included infrastructure location, nature of the route, depth, and more. They made it possible to establish accurate fire plans for the IAF and the ground forces, as well as to execute the “Lightning Strike” operational program – the destruction of Hamas’ “metro” (offensive tunnels).³⁵ Unit 9900 also succeeded with the help of AI systems by launching smaller drones to spot “ground violations” designed to hide rockets, building tunnels, and bunkers, and thus produced additional targets to attack.³⁶

The multidisciplinary base – a new facility – was also first put into use. This base was attached to all of the Military Intelligence Directorate’s capabilities and worked in tandem with the IDF’s Southern Command and General Staff. Its aim was to rapidly identify high-value targets in real time. The facility demonstrated the Military Intelligence Directorate’s emerging capabilities with AI and that by connecting man and machine, significant intelligence output was produced.³⁷ It also contributed to preventing Hamas and the Global Jihad from carrying out the surprise attacks they had planned.³⁸

Air Defense

AI is also reflected in the IDF’s use of air defense systems that are characterized by a high level of autonomy.³⁹ The Israeli air defense is based mainly on the Iron Dome system. This is a mobile active air defense system used to intercept short-range rockets, mortar shells, and UAVs that was developed and

31. Kornet is considered one of the most advanced anti-tank missiles in the world.

32. A. Bohbot, *art. cit.*

33. Unit 8200 – Central Collection Unit of the Intelligence Corps. See: Israel Defense Forces, “[Military Intelligence Directorate](#),” *Israel Defense Forces*, 29 December 2021.

34. Unit 9900 – Unit 9900 is responsible for gathering visual intelligence including geographical data from satellites and aircraft. See: *ibidem*.

35. A. Bohbot, *art. cit.*

36. *Ibidem*.

37. IDF Website System, “[There was no operation conducted with such a coverage of intelligence: the chief of staff visited a factory that produces quality targets in real time](#),” *Israel Defense Forces*, 22 May 2021.

38. R. Yishai, “[The planes are in the air, the buildings are in danger](#)”: the IDF warned – and Hamas did not fire the final barrage to the center,” *YNET*, 22 May 2021.

39. International Human Rights Clinic and Human Rights Watch, “[Losing Humanity: The Case against Killer Robots](#),” *Human Rights Watch*, Accessed 13 March 2022.

manufactured in Israel. The system operates in all weathers and is capable of dealing with a large number of threats simultaneously and has been operational in the IDF since 2011. In recent years, the system has undergone now capable of withstanding the heavy Hamas fire during Operation GW. Improvements in logistics around the system have also allowed high-powered interceptions. Another upgrade has given one battery of the Iron Dome the capacity to intercept threats in another battery sector, subsequently gaining the ability to endure multiple rocket barrages in a short period of time.⁴⁰

Alongside this system, two other systems operated in parallel: the ‘Drone Dome’ (an electronic warfare system that disables drones) and the ‘David’s Sling’ system.⁴¹ The latter is an air defense system that was declared operational in the IDF in 2017.⁴² This classified system – a joint development of the Israeli company *Rafael* and the U.S. company *Raytheon* – has an interceptor missile that maneuvers quickly and directs itself by using a radar and an electro-optical sensor. This system is designed to be complementary to the air defense already provided by the Iron Dome.⁴³

Advanced Digital Technology Used by Ground Forces

No large ground maneuvers were executed during Operation GW as it was the case in Operation Cast Lead and Protective Edge. Among the ground activities that especially stood out were the units with the ability to use advanced technology.

For the first time, the ‘Multi-Domain Unit’⁴⁴ (intended to enhance the combination of all the different dimensions with an emphasis on connecting ground forces to fighter jets) was employed in an operational setting.⁴⁵ The Unit enabled a combination of elite fighters, drones, smaller aircrafts, ISR gathering systems, sensors and cyber activities, as well as command and control systems that worked with ground and air intelligence forces, to provide the timely exposure and destruction of the enemy. Specifically, during this operation, more than 20 enemy hideouts and bases were uncovered in the ‘Sajaiya’, where one of Hamas’ most powerful battalions operated.⁴⁶

In addition, the IDF operationally deployed a drone swarm to identify and destroy targets. AI capabilities enabled a group of drones to cooperate and form

40. U. Rubin, *art. cit.*

41. Formerly known as “Magic Wand”.

42. U. Rubin, *art. cit.*

43. A. Bohbot, [“An important milestone”: the successful experiment of the “magic wand” system – documentation](#),” *Walla*, 19 March 2019.

44. The unit is also known as a “Ghost Unit”, and considered as a plan for the IDF’s future Multi-Domain battalion.

45. T. Eshel, *art. cit.*

46. A. Bohbot, [“Locate from remote sites and attack quickly: The ‘ghost unit’ that changes the rules of the game in the ID,”](#) *Walla*, 21 August 2021.

a unified platform, equipped with a combination of sensors and weapons.⁴⁷ The swarm was activated by the “Exposure-Assault” squad from the Paratroopers Brigade.⁴⁸ It has contributed to uncovering Hamas’ hideouts, while working in coordination with weapon systems to attack dozens of targets miles away from the border.⁴⁹ The swarm succeeded in locating the enemy even within complex and crowded rural and urban areas, and in engaging and carrying out an assessment of combat damages (BDA) within minutes.⁵⁰

The mission of the drone swarms during this conflict was to locate and strike terrorists who fired rockets at Israel before they had the time to escape and, in some cases, even before they had the time to launch their munitions. Drones are advantageous because they can travel a long distance across borders, remain in place, and maintain continuous surveillance, while posing a lower risk to fighters. Despite not disclosing the types of drones used, it is known that the swarm contained several types of drones with different capabilities that together form a complete system. Additionally, the IDF used advanced technology to transfer intelligence from the swarm to its command system, enabling the activation of additional forces via the data they supply.⁵¹

The IDF’s command and control system also proved its importance. The system enabled, among other things, the rapid transfer of information, evaluation, and decision-making that qualified a variety of operations. Notably, the IDF employed the Elbit *Digital Army 750* system (*DAP 750*): a C4I platform that shows commanders both in the field and in the command rooms the location of friendly forces and enemies in the field.⁵² This system is a multi-dimensional force multiplier. Combined with it was the *Torch 750* system, which allowed battalion-level commanders to direct an attack from the air and to close fire circles in a short timeframe. This renders the maneuver more accurate and shortens the process required to attack the enemy.⁵³ The AI system also provides decision-making support to help commanders process information by displaying available forces and their locations, as well as the safe and legal aspects of their use, while recommending possible alternatives.⁵⁴

47. Z. Kallenborn, “[Applying Arms-Control Frameworks to Autonomous Weapons](#),” *Brookings*, 5 October 2021.

48. A. Bohbot, “[Exclusive: IDF Drones Swarms took part in the fighting in Gaza, and the rules of the game are expected to change](#),” *Walla*, 5 June 2021.

49. Z. Kallenborn, “[Israel’s Drone Swarm Over Gaza Should Worry Everyone](#),” *Defense One*, 7 July 2021.

50. T. Eshel, “[IDF Debuts Drone Swarms to Seek and Attack Hidden Targets](#),” *Defense Update*, 13 June 2021.

51. D. Hambling, “[Israel’s Combat-Proven Drone Swarm May Be Start Of A New Kind Of Warfare](#),” *Forbes*, 21 July 2021.

52. T. Eshel, “[Information Technology Drives Massive...](#),” *art. cit.*

53. A. Dombe, “[Five-dimensional combat: Cyber and electromagnetic spectrum targets gain legitimacy in ‘Guardian of the Walls’](#),” *Israel Defense*, 31 May 2021.

54. T. Eshel, “[Information Technology Drives Massive...](#),” *art. cit.*

Ground forces also used drones, like the relatively quiet THOR multirotor, designed for military users, capable of flying at altitudes of up to 3,000 ft, operational at temperatures up to 40 degrees Celsius, and with a carrying capacity of 3 kg.⁵⁵ In addition, it is known that the IDF also operated the *Spike Firefly* drone, which is also a loitering munition that weighs about 3 kg and is built in the shape of a cylinder that stands on a pair of folding rotors. The drone has some autonomous capabilities and is capable of attacking stationary as well as moving targets, such as vehicles, motorcycles, or walking persons.⁵⁶

Prominent Successes and Failures: What Can Be Learned from the Use of Technology in Operation GW

During Operation GW, the IDF accomplished many achievements, including substantial protection of the Israeli home front, as well as damage to Hamas. However, criticism about the operation was also made and it is clear that this was not an unambiguous success. Considering the large number of innovative technology used by the IDF as well as the high intensity of their use, it is natural to wonder what impact such technology has had on the operation against Hamas and the lessons that can be learned.

According to their own summary, the IDF managed to destroy large parts of Hamas' underground tunnels and neutralized dozens of senior officials and commanders of various ranks in Hamas and the Palestinian Islamic Jihad, along with about 200 other operational terrorists.⁵⁷ The IDF also hit more than 500 different components belonging to high-trajectory weapons or surface-to-surface rockets, and about 70 multi-barreled rocket launchers. Additionally, the IDF also damaged some of Hamas' future production and intensification capacities.⁵⁸ Finally, the IDF also attacked government buildings, including government ministries and the banks managing terrorist funds, as well as terrorist infrastructures such as camps, outposts, and command rooms.⁵⁹

While the IDF indeed carried out massive attacks on the terrorists, it is impossible to ignore the success of the terrorists, who fired 4,360 rockets and mortar shells on Israel for 12 consecutive days – more than which were fired during Operation Protective Edge over the course of 51 days. The IDF also confirmed that despite the achievements of this operation, only 10% of Hamas' rocket arsenal was destroyed by their various attacks.⁶⁰ The Israeli military has thus failed to achieve significant results in this operation. Due to the principle of “Mowing the

55. T. Eshel, “IDF Debuts Drone Swarms...,” *art. cit.*

56. Y. Stoller, “[Rafael and IAI Put their trust on Suicide drones](#),” *Calcalist*, 26 June 2018.

57. “[Operation Guardian of the Walls](#),” *Ministry of Foreign Affairs of the State of Israel*, 20 May 2021.

58. *Ibidem*.

59. *Ibidem*.

60. Y. Yehoshua, “[Half a year into Operation ‘The Guardian of the Walls’: How many terrorists were actually killed in the metro?](#),” *Ynet*, 12 November 2021.

Grass”⁶¹ (which seeks to deter terrorists and postpone the next round of fighting as much as possible), a significant part of Hamas’ capabilities were preserved, resulting in a limited achievement for the IDF. Hence the techno-tactical success, brought forth by the innovative capabilities developed and implemented by the IDF, did not, in fact, lead to real operational success. This is not necessarily due to technology but rather, to a variety of other factors.

Evidently, despite many changes, the IDF’s ability to act remains limited in a combat against a terrorist group that has deliberately assimilated among civilians in densely populated areas. This is not only an IDF weakness. It shows how the enemy cynically uses international law and Western liberal values, as seen in other conflicts where Western forces have engaged with terrorists and guerrilla groups.

During Operation GW, the IDF has made use of notably UAVs that fly for long durations, equipped with various means of identification and methods of action, including roof knocking missions to minimize civilian casualties on the other side. According to the UN Commission on Human Rights, 256 people were killed in the Gaza Strip, including 66 children. At least 128 of those killed were civilians with 62 of them being Hamas and other armed organizations – the rest remain undetermined by the UN.⁶² Despite the fact that civilian casualties remained, its rate was relatively low compared to similar cases, whether in previous operations involving the IDF or in worldwide operations in which massive airstrikes were carried out on densely populated areas.

Although the IDF’s ground forces’ strength was not widely displayed in this operation, it is still doubtful whether ground maneuvers would have made a significant contribution to the destruction of Hamas’ rocket launchers. It is evident that the operation’s success was mostly due to the standoff fire, including the many unmanned and digital means employed. In addition, the IDF’s superior intelligence-gathering capabilities (which was achieved mainly through technology and demonstrated the ability to carry out an air campaign with relatively little civilian casualties) was also a significant operational achievement. It was also a strategic achievement for the State of Israel, which requires international legitimacy to operate its military.

Although the IDF was not able to destroy Hamas’ weapons stockpiles, it is clear that the Israeli citizens were well protected. While the Iron Dome was required to intercept 160 rockets a day and sometimes deal with heavy barrages of over 100 rockets within minutes to the same area, the Air Force maintained a 90% success rate in intercepting rockets and mortar shells.⁶³ However, despite this success, terrorist organizations have continued to improve both in terms of their armament and their firing capabilities as they learn more about Israel’s de-

61. E. Inbar and E. Shamir, “Mowing the Grass’: Israel’s Strategy for Protracted Intractable Conflict,” *Journal of Strategic Studies* 37, no. 1 (2014): 65-90, DOI: 10.1080/01402390.2013.830972.

62. AP, “[Human Rights Watch accuses Hamas of war crimes in Operation Wall Guard](#),” *Haaretz*, 12 August 2021.

63. A. Levin and Y. Bustan, “[The stick and the laser...](#),” *art. cit.*

fenses. This has led some to argue that Israel needs an alternative system in addition to the Iron Dome, as the system's effectiveness may erode as barrages increase and rockets become more accurate.⁶⁴ In conjunction with other air threats, such as UAVs and drones of various types, Operation GW demonstrated their potential more than any prior operation.

Another issue that may be considered a technological failure is the case of the Iron Dome intercepting an IDF *Skylark* tactic-UAV. This was due to a lack of coordination between forces.⁶⁵ However, the interception itself is a success since the Iron Dome proved itself capable of hitting small and slow UAVs, similar to some of those used by terrorists to threaten Israel.

Another case of technological success with operational failure is the "Lightning Strike" operational plan, in which the IDF had hoped to neutralize hundreds of Hamas operatives in their underground tunnels. The plan, using deception, deployed a limited ground operation near the fence to mislead Hamas into thinking that the IDF had begun ground maneuvers. During this operational set-up, 160 aircrafts attacked about 150 underground infrastructure targets, according to an IDF report.⁶⁶ IDF's initial estimates of Hamas casualties were dozens, but after an updated assessment, it appears only 10 terrorists were killed.⁶⁷ In spite of technological success, it failed operationally. The advanced technology described in this article nonetheless allowed the IDF to find and destroy the tunnels quickly. However, even after destroying over 100 km of tunnels, it remains clear that the IDF was unable to inflict significant damage on Hamas' operatives, as originally planned.

Summary and Conclusions

Operation Guardian of the Walls brought the IDF many successes, but also a number of failures. It demonstrated the operational use of a wide range of innovative technology, as well as their combined use. Israel effectively showcased their impressive capabilities of both AI and UAV aspects in an asymmetric warfare. Their success has been the greatest in the protection of Israeli citizens via their advanced air defense systems and the use of advanced technology for locating and attacking targets in Gaza, all the while maintaining a relatively low rate of civilian casualties.

Such widespread media coverage of the use of AI in this operation did not happen without reason. Indeed, integrating these into warfare had a very significant impact on improving the IDF's capabilities. AI has demonstrated a great

64. *Ibidem*.

65. Y. Kubowitz, "[An Iron Dome accidentally intercepted an IDF unmanned aerial vehicle during the fighting in Gaza](#)," *Haaretz*, 25 May 2021.

66. Y. Ziton, "[The scam worked in part: only a few dozen activists entered the 'Hamas metro'](#)," *Ynet*, 15 May 2021.

67. *Ibidem*.

deal of accuracy and has shortened the time it takes to locate and engage targets. Furthermore, the technology not only helps its users but also has a significant impact on protecting civilians on the other side. Whether it is used in intelligence systems, a swarm of drones, air defense systems like the Iron Dome, or command and control systems, this is an emerging technology with evidently great potential, yet to be fully realized. Moreover, when it comes to the IDF's implementation of AI in weapons systems, it is clear that questions over the uncontrolled and immoral use of AI in military systems are still very much unanswered. Nevertheless, this demands further attention in the future due to the exceptional capabilities that this technology grants, particularly when it comes to less cautious users beyond liberal democracies.

Although technological improvements have allowed both the IDF to protect Israeli citizens and to neutralize Hamas targets in Gaza, they are not yet capable of stopping Hamas' fires during an operation or of destroying its future capabilities. In addition, while the IDF indeed located and destroyed Hamas' underground tunnels, no significant damage was done to Hamas' operatives, unlike what was intended. Despite the IDF's advanced technology, it appears that as a result of Israel's desire to maintain the legitimacy of their operations and to prevent civilian casualties, they were at times constrained in their ability to operate in Gaza. Israel thus faces a range of problems, namely Hamas' "learning curve" with the IDF, their use of both primitive and technological forms of warfare, as well as the restrictions of international law, all of which overall reduces Israel's technological advantage.

It appears that lessons learned from Operation Guardian of the Walls can also be applied by militaries in other countries, especially liberal democracies, in their efforts to combat terrorist and guerrilla activities. While democracies use advanced technology to deal with asymmetric warfare, their ability to fight and defeat terrorist groups remains limited by their desire to comply with international law and respect for human rights, which is cynically exploited by the "other side". Despite continual technological progress, such as that made by Israel, the "paradox of power" seems likely to persist for so long as there is an asymmetry in worldviews between terrorist groups and liberal democracies that affect how they wage war. Even in the face of these limited achievements, democracies must remember the benefits that technology can bring and continue to pursue and use their advantages to prevent the "other side" from doing the same.

VARIA

Russia's Use of Air Power: Early Lessons Learned from the First Month of the Conflict in Ukraine (24 February – 24 March 2022)

Gwenvaël Coulombel, lieutenant Malcolm Pinel, colonel Xavier Rival

Xavier Rival has carried out numerous military operations as a fighter pilot and fighter squadron commander in Central Asia, the Middle East, and Africa. A graduate from the French École de l'Air and the United Kingdom's Advanced Command and Staff Course, he also holds a Master of Arts in Defence Studies from King's College London. Currently, he is extending his education at the Royal College of Defence Studies, also situated in London.

Gwenvaël Coulombel holds a degree in economics from the Instituts d'administration des entreprises Nantes – Économie et Management, as well as in business management from the Grande École Audencia Nantes. He is currently a professor of economics for the ENC Group's Écoles Nantaises de Commerce. His expertise lies in strategic and economic issues within the military aerospace industry. Specifically, his research examines A2/AD postures.

Malcolm Pinel is a PhD candidate at the Laboratoire Interdisciplinaire Mutations des Espaces Économiques et Politiques – Paris-Saclay, while being associated with the Institut de Recherche Stratégique de l'École Militaire. He specialises in post-Soviet space security issues, as well as on Russia's aerospace power. He is a graduate from the École de l'Air and holds a Master's degree in political science from the Université Jean Moulin – Lyon 3. His dissertation addresses Russia's air strategy in the Middle East from the 2000s and onwards.

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Introduction

On the night of 23 to 24 February 2022, a volley of cruise and ballistic missile salvos marked the beginning of Moscow's "special military operation" in Ukraine.¹ From the ground, a Russian offensive on a scale not seen in Europe since the end of the Second World War was also launched in parallel.

1. специальная военная операция: *spetsialnaiya voieniannaiya operatsiya*.

180,000 Russian soldiers flocked in on all three fronts in the north, east, and south of Ukraine. Kyiv, which relies on a regular army of around 200,000 soldiers,² arranged themselves for a widespread mobilisation. After one month, the Ukrainian people and their army continue to resist the invasion without faltering. This has forced Moscow to reconsider its trajectory: resigning from their goal to seize Kyiv and redeploying to the east of Ukraine.

This initial failure can be considered the result of numerous factors. Amongst the many reasons often alluded to is the rather ill-use of the Russian aerospace forces (*VKS*)³. Russia not only failed to acquire air superiority in Ukraine,⁴ but also suffered significant aircraft losses.⁵ While there were indeed regular aerial bombardments over a large part of Ukraine, the “high position” of the third dimension constitutes an indispensable asset for successful ground operations – had not been seized.

At the beginning of the conflict, the *VKS* was granted a substantial advantage over the Ukrainian Air Forces. The latter only possessed about 100 combat aircraft⁶ and around 50 helicopters⁷ with limited and near-obsolete air defence systems. This is in stark contrast to the far more modern assets belonging to Russia, which it acquired after significant post-2008 military reforms. Despite Russia's air force having achieved very mixed results in Chechnya and Georgia, and its subsequent absence in the 2014 Crimean annexation, it nevertheless demonstrated clear operational capabilities in Syria since 2015.⁸

Although it may be premature after only one month into the conflict for this article to embark on an analysis amidst much disinformation,⁹ it is nevertheless essential to discern *VKS*'s role in Ukraine during late February and throughout March 2022. Taking into account the available open source data with a lot of reserve, this article questions – following the one published in *Vortex*'s second issue¹⁰ – the way in which Russia has employed its air power. Furthermore, it ar-

2. V. Akimenko, “[Ukraine's toughest battle: The challenge of military reform](#),” *Reforming Ukraine project, Carnegie Endowment for International Peace*, 22 February 2018.

3. The *VKS* (*Vozdouchno-kosmicheskiye sily*) includes the air force (*VVS*), the (*Kosmicheskiye voyska – KV*) and the air and missile defence forces (*Voyska protivovozdushnoy i protivoraketnoy oborony – V PVO PRO*).

4. K. Osborn, “[The Overlooked Reason Why Russia Can't Control Ukraine's Skies](#),” *The National Interest*, 06 May 2022.

5. S. Mitzer and al., “[List Of Aircraft Losses During The 2022 Russian Invasion Of Ukraine](#),” *Oryx blog*, 20 March 2022.

6. Y. Mahé, “Guerre en Ukraine, combats aériens dans le ciel d'Europe,” *Aéro journal*, No. 87, (2022): 5.

7. Including 34 upgraded Mi-24PU1 *Hind*.

8. A. Lavrov, “Russia in Syria, a military analysis,” in N. Popescu and S. Secieru (ed.), *Russia's return to the Middle East, building sandcastles. European Union Institute for Security Studies, Chaillot Papers*, (2018): 47.

9. This article was written in April 2022.

10. X. Rival, M. Pinel, “Aspects qualitatifs de l'intervention russe en Syrie,” *Vortex* 2, (2021): 135-151.

gues that the Russian command had launched its military operations into Ukraine without much reliance on its *VKS*, which it perceived as being limited in power. In short, Russia's General Staff was perhaps overconfident that victory could be achieved without a significant use of air power.

This article thus attempts to outline the Russian manoeuvre in the first month of the conflict *via* two encompassing but distinct phases, further dissected into five assertions. To begin, the rapid capture of Kyiv seemed to have been the topmost priority during the conflict's first two days. However, the decision to carry out a massive bombing campaign – mirror that of Iraq in January 1991 – soon failed to be realised. To compensate, Moscow subsequently deployed its armed forces to brutally target civilian populations without any hesitation with artillery. Secondly, the *VKS* had also failed to acquire air superiority due to a combination of inadequate weaponry to deal with a contested environment and the economic sanctions imposed on Russia in 2014. Thirdly, Russian forces were also held back by a outdated, short-sighted vision of air power without being able to renew itself.¹¹ As a result, gaining air superiority became dependent on the neutralisation of ground-to-air systems. Fourthly, in the meanwhile, Ukrainian forces on the ground were beginning to push back against Russian soldiers, who had neither the support nor the ability to protect themselves in and through three dimensions. Lastly, the conflict may well have lasting consequences on Russia's aerospace industry as well as on the regeneration capabilities of the *VKS*.

The *VKS*: Excluded from Russia's Initial Plans?

Russia's initial plan seemed to have favoured a *fait accompli* strategy based on decapitating the existing regime in Ukraine. Reminiscent of Crimea 2014, this would translate into a manoeuvre of lightning speed. A classic air campaign would thus have been drawn out by several weeks before any Russian ground invasion could take place. This would remove the element of overwhelming, which would have been essential to the strategy's success. Admittedly, before the outbreak of hostilities, it was highly possible for Kyiv to fall. Due to geographical factors, Ukraine could not concentrate their forces around their capital if they were to fend off the Russian forces semi-encircling their borders. Not only is the area north of Kyiv sparsely populated, separating it from the Belarusian border is only a mere 150 kilometers. Moreover, the Gomel base in Belarus – Russia's first major logistical point to support its engagement in Ukraine – is only 260 kilometers from Kyiv.¹² To contextualise this on the scale of France, notwithstanding the nature of the terrain, this is the equivalent to Paris being threatened by foreign forces amassed in Reims and Sedan. Thus, for Moscow, the decision to impose a *fait accompli* was not completely absurd.

11. The vision of operative art; “оперативное искусство” – *operativnoye iskusstvo*.

12. A morning's drive for a military convoy consisting of reconnaissance vehicles, light armoured vehicles, troop carriers and trucks.

Although these issues can be debated, this article posits that Moscow intentionally disregarded the acquisition of air superiority during the first phase of its *blitzkrieg* towards Kyiv. To be fair, a systemic air bombardment campaign on Ukraine's command and control (C2) infrastructures, and air defence capabilities could have very well provoked even further international outcry that would prevent Russian armed forces from entering Ukraine whatsoever.

Ultimately, a series of strikes was chosen as the optimal engagement, as opposed to a long-lasting, intense bombing campaign. These strikes were carried out by both the SS-21 *Scarab* (Totchka-U) and the SS-26 *Stone* (*Iskander*) tactical ballistic missiles.¹³ There were also more than 300 cruise missiles¹⁴ fired from ships in the Black Sea, as well as from Tu-95MS and Tu-160M strategic long-range aircraft bombers (*dal'nyaya aviatsiya*) operating from Russian and Belarusian airspaces.¹⁵ However, the targeting process for these munitions are much too rigid to be effective against mobile systems, such as the S-300. Thus, these strikes focused on C2 centres, fuel and ammunition depots, radar sites and fixed ground-to-air defence sites. Airfields were avoided, perhaps with the intention of reusing them should victory be obtained.

These attacks, although concentrated on military targets, could have also served a double objective of also breaking the resolve of both Ukrainian civilians and its military. The operational gamble here is that the decapitation of government structures could, on the contrary, backfire as the population may be enraged even more to fight back. In any case, the air campaign ended too soon with an intensity that was too low without any strategic objectives set. Specifically, it did not set the stage for a conquest of air superiority, especially since Ukrainian armed forces had learned of the imminent strikes, and as a result, they dispersed a large part of their arsenal.¹⁶ Almost a reflection of what the Finnish armed forces did during the Soviet aggression in 1939 to 1940, Ukraine was able to considerably limit the impact of its enemy strikes.¹⁷

The turning point for this extremely short first phase of the conflict was the audacious helicopter assault on an airport near Kyiv. To seize the Hostomel airport on 24 February 2022, several dozen Mi-8MTV-5/AMTsh *Hip* helicopters had transported 300 paratroopers¹⁸ from the Russian Airborne Forces (VDV),¹⁹

13. After a month of conflict, more than 1,000 ballistic missiles are reported to have struck Ukrainian territory, see A. Mahsie, "[Air War Ramps Up in Russia-Ukraine Conflict as Russian PGMs Run Out](#)," *Airforcemag*, 21 March 2022.

14. T. Robinson, "[Air War over Ukraine – the first days](#)," *Aerosociety*, 2 March 2022.

15. E. Tenenbaum, "War in Ukraine: a lesson in strategic grammar," *Briefing de l'IFRI* (2002).

16. T. Cooper, "[The MiG-29s and Su-25s that EU could donate to Ukraine and Why the Russians have not achieved 'Total Aerial Superiority' in the Ukrainian skies](#)," *The Aviation Geek Club*, 28 February 2022.

17. I. Rehman, "[Lessons From The Winter War: Frozen Grit And Finland's Fabian Defense](#)," *War on the rocks*, 20 July 20216.

18. Y. Mahe, "Guerre en Ukraine: combats aériens dans le ciel d'Europe," *art. cit.*, 11.

19. *Vozdushno-desantnyye voysk*. Here the 11^{ème} Guards Airborne Brigade reinforced by the 31st Guards Airborne Assault Brigade and GRU *spetsnaz*.

while being escorted by a few Su-25 *Frogfoot* and Ka-52 *Hokum-B* for close support. Yet, before arriving at their destination, several Russian helicopters were shot down by Ukrainian soldiers equipped with man-portable air-defence systems (MANPADS). This counter-offensive was led by the Ukrainian National Guard's 4th Rapid Reaction Brigade, and supported by their Air Force's MiG-29 *Fulcrum*, Su-24M *Fencer*, and Mi-24 *Hind*, ultimately forcing the paratroopers to withdraw.

Despite this first setback, which could be argued as the turning point of this first phase of the conflict, the Russian forces nevertheless launched a second assault in the morning of the 25th. It was carried out by a military column of ground forces, and 200 helicopters carrying nearly 1,500 paratroopers, amongst them the *Spetsnaz*.²⁰ While the airport's platform was successfully seized, the initial political objective was not: the Ukrainian regime did not collapse, but rather it was able to successfully mobilise its armed forces. The population also rallied behind Ukrainian President Volodymyr Zelensky, who quickly proved his legitimacy as a wartime leader. As the fighting raged on, the Kremlin was forced to adopt a new strategy.

In short, obtaining air superiority was not deemed as a necessity in the initial plans of Russian officials. They most likely thought that it would have been impossible to entrust the *VKS* with such a mission. The scale of such a task was too demanding while the resources to do so were far too little. Indeed, the vastness of the Ukrainian airspace rendered the pursuit for air control a near-sisyphean task. Moscow would have had to launch thousands of missiles – which they did not possess at the start of the conflict – in order to destroy all the systems spread across Ukraine.

On the other hand, the means needed to destroy mobile ground-to-air defence systems was almost non-existent within the *VKS*. They only had a limited number of anti-radar missiles and fighter-bombers, an inventory unequipped for such missions. Moreover, despite the operational expertise showcased by the Russian crews deployed to Syria,²¹ this particular mission, on the contrary, demanded vastly different skills.²² The *VKS* continues to remain incapable of conducting massive and complex air raids that require several dozen combat aircraft able to achieve strategic outcomes. The few available air-to-air refuelling tankers were allocated primarily to its long-range aircraft.²³ This significantly delayed Russian fighter crews from immediately assembling into dominating formations. As a

20. Y. Mahe, "Guerre en Ukraine...", *op. cit.*, 13.

21. T. Cooper, "[Here's why Moscow declared 'Total Aerial Superiority' in the Skies over Ukraine and why Russia does not use its Jets as Multi-Role Aircraft](#)," *The Aviation Geek Club*, 1 March 2022.

22. D. Leone, "[Former US Navy Operations Specialist explains why Russian Air Force pilots have the capability to defeat Ukrainian air defences but they're not good at it](#)," *The Aviation Geek Club*, 07 May 2022.

23. J. Bronk, "[Is the Russian Air Force Actually Incapable of Complex Air Operations?](#)," *RUSI*, 4 March 2022.

result, flights were limited to four or even two aircraft at a time, rendering them powerless against multi-target, mobile ground-to-air systems.

All in all, the *VKS* was not ready to acquire air superiority. This is quite bewildering, considering that after 2008, Russia went through profound reforms to acquire several hundreds of new aircraft. The reasons for these capability shortfalls hence deserve to be explored.

Russia's 2014 Adventurism Stumps *VKS* Growth

In order to understand these shortcomings, it is necessary to return to 2014. It was a time when Russia's defence's industry was still highly interdependent on Ukraine's. This was due in part to historical roots, stemming from the Soviet era. At the time of the USSR's dissolution in 1991, approximately 30% of the Soviet defence industry had been located on Ukrainian territory.

Moreover, up until the annexation of Crimea in 2014, Russia had continued to be the third biggest client in Ukraine's defence industry. Notably, Russia's helicopter engines were produced by *Motor Sich*, a company located in Zaporizhia in southeastern Ukraine. A large part of its transport aircraft fleet was also linked to the Kyiv-based aircraft manufacturer *Antonov*.²⁴

Ukraine also played a key role in supplying the *VKS*²⁵ with air-to-air missiles. The design and production of the *Vympel* R-27 (AA-10 *Alamo*), the R-73 (AA-11 *Archer*), and the R-77 (AA-12 *Ader*) missiles were done at the *Artem* factory in Kyiv. Ironically, the hydraulic system of the Su-34, which was used to provide air support to Russian troops during the invasion, is also of Ukrainian origin.

After Russia annexed Crimea, *Ukroboronprom* (a Ukrainian government holding company, created in 2010, with nearly 100 state-owned subsidiaries in Ukraine's defence sector) ceased all military equipment exports to Russia. This decision came into force on 17 June 2015 by then Ukrainian President Petro Poroshenko, who categorically forbade any industrial military or technological cooperation with Russia.

Inevitably, this embargo also delivered a substantial blow to the economic survival of many Ukrainian aerospace companies, albeit some managed to develop other products, such as the AI 222-25 engine (designed by *Ivchenko-Progress* and produced by *Motor Sich*) for the Chinese *Hongdu* L-15 advanced trainer. Nonetheless, the Russian military industrial complex and the growth of the *VKS* still suffered severe consequences. Firstly, any production of Russian equipment that relied on Ukrainian subcontractors was largely curbed. Second, the production of radar models, missile homing devices, and guided bombs, as well as

24. "Russia & Ukraine Military Industry," *Global Security*, 21 July 2021.

25. T. Cooper, "Know Your Enemy: why the Russian Air-Space Force is not meant to fight the way Western Air Forces do and Why it rules the Ukrainian skies – above the frontline," *The Aviation Geek Club*, 11 March 2022.

electronic warfare modules were also impacted by the cessation of imports of electronic components and sub-systems manufactured by Ukrainian companies. The General Staff of the Armed Forces had tried to substitute these imports with Russian products, but has only been partially successful thus far.²⁶

Furthermore, financial resources proved insufficient in acquiring stocks sufficient enough to supply the necessary amount of ammunition for an intensive bombing campaign. The industrial process of producing Russian guided munitions²⁷ was particularly costly as it was never streamlined. There exists no modular guidance kits for converting bombs into guided munitions. The *VKS* has therefore had to draw on its remaining few stocks of guided ammunition, which had already been depleted by its operations in Syria. The production and procurement of designation pods suffered from the same supply difficulties and a long-term underinvestment. Finally, in the field of jamming, the *VKS* have chosen less expensive solutions that can be integrated onto several aircraft models, such as the *Khybini* pods.²⁸ The trade-off is a reduced maximum weight load capacity.

Considering this, Russia's strategy to "demilitarise" Ukraine was either to seize core components of Ukraine's defence industry or destroy them. Indeed, capturing certain Ukrainian industries may well fill in the aforementioned gaps in Russia's own military industry.²⁹ It was this precise strategy that had been implemented upon the annexation of Crimea in 2014. Russia had then taken control of the Zaliv shipyards in Kerch. As a result, it was able to fill a significant capability gap by launching the construction of its current *Ivan Rogov*-class, assault helicopter carriers.

In parallel, Moscow aimed to destroy any infrastructures that produced ammunition or repaired/maintained the equipment needed to sustain Ukraine's war efforts. The attacks on the aeronautical maintenance centre in Lviv may be interpreted as such.³⁰ As the conflict continues onwards, more clarity of this prevailing strategy will come to light following any possible actions taken against industrialists, *Yuzhmash/Yuzhnove*, in Dnipropetrovsk (*Zenit* launchers and SS-18 *Satan* intercontinental ballistic missiles) and engine manufacturers, *Ivchenko-Progress* and *Motor-Sich*, in Zaporizhia.

Moscow has thus found it very difficult to equip all of its latest generation fighter aircraft with advanced equipment. Acquiring large fleets of fighters seems to have been prioritised over the development of a smaller but state-of-the-art

26. J. Johanneson, "Russia's war with Ukraine is to acquire military industrial capability and human resources," *Journal of International Studies* 10, n° 4 (2017): 63-71.

27. *Vysokotchnoye oruzhiye – VTO*.

28. Su-27, Su-34 and Su-35S.

29. Also on the global space industry due to the destruction of the An-124 *Condor*, see J. Rainbow, "[Antonov shortage threatens delivery delays for the biggest satellites](#)," *RUSI*, 7 April 2022.

30. J. Beale, "[Ukraine war: Russia destroys aircraft repair plant near western city of Lviv](#)," *BBC News*, 18 March 2022.

air force. While the Kremlin seems to have intended to keep a large number of relatively modern aircraft in commission, their development has nevertheless suffered from budgetary constraints. This choice is based on a constricted doctrinal vision characteristic of Russian armed forces and strategists.

Air Power's Minimal Role in Russian Operational Art

Analysing Russian air operations through the eyes of Western perspectives may sometimes lead to further questions. Indeed, Russian planners do not conceive the use of air weapons in terms of effects, but as a means of applying firepower on the battlefield or penetrating deeply into an enemy's military structure. The planning of Russian operations is ultimately the result of a doctrinal corpus resolutely different from the West's. Russian operative art was borne of the theorisation of the "deep battle" concept³¹ by Vladimir Triandafillov, developed in his 1928 *The Nature of the Operations of Modern Armies*.³² In short, the importance of aviation³³ during its fledgling years at the time was still quite under-acknowledged.

The pivotal moment was heralded by the publication of Georgii Isserson's 1936 *The Evolution of Operational Art*,³⁴ which integrated armed components into manoeuvring. He defined operational art as obtaining a succession of effects at the theatre level *via* the combination of various land weapons (infantry, cavalry, artillery, etc.). The aim is thus to break through the front lines in various locations with heavy firepower, and to then exploit these gaps by launching mobile troops deep into the enemy body to induce its collapse by destroying its "nerve points". The essence of operative art is the search for victory at the strategic level by combining means to analyse the enemy's system in its depth.

Aviation was again hardly mentioned. Rather, Isserson insists on the quantitative and qualitative weaknesses of combat aircraft at the end of the First World War.³⁵ Interpreting this poor performance as a *fait accompli*, he judges that air forces, in its small number, should first and foremost serve the purpose of ground troops.³⁶ The air force must therefore contribute to the rupture of the enemy front with its fire,³⁷ and support the offensive in the long-term by striking at enemy reserves.³⁸ It was this use of air power that the Soviets retained throughout the Second World War, but this time at an industrial scale. Specifically, it was to establish the tank-aircraft pairings during a series of victorious offensives that had forced the German armies back to Berlin.

31. *Dalnaya voeyna*: deep trouble, *dalnaya glubovskaiy*: deep battle.

32. V. K. Triandafillov, *The Nature Of The Operations Of Modern Armies* (Oxon: Routledge 1994).

33. Triandafillov reduces combat aviation to its core as: "[forces] performing direct combat mission accomplishment usually concentrated on the operational-tactical and tactical levels".

34. G. S. Isserson, *The Evolution of Operational Art*, *Combat Studies Institute Press* (Fort Leavenworth, KS: Combat Studies Institute Press, 2013).

35. V. K. Triandafillov, *op. cit.*, 72.

36. G. S. Isserson, *op. cit.*, 62.

37. *Ibidem*, 66.

38. *Ibidem*, 67.

This interpretation of operative art had then dominated Soviet thinking throughout the Cold War. If this vision of Russian air power has evolved today,³⁹ Russian officers, during discussions in the magazine, *Voennaya Mysl* (*Military Thought*), still struggle to combine new theories to old practices. In the Syrian conflict against irregular armed forces,⁴⁰ Russia has continued to direct their focus towards the ground.⁴¹ In particular, it tends to refer to the notion of fire superiority rather than air superiority.⁴² Based on what was learned from the Syrian conflict, military leaders have grown to emphasise the development of infantry and artillery capabilities with their associated C2 systems to draw upon simplistic conclusions.⁴³ Moreover, confidence in the Russian air force's relative success in Syria may have cultivated a certain negligence towards exploring more alternative uses of airpower. Such a mindset rendered them unprepared in the face of the conflict with Ukraine.

Hence, from Russia's point of view, air superiority over the battlefield is therefore not an objective of utmost urgency, but simply a condition for achieving fire superiority within a theatre. Furthermore, there was no impetus to reorganise air defence forces in order to protect ground units from TB2 drones – even though they were acknowledged as a veritable threat after the conflict in Nagorno-Karabakh.⁴⁴ There were also severe shortcomings in terms of the suppression of enemy air defences (SEAD). Russia had carried out a succession of strikes without substantial coordination during a mass missile-aircraft strike (MMAS) campaign⁴⁵ against enemy air defences. Ballistic missiles (*Iskander-M*) and cruise missiles (*Kalibr*, Kh-55, and Kh-101) were fired at Ukrainian ground-to-air batteries with only relative success with some being intercepted.

To make matters worse, the VKS has very little influence in the Russian government, which is filled with those without a military aviation background. For instance, at the head of the Russian Air Force is a general from the Russian Ar-

39. V. Turret, "Russian and Chinese Multi-Domain Approaches: the Same Aerospace Battle?," *Vortex* 1, (2021): 39-51.

40. Col. K. A. Trotsenko, "Hostilities in Syria: Just an Incident, or an Advance in Methods of Conducting Combined-Arms Combat," *Military Thought* 30, no. 1 (2021): 75.

41. "Then verify the conclusions made during field experiment, arm current domestic tactics with the guiding idea of combined-arms combat, and start developing the modern basics of the army and strategic operation," *ibidem*, 79.

42. "Superiority in the possibilities of target reconnaissance and target designation as a type of fire preponderance and a constituent of fire superiority is precisely what ensures high speed advance. In the absence of similar preponderance, an attack will invariably encounter a variety of ambushes, firing lines, wandering tanks, armor groups, and other small-tactic inventions that necessitate depositing many tons of ammunition ahead of advancing troops," *ibidem*, 95.

43. Col. A. P Korabelnikov, Col. Yu. V. Krinitsky, "Evolution of Operational Doctrine and Tactics of Fighting in Aerospace," *Military Thought* 30, no 4 (2021): 80-90.

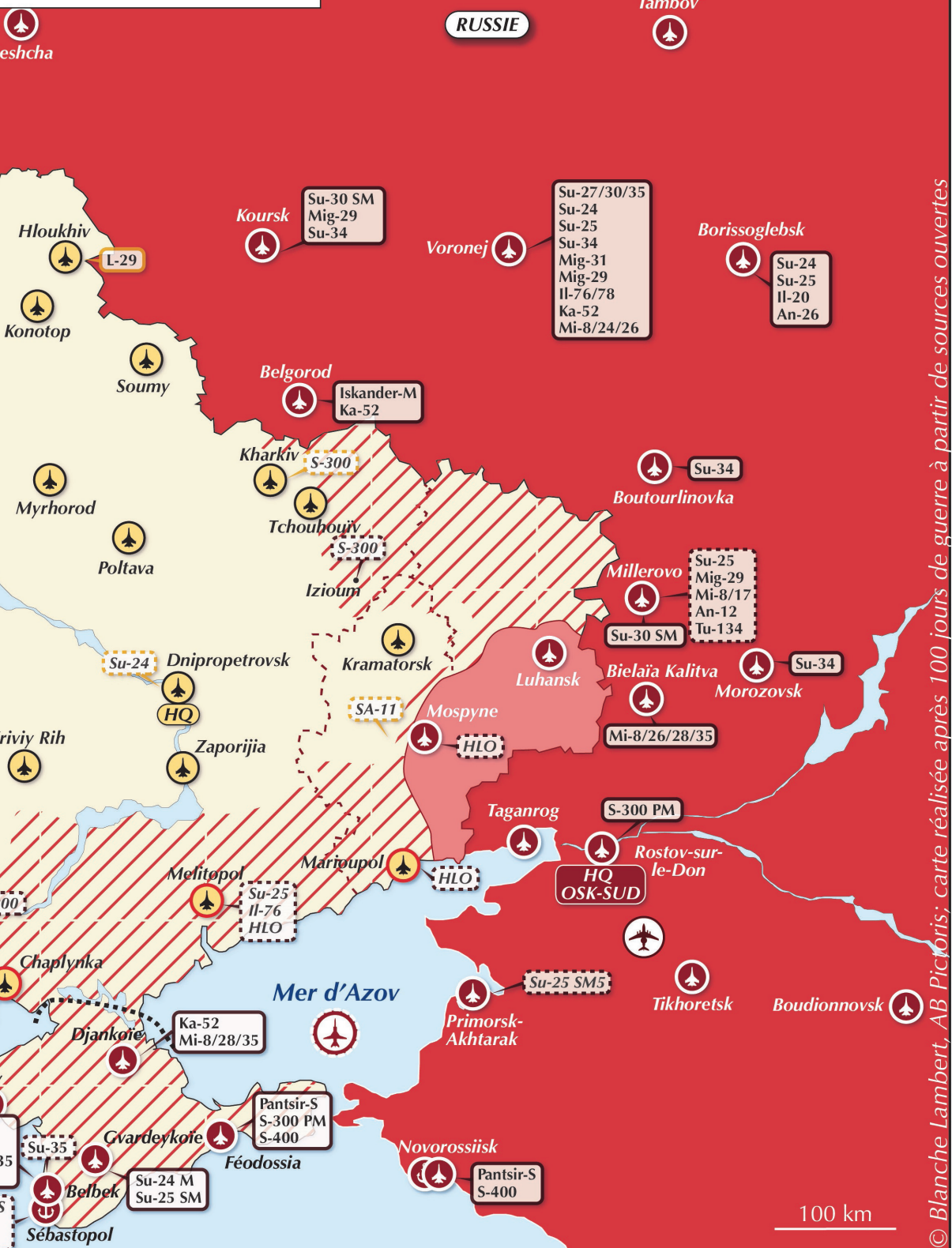
44. Col. A. V. Shubin, Col. I. V. Kot, Col. A. A. Kuzenkin, "Changing Conceptual Approaches to Aviation Use in Wars of the Future, Based on the Nagorno-Karabagh Conflict," *Military Thought* 30, no 4 (2021).

45. Col. V. N. Tikshayev, Lt. Gen. V. V. Barvinenko, "The Problem of Fighting Unmanned Aerial Vehicles and Possible Solutions," *Military Thought* 30, no. 2 (2021).

La bataille aérienne



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my.⁴⁶ Indeed, even the Special Operations Forces (SSOs) that took charge of the Russian forces in Ukraine at the joint level are mostly from the cavalry, infantry, or artillery. Meanwhile, the Minister of Defence is a former civilian with a vision better defined as a reformer rather than a strategist.⁴⁷ Finally, for Russian President Vladimir Putin, who is deeply rooted in the KGB culture, it rarely seems to occur to him to employ air power beyond counterterrorism, internal security operations, or clandestine operations – despite the large fleet of helicopters and planes in his possession.

Simply put, *VKS*'s capability modernisation, which began in 2010, was not accompanied by the doctrinal reforms necessary to integrate Russian aerospace power into strategic or even operational planning. The *VKS* therefore reverted back to their old operational habits, giving priority to their air artillery role rather than to the conquest of air superiority over all of Ukraine.

Insistence to Continue the War in the Air by Other Ways

When the initial plan failed, the *VKS* redirected their efforts in the second phase from low to extremely low altitudes in order to support ground troops. The challenge was then to avoid being shot down by Ukraine's medium- and long-range ground-to-air systems. So as to not stray away from the tenets of Russian operational art, almost no vital Ukrainian infrastructures were targeted, and therefore no strategic effects were generated. A significant portion of the *VKS* would also have been placed in reserve to deter or counter a potential NATO attack. Indeed, external threat perceptions continue to be largely exacerbated due to Russia's traditional, incompressible encirclement complex: evoking a security paranoia of a besieged fortress is an integral part of the Kremlin's strategic grammar. The aerial war then takes an unexpected turn, ultimately influencing the outcome on the ground.

As alluded to previously, the use of the *VKS* in Ukraine is reminiscent of the one in Syria: an alternation between periods of engagement and operational pause. The circumstances also mirror the support provided to the Syrian Arab Republic troops near the Idlib pocket, where the efforts to establish humanitarian corridors were ignored. Subsequently, like then, the *VKS* mainly fired unguided bombs. They were forced to confront Ukraine's considerably short-range ground-to-air threats by operating, at times, in urban areas and at others, during poor weather conditions.

The number of Russian aircraft shot down increased significantly at the beginning of this second phase, which started on 26 February. The Russian armed forces lost at least three helicopters (Ka-52, Mi-35) and four fighter planes (Su-25, Su-30, Su-34 and Su-35) within six days.⁴⁸ Thereafter, attack missions

46. *Sukhoputnye voyska*.

47. M. Zygar, *All the Kremlin's Men, inside the court of Vladimir Putin* (New York: Public Affairs, 2016): 271.

48. S. Mitzer, "Attack on Europe: Documenting Equipment Losses During The 2022 Russian In-

appeared to have mostly taken place around dawn and dusk. This not only granted aircraft less exposure to MANPADS, but also a bit more luminosity to their crews – as opposed to what little could be seen through night-vision goggles and *FLIR* systems.⁴⁹

Needless to say, the Ukrainian air force did not sit around idly but relentlessly launched their own attacks. Because Russian forces were much more static – not to mention, poorly equipped, they seemed to have been easy targets for the remaining Ukrainian fighter planes (Su-24, Su-25UB, Su-27) and drones.⁵⁰ Aerial combat continued to be observed. Concurrently, free-fighter missions were also carried out⁵¹ by the Ukrainian Air Force.⁵² For these, infrared missiles were preferred over the use of precise radar-informed target designations.⁵³ Ukrainian air defence fighters thus operated under the orders of ground controllers (GCI).⁵⁴ They also relied on a visual lookout network and did not hesitate to use highways as take-off or landing strips.⁵⁵

From a different point of view, combat in the third dimension was paradoxically epitomised in the battle against mobile ground-to-air defence systems. The latter generally poses such a constant threat that crews would often be more preoccupied with protecting themselves than completing their missions. Indeed, when there are no means to establish an enduring SEAD, the ability to use the third dimension would then normally default to the belligerent that has deployed its adapted ground-to-air systems.

In this context, the Russian armed forces seem to struggle to prevent Ukrainian aircraft, especially drones, from flying over their units. At times, their ground-to-air defence systems (SA-15, SA-17, and SA-22) could neither provide adequate air surveillance nor a protective shield, despite being integrated at the regimental level. A lack of communication, inter-brigade coordination, support, and supplies (fuel, repair services, mapping, lack of operator training) were the likely causes. Moreover, seeing how Russian ground-to-air batteries were left abandoned and then towed away by Ukrainian civilians only speak to the Russian forces' weak commitment to the conflict. Indeed, the Russian operators' weak resolve and quick abdication in the face of war's hardships could be illustrated by the testimonies of many conscripts. They claimed that

vasion Of Ukraine”, *Oryx Blog*, 24 February 2022.

49. J. Bronk, *art. cit.*

50. S. Mitzer and al. “[Defending Ukraine – Listing Russian Army Equipment Destroyed By Bayraktar TB2s](#),” *Oryx Blog*, 27 February 2022.

51. T. Cooper, “[Here’s why Ghost of Kyiv, the Ukrainian Mig-29 pilot credited for having shot down 6 Russian jets is just an Urban Legend](#),” *The Aviation Geek Club*, 25 February 2022.

52. According to J. Bronk: 200-250 air sorties are observed per day for the *VKS* but very few are flown over Ukraine; 5-10 air sorties are observed per day for the Ukrainian Air Force, which reportedly keeps about 55 combat aircraft operational.

53. T. Newdick, “[Ukrainian Mig-29 Pilot’s Front-Line Account of The Air War Against Russia](#),” *The War Zone*, 1 April 2022.

54. *Ground Control Interception*.

55. T. Newdick, *art. cit.*

their commanders had manipulated them into thinking they were participating in military exercises before being herded into a deadly conflict against their slavic brothers.

In terms of morale, the Ukrainian population appeared to have been greatly galvanised by the aerial achievements of the “Ghost of Kyiv”. Whether myth or fact is irrelevant as it succeeded in what it was intended for: a united national fervour to fight and defend Ukraine was ignited. The song, celebrating the TB-2 *Bayraktar*,⁵⁶ did the same. Indeed, these tales and hymns only prove that the realm of aerial warfare continues to enthuse public opinion and enthrall their imagination. This also mirrors the effects produced by the video games designed to achieve aerial victories over Russian fighter planes (MiG29 against Su-27).

Given its operational importance and impact on morale, it seems only natural that Zelensky considered the third dimension a pivotal factor for Ukraine. He has repeatedly called on his Western partners to “close the skies”. Insisting in the U.S. Congress on establishing a no-fly zone over Ukraine, he has even referenced the casualties suffered from the Pearl Harbor attack and the tragedy of 9/11. Eastern European countries, such as Poland, have offered to provide the MiG-29s still in their arsenals. Likewise, Russia has also announced that the use of foreign airfields by the Ukrainian air force would constitute breaching a “red line” that would lead to an escalation of the conflict. In both cases, all accounts are being explored in order to seize the third dimension and exploit all that has to offer before their adversary does.

The Impact of Sanctions on Russia's Aerospace Industry

Sanctions are likely to cripple Russia's aerospace industry and the *VKS*'s operational capabilities. As a result, their arms exports specific to aerial warfare may decline in the near future, owing also to the subpar performance of the Russian armed forces' during the initial phase of the conflict. However, it is difficult to predict the exact extent of its industrial decline, as its engineers have demonstrated high adaptability not too long ago.

While the Syrian campaign was akin to an exposition for Russian equipment – and most likely led to an increase in exports, the repercussions of Western sanctions have already taken hold. For instance, the Ulyanovsk factory has stopped productions of anti-aircraft systems, such as the SA-19 *Grizzon* (2K22 *Tunguska*) and the SA-17 *Gadfly* (Buk M3).⁵⁷

Additionally, the arrival of the new Russian *Beriev A-100* airborne warning and control system (AWACS) was delayed.⁵⁸ The aircraft, initially intended to

56. “*Bayraktar Ukrainian War song*,” Youtube, 4 March 2022.

57 E. Le Meitour, “*La Russie asphyxiée: elle met fin à certaines de ses productions militaires modernes*,” *Air&Cosmos*, 20 April 2022.

58. T. Newdick, “*Western Sanctions are driving delays in fielding Russia's New A-100 Radar Plane: Report*,” *The WarZone*, 3 February 2022.

replace the *Beriev A-50 Mainstay*, had its productions suspended due to sanctions on the supply of critical electronic components. As a result, the aircraft will not enter service until at least 2024. Similar problems also lie in the production of T-90 and T-14 tanks, as well as at the Vladivostok shipyards.

From a short-term outlook, the sanctions seem to be taking on a positive effect. What could decisively turn the tide in the long run would be Russia's industrial capacity to execute nation-wide solutions, especially if material losses continue to rise. Inevitably, circumvention strategies are possible. Although it remains hypothetical today, portions of Western sanctions may be compensated by other states. These countries seem to be currently positioning themselves as potential intermediaries in the flow of goods and especially for payments between Russia and Western countries.

The sanctions have also affected the civil aviation sector as Russian airlines have been banned from flying to a proportionate number of Western countries. *Airbus* and *Boeing* have also stopped supplying spare parts⁵⁹ and training programs to their Russian clients. The impact from this shortage could be felt as early as 2023: the smooth functioning of domestic air transport is crucial to Russia's economy, given its size. In response to these sanctions, Putin enacted a law at the onset of the conflict to compensate for the drop in their domestic flights. This permitted Russian airlines to commandeer any Western airline aircraft that had ceased its operations in Russia but still remained on Russian soil.⁶⁰ This amounted to nearly 500 Western *Boeing* or *Airbus* aircraft belonging mostly to leasing companies located mainly in Ireland. The *Sukhoi* could also take advantage of this situation by boosting its sales of the Superjet-100 and *Irkut MC-21* aircraft. The generated revenue would be highly welcomed as it would enable the company to finance its R&D military spendings.

Russia's space industry is also affected by the conflict's consequences, as U.S. President Joe Biden has stated. For instance, Russia has stopped supplying the RD-180 and RD-181 engines which power the rockets commercialised by the *United Launch Alliance* and *Northrop Grumman*. The launch of Baikonur's *OneWeb* satellites was also rendered conditional upon the guarantee that they would not be used for military purposes. The conflict could therefore lead to longer delays in the production and launch of future military satellites. On the other hand, Ukraine has had recourse to private satellite operators, such as *Starlink* for communications, and *Maxar*, *Capella Space*, and *Planet Labs* for imaging. The question that remains hanging is whether or not using these private satellites for military purposes would also mark them as potential military targets.⁶¹

59. L. Barnier, "[L'état se serrer encore autour de l'aviation civile russe, lâchée par Boeing et Airbus](#)," *La Tribune*, 3 March 2022.

60. L. Barnier, "[Ukraine: Russian airlines and air charter companies caught in the crossfire of sanctions and counter-sanctions](#)," *La Tribune*, 17 March 2022.

61. Lt. Col. T. Goines, J. Biller, Maj. J. Grunert, "[The Russia-Ukraine war and the space domain](#),"

In short, no matter the belligerent, this conflict will leave behind significant repercussions. Russia would suffer extensive financial losses due to the cessation of Western satellite launches. Ukraine could also witness the partial destruction of its industrial organism. In order to surmount this new environment, Russia has reoriented itself towards China for space cooperation. From a technical perspective, this indeed provides quite the added value. However, it still does not allow Russia to finance its space industry, which largely depends on foreign launch contracts.

The multiple consequences of economic sanctions on Russia's civil and military aerospace industry will severely cut down its production rate and ability. Concomitantly, they could also lead to a strengthening of bilateral regional aerospace cooperation, especially with China.

Conclusion

Russia's two airborne assaults on the Hostomel airfield on 24 and 25 February were not enough to bring about a regime change. Was overconfidence the culprit behind the failure of the offensive's first phase? It is likely that Russia deliberately limited the use of their air power by overestimating their ground capabilities and by misjudging the level of resistance from Ukraine. Russia was unable to "recreate" the same victorious scenario as the annexation of Crimea. Rather, it could become bogged down in a conflict that is as dramatically costly in terms of human losses as it is in material losses.

In the end, the *VKS* did not produce the effects usually characteristic of Western air forces. With an inefficient defence industrial and technological base, coupled with a doctrinal apparatus that mostly overlooks air power, Russia was unable to achieve air superiority. This caused long-reaching consequences that severely impacted the combat on the ground. Concurrently, Kyiv capitalised on each victory in the air it achieved to galvanise the national response to the invasion.

Nevertheless, many experts continue to question the extent of the *VKS*'s capacity for a sustained engagement against more seasoned air powers. Indeed, paranoid of possibly facing an integrated massive airstrike campaign,⁶² Moscow has most likely reserved its most modern air forces for the defence of its own territories.

The Russian forces currently mobilised in Ukraine, especially the casualties suffered, will significantly weaken the conventional capabilities on which Mos-

Lieber Institute – West Point, 14 March 2022.

62. P. Gros, S. Delory, V. Tourret, "Stratégies russes et guerre en Ukraine: état des lieux," *Fondation pour la Recherche Stratégique*, Note, n°03/22 (2022).

cow has been depending. This could take years to recover. As a result, Moscow's strategic position may be strongly challenged, especially in its "near abroad" – meaning, the Middle East.

Russia's Offensive Cosmostrategy

Lieutenant Anne Maurin

Anne Maurin is a French Air Force and Space Force Officer working at the Centre d'études stratégiques aérospatiales and a PhD candidate in Geography at Sorbonne Université. Her research focuses on the strategic use of extra-atmospheric space by Russia.

On 2 March 2022, during the early days of the war with Ukraine, Dmitry Rogozin, head of *Roscosmos* (Russia's federal space agency) decried an execution of cyberattacks launched at its satellite infrastructure, going so far as likening them to *casus belli*.¹ Subsequently, a month later, the United States then, in turn, accused Russia of jamming its own navigation satellites.² To reflect in hindsight, these two cases all but demonstrate that even a partial paralysis of space assets could become an unavoidable event in the midst of a large-scale conflict.

Considering this new strategic shift, it is precisely the study of “cosmostrategy” that may grant a better understanding to this unfamiliar context. Like its name suggests, cosmostrategy stems from the term “geostrategy”. The latter, to recall, is the study of strategic manoeuvres in a given geographical environment, for the purpose of acquiring command over the said environment, where it can be exploited for power purposes.³ In conjunction, cosmostrategy designates these manoeuvres to outer space and the cosmos. The study has been awarded its marker of legitimacy as outer space becomes more and more indispensable by the day – not only for implementing military and economic strategies, but also for everyday use.

1. Interfax, “[Rogozin: kiberataki na rossiyskiye sputniki – eto casus belli \[Rogozin: cyber attacks on Russian satellites are casus belli\]](#),” *Interfax – Agentsvo voennykh novostei*, 2 March 2022.

2. General David Thompson (United States Space Force Vice-Chief of Space Operations) claims that “Ukraine may not be able to use GPS because there are jammers around that prevent them from receiving any usable signal.” See NBC Nightly News, “[Russia is jamming US-provided GPS signals in Ukraine](#),” *NBC Nightly News*, 4 April 2022.

3. F. Debié and al., “[À quoi sert la géostratégie ?](#),” *Géostratégie, Stratégique*, no. 50 (1991).

Indeed, since the 1990s, military operations have relied on civilian, military, or dual-use satellites that constantly fine-tune information regarding terrains and operational situations, all while facilitating the conduct of actions in a coordinated, faster, and more precise manner. Considering the valuable resources they provide, satellites must be protected at all costs against numerous threats, both human and natural. Such threats only increase with the growing congestion of orbits due to collision risks. To use the expression of Julien Gracq in his *Carnets de grand chemin* (further developed by Yves Lacoste in his *Dictionnaire de géopolitique*), outer space has become a “dangerous landscape”.

Cosmostrategy, when applied to Russia, gains quite the nuance. During the past decade, experts have been asserting that Russia has been lagging behind industrially, especially in relation to outer space. Yet, the media and open source networks around the world regularly reveal troubling conduct by Russia in this theatre. Indeed, while Russia's satellite range remains incomplete, recent months have witnessed a turnaround, most likely due to the ongoing conflict with Ukraine. In particular, from 5 February 2022 onwards, there have been five military launches, four of which have been satellites with the remaining a test. As a result, within but three months, Russia has launched more military satellites than in all of 2021. Hence, the enigma inevitably emerges as to how Russia manages to maintain an offensive military strategy in space with seemingly limited resources.

Yet, contrary to popular opinion, Russia's space fleet is, in fact, relatively complete – albeit precarious, which, as a result, allows the country to maintain its space defence strategy. To detail, its non-kinetic offensive actions in orbit encompass a guerrilla strategy with the power to cause harm. Subsequently, it is able to buy more time to gradually reinstall its offensive capabilities in space and remain, under all costs, a military space power.

Russia in Space on (Nearly) All Fronts

On 12 April 2021, the sixtieth anniversary since Yuri Gagarin's first flight to space, President Vladimir Putin stated that in the twenty-first century, Russia must adequately sustain its status as one of the leading nuclear and space powers, due to the fact that the space industry is directly linked to its defence. This only highlights even more so the strategic importance of space for the Russian Federation.

For it to be possible to conduct an autonomous cosmostrategy, spatial access is first and foremost essential. Today, Russia possesses several launch pads, known as “cosmodromes”. The oldest is located outside of Russian territory in Baikonur, Kazakhstan – which ironically impedes on its increasing priority of and endeavours towards self-sufficiency. *Vostochny* was opened recently in the Siberian Far East, a few hundred *versts* from the Chinese border. *Plesetsk*, originally a strategic missile base, is another cosmodrome located 800 km north of

Moscow in the Arkhangelsk region. This area is fully enclosed and defended by the *Vozdushno-kosmicheskoye sily* (VKS), the Russian Aerospace Forces. From there, missiles and rockets carrying military payloads are regularly launched. *Kapustin Yar*, and to a lesser extent *Iasny*, are also launch sites for military satellites. Lastly, up until March 2022,⁴ Russia was present on the North American continent thanks to the *Soyuz* launch pad at the Guiana Space Centre. Every one of these infrastructures make it possible for Russia to position its satellites, spacecrafts, probes, etc. across a wide range of orbits.

A Seemingly Complete but Precarious Russian Military Space Park

Quantitative Aspects

In general, it is difficult to identify Russia's exact battle order in space. The military, civil, commercial, or dual usage (*i.e.* combining civil or commercial use with military) of space objects in the Russian Federation is often ambiguous. Nevertheless, there are approximately 120 Russian satellites (of all categories: civil, commercial, dual, and military) that are operational in orbit.⁵ This is a quite low number that lies in stark contrast with the high rate of space launches by other space powers, state or otherwise. For *Starlink*, tens or even hundreds of nano-satellites are regularly launched on a daily basis. The same is the case, although to a lesser extent, for *OneWeb* or even for China. On the contrary, the number of Russian military (or dual-use) satellites in service is estimated to be at around eighty.⁶ This is excluding any civilian or commercial programmes whose use, according to Russian law,⁷ must be made available to the state according to its needs (particularly the operational ones).

Qualitative Aspects

Although access to space is guaranteed, Russia's space component is quantitatively reduced. Many satellites are gradually becoming obsolete as the number of military launches can no longer catch up, thereby creating gaps in some constellations. The current analysis of its space fleet, either military or civilian, shows that Russia is far below the standards it had upheld during the Cold War;

4. Following the widespread sanctions against Russia in response to the conflict in Ukraine, *Roscosmos* closed its *Soyuz* launch pad in French Guiana and recalled all its employees to Russia.

5. The term "operational" in this article refers to the satellite appearing to be operational on 7 April 2022 according to open source databases. This figure may seem to fall short of Russia's self-claimed amount of 160 by June 2022.

6. This estimate is relative, as it depends on various databases, namely the *Union of Concerned Scientists (UCS) Database*, which is updated regularly. For a more precise account of the operational status of certain satellites, this article refers to the database created by astrophysicist Jonathan McDowell, which lists a launch date (LDate) and a date on which the satellite is known to be no longer operational (TDate) for each object launched into space since 1957. It is then necessary to assume, and thereby difficult to verify, that in the absence of a TDate, the satellite remains potentially still operational.

7. Russian Federal Law: Zakon RF ot 20.08.1993 N 5663-1 (red. ot 11.06.2021), *O kosmicheskoi deyatel'nosti* [*The concept of space activities*], Article 2.

the country increasingly struggles to hold on to its position as a space power. The rare budget increases for the renewal of its satellite programmes, the lack of essential components due to economic sanctions, corruption, and embezzlement, as well as the difficulties in programme monitoring and management have led to repeated deficiencies and delays in many of its programmes. The only area where Russia had a monopoly (up until spring 2020) was manned space flight. However, this privilege is now shared with the private U.S. actor, *SpaceX*. Nonetheless, military space remains a priority for Russia, particularly in a tense geopolitical context.

The space component of Earth military observations (optical and radar) is undoubtedly the weakest pillar constituting Russia's space capabilities. Optical Earth observation is provided by two post-Soviet programmes, *Persona* and *Bars*. Although quite old and with a rather low resolution (around 50 cm for *Persona*), five satellites continue to be operational in sun-synchronous orbits (allowing a wide view). Radar observation capability – which has imaging advantages that can penetrate cloud layers and remain unaffected by weather conditions – is almost non-existent. There is no certainty that the *Kondor* satellite, dedicated to this task, is still operational. However, said capability could be reacquired with the *Neutron.1* satellite (launched on 5 February 2022) that purportedly has both optical and radar imaging capabilities. Regardless, Russia's military forces can still rely on its civilian and commercial constellations, which are most likely already providing their images for state use (*Kanopus* and *Resurs*, or *GEO IK2* for mapping).

Beyond surveillance and observation missions, the Russian Aerospace Forces also manages space-based early warning capabilities (namely, the *EKS* constellation, comprising 4 satellites launched between 2017 and 2021), as well as electromagnetic and signals intelligence. The *Lotos* satellites⁸ intercept radio signals, making it possible to locate and identify possible military targets (mobile or otherwise). The *Pion* satellites are new-generation electronic listening devices, of which only one is currently in orbit (launched on 25 June 2021). It has a radar, making it essential in supporting land or naval operations and in detecting targets that do not emit radio signals.⁹ The ELINT component (KREN in Russian) is moving upmarket, after being in the hands of a high-risk state. It has had three satellite launches since 2021. Such a high number may be hinting at Russia moving to prioritise this component and secure its space capabilities in this area. Further supporting this hypothesis are the *Akvarel* and *Repei* programmes,¹⁰ which are both already in development to ensure ELINT's replacement.

Another key military space priority is the maintenance of an autonomous Russian satellite navigation constellation. The *Glonass* programme, designated

8. A. Zak, “[Soyuz launches an ear in the sky](#),” *Russianspaceweb.com*, updated on 7 April 2022.

9. B. Hendrickx, “[The Space Review: The status of Russia's signals intelligence satellite](#),” *The Space Review*, 5 April 2021.

10. *Ibidem*.

for this purpose, had embarked in the 1980s. Today, Russia's navigation component consists of approximately 24 satellites. This is the minimum amount needed to obtain a relatively accurate position without the use of other global navigation satellite systems (GNSS). New *Glonass* satellites had been launched every year or so. Yet, the most recent launch was back in October 2020. This absence since then may play a factor in hindering future performance levels.

Finally, Russia's communications component is the largest in number of all (61 operational satellites in all fields). Commercial constellations are developed by companies whose majority shareholder is *Roscosmos* (*Gonets*, *Yamal*, *Ekspress*, etc.). The *Loutch* constellation supposedly serves as a relay linking terrestrial and space-based communications, namely the International Space Station. This constellation may seem small at first glance, as it only comprises four satellites. However, it originally housed the *Loutch-Olymp* spy satellite, which regularly undertakes SIGINT missions on foreign satellites, particularly French ones.¹¹

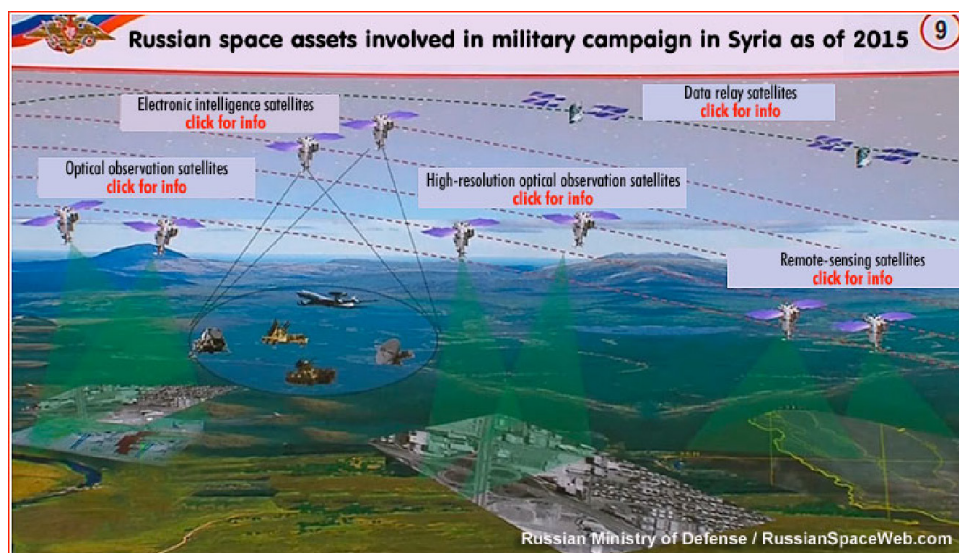
The military communications component involves 29 satellites. Military telecommunications (data transfer, etc.) are provided by the *Blagovest* constellation (composed of four operational satellites, launched between 2017 and 2019). The constellation of 16 *Rodnik* satellites – launched between 2009 and 2018 in low orbit of 1 500 km apogee – offers the Russian government, military, and its intelligence services the possibility of having a protected communication relay. This *Rodnik* constellation is nevertheless rather old. Most of its satellites may be obsolete. This is why Russian forces may use the *Gonets* for their secure communications. In addition to the old *Raduga* satellites, smaller modern constellations (such as the *Meridian* with six satellites launched between 2010 and 2022) are operating within the *Molniya* orbit. They enable military communications to be established in uninhabited or difficult-to-access areas (such as the Arctic, Siberia, and the Russian Far East) between ships, aircrafts, and ground or mobile stations.

All these space assets are intended to be integrated into a high-performance combat system. The Russian Ministry of Defence (*Minorobony*) regularly publishes¹² – as it did during the intervention in Syria – diagrams explaining the use of its space components on a battlefield. However, considering the actual state of its constellations, along with the apparent difficulty its armed forces are having in optimising their C2, doubts are raised regarding the system's level of functioning. Firstly, the number of satellites is too low for each to function perfectly in continuation. Moreover, Russia's spacecrafts were not always operational nor were there a sufficient number to cover across several theatres. Media articles and analyses¹³ published throughout the conflict in Ukraine also highlight this problem.

11. Statement by French Minister of the Armed Forces Florence Parly on space defence, given in Toulouse on 7 September 2018.

12. Found on <https://syria.mil.ru/split.htm>, a website dedicated to monitoring the operational situation in Syria.

13. M. Krutov and S. Dobrynin, “[Slepaya Rossiya. Armiya Putina proigryvaet sputnikovuyu voï-](#)



On the other hand, these difficulties that Russia encountered in its invasion of Ukraine could very well be what will accelerate the many programmes that were months or even years behind schedule. *Roscosmos's* Rogozin is increasingly referring to these problems in an effort to prioritise defence space programmes. On 11 April 2022, the day before Cosmonautics Day (the annual commemoration of Gagarin's flight with 2022 being its sixtieth anniversary), he made the following statement in an interview for the *Rossiyskaya Gazeta* channel:

In a situation where it is necessary to aid our armed forces, we have rather modest resources at our disposal. This worries me personally. Therefore, a decision has been made: to devote all attention – which previously did not regard as a primary importance in this particular situation – towards ensuring that allocated funds are entirely directed towards the creation of new spacecrafts. We need to double our orbital constellations. Let's pour all our resources into this: design, organisation, production, technology, and funding. We need to see everything, hear everything, and be able to transmit all necessary information.¹⁴

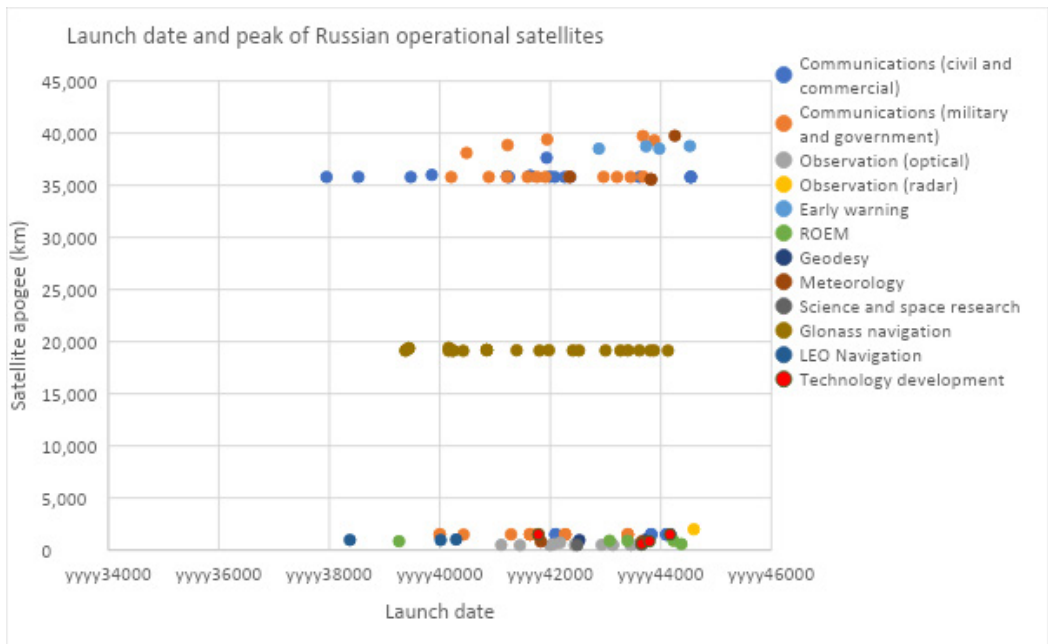
Indeed, the conflict in Ukraine seems to have accelerated the launch of military satellites to complete certain constellations. On 5 February 2022, the Russian armed forces placed a *Neutron* satellite into orbit to allegedly capture radar imagery. On 22 March 2022, Russia announced the launch of a *Meridian-M* military communications satellite into the *Molniya* orbit, a distant, ultra-elliptical orbit of more than 40,000 km apogee. On 7 April 2022, the Russian Ministry of Defence declared that it had placed a *Lotos-S1* military eavesdropping satellite into low-Earth orbit. With the first launch of the *Angara* heavy launcher on

nu [[Russia Blinded. Putin's army is losing the satellite war](#)],” *Radio Svoboda*, 8 April 2022.

14. Editor's translation of N. Yachmennikova, “[Rogozin: Nash prioritet segodnya – orbital'naya gruppirovka nablyudeniya i svyazi](#) [[Rogozin: Our priority today is an orbital observation and communication constellation](#)],” *Rossiyskoy gazety*, 11 April 2022,

29 April 2022 came the opportunity to put into orbit the Ministry of Defence's space object, *Cosmos-2555*.¹⁵ Even more recently on 19 May 2022, again from *Plesetsk*, a *Soyuz 2.1a* put into orbit a new optical observation satellite for the *Bars* constellation.

To juxtapose, 2021 only saw three Russian military satellites launched, while the first half of 2022 already had five military objects launched into space. This pace is only expected to continue in the coming weeks and months. The bottlenecks hindering many military programmes – often put on hold for various reasons (political, administrative, industrial, civil) – seem to be rapidly dissipating. This change of tempo, borne after the abandonment of many scientific space programmes, has led to a twofold observation: Russia is now acknowledging the insufficient level of their constellations and is thus realigning their priorities towards military space.



Cosmostrategy: The Study of Russian Manoeuvres in Space

In Russia's inventory, a handful of satellites – whose characteristics remain unknown – stand out for their unusual uses: manoeuvres in space, orbital rendez-vous, and its self-professed “technological development” missions. Similarly, activities left unclaimed occur regularly, especially during periods of geopo-

¹⁵ Some sources initially identified this to be an EMKA observation satellite (about 0.5 m in accuracy), which now has no object in orbit. However, it now appears to be gradually plunging towards Earth and disintegrating in the atmosphere. This suggests instead that it was more so a test for a far-orbiting satellite launch.

litical tensions or conflicts (e.g. the jamming of navigation satellites, U.S. GPS, internet relays, and communications used in the Ukrainian crisis). Ground-based and space-based operations attempt – nearly always indirectly – to harass or temporarily paralyse state or private entities. As these activities are not often easily attributable, their perpetrators continue to be shadowed by a question mark. Nevertheless, a new front line is emerging, despite its relatively obscure nature.

Inspector Satellites: Intelligence Agents in Orbit

On 23 May 2014, a *Rokot* rocket from *Plesetsk* placed several military satellites, including three *Rodniks*, into low orbit. In addition, observers noticed that in close proximity of these three communication satellites was the presence of another unidentified object. This situation is reflective of a similar occurrence from a few months earlier.¹⁶ Initially thought to be debris, the object had seemingly performed a number of manoeuvres in a progressive manner, changing its apogee and perigee by a few kilometres. It was eventually listed and numbered as *Cosmos-2499*.¹⁷ Undoubtedly, its manoeuvres led to many unanswered questions about this entity's role. However, neither *Roscosmos* nor the Ministry of Defence provided any details to Anglo-Saxon researchers and officials, who perceived these activities as a threat to the proper functioning of their own spacecrafts.

The movements of *Cosmos-2499* are worth remarking for several reasons. Such a capability that Russia is deploying is not directly meant to be aimed towards foreign assets. Indeed, such actions would be outrightly considered as aggression. Rather, these manoeuvres are meant to provide the opportunity to perform tests and carry out training in preparation to execute a space offensive, should the occasion call for one. Developing the capacity to move a mobile object in space and project it from one orbit to another remains essential techniques to have at hand. *Cosmos-2499*, in particular, can change its trajectory to move closer towards a target. As a result, it is purported to be able to intercept images and communications from its target to eventually photograph and transmit the intercepted information to ground stations. In addition, this type of survey satellite is predicted to also possess the capability of launching a high-speed projectile or even a satellite from space. Such an ability to launch a projectile from an orbiting spacecraft requires a high degree of technical sophistication. Needless to say, it fosters added fears of the possibility of a new, emerging paradigm where space itself becomes “weaponised”.

From 2014 to 2016, *Cosmos-2499* was noted to have performed several manoeuvres around the *Rokot* launcher's rocket stage, *Briz*. *Cosmos-2499* approached *Briz* to position itself in a parallel orbit of close proximity, before finally overtaking it at low speeds. This kind of “space rendez-vous” requires a scrupulous accuracy in the piloting of the “hunter” satellite, so that it may accurately adapt its trajectory

16. A. Zak, “[Kosmos-2499: Is it a spy or an assassin... or both?](#),” *Russianspaceweb.com*, 30 April 2017.

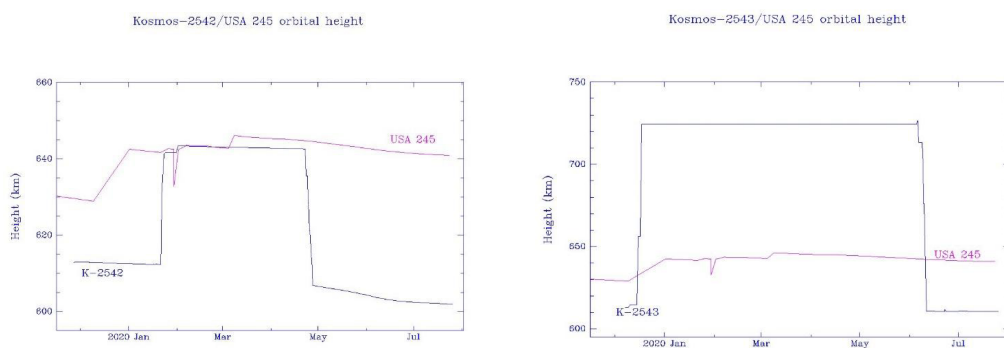
17. *Ibidem*.

to that of the “hunted” object. However, *Cosmos-2499* is not the only satellite type that holds a monopoly on such capabilities. Other devices have also been identified, and subsequently categorised together under the name, *Nivelir*, by Western experts. According to observer and astrophysicist Jonathan McDowell:

“In 2017 Russia started launching a new series of satellites which performed proximity operations and released subsatellites. The satellites were launched by Soyuz-2-1v from Plesetsk. These satellites appear to be follow-ons to those launched along with communications satellites on Rokot missions in 2013-2015 (Kosmos-2491, 2499, 2504). The US government has suggested that the satellites represent tests of space weapons. Bart Hendrickx has suggested the satellites are part of the Nivelir program”.¹⁸

Indeed, after the three aforementioned satellites, *Cosmos-2519*, -2521, -2523, -2535, -2536, -2542, and -2543 – some of which were nicknamed as “Russian dolls” – were noted to have performed the same modes of action. These were placed into orbit between 23 June 2017 and 25 November 2019, both from Earth and from space. Since then, a number of orbital manoeuvres have been carried out, either around launch vehicle stages and debris or from domestic and foreign satellites.

From 2013 and onwards, about four of the eleven *Nivelir* satellites launched are believed to be currently operational in space. The others seemed to have been deactivated or re-positioned into the atmosphere. It is possible, however, that the deactivated ones may “awaken” in the coming years. In addition, there seems to have been other manoeuvres that had been intentionally coordinated. Notably, these include the nearing of *Cosmos 2542* (in January 2020 and August 2021) and *Cosmos 2543* (in December 2019 and June 2020) towards the U.S. imaging satellite, *USA 245*.



A case in point is the *Cosmos-2543* fighter, which, after its “rendez-vous” with the *USA 245* satellite, had ejected an object in June 2021, before being immediately registered as the *S45915*. The Russian Ministry of Defence was

18. J. McDowell, “*Nivelir (Kosmos-2519 and al): A new series of Russian military satellites*,” *Jonathan’s Space Report*, Accessed 1 June 2022.

severely criticised, especially by the United States, who had denounced these movements as offensive actions. However, the *Minorobony* repeatedly insisted that these missions were carried out within the framework of satellite maintenance and experiments, similar to when *Cosmos-2542* itself had launched the -2543 satellite on 6 December 2020.¹⁹ This capacity to launch from space – an environment that is difficult to observe – calls for the necessity of a permanent and continuous monitoring of Russian space objects. It is no longer solely a question of assessing the danger of natural debris, but also of monitoring the possible increase in the number of Russian satellites in space.

Much speculation has also arisen regarding the potential capabilities of a handful of Russian inspector satellites inspectors, which constitute but a small percentage of the Russian space fleet. Recent events have signalled that Russia's strategic thinking is veering towards adopting an asymmetric and discreet military response. With neither the necessary quantitative resources nor the desire to wage an ostentatious war in space, the Russian Aerospace Forces are hence defaulting to a semblance of guerrilla warfare²⁰ to destabilise opposing space powers via exercises or actual interventions. This strategy is illustrative of Marshal Alexander Suvorov's famous maxim: fight not by numbers but by skill.

Nevertheless, Russia is not the only country equipped with “fighter” satellites. The United States (the *X-37B* shuttle) and China also possess similar instruments. Yet, these operations from Moscow – comparable to slipping a “pebble into a shoe” as evoked by geographer Isabelle Sourbès-Verger who specialises in space – not only grants additional time for Russia, but also allows the country to continuously showcase its presence in this increasingly contested environment. This ballet of “inspectors” is but an adamant reminder for the West that Russia still maintains nuisance capabilities in space, despite deceitfully projecting the image of neglecting its offensive means during the past decades. Notwithstanding all the difficulties that Russia is facing in maintaining its status as a space power, Moscow continues to present itself as a worrisome threat.

War or Peace? From Secret Missions to Confrontations in Orbit

All in all, the capabilities developed from “inspectors” would still be insufficient in the event of a high-intensity conflict. Here, belligerents would endeavour

19. Editor's translation: “Today, as part of the ongoing testing of new space technologies, the Ministry of Defence of the Russian Federation conducted an experiment to separate a small spacecraft from a unified multifunctional space platform. The purpose of the experiment is to continue endeavours to evaluate the technical status of domestic satellites. The visualisation information is transmitted to ground processing facilities to determine the technical status of the satellite under study”. See Russian Ministry of Defence, “Minoborony Rossii prodolzhaet ispytaniya novoi kosmicheskoi tekhniki [Russian Defense Ministry continues testing new space technology],” *Russian Ministry of Defence*, statement made on 6 December 2019 at 17:23.

20. A parallel can be drawn with “cybernetic guerrilla warfare” as seen in J.-S. Mongrenier, *Le monde vu de Moscou: Dictionnaire géopolitique de la Russie et de l'Eurasie postsoviétique* (Paris: Presses Universitaires de France, 2020): 183.

to weaken all orbital components of their adversaries. Beyond inspection missions and closing-in manoeuvres, electronic warfare operations would be carried out in addition, including those involving anti-satellite weapons (ASATs) and laser weapons. These would manoeuvre more or less from Earth, although an offensive capability directly in orbit is gradually being developed overall. Russia specifically, despite its limited resources, is also involved in these areas.

Electronic Warfare Extending All the Way into Space

Should there ever be a destruction of an object in orbit, an adversary could consider this as *casus belli*. On the contrary, the use of electronic warfare is much more discreet, allowing its user to achieve significant results without necessarily leading to a declaration of war. Regarding this issue, Hendrickx writes that “[e]lectronic warfare is probably perceived by Russia as a relatively inexpensive, asymmetric response to Western military technological development”.²¹

A two-point mission has thus gradually emerged in the discourse amongst Russia’s governmental, military, and industrial authorities. On the one hand, such a mission permits the protection of the country’s national interests, while on the other hand, it has the ability to paralyse or even suppress enemy radio-electronic systems. Russia’s electronic warfare programme, published in 2013 with projected developments up until 2020, had already indicated the need to deploy multifunctional electronic warfare programmes in space – although they are currently mostly deployed on the ground. At the time, they were meant to enable reconnaissance and the suppression of radio-electronic systems, employed by radar, navigation, and communication systems.²²

John Venable, a defence policy researcher at the *Heritage Foundation*, wrote in February 2022 in finer detail that Russia’s space portfolio includes a sophisticated offensive capability that can jam sensors in space and blind them.²³ Moscow is currently implementing jamming systems that can be deployable from the ground,²⁴ which would threaten not only GNSS capabilities, but also internet

21. B. Hendrickx, “[Russia gears up for electronic warfare in space \(part 1\)](#),” *The Space Review*, 26 October 2020.

22. M. Doskalov, “[Perspektivy razvitiya sistemy radioelektronnoi borby rossiskoi federatsii na period do 2020 goda \[Prospects for the Development of the Russian Federation’s Radio-Electronic Warfare System for the Period until 2020\]](#),” *Defense complex of the Russian Federation*, 21 May 2013, .

23. T. Novelly, “[The First Shots in a Ukraine Conflict May Be in Space](#),” *Military.com*, 15 February 2022.

24. These electronic warfare systems can be extremely mobile as they are apparently mounted onto trucks, including the *Krasukha 4*, which is capable of jamming satellite waves, including GPS. The *Murmansk-BN* electronic warfare system is another high-performance system, which was abandoned in the 1990s, but then revived and deployed in 2018. Some specialised press articles, such as <http://www.avia-pro.fr> (but no doubt re-framed by Russian media), report that the system disrupted the operation of *F-35s* during a NATO exercise in the Baltic Sea at the end of 2021. The communications of these fighters, notably via satellite relays, could have been completely obstructed and cut off. These electronic warfare systems could be put into use by Russia in the ongoing conflict with Ukraine.

and communication relays used in a particular region. In April 2022, the United States accused Russia of blocking a satellite navigation signal (presumably *Navstar*) that had been covering Ukraine.²⁵ Even shortly before the start of the conflict, similar accusations were already made against Russia, after issues with GPS signals over the Baltic region and northern Europe had arisen. *Space X* officials also decried Moscow for similar acts carried out against its *Starlink* system. These activities had sought to prevent the functioning of the private entity's internet coverage that it was providing to Ukraine. Thankfully, an update to the system restored its capabilities.

These acts by Russia and their subsequent accusations by the West only demonstrate Moscow's premeditated planning of such spatial operations. The evident motive to act below the threshold of war may indeed be considered as a strategic choice to avoid escalation. It may also be interpreted that Russia is well aware of its weakness should there be retaliatory strikes launched against its own assets upon the execution of an overly aggressive manoeuvre. With limited means at its disposal, it currently has to settle for solely the ability to momentarily paralyse the specific functions of its adversary, as in the case of the conflict with Ukraine. However, should Russia wish to remain as a leading space power, these modes of action will not be enough to satisfy such an ambition.

Russia's Offensive Capabilities in Space

To significantly improve its offensive capabilities in space, Russia is already presently designing or even developing other programmes. These are at times detected by experts, owing to statements and industrial fact sheets presented in the Russian media. In this particular context, initiatives in the field of directed energy (laser) weapons, especially against satellites, or ASAT missile propulsion from Earth, air, or space²⁶ can be especially highlighted. Laser is an intermediary offensive tool less impressive than ASAT weapons. This is why *Peresvet* is a mobile truck-mounted laser weapon officially brought into service in 2018. Since 2019 it has been used by four strategic missile divisions. *Peresvet* can blind, even occasionally, the enemy's optical tracking systems, including space ones. According to the 2021 version of the annual *Global Counterspace Capabilities* report, Russia has been endeavouring since the 2010s to rebuild its ASAT capabilities either from Earth or co-orbitally in order to acquire an operational ASAT range.²⁷ However, furthering this development will only be feasible if military space becomes a true priority at the budgetary level. The destruction in direct ascent (*i.e.* with a *Nudol* missile fired from Earth) of one of Russia's for-

25. NBC Nightly News, "[Russia is jamming US-provided GPS signals in Ukraine](#)," *art. cit.*

26. B. Weeden and V. Samson (eds), *Global Counterspace Capabilities – An Open Source Assessment* (Washington, DC: Secure World Foundation, April 2021).

27. In response to Russian launching an anti-satellite missile in November 2021, the Chief of Staff of the French Air Force, General Stéphane Mille, stated in an interview with French newspaper *Le Monde* on 1 December 2021 that Russia had demonstrated that they were now capable of acting in space across the entire spectrum of conflict. Editor's Translation.

mer low-Earth orbit electronic listening satellites on 15 November 2021 – now inoperative – is emblematic in this respect. The firing of the *Nudol* proves that Russia no longer intends to act in a discreet and irregular manner. It nevertheless violates two taboos: the generating of a substantial amount of debris and the potential placing of weapons of mass destruction into orbit.

02 RUSSIE

LÉGENDE: AUCUNE CAPACITÉ (R) CAPACITÉ FAIBLE (Y) CAPACITÉ IMPORTANTE (G)
CAPACITÉ INCERTAINE ** PAS DE DONNÉES **

	R&D	ESSAIS	OPÉRATIONNELLE	UTILISATION EN CONFLIT
Ascension Directe (Orbite Basse)	G	G	G	R
Ascension Directe (Orbite Moyenne et Géosynchrone)	Y	Y	—	R
Co-orbitale (Orbite Basse)	G	?	—	R
Co-orbitale (Orbite Moyenne et Géosynchrone)	Y	—	—	R
Énergie Dirigée	G	Y	—	R
Guerre Électronique	G	G	G	?
Connaissance de la Situation Spatiale	G	G	G	?

Figure 3: Status of Russia's ASAT capabilities in April 2021
(Source: Global Counterspace Capabilities 2021)

	China	Russia	U.S.	France	India	Iran	Japan	North Korea
LEO Co-Orbital	Y	G	Y	R	R	R	R	R
MEO/GEO Co-Orbital	Y	Y	Y	R	R	R	R	R
LEO Direct Ascent	G	Y	Y	R	Y	R	R	R
MEO/GEO Direct Ascent	Y	Y	Y	R	R	R	R	R
Directed Energy	Y	Y	Y	Y	R	R	R	R
Electronic Warfare	G	G	G	Y	Y	Y	R	Y
Space Situational Awareness	G	G	G	Y	Y	Y	Y	R

Legend: none (R) some (Y) significant (G)

Figure 4: Comparison of the ASAT capabilities of the various world space powers
(Source: Global Counterspace Capabilities 2021)

Conclusion: What Kind of Offensive Cosmostrategy Will Russia Adopt Moving Forwards?

Political and military statements are regular reminders that space is entirely subordinate to the security and defence interests of the Russian Federation. Of particular interest is Rogozin's televised speech broadcasted on the *Perviy Kanal* channel as a part of the sixtieth anniversary celebrations for Gagarin's first flight. The head of *Roscosmos* describes that even though the objective is to be one of the top three space powers, Russia intends to fully ensure its nation's strategic shield and defence via the use of space. Indeed, he insists that this is because *Roscosmos* is the entity that creates the material basis for strategic nuclear forces. This, Rogozin explains, makes it all the more vital for the country to construct itself in its own spirit, by way of its own independence and sovereignty.

Regardless, the consideration of outer space as a military theatre is nothing novel. In fact, several Soviet strategists as early as the 1960s,²⁸ referred to this theatre in the same way as they did for land, sea, and air. This is not to mention that the use of outer space remains strongly connected to the implementation of nuclear components due to ballistic technology. Indeed, the propulsion technology of a rocket finds its origins from that of a missile. Fittingly, both the terms for "missile" and "launchers" in the Russian language are identical: "*raketa*". Since the fall of the Soviet Union, several Russian publications have sought to either adapt military space to new forms of armed conflict, or to incorporate it into high-intensity wars. In 2000, in the conclusion of a strategic history text whose editing was overseen by General Vasilii Zolotarev, space was described as the main arena of struggle.²⁹ Specifically, the text outlines that military operations would likely begin in space long before the deployment of any large-scale strategic operations on land, in the air, or at sea. The main objective in such a case, the publication claims, would therefore be the mutual destruction of military and support assets in space, including the execution of a covert destruction of these assets.

More recently is a critical article, found in a Russian military strategy journal, that was published in March 2022 by Colonel Yuri Krinitsky, professor at the Tver Military Aerospace Defence Academy. The author argues that it is essential to recognise outer space as a "niche to be occupied" through the development of all necessary weapons and equipment. In Krinitsky's view, the foremost priority in the conquest for aerospace superiority would be acquired not only by blinding, suppressing, and defeating air defences, as well as infrastructure facilities on the ground and in the air, but also by similar effects on the enemy's spacecrafts and orbital systems.³⁰

28. V. D. Sokolovsky, *Soviet Military Strategy*, trans. H. Dinerstein, L. Gouré, T. Wolfe (Santa Monica, CA: The RAND Corporation, 1963): 21.

29. V. A. Zolotarev and al. (eds), *Istoriya voennoĭ strategii Rossii (Rossiiskaia voyenno-istoricheskaya biblioteka)* [History of Russia's military strategy (Rossiiskaia military history library)] (Moscow: Poligrafresursy, 2000): 534-535.

30. Y. Krinitsky, "[Napravleniya razvitiya form i sposobov deystviy voysk \(sil\) vozdušno-kosmicheskoy oborony](#) [Directions for the Development of Forms and Methods of Action of Troops (Forces) of Aerospace Defense]," *Voyennaya mysl' [Military Thought]*, no. 3 (2022).

Yet considering the above, Russia's space sector is, on the contrary, in crisis, while the Russian Aerospace Forces' space operational assets remain precarious. In short, a gap exists between Russia's strategic thinking and the veritable reality. If Russia manages – despite the imposed upon sanctions – to mobilise and recreate an effective and offensive space battle order, then it may very well obtain the means to pursue its envisioned strategy. However, it currently does not have the most modern, technically advanced, or precise arsenal. It uses rustic tools that are indeed functional, but whose technical performance is nevertheless oftentimes inferior to that of other major space powers, particularly the United States. As such, it is rather its ability to act across the entire space spectrum and to subsequently attack (should it be necessary) that actually guarantees its place in the exclusive club of space powers.

From the conflict in Ukraine, the results in space reveal that Moscow is currently adhering to a form of pragmatism that carefully considers the escalation risks at hand, should either the U.S. or European spacecrafts indirectly serving Ukrainian forces be destroyed. Russia's "special operation" in Ukraine does not witness any activities of a kinetic nature from its side. This is most likely because Moscow wishes to establish a certain level of consistency with its intentionally woven narrative, which adamantly refers to the conflict in Ukraine as a simple operation and not as a war. For the former, the use of destructive measures against its competitor is not required, at least not theoretically. To be precise, the targeted adversary, the Ukrainian state, does not own a space programme, only its latent adversaries – mainly NATO Member States – do. Because the latter are not deemed as co-belligerents, should their space assets and infrastructure be destroyed, there would be a gross misalignment with the Russian authorities' account of events.

Indeed, such an operation would have an extremely high escalation risk. As it is highly dependent on its space sector – be it at the military, private, or societal level, Russia would be at a disadvantage with much to lose should it plunge into a high-intensity war in space. Inevitably, it could neither protect itself nor retaliate in a substantial manner. This element most likely encapsulates Russia's overall communication strategy, which remains strongly committed to international institutions against the weaponisation of space. As such, the options of employing asymmetric and covert manoeuvres continue to be Russia's most preferred method to inflict harm upon its adversaries. But there is risk of even occasional offensive action by Russia. Moscow wants to show the world that it has the appropriate capabilities for these specific operations (in-orbit propulsion, space *rendez-vous*, laser, ASAT missiles, etc).

The situation moving forwards will continue to witness an increasing amount of advanced offensive equipment placed into orbit, functioning as an insurance policy of sorts for major space powers to hold on to their positions. The lessons learned from the conflict in Ukraine could catapult a reorientation of Russia's space programmes towards an "all-military" approach. On 3 March 2022, Ro-

gozin announced on *Rossiya 24* that the Russian space programme, against the backdrop of sanctions, will be adjusted to prioritise the creation of satellites in the interests of Russia's defence. The recent launch of military satellites at such an accelerated rate seems to be in line with this statement. Consequently, two aspects must then be carefully monitored: the renewal of offensive space capabilities, and of course, the competence of Russia to put them into use.

Traps & Holes : Defending the Russian Airspace

Pierre Grasser

*Doctor (PHD) Pierre Grasser, fellow researcher at SIRICE laboratory,
Sorbonne Université*

On the 10th of February 2007, during the Munich Security Conference, Vladimir Putin pronounced a speech in which he stresses that:

*“no one feels safe! Because no one can feel that international law is like a stone wall that will protect them. Of course such a policy stimulates an arms race. The force’s dominance inevitably encourages a number of countries to acquire weapons of mass destruction.”*¹ Global rearmament, siege mentality, proliferation: the reasons behind Russian rearmament are announced. The country gathers many delays, after the 1990s’ downturn. Two decades later, most of the Soviet arsenal has been abandoned and Moscow is relying on a modern ground-to-air army. The new anti-air systems are indeed efficient against the threat identified in the 1990s, like tactical drones and cruise missiles. The means deployed for training are also numerous and renewed.

In contrast to Cold War era, the manpower is insufficient to sanctuarise the vastness of Russian territory. The fleet of jetfighters held by aerospace forces (VKS) and the navy (VMF) is limited to 560 operational aircraft. The spine of the defence, the ground-to-air systems are in a better place, but they can not guarantee the impermeability of borders. Modern, multi-domain but with restricted ambitions, the Russian access denial concept is to be analysed in its forms.

1. V. Putin, “[Speech and the Following Discussion at the Munich Conference on Security Policy](#),” *Kremlin.ru*, 10 February 2007.

I – First world defensive arsenal: what weapons?

Building a fortress: against what?

The theoretical organisation of Russian forces is adapted to face a range of situations, set out beforehand. This army is rather generally conceived for defensive situations. The command is considering that it is risking to loose the air superiority against a symmetrical adversary, whether western or eastern. It expects to endure attacks, near the front line and against command and control centres, from various incoming simultaneous directions. These attacks would mainly comprise, according to Moscow, several cruise missiles waves, subsonic or supersonic. These very long-range devices (beyond 3 000 kilometres for some of them), flying most of the time close to the ground, are difficult to detect. They only leave the defences a short period of time to intercept them. These cruise missiles were employed for the first time by United States in 1991, against Iraq's ground-to-air systems. The attacks shocked Russian mindset and played a determining role to redirect Russian defence, which was until then focused on the aircraft threat. In a different theatre, the protection against middle-range ground-to-ground missiles (less than 500 km) is earning interest again, in Far East.

For the air defence: recognising and reducing danger

Against air threat, Russian capabilities are modern and effective. The mission of the air defence is to hold aircraft launching cruise missiles the most afar possible. If they are launched anyway, Russian fighters must intercept a maximum of them in-flight. In order to allow the necessary time for interceptions, the 20 air bases hosting fighters jets are a few hundred kilometres away from sites to defend (see map 2).

Concerning air defense², the *VKS* are the main owners of the systems:

- *The air fleet of the VKS, the backbone*: on the 22nd of February 2022, 459 fighters are gathered in this component. Among these, 272 have been produced since 2008³, and 168 others have been upgraded. There are two categories of interceptors: the first one consists of aircraft which purpose is to fight under the speed of sound, against targets of the kind of conventional cruise missiles and drones. *Sukhoi* Su-35S⁴ and Su-30SM⁵, respectively 101 and 92 aircraft have been delivered since 2012, and form the backbone of this category. The second category is rather grouping high-speed interceptors, the MiG-31BM, which *VKS* is equipped with 148 units. All of them have been upgraded between 2008 and December 2021 and can nearly reach

2. Air defence includes all airborne systems: jet fighters, early-warning planes, refuelling planes.

3. "[Postavki Minoboroni Rossii samlioty](#)," *Aviation21*, 8 February 2021.

4. "[VKS Rossii polutchili pervie v 2021 godu Su-35S](#)," *Bmpd.livejournal*, 14 December 2021.

5. "[Postavki boevikh samaliotov v Voorujennie Sili Rossii v 2018 godu](#)," *Bmpd.livejournal*, 13 January 2018.

a speed of Mach 3. They can intercept fast targets, like supersonic cruise missiles.⁶⁷ The fighters can be supported by 7 Advanced Early-Warning A-50, including 6 upgraded A-50U, affected to missile launches detection, and if possible to follow their trajectories.⁸



(DR) Navy's MiG-31D3 in Kamchatka, on the 6th november 2018.
It is then one of the last 19 not upgraded MiG-31 flying in Russia.

- *VMF's air arsenal set back.* The navy is operating, as of April 2022, 100 fighters⁹. Among them, 21 MiG-29K and 26 Su-30SM/SM22 have come out of production line since 2013, whereas 5 MiG-31BM have been upgraded. All the other jets left are old, slightly upgraded around 2002 (around 15 of carried fighters Su-33), or come directly from the Soviet era (19 MiG-31 are to be upgraded, 14 MiG-27 are to be replaced). While those interceptors have the same function as *VKS*' ones, the VMF does not operate any advanced early-warning planes, and tend to select experienced pilots.^{10 11}

Anti-air defence to break the assault.

Ground-to-air defence is probably the branch of the Russian military that has recovered best from the fall of the USSR. Although the number of 150 S-300PS/PT batteries in 1991 has decreased over time,¹² the new assets in service have a longer range and can deal with several threats.¹³ They are placed in the vicinity of priority points (see map 1) and belong to both the *VKS* and the ground forces.

6. The youtube video linked below, shot in 2019 from Monchegorsk, near Finland, makes one understand that an attack is expected in this area, by nuclear-charged supersonic cruise missiles.

7. "[Poliot v stratosféru na samaliote MIG-31](#)," *Youtube*, from 33:54, 15 October 2017.

8. A. Kulikov, "Bolchie problemi maloï dalnost," *VKO* (2009): 38.

9. This total does not take into account the 22 MiG-31BMs based in Monchegorsk, near Murmansk, which were *de jure* attached to the navy in February 2019 and are still armed and coordinated by the aerospace forces. The 22 Su-30SMs and four Su-30SM2s delivered to the Navy are accounted for. Originally used to replace the Su-24M tactical bombers, these aircraft are now occasionally used for air defense patrols.

10. "[Mirotvorets. ustanovbil vsiekh rossiskikh letchikov Admirala Kuznetsova](#)," *Spilno*, 1 January 2016.

11. "[Aviapolk palubnikh letchikov Severnovo flota vosglavit Pavel Podguzov](#)," *Severpost*, 10 February 2015.

12. S. Linik, "[Osnova nazemno segmenta PVO RV](#)," *Topwar.ru*, 09 March 2020.

13. The S-400 employs long-range 48N6 missiles, which are effective against aircraft, but also the all-new 9M96 actively guided missiles, which are manoeuvrable and optimised to combat cruise missiles.

- *VKS ground-to-air defences: low-level shield.* They are mainly responsible for fighting against aircraft, drones or cruise missiles. For this purpose, they have 58 batteries of S-400/SA-21 (250 km range) as of 1 January 2021, 5 of S-300PM/SA-20 (200 km range)¹⁴ in addition to some 20 old S-300PS/SA-10 batteries (75 km) currently undergoing retirement.¹⁵ These are to be replaced in the long term by the S-3501, which have a practical range of 80 km and are much more effective against cruise missiles. Two batteries of S-350¹⁶ are in service, one of which is used for training. The *VKS* also protect these batteries against short-range strikes, thanks to the *Pantsir* ground-to-air systems. Between 2006 and 2021, 236 *Pantsir* systems, each equipped with two electronically scanned radars, were handed over to the *VKS*.^{17 18}
- *Land forces' anti-aircraft defences or the hope to cover everything.* The ground forces have their own anti-aircraft assets. With little interaction with the *VKS* in Russia's western military region, they interact more with their air counterpart in the Far East. Its arsenal is primarily intended to counter threats in the lower atmosphere, such as drones, helicopters or cruise missiles. Its *Tor*/SA-15 and *Buk*¹⁹ versions, with 12 and 40 km of range, are effective in this role. However, the picture is nuanced by the presence of old equipment, such as *Osa*/SA-8s that have not all been replaced by the *Tor*, and some *Buk* batteries that have not been modernised since the Soviet era.²⁰ The careers of ground-air operators in the ground forces are also more limited than in the *VKS*. An anti-missile capability is provided against in-theatre ballistic munitions (300 km), with S-300V and V4, of which five batteries are operational.²¹



(PG) This *Pantsir* system belongs to the *VKS* (to the left) and this *Tor* M2 to the ground forces (to the right), in Moscow, in May 2016, are the ultimate of the Russian short-range ground-to-air defense. Their weaponries range to respectively 12 and 9km against targets like MALE attack drones.

14. “[Modernisation of the S-300PM-2 in the Voronezh Oblast](#),” *Telegram*, 26 November 2021.

15. S. Linik, “[Osnova nazemnovo segmenta PVO RV](#),” *Topwar.ru*, 9 March 2020.

16. D. Grigoriev, “[VKS Rossii poluchat neskolko divisionov noveichikh ZRPK ‘Pantsir’](#),” *Rg.ru*, 10 June 2017.

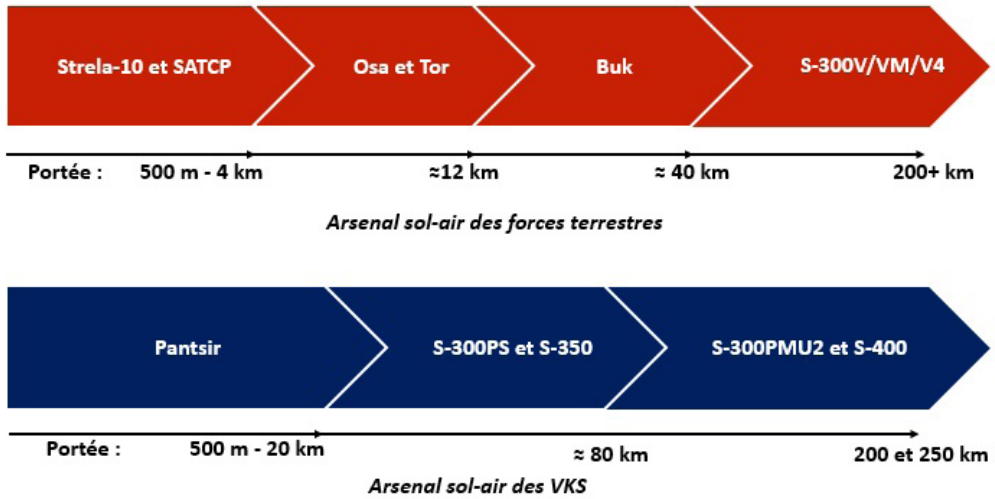
17. A. Berestovaya and N. Baranov, “[Tri divisionnikh komplekta Pantsir-S postupiat v VKS RF](#),” *Tsvetazda.ru*, 10 December 2021.

18. “[Tri divisionnikh komplekta Pantsir-S postupiat v VKS RF](#),” 10 December 2021.

19. The ground forces use four versions of the *Buk*: M1 and M1-2 (SA-11), *Buk* M2 (SA-17) and *Buk* M3 (SA-27)

20. Russia has, as of March 2022, 8 *Buk* brigades of the following types: M1 (1985), M1-2 (1998), M2 (2008) and M3 (2015)

21. “[Raketnye brigady protivovozdušnyh vojsk](#),” *mil.ru*, 4 June 2022.



II – Staying alive and letting strike: the rationale for a six-bastions defence.

Protective bubbles rather than a high wall border

Given the vastness of Russian territory, Moscow cannot completely prohibit raids along all its borders. Its strategy is rather to concentrate its equipment in strongholds, around six points considered crucial (see map 1) for political or military reasons. This choice provides the opportunity to rationalise the use of equipment and to regroup its operators around relatively populated and attractive areas.

The bastions of Moscow and St Petersburg. The country's two largest population centres each have a protective belt. The Russian capital is covered by 10 S-400 batteries, and St. Petersburg by 8 batteries of the same type. The Moscow bastion, which received the first S-400 batteries in 2006,²² is gradually replacing them with more modern versions. The new 51P6 launchers, introduced at the end of December 2021 to the 210th Anti-Aircraft Regiment,²³ can use the 9M96 missile, which is optimised to intercept cruise missiles.

Three port bastions. Some coastal areas have reinforced defences. For Crimea and Kaliningrad – four S-400 batteries each – this is justified by a geographical location exposed to rivals. The Murmansk-Severodvinsk area in Russia's far north is home to Russia's largest surface ships and half of the naval deterrent component. This arsenal justifies the presence of six batteries, protecting vulnerable Russian vessels in port. They only arm their defences during missions at sea.

Sanctuarising the Russian Far East. The ovoid expanse from Vladivostok to Petropavlovsk on the Pacific coast is exposed to Russia's declared competitors,

22. “[Novi raketniĭ polk PVO Moskvi na S-400 razvernuli v Elektrostali](#),” *lenta.ru*, 29 January 2016.

23. “[210-i zenitniĭ raketniĭ polk polutchil novii kompleks S-400](#),” *LiveJournal*, 26 December 2021.

such as Japan and the United States, and to China, which has an unspoken fear of Moscow. A total of 8 S-400 batteries are spread over this area. A notable particularity is the island of Iturup in the Kuril Islands, where the airspace is defended jointly by a battery of S-300VMs from the ground forces for ground-to-air defence and by three *VKS* fighter aircraft. These three aircraft have been in place since August 2018, with regular rotations. Initially provided by Su-35S,²⁴ since the summer of 2021, the operational permanence is based on Su-30SMs, which are more versatile.

Clustered in six bastions, Russian defences are present, to a lesser extent, at other points. Central Russia hosts S-400 batteries near military sites such as Engels or Domna, or industrial sites such as Togliatti or Samara. These defences are likely to be transferred according to the needs,²⁵ and serve as a transferable reserve. Combat aircraft are being trained to deploy to areas with little cover. MiG-31BM loosening has been observed on the eastern Arctic seaboard, such as at Anadyr in April 2019,²⁶ or Rogachevo — Western Arctic — in February 2021.²⁷ These activities are meant to make the task of rival planners more complicated.

A learning defence with the tools to prepare itself

Judging by their training tempo, the Russian forces appear to be performing well. Major exercises are first held in September each year. The different military regions are involved in turn. They are an opportunity to bring together 300,000 soldiers, of all arms, playing the role of attacker or defender. These manoeuvres enable defensive zones to be connected together in the face of airborne perils. Innovations are made to the scenarios of each edition. The Zapad-2017 exercise, held a few months after the American strikes on the Syrian base of Shayrat, highlights the threat of cruise missiles. For Vostok-2018, in the Eastern military region, it was added the intervention of enemy drones.²⁸ As for Tsentr-2019 and Kavkaz-2020, the former aims to evaluate defences in a jamming context,²⁹ while the second employs a joint framework with anti-aircraft systems of the land forces, *VKS* and the navy to work in a coordinated manner around the Black Sea.³⁰

On a more regular basis, units train to repel mock attacks, digitally represented in the control posts of ground-to-air batteries. The Ashuluk and Kapustin Yar ranges near Kazakhstan are used for live-fire training throughout the year. This training is conducted against a range of target munitions. The recent E-95 rock-

24. “[Na ostrove Iturup zastupuili na opitno-boevoye dejurstvo Su-35S](#),” *Aviation21.ru*, 6 August 2018.

25. The Samarra battery was among the first one to be redeployed to join the Ukrainian area, around the 23rd of January, 2022.

26. “[MiG-31 Tikhookeanoskovo flota v Arktikee](#),” *militarynews.ru*, 4 April 2019.

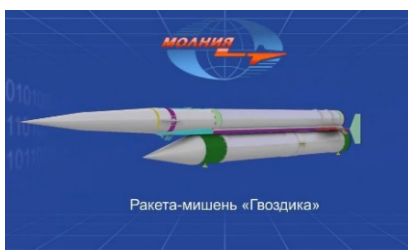
27. “[Liotchiki Severnovo flota na Novoï Zemlie](#),” *function.mil.ru*, 8 February 2021.

28. “[Kak prokhodili I tchem zaverchilis manevri Vostok 2018](#),” *TASS Russian News Agency*, 18 September 2018.

29. N. Valkhanskaya, “[Podrazdeleniya REB vitchislili terroristov na utchenia Tsentr 2019](#),” *TV Zvezda*, 20 September 2019.

30. A. Lavrov and R. Kretsoul, “[Znitnoye polojenie: voennye obedili sistemi PVO v edini kontur](#),” *Izvestia.ru*, 6 October 2020.

et-powered target drones are cruise missiles. Their first significant engagement took place in September 2017, when 25 of them are launched simultaneously for the Zapad-2017 exercise, to simulate a wave of cruise missiles.³¹ Others, more agile models, such as the E-08M, are undergoing state licensing.³² To train S-300V and S-400 operators against theatre ballistic missiles, Russia has long fired old S-25/SA-2 and 2K11/SA-4 missiles³³. Stocks of these recycled munitions are running out, and are to be replenished with 200 faster more manoeuvrable *Gvozdika* target missiles, ordered in November 2018 to better represent threats.³⁴



(DR) The new target-missile Gvozdika, produced by the Molnia study center.

The *Russian Integrated Air Defence Systems* (IADS) was able to undergo an operational test during operations in Syria that began in September 2015. The projected capability was initially a reduced format, with four Su-30SM fighter aircraft and four short-range *Pantsir* surface-to-air systems deployed in Latakia.³⁵ Clashes with Turkey then forced the deployment of an S-400 battery in October 2015, followed by another in June 2017. These systems, together with an increasing number of *VKS* fighter aircraft in Syria, are intended to reduce the risk of strikes on the Syrian regime. The Russian military has been able to practice operations in contested airspace by leading air forces such as the coalition and the Israeli Air Force. While it is not possible to confirm that 90% of the fighter pilots have been deployed, as the Russian Defence Minister claims in November 2021,³⁶ there is evidence that all *VKS* fighter units participated in the operation.

III – Modernising the arsenal up to 2030

The ambition of the equipment plans

The capital for the re-equipment of the Russian forces of tomorrow is secured. Indeed, the modernisation of air defence began in 2007 and interrupted the decline began with the fall of the USSR. However, it was not until 2010 that the budgets

31. “[‘Na ‘boevom sodrujestve’ v pervie ispolzovali imitiruiuchchuyu BLA michen](#),” *Novosti VPK*, 25 September 2017.

32. “[‘Vozduchnaya michen E08M Berta](#),” *bastion-karpenko.ru*, 8 February 2021.

33. N. Klein, “Export potential of the Kalinin Engineering plant,” *Military Parade* (1998): 35.

34. “[‘Programmiy kompleks konsortsiума RazvITie](#),” *Youtube*, 14:36, 13 August 2019.

35. D. Williams, “[Russia sending advanced air defenses to Syria](#),” *Reuters*, 11 September 2015.

36. A. Kasatkina, “[‘Cholgu zavit, chto 90% rossijskikh letchikov imeiout boevoi opit](#),” *TV Zvezda*, 7 November 2021.

recovered. An exceptional financing plan, the GPV 2020, was first allocated for the period from 2011 to 2020. Its amount of 20.7 trillion roubles³⁷, €504 billion at the time, is reserved for equipment orders. It is distinct from the funds of the Ministry of Defence, which are used for the functioning of the forces: training, soldiers' pay, operations. By comparison, the US defence budget amounts to \$700 billion annually, but includes expenses related to numerous deployments. A new Russian funding plan, GPV 2027, was adopted in 2018 and covers the period 2021-2027. It is two years shorter than GPV 2020, and safeguards an equal equipment envelope of 20 trillion rubles (€290 billion as of June 2022).³⁸

The Russian air fleet has been extensively modernised by the GPV-2020 and comprises 319 modern fighter aircraft, assembled in the period 2014-2016. The new GPV-2027 provides for the delivery of 121 supplementary aircraft. These include 21 Su-30SM2s for the naval aviation,³⁹ with enhanced air combat capabilities or 30 Su-35 fighters, 5 of which have already been handed over in 2021.⁴⁰ It is planned to complete with some additional Su-35SM,⁴¹ able to deliver the long-range air-to-air RVV BD missile.⁴² Finally, 70 Su-57 stealth fighters are expected by 2027.⁴³ Modernisations of older aircraft are continuing at the same time. The last non-upgraded MiG-31s of the Navy, parked at Elizovo in Kamchatka, are to be upgraded to BM⁴⁴. About 20 MiG-31BM, from the Monchegorsk Arctic air base are going to be modified to resist polar magnetic interference.⁴⁵ Finally, the GPV-2027 includes a broad procurement of modern air-to-air ammunition,⁴⁶ that were neglected by the previous plan.

A similar evolution is observed for the ground-to-air equipment. The last budget planned to allocate 14 S-400 batteries to VKS up to 2027,⁴⁷ which should bring the total number of deployed batteries to 72. In addition, there are 12 batteries of

37. R. Connolly and M. Boulègue, "[Russia's New State Armement Programme](#)," *Chatham House*, 10 May 2018.

38. P. Luzin, "[Russia's GPV-2020 State Arms Programme](#)," *Riddle*, 18 April 2018.

39. "[Dlia Morskoj aviacsii postroeni pervie tchetire istrebiteliya Su-30SM2](#)," *LiveJournal*, 21 January 2022.

40. "[Kontrakt Ministerstva oboroni na novuyu aviatsionnuyu tekhniku](#)," *Livejournal*, 27 August 2020.

41. "[Modernizirovannyj istrebitel' Su-35SM bort 52 na ispytaniyah v 929-m GLIC](#)," *Livejournal*, 19 October 2020.

42. The RVV BD (or AA-13 in NATO designation), is an evolution of the R-37 developed in the late 1980s. This bulky missile (mass 510 kg, diameter 380 mm) has a maximum kinematic range of 120 km. Originally seen on MiG-31BMs, it has since 2020 been seen in evaluation on the specially lightened Su-35SM prototype.

43. Russian Aviation, "[Over 70 Su-57 fighters to enter operational service with Russian troops by 2027](#)," *ru.aviation*, 15 October 2021.

44. "[Na Kamčatke razvernut novyj aviapolk MiG-31](#)," *Voennoe obozrenie Novosti*, 21 February 2019.

45. "[Istrebiteli MiG-31BM polučili novejšuju navigacionnuju sistemu dlja raboty v Arktike](#)," *The Arctic*, 8 April 2021.

46. In addition to the RVV BD/AA-13 long-range missiles, work is currently underway on the production of medium-range RVV SD/AA-12Bs with new radar seekers, as well as K-74/AA-11Bs with matrix infrared seekers. Eventually, the Izdelie 180 missile, under evaluation in 2020-2022, is expected to displace the RVV SD family and become the standard Russian active radar-guided missile.

47. Operator S-500, "[Rossijskaja armija v bližajšee vremja polučit pervye novejšie zenitnye raketnye sistemy S-500](#)," *Telegram*, 1 November 2021.

S-350s, acquired to replace older S-300PS.⁴⁸ The effort is substantial, since each S-350 battery has 72 9M96 missiles, with active radar guidance and force control.⁴⁹ The anti-aircraft defences of the ground forces should also evolve. After a long development period,⁵⁰ the new *Pantsir* SM-SV — derived from the *Pantsir* S1 of the *VKS* — is set to enter service.⁵¹ This system offers 10-20 km of protection and increases the range of the *Tor* and *Osa* short-range systems, which have so far been limited to 9-10 km. At very short range, the *Derivatsia* self-armed anti-aircraft gun is to replace the ZSU-23-4 and 2S6 *Tunguska* still in service. It is armed with a 57mm automatic gun with programmable shells⁵² and is to provide a 3,500m protection bubble against loitering munitions.⁵³ A new shoulder-launched missile, the *Metka*, is finally to replace the *Igla* and *Verba* in service.⁵⁴



(DR) Lanceur 77P6 du système S-500, photographié à Kapustin Yar en 2021

The S-500 system should finally enter service by 2025. This equipment, promoted by Russian communication, is essentially designed to destroy ballistic missiles on terminal approach. The S-500's 77N6 missile must, according to its specifications, be able to carry out an interception up to an altitude of 200 km, facing a target capable of a speed of 2,700 m/s.⁵⁵ The first S-500 battery has been assigned to the Moscow cover since 13 October 2021, within the 15th Army of the *VKS*.⁵⁶ It is complementary to the *Gazel* anti-ballistic system already in place. New batteries should be produced for the other bastions, which do not yet have a defence against these threats. Moscow's S-500 battery

48. A. Lavrov and al., "[Zastava 'Vitjazej': komplekсы S-350 ukrepjat oboronu juga strany](#)," *Izvestia.ru*, 15 July 2020.

49. Drive hard: use lateral jets to steer the missile. The missile is steered quickly, even in anaerobic environments.

50. A. Arkadiev, "[V 2022 godu zaveršatsja raboty nad kompleksom Pancir'-SM-SV](#)" s uveličennoj zonoj poraženija," *TV Zvezda*, 24 December 2021.

51. Vestnik PVO, "[V soedineniya vojskovoï PVO Sukhoputnykh voïsk prodoljaetsia planomernaya postavka](#)," *Telegram*, 23 October 2021.

52. The "programmable shells" receive information before they enter the chamber in order to detonate as close to the target as possible. This data transmission — first reinvented by Oerlikon for its 35×228 mm anti-aircraft ammunition — can be done digitally or by barcode systems.

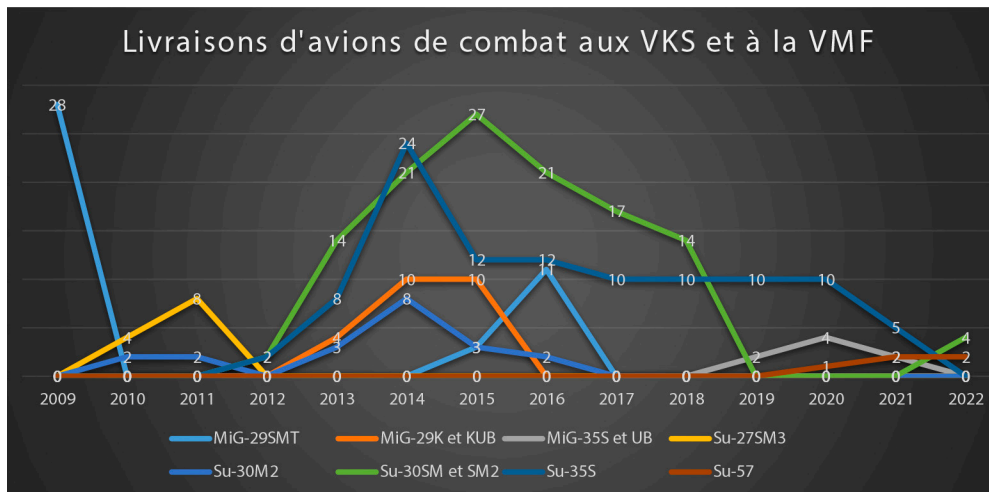
53. L. Aleksandr, "[PVO v četvertom pokolenii – čast' II](#)," *vpk-news.ru*, 20 February 2017.

54. Vestnik PVO, *op. cit.*

55. A. Tsimbalov, "Zadatcha – Obespečhit stretegitcheskouyou mobilnost," *VKO* (2012): 39-55.

56. Vestnik PVO, "[Pervyj brigadnyj komplekt novejšej zenitnoj raketnoj sistemy \(ZRS\)](#)," *Telegram*, 13 October 2021.

was evaluated in the Murmansk sector in December 2021.⁵⁷ The S-500 is a modular system that can be used in a variety of ways. As a modular system, the S-500 is expected to evolve and eventually gain a long-range anti-aircraft capability⁵⁸ in lower atmospheric layers.



Jet Fighters deliveries to VKS and VMF

New technological threats more difficult to counter

With this re-equipment, the arms of the Russian military involved in airspace defence are able to deal with the threats identified in the early 2000s. These threats are changing and threaten battlefield targets or strategic infrastructure.



(PG) The American helicopters (Apache, FARA) will be able to carry eight of these suicides drones Altius-600.

Long-range anti-tank missiles and suicide drones. New missiles, capable of flying for tens of seconds, can be guided against distant targets hidden by hills, out of the shooter's sight. Azerbaijan has engaged the *Spike* NLOS,⁵⁹ with a range

57. "Voennaja BaZa, "S-500 priroet Rossiju s Severa," *Telegram*, 30 December 2021.

58. Vestnik PVO, "Perspektivnaja zenitnaja raketnaja sistema (ZRS) S-500 'Prometej' načala postavljat'sja v rossijskie vojska posle zaveršenija gosispytanij," *Telegram*, 16 September 2021.

59. The Spike NLOS is ordered by the US Army to equip future Apache, FLRAA and FARA combat helicopters.

of approximately 30 km, against Armenia in late 2020. Other anti-tank munitions such as the Indian SANT (20 km range) are undergoing accelerated development, confirming the generalisation of the phenomenon. The battlefield is also threatened by “suicide” drones. The existing models, which evolve in isolation and are propelled by thermal engines, constitute a challenge for ground-to-air defences. A new generation, capable of swarm navigation, is being tested by the US Army.⁶⁰ Spearheading this study, Raytheon’s *Altius* 600 UAV is electrically powered, which complicates infrared detection, and flies at very low altitudes, complicating detection by radar.

Aeroballistic missiles. These long-range weapons are launched from aircraft and reach their target after a parabolic flight. Their high-speed plunging trajectory, above Mach 5, puts them beyond the reach of most defences. Aerial launches offer more opportunity than ground-based missile launches, such as the Russian *Iskander* or Israeli *Lora*. The trajectories followed can pass through areas not protected by ground-to-air defences. Russia was the first to introduce such a weapon, on 1 March 2018, with the *Kinjal* missile carried by MiG-31K fighters. The United States is developing its own AGM-183 missile for the same purpose, which had its first successful launch on 14 May 2022.⁶¹ Carried by 31 B-1B bombers, this weapon could be used in future US saturation strikes, particularly against enemy ground-to-air defences.

Early warning satellites. In orbit, the American infrared anomaly detection system must detect the departure of a ballistic missile and activate an appropriate warning chain. The satellite’s sensors filter out the light spectra characteristic of the combustion of certain propellants. The US *Shared Early Warning* (SEW) protocol allows these alerts to be broadcast to selected allies. Among the alerts transmitted are those of strategic ballistic missile launches, but also of tactical missile launches.⁶² a category to which ground-to-air systems belong. This system makes it possible to characterise and locate a ground-to-air battery that is firing, without using its radar and despite possible optical camouflage. Equipment revealed in this way is exposed to neutralisation strikes. This reactive detection process should become more important, given the potential offered by the European *ODINs EYE* early warning system, for which funding has been agreed in 2020.⁶³

Faced with these threats, Russian defences find themselves rather lplless. Infrared sensor know-how remains insufficient against objects with a low heat signature. In the face of manoeuvring in-theatre ballistic missiles, the West responds mainly with anti-ballistic systems at sea. Russia’s naval capabilities are weak by comparison and ships capable of carrying the naval version of the S-500 — the *Lider* cruiser, and *Super-Gorchkov* frigates — are not expected before the end of the decade at best. Russia is investing in training, but the replicated threats

60. D. Parsons, “[US Army to test interactive drone swarm over Utah](#),” *The Drive*, 22 April 2022.

61. S. D’Urso, “[AGM-183 ARRW Test Launch Finally Succeeds](#),” *The Aviationist*, 17 May 2022.

62. “[SEWS, Mission description and Budget justification](#),” *Globalsecurity*, February 2015.

63. Directorate-General for Defence Industry and Space, “[ODINs EYE](#),” *Ec.europa.eu*, 30 June 2021.

would benefit from being updated. Combat aircraft do little live firing, never engage tactical or, *a fortiori*, suicide drone targets. Anti-aircraft training is hardly more suitable and simulated cruise missile raids pass through defences. These trajectories are unlikely to be used in operations.



(DR) Belarus Su-30SM , in December 2021.
Four has been delivered out of 12 ordered by Minsk

A new restraining environment for defence.

For Russia, the changing geopolitical environment poses another considerable challenge, including for air defence. First, the changing diplomatic climate is upsetting many plans. With the conflict in Ukraine, the risk of air strikes against Russian territory has become a reality. Unguarded borders are a gateway to the heart of Russia. These risks must be mitigated by the CSTO agreements,⁶⁴ which commit a community of adjacent allies to work together in the event of an attack. Moscow should support their rearmament to provide a credible buffer zone.

Among the countries receiving Russian aid is Belarus. It should receive S-400 batteries from the *VKS*, according to an agreement unveiled on the 11th of May 2022.⁶⁵ These deliveries accelerate the reinforcement of this country, which borders the largest Russian cities. Minsk's only acquisitions were 12 Su-30SM fighters in 2017⁶⁶ and a battery of S-400s in September 2021.⁶⁷ Kazakhstan, for its part, has not yet made any progress in the fight against terrorism. For its part, Kazakhstan is unable to better defend its extensive territory. Russia, which has tank and aircraft factories on the border in the Urals, donated five old S-300PS batteries in June 2016 to the Kazakh forces. However, the popular uprising on the 2nd of January 2022 is likely to deter Moscow from delivering supplementary modern equipment. Such reliability doubts apply to other members of the CSTO agreements. Political uncertainties do affect Russia's air defence.

This defence is also troubled by climate change. The thawing of the Arctic Ocean is a matter of time and should open up communication routes between

64. CSTO: Collective Security Treaty Organisation. Founded in 2002, it has seen a resurgence of interest and mobilisation of resources since 2015. It includes Armenia, Belarus, Kazakhstan, Kyrgyzstan, Russia and Tajikistan.

65. "Lukašenko: 'Belarus' ostavit u sebja rossijskie S-400 i Iskandery,'" *Eurasia.expert*, 11 May 2022.

66. S. Tsigankova, "'Belarus' polučila vtoruju partiju rossijskih Su-30SM,'" *Rg.ru*, 20 November 2019.

67. "Postavok v Belorussiou rossijskikh zenitnikh raketnikh sistem S-400," *Telegram*, 3 September 2021.

Asia and America. In order to guarantee the sovereignty of its approaches in this sector, Moscow aspires to strengthen its military footprint there. These objectives were presented in June 2012 by Major General Alexander Tsimbalov in the aerospace defence journal *VKO*. The aim was to establish regional command air centres in Tiksi and Anadyr on the central and eastern Arctic coast.⁶⁸ Their establishment would improve the security of future oil ports — the thaw should make it possible to extract and transport untapped hydrocarbon wealth⁶⁹ — and protect this area where Russian submarines operate.⁷⁰ However, it was not until April 2020 that the first battery of S-300PS arrived in Tiksi.⁷¹ Plans to base fighter aircraft there have been postponed indefinitely. These new bases and centres require human resources that have become scarce, especially when it comes to reaching such difficult and isolated areas.



(DR) One of the three winter version Pantsir, during a test in 2014. These devices have then been sent to the Arctic island of Kotelni, near Tiksi.



(DR) The 5P85D launchers equipping the S-300PS battery – 414th anti-air regiment – set up in Tiksi in April 2020.

Conclusion, a sturdy shield facing a sharpening sword.

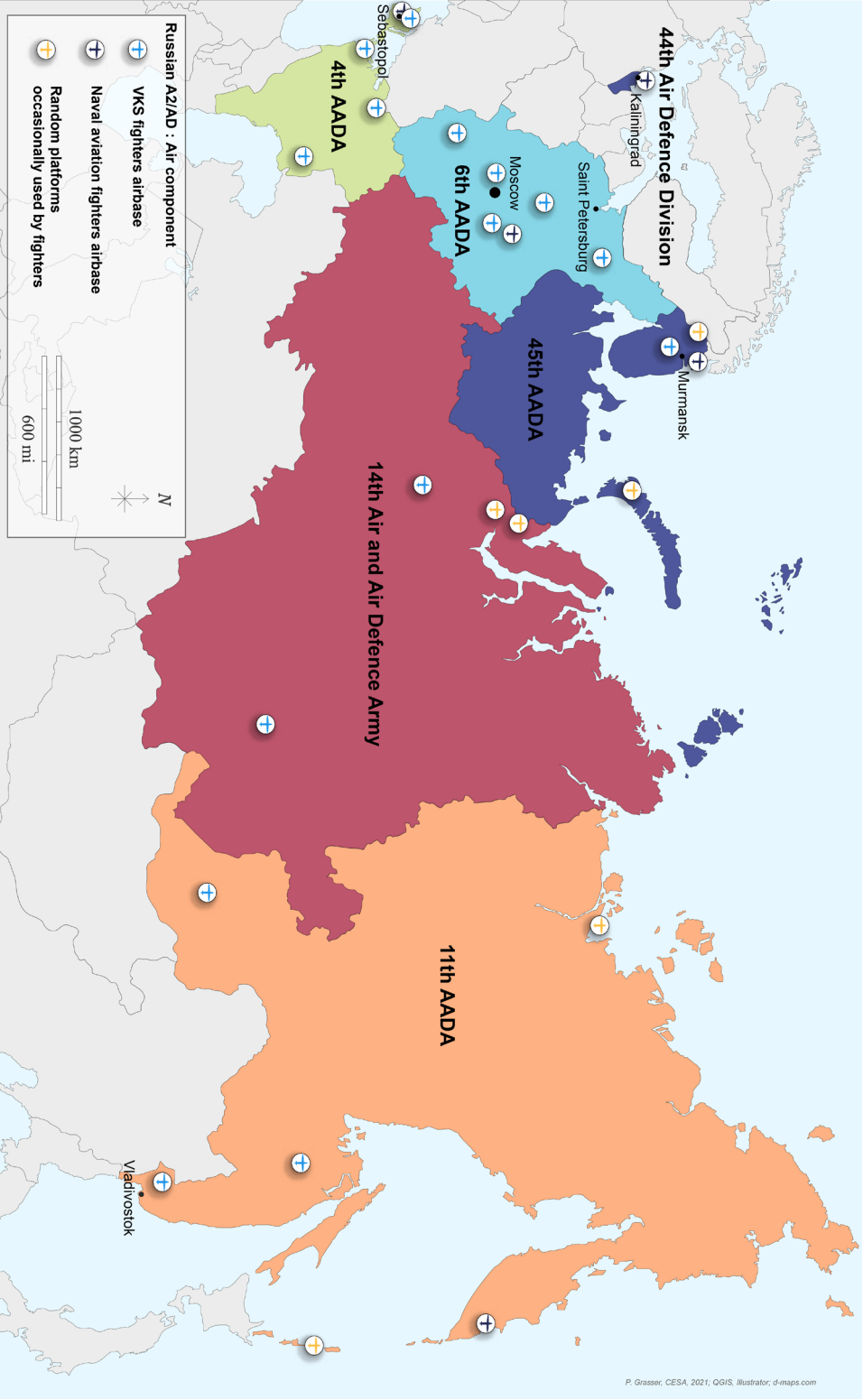
The defence of Russian airspace remains a key priority and is credible in the face of attacks on the most strategic sites. The routes potentially used by raids on the territory are known and are littered with traps. This system could last for a long time, since its foundations are solid and can be adapted to the unexpected. On the other hand, the new attack munitions sound like threats. The Russians' main asset remains their funding, which is secured until 2027, and which can ensure the supply of systems, ammunition and training equipment. Russia also retains the desire to have a variety of equipment, depending on the threat to be faced. This is a costly choice, based on the principle that versatile and effective systems do not exist. Finally, the holding of major exercises remains, despite times of economic tension. The budget allocated is significant. Live-fire campaigns allow for better control of the operation and effectiveness of munitions.

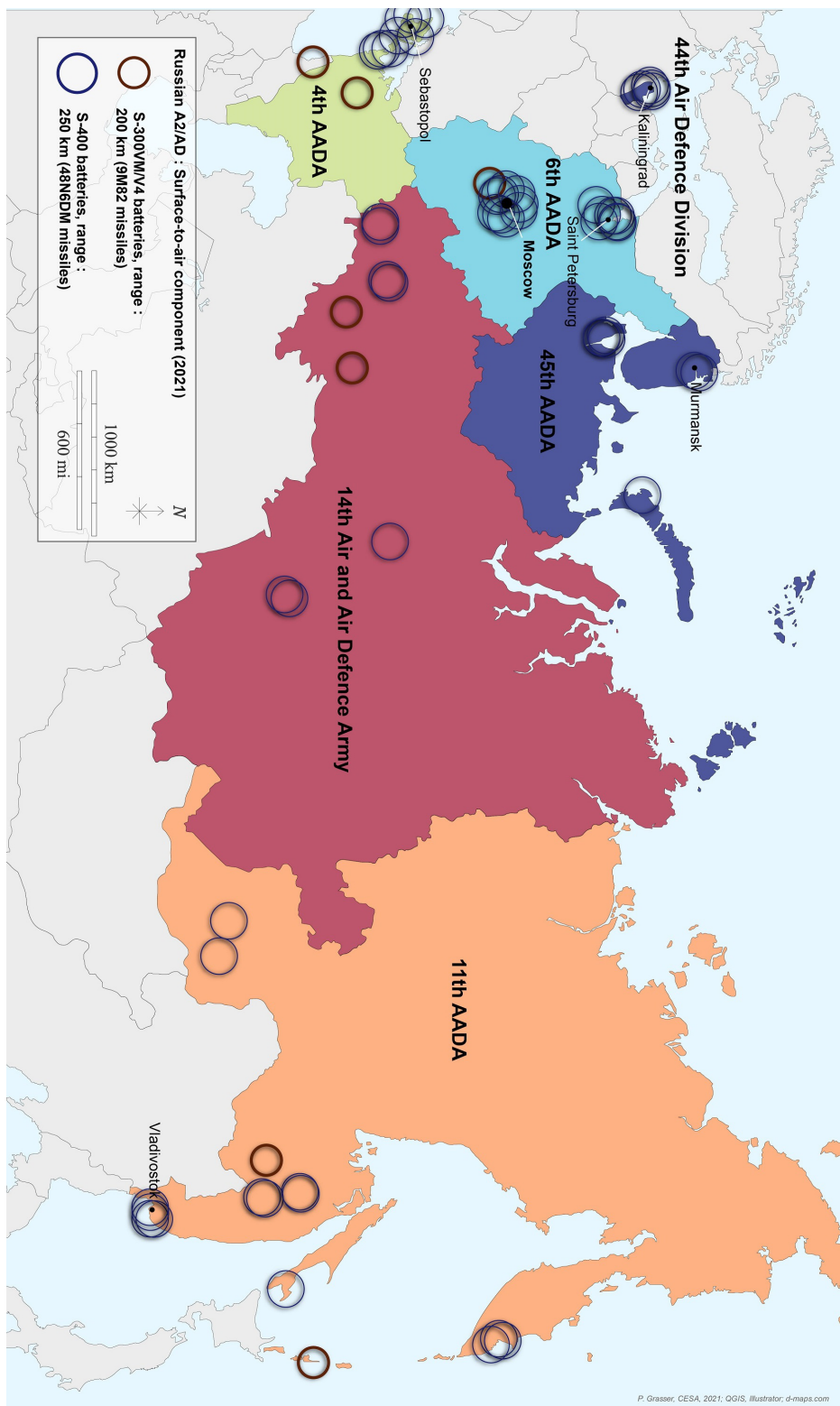
68. A. Tsimbalov, "Zadatcha – Obespechit strategicheskuyu mobilnost'," *VKO*, 2012-03, p. 37

69. Y. Loukin, *Mnogolikaya Arktika v potoke vremeni i smislov*, autoédition, Arkhangelsk, 2019, p. 67

70. "APL Aleksandr Nevskii popolnila Tikhookeanskii flot," 30 September 2015.

71. "Novii zenitniĭ raketniĭ polk v Tiksi na zenitnikh raketnikh sistemakh S-300PS," 4 April 2014.





HISTORY

Rebuilding French Air Defence After 1945: Ten Years of Balance Between Sovereignty and Integration

Capitaine Loris Paoletti

Loris Paoletti is a PhD candidate in history with the École pratique des hautes études.

Introduction

France's defeat of 1940 is a chapter in military history, whose pages have been worn down from being studied so extensively. It is analysed through and through in terms of its causes, its course, and the dark hours that followed. The Vichy regime, which had taken control of a substantial part of the national armed forces, sought to identify and punish all those who were responsible for this failure. It was consequently the fledgling French Air Force (FAF) that fell prey to this persecution. Inevitably a traumatic blow, the campaign also became the founding block from which today's French aviators were born. Coupled with the lessons learned from the Anglo-Saxon air forces, FAF decision-makers were adamant in their insistence to build a robust air defence during France's Liberation. This was to be done in accordance with the Provisional Government of the French Republic (PGFR), which had been endeavouring to rapidly restore national sovereignty over its metropolitan territory. To this end, General René Bouscat (then commander of the air forces involved) and General Martial Valin (then Chief of the Air General Staff) prepared a decree in November 1944, which gave birth to the territorial air defence force (TAD). The decree was subsequently ratified by General Charles de Gaulle, head of the PGFR, on 20 January 1945, while France was still engaged in the Second World War. It essentially entrusted all national air defence resources to the general in command of the TAD.

This was what had marked the beginning of a ten-year-long period during which said command had strived to establish itself, both conceptually and materially, within an environment as strategically unstable as it was financially. In these first post-war years (1945-1947), France had begun to seek its place in a new world order. While the air defence command had been allotted a dedicated command with an adequate organisation, it nonetheless suffered from a lack of resources. In order to brave the air threats at the onset of the Cold War (1947-1949), France had turned to the United Kingdom (by signing the Treaty of Dunkirk in 1947), and then to Belgium as well as the Netherlands (with the signing of the Brussels Pact and the Western Union in 1948, respectively). This collective approach to European defence was what paved the way for Washington to forge the Atlantic Alliance of 1949.

This had subsequently ushered in the succeeding post-war period for France (1950-1955), where it had sought to find a stable ground between preserving its independence and receiving the United States' help and protection. The FAF, and air defence in particular, had also been dragged into walking this tightrope. Contrary to the substantial material, doctrinal, and organisational contributions of the Anglo-Saxons, Paris ultimately refused to integrate its air defence resources in 1955. It then began to distance itself from NATO – a decision set in stone by de Gaulle's return to rule. This article therefore examines the evolution of French air defence post-World War II, namely its purpose that oscillated between being a means to assert national sovereignty and a military instrument for diplomacy, all within a period where France struggled to restore its status as a global power.

Rebuilding A National and Independent Air Defence (1945-1947)

During the period of 1942 to 1945, the FAF compared several blueprints of both Allied and enemy models for its own reconstruction. This deliberation led the founding generals who rebuilt the FAF after 1945 (Bouscat, Paul Gérardot, and also Valin in London) to settle for the Anglo-Saxon strategy, where air superiority was systematically pursued before launching any other military action. The control of the skies henceforth became non-negotiable. However, this prerequisite must be enshrined in the doctrine for engaging the FAF, which, at the time, was still part of both the U.S. and British air forces. Indeed, French fighters' missions had been to cover enemy territory, but the problem that remained unsolved was the protection of its own national territory. As this evidently contained strategic targets, they would naturally fall within a theatre of operations. Thus, the protection of these potential targets would therefore have to be integrated into the FAF's missions in order to counter any mass raids and missile launcher.

Conceiving A Modern French Air Defence

Indeed, when France established its Air Defence Command, its borders had been rendered nebulous by the war waged against the Axis powers. As remarked

earlier, the FAF was under Allied command at this time. As a result, they were organised into integrated units with missions that mainly provided bombing and tactical support. For French fighter units, on the other hand, their missions primarily involved strafing or providing cover; for those with fighter-bombers, these also included carrying out assaults. Within this context, air defence over France itself had depended on the Allied units stationed within French territory, which was considered an interior zone. The 1945 decree had thereafter separated this rear-end portion of the advanced air defence zone; this was where French air defence units were located, including but not limited to fighter crafts, the anti-aircraft ground forces, and other detection means.¹ The responsibility would then fall upon the TAD commander to organise an air defence with any available or recoverable means.² Their operations were to be coordinated between the rear zone and the zone where the rest of the armed forces were stationed. This would include the anticipation of future organisations that would occur during peacetimes.

This geographical division between the front and rear zones was the result of negotiations between Bouscat and then Minister of Air Charles Tillon. Bouscat aspired to attach the TAD command to frontline forces in order to ensure the continuity of actions between zones. On the other hand, Tillon preferred to keep it within the Air Ministry³ to ensure a better exertion of control. As for Valin, he considered that only a general officer, whose rank and seniority granted him unquestioned authority, would be able to ensure this inter-army and inter-ministerial function.⁴ This organisational quarrel was unfortunately reminiscent of the doctrinal disaccord that had ultimately led to France's brutal defeat in 1940.

The TAD was finally placed under the responsibility of the Minister of Air (by virtue of Article 6 in the legislation enacted on 11 July 1938, regarding national organisation in times of war), while all other national air defence assets were placed under the disposition of the TAD commander. This decision resulted from a permanent government delegation, which implied that the TAD had the authority to employ all interministerial means of air defence. An air defence plan was henceforth defined. It covered metropolitan France and North Africa from March 1945, pre-approved by the Air General Staff in May 1945 with hopes to extend this to the rest of the Empire's territories. The TAD now had a single command (as opposed to 1940), with representatives in air defence zones who ensured local command of active and passive means. On the other hand, the National Defence Staff (commanded by General Alphonse Juin, General Officer of the Army, who had little insight on air power's potential) retained a right of review over the activities of this new command.

1. Letter n°519/DAT/S from General Bouscat to the Minister of Air, dated 2 December 1944, SHD/EMDN, GR 4 Q6.

2. *Ibidem*.

3. P. Facon, *L'armée de l'air de la victoire, 1942-1945* (Paris: Economica, 2006): 208.

4. Letter n°448/Cab.EMGAA from General Valin to the Minister of Air, dated 6 December 1944, SHD/EMDN, GR4Q6.

Rebuilding Territorial Air Defence

The theoretical framework, which determined how a unified command could concentrate its means over an entire territory, was based on the idea of creating air zones by isolating divisions previously operated by ground and maritime forces. However, at the end of the war, the TAD was confronted with more prosaic concerns: assembling the necessary equipment, resources, and arms needed to perform missions. While the III/6, II/6, and II/9 fighter groups came under its command in January 1945, the I/9 was only incorporated in March 1945.⁵ The dissolution of the Coastal Aviation Command made it possible to recover its resources, and then to transfer them to 502 and 503 defence zone commanders, which fall under the TAD commander.⁶ Yet, neither the personnel nor equipment were suitable for night missions or for radar and transmission networks. To add insult to injury, the French Army still held some authority over the TAD because it was the anti-aircraft ground forces who were responsible for the anti-aircraft defence.

Furthermore, the rearmament of air defence systems continued to be dependent on – as it did for the FAF – the deliveries of Allied equipment. The first came from the U.S., which rearmed the units based in North Africa from 1943, according to the armament plans on operational needs, as outlined by French authorities. However, France was still obligated to diversify its suppliers. Indeed, U.S. General Ira Eaker (then-commander of the Allied Air Forces in the Mediterranean in which included a substantial portion of the FAF at the time) had expressly related to Bouscat Washington's lack of willingness to continue France's rearmament post-war through its rejection of the VIII plan.⁷ Moreover, disagreements between France and the U.S. over the occupation of Aosta and Stuttgart had already suspended U.S. deliveries until the end of the war, putting an early cessation to the law of loaner ships.

Apart from the U.S., the FAF also fielded rearmed units that were timely contributed by the Royal Air Force (RAF) and the British Air Ministry as early as November 1944.⁸ Of interest to note, it was Field Marshal Charles Portal, then Chief of Staff of the RAF, who had invited to Bouscat, as well as to his Belgian and Dutch counterparts, that the FAF be reorganised based on the British model.

Soviet aircrafts used by Normandie-Niemen were also sent to the FAF. Nevertheless, these aircrafts were only repatriated after the German capitulation and ultimately, did not carry out missions for the TAD during this period. The TAD also employed German equipment (*flak* parts, air defence, and air security equipment).

5. Instruction n°136/3.S/EMGA, of 19 March 1945, SHD/EMDN, 4Q68.

6. Instruction n°EMGA/4399-1/O-S on the dissolution of the Coastal Aviation Command, dated 12 March 1945.

7. M. Vigneras, *Rearming the French: United States Army in World War II* (Honolulu: University Press of the Pacific, 1957, reprinted in 2003): 373-377.

8. Paper from lieutenant-colonel Lassalle, dated 20 november 1944, about air rearmament, SHD/EMDN 4Q6.

To rearm in the short term, three hypotheses had been envisaged: either purchasing equipment produced abroad, purchasing foreign equipment produced under a licence, or simply using equipment produced domestically. The latter, however, required a reconstruction of France's industrial sector. In addition, the National Defence Committee insisted on the need to procure equipment that would not only meet political requirements, but also technical specifications. This task had been ultimately assigned to Lieutenant-Colonel André Hartemann⁹ of the Air General Staff's planning section, who decided to opt for the British option. His exchanges with the RAF eventually served as the basis for France's air defence model, established from 1945. Moreover, for compatibility reasons, ground infrastructure (radars, radio navigation systems – "Gee" channels, etc.) was also acquired from the UK. Subsequently, de Gaulle sent a mission to London in April 1945 to negotiate the purchase of fighters.

From a political point of view, France had been in a situation of greatness without means and possessed an illusory security without an autonomous arms industry.¹⁰ This material impotence due to an overall lack of resources prevented any concrete foreign policy and security discussions from taking form – a prerequisite for the country to define a clear national defence strategy. Indeed, this was partially the reason behind why the French National Defence Staff (NDS) ultimately accepted the FAF's continued integration with major Allied air commands even after it had embarked on its reorganisation.¹¹ However, within this inter-Allied framework where the FAF specialised in ground support missions, there existed a divergence of objectives. On the one hand, this was due to the NDS's own ambitions, who wished to cultivate the FAF into a strong, cooperative, tactical air force. On the other hand, the FAF itself wished to deploy forces to obtain air superiority as a means to protect its bombers and the air defence of France's national territory.

Concurrently, the PGFR President de Gaulle entrusted Tillon (a communist in strong opposition to Juin who had been in charge of the NDS) with the task of reviving France's aeronautics industry.¹² The objective was to reconcile the needs of the economy and those of the military by producing national equipment to wean off its dependence on Allied armaments. This reliance hampered the country's freedom of action, especially after January 1945,¹³ when Allies explicitly expressed their intentions to cease France's rearmament upon war's end.

9. The future General A. Hartemann appeared to be a natural candidate for this liaison mission. Before the Second World War, he held various commands in North Africa where he established cooperative links with the RAF in Malta and Egypt. He extended his liaison missions by becoming a member of the *Joint Air Commission* in Algeria after Operation Torch, which made him a key player in negotiations with the Allies.

10. J.-P. Rioux, in *De Gaulle et la nation face aux problèmes de défense, 1945-1946*, conference report (Paris: Plon, 1983): 65.

11. C. Christienne (General); in *De Gaulle et la nation face..., op. cit.*, 45.

12. M.-C. Dubreil, "Fernand Grenier et Charles Tillon, deux communistes au ministère de l'Air," *Revue Historique des Armées*, no. 2 (1995): 69.

13. "Compte-rendu de la conférence tenue au bureau des Plans," Ministère de l'Air, 1er complément au Plan VII, Paris, 5 January 1945, SHAA, 4 D 2, quoted in M.-C. Dubreil, "Fernand Grenier et Charles Tillon, deux communistes au ministère de l'Air," *Revue Historique des Armées*, no. 2 (1995): 72.

The challenge was therefore to increase the country's own industrial level, which, by the end of the occupation period, was quite low. Indeed, despite equipment being more or less acceptable, production lines required modernisation as France had been facing major shortages, including a demobilisation of personnel.¹⁴ In terms of air defence, as early as December 1944, the French Ministry of the Air Force had sought to rapidly manufacture jet aircrafts. Consequently, by the end of 1945, the aeronautics technical service¹⁵ released a report, outlining all the experimental projects (*Leduc, SO. 6,000 Triton, SO. 6,020, SE. 2,400*) it had undertaken. Regardless, this industrial dynamism ended up being a dispersion of resources.

All in all, the state of the country was in dire need of an economic recovery, rather than a reconstitution of its military forces since another conflict post-1945 remained unlikely. The TAD was therefore put on a backburner up until the onset of the Cold War, when France took measures to counter the Soviet air threat, while strengthening its cooperation with Allies.

The Dawn of Alliances: The Idea of Integration as the Backdrop (1947-1949)

Recognising the vulnerability of its resources, the French government turned to the RAF to rebuild its own air defence. The creation of the Western Union (1948), then of the integrated military command of the Atlantic Alliance (gradually developed after 1950) became the steppingstones for France to construct a modern air defence. This ironically exposed the paradoxical nature of the emerging concept of the TAD. Indeed, TAD was created with the purpose of enforcing national sovereignty. Yet, it could only be fully guaranteed in the face of changing threats (when either the speed and range of bombers had increased, or when the launch of Soviet nuclear bombs became imminent), whose price was, in turn, a concession of national independence.

The First Stage: The Treaty of Dunkirk

France and its long-time military partner, the United Kingdom, had signed the Treaty of Dunkirk in 1947 to protect themselves against any resurgence of German militarism. The RAF had henceforth continued to be the preferred partner to accompany the rise of French air defence. Its Fighter Command – with its long operational and organisational experience – served as a well of valuable expertise for France. London had regularly deployed officers across the Channel to provide advice to the FAF on the architecture of its air defence.¹⁶ This mostly took place northeast of France's metropolitan territory, along the French-German border. This region had henceforth constituted the continent's first line of an advanced defence that was to protect the British Isles. In addition, the United Kingdom began to

14. Oral testimony of Mr. Charles Tillon, produced by the Service historique de l'armée de l'air.

15. "Note n°53 of the aeronautics technical service," quoted in M.-C. Dubreil, *op. cit.*, 72-73.

16. Under the command of Air Commodore Fressanges, Director of Operations at RAF General Staff.

supply France with air defence equipment, including fighter aircrafts, as well as detection and control equipment. While waiting for its own models to be produced, the FAF fielded its first jets, the *Vampire*, which was constructed by De Havilland but of British origin. In addition, France had obtained licences that allowed French manufacturers to produce modern aircrafts and engines much quicker.

Nevertheless, the plan had proven to be too grandiose for an air force that had been undergoing substantial downsizing and immense difficulties in reconstruction. For one, France's industry was unable to supply electromagnetic detection equipment, and its financial state could not compensate for this deficit by purchasing abroad. The British aeronautics industry, on the other hand, had to prioritise the orders made by the RAF first. As a result, FAF received its shipment of *Vampires* only afterwards and in slow increments. Nevertheless, aware of the USSR's air threat, Generals Charles L  ch  res and Arthur Tedder (respectively the FAF and RAF chiefs of staff) met on 9 March 1948 to decide on the air defence organisation across Europe. While France had certainly been dependent on its partner's support at the time, Britain, likewise, was also dependent on strong French participation in European air defence: both states placed air defence as their first and foremost priority.

The Treaty of Dunkirk was thus the birth of a shared air defence within Western Europe. Its objective had been to eventually integrate both Belgium and the Netherlands into a framework of a much more expansive multilateral treaty. Within this system, France would come to occupy a central place due to its geographical location and the scale of the future resources it would mobilise. Aware of the benefits that would come with an advanced defensive across the continent, the United Kingdom committed itself to providing as many modern aircrafts and detection and control equipment as possible.¹⁷ The RAF was then given the task of training Allied airmen towards air defence missions. These agreements subsequently marked the beginning of a harmonised European air defence, built upon a common employment doctrine, ensured by similar resources. This shared vision was set into stone by the Treaty of Brussels.

The Treaty of Brussels and the Western Union

Amidst the growing dangers of the Cold War, the Treaty of Brussels was adopted on 17 March 1948. Ratified by the United Kingdom, France, Belgium and the Netherlands, it set the stage for the beginning of a European integration, providing, in particular, a collective self-defence clause upon any armed aggression in Europe.¹⁸ On 28 September 1948, Member States of the Brussels Pact established the Western Union (WU) defence organisation, consisting of a unified military high command that served as a joint staff (air matters were

17. M.-S. Decup, *France-England, Les relations militaires de 1945    1962* (Paris: Economica and Institut de Strat  gie Compar  e, 1998): 209-210.

18. It should be noted that this agreement was no longer aimed solely at Germany and therefore did not exclude the possibility of a Soviet invasion.

entrusted to the British airman, Air Chief Marshal Sir James Robb), along with a committee responsible for armaments. In a sense, it was the WU that allowed the incorporation of the “Benelux” countries into the Treaty of Dunkirk, already jump-started by previous French-British negotiations. Consequently, the burden of European security was more evenly distributed and the number of countries to oppose Soviet forces had increased.

For France, the objective was also to allow its northeastern front to push back against enemy advances to as far east as possible – before ensuring the WU’s air defence. Intervention forces were to consist of tactical groups, while fighter groups were also to be organised. Belgium and the Netherlands, which were likely to be invaded first, would focus on tactical aviation to halt the ground advance and, if necessary, provide air defence. France would then provide the majority of ground troops, but also participate in air control through its air defence.

To fulfil its own treaty obligations, the United Kingdom was to provide most of the equipment (radar, aircraft, support, and maintenance) to France, but also to Belgium and the Netherlands – both of which were facing severe shortcomings in the area of transmissions. In short, the Treaty had little military value as it was far too ambitious in relation to the resources of its members. Moreover, the British industry could not simultaneously meet the needs of its RAF, in addition to the WU’s air forces. It thus served as more of a declaration of intent, but which eventually convinced the United States to re-engage in Europe. The return of the United States would come to accelerate the development of France’s air defence, which had but a framework and insufficient resources. For the TAD – having been neglected for years¹⁹ – to increase in power, it would require a political, financial, and industrial thrust forwards that the Atlantic Alliance could provide.

From the Western Union to NATO

The United States broke out of its isolationist posture with the adoption of the Vandenberg Resolution of 11 June 1948. The process leading to the creation of NATO began and was completed in April 1949. The Mutual Defense Act was passed on 6 October 1949 and was finalised by a bilateral French-U.S. agreement.

The Washington Treaty had not come as a strategic surprise. The involvement of the United States had been inevitable in the event of an invasion of Europe. It was only a matter of it being officialised as the security context became increasingly precarious.

For France, joining NATO would come with two concessions. First, France would be forced to acknowledge its inability to defend itself without Allies, particularly the United States. Second, as a Member, it would be forced to yield a part of its sovereignty, which would be an admission of failure in upholding the

¹⁹. Oral testimony by General Montrelay, produced by the Service historique de l’armée de l’air and available for consultation at the SHD.

1945 Gaullist ambitions. France therefore remained solely attached to the WU, which it had viewed as an appropriate counterweight to the heavy British-U.S. relations in NATO. For French diplomacy, however, the Atlantic Alliance was a privileged instrument that controlled Germany through the force of its Allies. Likewise, the Charter did not prevent Member States from developing their own autonomous capabilities, which would be an overall benefit to France's TAD. Above all, NATO accelerated the integration of Allied armed forces and their equipment standardisation under the September 1949 military assistance plan. In an article published in June 1949 in the journal, *Forces aériennes françaises* ("French Air Forces"), General Léon Montrelay, TAD's Commander, proposed to have his command assessed a few months before the signing of the Washington Treaty. He had recognised TAD's mutual dependence in France and in Western Europe. He thus wrote that he was in favour of a common organisation, the pooling of resources, and a collective research effort. Furthermore, this article served as a major factor in turning the tide: the commander of the TAD had affirmed his support for an integrated air defence. He then endeavoured to achieve this through the assistance of the United Kingdom, which had still been reorganising France's TAD²⁰ and that of the Brussels Pact Allies.

Indeed, joining the Alliance raised many new questions. For instance, the relations between the National Authorities and the Allied Wartime Operational Command would impact National Sovereignty – a factor that any incorporated solution must safeguard, in addition to facilitating the efficient conduct of operations.²¹ The distribution of missions between the operational zone and the interior zone also remained unknown in the early days of the Atlantic Alliance.²² Moreover, the FAF had to redefine its role should there be a conflict between NATO and a "USSR-type" enemy,²³ notably regarding the type of means it should use and where they should be stationed.

Thus, in 1949, NATO's beginnings were mainly shaped by a new diplomatic setting. The military advantages only arrived in the form of rearmament following the Korean War. However, this Atlantic commitment ultimately hindered the development of the French TAD, which was also compelled by the Indochina War.

A Tumultuous Rebirth of French Air Defence (1950-1955)

In the early 1950s, the Soviet air threat was very much present. In addition to nuclear weapons, the USSR had 8,200 fighters, 3,700 medium and light bombers, as well as 1,200 heavy bombers.²⁴ The French national defence staff estimat-

20. Étude comparée des organisations de DAT française et britannique, 21 October 1949, SHD/Air, AI 02 E 2819.

21. SHD/Air, AI 02 E 2819.

22. *Ibidem*.

23. SHD/Air, AI 02 E 2811.

24. J. Bertin (Captain), "Aviations étrangères," *Forces aériennes françaises*, no. 71 (August 1952): 700-708.

ed that Soviet forces would reach south-western France in only twenty days in the event of an invasion. In the face of this growing threat, France had few means to carry out an aerial confrontation, as its air defences were scarce and outdated. It was consequently a NATO membership that would provide the financial support needed for TAD's equipment.

Air Defence at its Limits or a Need for Atlanticism?

In terms of air defence, NATO covered Western Europe by establishing operational zones, regardless of national borders. France was therefore divided into two: the northeast of the country became a part of NATO's First Tactical Air Command and was integrated into its Fourth Allied Tactical Air Force, while the rest of the French territory fell under the command of the TAD. The advantage of this division was that NATO's inter-Allied system would slow down the first shock of a potential Soviet offensive. After this first enemy wave, the French air defence in the second line would repel this attack whose momentum had been blunted. Likewise, the format on the Rhine served as advanced detection that compensated for the lack of depth to France's national territory. On the other hand, a qualitative difference had emerged between the two zones. The defence on the Rhine had a concentration of the most modern equipment, whereas the French air defence relied on obsolete aircrafts, whose modernisation depended on military aid plans and the revival of its national industry.

Equipment deliveries made under the military assistance plan of May 1951 included the first F-84 *Thunderjet* fighter-bombers that were immediately fielded. While these aircrafts had only been used in the integrated units, they still served as a standard of reference for the French industry to manufacture its own interceptors. Subsequently, the *Ouragan*, the first nationally-built fighter, was produced. Tested by U.S. pilots, it was judged to be efficient enough to be integrated into the Allied system and to ensure TAD missions at the national level. The validation of the aircraft's performance by the United States also opened the door to off-shore contracts. As a result, the French aeronautics industry was then able to produce more fighter aircrafts, which were paid for by Washington but placed at the disposal of the FAF, free of charge. As fighter squadrons continued to use more and more French equipment, this became the fuel to boost France's own industrial level.²⁵ This revolving door financed the delivery of 185 *Ouragans* out of the 350 received by the FAF after 1952.²⁶

This consequential process was enhanced by the establishment of U.S. and Canadian bases in France. While the United States considered France as a rear base for its logistics, Canada deployed an entire air division to the Metz region,

25. J. Doise Jean and M. Vaïsse, *Diplomatie et outil militaire, Politique étrangère de la France 1871-2015* (Paris: Éditions du Seuil, 2015): 517.

26. A. Houizot, *Le problème de la défense aérienne à l'heure de l'OTAN, 1949-1966* (Paris: Service historique de la défense, 2007): 27.

which comprised two air bases (Marville and Grostenquin) and a headquarter. Between 1952 and 1954, the Royal Canadian Air Force (RCAF) fielded about 75 *Canadair Sabres* (this number increased in the late 1950s²⁷), capable of carrying out air defence missions. By way of comparison, the number of interceptors deployed by the FAF at the time varied between 225 in 1950 and 275 in 1953.²⁸

Overall, NATO's contribution to France's air defence drew mixed reviews. Firstly, few of the integrated units carried out such missions beyond the north-eastern French region, as the Alliance had delegated most of its airspace defence to France. Moreover, Allied radar and control centre operators essentially only supported their own national air forces – although the Canadian radar near Metz (involved in RCAF interception missions) occasionally cooperated with French units.²⁹ Nevertheless, NATO offered valuable doctrinal and technical foundations from 1949 and onwards, which had aided in the modernisation of FAF's own interceptors.

Reconciling NATO Requirements with French Sovereignty

In the aerial domain, the integration of French tactical air forces became effective at the end of the 1940s, as noted by historian Aurélien Poilbout.³⁰ For air defence, the problem was more complex. From a strictly military point of view, the need for cooperation was obvious. The TAD and the FAF were in favour³¹ of harmonising means and procedures, including the sharing of intelligence. Yet, from a diplomatic point of view, the French government opposed integration in the name of independence and national sovereignty – a move arguably made to maintain its hold on the decision-making authority to open fire.

While several development attempts were made to merge the different air defences after the signing of the Atlantic Treaty, it was only truly launched in 1954 in the form of the Supreme Headquarters Allied Powers Europe (SHAPE). This included a technical component, a capability component (interception means and ground infrastructure), and an organisational component (division of Europe into air defence regions under an integrated command).³² It began with Air Chief Marshal Sir Basil Embry (Air Commander of the Allied forces in Central Europe), who had proposed in 1954 the integration of the French, Belgian, Dutch, and West German skies in Central Europe under a single inter-Allied operational command. However, the French government tempered with this initiative in an attempt to defend its independence in air defence matters.

27. *Ibidem*, annex III: Order of battle and origin of the air defence system in France, Graph 2: "Origin and quantitative importance of the air defence system in France."

28. *Ibidem*.

29. *Ibidem*, 43.

30. A. Poilbout, *Les forces aériennes tactiques intégrées à l'OTAN et ses incidences sur la politique et la stratégie françaises de 1946 à 1966*, Master's thesis in History under the direction of J.-P. Bled, Université Paris Sorbonne Paris IV, academic years 2005-2007, 6.

31. See the numerous articles published by airmen in the magazine *Forces aériennes françaises* in 1948.

32. J. de Lespinois, "Déjouer la menace verticale: l'unification de la défense aérienne de l'Europe occidentale, 1947-1961," in *Revue historique des armées*, no. 236, (3rd quarter 2004): 80.

Air defence negotiations between France and NATO reached its first impasse in 1955 when French General Paul Bailly, Chief of Staff of the Air Force, rejected the principle of a pure and simple integration. Against a backdrop of diplomatic tensions, France refused to accept the TAD and other national air defence commands to be treated as NATO commands, which would result in France losing their already small number of units to an integrated command³³ – not to mention that the FAF had been engaged in Indochina and would then again in Algeria. Thus, even the negotiations that followed continued to be marked by the same diplomatic and strategic differences. Although airmen were rather in favour of integrating the TAD, the return to power of General de Gaulle in 1958 only cemented France's definitive rejection. Anxious to reaffirm national independence, the new President of the French Republic turned down any form of TAD integration into NATO. In its place, rather, he left the door open to an extensive "technical cooperation", which included the implementation of a unified detection and intelligence system, or the application of common procedures.³⁴

Conclusion

General de Gaulle's refusal was a strong diplomatic statement delivered by France with the intention to restore its previous grandeur. This eventually led to its exit from the Alliance's integrated command in 1966. For the TAD, the impact from this was ultimately quite low. Under the Puget-Norstadt agreements of 28 August 1961, France and NATO had coordinated their plans and operations, as well as exchanged information on the air situation.³⁵ This allowed the TAD (which became the Air Command of the Air Defence Forces after 1961) to have an eye out in the East beyond its metropolitan borders, without losing a unilateral possession of its interceptors. France ultimately obtained a diplomatic victory when it was granted a special regime within the Alliance, where its independence in terms of air defence was retained. Contrarily, the United Kingdom had become one of NATO's air regions and its Fighter Command was placed under the orders of Supreme Allied Commander Europe (SACEUR) on 1 May 1961.³⁶ Indeed, preserving this autonomy was what had eventually granted French air defence the necessary freedom of manoeuvre to accompany the birth of its military nuclear power.

33. Letter No. 1362/EMAA/BPE/S of 13 September 1955 addressed to the Minister of National Defence and Armed Forces, SHAA, E 2 922.

34. Letter from the French Government of 10 August 1960, quoted in A. Houizot, *op. cit.* Annex VI.

35. J. de Lespinois, "Déjouer la menace verticale...", *op. cit.*, 80

36. C. Carlier, *Chronologie aérospatiale, 1940-1990, 50 ans d'aéronautique et d'espace français* (Paris: Economica, 1992): 76.

INTERVIEW



Interview with général d'armée aérienne Stéphane Mille, Chief of Staff of the French Air and Space Force

Jean-Christophe Noël



DR

To begin with, can you tell us more about your background and whether you grew up in an aeronautical environment?

My family lives in the South-East of France, in the Orange region, but I grew up in different regions of France, mainly in the North-East, as my father was in the military. He was an officer-mechanic in the French Air Force and was predominantly assigned to units equipped with Mirage IIIs (Orange, Nancy, Colmar). Of course, I followed him in all his assignments. I was rather attracted to sports when I was a child, but sometimes I had the opportunity to hang out in the hangar or to grab a pilot's helmet and proudly wear it. So, yes, at a very young age I was already exposed to my future professional environment.

Were these early contacts with the military world decisive for the choice of your professional career?

They obviously played a role, and I remember that I already felt the strong constraints of the military profession and wondered about them. In fact, it was the way the air community mobilized after my father's accidental death in a

bicycle accident that decided my future. In the first few hours after the tragedy, different people gathered around my family. They supported us in our mourning and accompanied us daily to overcome all kinds of hurdles that arise when a husband or father suddenly disappears. For me, from then on, it was a matter of course. I decided to join the Air Force.

Your career as a fighter pilot has primarily been in air defense (AD) units. Was this your choice or was it a coincidence?

I had the opportunity, along with my classmates, to fly fighter aircraft during our training at Ecole de l'Air. My first flight took place in Istres in a Jaguar, but most of my aeronautical activity in the Air Force combat units took place in Orange on the twin-seat Mirage F-1 B. I flew a lot during a AD exercise. I was able to follow intercepts from the rear seat and enjoy unique sensations during air combat. I was enthusiastic about this experience and the atmosphere in the unit. The staff, despite the high daily pressure, were particularly kind to me. I found the same feelings of solidarity and humanity that I had experienced after the death of my father. The environment, the mission, I enjoyed everything/all of it, and that's what I wanted to do.

Among the hurdles to overcome in order to join an Air Defence squadron, there is the “amphitheater“ at Cazaux. The young pilots receive their assignments according to their ranking. How did you rank?

I ranked third in my class and as soon as the training finished, we all considered all possible combinations to try to imagine which unit we could be sent to. We were informed of the places available the day before, and after a long discussion with my colleagues, I came to the conclusion that a posting to the Mirage F1C in Reims was in my sights. This suited me perfectly because it was an Air Defense (AD) wing and, what's more, it contributed to the bulk of AD deployments on overseas operational deployments or *opex* as they are known. But the allocation system does not simply follow rank. The aircrew HR advisor divides us into several groups of three. Three slots are then offered per group. Considering my position, I had no choice but to take the last one that was offered. The first pilot of my group was assigned to Orange, the second to Cambrai, and I was finally assigned to Strasbourg on Mirage F1CR. At this point, I asked, with an audacity that still surprises me, if there was still a position at Orange. The HR advisor answered yes and surprised me by announcing that he was sending me ... to Orange! I pointed out to him, and I'm not sure what I was thinking at the time, that the second in my group would have liked this posting and that I would gladly let him have it. In a decision combining exhaustion and irritation, he decided to let us choose our postings ourselves according to our position on the list! So there I was posted to Reims, as I had hoped for the day before.

That was back in 1990. Did your new fighter squadron welcome you with enthusiasm?

The reception was chilly. A sign reading ‘Disciplinary Squadron 1/30 Valois’ was prominently placed above the entrance door of the unit. But I kept smiling and after a few days, the flight commander made me understand that the squadron accepted me. Because a fighter squadron, especially at that time, was and remains a really special unit. The number of pilots was much smaller than today, and the facilities were much more rustic than those of our current units. Human relationships were essential. You had to make a place for yourself in the group, without losing yourself. To be recognized and valued from a professional point of view was essential. Knowing how to be decisive, as I was during the weekly soccer games against the other two fighter units stationed on the base, was another great asset!

What was the atmosphere like in the Mirage F-1 C air defense squadrons at that time?

The activity was intense, just like today. Two main missions set the tempo in the life of the unit. First, maintaining operational readiness was a major part of everyone’s schedule, in a context where Cold War reflexes were only slowly being lost. Then, the detachments to Africa would follow one after the other. I remember the luggage that would regularly hang around in the unit, waiting ready to be shipped to Chad. At the time, the Mirage F-1C was the only air defense aircraft deployed to Africa. This is one of the reasons why I wanted to join Reims. I wanted to deploy as soon as possible.

Did this happen?

Yes, I quickly gained my professional qualifications and had the opportunity to go to Djibouti before even being qualified as an operational pilot, and then to N’Djamena once I was qualified.

What do you remember about your first trips to Africa?

It was in Africa that I experienced the adrenaline of a real operational mission for the first time. I was sent to Djibouti in 1991 to toughen up as a pilot-in-training (PIM). I was on a training mission when the local Commander of Operations (COMOPS) suddenly intervened on our frequency. He sounded out of breath. He asked us to confirm the weapons that we were carrying and informed us that two aircraft, MiGs, were rapidly approaching Djibouti. We had to intercept them and assess their intentions if they penetrated the airspace we were patrolling. As fate would have it, I was the only one armed — with actual live weapons — on my plane. In a second, everything changed and I understood that the success of the mission would depend on me, if the intentions of the Mig pilots were hostile. As a pilot in training, I had not even carried out a single live firing sortie yet! Sensations were then running very high. The excitement was rising, but I had to keep calm in order to continue to fly my plane well, follow my leader and man-

age my weapon system. The two Migs finally turned back, the pressure dropped but I understood that day that I had definitely made a good professional choice.

Otherwise, from the point of view of sensations, from my first Africa deployments, I remember the characteristic smells, the sometimes oppressive heat and this impression of immensity when you fly, with sand seeming to expand to infinity. It's also a tremendous space for operational engagement, with virtually no limits. On board Mirage F-1 C, you only have your eyes, a map, a watch and a compass to find your way or to navigate. Finding a refueling tanker in this vastness is not easy, despite our radars. Mistakes are not forgiven, because there are no diversion areas to catch them, like in France. We grow up, and we grow up fast.

Modern means of mission evaluation did not exist at that time. How do you go about debriefing missions in air defense?

The debrief was verbal then. It was often said, in jest, that the mission was won during the debrief. Some people have sometimes been able to save very compromised situations in flight thanks to peremptory arguments on the ground! But that's not the main thing. In addition to the essential qualities of piloting, the ability to express yourself calmly, to be able to explain a situation with confidence, to describe sometimes complex engagements with accuracy were indispensable. These virtues were also very useful for the rest of your career, especially in situations where you had to convince an inexperienced audience or doubtful leaders of the interest of your ideas. It was a real school of leadership.

How does the arrival of Mirage 2000 change the game?

The Mirage 2000 C is one generation ahead of the Mirage F-1C, and the question for all F-1 squadrons is how to keep up with this newcomer, even though we know that we're not on a level playing field. What is true today was, of course, true yesterday. To ensure air superiority against modern, technologically advanced aircraft, we employ more aircraft. We try to counter quality with quantity, with the risk of suffering significant losses and being driven out of the sky. We must also be able to make all these aircraft evolve together. This was the theme of my thesis to obtain the qualification of Patrol Leader (PL): how to lead a Mirage F-1 patrol in order to remain relevant against the new generation aircraft? I imagined placing the leader of this platform in the back of a Mirage F-1B so that he could focus solely on conducting the engagement.

Will you soon have the opportunity to test the qualities of Mirage 2000 RDI yourself?

Yes, indeed. I became a flight leader (FL) in less than three years and, with little time to spare, I volunteered to become a *Joint Terminal Attack Controller* (JTAC) in Bosnia. My job was to guide the attack aircraft during their attacking passes in support of our ground troops. However, shortly before leaving, I was transferred at short notice to Orange AFB to harmonize the numbers of flight leaders and future flight commanders in the units.

Is it difficult to switch from one aircraft to another?

Dassault aircraft have a lot in common, and it is fairly easy to switch from Mirage F1C to Mirage 2000C. However, it is very rare for a young pilot to surprise a more experienced pilot on Mirage F1C. Experience, intimate knowledge of the aircraft and its flight envelope, and the use of flaps in low-speed phases always gets you out of a tight spot. On Mirage 2000, it's much more difficult, and I quickly realized that the qualities of the aircraft sometimes outweighed the quality of piloting.

On the other hand, the debrief of a mission is often more intense thanks to the more modern means of reproduction. We learn a lot, and the tactics specific to the Doppler radar can be tested and refined. In short, you have to be humble and work to regain your rank when you arrive on a new unit.

Is the theater of operations changing as well?

Yes, I wasn't familiar with Bosnia on the ground, but I was flying over the region regularly as part of the implementation of the No-Fly Zones. The mission was changing significantly compared to Africa, because it was carried out in a joint framework, and no longer just in France. Air defense patrols must fly over their assigned zones 7 days a week, 24 hours a day, to prevent any penetration by hostile aircraft. Personnel and equipment must last.

How do you maintain your concentration and even your motivation when potential targets are rare, due to the presence of Western fighter aircraft?

It is true that these missions can last 4 or 5 hours, with several air-refuelings brackets to be able to stay airborne. In my personal case, I have never had any problems with concentration. Once the mission starts, I am totally focused on it. You may feel a little tired when you are flying the 3 a.m. shift, for example, but it is only temporary. And I can assure you that everyone remains highly motivated. Something can always happen in theater, you have to be ready to react, that's why we are here.

Orange 5th Wing was the only air defense unit to have participated in the Gulf War in 1991? What remains of the experience gained in that period four years later?

I would say that from an operational perspective, the experience was widely shared and disseminated within the units. However, what impacts the crews was not so much their ability to adapt to the new rules of air warfare, but the welfare problems that emerge with the repetition of long absences. The Gulf War marked the beginning of a sequence from which we have not emerged yet, with extremely busy units. Family situations became more tense at times, and some couples do not withstand the numerous absences of a husband and father, or a wife and mother. This is when we can feel the importance of solidarity between the members of the same unit, with their spouses of course, to help each other overcome, or at least attenuate, the difficulties they face, and for which they are not always prepared.

To return to the operational aspects, the Gulf War also heralded a period of some 30 years in which Western air superiority was obvious. How does this feeling of superiority translate once you sit in the cockpit of a Mirage 2000 C?

We know that we are on the right side and that we can benefit from dissymmetric advantages. The tension in a symmetrical type of engagement would definitely be different. We also know that we can benefit from this superiority through continuous improvement of our equipment and coalition work. The way we work evolves as capabilities improve, even though the tactics remain fundamentally the same. But again, there is uncertainty in every intercept. You have to be humble and focused. The mission can even be prematurely terminated if there is a problem with in-flight refueling, which, as any pilot can attest, is not for the faint hearted.

After a period at *Ecole de l'Air*, where you conveyed your enthusiasm and energy to the younger generation, you were transferred to Cambrai. You have therefore served in three of the four air defense wings of the time. Are the atmospheres different ?

Yes, of course, in addition to the identity of each unit, built around its location, its position on the base, its history, the types of aircraft the pilots have flown and the mechanics have worked on and the type of operations which you participate in largely determines the atmosphere. For example, operations structure the daily training and the long-term program. In my time, the essence of Reims wing was Africa. The former Yugoslavia set the place of the units of the 5th Wing. And in Cambrai, it was the detachments in the Levant, more precisely in Saudi Arabia, that left their mark on everyone. Our mission was to prevent Iraqi planes flying South of the 42nd parallel. We took the opportunity to train with the American units. When the Americans arrived in the theater, they didn't necessarily see the point of rubbing their majestic F-15s against tiny Mirage 2000s. After two or three engagements, and let's say a few strong disappointments later, they were very interested in this type of meeting to improve their skills.

Your career as a fighter pilot came to an end after your assignment to Cambrai, but you were not done with operations. You became the number 2 in Operation Barkhane for a year, starting in July 2016. You were switching to a joint environment. How was the transition from air defense to air-land warfare ?

Very good, because we were well prepared. I was fortunate to know the Force Commander (COMANFOR) of the operation, with whom I got along very well. We had many briefings together, especially at the Operations Planning and Managing Centre (CPCO). This period of preparation was very intense, but essential. Furthermore, taking an interest in the job and making the necessary efforts to master its various aspects remains the best recipe, whatever the activity.

How do you balance belonging to a force and working in a joint force ?

By having the will to bring together the cultures of the three services. Mind you, I say bring them together, not dissolve them. Each member of the military



must retain their professional identity and must also learn to work usefully with others. And this is not always self-evident. In any case, it is not spontaneous, as each person has his or her own reflexes and habits, and implements a particular vision of war. Working together allows a better understanding of each other's needs, but also what they can contribute to the common effort. I found that this joint spirit prevailed at the Joint Theater Command Post in Barkhane, and it is with this same state of mind that I have tried to provide inspiration in my subsequent postings.

Which operations did you command with the Force Commander? How did contributing Air Arms differ ?

This was the moment when the major engagements in Northern Mali came to an end and the main effort of the operation shifted to the wider Niger loop. From an aerial point of view, the focus shifted from large desert areas to regions where the vegetation was more luxuriant and where detection was obviously more difficult. Nevertheless, the advantages of air power remained. Our aircraft move quickly throughout the theater. They intervene far, fast and hard when the situation deteriorates during a tactical engagement.

And there are drones, of course.

They do indeed a remarkable job, but their capabilities are still limited. They are not armed and are not equipped with SIGINT sensors. As the saying goes, they look at the terrain through a straw. They excel at identifying, but not at searching. It is important that we have been able to evolve *Reaper* in recent years into a more complete weapons systems.

More generally, which missions can air power be given in these irregular conflicts?

Air power is present across the entire spectrum of operations. In addition to fire support, it participates, for example, in intelligence gathering, significantly improving the mobility of troops, enables them to be supplied, and ensures links with the homeland. And of course, it can destroy structures in the depth of the enemy's position. This is what was done in the Levant with ISIS' command posts as soon as they were detected.

You had to give fire clearances during missions in Africa and the Levant. One suspects that the information in your possession was often limited when you had to give the green light for a strike or, on the contrary, forbid it. You are not on the ground. Apart from the framework set by the rules of engagement, what criteria lead you to decide one way or the other?

You are referring to the famous friction that Clausewitz defined two centuries ago. Even what seems simple is difficult to achieve in war. A situation is never white or black, it is always grey. I believe that it is the role of the leader to make decisions within themselves, based on reasonable certainty. Absolute certainty is very rare.

Even so, the leader is not alone. Experts accompany their decision-making process. I am thinking of the Legal Advisor (LEGAD), for example, who offers sound advice based on the rules set for us by the higher authority. And there are many other players. There are also all the sources of information available, whether it's images, listening to a recent radio message or immediate reports. You can even delegate the authorization to engage in case of self-defense or if someone is in a better position than you to decide. But in the end, the responsibility for the engagement is yours and you will have to own that responsibility.

The action of the air arm in these irregular conflicts is rarely autonomous, it is linked to a joint maneuver. How can we make the most of each others' advantages?

From a technological point of view, it is essential that all the actors are linked together and can communicate on compatible networks. Unfortunately, this is not always the case.

From the point of view of the design and conduct of the operation, it is essential that the leader knows how to simply present their intentions to the subordinate echelons, and how to listen to and discuss with their deputies representing the different components. This enables the leader to fully appreciate what each one can contribute in the precise context of a maneuver. These discussions are invaluable because no one can claim to know everything or to have complete control of all the capabilities available to us. It is only after listening that we can decide and define, if necessary, the level of delegation of decisions during the operation, based to the cases encountered. Of course, I have sometimes favored land or sea-based resources on certain occasions, because the solutions suggested by my colleagues in the other services were, at the time, more appropriate to the situation.

You commanded the CPCO. What distinction do you make between the strategic and operational levels?

The strategic level is the level at which the desired military end state is defined. It is embodied by the Chief of the Defense Staff, with the CPCO as his armed wing. The operational level is that of the integration of effects: the final destination is known; the path must now be traced. An operational level staff can be placed in theater. When I was involved in Barkhane, the Joint Theater Headquarters (*PCIAT* in French) was in N'Djamena, which did not raise any particular problem. To be complete, let me add that the tactical level is the one that conducts operations and produces effects. Several years ago, the Air and Space Force chose to set up its tactical headquarters at Lyon Mont Verdun.

Don't you lose influence by moving away from the theater?

First of all, we gain in personnel because significant economies of scale can be achieved. Several operations can be conducted from the same location, whether they are in Europe, Africa, the Levant or the Pacific. This centralization also

makes it possible to switch resources between different operations. But we are actually talking about the tactical level. It is important to maintain a significant presence of military personnel in the operational headquarters to be able to make the most of aerial modes of action.

You finished your operational career as Deputy Chief Operations at the General Staff . Does the political-military dimension have to take precedence over considerations in this role?

Indeed, the thinking spectrum is a little broader than at CPCO. The preparation of operations is also more prominent, thanks, in particular, to the Joint Operations Command (JOC). The portfolio also includes the management of our overseas presence and a closer relationship with the political level in direct support of the Chief of Defense.

Is this operational experience the basis of your vision for the Air and Space Force?

Of course it is, even if it does not stop at these operational aspects. In fact, my vision is based on three observations. First, I have been able to confirm in all these positions of joint responsibility that the Air Force has always been at the crossroads of operations and has acquired a credibility unequaled in the last decades. There are countless examples. If we stick to the most recent ones, during very different operations, Air Force personnel have distinguished themselves in the Sahel since 2013, in the Levant against ISIS since 2014 and above the Mediterranean during Hamilton in 2018. They participated in the evacuation of Kabul last year on very short notice and in very precarious security conditions. Of course, I want to make sure we continue to showcase that operational excellence.

Are your other observations more related to the operational environment?

Absolutely. My second observation concerns the development of sophisticated equipment. Many competitors have been investing over the last ten years to produce or buy 4th or even 5th generation aircraft. They are improving their denial of access capabilities. At the same time, the size of our fighter aircraft has been reduced. Regional powers have air forces whose capability, at least technologically, is very close to ours. The days when Western air forces dominated the skies are long gone.

I would add that the same trend can be observed in space, with an exponential development of commercial and military activity and the sometimes ambiguous use of dual capabilities with the arrival in several arsenals of satellite neutralization capabilities.

Is this trend reversal already noticeable in operations?

We can measure the effects of a return to competition for control of the sky. Over the past 10 years, in conflicts on the periphery of Europe alone, before the Russian invasion of Ukraine in February, 98 fighter aircrafts, 24 transport

aircrafts and 335 drones of all types had been shot down in combat, or destroyed on the ground to weaken the enemy's ability to control the sky. That's almost the number of *Rafale* we have in our inventory here in France.

Since you mention drones, how do you interpret their unabashed use in Nagorno-Karabakh or Hamas' retaliation against Israel with this type of device in May 2021?

This is my third and final observation. Low-cost offensive air systems can now be acquired by state or non-state actors. There is a democratization of air power. Even those with limited economic resources can consider conducting an air war to temporarily, at least, level out air capabilities.

How can we respond to these structural changes if we do not want to risk military paralysis?

Or even strategic downgrading... Well, first of all, we have to rely on our greatest asset, the personnel of the Air and Space Force. We must make the most of our capability for innovation, which I believe is in our genes, due to the nature and history of military aviation. I also want us to take into account the current movements in the civilian world. We must evolve and vibrate at the same pace as society. Like society, the Air and Space Force must continue to evolve to become even more open, more agile and more connected. Thanks to this mindset, we will be able to effectively guarantee, today and tomorrow, the deterrence and air — and soon space — defense postures we hold. We will also be able to provide the CHOD original response options to obtain decisive effects from the third dimension.

What kind of effects are you trying to achieve?

These are the 3Ds of my strategic vision, a nod to link the vision of the Chief of Defense and that of the Air and Space community: Discourage in the case of competition, Defend in the case of challenge and Defeat in the case of confrontation.

Can you go into a little more detail about these 3Ds?

Of course. In order to prevent crises, we must discourage any foreign will that seeks to weaken France's strategic positions, threaten our interests or hinder our freedom of action. In this context, the Air Force will be able to conduct intelligence missions to anticipate and provide visible and reversible actions to show our determination, to send a strong message to our competitors, and prove our credibility.

As aviators, we also have a duty to defend and protect our fellow citizens, wherever they may be in the world. We must be ready to intervene, when asked, if they are threatened, be able to respond in the case of a serious political crisis and be ready to evacuate them if necessary. We can also help if they are victims of natural disasters.

Finally, we must defeat any adversary who would impose its will by force, if necessary in the context of a high-intensity conflict. We must know how to do this in a joint framework, nationally, with allies or within an *ad hoc* coalition.

Isn't that what we have already been doing?

Yes, but this time we are committed to working across the spectrum. Our image is very much linked to high intensity and we will continue to promote this excellence. We simply recognize that we must also act before a conflict breaks out, in order to “win the war before the war”, as our Chief of Defence Staff repeats. The Air and Space Force has the means to act before conflicts arise. Let's be aware of this and let our partners, competitors and potential adversaries know it.

What are the consequences of this new vision in terms of equipment?

In order to cope with the rise in technology and new threats posed by our competitors, we have to quickly reach the thresholds of the formats defined through our operational ambitions and modernize our equipment. Our major challenge is to find a sustainable balance between quality and quantity in this environment.

I also think it is necessary to promote agility in the acquisition process. If I consider defense against drones, for example, it would be relevant to acquire what is available and already works, rather than waiting too long for equipment that will certainly be excellent but is not yet off the drawing board. It is better to be able to protect yourself now against certain new threats than to wait, powerless for years, for the infallible system that will be able to oppose all types of drones, whether they are small or large, whether they fly alone or in a swarm. The same applies in the space domain. Many things are already on the market; let's take advantage of the opportunities offered by the New Space. Let's be more flexible by being guided by an operational purpose, in the service of our citizens.

Do you plan to give drones a greater role in the Air and Space Force?

Drones are part of the Air Force's weapon systems, just like aircraft and ground-to-air systems. Each of these systems is complementary. We are also considering with FCAS program, the ideal distribution between fighter aircraft and Unmanned Air Vehicles (UAVs) depending on the mission. We are exploring all possible combinations from a theoretical viewpoint by varying the types of UAVs (small, large, armed, etc.) and their number in order to evaluate which procedures with fighter aircraft are the most effective for each mission. It is also important to observe what is happening on the current battlefields, to learn the lessons of recent conflicts in order to anticipate future uses, to be inspired by them but also to protect ourselves from them.

Will other French institutions also want to use them more and more?

Absolutely, and the issue of integrating drones into air traffic, whether military or civilian, is essential. If we want to defend ourselves, we must know the

origin and the intentions of the drones that fly over our territory or our troops. As you point out, more and more actors want to have these devices for very legitimate reasons. In France, these are often ministerial actors. I think we need to identify the ambitions of all the players and stimulate interministerial discussion to guarantee the State's action in the air and better manage the needs of some without harming others. The Air and Space Force must be at the heart of these discussions by enhancing the value of the Air Defence and Air Operations Command (CDAOA), which already has the expertise in managing the 3rd dimension for manned systems.

With the multiplication of drones in the air, do you think that air warfare will mobilize more and more automated or even autonomous machines?

The French position sets a limit. We do not envisage fully autonomous weapon systems. As the Minister has proclaimed on several occasions, there will be "no Terminator on July 14 on the Champs-Élysées". Nevertheless, I note that an increasing number of my counterparts are questioning technological progress in this field and the place to be given to it.

Still on the subject of the war of the future, do you think that air weapons have a role to play in urban warfare? Can we not fear too much collateral damages?

I think that the Air Force showed the full extent of its capabilities quite recently, in the operations over Mosul, in the face of a fanatic enemy. Without its presence, the losses on the ground would have been much greater and the recapture of the city would have taken much longer.

From an ethical and operational standpoint, our targeting guidelines are now very effective and provide precise enough criteria to ensure the best operational effectiveness, take into account the safety of all players, and establish the responsibilities for opening fire. Personnel are also highly trained. But then, let me say again that lethal engagement is a result of a reasonable certainty justified by specific circumstances: this is as true in the desert as in a city.

Can we not still fear that the enemy will invent a false collateral damage narrative? Shouldn't communication on the effects of air weapons be better considered?

Yes, like you, I think that there is a risk of media manipulation and one of my areas of effort is to act to prevent this.

The success of an air campaign also depends on the public messages associated with it. First, to our citizens, to explain what we can do, what we cannot do, and what effects we are actually achieving. To convince them that we are acting in the right way, taking all possible guarantees.

But communication must also serve to oppose the enemy's propaganda, which knows how to exploit the smallest loopholes to try and weaken us, especially in

phases of competition or contest. Therefore, we must leave as little room as possible for the enemy's narrative. And a first step to constrain the enemy's strategic communication is to consider it in the operational and tactical preparation of our missions. We must systematically think about it, and favor modes of action that minimize any potential exploitation of our actions by the adversary. We must master the cultural, social, humanitarian and even local environment to optimize our strikes and never have to rush at the decisive moment. Once again, the enemy's room for maneuver must be limited in this area, as we naturally try to evade their ground-to-air or air-to-air defenses. In this way, we will multiply our effects.

Space is another area of competition. What steps would you like to take to consolidate its new position within your institution?

My operational ambition is to give the CHOD the means to monitor and to act in Space. Competition in this environment is particularly fierce. Some states are increasing the range of their capabilities and may challenge the use of this now strategic domain. We must therefore know what is going on in space to better protect and defend ourselves against hostile acts. Having an Air Command and Control (C2) system that is interconnected with the other joint C2 systems seems to me to be indispensable.

And what about the staff ?

Aviators must become more and more sensitive to space affairs. Their acculturation must be gradual, but regular. Furthermore, we will need experts and we are currently thinking about building motivating career paths.

Broadly speaking, what technologies will become essential in the war of the future?

I won't surprise anyone if I mention connectivity, which is essential for conducting combat collaboratively. For example, integrating manned air platforms and drones into our missions will tactically transform air warfare. But we need to provide links between them. Again, our thinking in this area is stimulated by the FCAS program.

Connectivity implies protecting our networks and making sure they work. But cyber depends on commands other than yours. Is this a vulnerability for you?

Modern warfare is such that everyone depends on one another to complete their actions. If I don't ensure air superiority over the battlefield, our Army colleagues will very quickly lose their freedom of maneuver. Today, everyone must do what they train and prepare for in order to provide what others expect. So, to answer your question, I don't need to own all the cyber assets. I do not share the "it is mine" logic as long as we build the right mechanisms to take advantage of the effects produced collectively, including in the cyber domain.

Connectivity will depend in particular on the development of artificial intelligence (AI). What efforts is the Air Force willing to make in this area?

After developing connectivity, my second focus for continuing our technological modernization is on mastering AI. We have just purchased two supercomputers with massive data storage capabilities for our operations in space. We will be able to better understand the trajectories of objects in space and anticipate actions against our interests. This is a first step, which we must accompany by a better acculturation of our personnel to this technology.

Are you thinking of getting personnel from the civilian world to accelerate the implementation of AI in the Air and Space Force?

Again, we are exploring all possibilities to meet our AI needs. There is little chance that I will be able to attract young engineers from the top AI schools with a financial argument. On the other hand, I must attract them because of the quality of our project. Moreover, I am also keen on an internal solution, a formula that has worked for some of our largest industrialists. The idea would be to select experts by business line and to think with them about what AI could help them to fulfill their tasks in the best possible way. We would then provide them with the capabilities they need and teach them how to use them. This would not preclude having AI specialists in the organization who can shed light on certain problems and ensure that the Air and Space Force keeps up with technological developments in this area.

The data that feeds AI seems to offer its full potential when it can be combined with as many other data sets as possible, to detect opportunities and suggest original courses of action. In this context, should we promote a single joint C2 that would collect and digest all this data, rather than component C2s with more specialized data, limited in volume and adding an intermediate level of command?

We must remember that every maneuver in a given environment needs consistency, and consistency is the key to success. An air campaign has its own momentum, and the data collected is also valuable to the Combined Air Operations Centre (CAOC) officers if they are to effectively monitor events and adapt the operations they conduct. Depriving them of data, or limiting them in favor of a higher level of integration would ultimately hurt everyone. Instead, I believe that AI will be used in headquarters to free officers from thankless tasks, and give them more time to think.

In any case, I am convinced that we must accelerate the digitization of all services related to operations, as we are doing in Space. I would also like to mention the areas of maintenance and administration, where significant gains can be made thanks to artificial intelligence. For example, it should enable us to significantly improve the availability of our aircraft while reducing costs. Civilian airlines have demonstrated the benefits of these practices. In the case of

administration and human resources, for example, training could be accelerated with the deployment of AI to support teaching during the initial or specialist courses of our personnel. Learning would be more personalized. Assisted by their digital applications, students or trainees could individually spend more time on the points where they encounter difficulties or, conversely, quickly tackle the areas they understand without problems. The digital applications could in turn adapt to the level of their users and suggest the best teaching routes.

Do you see other technological advances that will impact the Air and Space Force?

Yes, hypervelocity. The strategic consequences of the introduction of missiles flying at more than Mach 5 with very high maneuverability capabilities will be profound. It is important that Air and Space Forces are able to implement this type of equipment as soon as possible. We must therefore prepare for the arrival of the ASN 4G nuclear missile to maintain the credibility and sustainability of the airborne nuclear component. I will make sure that this is done, and I will particularly invest a great deal of effort in this.

Do you think that technology alone will make it possible to deal with the complexity of the world?

While technology is essential, it is far from sufficient. Like any army, we are made up of people who work and interact with people from other institutions, both civilian and military. I am particularly keen to value these links. The stronger they are, the more effective we will be.

Who would be your preferred partners?

From a military point of view, my background and my convictions encourage me to constantly strengthen our joint, interdepartmental and interallied working capabilities. If the principle is simple, *i.e.* to offer our services and expertise to amplify the effects we produce at the operational, strategic and political levels, the realization is more difficult. We must continue to work on interoperability at all levels. We are working on it.

Are you also thinking of civil partners?

As I previously said, I am very keen to maintain a strong link with society, to follow its evolution, while maintaining our identity of course. Firstly, because in combat, we carry the values of our citizens, of our country, in whose name we fight. Secondly, because we recruit future aviators from society. It is important that they find a professional space that can meet their aspirations. Our institution must not be a place of self-interest, but must absorb the best of what is done outside and adapt it to our principles.

What concrete projects reflect this desire?

The Air and Space Force recruits from all population groups and all social categories. Diversity is an asset, because it brings different points of view and

suggests different solutions to problems. I am very attached to equal opportunities. No matter what your background, anyone should be able to seize opportunities to express their full potential. There is a place in the Air and Space Force for anyone who is motivated, really wants to get involved and wants to live an exciting adventure.

I am also sensitive to the issues of sustainable development. For obvious reasons of safeguarding our planet, but also for the operational advantages that they can provide. For example, if we manage to ensure the sustainability of an air base, we will limit our dependence and make financial gains. We will win on all fronts.

To conclude this interview, how do you imagine the aviator of tomorrow?

I would like them to remain faithful to the values of our elders, by preserving their audacity, their passion, their capability to adapt and their intellectual agility. Our history is rich. It is sometimes happy, sometimes tragic, but useful lessons can always be drawn from it. Let us know it better and be inspired by it.

At the same time, aviators must be people of the 21st century, knowing the opportunities that our society and technology offer and knowing how to exploit them.

That's why I want competence recognized, responsibility encouraged and initiative valued. And, as in the digital economy, that failure be accepted as an inevitable process on the way to success.

Aviators who join the Air and Space Force today in a given specialization will, over the course of their careers, occupy jobs that we cannot even imagine today, due to the rapid and relentless progress of information technology. Let's train them accordingly, teaching them to stay open and to harness change. Knowledge is not enough. You have to know how to update it and be able to change yourself to make the most of progress.

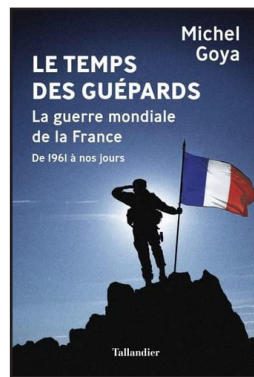


REVIEWS

Le temps des guépards

La guerre mondiale de la France : de 1961 à nos jours

Michel Goya



Reviewed by Ivan Sand

Former colonel in the Marine Corps, Michel Goya is a military historian who specialized in the analysis of 20th century conflicts from the perspective of the adaptation and modernization of armed forces. Prolific author and analyst who is well known throughout the French defense studies community, he runs a blog entitled “La voie de l’épée” and is a regular contributor to podcasts, radio and television programs. He has published two remarkable works on the First World War¹ and more recently a book on the evolution of armed forces.²

His latest book, dedicated to external operations (*opex* in French), has the main ambition of setting at the heart of our national military history the numerous interventions carried out by the French armies since the 1960s. Generally unknown to the public, these operations form a historical object of their own, sometimes difficult to define – the debate on the use of the terms *opex*, interven-

1. M. Goya, *La chair et l’acier: l’armée française et l’invention de la guerre moderne* (Paris: Tallandier, 2004) and M. Goya, *Les Vainqueurs: Comment la France a gagné la Grande Guerre* (Paris: Tallandier, 2018).

2. M. Goya, *S’adapter pour vaincre: Comment les armées évoluent* (Paris: Perrin, 2019).

tion or war regularly resurfaces – even though they constitute today one of the strongest markers of the identity of the French military. What are the main historical ruptures and lessons that can be drawn from the analysis of these 32 major operations and the hundred or so others of smaller scale? This is the question that the author answers in a synthetic and striking book, which opens up numerous stimulating reflections, particularly with regard to the effectiveness of military operations.

A special place in a small but growing historiography

Although few works are devoted in their entirety to the external operations of the French armed forces, a few recent publications attest that the growing interest in this field of research within defense studies. Published in 2020 under the direction of Jean-Marc Marill and Philippe Chapleau, the *Dictionnaire des opérations extérieures de l'armée française (Dictionary of French Army External Operations)*³ devotes a note to each of these operations and also offers thematic approaches, whether they are capability-based, organizational or media-related. This collection provides an account of the diversity of the many operations conducted since the 1960s and highlights certain cross-cutting issues, ranging from force projection to logistics and material developments.

The same year was also published '*Les opérations extérieures de la France*',⁴ a collective work edited by Julian Fernandez and Jean-Baptiste Jeangène Vilmer, which addresses the issue from a variety of angles, notably those of French strategic culture with Olivier Schmitt and the media coverage of operations with Bénédicte Chéron. Shortly before, two books published by the national association of participants in external operations (ANOPEX) analyzed opex from more precise angles, for example, the legacy of de Gaulle's policy in the interventions conducted by France or the casualties.⁵ Although these different works approach the theme of operations from different angles, they tend to study each one separately by juxtaposing them.

With '*Le temps des guépards*' – the title refers to the books on the history of the Algerian war by Yves Courrière, whose volume 2 is entitled '*Le temps des léopards*'⁶ – Michel Goya shows originality compared to the publications described above: the *opex* are studied as a historical whole, not as a series of events. The author endeavors to group these operations together – according to the period, but also according to the type of enemy, the size of the forces

3. P. Chapleau and J.-M. Marill (dir), *Dictionnaire des opérations extérieures de l'armée française. De 1963 à nos jours* (Paris: Nouveau Monde éditions, 2018).

4. J. Fernandez and J.-B. Jeangène Vilmer (dir), *Les opérations extérieures de la France* (Paris: CNRS éditions, 2020).

5. H. de Champchesnel, *Opex. Des vies pour la France. Une histoire des opérations extérieures depuis 1963* (Paris: Historien-Conseil, 2019) and J.-P. Pakula, *L'invention des opérations extérieures. Une intuition gaullienne* (Paris: Historien-Conseil, 2020).

6. Y. Courrière, *La guerre d'Algérie. Tome 2. Le temps des Léopards* (Paris: Fayard, 1969).

engaged, or also the war objectives – and to compare them in order to highlight certain breaks in the period between 1961 and the present day. Mr. Goya joins the position of certain researchers who consider this cycle of operations as a period of French military history on its own. Historians Hervé Dré villon and Olivier Wieviorka had adopted the same division in their recent collective works,⁷ which cover, in two volumes, the military history of France from the Merovingians to the present day.

The date of the beginning of this period seems to be debated: 1963 and 1964 are the years most commonly used by current historiography, while Michel Goya prefers to retain 1961, the year of the assault launched to break the blockade of the naval base of Bizerte by the Tunisian forces. The originality of this approach is therefore to start this “world war of France”, according to the subtitle of the book, before the end of the Algerian War. In this regard, it should be noted that other previous operations could meet the criteria used by the author to characterize an *opex*, i.e., an engagement conducted outside the national territory. The intervention of France during the Suez crisis in 1956 is an example. Nevertheless, by opening his book with the evocation of a speech by General de Gaulle in Strasbourg in November 1961, which refers to the end of decolonization, Michel Goya subscribes to the idea that the period of operations began with the end of the Algerian War and the wars of decolonization. From then on, the French defense model “matches to two perfectly opposed employment hypotheses: on the one hand, the scenario of an apocalyptic war [...] and, on the other, small probable but distant engagements.”⁸ While a potential conflict against the Warsaw Pact focused the attention of French strategists at the time, the external operations are now considered as the most significant events in the history of the French armed forces.

At the political level, a tool in the hands of the president: the benefits and pitfalls of the executive’s strong involvement in *opex*.

One of the main theses defended by the author is the French specificity in terms of political decision-making. The concentration of power at the level of the President of the Republic, as well as the modest role played by parliamentary control over these issues, would first explain the high number of operations carried out by France, in comparison with other European countries such as Germany. Michel Goya thus adopts the presidential term of office – seven years and then five years – as one of the prisms of temporal analysis for the purpose of his study, comparing the record of the presidents of the Fifth Republic in this area. Few operations took place during Georges Pompidou’s term, whereas the second half of Valéry Giscard d’Estaing’s term was marked by an acceleration of the pace of interventions, which the author refers to as “*the time of lightning (1977-1980)*”.⁹

7. H. Dré villon and O. Wieviorka, *Histoire militaire de la France. II. De 1870 à nos jours* (Paris: Perrin, 2020).

8. M. Goya, *Le temps des guépards. La guerre mondiale de la France: de 1961 à nos jours* (Paris: Tallandier, 2022): 12.

9. *Ibidem*, 47. The author picks up a phrase originally formulated by admiral Labouérie.

Contrary to popular belief, the left-wing presidents are not more reluctant to commit the French armed forces than the rightists. For the author, François Hollande is even the president who “*will pile up endless operations*”.¹⁰

The analysis of this strong involvement of the executive branch carries a major criticism: the messages associated with *opex* are often addressed more to the French public opinion than to the enemy being fought. The most critical example used by Michel Goya is Vigipirate (although it is strictly an internal operation and not an *opex*). But it is also a flaw that the author notes in relation to the war in Afghanistan, during which “*the political level interfered as it rarely did before, in conducting operations*” while “*the enemy was the last concern of this war*”.¹¹ This tendency would also lead to vulnerability: it suffices “*to kill our soldiers, if possible several at a time, or to capture journalists, to obtain a retraction of the action taken against him, to the point of paralysis, and then a faster than expected withdrawal*”. Taking up an idea expressed by Barack Obama in a famous formula,¹² Michel Goya intends to establish a clear distinction between the objectives of an operation and the causes of its launch: “*if it is easy to engage armed forces – it is enough to decide to do so – it is often more difficult to disengage them, because it is rare that the basic problem for which they were sent is quickly and definitively resolved*”.¹³

At the political-military level, what are the criteria for a successful OPEX?

The difficulty of ending wars seems also more prevalent in asymmetric conflicts, *i.e.* when France is fighting an insurgent group. Michel Goya calls for considering the enemy as an interlocutor that one should not necessarily seek to annihilate and, for example, that “*wanting to destroy the Taliban was a mistake*”.¹⁴ He notes that the wars that were successful generally met the following criteria: confrontation against a state with objectives limited in time and space. The author illustrates the importance of the spatio-temporal scale by comparing operations Serval and Barkane: if the first was successful, it is because the means were proportionate to limited and clearly defined objectives.

Moreover, confronting armed organizations usually means getting involved in an often complex civil war. Asymmetric wars cannot be won by relying on the recipes applied during interstate conflicts. Similarly, “peace management” operations¹⁵ are judged rather negatively. The idea developed by the author is that an army intervening on foreign territory cannot have the principle of neutrality

10. *Ibidem*, 47.

11. *Ibidem*, 221.

12. According to a quote attributed to president Barack Obama : “It’s easier to start wars than to end them”.

13. M. Goya, *Le temps des guépards. La guerre mondiale de la France: de 1961 à nos jours*, *op. cit.*, 225.

14. *Ibidem*, 302.

15. *Ibidem*, 199.

as its main concern. Otherwise, the in-between position generally results in a prolongation of the conflict, as in Rwanda or Bosnia.

At the military level, how can the effects of operations be measured?

The book also opens up other perspectives on the assessment of *opex* by using criteria that are more precise than the simple achievement of objectives. The author uses some quantitative data such as the number of soldiers deployed per inhabitant (1 soldier for 25 inhabitants during the Algerian war compared to 1 for 1,250 in Chad in 1970)¹⁶ and insists on the question of the cost per enemy killed (1 million euros during the war in Libya and between 500,000 and 1 million for the Barkhane operation according to the author). These figures seem to support a critical view of what he calls “prudent warfare”.¹⁷ This mode of action, in which France does not lose soldiers but which is very costly, as in the war in Libya, is, according to Mr. Goya, beyond the means of France and of most other nations.

In this vein, he tends to criticize a supposed French desire to confine itself to the rank of “brilliant second”, which would have become “its main ambition in coalition operations”.¹⁸ He regrets that the French army does not seek instead to invent different operational systems. For the past three decades, coalition operations have often involved an air campaign to gain superiority in the third dimension, or even to make the adversary fold. This concept is not always fruitful according to the author, who seems, for example, to doubt the real effects of the allied air force during the war in Kosovo: “*it is not clear how much of the Serbian government’s submission was due to the air campaign, compared to the fear of a ground offensive or, perhaps more importantly, the abandonment of Russian support under American pressure*”.¹⁹ Readers may regret that this idea is not more widely supported or solidly argued. More generally, if the effects of air power are rarely mentioned specifically in the book, the author seems to distinguish its use, which was dazzling and effective in the operations carried out in Africa in the 1970s, from the more lengthy air campaigns, which were judged to be too cautious, that had been set up from the 1990s. However, this assessment seems to ignore the difference in the nature of the enemies being fought and the need to acquire air superiority when the adversary has a substantial air force and ground-air defences.

Moreover, one can note a form of paradox when the author regrets the use of a mode of action based on air power, which saves human losses, while he identifies the death of French soldiers as one of France’s points of vulnerability. The argument on the effects and costs of operations involving large air and naval forces, gathered within a coalition led by the American forces, leads to a form

16. *Ibidem*, 38.

17. *Ibidem*, 299.

18. *Ibidem*, 151.

19. *Ibidem*, 151.

of advocacy for increased investment in ground forces, while “the soldiers who suffer three quarters of the losses, those who go into contact with the enemy, are traditionally the last to be served in terms of material investment”.²⁰ On the lack of means of the army, Michel Goya proposes the following innovations for asymmetric conflicts: “*calling on mercenaries [...] mixing French forces with local forces, having more active or reserve infantry sections that are indestructible in contact, would double our counter-insurgency capacities for the price of an aircraft carrier*”. *It might not be as glamorous, and the industrialists would not fail to use arguments to influence political choices, but it would undoubtedly be more useful in the fight against armed organizations*”.²¹ These ideas echo some of the operational modes of the 1960s and 1970s, such as when France set up Franco-Chadian joint battle groups, which echoes the current concept of operational military partnership (OMP).

Stimulating reflection on external operations

These last remarks should not, however, distract potential readers from this very useful and fascinating work. The author’s historical perspective and rigorous method of critical analysis allows him to put into perspective a rare set of very different operations from which he manages to draw general reflections on the French defense model. It should also be noted that this book has the merit of revisiting certain rarely mentioned operations, with Michel Goya insisting, for example, on the French engagement in Somalia in 1993. Let us hope that this book will give rise to other research works on the rich theme of French *opex*, especially in light of the progressive opening of archives concerning these operations.

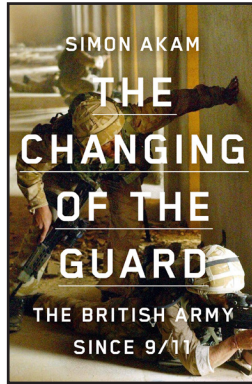
20. *Ibidem*, 312.

21. *Ibidem*, 313.

The Changing of the Guard.

The British Army since 9/11

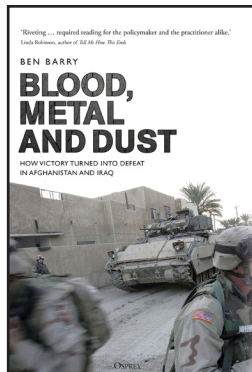
Simon Akam



Blood, Metal and Dust.

How Victory Turned into Defeat in Afghanistan and Iraq

Ben Barry



Cross Reviews by Olivier Schmitt

A Strategic Impasse? The British Army in Iraq and Afghanistan

The armed conflicts in and occupations of Iraq and Afghanistan have been evaluated as quite the loss for the “Best Little Army in the World”.¹ Despite the British soldiers’ proven fighting skills and high adaptability, both campaigns remain as operational and strategic defeats. Offering differing, yet complementary

1. S. Akam, *The Changing of the Guard: The British Army since 9/11* (London: Scribe, 2021), 19.

explanations for these failures, Simon Akam describes the British military (particularly the Army) as being much too arrogant and careless, while Ben Barry explores the structural faults in the strategic conduct of these two operations.² Nevertheless, both pieces neatly complement the official reports (notably the Army's analysis of the Afghanistan campaign and the "Chilcot" report on the Iraq War's decision-making process), as well as previous works on the subject (*i.e.*: Theo Farrell's seminal text on the Afghanistan campaign, *Unwinnable*)³. The two thereby constitute an important starting point for grasping contemporary British society vis-à-vis its armed forces.

Like other Western militaries, the British armed forces entered the twenty-first century with a focus on "revolution in military affairs". Yet, they were forced to adapt to the rise of counterinsurgency in Iraq and Afghanistan. Moreover, military action today must further take into account great power competition. Any "use of force" must also be sufficiently justified to a sceptical British public (and government bodies), who no longer believe in its efficiency after the failures in Iraq and Afghanistan.

Furthermore, these two conflicts took place under the broader political context of the 2008 financial crisis. Because of the priority granted to the protection of the City of London's interests, the British population suffered heavy social consequences. Inevitably, this provoked a profound feeling of mistrust towards its elites, causing an irruption of the populist vote which ultimately reconstructed the British political fabric. More than a decade later, 52% of the British population continue to be opposed to any form of military intervention.⁴ Indeed, this socio-political context had been partly generated by the political-strategic decisions made in the early 2000s, especially those calling to intervene in Iraq and Afghanistan. Consequently, these two conflicts conditioned the future of the British armed forces. As such, these two texts are vital in outlining the evolutionary trajectories of the British armed forces and its political context during the past twenty years.

While both address the interventions in Iraq and Afghanistan, Akam and Barry each employ an organisation and style contrary to the other. To begin, Akam is a journalist who had served briefly as a lieutenant in the army. His *The Changing of the Guard* is essentially a collection of anecdotes and observations drawn from his own experiences and the various investigative interviews he had conducted. The resulting piece is indeed unique in its kind, albeit at times confusing. Beyond his rich anecdotes, the only regret may be the absence of a true sociological analysis of the cultures and subcultures within the British Army (as can be found in John Hockey's classic, *Squaddies: Portrait of a Sub-*

2. B. Barry, *Blood, Metal and Dust: How Victory Turned into Defeat in Afghanistan and Iraq* (Oxford: Osprey, 2021).

3. T. Farrell, *Unwinnable: Britain's War in Afghanistan, 2001-2014* (London: Bodley Head, 2017).

4. F. Holmes, "[Public Attitudes to Military Intervention](#)," *British Foreign Policy Group*, January 2020.

culture⁵). Similarly, Akam's passages on operations are limited to surface-level explanations, rendering them unsuitable for readers seeking a detailed military analysis. Thus, being neither a sociological essay nor a historical recount of recent campaigns, Akam's work is as rewarding as it is frustrating for those who wish for more.

A former brigadier general, Barry is currently an analyst at the International Institute for Strategic Studies. His *Blood, Metal and Dust* strategically formulates relevant feedback by analysing campaigns. It can thus be seen as a lessons learned analysis (LL) of a semi-official, political-strategic nature. Moreover, with his various contacts within the armed forces, the author grants the reader privileged access to many renowned figures and sources. In short, on the one hand, Akam explores the disconnect between the British armed forces and the society they serve. On the other hand, Barry analyses the disconnect between political and military objectives. Indeed, Akam is critical of an institution he finds lacking, while Barry is critical of an institution he admires.

Barry's main argument is a classic one: any hope of success in Afghanistan died with the United States's and the United Kingdom's decision to invade Iraq. This invasion's strategic disaster inevitably diverted efforts away from the other more legitimate and critical conflict unfolding in Afghanistan. For Britain, the misalignment between ambitions and means was exposed in the attempted occupation of Basra – an operation that called for capabilities beyond what had existed at the time. Barry describes these failures to be fundamentally due to the inability of political leaders – particularly Tony Blair – to prioritise strategic objectives and to allocate all the necessary resources. However, this is a skewed interpretation that paints the British military in a favourable light. It conveniently shifts the responsibility away from the military by citing political incompetence (mirroring, for example, the infamous “stab-in-the-back myth” that had spread in the aftermath of the First World War).

On the contrary, Akam, through his interviews and precise quotes, provides a wholly different interpretation. Rather, he sees the gap between ambition and means as mainly due to an army who was preoccupied with preserving its institutional status. Pressure was thus put on political leaders to engage militarily as much as possible in Iraq and Afghanistan. Akam quotes, for instance, General Lord Richard Dannatt, former Chief of the General Staff of the British Army, justifying his recommendations to political leaders on the basis of institutional protectionism rather than of military logic: “it's use them or lose them”.⁶ This ultimately portrays the armed forces as forcing the hand of political leaders in order to defend their existence.

The most interesting passages in Akam's work are the ones that speak of the corrosive motivations within the British Army born of the so-called “interven-

5. J. Hockey, *Squaddies: Portrait of a Subculture* (Exeter: University of Exeter Press, 2006).

6. S. Akam, *op. cit.*, 245.

tions myth”. According to him, a substantial number of companies in both Iraq and Afghanistan deliberately sought enemy contact to acquire boasting rights of having been under fire. Likewise, the overly generous policy of awarding medals also negatively galvanised officers and soldiers to score a Victoria Cross at almost any cost, often at the expense of military logic (particularly in the context of counterinsurgency). This institutionally-provoked aggression led to the development of a subculture that glorified extreme violence amongst British soldiers. Videos of such were widely propagated between regiments. Similarly, the “ally”⁷ trend – the “re-styling” standard uniforms while disregarding regulations in order to appear more “warlike” – also contributed to the degradation of discipline and a tolerance for brutality. Akam directly links this to the torture and murder of Baha Mousa⁸ by British soldiers in Iraq, as well as the killing of an Afghan prisoner of war by a British noncommissioned officer.

Both Barry and Akam insist that while the main British strategic objective had been to maintain the transatlantic bond, the two Afghanistan withdrawals (Musa Qala in 2006 and Basra in 2007) permanently weakened the British military’s credibility amongst their U.S. partners. However, despite this shared reflection, neither provide any in-depth details of what truly caused this transatlantic rift between these brothers-in-arms. Barry solely alludes to the British officers’ overconfidence in their tactical and operational counterinsurgency skills, while belittling the U.S. to be boorish and lacking sophistication (a perception also widely shared by France in the 2000s). Alternatively, Akam argues that the U.S. officers were rather unimpressed with the contribution of the British General Staff. Nevertheless, beyond these brief observations, neither authors present any genuine empirical research that uncovers the deeper reasons behind the U.S. estrangement.

Where the two texts differ in their analyses is on the adaptability of the British armed forces, contrary to their unanimous agreement of the U.S.’s comparable swiftness to adapt, learn, and innovate. Barry argues that although the British Army were able to quickly integrate any necessary tactical adaptations – particularly when under the threat of improvised explosive devices (IED), the inflexible bureaucracy within the Ministry of Defence (MoD) then slowed down the implementation process. Albeit in agreement, Akam, however, wholly believes in the effectiveness of off-the-shelf procurement programmes authorised by the Urgent Operational Requirements scheme (financed by the British Ministry of Finance and therefore part of the defence budget), which account for close to 10% of the MoD’s annual budget. In the end, both are pertinent observations: while faster organisation had been the objective, the adaptations to meet the needs in the field

7. “Ally”, pronounced like “Sally”, is a military lingo, referring not only to a certain fashion sense but also the way a soldier carries themselves. It is often associated with appearing “tacticool” (another military slang) without being solely tactical. See Max, “‘Ally’ Helmet Scrim Competition,” [Max Velocity Tactical](#), Accessed 5 April 2020.

8. Baha Mousa was an Iraqi who died in September 2003 in the custody of the First Battalion, the Queen’s Lancashire Regiment. The investigation into his disappearance revealed that he suffered 93 injuries upon his death.

ultimately took place at the institutional (and financial) level, which allowed for the acquisition of new equipment.

In regard to the systemisation of tactical and operational LL, the focuses of the two texts diverge. For one, Akam provides a long list of cases where tactical adaptations or joint coordination measures had been forgotten only to be constantly re-learned. This analysis, revealing a lack of institutionalisation, also echoes that of Catignani.⁹ Separately, Barry explains that because the Staff College's curriculum on counterinsurgency had been discontinued in the 1990s, the subsequent generations of officers were ill-prepared for Iraq and Afghanistan. This is a phenomenon also observed in the United States.¹⁰ Nonetheless, one could argue that even if this had been continued (including a study on the conflicts fought in Malaysia and Northern Ireland), it would not have necessarily served as a reliable professional resource for British officers. In the early 2000s, the literature was still heavily tinged with triumphalism, depicting solely the alleged "success" of British-style counterinsurgency. It was only after the 2010s that more accurate depictions (including their strategic impasses) emerged through academic endeavours.¹¹ As such, it remains highly doubtful that a distorted historical analysis could have possibly served as applicable operational training for a sharply different reality. Indeed, this opens up to the wider question of what forms of knowledge would be relevant to senior officers, which is beyond the scope of this review.

To conclude, both authors raise important questions concerning the evolution of British armed forces yet they also overlook a more structural issue. Indeed, the UK's presence in these campaigns was only as a "junior partner" whose strategic parameters had been determined by the U.S.¹² In this sense, if these campaigns were successful, then the British performance would appear in a very different light today. Regardless, one substantial question remains: what other credible options did British leaders have? In Afghanistan, Theo Farrell's answer is that foreign forces should have left after 2003.¹³ In Iraq, the Chilcot Commission's response pinpoints Tony Blair's obsession to flaunt his close relationship with the U.S. as the catalyst behind the UK's presence in the invasion, despite overwhelming objection from his population. An alternative grand strategy for these two campaigns that do not acquit the British military of their operational and strategic failures was possible – especially as counterinsurgency seems to have become a political impossibility, and therefore, a dead-end for Western armed forces.¹⁴

9. S. Catignani, "'Getting COIN' at the Tactical Level in Afghanistan: Reassessing Counter-Insurgency Adaptation in the British Army," *Journal of Strategic Studies* 35, no. 4 (2012): 513-539.

10. D. Fitzgerald, *Learning to Forget: US Army Counterinsurgency Doctrine and Practice from Vietnam to Iraq* (Palo Alto: Stanford University Press, 2012).

11. A. Mumford, *The Counter-Insurgency Myth: The British Experience of Irregular Warfare* (London: Routledge, 2012).

12. O. Schmitt, *Allies that Count: Junior Partners in Coalition Warfare* (Washington, DC: Georgetown University Press, 2018).

13. T. Farrell, *op. cit.*

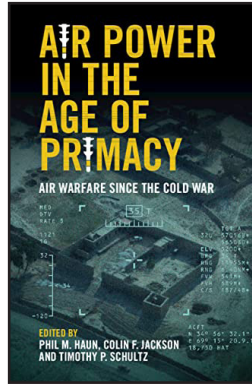
14. M. Smith and D. Jones, *The Political Impossibility of Modern Counterinsurgency: Strategic Problems, Puzzles, and Paradoxes* (New York: Columbia University Press, 2015).

For France, these two enriching texts provide an insightful yet inevitable comparison with its own armed forces. The British capacity for self-criticism illustrated by these two works is greatly admirable in the face of the French strategic debate. Specifically, the French intervention in Afghanistan remains conspicuously absent of any political-strategic LL, as will most likely be the case for Operation Barkhane as well. No one, it seems, can criticise the executive without impunity. Of further importance are the three parallels outlined between: firstly, conducting intensive military campaigns in the more general context of transfiguring and reducing the size of armies; secondly, possessing a confidence that borders on arrogance in one's counterinsurgency capabilities; and finally, selectively importing U.S. military practices.¹⁵ In a different way, questions are evoked regarding the future missions of armed forces after three decades of OPEXs. A decisive statement by British decision-makers in the 2021 strategic review seems to have declared a mistrust for military leaders. From this point of view, contrary to the UK as described in these two books, decades of French OPEXs have not insofar led to the collapse of its military model. As such, how the British military reinvents their missions and finds their footing in today's new strategic context will be a deciding factor in the future of European security, thereby becoming a direct concern for France.

15. O. Schmitt, "French Military Adaptation in the Afghan War: Looking Inward or Outward?," *Journal of Strategic Studies* 40, no. 4 (2017): 577-599.

Air Power in the Age of Primacy

(eds.) Phil M. Haun, Colin F. Jackson, Timothy P. Schultz



Reviewed by David Pappalardo

Could the mystique of air power, with a thirty-year streak of unchallenged triumph, persist with the return of strategic competition? This question naturally arises after reading through the collective work of *Air Power in the Age of Primacy*. Published in early 2022, it is edited by Phil M. Haun,¹ Colin F. Jackson,² and Timothy P. Schultz,³ all of whom are members of the United States Naval War College.

This exceptional resource successively examines ten armed conflicts since the end of the Cold War, in which air power has played a prominent role in the context of military supremacy.⁴ Valuable lessons are drawn from air power's evolution with a *post hoc* assessment of its effectiveness in achieving military and political objectives. Indeed, the authors explain how the technological superiority relished by air forces has not only allowed them to wage wars from above and limit the risks to their own forces, but also to manage escalation through the reversibility of air power. Yet, despite the initial strategic objectives achieved, the results on the battlefield, by contrast, have not been converted into political

1. Retired Colonel of the United States Air Force, a former A-10 pilot, and currently, the dean of the US Naval War College.

2. Former Undersecretary of Defense for Afghanistan, Pakistan, and Central Asia (2017-2019) and currently, the Strategic and Operational Research Chair at the US Naval War College.

3. Retired Colonel of the United States Air Force, former dean of the USAF's School of Advanced Air and Space Studies (SAAS), and currently, the associate dean of the US Naval War College.

4. In succession: firstly, drone warfare, then operations in Bosnia, Kosovo, Afghanistan, Iraq (2003), Lebanon (in 2006 by Israel), followed by Libya (in 2011 via NATO), Yemen (by the Saudi-led coalition), Syria (by Russia), and finally, the battle of Mosul against Daesh (2016).

success nor towards a “better state of peace”⁵ than it was pre-conflict (as illustrated by the Libyan case in 2011 or the current war in Yemen).

These wars have progressively made us forget that the adversary gets a vote in the third dimension. The air forces have thus been able to move with impunity over enemy positions, going so far as to set up a real and persistent *Reconnaissance-Strike complex* with the emergence of armed drones. However, this historical anomaly is ending with the return of strategic competition. As a result, air forces must refocus on their primary mission: to achieve and maintain air superiority, even if only locally and temporarily.

“Missions that were feasible in an era of unchallenged air supremacy – CAS and persistent ISR – may be impossible in an operational environment dominated by enemies possessing resilient IADS and long-range strike capabilities of their own”.⁶

Aerial Warfare in the Age of Supremacy

Triple Asymmetry in Power, Interests, and Technology

The air wars waged since the end of the Cold War can be categorised into three asymmetrical relationships of power, interests, and technology. First, Air superiority being easily acquired, air forces have been able to concentrate their efforts on other missions, taking full advantage of their intrinsic virtues : global reach for in-depth manoeuvres; reactivity and relative ubiquity conferred by speed; improving precision; or even persistence with the advent of MALE drones. Thus, air power has systematically created an asymmetric advantage over the adversary in the age of primacy.

Moreover, air power was employed in a context where the belligerents were engaged according to different logics. Local actors were fighting tooth and nail for their very existence with all the desperation that this implies. Conversely, the interests of intervening powers usually weighed from a simple peripheral concern to, at most, an important one. As this requires only a limited engagement from Western forces, it thus yields three justifications designating air power as the naturally preferred choice. The first is borne out of the desire to reduce risks to ground troops (with the notable exception of the 2003 Iraq war). A favoured pattern thus slowly had emerged, coined as the “Afghan model”, which consists of mobilising local actors (proxies), Special Forces, and air power. Secondly, as there are restrictive rules of engagement governing the use of air power, this lowers the possibility of collateral damage, which could be detrimental to public support and the buy-in of local allied forces. The final reason pinpoints how air power is instrumental in constraining conflicts below

5. B. Liddell Hart, “[The Objective in War](#),” *Naval War College Review* 5, no. 4 (1952): 2.

6. P. Haun, “Air Power in the Age of Primacy: Air Warfare since the Cold War,” in P. Haun and al. (eds), *Air Power in the Age of Primacy* (Cambridge: Cambridge University Press, 2022): 25.

a critical threshold of violence, because, “*like modern courtship, it appears to offer gratification without commitment*”.⁷

The last asymmetrical relationship mentioned is technological, from which air power’s effectiveness is improved in three ways: an increase targeting accuracy, including at a medium altitude; the rise of a persistent stare on the theater with high resolution motion imagery; and finally, a transition into network-centric warfare thanks to the advances in digital technology. In sum, the United States’s technological superiority has consequently led to the development of a veritable C4ISTAR⁸ architecture, from which the key to air power became precision targeting, with targeting itself being based on intelligence quality.

High Military Effectiveness Comes at a High Cost

Almost all the aforementioned conflicts explored in the text demonstrate that air power is unequivocally decisive in rapidly achieving its initial objectives. However, its long-term military effectiveness, in contrast, cannot be easily measured. Four lessons can therefore be drawn, albeit some of which could be counterintuitive to airmen. Firstly, air power’s effectiveness is measured beyond the number of targets it destroys or opponents it eliminates.⁹ Rather, it is air power’s coercive value against a weakened state or proto-state that is the most striking in almost all the text’s ten conflicts.¹⁰ Its effectiveness is thus obtained more so in the *denial* of the enemy’s ability to achieve its strategic objectives (by preventing it from regrouping and forcing it to prioritise its survival over the offensive), rather than in a *punitive* strategy, whose results are limited given the asymmetry of interests and wills. Nevertheless, airstrikes alone are rarely capable of completely changing an adversary’s behaviour (the “compellence” dimension of coercion). In 1999, for Milošević to finally heed to the United States’s demands, it was due in part to Moscow withdrawing its support to Belgrade as much as it was to the 78-day, coercive air campaign.¹¹

Another noteworthy assessment counters Colonel John A. Warden III’s theory on systemic strategic attacks, for which he advocates in *The Air Campaign*. Despite being the institutionally preferred option, systemic bombing has rarely generated favourable results. In particular, leadership targeting in Afghanistan and Iraq have only reinforced the social ladder within jihadist organisations.

7. E. Cohen, “[The Mystique of U.S. Air Power](#),” *Foreign Affairs* 73, no. 1 (1994): 109.

8. Command, Control, Communications, Computers, Information/Intelligence, Surveillance, Targeting Acquisition and Reconnaissance.

9. “Success is measured not by tank kills or body counts but by the degree to which one’s military objectives are achieved, and the enemy’s objectives are denied” as quoted in P. Haun, *art. cit.*, in P. Haun and al. (eds), *Air Power in the Age of Primacy...*, *op. cit.*, 18.

10. In *Arms and influence* and *Strategy of conflict*, T. Schelling distinguishes between two types of coercion: “deterrence” (to prevent an actor from initiating an unfavourable action) and “compellence” (to force an actor to stop an action in progress).

11. A. L. Stigler, “Hoping for Victory: Coercive Air Power and NATO’s Strategy in Kosovo,” in P. Haun and al. (eds), *Air Power in the Age of Primacy* (Cambridge: Cambridge University Press, 2022): 76.

Similarly, the first phase of Operation Allied Force in Kosovo neither curtailed nor altered Milošević's behaviour, illustrating the limits of systemic targeting on the coercion of an adversary.¹² Paradoxically, attacks on opposing military forces had the greatest effect on the campaign's outcome, despite having been pinned as a last resort.

Furthermore, the authors explain how the effectiveness of air power maximises when their effects are synergistically integrated with those produced in other domains. For example, the combined use of ground and air forces corners the adversary into a dilemma. If they were to regroup with friendly ground forces to concentrate their attacks, then they become vulnerable to an airstrike. Yet, if they were to disperse to escape enemy air power, then they expose themselves to ground attacks. Thus, this analysis is essential not only for air forces, but also for ground forces. While some military analysts tend to neglect – more or less knowingly – a counterfactual approach draws a completely different picture: without air power, ground forces would see their freedom of action significantly reduced.

Finally, the ten armed conflicts analysed outline that while air power may constrain the enemy, it still comes at an extremely high cost as it employs platforms of a very high technological added value. The obligation to minimise collateral damage is one of the factors contributing to these explosive operational costs. To achieve such an objective requires the designing of precise targeting architectures (data links, real-time effects analysis, “smart” munitions, etc.), which is particularly demanding.

The Political Aftermath of Victory Achieved from the Air

Most of the conflicts studied in the text result in political failure (with the exception of Kosovo in 1999 and the military intervention of the *Tsahal* during the second Lebanon war in 2006, where air power contributed to restoring the deterrence of the Hebrew state¹³). However, it is unfair to place this responsibility solely on air power under the pretext that it was the preferred means of using force. According to the authors, it is rather the choice of foreign policy as a whole that must be critically questioned.

Nevertheless, policy-makers and airmen must be wary of ceding to two destructive utopias. Firstly, the reality is that air power alone will never be enough to attain a political objective should that be achieving sustainable peace in failed states:

“The allure of air power in the age of primacy with its promise of easy gains at low costs and little risk to soldiers and airmen may influence short-sighted leaders to discount the long-term costs of occupation or the externalities associated with failed states. Under such conditions, air power may generate a moral

12. *Ibidem*.

13. N. Hagilad, “Israeli Air Force Effectiveness during the Second Lebanon War (2006),” in P. Haun, C. Jackson, T. Schultz (eds.), *Air Power in the Age of Primacy* (Cambridge: Cambridge University Press, 2022): 148.

hazard for myopic political leaders to ignore the full costs of war".¹⁴

Secondly, air power will never replace ground forces in controlling a territory, notwithstanding the emergence of theatre drones and their ability to fly permanently over theatres of operations. As such, air power advocates, who tend to succumb to these two idealities, lose sight of the ultimate goal of any military engagement. This is because they simply replace victory theories with the logic of attrition by tirelessly prolonging an armed conflict.

Air Power in the Age of Great Power Competition

The Persistence of Asymmetric Warfare and the Return of High Intensity

In the final chapter of the text, Colin F. Jackson examines the possible evolution of air warfare as strategic competition comes back to the forefront. He highlights two major trends: the likelihood of persisting asymmetric warfare and the reemergence of high-intensity air warfare. For Jackson, the true ordeal to overcome is reconciling these two challenges at an acceptable human and financial cost.¹⁵

Faced with this obstacle, Jackson proposes three avenues of transforming air power to be more sustainable in the long term. The first concerns the high/low mix of the force structure. He begins by questioning the value of light combat aircrafts, which is meant not only to relieve the pressure off of the systematic overuse of the latest generation of fighter aircrafts, but also to reduce overall operational costs. Thus, room for maneuver can be created to improve operational readiness in high-spectrum missions.¹⁶ Jackson's second suggestion, on the other hand, is rather daringly controversial. According to the author, "The US pays a very high price for a clean conscience in small wars".¹⁷ In his view, such a decision will have to be reevaluated as high-intensity warfare makes its return. Finally, he recommends that the complexity and cost of munitions used must be reduced to meet the growing imperative of high-intensity combat.

Increasing the Cost of Entry into Operations

Beyond these three recommendations, Jackson explains how the reemergence of strategic competition will naturally redirect air forces back to their primary mission: to acquire and maintain air superiority. Notably, this refocus of resources will be costly and difficult to do in the dual context of a – more or less permissive and complexed – IADS¹⁸ dissemination, as well as the vertical and

14. P. Haun, in P. Haun and al. (eds), *Air Power in the Age of Primacy...*, *op. cit.*, 19.

15. "How can great powers squarely focused on the prospect of high-end warfighting manage peripheral challenges at acceptable human and financial cost? The Holy Grail remains the development of a management strategy that saves blood and treasure" as quoted in C. Jackson, "Retrospect and Prospect: Air Power in the Age of Primacy and Beyond," in *op. cit.*, 298.

16. See D. Pappalardo, "The temptation of light combat aircraft," *Vortex* 1 (June 2021): 151-164.

17. C. Jackson, in P. Haun and al. (eds), *Air Power in the Age of Primacy...*, *op. cit.*, 299.

18. Integrated air defence systems.

horizontal proliferation of missiles (cruise, ballistic, drone-munitions, etc.) that holds at risks our critical infrastructures during operations.

The reappearance of strategic competition at the higher end of the operational spectrum could therefore alter the future role of air power. To begin, air bases will no longer be sanctuaries where power can be projected and would then need to be better protected. Secondly, the FOG of war may further obscure the targeting process, reducing the effectiveness of the C4ISTAR chain, on which the effectiveness of air power now depends:

*“Unchallenged air superiority at medium altitude gave great powers the ability to loiter over the battle space with limited risk. This simplified intelligence gathering and made great powers accustomed to the unblinking eye and unsleeping ear of imagery and signals collection”.*¹⁹

Unfortunately, such an unprecedented exception has become a luxury that is already being undermined by strategic competition. The intelligence deficit along with the difficulty in measuring *ex post* effects will continue to confine the use of air power familiar to air forces today. As such, the tracking and destruction of moving targets will be particularly challenging moving forwards.

Lastly, Jackson observes that to secure air superiority, the role of combat aircrafts is gradually being eroded in favour of missiles due to salvo competitions:

*“The growing lethality of long-range precision strike also means the revisionist powers need not overcome the US advantages in fifth-generation air-to-air capability. Missile warfare may in this sense bypass the air-to-air construct on which US defensive doctrine has been built since World War II”.*²⁰

For him, the United States must prepare for this major shift to meet the challenge of expanding missile defences, including their offensive dimension. In a competition of salvos, the first counts just as much as the last, demonstrating the need to acquire substantial stocks and adaptable logistic flows. Nevertheless, combat aviation will always have a role to play due to the political uniqueness of its strategic warning aspect and its ability to contain a conflict's violence below a critical threshold.

In conclusion, this collective work fills a gap in the overall analysis of conflicts since the end of the Cold War, particularly from the air. Its contribution is all the more meaningful as it challenges certain ideas that are well-established amongst airmen. Finally, the text offers a fresh perspective on the future of air warfare.

Indeed, the return of strategic competition is a reminder that air superiority is increasingly challenged by the adversary, not only through the joint use of combat aircrafts and surface-to-air defence systems, but also through offensive missiles. Four priorities could thus be outlined for air forces with this analysis: obtaining

19. C. Jackson, in P. Haun and al. (eds), *Air Power in the Age of Primacy...*, *op. cit.*, 301.

20. *Ibidem*, 303.

and maintaining air superiority; protecting bases, especially with integrated air and missile defences; strengthening deep strike capabilities by combining range, penetration, and precision; and finally, tightly managing ammunitions inventory, which must not be exhausted even after the first salvo exchange with the adversary.





**MINISTÈRE
DES ARMÉES**

*Liberté
Égalité
Fraternité*

