Air operations and Space

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As soon as it came to power, the Nazi regime studied the possibility of acquiring a capacity to strike the American territory, no doubt rightly sensing that its existence could at some point depend on a military confrontation with the United States. It was with this in mind that the Austrian engineer Eugen Sänger developed the *Silbervogel* (Silverbird) “Rocket Bomber” in Peenemünde in 1936. Designed to be propelled from Germany to low orbits by rocket engines, then gliding to American territory by bouncing off the upper layers of the atmosphere, this rocket bomber was then to be capable of dropping four tons of bombs on the United States before landing on a runway located somewhere in the Pacific, on territory held by the Japanese ally. In 1942, as the Nazis were beginning to lose their grip on the war, the Silverbird program was abandoned in favor of technically less ambitious projects, including the V2 rocket, the first object sent into outer space by man and the first ballistic missile. On September 8, 1944, six Parisians were the first victims of this new weapon, which opened a new era in the history of armed conflicts. This look back at a dark page of our history shows that the idea of extending the scope of military air strikes beyond the atmosphere to include aerospace operations is by no means a new idea. It also shows that, in a way, the ballistic missile option was initially presented as a fallback solution to that of the Silverbird Rocket Bomber, an aircraft whose planned mission trajectory involved flying both through and above the atmosphere. Thus, at the time, the ballistic missile was perceived to be a second-best solution by airmen, a sort of pilotless aircraft, while ground forces saw it as an extraordinary “super-artillery”.

With the collapse of the *Third Reich*, the engineers who had developed the most advanced aeronautical and astronautical programs for the Nazis emigrated to the Allied countries where, suddenly imbued with newly acquired "virtue", they became the initiators of an unprecedented move towards "space conquest". However, the primary purpose of the research efforts then deployed was far from the ideal of exploration that this name suggests. On the basis of the V2, it was in fact a question of acquiring as quickly as possible, in the context of the emerging Cold War, a nuclear weapon with intercontinental range. The ballistic missiles gave rise to civilian versions used to launch crews and satellites into space for both civilian and military applications. Thus, space capabilities were developed to support military operations, mainly in the fields of intelligence and telecommunications, the indispensable nature of which is now recognized by all.

For seventy-five years, the general pattern has been that of two distinct military operational domains – air and space – involving specific concepts and doctrines of use, for which common strategic principles are applied in different ways due to their respective physical singularities. Nevertheless, it is important to recognize the possibility of combined implementation of these environments, whether collaboratively or, on the contrary, in an offensive posture. The bridge between these two "worlds" is embodied by the space plane, which the state of the art of military technology still limits to a marginal role at this stage. Thus, Air and Space strategy coexist today, while the existence of an aerospace strategy still appears uncertain.

A third dimension of a strongly heterogeneous nature: the air and space environments are contiguous yet fundamentally different in their nature as well as in the operational potentials they offer.

The air and space environments are contiguous and apparently of the same nature, the first being the necessary point of passage to reach the second. This is clearly a very different situation from that which differentiates the terrestrial and maritime environments. In considering the air and space environments, the first difficulty is the absence of a clear and legally established boundary between them. In a way, there is a grey zone in which the regulatory logic applicable to the air domain is blurred and replaced by another regulatory logic, which is less clearly defined and thus more permissive. No international agreement has ever been reached on the boundaries of space. Some countries have opted for an altitude arbitrarily fixed at 100 kilometers above sea level. This is the case, for example, of Australia and Denmark. Some argue that the line, known as von Karman's line, from which flight becomes impossible, around 80 kilometers above sea level, is more relevant, while others prefer to retain the minimum altitude at which it is possible to remain in orbit, around 125 kilometers. Confronted with these divergences, the international community has remained ambiguous, and no one knows today where space begins. In fact, this situation has become acceptable, and at this stage it does not constitute an obstacle to activities in space, nor a cause of legal disputes. The future, however, will see a considerable increase in space activities, whether commercial, governmental or scientific, and the boundaries of space may have to be further defined as the stakes of all kinds of endeavors become both more important and disputed.

Although there is no commonly accepted definition of the boundary between air and space environments, many differences in their physical characteristics allow us to clearly differentiate them: chemical composition, temperature, conditions under which the law of universal gravity is exercised, intensity of cosmic rays, conditions of wave propagation or the observed electromagnetic field are all fundamental differences distinguishing the air and space environments. For military operations, the most discriminating element is undoubtedly the move from a Newtonian to a Keplerian reasoning when a mobile device moves from air to space. An orbital system is subject to Kepler's laws and not to aerodynamics, it does not "fly" but rotates around the Earth in a movement that is similar to a never-ending fall. Changing the plane of its orbit is extremely energy consuming and rendezvousing with another orbital system is possible in a given plane that is known at launch but is otherwise very difficult to achieve. The maneuverability and flexibility of a satellite are thus far from being comparable to an aircraft.

Another very differentiating factor between air and space environments is the recognition of the principle of national sovereignty in their respective air zones, whereas outer space completely disregards this principle. Admittedly, the sovereign national airspaces only represent about a quarter of the surface of the globe, yet they are the unavoidable points of passage for any air activity which, by definition, begins and ends on an airbase located on sovereign territory[1]. Aircraft stationing rights, flyover authorizations, compliance with specific operating regulations and landing fees are some of the restrictions imposed on aviation activities by sovereign states. On the other hand, space-based activities are largely unrestricted, allowing, for example, to legally and discreetly bring any point on the globe within the range of a satellite sensors.

Airpower also has the characteristic of being transient by nature. The vectors that airpower uses have the characteristic limitation of not being able to stay in the air for more than a few hours, or in certain cases, a few dozen hours. New high-flight devices, called "pseudo-satellites", enjoy days-long or months-long operating autonomy, and are harbingers of a new era. However, such devices are largely experimental at this stage, and do not yet allow air warfare to break with the limits of transience. On the contrary, the laws

1. Airborne operations conducted from a naval platform cruising on the high seas are not subject to this rule, provided they are confined to this environment. However, this represents an infinitesimal quantity of worldwide airborne activity.

of space mechanics enable a spacecraft to conduct missions for several years without interruption as shown by the *International Space Station* which has been in orbit for more than 20 years and our *Syracuse III* military telecommunications satellites which have been fulfilling their mission for some 15 years.

Nevertheless, the air and space environments have common characteristics that make them unique as compared to other operational environments.

Airborne vectors and orbital platforms evolve in three dimensional environments, whereas ships and land-based vehicles are limited to largely "flat" maneuvers on the surface of their environments.[2] Access to "high points" offers airborne weaponry and space systems unquestionable strategic advantages that free them from the environmental discontinuities observed on the surface of the Earth. They thus have the potential for direct action in all *Three Spheres of War* described by the British strategist John Frederick Charles Fuller: the physical sphere, where fighting capacity resides; the mental sphere, where war is conceived and planned; and the moral sphere, where the capacity to resist the effects of war stands. It must be noted that naval and land-based vectors cannot claim such easy access to these last two principles, as they must generally first go through a confrontation in the physical sphere to reach them. With this ability to carry out military action into the three spheres of warfare, i.e., into the very heart of the enemy, airpower and space systems offer those who have them a considerable strategic advantage over an adversary who does not.

Moreover, air and space environments have the common singularity of not hosting any form of life in a permanent way[3] and of requiring that any object or living organism found there must be set into motion. These environments are also transparent, even if they are not all transparent in the same way, for example regarding electromagnetic waves propagation. The result of these two characteristics is that these two environments are first and foremost places of transit, of flow. The air environment is in fact an important area of transit of goods and people, whereas, similar to cyberspace, the space environment is a place of reception and transmission of digital data, which have become both the fuel and the product of space activities. Our daily lives, as well as many public policies, such as defense and national security, are closely dependent on the ever-increasing number of applications based on the use of space-based data. This situation makes space infrastructures of vital importance to our societies.

2. Submarines also operate in the vertical plane but remain very close to the surface of the sea, their maximum working depth not exceeding a few hundred meters. In addition, they are not able to maneuver in the third dimension with agility.

3. Except for a limited number of astronaut crews, especially those being involved in the *International Space Station*.

Finally, access to the third dimension is very demanding in technical terms and in terms of the skills required. The air and space environments are very selective, since they can only be accessed through a small number of highly qualified professionals, unlike the land and maritime environments, where everyone is able to act. The world's air traffic thus mobilizes only a little less than one and a half million professionals, a third of whom are pilots. It is this small population that has the capacity to operate in the air and not the vast majority of people who are just consumers of the services offered. Even for leisure purposes, access to airspace remains very much restricted, as most human beings do not have the financial resources or the technical skills to fly. The same observations apply, with even more relevance, to outer space which is certainly a shared space, but a very elite shared space. In fact, less than half of all countries are present in outer space, even if they all benefit from space services. Only three percent of them have autonomy of action in space, i.e., the ability to design, produce, launch and operate orbital platforms on a regular basis. As for the countries that can be considered true military space powers, by endowing their defense policies with a coherent space component based on autonomous capabilities for space surveillance, launch, satellite services of all kinds and actions in space, they represent only a little more than one percent of all countries.

Air strategy vs space strategy, two strategies for two environments with distinct characteristics and which are very differently concerned by military affairs.

In his book *Introduction à la stratégie (Introduction to Strategy)*, André Beaufre doubtless puts forward one of the most convincing definition of strategy. He sees it as *"the art of the dialectic of wills using force to resolve their conflict"*. Beaufre also rightly recognizes that *"if strategy is one in both purpose and method, in its application, it is necessarily subdivided into specialized strategies valid only for a particular field of conflict. This is because it must take into account material data, and the characteristics of the material data specific to each field of the conflict produce a different system of consequences in each of the fields; naval strategy, for example, has always been different from land strategy, etc.*[4]". In a few lines, Beaufre clearly states that even though the major strategic principles – freedom of action, economy of means and concentration of efforts, surprise, security – have a universal dimension that makes them relevant to any operational environment, they cannot be applied uniformly from one operational environment to another. The differences between air and space environments, and their consequences on the modes of operation of aircraft and spacecraft, are such that they require a distinction between air and space strategies, while being careful not to unwisely merge them into a single "aerospace strategy", which is sometimes evoked without justification. In this respect,

4. A. Beaufre, *Introduction à la stratégie*. Paris, Fayard, 1963.

the same reasoning leads to the dismissal of the concepts of an "air-land strategy" or an "air-sea strategy", while recognizing that air, land and naval strategies combine their effects during a joint engagement.

As regards the air and space environments, it is very clear that the main principles of military strategy cannot be taken into account in the same way. First of all, freedom of action is subject to much greater technical and financial constraints in space operations than those confronting air power. Space operations are also subject to the limitations of Keplerian movements of orbital platforms and are far less agile than aircraft.

The notion of massive actions is then hardly conceivable in space. Satellites for military use are few, and there is – at least at this stage – no firepower capability in orbit. It is therefore difficult to advocate, with the same force as in airpower, the principles of economy of means and concentration of efforts. Even with the observed increase in the number of orbital systems for military use and the possible appearance of kinetic actions in space, a discriminating effect of scale remains obvious as compared to air domain.

Another great strategic principle, that of surprise, must be viewed in comparison with the quasi-absolute predictability of orbital movements and the transparency of exo-atmospheric space. As for security, one cannot identify combat zones and "rear" zones in space where it would be possible to take cover to preserve or regroup combat potential. To summarize, air strategy and space strategy certainly share the same DNA, that of relating to physical environments structured in three dimensions, but their application responds to such different requirements that it is appropriate to make clear distinctions between them.

However, as indicated above, air and space environments share strong intrinsic characteristics that distinguish them from other operational environments (three-dimensional space, absence of life, need to be in motion, and selective access). For this reason, and because the former is the necessary place of passage to access the latter, strong interactions between air and space strategies exist and are bound to develop. These are strong arguments in favor of making Air Forces responsible for implementing these two strategies, without confusing them. Moreover, airpower increasingly relies on space capabilities to achieve its objectives.

Airpower "boosted" by orbital systems

A simple effort of imagination is enough to realize that there would be no significant military operations if satellites were to fail. Without them, there would be no long-endurance UAVs, no cruise missiles, no all-weather precision strikes, no long-range communications, no accurate weather forecasts; without them, the very precise and widespread means of navigation would disappear and the C4ISR means[5] would be very degraded. Without them, an army would more or less regress to its operational level at the end of the Second World War. Without them, everything that makes the Western armed forces superior would disappear.

The example of Operation *Hamilton* conducted in 2018 by the American, British and French forces against the Syrian regime is particularly illustrative in this regard[6]. It highlights what military air operations owe today to space systems. The decision to commit to the operation *Hamilton* was partly decided on the basis of space intelligence, planned thanks to it, conducted via space telecommunications, and the results could be assessed thanks to satellite images. The execution was based on weather forecasts from satellite observation, on navigation data provided by the military GPS system, and also on digital terrain models developed from space data, which were essential for the hundred or so cruise missiles fired to reach their targets with great precision. *Hamilton* has demonstrated that space-based data are currently underpinning airborne military operations. And what was observed in this high-profile operation is also observed in more "rustic" joint operations, such as those conducted in the Sahel-Saharan strip where MALE[7] UAVs are able to provide considerable operational added value thanks to satellite transmissions.

The so-called "New Space" program, which has led to a proliferation of military and civilian projects for low-earth orbit satellite constellations, will also very quickly benefit airpower. On the military side, the movement that is underway consists of adding tactical systems to strategic space systems. The most ambitious projects aim to set up constellations providing permanent coverage over a theater and capable of communicating with a substantial number of weapons systems, in particular to transmit target coordinates in real time. With more complete and less dated intelligence, military air vectors will be better directed and better coordinated and therefore much more effective. In the civilian sector, there are countless projects for low-orbit satellite constellations to ensure better connectivity. In the United States, where connections between these new systems and military air platforms are being tested, a new form of airpower is taking shape, offering permanent, resilient and globally extended connectivity to all its actors.

However virtuous they may be in terms of operational efficiency, these developments make the implementation of air strategy by the most modern forces increasingly dependent on space systems. The situation is tantamount

5. C4ISR: Computerized Command, Control, Communications, Intelligence, Surveillance, Reconnaissance.

6. Operation *Hamilton* destroyed a Syrian research center and chemical weapons production facilities in April 2018 through air strikes by cruise missiles fired from air and naval platforms. One hundred and five cruise missiles, including twelve French and British, were fired.

7. MALE: Medium Altitude Long Endurance.

to a kind of space addiction. Vulnerabilities are emerging that deserve to be taken into consideration. Otherwise, certain countries could expose themselves to the risk of a "space Pearl Harbor", to use the expression of the Rumsfeld Commission which, in 2001, published a report assessing the US national security space management and organization. In this case, the commission pointed out the risk for the United States of being the victim of an unexpected and very disabling attack. Twenty years later, no one will dispute that this risk is shared by countries other than the United States.

The forays of airpower beyond the limits of the atmosphere herald the coming advent of aerospace power.

On 13 September 1985, a US Air Force *F-15* fighter destroyed an end-of-life scientific satellite placed in orbit at an altitude of 525 kilometers by means of a missile. This historic first demonstrated the feasibility of a kinetic action initiated in the atmosphere by a conventional air vector and producing effects in space. Air power thus demonstrated its capacity to significantly widen its field of intervention. However, this experiment did not lead to any operational development and, to this day, no other country has committed to this approach.

More than the ability to destroy a satellite from an airborne vector by means of a missile, which has very deleterious effects on space operations by producing large amounts of debris, this test above all demonstrated the ability of an aircraft to send objects into low Earth orbit that can carry out a mission that may target other orbital systems, or that can simply transit before returning to the ground. The major aeronautical nations have all studied these options and have more or less mature military programs in this field.

In France, for example, the launch of small satellites (up to 150/200 kg) to low earth orbits by a *Rafale* fighter (*Aldebaran* project) or by a drone (*Altaïr* project) has been studied. In the United States, the same approach has been taken in the *Alasa*[8] project to provide an airborne launch capability for a microsatellite by an *F-15*. The military interest of these formulas lies in the autonomy of action, since they make it possible to free oneself from a launch service, usually civilian, and in the time frame constraints that are concomitant. This strengthens the overall resilience of their space systems. The U.S. Space Force is following with interest ongoing developments in this area and has contracted *Aevum*[9] to demonstrate a 24-hour satellite orbit capability in 2021 (*Mission Aslon 45*). While the trend is towards a reduction in satellite mass and the development of low-orbit constellations, there is renewed in-

8. *Alasa: Airborne Launch Assist Space Access.*

9. *Aevum* proposes an autonomous launch system capable of placing 100 kg in sun-synchronous orbit at 500 km, combining a *RavnX* drone (25-ton class) and an autonomous launch vehicle. The system is described as extremely flexible (operable anywhere in the world from a conventional runway) and very responsive (3 hours between consecutive launches).

terest in airborne launches for the military. However, the technical difficulties and financial requirements associated with airborne launch should not be underestimated, at a time when the size of combat aircraft fleets is constantly being reduced and such valuable resources must be reserved primarily for their traditional missions.

The interest of the military seems to be even greater for aeroballistic missiles, which are ballistic missiles, part of whose trajectory leaves the atmosphere, and which can be equipped with a hypersonic boost-glide head, fired or dropped from a combat or transport aircraft. This interest is not new, since at the end of the 1950s, the US Air Force carried out experimental firings of nuclear-capable ballistic missiles from its strategic bombers (*Bold Orion* missiles by *B-47* and *High Virgo* by *B-58*) with measured success. More recently, in 1974, a *Minuteman* nuclear ballistic missile, normally fired from a buried silo, was dropped from a *C-5 Galaxy* cargo plane before igniting its thrusters and completing its intended trajectory. Today, in several countries, aeroballistic missile projects have reached an operational status or will reach it soon. This is notably the case in Russia, where President Putin has presented as operational since 2017 the *Kinzhal* missile, an airborne version of the *Iskander* fired by a *Mig 31* fighter, and in the United States, where the US Air Force has announced that its *B-1B* and *B-52* bombers, and even the *F-15* fighter, will be able to carry *AGM-183A* missiles with a warhead consisting of a hypersonic glider as of 2023. As for China, which remains discreet about this type of development, everything leads one to believe that it now has a new version of its *H-6* bomber capable of firing a ballistic missile which, according to some observers, would be a variant of the *DF-21* "carrier killer" missile.

However, physically reaching a target located in a particular environment from another environment with a weapon remains quite common. Air-to-ground strikes, ground-to-air defense, and attacks from the sea have been part of military modes of action since the early days of military aviation. However, apart from missiles with a change of environment (ballistic or cruise missiles fired from a submarine or naval platform), for which this phase is very specific, armed delivery systems generally maneuver in a single environment. Aeroballistic missiles herald a new era in which combat vectors, piloted or not, will conduct missions including atmospheric flight phases and exo-atmospheric trajectories[10]. The concept of aerospace power will then take on its full meaning, with its main advantages being reach and lightning speed. It will then become relevant to speak of the existence of a truly "aerospace" strategy. As for submarine warfare, which is the respon-

10. The US Air Force already conducts secret long-duration missions in low-Earth orbit using the *X-37B* spaceplane, a kind of mini-space shuttle with a cargo bay and great agility in orbit. A Chinese aircraft of the same type was also tested in 2020. In France, *Dassault Aviation* is also conducting studies on a spaceplane concept (the *Verha* project, which *stands for Hypersonic Reusable Air launched Vehicle (VéHicule Hypersonique RéUtilisable AéRoporté).*

sibility of naval forces for obvious and indisputable reasons of operational coherence, the implementation of this new strategy can only be the responsibility of air forces, which have become aerospace forces.

At this stage, military practice implements two distinct strategies for the air and space environments. While the implementation of the former is universally the responsibility of Air Forces, several models exist for the latter. The United States and Russia have created autonomous space forces alongside land, air and naval forces. In other countries, joint staffs or air force staffs are entrusted with the responsibility for implementing a country's space strategy.

In the relatively near future, military space planes should reach an operational status and give substance to a true aerospace strategy, the responsibility for which can only belong to air forces. In a more distant future, as soon as technology allows it, there is no doubt that man will take the field of military affairs beyond circum-terrestrial space, convinced as Lyndon B. Johnson was in 1958 "*that there is something that surpasses any weapon. It is the ultimate position, the position that offers the possibility of a total control of the Earth and that is somewhere in space*".

It will then be appropriate to consider the existence of a true Space Force alongside the "armies of the Earth".