Technology and Connectivity

X

An Essential Bond for a Modern Air Force

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'Any Air Force which does not keep its doctrine ahead of its equipment, and its vision far into the future, can only delude the nation into a false sense of security.'

General Henry H. Arnold[1]

Introduction

Air and Space Power (A&SP) are intrinsically linked with technology and connectivity, in fact, they are two sides of the same coin. To fully understand the complexity of modern A&SP, it is paramount to consider the specificities of the aerospace environment as well as the implications of technological evolution within the Air domain.

Today, modern Air Forces are required to operate in the third dimension at supersonic speeds, guarantee the persistence of the Air power in operations, even when operating far from home, and support Land and Sea components,

including the projection of forces. All these elements cannot be satisfied without the extensive use of advanced and innovative technologies.

Since its beginning, the aviation world has been strongly influenced by the evolution of technology. Over the years, the application of and experimentation with emerging technologies have been applied to A&SP and their use has gradually increased as an essential requirement for any complex military operation involving A&SP.

Technological innovation today has seen a 'rate of change' never before experienced. This is due, at least in part, to the extensive use of new technologies which have expanded the upper limit of the aerospace dimension from 20 km, which historically was the customary boundary regarding commercial and military flights, to 100 km, the conventional border between the aeronautical (or Earth's atmosphere) and Space environments (or Outer Space) known as the 'Karman Line'.

Technological advancements will soon produce both suborbital carriers and hypersonic vehicles that operate with greatly increased range, such as more focussed cyber-attacks, swarms of drones, and new systems that exploit the advantages of robotics and artificial intelligence. The latter, in particular, will allow the automation of highly complex processes, manage the storage of huge amounts of data and process that data via Edge Computing[2], with the aim of maximizing information collection in the area of operations (information superiority) and enabling fast decision-making models (decision superiority). An essential element of the previously mentioned decision-making superiority is interconnectivity or digital connectivity. It can be defined as the technology that will allow all the different systems present in the operational environment (in NATO's five operational domains) to be connected and able to exchange information in near-real time for the benefit of key decision-makers (from the commanders in the field, up thru the political authority).

From Analogue to Digital Connectivity

The exploitation of the radio sector of the electromagnetic spectrum, via wireless technology, which initially aimed to improve communications in military operations, has undergone a progressive and radical transformation thanks to applications based on Internet Protocols (IP). These applications have allowed for the transfer and sharing, in real-time, of information coming from different channels.

Today, in the digital era, which includes the Internet of Things[3] (IoT), the ability to interconnect various devices has become a consolidated and essential requirement for the collection, exchange, distribution, and storage of information (so-called Big Data[4]). The Digital Connectivity, defined as the ability to connect sensors in a 'system-of-systems'[5], is the main enabler of decision superiority.

Achieving Air superiority, however, is a more complex endeavour than a 'simple, combination of systems and Digital Connectivity will soon become the decisive factor in the conduct of Multi-Domain[6] Operations (MDO[7]). In order to ensure continuous information sharing between commanders and operators in the field, interconnected systems will be required to be highly resilient and 'intelligent.' This will ensure a speed of command and control that will transform the advantage of information (or Big Data) into real decision superiority over the adversary. Interconnectivity will create a shared picture of the theatre of operations capable of connecting the right sensor to the right effector at the right time (sensor to decision-maker to shooter) to create complex dilemmas for the adversary.

Paraphrasing General Denis Mercier[8] (FR), it can be assumed that the keyword for the Future Combat Air System (FCAS) is indeed 'system'. In fact, it will not be a manned aircraft or a drone, but a system of systems integrating, within a cloud, sensors and effectors of various types and different

generations. And, the backbone of this system will be a Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance core.

The Joint Nature of Air Power and the Merging of New Domains

Since the recognition of Air as a separate operational domain, Air Power has been intrinsically multi-domain by nature. Historically, armies and navies expressed their power by acting in the domains of Land and Sea, respectively. Only with the advent of the aircraft, did military operations become truly joint, and today no operation can occur without the support of aerospace capabilities.

In this vein, for a modern Air Force to keep its 'joint-by-design' feature and effectiveness (which differentiates the Air Force from other armed forces), it is necessary to broaden the joint approach to the emerging domains, such as Cyberspace and Space.

As a matter of fact, Air, Space, and Cyberspace operations have developed an interdependent relationship that grows day by day. Space and Cyberspace resources (i.e., satellites, antennas, and waves transmission) are, in fact, inseparable from the third dimension, and similarly, Air operations use computer networks and Space assets regularly. As indicated by General Mercier, due to this interdependence to fight in the Air and in Cyberspace, it was mandatory for the Air Force to include the nature of this new strategic environment. He recognized the ability of Space and Cyberspace operations to improve and support 'conventional' operations through the intensive use of new technologies which push for greater and greater interconnection every day. In fact, to allow Air Power to use the full spectrum of modern technologies, it is critical to recognize that connectivity has a leading role.

Multi-Domain Operations and Connectivity

As previously mentioned, the power expressed by the Air Force has always been extended to the other physical domains (Land and Sea) and, in the future, is going to be more and more interconnected to the emerging ones, namely Space and Cyberspace. This requires an evaluation of the threat coming from new and emerging technologies, which has evolved with all available means, rapidly, often at low cost, and from not well-defined sources to deny the strategic advantage gained by AP.

Consequently, a requirement for Air forces is to develop the ability to coordinate, at national and multinational levels, the delivery of synchronized effects in multiple domains in sequence or, preferably, simultaneously.

However, this involves a significant conceptual evolution, as it moves from the current joint and inter-agency construct (already complex and articulated) to a multi-domain approach which, with the integration of Cyberspace and Space, allows for the conduct of MDO or, in the most recent terminology, Joint All-Domain Operations (JADO).

In this context, the goal of a modern Air force will be to develop an ad hoc info-structure, based on Internet Protocol, and to use a combat cloud capable of connecting all sensors, effectors, and command and control nodes in real-time. Contextually, it will use the emerging technologies (e.g. artificial intelligence) associated with, and in support of, the human component.[9]

Emerging Technologies and Connectivity

The use of emerging technologies[10] in the military sector, as well as in all civil and economic sectors, is certainly aimed at pursuing a concrete competitive advantage.

Intelligent and more autonomous systems capable of transferring and processing enormous amounts of information are supplanting and overcoming some typically human capabilities.

To date, such autonomous or semi-autonomous systems have been limited, requiring rigid operating rules and direct human control. The use of artificial intelligence will allow new systems to enable increasingly sophisticated decisions (through ad hoc algorithms) and will create a new complex concept of the 'man-machine' team. Future intelligent systems will provide, from the strategic to the tactical level, rapid analysis, advice and courses of action which will enable an increased effectiveness of the Observe, Orient, Decide and Act (OODA) cycle and therefore allow for more innovative strategies.

In order to get the advantage offered by these technologies, it will be essential to ensure the interconnection between domains, and between sensors operating in or through them. By carrying out functions of collecting, processing, and exchanging information, they will fulfil the prerequisite to achieve Decision Superiority.

Connectivity: The Centre of Gravity for Future Aerospace Systems

Therefore, Digital Connectivity (or Native Digital Connectivity), represents the centre of gravity of future aerospace systems. Starting from Clausewitz's definition of 'the hub of all power and movement, on which everything depends', it is possible to use the metaphor of the human body to illustrate the analysis of connectivity as the centre of gravity for modern and future Air forces. The human body would not function without a heart, but today's technology can keep a human body alive by using an alternative energy source. The joints provide physical strength and movement

but complement the 'human body system' and are not its centre of gravity. The brain, instead, represents a source of power. It can provide the physical body the will to act and then the ability to do so. Still, without blood flow and oxygen (connectivity), the brain would stop functioning and with it the control centre of the entire body. Implementing the connectivity principle in the development of future aerospace capabilities is therefore crucial. The 'native' interconnection will allow the new generation and advanced systems to act as a 'single entity', within a 'system-of-systems', and be able to realize the integration of all relevant information. This will concretely improve the Commanders' decision superiority, at all levels (strategic, operational, and tactical), as well as the ability to anticipate and rapidly respond to new emerging threats coming from all domains of operations.

Therefore, capability development will have to evolve in the direction of 'Native Digital Connectivity'. This will transform today's information technology into a more competitive advantage of tomorrow. In that venue, collaboration with industries and academia is strongly envisaged, as well as the enforcement of the current paradigms of cyber-resilient-by-design and cyber-resistant-by-design. In short, any new future aerospace capabilities will have to be designed and developed considering Native Digital Connectivity and Cyber Security as intrinsic requirements.

Conclusions

The future of technology and programs are clearly and unambiguously moving towards increased system integration and connectivity, where each platform is no longer a stand-alone system but part of a distributed and connected intelligence. Therefore, technological development represents a challenge, but also an opportunity that cannot be missed. It is a train that does not stop and does not wait, and to which all Air forces and

members of the aerospace industry must remain connected, otherwise, they will face future irrelevance. Recalling the words of General Giulio Dohuet: 'Victory smiles upon those who anticipate the changes in the character of war, not upon those who wait to adapt themselves after the changes occur.'[11]

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Endnotes

1. General of the United States Army Air Force (USAAF) in the Second World War, theorist of strategic bombing and the independence of the air component from the Army and Navy.
2. Distributed computing paradigm that brings computation and data storage closer to the location where it is needed in order to improve response times and save bandwidth.
3. Extension of the Internet to the world of real objects and places.
4. Extensive data collection in terms of volume, speed and variety that requires dedicated analytical technologies and methods for the extraction of value or knowledge.
5. Complex system that offers more functionality and performance than the simple sum of the subsystems. In the aerospace domain, it implies the ability to connect in a single 'information cloud' piloted elements with other unmanned or even autonomous elements. This principle can be further extended to the whole operational environment, in which all the different 'information clouds' are interconnected.
6. Air, Land, Sea, Cyberspace and Space.
7. MDO: as reported by JAPCC at https://www.japcc.org/conference-proceedings-2019-theme-1/, Multi-Domain Operations (MDO) is the ability to use information-enabled command structures and combat capabilities, across an array of domains, to present multiple, simultaneous dilemmas to an adversary with the aim of overwhelming him.
8. 'Les opérations aériennes et le cyber: de l'analogie à la synergie', 2015.
9. To ensure compliance with law and ethics principles.
10. Including Emerging Disruptive Technology (EDT): Big Data, Artificial Intelligence (AI), Autonomy, Space, Hypersonic, Quantum, Biotechnology.
11. General Giulio Douhet, 'The Command of the Air', 1921.