Air Power and Technology: A Tentative Approach to the Year 2025 and Beyond

by **Colonel Basilio Di Martino**

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Since the end of the Cold War era, and the collapse of that long-standing scenario, a lot of things have changed, last but not least the phenomenon of war that now occurs in a way that seems to belong to days gone by. In other words, we have a return to so-called 'small wars', a peculiar type of conflict which is the arena of non-regular forces and was well known to the officers of the European armies called to lead colonial police operations at the beginning of the past century. It is a very complex scenario that requires a response strategy based not only on military action but also on political, economical and social measures, while at any time the use of force has to be carefully weighed and balanced.

In such a context a purely technological approach, typical of what we might call the Western art of war, has inherent limitations. The kind of operations that every air force has been traditionally organised to execute is no longer so meaningful as it used to be, but the fact that these operations are somehow identified with the very essence of an independent air force may lead to wrong solutions based on an unsuitable doctrine.[1]

Since terrorists and guerrillas are not likely to offer relevant targets, and therefore do not lend themselves to allow a large-scale use of air power, its indirect application has to be considered as the most appropriate. This means reversing established priorities and giving greater importance to support operations, such as surveillance, reconnaissance, transport, psychological warfare, while underlining the marginal utility of pure combat operations, with the possible exception of close air support.[2] This is the direct application of air power most often sought in such scenarios because of the wide-spread precision engagement capability, but even when exploiting the most advanced guidance technology, the direct application of air power can hardly be more relevant than the contribution that air power can offer to the achievement of information superiority.

Small wars are indeed largely fought in the information domain, where acquiring and maintaining an overall superiority has the same impact on the final outcome as the conquest of air superiority in a more traditional context.[3] Surveillance, reconnaissance and psychological warfare operations will play a major role when air power is used in counter-insurgency scenarios.[4] In 1996 a USAF study known as *Air Force 2025* identified some specific guidelines:

- Maintaining the desired level of superiority is difficult but not impossible, even if technology, particularly information technology, is not a one-sided affair.
- Air superiority has to be tightly integrated with space superiority and information superiority.
- Information is no longer a staff function but an operational function, with its own lethality.
- Information superiority may come from a better exploitation of current technological capabilities as well as from true innovation.
- The growing confidence in technology, together with the courage to follow that path, will ensure that more and more missions will be performed by unmanned air vehicles.
- Progress in the field of information technology will maintain a pace that will necessitate substantial changes in the planning, budgeting and procurement processes.
- The same resolute approach that in the past led to mastery of flight is required to achieve an effective operational capability in both the space and the information domain.
- These statements were confirmed by the results of a more recent effort to interpret the future, the study *Horizon 21.* USAF leadership entrusted the officers attending master classes at the Air Command and Staff College and the Air War College with the task of identifying trends in technology areas of potential interest and capabilities destined to have

Two AM-X flying at low level in the Goose Bay (Canada) region. Since November 2009 four AM-X have been deployed in Afghanistan in support of Coalition forces [MoD Italy]

a significant impact on the evolution of air power. Class 2007 was focused on four specific areas – nanotechnology, cybertechnology, directed energy and biotechnology.[5] If you leave aside the controversial area of biotechnology, which can anyway give significant results in the field of alternative energy, the other three areas are of obvious interest.

Microelectronics and Nanotechnology

The headlong growth of microelectronics is based on the ability to miniaturise semiconductor structures with nanometre precision, placing an ever-growing number of elementary components on a single device. For nearly half a century the technology of materials, namely silicon, has moved along the same path, continuously reaffirming the validity of Moore's Law.[6] However, the day is coming when this miniaturisation process will reach its physical limit and it will be necessary to go beyond the use of new materials, moving from microtechnology to nanotechnology. This neologism refers to research activities in the range from one nanometre to one hundred nanometres, which means manipulating matter at atomic or reticular level to create structures that can provide superior electromagnetic characteristics.

It is difficult to say what the results of this effort will be, but there is no doubt that such a change, in reviving the trend defined by Moore's Law, will spin out in many applications, providing a clear advantage to whoever will be the first to exploit it.

The reasons are obvious: laser weapons allow high-precision engagements at the speed of light, minimising the risk of collateral damage

The likely developments in the field of information technology in the next quarter century will alter the configuration of air instruments. The diffusion of automated and remotely controlled solutions will affect the size of the fleets of manned aircraft and will also substantially affect the conduct of operations, with the integration of manned and unmanned aircraft.

The final stage will be represented by swarms of small unmanned air vehicles (UAVs), the size of an insect, capable

The Italian MoD communication satellite SICRAL was launched in February 2001 and has now been joined by a second satellite [MoD Italy]

of operating in a cooperative way to perform mainly ISTAR missions, given the limited lethality that such a weapon system could have. Nano Air Vehicles (NAVs), no larger than 7.5 centimetres and weighing no more than 10 grams, are not yet a reality, but their feasibility is confirmed by the fact that the first Micro Air Vehicle (MAV) is no longer a laboratory curiosity. With a wingspan of about 15 centimetres, equal to the length of a pencil, the Aero Vironment *Black Widow* has a range of half an hour and can send a colour video to a ground terminal. In the same time frame, around 2025, it is not unlikely that developments in the field of high-energy materials will allow combat missions to take advantage of what a 'smart' swarm can offer in terms of widespread presence and infiltration capability.

Cybertechnology

A similar effort is required to protect our own technology systems as well as to undermine the capabilities of potential adversaries. The emergence of cyberspace as a possible battleground requires the definition of a new kind of high-tech mission that parallels the evolution of aeronautical and missile technology that shaped the present concept of air power. The theories on strategic bombing in the 1920s were not based on technology. However, the pressure to go beyond what was possible, and to aim at what might be possible, led quickly enough to the building of aircraft able to achieve the vision by synchronising doctrine and technology. The process continued with the creation of a strategic nuclear force, pushing the technology to develop long-range bombers and intercontinental missiles, and later with the ability to operate in space and from space.

In a similar way air forces now have to prepare to fight in cyberspace, by making the best possible use of their natural tendency to anticipate the trends in technology and to steer the path of development.

This statement remains true even if fighting in cyberspace is not approached as a single-Service activity. An air force is intrinsically a technology-based organisation and can therefore contribute in a decisive way to the build-up of whatever Joint structure will be entrusted with the task of defining the kind of organisation, the training and the equipment necessary to counter and defeat potential adversaries on this new battlefield.

Defending computer networks from cyber attacks, and therefore defending one's own cyberspace from possible infiltrations, is an integral part of this vision and has to be dealt with most urgently. Military systems are increasingly based on commercial hardware and software in order to ease the financial burden and to accelerate the acquisition process. Due to this inherent vulnerability there is a need to implement a defence that is not purely passive and has to include some form of preventive action. However, the uncertainty about what has to be done is as strong as the need for action, and it is therefore right to combine study and research activities with the quest for a doctrine, starting with the definition of suitable scenarios.

Directed Energy

The impact of information technology on air operations is also affecting long-standing and so far undisputed principles. One of them is that planning and control are centralised while execution is decentralised. Such an approach is inconsistent with a net-centric environment, if it is true that a net-centric organisation is self-synchronised and does not allow the full exploitation of the common level of situational awareness, which is typical of this new model. Hence the need to define command and control solutions based not only on automated or remotely controlled sensing and shooting functions, but also on a new formula of decentralised control and decentralised execution.

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One of the overriding concerns in the aviation world is the ageing of combat aircraft, with the consequent need for lengthy and expensive modernisation programmes. To this extent nanotechnologies offer interesting opportunities, not only in avionics but also in materials, with regards to coatings and their low observability characteristics. In the same category, we can also place directed energy weapons, especially high-energy lasers.

The reasons are obvious: laser weapons allow high-precision engagements at the speed of light, minimising the risk of collateral damage and furthermore, assuming an adequate power source, they may provide an almost unlimited autonomy of fire. The technologies needed for a high-energy laser of a size that can be installed on a combat aircraft will reach a sufficient level of maturity in 15 to 20 years, and this applies to all critical components, such as power generation, thermal management and beam control. It is not by chance that Lockheed Martin has proposed a research and development programme that, between 2020 and 2025, should lead to a prototype Laser Strike Fighter derived from the F-35. In the same time frame, research programmes related to 100kW solid-state lasers will enable the arming with a laser pod of previous generation aircraft and even existing UAVs.

When focusing on less bulky solid-state lasers to solve installation problems, the interaction between the different types of materials and the incident laser energy has to be carefully assessed. At least 40% of potential surface targets are susceptible to the action of a high-energy laser, but the damage mechanism has to be characterised creating a sort of Joint Munitions Effectiveness Manual. Once again it is necessary not only to give the required priority to specific research programmes, most of all in terms of funding, but also to develop new operational concepts based on the concurrent and simultaneous use of kinetic energy and direct energy weapons.

Laser technology also offers interesting perspectives with the ladar, or laser radar, that allows the build of a three-dimensional image of an object with a high degree of accuracy, meeting the most stringent requirements in terms of recognition and identification. This capability, when combined with good image processing and automatic recognition algorithms, has clear implications for the warfighter. However, in order for them to materialise, research activities have to be properly directed, and the ladar has to be looked at not as a mere laboratory curiosity or a useful research tool, but as an essential component of a weapon system – to allow target identification at a greater range than any other device, thus reducing the risk of friendly fire or collateral damage.

Space

As for space – the natural projection for air power – one of the main concerns is maintaining an adequate situational awareness, defined as the ability to detect and track any object in order to determine its nature, purpose and potential danger. A possibility is the management of the existing network of sensors in a 'smart' way, through the use of adaptive algorithms which can identify objects or events of interest. It would therefore be the network of sensors itself to decide where to focus, using artificial intelligence techniques.

Furthermore, satellites can be protected from intentional attacks by neural networks, namely a set of electronic devices programmed to react when a predetermined threshold is exceeded and to learn to answer new stimuli by storing response actions, not unlike the human nervous system. Such a memory, built using data derived from experience, enables

One Aeronautica Militare Predator UAV deployed in Afghanistan. Several Predators have been acquired and are now routinely used both at home and in theatre [MoD Italy] neural networks to become autonomous in time, since a given input will trigger the same action already taken in the past under similar circumstances. Once a satellite identifies a possible attack, the neural network will reconfigure it in order to grant the required protection against the incident energy, restoring its full operational capability when the threat disappears. For a low orbit satellite the out-of-service time would be a few minutes, while today lengthy and complex operations from the ground station are needed.

While analysing the space environment one cannot ignore the increasingly strong presence of commercial remote-sensing satellites. Digital information is available in near-real time to all sorts of users through simple commercial transactions, and if on the one hand this capability is extremely useful to supplement the over-stretched resources of military and government constellations, on the other hand there is a good reason for concern. International agreements may try to regulate this type of market, but this is a rather weak form of control that must be complemented by counter-ISR techniques, such as disturbing and deceiving synthetic aperture radars, deploying high-energy lasers and, last but not least, attacking data processing networks.

Conclusion

If it is possible to identify with some degree of accuracy where technology is going in the short term, it is harder to see the end of the path, which is far from straightforward. A major role will be played not by aerodynamics or propulsion, but rather by cybertechnology*,* nanotechnology and direct energy weapons, with a special focus on their space applications.

The microprocessor industry will continue to grow at a rate that will remain exponential, at least while the current semiconductor technology allows, with direct implications not only on the advancement of knowledge but on the world order itself. Most of these developments no longer occur in the western world and within the controlled environment of government laboratories. Since more than 70% of these activities take place outside the United States, and a vast majority see the involvement of the private sector, information technology is not the equivalent of bolt-action rifles and machine-guns in the colonial campaigns. It is available to everybody and offers unexpected opportunities to new actors.

The AM-X ACOL cockpit. ACOL is an upgraded variant of the AM-X fighter-bomber intended to solve obsolescence problems and to introduce new capabilities, like the JDAM ammunition. The programme will modify 42 single-seat and 10 twin-seat aircraft. It has been under way since 2003 and will be completed this year [MoD Italy]

Since governments have growing difficulties in controlling the direction of research, as well as the quality of the results, the technological superiority which the West has so far enjoyed is at risk. We must also consider that future developments will be less and less incremental – the effort to do what is already possible better and quicker is discontinuous, and therefore potentially destabilising. In this context the traditional superiority factors – number, firepower and speed of action – give way to the capability to anticipate and respond to changes. Boyd's Law must therefore be reinterpreted since the OODA loop (Observe-Orient-Decide-Act) no longer applies to a situation of physical confrontation, but to a situation of intellectual confrontation, in which outmanoeuvring the opponent does not mean acting faster but being smarter.

In the industrial age first, Europe and then the United States enjoyed a substantial advantage from mass production, but in the information age what is important is not to produce more but to think faster. If you cannot do this, and adapt to a world where the rate of evolution is not linear but exponential, you are likely to encounter a technological surprise that would immediately affect operations in a devastating way. ■

NOTES

[1] K.Beebe, 'The Air Force's missing doctrine: How US Air Force ignores counterinsurgency', *Air & Space Power Journal*, Spring 2006

[2] J.S.Corum and W.R. Johnson, *Airpower in Small Wars*, Chapter 10, University Press of Kansas, Lawrence, KS, 2003

[3] R.F.Stuewe, 'One step back, two steps forward: an analytical framework for airpower in small wars', *Air & Space Power Journal*, Spring 2006

[4] The U.S. Army-Marine Corps Counterinsurgency Field Manual, U.S. Army Field Manual No. 3-24/ Marine Corps Warfighting Publication No. 3-33. 5, The University of Chicago Press, Chicago and London, 2007, Appendix E

[5] Blue Horizons 2007: "Horizon 21" Project Report, Air University Center for Strategy and Technology, Maxwell AFB, Alabama

[6] In 1965 Gordon Moore observed that the density of transistors in an integrated circuit doubled at a 12-month interval, while cost decreased. Ten years later Moore expanded the time interval from 12 to 24 months