Space
for Operations

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Glossary

AIS : Automatic Identification Signal
Athéna-Fidus : Acces on Theatres for European allied forces Nations – French-Italian Dual Use Satellite
AWACS : Airborne Warning and Control System
BDA : Battle damage Assessment
BOC : *Besoin opérationnel commun*
CDAOA : *Commandement de la défense aérienne des opérations aériennes*
Ceres : *Capacité de renseignement électromagnétique spatiale*
Cerise : *Caractérisation de l'environnement radioélectrique par un instrument spatial embarqué*
CIE : *Commandement interarmées de l'Espace*
CMNO-MS : *Centre national de mise en œuvre de moyens satellitaires*
CNES : *Centre national d'études spatiales*
COPUOS : *Comité des Nations unies pour les utilisations pacifiques de l'Espace*
Cosmos : *Centre opérationnel de surveillance militaire et d'observation spatiale*
COSMO-SkyMed ou CSM : Constellation of small Satellites for Mediterranean basin observation
CSAR : Combat Search and Rescue
CSO : *Composante spatiale optique*
DAS : *Délégation des affaires stratégiques*
DGA : *Direction générale de l'armement*
DIRISI : *Direction interarmées des réseaux d'infrastructure et des systèmes d'information*
DSE : *Division surveillance de l'Espace*
EGI : *Établissement géographique interarmées*
EGNOS : European geostationary navigation overlay service
ELDO : *Organisation européenne de développement de lanceurs d'engins spatiaux*
ELINT : Electronic Intelligence
ELISA : Electronic Intelligence Satellite
EUSC : European Union Satellite Centre / CSUE : *Centre satellitaire de l'Union européenne*
ESA : European Space Agency / ASE : *Agence spatiale européenne*
Essaim : *Expérimentation d'un système de suivi et d'acquisition d'informations par microsatellite*
GMES : Global Monitoring for Environment and Security
GPE : *Groupe parlementaire sur l'Espace*
GPS : Global Positioning System
Graves : *Grand réseau adapté à la veille spatiale*
IGN : *Institut géographique national*
IMINT : Imagery Intelligence / ROIM : *Renseignement d'origine image*
JFACC : Joint Force Air Component Command
LRIT : Long Range Identification and Tracking
MOI : *Main d'œuvre industrielle*
MUSIS : Multinational Space Based Imaging System for Surveillance
NASA : National Aeronautics and Space Administration
OODA : Observation-Orientation-Decision-Action / OODA : *Observation-Orientation-Décision-Action*
R&D : *Recherche et développement*
Samro : *Satellite militaire de reconnaissance*
SAR-Lupe : Synthetic Aperture Radar-Lupe
SARSAT : Search and Rescue Satellite
Satam : *Systèmes d'acquisition et de trajectographie des avions et munitions*
Scalp : *Système de croisière conventionnel autonome à longue portée*
SHOM : *Service hydrographique et océanographique de la Marine*
SIGINT : Signals Intelligence / ROEM : *Renseignement d'origine électromagnétique*
Spirale : *Système préparatoire infrarouge pour l'alerte*
Spot : *Système probatoire d'observation de la Terre ou Satellite pour l'observation de la Terre*
SSA : Space Situational Awareness
SWOT : Surface Water and Ocean Topography
Syracuse : *Système de radiocommunication utilisant un satellite*
TIRA : Tracking and Imaging Radar

Foreword

Bernard Norlain

General (Air, Retd), Director of *Revue Défense Nationale*.

It is with great pleasure that *Revue Défense Nationale* is publishing this special edition dedicated to space, on the occasion of the 49th Paris International Air Show at Le Bourget. It has been compiled by the *Centre d'Études Stratégiques Aérospatiales* (CESA – the Strategic Aerospace Studies Centre), directed by Brigadier (Air) Gilles Lemoine.

Its timing is propitious, for more than ever this special edition underlines the vital importance of space for our country's strategic autonomy and ability to act independently. It also draws attention to the major risk involved if spending on space is allowed to dwindle.

For me, three things in particular stand out from the articles in this edition: they might be obvious to some but their importance makes them worth underlining:

- The exo-atmospheric space environment is key to the strategic challenges of our defence and security structure. Not only is it a strategic environment, but also today essential for the planning and execution of operations.

- As a result of ambitious and successful public policy, France has over the years acquired a leading position in the field. This position has been achieved through effort in research and development, and by the creation of a broad industrial base. Furthermore, space technology is characterised by duality of use, civilian and military, and by the inescapable necessity for cooperation within Europe for the conduct of these extremely costly programmes. Given these conditions, space holds a favourable position as one field in which European Defence could genuinely be created, provided that there be no slackening of effort.

- The other side of this coin is that our dependence on satellites is creating new vulnerabilities for security in its broadest sense, and as a result is accelerating the militarisation of space, which carries with it the risk of war in space. Because of this, we need to direct our attention to a new form of deterrence, space deterrence, for in it lie many of tomorrow's strategic challenges.

In conclusion, this special edition has the key merit of highlighting the importance of exo-atmospheric space as a natural extension of atmospheric space, not only for the strategic and operational aspects of our defence but also for the wider security of our country. This being so, reduction of expenditure on space would amount to a considerable error for France's vital interests.

Editorial

Gilles Lemoine

Brigadier (Air), Director of the *Centre d'études stratégiques aérospatiales* (CESA - centre for strategic aerospace studies).

> Any point on the surface of the globe can now be observed, examined, listened to, and photographed at any time; this all started with Sputnik in October 1957. Following this the development of a group of specialized technologies of all kinds was rapid, together with the emergence of a powerful space industry which, with its by-products, has transformed for ever the strategically vital techniques used in surveillance, intelligence and telecommunications.
>
> Admiral Guy Labouerie, *Stratégies – réflexions et variations*, 1993

A steadily increasing number of countries have acquired, or intend to acquire a military capability in space. The arrival of a number of emerging powers in the field of military space activity is striking; the great powers no longer have a monopoly. The field of reconnaissance is the most active area. On 22 October 2001 India launched its first experimental satellite. On 10 December 2001 Pakistan placed a satellite in orbit. Following this it was Egypt's turn, then Saudi Arabia, and then Taiwan in 2004, to launch their first satellites. In 2009 Iran placed its first satellite in orbit, an event which could well have been a first step in the development of military capabilities. This interest from a large number of countries, driven also by consideration for major long term investment, demonstrates the extent to which the use of space for reasons of military and national security has made it essential for the defence of our own interests in the context of the new strategic situation identified by the *Livre blanc* (the defence White Paper).

Space was initially exploited by the (then) two superpowers in the strategic context of nuclear deterrence. Nowadays the strategic benefits sought from the use of military space capability have widened in scope. During the Cold War the major strategic preoccupation was to maintain close watch on the nuclear activities of the adversary. Accordingly, both the USA and the USSR developed a range of observation and communications monitoring satellites.

The First Gulf War marked a watershed in the use of space technology, in that it was widely used to support land, sea and air operations.

We are now seeing a step increase in the tactical use of space technology, with its widespread integration into both individual weapon systems and the processes of planning and command and control. Observation satellites, used originally as a means of surveillance, are today used for reconnaissance. The GPS positioning and navigation system now adds high precision to the terminal guidance of missiles and bombs. Telecommunications satellites accelerate data transfer, enabling commanders to get inside an enemy's OODA (Observation-Orientation-Decision-Action) loop; indeed, they can now be defined as the keystone of any military operation.

It would therefore be as wrong to view space activities as solely strategic, as it would be to consider them solely as a technical support for operations. Not only has reliance on space technologies grown exponentially, but these technologies are also now at the heart of all the assets (at both the strategic and operational/tactical levels) that are used and coordinated to achieve success in any operation.

We have been at pains to include articles by those involved at many different levels in the chain of users of military space technology. Once the political context has been set, the issues of general strategy and of programming investment can be considered. Knowing that we cannot afford unilateral investments at the national level, we need to think carefully about the terms on which we are willing to cooperate with others, while retaining our autonomy of decision-making. This autonomy is qualified not only by our capability to operate in space, but also by our ability to use our assets freely in this domain.

Indeed, even though space assets are considered as 'force multipliers', they are fragile systems which operate in a medium that is becoming increasingly hazardous with the ever growing presence of space debris and the risk of militarisation. Furthermore, our dependence on these assets constitutes a second source of vulnerability: to counter this France is acquiring powerful tools for monitoring space, a mission vested in the Air Force. Finally, studies are currently in progress with the aim of refining the concept of space defence.

This special 'Space' edition is therefore devoted to restating reality: that space assets now occupy a crucial place in military operations. It also underlines the fact that a major evolution (from the political right down to the tactical level) has taken place in the art of war.

I trust that it will succeed in this ambitious task.

Space, a Strategic Territory

Marie-Madeleine Marçais

Lieutenant Marçais is responsible for research at the *Centre d'études stratégiques aérospatiales* (CESA - centre for strategic aerospace studies).

War is above all a matter of position.
Napoleon

Exoatmospheric space was recognised by the French defence White Paper as having become 'as vital for the global economy and international security as the sea, the land and the air'. It possesses characteristics that by their very nature make it strategic territory. While the functions to which it has been put now include the tactical level, France rejects its use as a theatre for the conduct of combat operations.

At first sight, it is the inhospitality of the medium that is most striking. It is hostile both to mankind and to the systems that are deployed within it; inflexible, since the laws of physics oblige satellites to follow a fixed trajectory at a predetermined velocity; and vast, which makes it difficult to monitor and hence to control.

However, space has a multitude of advantages that convincingly demonstrate its strategic nature. Its all-encompassing nature offers a geocentric approach offering permanent surveillance of the surface and providing unique support for operations carried out on Earth. The absence of atmosphere, and hence friction, offers long life for deployed devices and its great altitude and legal status provide the user with unequalled perspectives and coverage, as it is not subject to overflight restrictions. No other environment can offer these advantages. In addition to these general characteristics, tangible strategic positions can be identified within exoatmospheric space. While this statement might appear incongruous when associated with a medium that bears greater similarity to inter-stellar space that to a geostrategic landscape, it is well founded.

Hervé Coutau-Bégarie definies a strategic position or zone as 'any position or zone, the possession of which confers on he who holds it a structural advantage for the conduct of a conflict'. Specific space zones or positions, within Earth orbit or inner space, fully meet this definition and can therefore be catalogued as 'astro-strategic'.

Low orbit (between 150-200 km and 1,500 km) offers qualities that are particularly favourable to communications and observation. The problem that arises is the premature decay of such satellites due to the residual atmospheric pressure added to atomic oxygen. This orbit is also encumbered by a vast amount of debris, which presents an ever-increasing threat. Finally, satellites in a low orbit are also vulnerable to possible anti-satellite weapons (laser blinding or missiles for example). The geostationary orbit (special case of the geosynchronous orbit) enables a satellite to remain vertically above a single point on the Earth's surface. The primary military use for this orbit is for communications satellites. The libration points, more often known as Lagrange points, are zones within which the gravitational effects of the Earth-Moon and Earth-Sun systems are in equilibrium. Their strategic advantage is that an object once placed at one of these points will possess long-term stability and use very little energy.

Having described the geostrategic value of this environment, one must not forget that such use relates solely to the Earth. France therefore considers that occupation of space is not an end in itself, in contrast to the old US vision of space dominance under which the United States ensured its supremacy in this field mainly by denying access to its adversaries, but a means available to it to impose its will within current battle spaces. France is convinced that it cannot ignore this environment if it wishes to perpetuate its autonomy and national sovereignty, and therefore intends to acquire this expertise without deploying weapons in space or against space systems. It is planning to achieve this in two ways:

First, by creating a strategy of resources, developed to exploit the environment in an optimal manner and enable the deployment of systems destined to support operations undertaken on the Earth's surface. This consists essentially of programme-related choices and greater investment in research and technology. At a time when 'war has become industrialised and technical', it is now vital to identify future resource requirements (Hervé Coutau-Bégarie). Undertaken in an increasingly demanding budgetary climate, discussions preceding programme choices are vital and will result in decisions that will condition national strategy for the future.

Second, through the monitoring of activities carried out in space. This is a defence role undertaken by the Air Force and involves the surveillance of the environment using increasingly sophisticated devices, which include the *Grand Réseau Adapté à la Veille Spatiale* (Graves - large network for space surveillance) telescopes, tracking and spectrographic radars), that are destined for incorporation in a C2-type operational structure, the future *Centre Opérationnel de Surveillance Militaire et d'Observation Spatiale*

(COSMOS). Ultimately, this space observation task will be incorporated within a broader concept of space defence.

While it is clear that space resources will henceforth be used for tactical purposes within terrestrial operational theatres, the space environment must remain contained at a sub-strategic level to avoid its transformation into an operational theatre.

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Space Policy and Strategy

Les Cahiers de la Revue Défense Nationale

Space: a Response to the Challenges of the 21st Century

Pierre Lasbordes

President of Parliamentary Space Group: created in the spring of 1994, the group is made up of elected French MPs, senators and MEPs who have an interest and commitment to civilian and military aspects of space.

As the new century gathers pace, Europe and France need to face up to new challenges: an unprecedented economic and financial crisis, and climate changes whose consequences for our planet are so complex that the scale of the phenomena and ensuing solutions are difficult to comprehend. Furthermore, we are faced with geopolitical upheavals and a rise in extremism that demand enhanced strategic vigilance. These fundamental challenges reflect the globalised nature of today's world. Although political decisions are needed, we also require structures that are capable of interpreting phenomena on a planetary scale. Satellites would seem to offer the appropriate capability to obtain the necessary overview. Space is therefore our only means of observing the planet for scientific or political ends, in addition to being a vehicle for economic growth as a result of the technological innovations achieved in this sector whose applications benefit society as a whole.

For more than 50 years France has invested in space technology and is the leading space power in Europe. This position must now be maintained by continued investment in this sector of the future. With this in view, on 22 June 2009 the President of the Republic launched the 'big loan' (the *Grand emprunt*). Faced with the need to retain this lead in new technologies, this big loan, of some 35 billion euros, aims to boost France's growth potential by funding 'future expenditure' in higher education (around 11 billion euros), research (8 billion euros), industrial sectors and SMEs (6.5 billion euros).

For the space sector, the government decided to set aside a sum of around 500 million euros, half of which will be allocated to launch vehicle development, according to the President's announcement in Vernon on 14 December 2010. The remaining 250 million euros will be assigned to the development of innovative satellite projects, including 170 million euros for the Surface Water and Ocean Topography (SWOT) satellite project, developed jointly by CNES and NASA. The data obtained from this will help to promote the emergence of industrial applications based on the work of researchers in such fields as meteorology, fisheries and agriculture. The 'Myriade-Evolutions' project for the development of a new generation platform for micro-satellites in the 200 to 250 kg range will receive joint funding of some 40 million euros. The first programme to benefit from this platform is the Franco-German Merlin project to measure methane levels in the atmosphere. Finally, the last 'Future Satellites' project will receive joint funding of 42.5 million euros for the design of a new generation of geostationary telecommunications satellites of between three and six tonnes, the aim of which is to achieve a 30 per cent improvement in competitiveness over the current generation.

Future technologies are fundamental to our industries as well as to our fellow citizens. History tells us that technological innovations have often given those who can master them a political, economic, financial and social advantage. Today the big loan is aimed at enabling the completion of projects of excellence, and it has to achieve three main aims.

Firstly, state intervention is essential at both the economic and industrial level. Since the financial crisis, it has become clear that aid from government sources is absolutely vital to encourage the development of the nation's industries. Some major investments cannot in fact be made by the private sector even though such investment generates very significant returns for the economy. It is the role of the government to help industry, to support and promote future technologies that in the end will create high value-added jobs that are difficult or impossible to relocate offshore and which, in turn, will generate employment in sub-contractors.

Secondly, the government invests because it sees in future technologies benefits for our daily lives. As Giradin said, 'to govern means to foresee': elected representatives, and indeed all political players, must be capable of anticipating future developments. That new technologies make their contributions to such anticipation is all the more evident in the space sector, where applications offer advanced tools in the service of the wider population. Satellite TV, meteorology and navigation are perfect examples. The Internet has become a strategic infrastructure with a major economic and social role, and the high data rates needed today are mainly reliant on satellite-based technologies. The development of television on mobile phones will doubtless be one of the next growth opportunities in the telecommunications sector. The debates within the Parliamentary Space Group show that space applications will play a major role in the decision making processes undertaken by elected representatives, and will support them in their subsequent actions in such fields as regional development and risk avoidance and management.

Finally, the big loan is also important politically. It is the product of a determination by government and authorities to relaunch the economy. Once the crisis had been addressed, cost-cutting measures were needed that have saved jobs—employment being the most important factor. The question now is how to relaunch active investment. In my opinion, this is now at the very heart of the strategy needed to recover from the crisis and is the main purpose of the big loan.

However, one must not forget that while the State can and should help the private sector to recover from the crisis, the private sector has also to learn how to regain self-reliance. The fundamental question of public deficits has painfully reminded us of this recently. The market must therefore take up the challenge now. Once the relaunch plan has been completed we must identify a new balance; this task will be all the easier if investments are made wisely and in consultation, so that today's decisions may result in tomorrow's successes.

International Military Cooperation

Yves Arnaud

Brigadier (Air), head of the *Commandement interarmées de l'Espace* (CIE - joint space command).

The French White Paper on defence and national security published in June 2008 states unequivocally that all types of satellite make an essential contribution to all strategic functions. President Sarkozy made the situation very clear in a speech he delivered at Kourou, French Guiana, on 11 January 2008: 'There can be no question for France, and I would suggest for our European partners, of any reduction in our efforts and ambitions in the space field'.

Space has become a major challenge and a defining element of both our defence and of society today. As a symbol of power it enables nations to demonstrate their scientific, technical, industrial and financial capabilities. It is also a powerful diplomatic tool as it gives governments an independent ability to monitor and assess situations and decide what action to take.

Nevertheless, at a time of economic constraint, international military cooperation is increasingly emerging as a vital element in attempts to continue the pursuit of space capabilities and their development. It is therefore time to define the levels and rules of cooperation that will enable us to protect national sovereignty, starting with an analysis of our capabilities and current and future cooperative plans.

Extended capabilities, multi-layered cooperation

The space capabilities currently employed by France are based on military systems (Helios, Graves, Syracuse, SAR-Lupe, GPS and, in the near future, ELISA), dual civil/military systems (COSMO-SkyMed and, shortly, Pleiades) or specifically civilian systems (commercial imagery, communications, emergency location, oceanography).

These satellite resources cover a range of fields, from optical and radar imagery through radio navigation to communications. The spectrum is a broad one and offers capabilities that are often complementary.

Space Situational Awareness (SSA), mainly achieved using ground facilities, contributes to the protection and optimisation of these resources.

In support of our status as a 'space power', we must ensure long life for these capabilities, develop or improve the way we use them and the manner in which they are integrated into operations. We must also secure our freedom to access and exploit space. Now and in the future, it is difficult to imagine carrying out military operations without support from space-based resources.

The types of military cooperation that are being implemented are varied in nature. Such cooperation may be operational or technical, and include the exchange of personnel, data or capabilities, or involve joint developments or system sharing. Cooperation may be bilateral or multilateral, and at a European, transatlantic or NATO level.

A striking example: earth observation

The international landscape is remarkable for the wide geographic dispersal of threats. Space-based devices offer rapid, discrete and repeated access to anywhere in the world. Perhaps the most obvious use of space is in earth observation using optical, radar and infra-red satellites which provide rich and varied images that enable managers to take well-informed decisions. Of course, space is not limited to this capability, yet for more than 15 years it has formed the basis for cooperation with our European partners thanks to the steadfast commitment of France and the reliability of the Helios space system.

The Helios 1 and 2 programmes were launched by France in the 1990s and offer European nations a significant optical capability.

- The Helios 1 programme, consisting of the Helios 1A and Helios 1B satellites, involves three European nations, France, Italy and Spain. The programme cost is around 1.9 billion euros, 80 per cent of which is borne by France.

- The Helios 2 programme brings together six European nations, France, Italy, Spain, Belgium, Greece and Germany (as an associate partner). France contributes 90 per cent of programme costs. An agreement has also been signed for the supply of Helios images to the European Union via the EU Satellite Centre (EUSC) located at the Torrejón airbase near Madrid. The gathering of optical images is highly dependent on meteorological and light conditions, which makes radar observation a vital and effective complement.

The Schwerin agreement signed in 2002 was the start point for Franco-German satellite imaging cooperation. It gave France access to a radar capability provided by the German constellation of five SAR-Lupe satellites. These satellites were launched from the Plesetsk cosmodrome (Northern Russia) between December 2006 and July 2008. In exchange, Germany has access to optical and infra-red imaging from the Helios 2 satellites. Cooperation between France and Italy is at an equivalent level. French operators now have the right to programme the Constellation of small Satellites for Mediterranean basin Observation (Cosmo-SkyMed or CSM) which is a dual civil-military system consisting of four radar satellites that were launched from the US site at Vandenberg AFB. The French party obtains radar images from the CSM in exchange for the right to programme Helios satellites. These operational exchanges started in July 2010 and occur over a link between the French ground station at Creil in France and the Italian station located at Pratica di Mare.

There is therefore a range of European observation resources: Helios (optical and infra-red), SAR-Lupe (radar) and CSM (radar) for military and dual-use systems. Access to all weather, day/night capability by France, Italy and Germany is achieved via bilateral or multi-lateral cooperation. These exchanges offer the three countries a real capability to anticipate and monitor international crisis situations as well as provide operational support while respecting each nation's sovereignty.

We must now capitalise on these cooperative ventures if they are to develop and bear further fruit.

Constantly evolving cooperation

Cooperation will continue in other fields, especially observation and SSA, although nations remain free to offer or withhold their programmes or capabilities as they see fit.

France, fearing the loss of an optical capability after 2015-2016, and faced with the timescale problems inherent in bringing new capability into service, decided to go ahead alone with the CSO programme, the Optical Space Component of the MUSIS programme (Multinational Space Based Imaging System for Surveillance). This programme is nevertheless open to cooperation, and interested countries are currently applying to join. This system will be designed with growth potential, and has an initial target of two satellites: a third could be added later, given adequate funding.

The SSA field is also the subject of bilateral partnerships. It is an important tool in support of strictly national ambitions and its aims are to gain an understanding of the situation in space in real time and hence assess the threat, detect any attack, and alert the authorities so that appropriate defensive or active measures may be taken.

We should not delude ourselves that any one state could alone possess the entire range of capabilities needed to monitor the space situation. The only way to acquire the desired capabilities would therefore appear to be via cooperation. France and Germany, the only two European nations with an operational SSA capability, agreed in 2009 a joint military requirement in this field. Already, the French Air Force and the Luftwaffe are cooperating, using the existing French Graves and German Tira radar systems.

The signature in February 2010 by the respective defence ministers, Alain Juppé and Robert Gates, of a 'Declaration of Principles' between France and the United States, will enable France to cooperate in depth with its US partners on this topic that plays an essential role in ensuring our freedom to exploit space. These recently established bilateral partnerships with the United States and with Germany represent the foundations of a genuine operational cooperation that has a very promising future.

As European institutions have an increasing need to access information related to the space situation, the reality of such cooperation must be taken into account. The strong links forged through this Franco-German cooperation could therefore serve as a basis for the creation of a European SSA capability. It is now clear that cooperation is essential. However, it must be guided by rules and principles.

Challenges and principles

In the current economic crisis that Europe is experiencing, no nation can afford to procure all the space-based facilities needed to meet all its requirements, so cooperation has always to be considered as a means of obtaining or sustaining capabilities that would be unattainable nationally for budgetary, industrial or technological reasons.

Maintaining capabilities or acquiring new ones is of course the prime objective, but care must be taken throughout the cooperation process to take due account of issues relating to sovereignty, national security, data protection and the rules governing the safeguarding of classified information. A clear policy for the exercising of control over capabilities and sensitive data is therefore an essential precondition for the implementation of any form of cooperation.

Moreover, any cooperation must be based on balance, effectiveness and if possible, redundancy or resilience. The aim must above all be to meet a capability target while also ensuring a return that is proportional to agreed budgetary provisions.

The necessary convergence of requirements and timescales sometimes conflicts with national interests. Tensions and divergences can only be overcome through compromise. Flexibility, patience, conviction and persuasion are vital elements of an approach that must above all be realistic.

Finally, France is faced with a proliferation of coalition operations; if it wants to fully exercise its role as framework nation, it must be in a position to offer its allies the space data it has at its disposal, knowing that it will be able to count on the complementary resources of its partners.

The commitment of nations in the Helios community in support of operations *EUFOR Chad* and *Atalanta*, the latter fighting piracy off the Horn of Africa, is indicative of France's desire to ensure participation by its allies and, in this particular case by European nations, in this sharing of capability. Space nations must therefore jointly take up the challenge represented by the free circulation within a coalition of information that has often been obtained using facilities originally intended for strictly national purposes.

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We thus face major challenges: the perpetuation and development of our space capabilities and their integration into operations.

In the light of the political, military, economic, technological and industrial challenges that such capabilities represent, space would appear to be an environment likely to excite enthusiasm within a European defence and security identity and via a robust transatlantic relationship. Any cooperation demands sustained and committed motivation and effort.

In the difficult and complex environment we face now and in the future and in a decidedly challenging budgetary climate, cooperation is the only route that will enable us to meet our operational requirements. It alone will enable us to retain the hard-won but highly effective resources that will enable France to retain its place as a major space power.

Defending Space – the Next Step?

Jean-Paul Granier

Colonel in the French Air Force Reserve and Counsellor (Space) to the director of the *Délégation aux Affaires Stratégiques* (strategic affairs directorate).

Space, in both its military and civilian applications, is a factor in strategic and operational pre-eminence in the defence and security fields. More generally, mastery of the space environment is synonymous with power, independence, autonomy and development.

A challenge for defence

The use of space is now an everyday occurrence in the defence field as well as in its civil and dual applications. Nations with access to space now feel the strategic need to acquire a space surveillance capability that will provide them with information on the space situation. There are several reasons for this: to facilitate access to space, to ensure protection against threats or potential risks to space facilities, to assess and prepare defence against capabilities perceived as hostile, especially those that could impact on their defence and security, and finally, to counter any possible weaponization of space.

This challenge is not currently within everyone's reach. The calculation of satellite or debris orbits requires a very sophisticated optical or radar tracking capability that needs to be supported by more specialised instruments where there is a need to characterise the objects detected. The United States has developed the very advanced Space Situational Awareness (SSA) concept. It has negotiated structured cooperation with France in this field, which led to the signature of an agreement between Alain Juppé and Robert Gates in Washington last February. France and Germany are also cooperating on this subject by exploiting the complementarity between the French Graves (*Grand réseau adapté à la veille spatiale* - large network for space surveillance) system and the German TIRa (Tracking and Imaging Radar) system. Finally, within the European Space Agency framework, Europe could in due course develop a programme that would give it a degree of space surveillance capability.

In the light of this, should we be making such a surveillance capability more widely available? Would this mean that we must accede to all requests from any nation with access to space and who wishes to have the capability? The answer depends on the objective: if the aim is merely to achieve better management of space, then no case can be made against it. However, if such openness could facilitate new conflicts then we would have to think again. No legal or political mechanism is currently available to preclude this second possibility. Given these conditions, what strategy should be adopted? Certainly one must avoid contributing to any proliferation of this type of capability, yet on the other hand building cooperative ties with nations lacking these capabilities would provide them with information enabling them to understand better, and contribute more effectively to the safety of space activities.

A rapidly changing environment

Capabilities based on the use of space-based tools are costly and few in number. Militarily, they are justified in France as a force multiplier under the 5 separate strategic functions (Knowledge and Anticipation, Prevention, Deterrence, Protection, Intervention), which it would be reckless, even suicidal, to abandon. Satellites are necessary for armed forces' effectiveness but also for our modern society's daily life and they have become a source of vulnerability that must be protected against international or other threats.

France has therefore launched or is contributing to several diplomatic initiatives aimed at securing the safety of space activities.* These include the French initiative 'Long term sustainability of space activities' proposed by the French Presidency of the Committee on the Peaceful Use of Outer Space (COPUOS) in 2007, and the EU draft code of conduct for exoatmospheric space activities of December 2008. However in a major crisis situation it would seem militarily natural and logical for any

*** The French position on space**

France bases its position on these three principles:
- Freedom of access to space for peaceful purposes,
- Ensuring the protection and integrity of orbiting satellites,
- Respect of a nation's right to legitimate self defence.

belligerent to seek to exploit the vulnerability arising from an over-dependence of his adversary on his own space-based systems.

Space must be monitored if it is to be better controlled

The very nature of satellites and the difficulty inherent in proving they have been attacked, and by whom, means that it is all the more problematic and disproportionate to classify such space-based assets, and especially their military applications, as amongst the vital interests of the nation and to place them under the protection of the deterrent force. We must therefore look closely at how we might respond to an unambiguous attack on a satellite and identify such responses in our defence policy.

Apart from attacks on ground installations using conventional means, weapons that could be used against currently identified exoatmospheric capabilities may be classified into five categories:

- Kinetic weapons: this involves achieving a direct mechanical impact or shock wave that destroys the satellite. Essentially two types exist, ballistic missiles and orbital interceptors.

- Electronic warfare weapons: EW techniques may be used to jam remote control systems or take control of the payload in communications satellites.

- Cyber warfare techniques: space systems, like all highly computerised devices, are potentially vulnerable to cyber attacks on software components (trap door, computer virus), the use of a Trojan horse, logic bomb, entrapment or identity theft.

- Directed energy weapons to neutralise or destroy a satellite. These include primarily high powered lasers and microwaves.

- High altitude weapons, especially exploiting EMP effects, direct radiation effects or the electromagnetic radiation effects of nuclear explosions.

Of course, some exotic experiments and anti-satellite tests took place in the nineteen sixties and seventies. However, the bipolar relations of that time limited the opportunity to extend these trials and additionally, the orbital environment was very different then from what it is today in terms of the number of objects and amount of space debris in orbit. This is a situation that the whole world must face up to. Space is an environment to which all have access, a shared medium which we must find ways and means to govern. One of today's preoccupations of the principal powers is to identify ways to manage this resource.

Anti-satellite capabilities have recently re-surfaced in spectacular fashion. They have been the subject of two deliberate demonstrations, followed by the accidental collision between two objects:

• 11 January 2007, China launched a device derived from a ballistic missile to destroy by interception one of its weather satellites that had reached the end of its life, Fengyun 1C, at an altitude of 800 km. The result was thousands of pieces of debris scattered across a frequently used family of orbits.

• 20 February 2008, the US Government used an SM-3 missile to destroy its US193 reconnaissance satellite before its uncontrolled re-entry into the atmosphere.

Similarly, some techniques could be seen as having a dual use and have already been suggested by some in industry. While some of these should be considered only for the longer term, they should enable:

• A reduction in the amount of debris by applying retardation using high power lasers, or by capturing them using cargo vehicles that, after an ISS re-supply mission, could embark debris prior to a destructive re-entry into the Earth's atmosphere;

• The re-supply, maintenance or repair of satellites in orbit using robots.

Keeping risks under control

It must not be forgotten, however, that under cover of public-spirited actions to clean up space debris or to maintain operational satellites, these techniques would also demonstrate an ability to neutralise a hostile space capability.

Regardless of the method used, any aggression could generate pollution of the most congested orbits by the creation of debris or even by out-of-control satellites. To reduce this risk, should the situation arise, those nations that are most dependent on their space infrastructure would not be able to limit themselves to the use of simple attack methods. They would have to develop more sophisticated, and hence more costly, 'non-polluting' space-based or non-space methods, such as EW or directed energy systems, that comply with their international commitments and would not increase the threat to their own orbital assets. If, through pursuing its capability improvements in the space surveillance field, France were to recognise this need as one that is becoming essential, it could be in a position to:

• Identify a potential threat to its space assets and hence plan a proportionate response;

• Associate a hostile satellite with a ground-based attack capability, with a view to neutralising or destroying it and thereby regaining or enhancing a favourable balance of forces.

Thus, once France has acquired the space capabilities needed to enhance its ability to monitor space for defence purposes, the search for an anti-satellite potential could form the third logical step in the military control of exoatmospheric space. Ultimately, it could represent a decisive resource for belligerents. The research and development activities needed to gain a foothold in this sensitive field are numerous, often protracted and always costly. Before selecting such a capability, it would be sensible to characterise the selected method so that only relevant technological building blocks are developed; defensive measures should also be taken within international regulatory bodies to avoid having to put the technique into practice.

Resolute support of international diplomatic initiatives

Diplomatic initiatives by the leading space powers within international regulatory bodies have up to now been aimed at outlawing methods and techniques that they themselves have already rejected. The United States possesses a wide range of operational techniques and is continuing research activity in this field. It has developed several concepts in parallel. So-called 'Space Deterrence' aims to introduce systems capable of identifying the origin of attacks, to characterise an event, and to give to the system owner the legal and political details needed to exercise a form of deterrence. It also aims to achieve the networking of allied nations' capabilities to deter a strike of limited effectiveness against any component of a set of resilient resources. This is the aim, for example, of the cooperative efforts around the 'Operationally Responsive Space' initiative to create a network of resilient capabilities and to meet the needs expressed by commanders in operational theatres. This idea also underlies the initiative from commercial communications satellites operators, the Space Data Association established on the Isle of Man, whose aim is to create a database combining all orbital parametric data for satellites in geosynchronous orbits and to provide continuous analysis of risks of interference or collision.

These efforts reflect the broader notion of 'Global Commons' that aims to establish with the allies of the United States a world order based on mutual dependence of space capabilities. This would doubtless suppose a leading role for the leading space power who claims to want to promote the responsible use of space for the benefit of all and future generations, and to ensure its balanced management *.

*** U.S. National Space Policy**

Published on 28 June 2010. In particular this states on page 2: 'The United States, therefore, calls on all nations to work together to adopt approaches for responsible activity in space to preserve this right for the benefit of future generations'. Further down the same page: 'The United States hereby renews its pledge of cooperation in the belief that with strengthened international collaboration and reinvigorated US leadership, all nations and peoples—space-faring and space-benefiting—will find their horizons broadened, their knowledge enhanced, and their lives greatly improved'.

Our US partners have included us in their debates on these concepts. We are contributing to such debate while aiming to maintain a fair balance between the principles of independent decision-making and action that underpins our defence. This participation reflects our desire to create mechanisms, procedures and interactions between those nations that share the goals of maintaining a stable space environment, enhancing security in space and establishing transparency and confidence between space players.

Space: Realm of Civil-Military Duality

Henry de Roquefeuil

General, Military Adviser to the President of the *Centre national d'études spatiales* (CNES, the national space study centre).

The CNES is responsible for advising the French government on space policy and for its implementation. Within the five strategic fields into which its activity is divided—access to space, Earth-environment-climate, public applications, security-defence and space sciences—only the latter involves activities related to purely civilian use. Launch vehicles are identical for both civil and military satellites, civil observation and image-based intelligence rely on the same technologies and military satellite communications benefit from advances made for civilian applications.

To exploit this duality, the CNES decided not to create a military directorate within its organisation but use the same departments that deal with civil programmes to address defence projects. Advances in the one therefore benefit the other. This closeness favours technological progress and offers savings.

Launch vehicles

The great space venture in France and across Europe is directly related to the future of Ariane and the Guiana Space Centre. Between them they have not only given us and our European partners independent access to space but they have above all offered the security and confidentiality that defence departments need when launching their satellites.

All French military satellites (Syracuse, Helios, Essaim and Spirale) have been launched from Kourou by Ariane launch vehicles. For future launches (Pleiades, ELISA, Athena-Fidus and the Optical Space Component of MUSIS and Ceres) the Ariane space catalogue will be expanded with the introduction into service in Guiana of Soyuz and Vega launchers. This wider range of Kourou-based launchers will make it easier to match the vehicle to the satellite mass and task and hence reduce launch costs.

The launch vehicle field is also of defence interest as it is linked to that of the strategic deterrent. The companies that build space launchers also manufacture ballistic missiles. The skills acquired by their research staff and designers in the space launcher field are complemented by those gained in the design of the deterrent force missiles. The work undertaken in the civil launcher field contributes to maintaining the Defence Industrial and Technological Base for the strategic missile sector. This explains France's interest in this capability and in its industrial landscape.

The mid-life update of Ariane 5 therefore aims to provide enhanced performance and greater flexibility in the carriage of satellites, thereby saving money. The European Space Agency (ESA) has also decided to carry out development studies into Ariane 6 that should enter service around 2025. This will be modular, with a variable number of boosters, and will be able to put payloads of between 2 and 8 tonnes into geostationary transfer orbits at significantly lower cost. France has decided to allocate 250 million euros in its long term costings to fund this project.

Communications satellites

Communications satellites are the most numerous class of all, as it is they that generate the greatest revenue. Wherever armed forces operate, they need communications links for which there are specific security requirements. These requirements become ever more crucial when the political dimension of deployed operations demands a permanent secure link between command centres in France and theatres of operation. The introduction of UAVs into front-line operations has led to new requirements for satellite communications.

Since the 1990s French defence forces have been using dedicated systems, such as the jamming and intrusion-protected X-band Syracuse, for the transmission of orders, intelligence, reports and a wide range of increasingly voluminous operational data. To meet their increasing needs, the military are now tending towards the use of civil resources: the dynamism of this sector offers them the benefits of new technologies and a reduction in both ground-based and vehicle equipment costs. To complement equipment such as Syracuse, France and Italy have therefore launched the Athena-Fidus satellite programme, which offers very high data rates based on civil Ka band technologies. This is being managed for the benefit of both nations' armed forces and security services and will considerably increase link capabilities at a much reduced cost, albeit with lower levels of protection.

Ever-expanding communications and increasing data rates mean that the military today depends more and more on space for the implementation of the network-centric warfare concept that is unaffected by distances, frontiers and mediums. Duality enables these limitations and budgetary constraints to be respected.

Navigation

The global challenges of satellite navigation for society are well known, as is the fascination that it has generated amongst the general public. Personal GPS devices have moved on from dedicated units in vehicles to an application on mobile phones.

The military field demands high levels of availability and quality in its location and timing data. Space is so important for the conduct of operations that force commanders in the United States are assisted by ‘space’ specialists who advise them on the situation of their space assets and help them to express their needs in terms of space services.

From 2014-2015, the European Galileo system, interoperable with GPS, will offer improved accuracy and redundancy. It will give Europe independence in a field that has become vital but which is controlled by the US Department of Defense. The CNES has made significant contributions to the launch of satellite navigation including the development of the system architecture for the European Geostationary Navigation Overlay Service. This European system that enhances GPS enables aircraft to fly and land safely using only GPS signals as a navigation reference.

Once difficulties in the setting up of the European organisation for Galileo had been overcome, Europe united in its commitment to a 5 billion euros programme to provide a strategic service to the general public, industry and security services.

Galileo is a civilian programme that will also be used by the armed forces of European nations, offering them services adapted to their tasks.

Earth observation

Earth observation comes in many forms that cover land, the oceans and meteorology. For all these tasks, the military uses either civilian services or resources made available for its use based on shared technologies.

For imaging intelligence, Helios 2B, launched in December 2009, is the last of a family that includes Spot and Helios satellites. This association enabled each of these two programmes to benefit from advances made by the other and thereby achieve consistent economies of scale.

The Helios 1 and Spot 4 satellites used the same platform and the same magnetic recorders for storing images. Both systems, and their successors Helios 2 and Spot 5, employed jointly-developed sub-assemblies and equipment in their platforms and payloads. CNES Project teams and industrial programme managers were the same for both programmes and shared the same ground installations and facilities, and the CNES acts as station-keeping operator for both systems from its site outside Toulouse.

This synergy between the Helios and Spot systems has enabled cost and risk sharing between the civil and military programmes. With each programme generation this mutually advantageous relationship has enabled France to make savings of around 150 to 200 billion euros and serves as an excellent example of the cost reductions that can result from the duality inherent in two major programmes.

The same strategy will be employed with the Optical Spatial Component of the Multinational Space-based Imaging System for Surveillance, Reconnaissance and Observation (MUSIS) which will be launched in 2016. Many systems, including sensors and those that contribute to its agility, are the result of developments undertaken in support of the dual civil/military satellite system Pléiades which will be launched in 2012. This duality keeps the French space industry at the cutting edge of technological innovation while containing costs.

In the cartographic field, defence needs are insufficiently specific to demand the development of dedicated programmes. Requirements are therefore targeted more at products (digital terrain modelling and digital maps, for example) than at imaging. Defence thus gives priority to the development of specialised processing using data from civil satellites in the Spot family. Agreements concluded with the *Institut géographique national* (IGN - the national mapping agency) and the contracts signed with companies in the sector enable it to meet its needs in terms of reactivity and theatre-related requirements.

The same applies to meteorology and oceanography; a major proportion of military needs is met by *Météo France* (the national weather forecasting service) and the *Service hydrographique et océanographique de la Marine* (SHOM – the naval hydrographer) from data they have gathered from civil satellites, either European (Météosat), or those developed in international cooperation (Jason).

As a last point, it should be mentioned that duality also impacts on the early warning role. This task, although specifically military, in fact depends on technologies that also have meteorological applications.

Maritime surveillance

Maritime surveillance is a role associated with the nation's operations at sea; in France it is assigned to the Navy. Whether providing protection against piracy, trafficking, illegal immigration or environmental threats, space offers the necessary overview and ability to revisit incidents in our approaches, exclusive economic areas and sea routes.

The Long Range Identification and Tracking (LRIT) system, developed within the framework of the International Convention for the Safety of Life at Sea, is a network of communications satellites that collect ship positional data every six hours. EU member nations decided to create a European LRIT data centre, which has been operational since July 2009; this identifies and tracks ships sailing under European flags.

The CNES is working with the EU and ESA on a more advanced satellite-based system for the detection of a ship's VHF Automatic Identification Signal; this will offer permanent detailed situation monitoring. The task is dual, as are the resources. Not only that, but it is one that only space-based assets and international cooperation can undertake. Much remains to be done in this field and studies are being undertaken at CNES, European agencies and ESA to move this capability forward.

Space situational awareness (SSA)

The surveillance of space known as SSA has two aspects: one civil, to avoid collisions with debris, and the other military, to monitor satellites overflying national territory or theatres of operations, and keep a watch over our own satellites.

Since Sputnik, 5,000 devices have been launched into space, more than three quarters of which are no longer functioning. This activity has generated many items of debris, including spent rocket stages, abandoned satellites and wreckage from collisions. It is estimated that more than 30,000 objects greater than one centimetre in diameter are in orbit.

The collision in 2009 between Iridium 33 and Cosmos 2251 created tens of thousands of additional objects. While such objects will re-enter after a few months if they are orbiting at 400 km, they may orbit for hundreds of years at the 700-800 km orbits used for observation satellites, and millions of years at the geostationary orbits used by communications satellites.

The orbital population must therefore be catalogued in detail. The GRAVES radar was funded by the *Direction générale de l'armement* (DGA – the procurement directorate) and designed by Onera, and is operated by the French Air Force. It gives France an operational and diplomatic tool: operational, as it enables the listing of all objects of average size of one metre, and diplomatic, as it allows France to detect satellites belonging to other space powers whose parameters are not included in publically available listings, thus providing the country with a bargaining tool.

There is close cooperation in this field between the CNES, as operator of most French military and scientific satellites, and the *Commandement de la défense aérienne et des opérations aériennes* (CDAOA – the air defence and air operations command) of the French Air Force, tasked by the Prime Minister with space surveillance. Their joint activities aim to improve our detection capabilities, to optimise cooperation with our allies and, where necessary, to diminish risks to our satellites by adjusting their orbits.

Germany has a radar that is complementary to our GRAVES equipment which, when targeted at debris, can accurately measure its orbital parameters. France is therefore cooperating with Germany to establish the core of a capability that Europe intends to acquire. Both nations have also forged links with the United States, which has powerful tools in this field.

Conclusion — the way forward?

Duality is a policy option sought by the Ministry of Defence for its new weapon systems. It offers savings and the ability to remain at the cutting edge of technology by adopting developments aimed at civilian markets. This direction is all the more advantageous in the space field where the techniques and technologies needed to meet both civilian and military requirements are closely linked.

The *Commandement interarmées de l'Espace* (CIE - joint space command) and the DGA are therefore carrying out studies with the

CNES to best exploit this duality in order to acquire operational capabilities, retain technical expertise, maintain the defence industrial and technological base and, of course, minimise costs.

Our defence infrastructure relies on the expertise and project management of CNES personnel who have worked in this field for almost 50 years. An innovative joint structure for the exploitation of duality has been introduced at the CNES. This defence team consists of CIE officers and DGA and CNES engineers, and aims to target R&D and initial programme design work to exploit the advantages of duality for the benefit of defence.

The Defence Implications of Space

Jean-Pierre Devaux

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Space: a strategic, economic and industrial challenge

Space capabilities are now essential to our societies. In the financial world, bank transactions are driven by satellite navigation and communication systems. Military uses include global surveillance and secure telecommunications. Even everyday life depends on space applications: television and radio broadcasting, weather forecasting, telecommunications and ground navigation are all publicly used services with their infrastructure in space.

Among these capability issues a central place is held by access to space, and thus what is at stake in this sector has become very important from an industrial and economic point of view. The European space industry represents 30,000 jobs, for the most part highly technical; over the past ten years it has generated an average turnover of some 5 billion euros. It is estimated that the by-products of investments in space technology are today worth some 19 times the original investments.

French industry, with its launchers and satellite technologies, is extremely well placed at the heart of the European industrial groups in this sector. Worthy of note is the place held by institutional clients such as the European Space Agency (ESA), national agencies, the EU and the armed forces, which generate around 60 per cent of European space turnover. Commercial activities, such as operators of telecommunications and commercial satellite launches, represent just 40 per cent of sales.

The space sector also includes much upstream activity relative to services and applications; these demonstrate continuous growth, and prospects are more than promising. Today Europe has about 25 per cent of this market, and the conquest of significant market share in this sector (which has strong added value) is an important factor for the future—particularly in the field of security.

Over and above the economic aspects, the access to and use of space remains a characteristic of national power: if the space race between the USA and USSR is now history, then that with China has only just started. The recognised strategic importance of space has led the United States, Germany and Italy to elaborate or update their space policies within the past six months, and the United Kingdom to create a National Space Agency.

The powers of the European Commission relative to space matters were reinforced by the Treaty of Lisbon. On 4 April 2011 it released a document on space policy called 'Towards a European Space Strategy for the European Union'. France is at the forefront, having decided on its launcher policy several years ago, and is giving a prominent place to space technology in its programme of future investment (for example, the *Grand Emprunt* – the 'big loan' from the government). Work is currently in progress at the Centre for Strategic Analysis, and on 23 March 2011 the Council of Ministers decided to produce a reference document by September 2011, setting out the principal axes of French space policy.

Defence aspects: the mastery of armament programmes

Space is at the heart of the strategic challenges of our defence effort, whether it concerns intelligence, telecommunications, environmental data (notably geographic), position-finding or satellite navigation. In the near future, to these will be added the monitoring of proliferation, maritime surveillance and the monitoring of space.

The Ministry of Defence has been able to build on the potential uses available, for example by launching the Helios optical observation programme, the Syracuse project for telecommunications, the Graves system for low-orbit detection, the Essaim, Cerise and Clementine demonstrators for electromagnetic monitoring and the Spirale early-warning system. The military use of space has become a major element of the French space sector because it has given our country capabilities which are for the most part unique in Europe. It has been the fruit of an effective R&D policy, and of programmes in which the critical parameters of cost, performance and duration have all been controlled with success.

Expanding on the priority given to the 'Knowledge and Anticipation' function in the 2008 White Paper on defence and national security, the French defence sector is:

• Renewing its spatial observation component (the CSO and MUSIS programmes),

• Completing its telecommunications inventory (the Sicral and Athena satellites, which are produced in conjunction with Italy),

• Planning the replacements for the Syracuse secure communications satellites around 2020,

• Preparing for the production of a permanent SIGINT space capability (Ceres), and

• Developing its early warning and surveillance capabilities in space.

The defence community makes an important contribution to the national R&D effort, including the dual R&D programmes conducted jointly with the *Centre national d'études spatiales* (CNES - the national space studies centre). Programmed investment in space research and its associated developments is 4 billon euros for the period 2009-2014, and 5 billion euros in the following five year period to 2020.

While it is true that these sums are very large, space programmes are by their nature expensive, and decisions need to be weighed with care. The list of projects which has finally been approved reflects a capability-oriented vision of the domains of knowledge, anticipation and protection, and which analyses the advantages conferred by the space dimension.

The initialisation and orientation stages of this vision were developed jointly by the Central Staffs and the DGA; they are embedded in the force systems of 'Command', 'Information Superiority', and 'Protection and Safeguard'. They allow us to highlight the key technologies which we must retain, and to remove the attendant risks by means of studies and demonstrators. At the planning and production stages, once the risks of technological failure have been minimised, it is still essential to be able to rely on strong, competent project management: defence space projects are conducted in exactly the same fashion as any other military programmes. CNES and DGA conduct these phases together, each organization bringing its own skills to the table.

Many of these programmes involve European cooperation. As the first example of 'pooling and sharing', the Helios programme is the fruit of joint collaboration with Italy, Spain, Belgium and Greece. The programme was complemented by image exchange agreements with Italy (Helios/Cosmo-SkyMed) and Germany (Helios/SAR-Lupe). France has long been accustomed to this sort of arrangement, including the resolution of issues of sovereignty such as those concerned with intelligence. If such cooperation is often justified by on cost-sharing grounds, this particular example well illustrates the federating effect it can also have on operational capabilities, organisations and industrial skills. Looking at the major investments in R&D that such projects require, it is clear that uncoordinated and competing national investments would have a disastrous effect on European space industry—particularly in the context of a highly competitive export market.

Industrial aspects

The French space industry is at the centre of the French defence industrial and technological base, and is the most important in Europe. It is the result of the sustained, very large investments made by our country since the nineteen sixties. Even today, Government orders remain critical to the economic viability of the sector: indeed, they support the competitiveness of the European space industry in the cyclical commercial markets of telecommunications, observation and launchers. Furthermore, and by the same logic, our competitors are sometimes even more strongly Government-supported than we see in Europe.

France has developed world-class industrial skills in several fields, often comparable to the level attained by the United States: one example is very high resolution optical imagery. These skills of the satellite industry also support a service industry which is the world leader in its field (including analysis, treatment and dissemination of images and by-products for numerical cartography, monitoring crop maturity and oil exploration). These skills have been acquired and maintained thanks to alternating national civil and military programmes during the nineteen eighties, nineties and through to 2000 and beyond (Spot, Helios 1, Spot 5, Helios 2 and Pleiades). Our specifically French skills in optical observation, shared between Astrium (of the EADS Group) and Thales Alenia Space, are critical to our strategic autonomy in crisis management, and must be retained.

On their side, Germany and Italy have developed skills in all-weather radar observation which are complementary to the French skills in the visible spectrum. This industrial specialization needs to be encouraged if we are to see a strong European industry compete in the world market.

In the field of military telecommunications, our industrial skills are supported by the civil commercial market, yet certain military requirements still call for dedicated research. The skills particular to secure military payloads are essentially held in France by Thales Alenia Space. They are supplemented by skills in design and systems engineering for the interoperability of military communications satellites with tactical radio networks, and with NATO allies.

France, Italy and the United Kingdom have the industrial capability to produce military space communications systems; the project management and platform expertise is to be found in Astrium and Thales Alenia Space. The bringing together of French and Italian industrial skills in the form of the 'Space Alliance' was a first, structural step which led to the Sicral 2 and Athena-Fidus joint programmes. The future of this sector is likely to lie in the cooperation between these three countries, and their industries, in the production of the next generation of systems when Syracuse 3 comes to the end of its planned life in 2018.

Launchers, a special case

While Ministry of Defence satellites have many purely military properties, their placement in orbit uses commercial launchers—the Ministry does not invest directly in development of the latter. On the other hand, the credibility of the French nuclear deterrent imposes the need to maintain an autonomous national capability in strategic ballistic missiles. The relevant industrial skills are specialised project management and system integration, solid fuel propulsion systems, and certain critical equipment such as the stellar navigation system.

These skills are shared to a certain extent with civilian applications (the Ariane launchers), but this sector of activity cannot be based on an economic model that follows a purely market approach. As far as national defence is concerned, it is therefore essential to maintain the project management skills (some 30-40 per cent of dual competencies). In this context, the future programmes involving the successor to Ariane 5, which will be adapted to new payloads, and the mid-life renovation of the M51 strategic ballistic missile, will be the major drivers for the maintenance of skills in this sector.

Space: a fundamental issue in the European debates to come

Whatever the segment of skills considered, all State actors in Europe must bear in mind that the search for economic efficiency must never be to the detriment of the great technological, industrial (and in the end, political) successes we have already achieved. We could pay very dearly if we succumb to the siren calls so regularly heard of renunciation, dumping, or the premature opening of markets.

Over and above its formidable ability to generate economic benefits, space remains above all a political issue; the emerging countries confirm this by their obvious determination to join the club. It is above all a question of State investment in critical infrastructure. We need the political will to develop technology to the highest level; we must maintain the efficient and competitive industrial base which guarantees us autonomy of means and access, and innovative solutions. Without this we could rapidly find it impossible to renew our current operational capabilities on our own, or to develop the future capabilities we know that we are going to need. France's launch of the federative space observation MUSIS programme in a difficult budgetary situation is, moreover, an excellent indicator of our determination. We trust that our European partners are willing to demonstrate the same resolution.

Industrial Cooperation in Space

Benoît Montanié
Jean-Claude Dardelet

Rear-Admiral (retd) Benoît Montanié is an advisor on defence and security, and Jean-Claude Dardelet is Vice President for European affairs with Thales Alenia Space.

Cooperation and the industrial base

France's industrial base is a national asset, the fruit of years of investment in the institutional and industrial cooperation which has been indispensable to the development of the space sector. Very few countries have managed to develop major space programmes on their own; it is cooperation which generally makes them possible, and cooperation is becoming all the more important with ever-shrinking institutional budgets and the dwindling of national operational projects to mere demonstration programmes. It is also becoming necessary with the growing number of participants in space activities throughout the world and the role which the European Union (EU) and the European Space Agency (ESA) expect to play in this club. Consequently, cooperation features prominently in the process of launching space programmes, including those concerning defence. It does not reduce their overall cost, their complexity, or the time needed to complete them. However, these programmes are cheaper for each individual country, more robust in the face of the unexpected, and meet the requirements of a greater number of participants.

In this climate of cooperation and in the light of commercial and institutional budgetary realities, the industrial base represents a considerable asset enabling more programmes to be launched and a larger number of societal challenges to be met, including in the fields of climate change, the environment, transport and security. Commercial and institutional consumers are keen to sustain the services available and the economic benefits resulting from their orders. They must therefore ensure that their domestic industrial suppliers are strengthened by cooperation. Experience shows that a strong industrial base and ambitious R&D budgets constitute the two pillars of a sustainable space effort. In this area, France has an incontestable European leadership to maintain, or risk seeing 30 years of investments and hard decisions thrown away in the turmoil of the financial crisis, not to mention the fate of the increasing number of actors depending on the space industry.

It is only at the price of upstream support of areas of excellence, namely R&D and innovation, that the industrial base will emerge stronger from space cooperation. Whereas some, in the guise of cooperation, are tempted to economize on technology, we must, on the contrary, back its development. Only the public sector and industry are in a position to take on this task. Investors and operators, for their part, will be more inclined to assume the market risk. Subsequently, industry will have to improve its products in the context of new cooperative ventures and outlets.

Make space cooperation succeed

Cooperation works best when the expertise of each partner is used to the best advantage in the service of a programme, for example in the form of 'win-win' commercial agreements such as Yahsat with the UAE, Iridium with the USA or cooperation with Russia, which has made many export contracts possible, particularly with Indonesia and Israel. Each contributes 'what the other doesn't have', guided only by the criteria of price, performance, delivery and the optimum management of risk. The example of French world leadership in constellations (Globalstar, Iridium and O3B) demonstrates the relevance of prior investment in R&D by the state in the Proteus platform, a series of 6 platforms financed by the Centre national d'études spatiales (CNES - national space studies centre) for a project of almost 150 satellites.

The example of French-Italian cooperation on the military telecommunications satellites Sicral 2 and Athena-Fidus is also interesting. Supported on one hand by an inter-governmental agreement and an inter-agency accord on the other, the participating users and ministries agreed to share as much as possible and to retain exclusive control only of what was essential to them. Industry thus achieved an optimal wholly-owned solution at the best price. This produced savings of no less than 25 per cent for each principal compared with an individual domestic procurement policy, and a saving of 20 per cent compared with outsourcing, without taking into account the total loss of independence which would have resulted from such an approach.

Franco-American cooperation in the field of oceanography should also be noted. It has enabled France to develop a unique range of space sensors (Topex-Poseidon and Jason) which are responsible for the discovery, understanding and prediction of previously unknown climatic phenomena, such as El-Niño and El-Niña. The cost was merely the sharing of data from these sensors.

It is undeniable that successful cooperative arrangements, i.e. those which ensure the success of programmes and provide the expected benefits, always result from a strong industrial base with long-term support from supervisory bodies, underpinned by clear governance and a 'can-do' spirit.

Consider market realities

The space domain is composed of a variety of markets in constant evolution. Although the telecommunications one is by far the most important, those of observation and navigation are also booming. All three meet the growing expectations of politicians, economic players and the public. Space solutions also complement terrestrial ones in general service everywhere. Space cooperation must therefore take account of a certain number of realities which require close attention:

The 'negotiating power' of commercial telecommunications firms is considerable, owing to their small number. The bulk ordering which they organize also places considerable pressure on the infrastructure providers, who can then no longer fund their R&D.

The demand for renewal of what industry offers continually requires more innovation, higher performance and risk-free off-the-shelf solutions, orbit qualified and rapidly available.

The weight of European institutional markets counts for little in the face of those of other parts of the world, where they are firmly devoted to the service of their domestic industries, for example in the United States or China.

Users are seeing their role expand as programmes respond from the earliest phases of development to the expectations of the greatest number, and also as they realize the extent of their direct contributions to the R&D of the programmes which they demand. Is such a model possible for the European space effort?

The space agencies, which have made and continue to make history in this area, must deal nowadays with a situation in flux. Originally based on science, these agencies must now face economic and societal realities. In these times of budgetary pressures, the centre of gravity of national priorities must shift to industrial R&D and support for cooperation.

Finally, the European Union, which has much left to do with its two key programmes, Galileo and GMES (Global Monitoring for Environment and Security), both half-complete with only half of their satellites ordered, is an actor in the making on which many hopes rest, especially in the budgetary area. The European Commission, which currently has less than 10 per cent of the European public budget in the field, finds itself increasingly at the core of many issues relating to cooperation, security, international relations and even space law, in the area of frequencies and industrial policy, for example. This support is indispensable for the development of the field. Similarly it has an assured role in providing continuity of service, and consequently infrastructure. Continuity is a new concept for the space industry, which is accustomed to new developments launched at the time of each new space mission, which probably explains the historic role of the French research ministry in this area. But things are changing and the progressive development of existing infrastructure is taking over from the developmental leaps associated with scientific advances which were at the origins of the sector's development. This new economic fact is central: although the gains are large, the risks in the event of an interruption or poor governance are considerable.

The role of the ESA is also important as it supports the ambitions of the member states. Boosted by its capability in space procurement, it provides technical guidance at the heart of operations for the major programmes allocated to it.

Create conditions for successful cooperation

As industry is at the core of cooperation it is important that it can inform, propose, anticipate and participate in current space thinking on national and European levels. The needs, constraints and risk management of each new project require new solutions and new cooperative ventures. Industry knows how to find these when the orders and the rules are clear—there is nothing it cannot solve. However, problems can arise from ill-judged arrangements which push the success of a programme or existing capabilities into the background. Industry can add value to public investment and provide solid returns on it, such as increased GNP, jobs, industrial excellence, influence and new technologies. But without the pre-condition of an ambitious R&D programme, domestic industry will be isolated, uncompetitive, or even excluded from major cooperative programmes in the face of competition from the public sector. Hence, whole sections of the economy will be weakened: from teaching to transport, telecommunications, security and the environment. For along with a decline of industry, services also suffer.

So, in the context of agreements between governments (for example, MILSATCOM with the United Kingdom) or between agencies (MERLIN with Germany for measurement of methane in the atmosphere), national decision-makers must look to the reinforcement of the industrial base and support for French jobs in the high-tech sector. As mentioned above, it will be the 'power of upstream R&D' which will determine the role of national industry in cooperative ventures and will make possible the savings and the rewards sought by our country.

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Industry must come together and contribute to wider cooperation and major space programmes. It has the resources and the will to do so, but there is no success without prior public support to R&D.

The motivation of government decision-makers in favour of such support must be at least a match for the size of tomorrow's markets for space programmes, be it in terms of political, diplomatic, economic, social or technological issues, as well as the volume of industrial activity, economic effects and employment.

This will doubtless be the case for very high-volume markets, for mobility, observation, highly-repetitive systems such as the GEO constellation, meteorology, maritime surveillance, the regulation of the carbon market and the surveillance of production capacities and stocks of raw materials and food.

Space is much more than a dream: it is a creator of high technology, jobs, markets and practical responses to many economic and societal issues. France and Europe must be able to count on a strong, diversified and internationally competitive space industry covering the whole value chain of systems, equipment and services which they need. But it is even more necessary that it should be nurtured.

What Future for our Independent Space Industry?

Bernard Molard

General (retd), Advisor on defence and security to the president of Astrium

The first years of the French Fifth Republic were characterised by a number of ambitious decisions which all converged on a single objective: to equip France with real strategic clout, as guarantee of its sovereignty and political independence. From his accession to power in 1959, General de Gaulle made his first priority the re-establishment of fiscal stability and the development of France's economic dynamism, before vigorously relaunching a national policy of research and technological advance. Over the fifty years which have followed this initial boost, the space industry has been at the heart of the issue of autonomy of which, in some senses, it represents the fundamental characteristics.

50 years ago

1971 was a key year for the future of France and Europe in space. On 5 November 1971, the European launcher Europa II exploded on its first qualification flight. The Germans and the French, the driving force behind the European space effort, had no choice but to call on the Americans to launch their Symphonie satellite. The Americans imposed draconian conditions for this, which pushed the Europeans to think about developing their own launcher.

After the success of the French Véronique and Diamant launchers, the European Launcher Development Organization (ELDO) undertook the initial research into the Europa III launcher but the *Centre national d'études spatiales* (CNES - national space studies centre), concerned about the technical and political risks associated with Europa III, launched its own research programme into a technologically simpler launcher, but with similar performance characteristics. Launcher L3S, later re-named Ariane, was born.

30 years ago

In 1981, with access to space guaranteed by Ariane, the French defence establishment recognized the value of space for the accomplishment of its operational missions anywhere around the globe where it might be called upon to intervene. It therefore decided to invest in an initial capability for military space telecommunications with the Syracuse 1 programme, consisting of a payload located on board the Telecom 1A civil satellite. At the same time, France began to invest in space observation with the first studies which led to the Spot satellite project, on the one hand, and Samro (which was to become Helios) on the other.

20 years ago

In 1991, the Gulf War, as unexpected as it was atypical, marked a double discontinuity. The first was strategic, with the realization that the world had changed and that the defence organization, still structured to confront the Warsaw Pact, would have to adapt to this new type of conflict. The second discontinuity related to capability, as this war demonstrated the place which space had assumed in battle management, both in intelligence functions and in the diffusion of information and military orders.

France had anticipated this. It already had Syracuse but not yet Helios. Most of the European states discovered what has since become evident, that to control space is to control one's own destiny. In 1991, Europe realized the extent to which it had become dependent on American space-based intelligence. It quickly pulled itself together and decided to set up an international centre for the evaluation of the international situation at Torrejón, in Spain. This Centre, the only one in the world, is innovative in that intelligence experts of different nationalities work together for the European Council on highly classified matters derived from space imagery obtained through governmental accords or commercial contracts.

10 years ago

In 2001, after having experienced, thanks to Helios, the strategic luxury of seeing and knowing what was going on all around the planet, of being able to detect the slightest signs of instability which often precede crises and of knowing when a risk becomes a threat, France took a decisive initiative for the future of space applications for defence. Drawing on lessons from Kosovo, Germany had just decided to make a start in space observation with the SAR-Lupe constellation of radar satellites, while Italy began its Cosmo-SkyMed programme.

France analysed the performance of its Helios 1 system (the Helios 1A satellite launched in 1995 and 1B in 1999), particularly the terrestrial section and the interfaces with its military users. It also studied the lessons of cooperation with Italy and Spain and prepared specifications for the next generation system (Helios 2). During the various meetings between the governmental partners and representatives from Astrium (project manager for the Helios 1 and 2 systems) for the space-based part and Cassidian (Cassidian was then called EADS Defense & Sécurité) for the terrestrial section, a new idea surfaced: to create multinational characteristics for a future system of European space observation, fully interoperable and shared, profiting from the synergy of expertise gained from optical, infra-red and radar observation. This concept, termed BOC (common operational requirement) took shape in a document signed by France, Germany, Italy, Spain, Belgium and Greece and which resulted in MUSIS (Multinational Space-Based Imaging System). The BOC is truly the founding document which defines the starting point of a future system capable of best satisfying the requirements of the military community of the partner states: intelligence services, geo-information services or operational formations deployed to external theatres. Astrium and Cassidian are currently offering solutions totally adapted to clearly identified needs thanks to the experience gained from the Helios 1, Helios 2 and SAR-Lupe systems.

Today, in 2011

In the field of space applications for defence, the year 2011 is the year when everything is happening:

- Astrium and Cassidian, both top-ranking European companies, are working in close cooperation on the successor to Helios 2, termed the *Composante spatiale optique* (CSO - spatial optical component) of MUSIS, to find the best possible solutions based on acquired experience and to decide on the third European cooperation satellite, which will guarantee the continuity of the concept of cooperation inherent in the MUSIS programme.

- As for electronic surveillance, after having been the project manager for the Essaim and ELISA demonstrators, Astrium is fully qualified to run the Ceres operational version which, in conformity with the White Paper recommendations, should be agreed this year, in order to close an existing capability gap at the time when defence has never needed this more.

• For early warning, a decision is also awaited this year to confirm the Spirale demonstrator which, under Astrium project management, has exceeded all its targets. As the White Paper sets out, such a capability allows surveillance of ballistic missile proliferation, increased credibility for deterrence and improved warning of attack for the population. It is therefore not a technological gadget but an absolutely vital capability at a time when the world beyond Europe is increasingly arming itself. In addition, this capability could, at the right time, be offered as France's contribution to the NATO anti-ballistic missile defence system. The Heads of State and Governments agreed this at the Lisbon NATO summit last year.

• In the area of space telecommunications, the year 2011 will be marked by the decision of the ministry of defence to outsource its two Syracuse satellites and to plan the next generation within the Franco-British defence treaty. Boosted by the know-how gained from the four Skynet 5 satellites and their outsourcing to Paradigm, a company and arrangement which fully satisfied the British Ministry of Defence's requirements, Atrium is ready to take up the challenge and make optimized proposals based on its concrete experience.

• Finally, to return to the strategic foundations of 50 years ago, the values of deterrence and space are combined in the M51 programme. Astrium has worked on deterrence for over 40 years, designing, developing and producing the range of French ballistic missiles, their infrastructure and the associated weapons systems. Astrium also provides operational maintenance for the Navy throughout the life of these systems. This expertise is unique in Europe and there are only three countries in the world which have a fully-independent operational submarine nuclear force: the United States, Russia and France. 2011 will see the entry into operational service of the new M51 ballistic missile system with the French ocean-going deterrent force.

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The French can be proud of the progress made over the last 50 years in space technology in the service of defence. This is the fruit of a driving political ambition, supported by sustained financing which has not been subject to the vagaries of the various crises encountered or to governmental changes. It is the result of timely decision-making backed by a clear, coherent and sustained vision of the higher interests of the nation. It is also the outcome of a permanent industrial engagement which has always sought the best technical-operational compromise to satisfy the defence end-user, who bears the heavy responsibility of ensuring the peace and security of the citizen.

All the indications are that the world will become more and more threatening and it would be imprudent to lower our guard today. Nevertheless, as far as the defence space budget is concerned, a gap is growing between the White Paper recommendations and the budgetary reality, well beyond the reductions demanded in other defence programmes. The continuation of this stealthy eroding of the budget allocated to space risks leading to the long-term weakening of the capabilities which underpin the strategic and political independence of our country, with the very real prospect of a drop in France's strategic status.

The year 2011 will be determinant for the future of the component of sovereignty represented by the space industry, one which is capable of providing the capabilities to give France its desired strategic autonomy by using the space dimension in the service of the interests of defence and security.

Space in Operations

Operational Benefits from Space

Bernard Rogel

Vice Admiral, deputy head of Operations, forces joint staff.

From the dawn of history nations have sought knowledge of the enemy's movements, of the ground on the other side of the hill, and of the enemy himself, in order to thwart his plans and protect their own interests. For the last fifty years or so, space has made a major contribution to the defence effort. In this historically short space of time, the geostrategic situation has witnessed a number of upheavals which have impacted directly on the development and the uses of space capabilities:

• In 1958, General de Gaulle took the decision to create a strategic ballistic force. Thanks to strong political will and considerable financial resources, that decision allowed our country to make its first step into space activities. At that time, it was a question of being able to deliver a nuclear strike to the enemy, with far greater guarantee of success than an air strike. In that light, Helios 1, the first European orbital military surveillance system was conceived in the 1980s, specifically for the acquisition of intelligence needed for the deterrence role.

• In 1991 the first Gulf War constituted the first breakthrough in the employment of space assets. The value of space capabilities in the field of surveillance and communications in the framework of conventional operations became obvious. The specifications for the Helios 2 and Syracuse systems would take this into account.

• The 9/11 attacks led to a new development in the use of these capabilities. Faced with the new dimension opened by international terrorism, France and her allies undertook to improve their exchange of intelligence in the identification of obscure and dispersed targets. This development will certainly not be the last of its kind.

Space assets are today's essential tool for operational planning and conduct.

Effective planning demands information on regions where free access cannot be guaranteed, whilst maintaining a level of discretion, particularly as to the intended targets. Satellites are able to garner information from every corner of the planet without legal constraints, since there is no commitment of resources on sovereign national territory, and thus provide an essential contribution to the first of the five major strategic desiderata: knowledge and forewarning. This is the guarantee of France's autonomy in assessment, and thereby in decision-making.

Once acquired, the imagery and the electromagnetic data are used for operational planning, preparation and conduct in the areas of intelligence, geography and targeting. Where the intelligence requirements exceed the satellite's capability, the challenge is to prioritise, whether at the strategic, operational or tactical level. The date by which the latest intelligence is expected as well as the age of such intelligence is determinant in the decision-making process, taking into account the acquisition constraints and the time needed to process raw intelligence.

From the start of operations, space assets retain their relevance and complement the land, air and naval resources deployed to enhance knowledge of the theatre of operations and the operational environment. Particularly where meteorological information and enemy locations are concerned, space asset capabilities must be integrated with the operational decision-making cycle. Management of these resources should also be taken into account in movement planning, and all the players should have as wide an access as possible to all the data acquired.

For the operators, telecommunication satellites like Syracuse often have a highly visible role in the conduct of operations. With their flexibility, secure transmission and high quality performance they contribute to intelligence sharing and the passage of orders right down to the lowest levels of command. They can also exercise long-range control of drones, necessary for dealing with real-time tactical situations.

Space also contributes to weapons development. Navigation aids, particularly the American GPS, and soon the European Galileo system, allow real-time location of the different elements of the forces deployed, making overall manoeuvre control much easier. The systems contribute also to the effectiveness of precision-guided weapons, especially those using contour flying and terminal guidance techniques achieved from satellite data.

Finally, our space surveillance capabilities make a discreet contribution to the protection of deployed forces by informing them of the adversary's possible satellite resources. Eventually, when French defence forces are equipped, the space component of an Early Warning system will allow them to take appropriate measures against the ballistic missile risk.

To put all our eggs in the space basket would be a mistake, but space assets have shown for several decades now that they represent an essential element of modern operations. Undoubtedly with future possibilities as yet unimagined, in the short term, with improved integration into overall operational planning, it should give our armed forces the advantage of a degree of strategic, operational and tactical superiority, ensuring both the effectiveness and security of our soldiers on operations.

In the operational sense, space is no longer just an environment, but a formidable and indispensable provider of operational assets.

The Operational Role of Observation Satellites

Jean-Pierre Serra
Axel Foliot

Brigadier (Air) Serra is deputy director (operations) of the military intelligence directorate, and Lt Col Foliot is a staff officer dealing with imagery intelligence in the same directorate.

Observation of the battlefield from the third dimension acquired credibility during the First World War, as a result of three major technological revolutions around the turn of the Century: aviation, photography and radio transmission. These same technologies, and the same basic principles, were adapted and developed to confirm even further the importance of the use of the air arm in direct support of theatre intelligence operations. The locating of Japanese air and sea forces by American long-range reconnaissance aircraft during the Battle of Midway is one of the most celebrated examples of the science.

The revelation

When the first French observation satellite SPOT* was launched, opinion in the different armed forces' General Staffs was divided on how it might be used to meet intelligence requirements in the context of operational planning and conduct. To believe that orbital observation would be useful for situational intelligence seemed at that time to be totally unrealistic.

It has to be admitted that with a resolution of ten metres one couldn't hope to 'see' Warsaw Pact tanks rolling towards Europe: nearly all

*** SPOT**

The acronym SPOT initially signified *Satellite Probatoire pour l'Observation de la Terre* (Experimental Earth Observation Satellite), which says something about the confidence and effectiveness that was attributed to such systems at the time.

commercial satellites today offer considerably superior resolution. Even the Helios class satellites designed to replace SPOT were not designed to such a resolution. Prior to Helios, the nation's defence received SPOT commercial imagery by virtue of a contract with the Company SPOT Images. The greater part of their intelligence activity was at the strategic level and for cartographic purposes. And yet the civilian satellite SPOT was the first French orbital optic sensor to be employed in direct support of air and ground operations during the first Gulf War.

Without accurate maps of the terrain, the SPOT satellites were programmed to produce the first imagery of the engagement zone on the Iraqi frontier, essential for the accomplishment of air reconnaissance missions.

It was a pleasant surprise to discover that on these photos, taken initially for mapping purposes, the Iraqi forces' overall defensive layout (front line, access routes and support weapons emplacements) appeared perfectly sketched against the desert background. From that point, satellite resources were heavily tasked for planning the offensive against Iraq.

Subsequently, SPOT satellites 1 and 2, still in the Iraqi theatre of operations, and as backup to air reconnaissance activity, continued to carry out such missions as Battle Damage Assessment (BDA) or location of missile sites.

Initial conclusions

When drawing conclusions from the war, the results have to be set in perspective: the use of satellites was greatly enhanced by several factors.

The Iraqi army had opted for a purely defensive strategy, based strictly on the Soviet pattern, with a deployment plan that was both very rigid and structured. This is why such a methodical layout on the ground could hardly pass unnoticed in a desert region which, by definition, offers very little opportunity for camouflage or deception.

It should be noted, however, that only the general outline of the positions (strong points, trenches and tracks) appeared on the satellite imagery. The poor resolution did not reveal whether these positions were occupied by men and equipment. A further factor contributing to the optimisation of satellite surveillance proved to be the immobility of the Iraqi army. Such a posture, unusual in modern warfare, offered the tremendous advantage of giving the analysts enough time to produce a detailed study of the enemy positions.

All these favourable factors combined to make the first use of orbital surveillance in support of air and ground forces appear as a masterstroke. In subsequent conflicts, where satellites were again heavily tasked, the results were more balanced. Even today, when France has the largest array of observation satellites after the USA, recourse to aerial reconnaissance systems (aircraft and drones) remains essential.

The Helios generation

In 1995, in partnership with Spain and Italy, France put the satellites Helios 1A and 1B into service, and in doing so becoming the third country in the world with a purely military satellite observation system. Helios 1 was nevertheless very little used in support of operations, whether in the Balkans or in Africa.

France, in common with other Western countries, was beginning to discover all the inherent difficulties of involvement in asymmetric warfare, and of committing conventional forces originally destined for a war of armoured divisions across the plains of Central Europe. Furthermore, Helios 1, in spite of its much better resolution (of the order of one metre), is not up to repeating as effectively the exploits of its cousin SPOT. It is no longer a matter of locating the positions of a huge army fixed in the desert, but of pinpointing check points on mountain roads, of distinguishing moving convoys of refugees from military convoys, and identifying other fleeting and untypical targets. Only airborne sensors, where they can be employed, have enough reactivity and permanence to achieve this kind of task.

So, to achieve effective use of observation satellites in operational theatres, we had to wait for the Helios 2A and 2B satellites, with their submetric resolution and a filming capability twice that of Helios 1. Even if it is still not possible to locate and follow convoys of pick-up trucks in the desert, satellites have proved indispensable for covering vast regions, for the acquisition of environmental data and, for example, for establishing the traffic frequency of a route.

Through capacity sharing agreements with Germany and Italy, France also acquires imagery from the radar satellites SAR-Lupe and Cosmo-SkyMed. This imagery perfectly complements the Helios imagery and overcomes, at least partially, the problems of poor meteorological conditions and lighting. Whilst waiting for the new very high resolution observation system MUSIS, the arrival in the next few months of the dual system Pleiades will offer almost twenty simultaneous high resolution images of the same zone of several hundred square kilometres. It will then be possible to cover, in a single pass, the intelligence requirements of a greater number of clients. Moreover, observation satellites have a formidable ally in space, the satellite system called 'listening satellite posts', dedicated to the capture of electromagnetic intelligence.

Electromagnetic intelligence

Currently two families of sensor share space resources: observation satellites dedicated to satellite imaging and those geared to electromagnetic intelligence systems. In view of the operational benefit that could accrue from the use of electromagnetic sensors, France started to develop technical demonstrators during the 1990s. Two micro satellites, Cerise and Clementine, were able to establish an initial foothold in the real-time electromagnetic environment and demonstrate the value of space activity in intercepting electromagnetic transmissions.

From late 2004 to 2010, the four micro satellites of the Essaim demonstrator (an experimental system for the acquisition and follow up of micro satellite information) have allowed us to distinguish and map transmitters and radar systems. The capability to intercept and locate surveillance and acquisition radars from space will be available for a three-year trial period from 2012 with the launch of a constellation of satellites called ELISA (Electronic Intelligence by Satellite). The experience that France has gained in this field, much of it from the development of the demonstrators, should lead to the launch of the first operational orbital electromagnetic intelligence system in cooperation with other European countries by the end of the decade. The military equipment programme foresees the completion of the Ceres programme (*Capacité de renseignement électromagnétique spatiale*: spatial electromagnetic intelligence capability), which should permit not only the interception but also the location of radar and telecommunication transmitters over a very wide frequency range.

The current situation

In general terms, satellites allow worldwide coverage and intelligence gathering over zones that are inaccessible by other means because of difficulties with overflight rights and distance, for example. Their advantages include their low level of vulnerability, their discretion and above all their ability for non-intrusive observation of any state whilst fully respecting international law and without violating the sovereignty of countries overflown. In the context of the commitment of forces to a theatre of operations, the use of satellites is primordial, particularly in the preliminary phase when no forces have yet been committed.

After considering the main advantages of satellite systems in comparison with complementary air and ground capabilities, it is opportune to look at the particular benefits offered by the two space components, Imaging Satellites and Electromagnetic Intelligence Satellites, in relation to conventional observation systems.

First of all, in a crisis-management situation, they allow us to gather volumes of data on targets of military interest, and their environment, before even contemplating action of any description. During the planning phase, tasking of space sensors consists essentially of locating and classifying the enemy's resources, updating any existing information, establishing Target Folders and identifying his alert status through changes in activity levels in certain installations, building new detection or telecommunications infrastructure or force movements, for example.

During the preparation phase preceding the commitment of forces, the satellites are tasked with analysis of the environment in which the forces will deploy, and of the organisation, capabilities and motivation of the adversary. Joint use of the two sensor systems, imagery and electromagnetic intelligence is standard: the listening posts detect and locate the transmitters (radar and communications), and the imagery sensors then validate and complement the electromagnetic observations. During the conduct of operations, the satellites' role is to backup the resources deployed with the forces in theatre, and consists essentially of following up the situation in depth or on the borders of neighbouring countries, and of the evaluation of the action taken during operations.

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In less than 30 years, France has created an effective multi-purpose observation satellite capability that is the envy of many. The country has also managed to enhance this capability over the years, benefiting from the most advanced technological developments.

Taken overall, these space sensors, combined with air and ground sensors, make our country a recognised and respected partner in every coalition in which we take part. It must not be forgotten that this powerful tool must evolve constantly, using new technologies, in order to meet operational requirements in a world where crises are a permanent state of affairs.

It is vital, therefore, that programmes like Ceres and MUSIS should be sustained, both financially and according to programme, if we are to consolidate all that has hitherto been developed and achieved.

Communications Satellites and Operations

Manuel Alvarez
Caroline Fabre
Patrick Fargeot

Colonel (Air) Manuel Alvarez, deputy director of the central operations and exploitation service of the DIRISI.

Lieutenant Colonel (Air) Caroline Fabre, Syracuse 3 programme officer.

Lieutenant Colonel (Army) Patrick Fargeot, commander of CNMO-MS.

There is little need to underline the crucial role played by telecommunications satellites in modern military operations. The deployment of forces in distant operational theatres, together with the ever increasing need for exchange of data for command and weapon systems on land, at sea and in the air, requires the commissioning of appropriate spatial assets to provide high capacity military telecommunications. These assets are available everywhere: unaffected by distance, propagation geometry or ground infrastructure, and put into operation by a dedicated resource, they guarantee forces a permanent, covered link. The defence satellite communications system has three components:

- The Syracuse 3 secure system;

- The system based on the Athena-Fidus satellite;

- The TELCOMARSAT system.

Management of these valuable resources has been allocated to the *Direction interarmées des réseaux d'infrastructure et des systèmes d'informations* (DIRISI - joint infrastructure network and information systems directorate), whose the *Centre national de mise en œuvre des moyens satellitaires* (CNMO-MS - national satellite operations centre) at Maisons-Laffitte, near Paris, conducts their planning and operational management.

Syracuse 3—the hard core of military spatial telecommunications

The Syracuse 3 secure system depends on:

• The two French Syracuse 3A and Syracuse 3B satellites, which each provide 9 SHF (Super High Frequency: 3-30 GHz) repeaters hardened against jamming, and 6 EHF (Extremely High Frequency: 30-300 GHz) repeaters;

• A component of the Franco-Italian Sicral 2 satellite, due to be launched in 2013.

The system's robustness and protection considerably exceed that of civilian satellites. Its receiving aerials are resistant to interference, it uses frequency-hopping modems protected against hostile jamming (MODEM 21), and has a robustly encoded remote command system. Thus with the two geostationary Syracuse 3 satellites, to which Sicral 2 will soon be added, France has secure, high speed military communications between the nation's centre and its forces operating outside the country. Orders and information are conveyed over long distances instantly and in complete security. Additionally, the satellites are fitted with mobile spots, which allow the CNMO-MS of the DIRISI to allocate optimal capacity over a limited zone in relation to the volume of assets assigned to the committed force. Given unpredictable nature of the world, these assets are perfectly adapted to the reactivity required for today's military commitments.

French forces have access to a variety of Syracuse satellite stations: naval stations in surface ships and submarines, and ground stations, from the man-portable type to those fitted into vehicles allocated to units requiring a link, such as joint tactical groups and major command posts.

Whether engaged as an independent unit, as part of a battle group, or integrated within a command post (CP), our users also benefit from the communications continuity offered by the Syracuse 3 architecture, from staff headquarters in the homeland to the most forward-placed units in operational theatres, for conventional services such as telephony and data transmission, including multimedia information transmitted using internet protocol (IP).

Athena-Fidus: new generation, greater capacity

The extension of Athena-Fidus capability will be applied to the French element of the Franco-Italian Athena Fidus satellite (Athena: access on theatres for european allied forces nations; Fidus: French-Italian dual-use satellite). Developments in operational concepts give rise to new requirements for additional data exchanges, some of which do not need the level of security afforded by the Syracuse constellation. There is therefore a need for increased high data rate transmission capacity that does not require any particular resistance to jamming. This is the principal challenge for the Athena system, to allow Syracuse to remain focused on its principal operational use.

The system will give permanent coverage in mainland France, and a set of mobile spots, which can be moved anywhere in the area of national interest, will provide communication with operational theatres and recovery of data from drones.

This communication system will therefore provide high-speed capability to those users fitted with Athena-Fidus terminals, giving them in-theatre access to the defence intranet, as well as the facility for data exchange between users in theatre. This link between system users and a ground network is provided via bridges set up in the anchor stations at Favières and France Sud (in mainland France) used by DIRISI for the Syracuse system.

Athena-Fidus will offer several types of IP service:

- A governmental and defence communication service;
- A service for transfer of aerial or satellite imagery and tactical data from mainland France to operational theatres;
- A service for communication with drones;
- A continuity service with the French Descartes network.

Through their Athena-Fidus terminals, users will therefore have access to a number of services, including telephony through IP, e-mail, instant messaging, file transfer and video conferencing. The system depends on maximum use of duality, with transmissions on Ka band, the latter covering civilian frequencies plus others reserved for governmental use. Low-cost technologies developed in the civilian sector are employed in the ground user segment. The communications standards based on DVB-S2 (a recent standard used for satellite transmission of multimedia content) will be used in order to provide vastly increased transmission capacity and to benefit from the lower cost of civilian technology. Use of these standards will give optimum cost benefit in the acquisition of the generic satellite terminals for operational personnel.

TELCOMARSAT, satellite communication for naval needs

The TELCOMARSAT system allows ships of the French Navy to communicate via commercial satellites on L, C, and Ku frequency bands.

The system is composed of:

- Fixed anchor stations deployed on DIRISI sites in France (Favières and France Sud) and overseas, which allow connection to the forces' infrastructure network;

- Naval stations embarked in ships of the French Navy deployed in the main maritime areas of Europe, the Atlantic, the West Indies and the Indian and Pacific Oceans;

Depending on the type of ship, the TELCOMARSAT system can use L band (1.4 to 1.5 GHz) via INMARSAT, or C (3.4 to 4.2 GHz reception/5.725 to 7.075 GHz transmission) and Ku (10.7 to 12.75 Ghz) bands. The space capacity of TELCOMARSAT is purchased on demand for a fixed period, according to a pre-arranged scale of cost and notification time in accordance with the Astel S or Astel L agreements, drawn up and managed by DIRISI. Services made available include telephony, fax, messaging, data transfer using IP and videoconferencing, also using IP. The system thus offers spatial communication to those warships not fitted with Syracuse. Similarly, it provides satellite communication to ships fitted with Syracuse naval stations, but which are operating outside Syracuse coverage.

The national satellite operations centre (CNMO-MS)

The central staff of the French armed forces allocated technical direction and supervision of use and support of the Syracuse network to the DIRISI. The national satellite operations centre (CNMO-MS) is a functional subordinate of the DIRISI's central service for operations and use, and its mission is to ensure the planning and operational management of satellite communications systems for the Ministry of Defence.

The headquarters centre is sited at Maisons-Laffitte, close to Paris, and a fallback centre, possessing identical equipment and data, is sited in a secure and hardened environment at the M3 ground station at Favières. If required, CNMO-MS can transfer to this secondary site in order to ensure continuity of service. CNMO-MS also remotely manages the two anchor stations in France, at Favières (M3), near Chartres, and France Sud (M4), near Toulouse. These two stations are the hub of our satellite communications links in France, and can connect them to transit infrastructure networks and to military (*via* Socrate) and civilian IP-based telephony and data handling services. Their location therefore guarantees geographic separation and contributes directly to satisfying the operational need for duality of telemetry links to our satellites, and for the majority of communication links.

Whilst allowing for occasional propagation problems and equipment breakdown, and also planned maintenance of materiel, the system must at all times be capable of ensuring these two critical services. The materiel and mechanisms set in place give permanent guarantee of accomplishment of this mission, in a manner completely transparent to the users.

Apart from the Syracuse system itself, the centre houses a pool of technical and human expertise in charge of the operational implementation of satellite communications systems. Hence it was quite natural that, in the summer of 2010, the centre took on responsibility for the TELCOMARSAT naval satellite network, and now conducts planning of resources and the supervision and remote management of the receiver stations in France. In the medium term (2013-14), it will take on new systems based on the Sicral and Athena-Fidus satellites, developed in partnership with the Italian Ministry of Defence.

Some sixty service personnel from the three forces operate the system, and industrial contractors are responsible for maintaining the two satellites in position, as well as for the planned maintenance of the CNMO-MS and the two ground stations in France.

A closer look at exploitation

The planning section of CNMO-MS, run by ten of the most experienced personnel in the centre, coordinates the different forces' requests for services to prepare the appropriate satellite configurations and networks in response to changing requirements, to support forces deployed in external theatres. Key elements of their work include:

- Definition of mobile spot coverage, and use of satellites' digital processors to permit optimal allocation of satellite resources in relation to the location of forces, including warships.

- Setting up security for links.

- Preparation of fallback plans to maintain operability of the most critical links.

• Operations section personnel ensure round the clock cover for all actions necessary for the operational implementation of the system and continuity of services.

• Generation of the entire package of technical parameters of all components of the system, from configuration of satellite payloads to metering of all ground station components, to ensure overall system coherence.

• Supervision/operation of communication networks that use satellite support.

• Remote management of the two anchor stations in France.

• Supervision of the two satellites' payloads and, in particular, close surveillance of repeaters and control of links.

• Policing the networks. Activity includes maintaining a check on network entry ports, general surveillance and banning of unauthorised stations.

• Implementing system protection measures, including anti-jamming mechanisms on board Syracuse 3 satellites.

⁂

Satellite communication assets are today an essential tool for the conduct of operations. They form the essential link in an effective and robust command chain and are fully compatible with the national ground network, and networks adapted to the specialised configuration needed for each theatre.

Space Situational Awareness: a Strategic Task in Support of Operations

Damien Gardien

Major (Air), Head of SSA, applied intelligence division of the air defence and air operations staff.

> 'Air defence is an unending task; its aim is to:
> 1. to monitor space, […] to identify and evaluate the threat;
> 2. to provide the authorities […] with space situational awareness (SSA) […] to enable them to make the necessary decisions
> 5. to contribute to the dissemination of alerts to the population […] in the event of an unforeseen threat […] from space'
>
> Defence Act – article D1441-1

Space situatonal awareness (SSA) is a relatively new task in Europe; it is above all a response to a strategic requirement, arising from the nation's space power status. In parallel with this, the operational force multipliers that space applications have become have created new dependencies. These must be taken into account at all levels of planning and execution, from the strategic to the tactical. SSA strengthens force capability on operations in terms of threat assessment, risk management and optimisation of the use of space resources.

The strategic requirement for SSA

> 'Constant detailed tracking of objects orbiting the earth is now the sole preserve of the United States and, to a lesser extent, Russia. Europe is dependent on other powers for the surveillance of outer space.
>
> Defence White Paper 2008

France is a space power that restated the vital importance of the space environment in the 2008 Defence White Paper. This environment has however changed significantly since the first stages of its exploration followed by its exploitation. The United States has described it as 'congested, contested and competitive'.

The ability to independently monitor space has thus emerged as a strategic requirement for France, and hence for Europe, several decades after the United States and Russia.

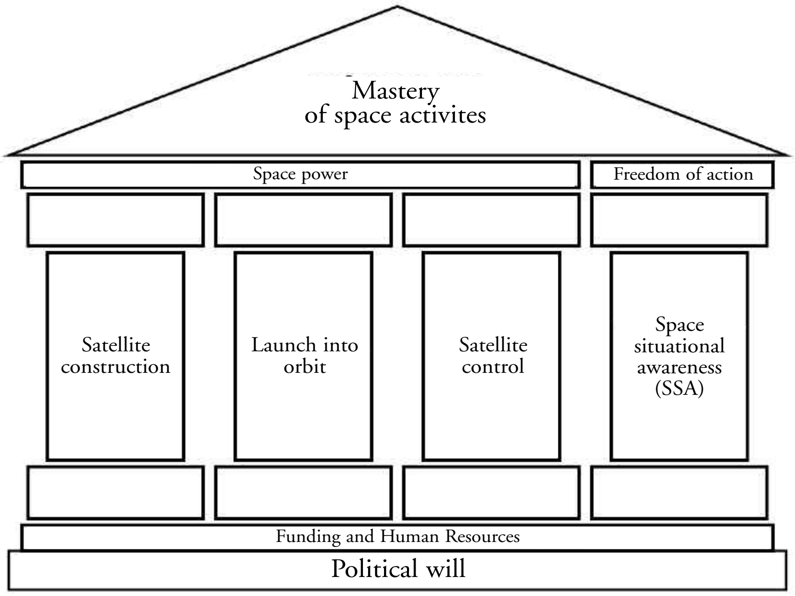
Fourth pillar of a space power

> 'Freedom of action in space is subordinate to several factors: […] mastery of the space environment involves knowledge, understanding and control over what is happening in space'.
>
> CIA – 3.3.10 (Joint service concept of 'The use of space for defence and security purposes' dated 19 July 2010)

A space power can be characterised some years in advance by the mastery of a triad of technological capabilities to:

- Construct a satellite,
- Launch it into orbit, and
- Control it from the ground.

If we are to continue with our space activities we must now acquire an independent capability to understand and assess the space situation. This fourth pillar guarantees freedom of action in space for France and Europe.



The efforts of an emerging space power understandably concentrate on the first three pillars until such time as the technological challenges that face it have been overcome. Once these technologies have been mastered, it is then natural to keep a wary eye on the environment in which objects costing millions of euros are being deployed. Adoption of SSA therefore seems at first sight to be a sign that a space power is assuming a degree of maturity and that it now wishes to perpetuate its newfound capability.

CNES expenditure in millions of euros	**2007**	**2006**
French contribution to ESA	685	685
Multilateral programme, including:	1 053	1 067
Access to space: launchers	393	381
Space applications, including:	574	576
Shared resources	146	145
General public	37	33
Long term development	85	95
Space sciences and preparations for the future	168	160
Security and defence	138	143
Central directorates	55	43
VAT	31	67
Total expenditure	**1 738**	**1 752**

Responsibilities

Above and beyond the need for any responsible player to monitor anything for which he is accountable, the space field is controlled by several international treaties, which France has ratified. Particularly relevant are the 1967 Outer Space Treaty, the 1972 Convention on International Liability for Damage Caused by Space Objects and the 1976 Convention on the Registration of Objects Launched into Outer Space.

These conventions were incorporated into French law in 2008 by the Law relating to Space Operations. This law, for example, makes operators responsible for damage caused by their satellites while they are active and under control. Once a satellite becomes debris at the end of its life, the French Government assumes responsibility on behalf of the operator. However, a nation that launches satellites cannot assume such responsibilities under all circumstances unless it possesses an independent space surveillance capability. Conversely, this surveillance enables an assessment of other nations' respect for treaty obligations, and makes it possible to establish responsibility for space events that lead to unwelcome consequences. In both cases, the ability to monitor space contributes to the protection of the interests of France and Europe.

Orbital congestion

> ' [...] such mastery of the space situation, however partial,
> is essential prior to any satellite launch
> and to guarantee its freedom to orbit,
> paying special attention to the collision risk.'
> CIA – 3.3.10

The lack of international regulation of space activities has resulted in an orbital situation that amply demonstrates the need for this 'protection of French and European interests.' The accumulation of debris from launch vehicles, time-expired satellites and the like poses a risk to active satellites. The conventional methods for protecting satellites include the use of appropriate armour or the carrying out of avoidance manoeuvres. Both require an understanding and continuous analysis of the space situation.

Mean time between two impacts of debris greater than the size given, on an object with a cross sectional area of 100 m² as a function of altitude			
	400 km	800 km	1 500 km
>0.1 mm	4,5 days	2,3 days	0,9 day
>1 mm	3,9 years	1,0 year	1,5 years
>1 cm	1 214 years	245 years	534 years
>10 cm	16 392 years	1 775 years	3 109 years

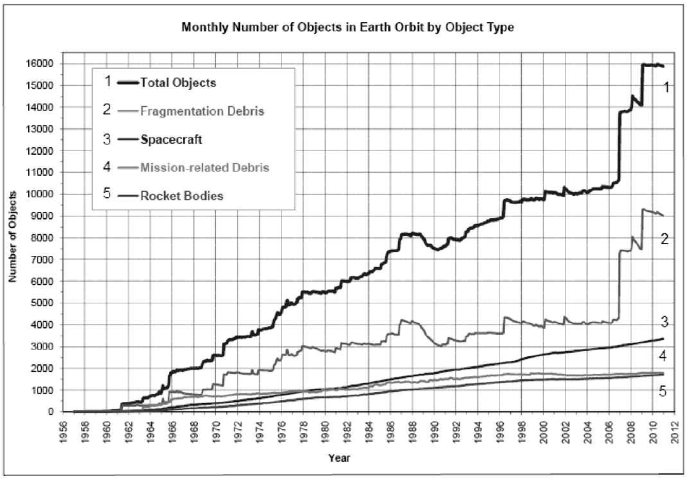
© ESA

A resource and an environment

'Outer space has become as vital to global economic activity and international security as the sea, the air or land environment.'
Defence White Paper 2008

The need to determine and analyse the space situation continuously will intensify as more and more nations gain access to space. Whilst the 'club' of space powers has not stopped growing, an increasing number of players is getting involved in space yet failing to understand the full implications of this newfound status. This growing colonisation of orbits can only exacerbate existing problems in an environment that is a limited resource shared by all.

Most space technologies have become available commercially, and are even free for certain applications. Initially this was limited to such services as satellite imaging, communications or satellite navigation (such as GPS: Global Positioning System). Today, even technologies for accessing space are available, sometimes from private companies with no state support. The company ILS (International Launch Services), for example, offers satellite launch facilities on a commercial basis. Access to space is no longer the prerogative of a small number of nation states. The satellite population is inevitably increasing as space activities develop: as a result, Earth orbit debris and its associated risks are increasing exponentially.



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Vulnerability of space segments

> 'Consequently, our country will make a special effort in the area of space to ensure its coherence with the needs of our defence and national security.'
> Defence White Paper 2008

During the Cold War the superpowers experimented with anti-satellite weapons. The consequences of this turned out to be detrimental to the long-term interests of the space powers, as illustrated by the deliberate destruction in 2007 of a Chinese satellite using one of their own missiles. This test generated thousands of debris objects that for decades will pollute a range of the most used orbits. Technologies capable of clearing debris from Earth orbit could also be targeted at active satellites. Furthermore, attacks against satellites could be carried out from the ground, without unwelcome effects in orbit, employing piracy and remote control, laser blinding or neutralisation of ground facilities, for example. Such threats must not be ignored. The assumption that orbiting objects are safe is a long-standing misapprehension arising from the great distances involved, and the difficulties inherent in accessing space; reality exploded these illusions in the nineteen eighties.

Space operations

Just beneath the surface, as in any environment, a wide range of operations linked to space activities has emerged. Some of course are well known: launch, orbital insertion and station keeping and, increasingly, avoidance and end of live re-entry manoeuvres. In parallel, and less obviously, other operations have been grafted on: launch operations protection (from the surface to orbit), assessment of collision risk, the monitoring of object re-entry into the atmosphere, alert management, and the investigation of space incidents etc. Most of these examples demand a certain level of SSA, as provided by space surveillance operations.

SSA in support of military operations

> '[…] the deployment in space of all types of satellites—communications, observation, listening, early warning, navigation, meteorology, etc.—has become an essential element for all strategic functions.
> Defence White Paper 2008

Apart from its use in support of space operations, SSA also enhances the effectiveness of military operations, both internal and external.

Use of space resources

'The relative scarcity of space-based systems demands
that their use be coordinated and optimised to ensure efficient operation'
CIA – 3.3.10

Using orbital mechanics modelling and space system simulation, knowledge of the current space situation enables the future position of a satellite to be predicted. The impact on the services provided by the satellites can then be deduced as a function of the location and timing of military operations. Space surveillance thus contributes to the planning and conduct of operations by providing the forces with forecasts for and current status of space services.

Dissemination of SSA

'The French Air Force, under the direction of the Joint Service Space Command,
will be responsible for surveillance of exoatmospheric space … '
Defence White Paper 2008

The *Commandement de la défense aérienne et des opérations aérienne* (CDAOA - Air defence and air operations command) of the French Air Force has since 2005 been operating the low Earth-orbit monitoring system *Grand réseau adapté à la veille spatiale* (Graves - large network for space surveillance). In 2008, the Air Force decided to supplement this monitoring service by approving the use of its *Systèmes d'acquisition et de trajectographie des avions et munitions* (Satam - Aircraft and weapons acquisition and trajectory measurement system) radars in the event of high priority space events such as collisions and hazardous atmospheric re-entry. With its extensive experience in space surveillance, and with a view to improving efficiency, the CDAOA handles the dissemination of SSA in formats that are usable by the armed forces. For several years, it has been preparing and distributing the following in support of exercises and operations:

- Forecasts of allied or commercial space-based observation opportunities;
- Forecasts of GPS degradation factors resulting from its constellation configuration;
- Weather trends derived from space-based meteorology.

Operational and organic training commands thus gain an enhanced ability to control their operations. This enables them, for example, to estimate the effectiveness of a strike using an earth observation satellite, thereby avoiding the need to dispatch air reconnaissance assets, a potentially more hazardous operation. They can also plan the use of GPS-guided weapons for periods of maximum signal accuracy, minimising the risk of collateral damage. Communications link losses can also be anticipated.

The current challenge is to enable operations to benefit from the same tools down to command level by enabling the timely monitoring of the availability of space-based services. This requires new resources, trialled by the Air Force for space meteorology and by the *Direction générale de l'armement* (DGA - french procurement directorate) for GPS signal monitoring, and also adequate numbers of qualified staff able to achieve a data generation rate that is compatible with the tempo of the battle and of space operations.

Assessing enemy capabilities

Space power status no longer guarantees a significant advantage over an adversary that itself is not a space power; there are too many ways to access space services. Any enemy's space capability must therefore be analysed as a matter of routine. Independent space surveillance is useful here right from the operational planning phase, enabling potentially hostile in-orbit capabilities and current activity to be assessed. An adjustment to active satellites' orbits, for example, may imply that the operating nation is shifting its zones of strategic interest.

Here again the CDAOA provides support during operational planning by supplying overflight forecasts for satellites available to our adversaries. Commanders may then decide whether it is appropriate to make a visible show of force, or, in contrast, to introduce enhanced concealment measures. These are of course on-going considerations as even outside conflict situations, some operations needing extreme discretion need to take account of this barely visible threat.

The way ahead

> 'In order to overcome this dependency, avoid foreseeable collisions and forestall hostile acts, France will encourage the development of a European project to detect and monitor objects likely to cause damage to missile launchers or satellites. In the short term, the project will form part of GRAVES, the French space surveillance system currently operational at the national level only'.
>
> Defence White Paper 2008

SSA, the result of space surveillance, is a strategic necessity for any power that has achieved maturity and wishes to retain that status. It also improves the operational effectiveness of space, military or even civilian activities both within mainland France and elsewhere. This greater effectiveness is an advantage for our professional armed forces that, with the growing constraints on size and rules of engagement, increasingly depend on technology and asymmetric operations.

France does not presume that it alone can achieve a level of surveillance that will cover all orbits and space phenomena. Space surveillance requires multiple sensors, preferably spread around the globe, accompanied by powerful data processing. If France is to retain a measure of autonomy as a guarantee of its sovereignty, it will, in the light of probable challenges and financial constraints, have to plan an approach at a European level. Nevertheless, it would seem wise to continue French efforts in three areas, within sensible financial limits:

- Finish organising and coordinating all French resources that could contribute to the establishment of SSA. These resources include French Air Force personnel, sensors and instruments, but also DGA sensors and innovations, scientific skills and operational space capabilities from the CNES, alongside intelligence and research expertise;

- Finalize and rationalise the French low-orbit surveillance capability with, as a minimum, an ability to classify and identify. This autonomy, already achieved in some sectors, would establish a measured national position that would be much more likely to attract supporters from within Europe, as occurred with the Ariane and Helios programmes;

- Complete the COSMOS project (*Centre opérationnel de surveillance militaire des objets spatiaux*: Operations centre for the military surveillance of space objects) for a centre dedicated to space surveillance as proposed by the French Air Force. This centre would ensure the effective execution of the task with 24/7 availability, the planning and conduct of operations and rapid activation of command and control structures following an alert. In other words, it would enhance the operational reactivity of our space surveillance organization in response to space and military operations. In liaison with other space specialists, this would enable France to fully assume its role and responsibilities as a space power at joint service, inter-departmental and international levels. Located within the CDAOA, this centre would benefit from the similarities of command and control procedures in air and space surveillance. Both tasks are operational even in peacetime. They require permanence and vigilance, employ military resources for the benefit of the public, and require operational cross-border cooperation for successful achievement of their objectives.

Les Cahiers de la **Revue Défense Nationale**

Space Based Assets in the Execution of a Long Range Conventional Strike

Olivier Fleury

Major (Air) head of sensors section, CDAOA (*Commandement de la défense aérienne et des opérations aériennes* - air defence and air operations command).

'Management of capacities in outer space is therefore an essential aspect of our force projection capabilities, all the more so in a context of force projection at a distance from the national territory'

Livre blanc (French White Paper on Defence and National Security), 2008

Space is a fact that cannot be ignored; its contribution to national operational capabilities is regularly and forcefully demonstrated. There are many examples of this input ranging from the release of satellite images in support of decisions whether or not to commit nations to a new armed conflict, to the ever-growing inclusion of space applications at the very heart of weapon systems. Air operations in particular rely on services provided by satellites to carry out conventional cruise missile strikes more than 5,000 km from air bases. Not only does the use of space assets represent a genuine force multiplier for such tasks but it has also become essential for their execution, making it vital to understand the space environment.

Strategic planning for a long-range strike therefore relies on space-based capabilities; hence the latter must be integrated into the planning of such operations, which itself demands an understanding of the space environment if maximum effectiveness is to be achieved through to mission completion.

Strategic planning and space systems

Because space sensors are non-intrusive and offer global surface coverage they are unsurpassed in their ability to support strategic operational planning. They offer an entirely legal means of locating and identifying potential strike targets over a very wide area, and they generate the technical data needed to carry out the attack.

Well before the crisis erupts, it is possible to collect information that will enable the establishment of a list of nerve centres of a potentially hostile nation or non-state actor. Such sites can be detected or confirmed without putting equipment or personnel at risk. Satellites operate in a medium where the concept of territoriality does not exist, in accordance with the Outer Space Treaty of 1967.

They are therefore very different from all other reconnaissance assets, UAVs included. Electromagnetic intelligence obtained from eavesdropping satellites helps in the detection of these potentially hostile sites and can monitor their possible return to active status. Communication and re-supply links, industrial and military installations or command and control centres cannot escape the interpretation of satellite images. When acquired on a regular basis, this enables the building of new structures to be monitored and information such as the thickness of walls to be gathered. Using interferometry,* radar imagery shows up changes such as underground or excavation work.

*** Interferometry**

Highly accurate measurement technique based on interference phenomena between EM waves.

Once targets have been selected, the images collected serve in the preparation of target files by the National Targeting Centre. Precise attack points are determined as a function of the effects sought. This highly detailed preparation minimises the number of targets to be attacked and hence the number of missiles to be fired. Furthermore, limiting damage to that which is strictly necessary accelerates the reconstruction of a country's infrastructure and hence its return to stability following a conflict. Conversely, it is possible to obtain greater impact with a given number of missiles. Forces thus find their effectiveness multiplied by the use of space-based assets.

As a complement to this initial work, other products of space imagery must be developed to support the employment of cruise missiles. Using these techniques the joint service geographic establishment offers accurate digital terrain models combined with a range of quality indicators to ensure safe guidance of missiles at very low altitude. Their final run to target is thus all the more discrete and effective. This establishment also produces three-dimensional target modelling. This contributes to the missile's terminal guidance by correlation between the model created during planning and the target environment as seen by the weapon's seeker head. A strike accuracy of around a metre can thus be achieved regardless of the selected approach heading to the target. Finally, the activity of the targeted sites, their air defence protection or the use of decoys can be monitored using observation and listening devices to enable the attack to be adjusted and to identify the best possible trajectory. These considerations enable missile attrition on route to the target to be significantly reduced, which once again introduces the idea of force multiplication that here enables a saving in operational resources while achieving the same desired effect.

Without satellite products, strategic preparation of cruise missile strikes could never be achieved other than by violation of national air space. To await the emergence of a crisis before carrying out this preparation would be to ignore the importance of intelligence and anticipation, endanger technical and human resources and lose the effect of surprise from the very start of operations. Furthermore, preparation based on satellite applications improves strike success rate, which equates to increasing the power derived from a given number of missiles. However, preparation amounts to nothing if it is not followed up by planning that itself incorporates the advantages offered by space systems.

Effectiveness and safety

By using the predictability of satellite orbits, planning can take full advantage of space services and improve the execution of operations approved during the strategic preparation phase.

Knowledge of active satellites in orbit enables the prediction of overflights of air base infrastructure or of assets deployed on operations. It is then possible during planning to exploit this advance knowledge of overflight times to ensure discretion for operations by carrying out preparations when or where they cannot be observed by those intelligence-gathering satellites to which the adversary may have access.* Conversely, if an actor wishes to display its force capabilities deliberately, a task can intentionally be conducted during such an overflight to demonstrate a determination to take action.

*** Intelligence**

Such intelligence may include imagery (IMINT), electromagnetic information (ELINT) and communications intercept (SIGINT).

In parallel, target overflight times for satellites offer the possibility of planning post-raid damage assessment using satellite imagery. Here again, such resources avoid endangering the aircraft that would otherwise be needed to carry out this mission, as well as enabling damage assessment images to be obtained beyond the range of such aircraft. Furthermore, the frequency of acquisition opportunities above a given target increases as the number of observation satellites increases, and with continuing improvements to their capabilities regarding sensor diversity, satellite agility and number of images in a given period. Radar imaging satellites, for example, are able to acquire images at night, in unfavourable weather or even in the presence of smoke. Assessment of damage inflicted may therefore be planned without unreasonably limiting the attack time to coincide with the passage of an observation satellite. The time between the taking of the image and its availability for interpretation, which amounts to the currency of the intelligence, is also a parameter that has been taken into account in the specification of military space programmes. This use of satellites can therefore accelerate sortie rates (characterised by the OODA loop: observe, orient, decide, and act) by enabling rapid assessment of damage and hence speed up subsequent decision making. Any disinformation activity by the adversary about the effectiveness of strikes can also be countered without delay.

Finally, some services supplied by satellites will encounter predictable variability that must be taken into account during planning. Communications satellites may suffer interference when aligned between the sun and the receiver. This phenomenon occurs at the time of the equinoxes during which interference or even drop-outs of up to an hour daily for about two weeks may occur. To provide for this, it is necessary to make arrangements to transfer the load carried by one satellite to another. Another inconvenience is that of variations in the accuracy of the positional information provided by navigation satellites; this accuracy depends on the geometry of the constellation as seen from a given point on the Earth. Starting with the predicted orbits of the satellites, the position accuracy is then assessed in advance and taken into account during the planning process. This enables operational safety (navigation and location) to be maintained, collateral damage to be limited and rules of engagement to be respected.

While the effectiveness of cruise missile strikes is significantly enhanced through the use of space-based resources during planning, full effectiveness in the execution of the task requires changes in the space environment to be carefully taken into account.

Space situational awareness (SSA): the key to effectiveness

The execution of a long-range strike may be affected by unpredictability resulting from the impact of the space environment on weapon systems. To adapt accordingly, the operator must be able to interpret it with support from specialists - this is SSA.

The space environment is the source of significant perturbations affecting weapon systems. These are primarily the consequence of solar activity: solar eruptions may induce ionisation* in the Earth's ionosphere, which in turn disrupts propagation of waves penetrating the outer layers. As a result, communications, navigation and positioning systems may suffer degradation in accuracy. Data and voice nets, including link 16, between AWACS (Airborne Warning and Control System) aircraft, communications satellites, combat and refuelling aircraft or CSAR (Combat Search and Rescue) and SARSAT (Search and Rescue Satellite) rescue assets may also suffer interference or disruption. The accuracy of GPS itself can also be significantly affected. The duration of such disruptions can range from a few minutes to several hours depending on the originating event and the geographical location of the operations. Finally, the sun, whose activities follow a cycle with a period of around 11 years, is currently entering its most active phase and disruptions are likely to become much more frequent.

*** Solar eruptions**

There are two distinct phenomena, not necessarily simultaneous: flares and coronal mass ejections (CME). Ionisation results from various mechanisms, including radiation, emission of high energy particles and disruption of the magnetic field.

Solar activity must therefore be analysed to enable preparations to be made to minimise any impact on operations. However, to anticipate the occurrence of an event is highly complex. Prediction of the eruption of a solar flare and of its impacts, for example, cannot yet be achieved despite research into possible precursor indicators, but a probability of occurrence can be given based on an analysis of sun spot activity. Conversely, the seasonal dynamics of the ionosphere is easier to predict, but only in the very short term: the validity of such predictions does not extend beyond a few hours.

Despite these constraints, account can still be taken of these phenomena during the conduct of operations with the support of specialists in space weather. These highly trained individual, whor are trained with the support of French research laboratories and US weather departments, can detect and assess events as they occur and brief the JFACC (Joint Force Air Component Command) within which they are located. This activity first of all enables confirmation that the disruptions observed are indeed associated with solar activity, avoiding the need to seek technical causes associated with equipment failure or attempts at jamming. It is then possible to derive an estimate of the duration of the interference so that current operations can be modified. Finally, a work-around may be developed based on an understanding of the nature of the phenomenon. A less-susceptible frequency band may be recommended.

The ability to analyse solar activity is thus a vital aid to decision making during combat air operations. This is especially relevant for those involved in the launch of cruise missiles, for which communications, navigation and positioning systems are so essential for long-range weapon delivery.

The way ahead

The annual exercise Iroquois, carried out by French Air Force units, is an opportunity to incorporate space-based capabilities into the control of air raids that terminate in the delivery of SCALP conventional long-range cruise missiles.

With the creation of COSMOS (*Centre opérationnel de surveillance militaire des objets spatiaux*, essentially: military operational space observation centre), proposed by the CDAOA (*Commandement de la défense aérienne et des opérations aériennes*: Air defence and air operations command), the forces will be able to ensure that the effects of this dependence on space applications is minimised. This unit will participate in monitoring the space environment and the protection of space assets. It will take over and expand the roles of the current space surveillance division of the CDAOA, and will ultimately offer its services on a permanent basis from a rear base or by detaching specialists to planning and command centres.

⁂

The projection of power far from home territory using cruise missiles is only possible today with the use of space-based assets. Space is therefore a vital tool in support of this type of operation, from the strategic preparation phase through to planning and weapon delivery. However, full effectiveness of our forces during the execution of their tasks depends on a comprehensive understanding of space and its characteristics. This includes the benefits of space applications, but also the dependency associated with their inherent characteristics and the risks associated with their use by adversaries.

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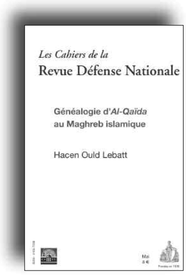

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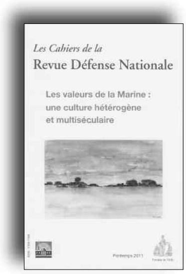

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