Access to space, the key to independence in space and a major challenge for Europe in the 21st-century

Workgroup[1] of the strategy and International affairs committee
of the French Aeronautics and Astronautics Association

Summary

Just as the great space powers of the 21st century, United States of America, the Russian Federation and the People's Republic of China, which has just strikingly demonstrated its technological prowess with the first space walk by a Chinese astronaut, the countries of Europe have their own means of accessing space: Ariane.

For almost 30 years, Ariane has guaranteed our independence in the launching of civil and military satellites that the Union's member states have needed for their development, defence and security. At the same time, it has been able to win a significant part of the commercial market, the extremely competitive context of which now imposes continuous adaptation in terms of missions and payload capacity.

The commercial market provides the Ariane system with the production volume indispensable for its reliability from which the institutional launches benefit directly. Institutional and commercial launches are intimately linked for that very reason. The commercial market responds to its own performance and price requirements ; therefore, the market share won by Europe will be all the larger if the launch system is flexible and can be adapted to the diversity of the demand. Two technical characteristics will enable the system to meet the demand: a large enough payload capacity and the injection of satellites into very energetic orbits including the final geostationary orbit.

Carrying out such missions with Ariane in dual launch is only possible if a new generation upper stage is used. With multiple refiring capabilities and the capacity to transfer two satellites totalling up to 12 metric tons into geostationary orbit, the European launcher will retain its commercial attractiveness and provide Arianespace, its operator, with the operational flexibility it needs for coupling the satellites whatever their masses and configurations and the uncertainties of delivery to Kourou.

The technological changes affecting commercial telecommunications satellites that can be expected in the relatively short term make that flexibility even more necessary. If not, we may see Ariane fighting at a disadvantage in its main market and, because of lack of competitiveness, only able to remain in it with the continuation of the EGAS production support system. This upper stage, powered by the Vinci cryogenic and reignitabe rocket engine, must then be developed as soon as possible, to be operational in 2015.

If the meeting of the European Space Agency Board at ministerial level in November 2008 decides on the launch of this programme, it will give Arianespace the means of maintaining its much coveted rank as leader. This upgraded Ariane 5 would be operational in the middle of the next decade. In addition, such a development would benefit the small European launcher Vega, which could also be equipped with it, giving it an increased payload capacity and strengthening the complementary natures of Ariane and Vega in their role for institutional missions.

---

[1] Lead by Philippe Henry. The following have also contributed to the study: Bertrand de Montluc, Claude Goumy, Didier Compard, Gérard Fouilloux, Jean Jamet, Louis Laidet, Michel Laffaiteur, Pierre Bescond.

From Symphonie to Syracuse :

Twenty two years after Sputnik, ten European countries, gathered together under the banner of the European Space Agency, saw their efforts rewarded by the first launch of Ariane, a success, on 24th December 1979.

This success proved that France and the countries that joined it in this project were right. After the failure of Europa, the era of the old continent's conquest of space had arrived. Ariane was capable of putting into orbit the satellites that Europe needed for its development, defence and security. But in spite of the progress made there was still the major difficulty of transforming this technological demonstration into an industrial programme with a production rate, controlled costs, repeated performances and a reliability equal to that of the launchers of the established space powers. The United States of America had already conquered the moon and the Soviet Union had an immensely powerful industrial complex with technological resources whose riches we would only discover much later. Europe became the third space power but there was still much to be done to ensure the durability of this status.

However, history will also record that it only acquired this status because it found it necessary to free itself from the dominance, deemed unacceptable in terms of autonomy, of its strategic ally the United States of America. The constraints imposed on the use of the Franco-German telecommunications satellite Symphonie and the state of dependency evident in the recourse to a third party for its launch were the obvious proofs that a technological and financial effort was essential for freely developing the essential tools for progress and its future. This meant above all operating its own launch system from its own territory. In 1973, the L3S ("Substitute 3 stage Launcher") project was launched. It became Ariane. The ESA was created in 1975 and took over the project management. Arianespace was formed in 1980 to run the commercial aspects. The cohesion of the "Ariane family" is ensured by the presence of its suppliers in the consortium's capital. This means that the European space industry is in the front line. It is associated with the European launcher's technological, economic and commercial development strategy.

From the very start, the basis of the European strategy for space activities common to the member states of the ESA was structured in this way. With the exception of some bi or multilateral scientific programmes, for which the Europeans provide the payload[2], the scientific satellites of the ESA and the French space agency CNES unfailingly use Ariane. The member states that run a national programme in parallel also call on Ariane, with a few rare exceptions[3]. Proof of the technological and operational capacities acquired by Europe**,** thanks to its industry and research centres**,** are successes such as the ATV (Automated Transfer Vehicle) and its entirely automatic docking with the International Space Station, the SPOT and Helios observation satellites, the meteorological satellites (Envisat, Météosat) and the military telecommunication satellites Sicral 1, Skynet, Syracuse etc., all launched by Ariane.

Today, almost thirty years have passed and considerable progress has been made in space techniques and this thanks to their applications. The change has taken place. Europe has entered the space era. "Useful space" has gradually become part of daily life. The use of satellites has played a part in providing almost 500 million Europeans with consumer goods and collective infrastructures that have transformed their lives by contributing convenience and leisure but it has also provided the means of ensuring their protection against natural disasters and threats to their security. Europe has become independent in the mastery of the space tools that contribute to its development in the complex, competitive and unstable world of the 21st century.

European construction and the international environment, factors in the development of the European Space ?

So is the future of an independent and durable European Space ensured for good and for ever ? There is absolutely no certainty about that.

It will only be so by exerting the same constant and unremitting will of maintaining its strategic independence, which brought it into being and has subsequently promoted its development.

The support that Europe needs is by nature political but must not be dependent upon the changeover of political power in the main contributing countries nor should it be dependent upon the enlargement of the European Union, with the joining of new member countries. The likely increasing involvement of European institutions in space policy, all the stronger if the proposed European treaty is adopted because it will give the Union competence in space matters, should also be a demonstration of this reinforcement. Any other course would endanger this capacity to carry out collective missions that Europe must undertake alone or in

[2] For example, Atlantic Alliance's NATO 4 satellites, the CNES – NASA cooperation on ARGOS and Jason, CNES – ISRO on Megha Tropique and ESA – NASA on SOHO. The launchers of the cooperating countries were chosen.

[3] The most recent example is the impending launch of the Italian Sicral 1B military satellite by Zenit 3 / Sea Launch.

cooperation within the framework of development and reconstruction programmes or that of military operations, when it is involved in the defence of its values and the protection of its sovereignty.

These are the reasons why all of the global and regional powers have developed independent means of accessing space in the last thirty years. After Japan, China became the fifth nation to launch a satellite from its territory in 1970. It was followed by India and Israel. In the Middle East, Iran is not far behind. In Asia, South Korea will put its first satellite into orbit in 2009. In Latin America, Brazil has not given up on a national launch capability. These states were dependent in the first phases of setting up their space activities but have gradually freed themselves from the constraints imposed by their suppliers, often purveyors of basic technologies.

Paradoxically, attaining this independence generally speaking only materialised due to the effect of the restrictions applied by third parties. China and India are two of the most striking examples. The first after the freeze in relations with the USSR at the end of the 1950s, and the second after the creation of the MTCR[4] under American leadership which committed the countries that signed to renouncing the sale of launcher equipment and technologies that could be used in ballistic missiles.

In France, the recent White Paper on National Defence and Security recognised the importance of space systems' contribution in terms of intelligence. The European satellite systems which automatically collect information complementary to that from human intelligence are an indispensable back-up for deployed troops and must not be allowed to suffer either from the unavailability of appropriate launch vehicles or from a unilateral decision imposed, in a situation of high geopolitical tension, by the political control of a state over the supplier that the Europeans would have to approach if they did not have their own.

Therefore, the current strategic position is based on the independence of access to space, which has been judged to be fundamental by the successive governments of the countries mentioned above. They devote a large part of their space budgets to developing, upgrading and producing their launchers. In China, the series of failures suffered at the start of the 90s have in no way suggested that its leaders felt no desire for an independent access. China obtained at the end a total success, since October 1996, including recently three manned missions, and the development of a completely new range of launchers with a capacity equal to that provided to the Americans by the EELV programme[5]. As for Japan, its government has never questioned the reasoning behind the H2A[6] heavy launcher, in spite of the failures and the total lack of commercialisation[7]. As for India, successive governments have been unshakeable in their ambition to position their country among the leaders in the use of space[8]. The first Indian lunar orbiting probe will be put into orbit this year by an Indian launcher[9]. By 2015, India will have a heavy launcher capable of putting all the military satellites it needs for its defence into geostationary orbit[10].

From all State to all commercial : a risky change of paradigm :

By agreeing to finance two thirds of the total cost of development of Ariane 1 to 4[11], France sent a strong signal to its partners indicating its wish to see a technological force emerge at the service of the policy of the European states. The target at the time was to launch at least two institutional satellites per year, with the possibility of commercial launches considered marginal.

Subsequently, the project of commercialising the launch service was justified as long as it could constitute a supplementary source of finance for the programme by sharing the fixed costs of operating the infrastructure at Kourou and the industrial production line, shared between the participating countries.

The performances of Ariane 1 were sufficient to be able to bid for the contract to put the first telecommunications satellites with an international role into orbit for the inter-governmental organisation

---

4 Missile Technology Control Regime created on the 16th of April 1987 by the United States, France, Germany, Great Britain, Italy, and Japan.

5 Evolved Expandable Launch Vehicle under US Air Force project management – Maximum capacity: about 14 metric tons in geostationary orbit and 24 metric tons in low orbit (200 km).

6 And its predecessor H2.

7 An evolution called H2B will be operational in 2009 to ensure the service of the Space Station. A new launcher family should succeed the H2A in the middle of the next decade.

8 With an annual budget of around a billion dollars, its objectives now exceed the original reason, which was to help its vast population escape from deep poverty and illiteracy.

9 By the PSLV (Polar Satellite Launch Vehicle).

10 GSLV MkIII (Geostationary Satellite Launch Vehicle) – About 4 metric tons in geostationary transfer orbit

11 A real expenditure amounting to 114% of the programme's forecast cost.

Intelsat, with most European countries as members. This successful initiative was the first step in the commercialising of the European launch services, which then approached the private satellite operators, of which there are an ever increasing number.

From this point on, the commercial market became a real driving in the search for technical and industrial performances and in learning about customer relations. The first laborious beginnings of Ariane 1 (two failures in the first five flights) were followed by an unprecedented success in the field, with more than half of all commercial geostationary telecommunications satellites launched by the European rocket.

This was only made possible by following three rules of prudence and also thanks to two favourable external circumstances, which were:
1. Reasonable programme choices, aimed first of all at reducing the risks of failure and minimising its consequences should it occur:

- Simple and robust technical solutions, based on the knowledge acquired from earlier programmes,
- Anticipation of the customers' requirements by financing in successive steps the evolutions of the launcher performances in GTO orbit in organized phases, increasing its payload from 1.85 metric tons in 1979 (Ariane 1) to nearly 5 metric tons in single launch[12] in the last years of operation of the most powerful version of Ariane 4[13],
- The operational coexistence of two consecutive versions, allowing the new one sufficient time to prove its reliability. This strategy proved its worth during the transition between Ariane 4 and Ariane 5 when the maiden flight of the latter failed. Its discontinuation in 2002, when Ariane 5 ECA arrived on the market, was damaging for the whole Ariane community[14].

2. The favourable international context also contributed greatly to the rise of Ariane :

- America's strategic choice in 70s and 80s to put all of NASA's efforts into the multifunction and partly reusable Space Shuttle concept (the orbiter and a part of the large solid propellant boosters) and abandon the much less sophisticated conventional launchers by privatising their operation,
- The context of the cold war in which the confrontation between the two blocks, the western one formed around the United States, the other the Soviet Union and its satellites, prevented any internationalization of a commercial market from which the soviets in fact excluded themselves.

From the start of the 80s, Ariane 5 became part of this basic logical pattern on the grounds that Ariane 4 had reached the limits of its development and that the predictable prospects of the telecommunications payloads market justified an increase in power and a new modern launcher with an increased reliability objective.

The consummate success of Ariane 4, fired at a sustained rate, seemed to give legitimate support to a way of thinking that saw space activities as commonplace and tended to allow the uninitiated to think that the technologies employed had less in common with highly skilled one-off work than with mass production and that the market had reached such a level of maturity that it could take over from the States in ensuring the future. However, it was succeeded by Ariane 5, a new launcher which no previous experience could prevent from an initial period of learning.

In this context, the two failures encountered during the first ten flights were not well received, notwithstanding the fact that the success of the Ariane 1 to 4 family was founded on two failures in five flights and four failures in eighteen flights.

Is Europe unable to tolerate the failures that the great space powers can take in their stride? The Americans mourned fourteen dead and the loss of two Shuttles but it has not stopped them from preparing their return to the moon. Three consecutive failures of the Titan military rocket resulted in a total loss of nearly 4 billion dollars. The Russians have just registered three failures of the Proton commercial rocket in two years. Zenit also failed recently, immobilising the maritime launch platform for a whole year for repairs and depriving Sea Launch, the operator, of five to six flights representing lost earnings of around 400 million dollars. As for the Japanese, they have suffered three failures during the first thirteen launches of the H2 – H2A family.

The harshest criticisms have been related mainly to the failure of the maiden flight of the Ariane 5 ECA "10 metric tons" version in December 2002. The error committed at the time was due to an incorrect analysis of the

[12] The particular feature of the Ariane launcher at the beginning was its capability of launching two geostationary satellites together, placed one above the other under the fairing and separated by an ejectable light structure called SYLDA, standing for "système de lancement double Ariane" (Ariane dual launch system).
[13] Called 44L because of the addition of 4 liquid fuel boosters to the launcher's central body.
[14] Failure of maiden flight 517

context which made Ariane 4 a success, added to which the manner of the response was not appropriate. In fact, at the start of the 90s, when Ariane 5 was still being developed, two major international events occurred :

- The Clinton administration made a major strategic change in direction: the United States decided to equip itself with a modern and less costly family of consumable launchers[15] with a range of performances greatly exceeding the capacities of Ariane 5. They seemed to have no hesitation in investing massively and started on the complete development of two families of launchers in 1998. It looked like the competition would be very intense because the stated objective in 1994 was to win back the international market abandoned to Ariane. These were commercial market shares won from Ariane which, according to the thinking adopted by the White House, should result in volume effects that reduce the unit cost of production and thus the budgetary costs of the numerous military satellite projects[16],
- The Soviet Union split into fragments in 1991. The Community of Independent States which succeeded it was disorganised and bankrupt. There was a lack of government funds, the Russian and Ukrainian factories were idle and talented young people were leaving the profession. American industrial companies immediately seized the rights to market the ex-soviet Proton and Zenit launchers, very suitable for launching geostationary commercial telecommunications satellites. Prices collapsed and the market quickly found itself in a situation of over-capacity.

The increase in competition in the second half of the 90s and the risk of a "saturation attack" on the market forced the Europeans to change their method of managing the launcher programmes by reducing the cycles and costs : shortened development cycles and the end of coexistence between two product lines offering redundancy capable of reassuring customers and guaranteeing the availability of a launch vehicle for government needs. Competition shifted the field of conflict to the economic one in a pseudo-competitive business which was not governed by any international market rules. Faced with the dumping practised by Arianespace's competitors, and bolstered by the very low production costs of the ex-soviet launchers, an effect reinforced since the start of this decade by an unfavourable Euro-Dollar parity[17], the Europeans tried to respond with savings.

The failure of flight 517 had a high cost, that of the restarting of the so-called "generic" Ariane 5 production, which had been stopped, and the slowing of the rate of flights. Was this decision based on a search for the economic profitability of an activity which everyone knows is generally unable to pay back its development costs[18]? Or was it an obligation to post positive operating results, whereas Arianespace, during nineteen consecutive years of operations[19] had only in reality achieved such a result three times, but without its existence or operating methods being questioned ?[20] It's still an open question.

It was not until this failure in December 2002 that a temporary system of financial support[21] for the commercialising of launches was set up to compensate for the distortion of prices in this unregulated market because, during the toughest part of the commercial battle, they could not be offered at the abnormally low prices practised by the competition to which the production costs in Europe could not structurally respond.

The underlying reasons for the devastating effect caused by this failure can be found in a series of concomitant causes :

---

15 Unlike reusable launchers, no components of expandable launchers are recovered for recycling on another launcher.

16 From the start, over budget (FIA, AEHF, SBIRS, SSTS, WGS), constantly re-estimated (TSAT), or abandoned recently (SRP).

17 Ariane is produced in Europe – the work is billed to Arianespace in Euros – whereas the launch service is usually billed in dollars on the international market.

18 No reliable and durable launch system in the world has seen the sum invested in its development paid back by the profits of commercial operations with the exception of Ariane 4 whose longevity and the hegemony for almost ten years resulted in a positive economic result. The programme's direct and indirect returns in duties and taxes exceeded the initial investment.

19 From 1983 to 1999 (see annual reports) – In 2000 and 2001, the gross and net results became very negative in spite of earnings comparable to the preceding years. Ariane 4 was still in operation and still captured an important part of the competitive market (16 satellites launched in the period). Faced with the dumping practised by the competition, in some situations the only options were to refuse a regular customer's contract or take it but at a loss.

20 The years in question were 1991, 1992 and 1995 (see annual reports) – the positive net result consistently posted by Arianespace between 1983 and 1999 was the result of exemplary management of its cash office and a strategy of extending the service provided to the customer in the form of a free launch insurance in the event of failure. The reliability of Ariane 4 made a major contribution to the earnings accumulated thanks to the sale of this guarantee.

21 EGAS (European Guaranteed Access to Space) : €960 M envelope under 2003 economic conditions, over the period 2004 – 2009 (see ESA/C-M/CLXV/Res.1 (Final) published in esabulletin 114 – May 2003.

- Substitution of the strategic approach, by its nature long term, based on the constancy of the objectives sought and the sufficiency of the means used to achieve them for a "tactical" approach, in which commercial analysis, immediacy and responsiveness to the customer took priority over analysis of the situation, perspective and prudence,
- Appropriation by the private sector of a product of public initiative, with which it managed to achieve a remarkable level of success but which could only be maintained in adhering to the rules of prudence that had proved their value,
- Focusing on the immediate economic profitability objectives of the launch activities led both to "playing to win" without first having demonstrated that reliability[22] and not defending the levels of finance compatible with the above mentioned rules of prudence with sufficient vigour when dealing with public authorities – certainly a difficult cause to plead in a situation of budget deficits and a general context in which economic orthodoxy seemed to have become the norm for national governments.
  In the light of experience, these rules had proved to be indispensable due to the extremely technological nature of this activity. The equipment is used at the very limit of scientific knowledge, in spite of the continual progress made in simulation tools[23]. However, these rules cannot pretend to guarantee the achievement of the degree of industrial control of medium and large production run products whose production volumes greatly influence the choice and reliability of processes and procedures.

The contradiction between the excessive confidence of an apparently self-assured activity and its intrinsic technical and financial fragility revealed by the successive failures obviously could not fail to disturb a political elite worried about budgetary allocations and until then reassured by the generally positive tone. Incomprehension was followed by doubt. Unfortunately, this was caused by the contradiction between satisfactory commercial indicators and a different systemic reality that was inadequately communicated to the decision makers.

This is once again the situation. While the available market information points to the conclusion that increased and more flexible capacity will be essential in the short and medium term to maintain the share of the commercial market that Ariane needs to affirm its reliability, without having indefinite recourse to an EGAS type production support system, not all of the players in the European space community seem to appreciate the impact.

<u>From public space to commercial space: two complementary aspects that are indispensable for the European Space :</u>

Ariane became increasingly dependent on its unprecedented commercial success, at least in minds, a success no one would have dared hope for in the middle 80s. The political reasons for its creation were gradually replaced by enthusiasm for an opportunist success.

The increase in production volumes to meet the demand of an increasing number of customers whose purchasing policies were mainly focused on a search for the quality and reliability of the launch service[24], contributed to the development of the industrial activity, favoured the emergence of new projects, allowed for the financing of technical developments and gave an increasing number of engineers and technicians the opportunity of entering this sector of activity. The explosion of the need for telecommunications infrastructures throughout the world was undoubtedly beneficial to satellite solutions[25]. With no competition for almost ten years, Ariane 4 became a “profitable business" (see note 18).

Should people have deduced from this that the commercial era had dawned and that the commercial market was sufficient to justify the existence and durability of Ariane 5, and that the new launcher would benefit from just as favourable circumstances as its predecessor ? In other words, were they right to believe in an ever growing development of the telecommunications market and expect constant profits from its operator ? From its origins Ariane has been a launcher of state sovereignty.

---

[22] The dominant feature of the marketing message in the pre V517 period was the concern with not making Ariane 5 ECA appear to be a new launcher.

[23] It is important to point out that these tools are often borrowed from other scientific communities and therefore are not entirely paid for by the space activities budget.

[24] Accuracy of injection into orbit, extension of lifetime by lower consumption of propellants carried by the satellite and rate of success in flight, mainly.

[25] Which nevertheless is simply a niche market in comparison to terrestrial solutions, of around a hundredth of the total turnover of worldwide infrastructures. Which, in spite of their specific nature and, in certain cases, singularity which no other solution could replace, is still a market with a limited size.

Haven't the latest failures favoured the emergence of a line of thought according to which, in the absence of a profitable commercial market, a European heavy launcher is not essential ? The withdrawal of Western states, as shareholders, from telecommunications operators and owners of satellites in particular[26], since the end of the 90s, has given credence to the principle according to which there is no logical reason for states to invest in a launcher for customers that are now private and posting considerable profits.

This analysis is in reality the direct consequence of three concomitant factors, one linked to the present economic and commercial context and two structural :

- The halt in the growth of the telecommunications market, firstly signalled by a fall in the number of satellites ordered and secondly by the stabilisation of that number[27], with no clear prospects of a significant new increase at some future time. Given that this restricted market is shared with two aggressive and technically well armed competitors and the medium term prospect of the arrival of additional competitors (China and the return of American launchers), it might make sense to moderate commercial ambitions for the coming decade, especially if not adequately prepared for it,
- The persistent weakness of the European institutional market which, in spite of an increase in the number of military satellites put into orbit or planned during this decade[28], offers no guarantee of stability of activity at such a level[29]. The planned decrease in real terms in the military space budgets in Europe in the coming years is proof of this. The slow growth in the ESA budgets, slightly above inflation, confirms this trend,
- The dimensioning of the Ariane 5 launcher, which basically responds to the need to put two satellites weighing several metric tons into GTO orbit simultaneously. Whilst it was possible to optimise the configuration of Ariane 4 to institutional payloads to a certain extent, due to its modularity, Ariane 5, which aims at the top of the range, has been able to launch a few large satellites from the ESA (Envisat, XMM) and the ATV for the service of the International Space Station (ISS) but is further from the economic optimum for lighter payloads. The strategic orientation of the space agencies in the 90s towards small and medium sized satellites has widened this divergence. The political differences in Europe about the support for manned flights and the usefulness of the ISS, the uncertainty on the American side about maintaining its commitment after 2015[30] and so about the future of the ATV have further added to the questioning.

Consequently, it is essential to get back onto the path of progress and mutual trust which is only possible if, in all transparency, a strategic vision affirmed by the leaders of the Ariane community and supported by convinced and united political decision makers is put into operational practice.

This strategic vision must reconcile the two parts of the launch activity: a basic state role, but one that alone is not enough to attain the level considered critical in terms of good quality industrial production, and, consequently, the need for a commercial market that provides the volume and is decisive in reaching the level of reliability and security of the systems deployed, from which all of the customers benefit, in the first place the European states.

Contrary to the United States, which spends more than twenty billion dollars per year on its military space programmes and thus provides its launchers with a large captive internal market, Ariane does not have this advantage and is unlikely to have it in the foreseeable future. The institutional operational payloads[31] represented 20% of the total put into orbit by the European launcher in the last ten years. They were included in

[26] Transformation of intergovernmental organisations Intelsat, Inmarsat and Eutelsat into private companies; abandonment of the role of satellite operator by national telecommunications operators and their privatisation (France Telecom, Bundes Telkom etc.).
[27] The forecasts of manufacturers, public bodies and specialised consultants indicate a range of from 20 to 25 commercial geostationary satellites per year.
[28] Mainly telecommunications with the satellites Syracuse (France), Skynet (Great-Brritain), Sicral (Italy), BWSatcom (Germany), Spainsat (Spain) and observation with the satellites Helios (France – Spain – Belgium), Pléiade (France – Spain – Belgium – Italy – Germany – Sweden - Austria), Cosmo-Skymed (Italy), SAR-Lupe (Germany).
[29] Around a billion Euros annually, at the peak, i.e. between fifteen and twenty times lower (depending on Euro / Dollar parity) than that of the United States, excluding "black programs".
[30] As a consequence of the loss of Discovery in January 2003, NASA has programmed the abandoning of the Space Shuttle at the end of 2010 and whilst awaiting a new service system – Orion Capsule, Ares I launcher – around 2015, the United States will be not capable in the mean time of reaching the Space Station by its own means. The current international context could have an impact on cooperation in space with Russia and the management of their complementarity.
[31] Models and microsatellites are not counted.

25%[32] of the launches that took place in the period and in half of the cases benefited from the presence of a commercial co-passenger sharing the cost of operations.

France has shown willingness to increase its research and development effort in the field of military space applications but it has not yet been successful in convincing its European partners to follow its example[33]. The budgetary pressure their governments are under will probably not encourage them to increase spending in the near future, spending that can only be justified by the perception of medium or long term threats.

In addition, the considerable means available to the United States, already mobilised during joint missions carried out within NATO, may induce our European partners to refrain from investing in what our American allies call a useless duplication. The difficult birth of the Galileo constellation, intended for satellite navigation and dating, is significant in this respect. Only the skill of its promoters in emphasising the commercial advantages and maintaining as long as possible the idea that its development could therefore be largely financed privately, has kept it alive. This strategy, made necessary by the inadequacy of a common defence policy supporting[34] the project, has led to a delay of five years in it coming into service.

In reality, in the coming years the institutional civil and military programmes will only provide the means to launch two Arianes per year, the average rate of Japanese launches, which have run into two problems: making their launch systems reliable and reducing production costs. This is why their launch policy is in constant transformation. Their H2A "heavy" launcher has not reached a cost level enabling it to enter the international market. This economic handicap comes in addition to a longer period to prove its reliability, which is an essential guarantee for customers who already have several established suppliers. It was the long and glorious history of the Russian Proton launchers, and even more so Soyuz, that, along with their selling price, was their main attractive feature when they appeared on the commercial market.

The commercial ascent of Ariane, like that of its Russian competitors, that started in the middle of the last decade can only be based on a pace that is maintained, supported by a market in which all of the commercially accessible payloads can be taken on without unacceptable operational constraints and using the dual launches which achieve the technical and economic optimum conditions.

Telecommunications satellites on the eve of a decisive technological change:

The typical configuration of the satellites launched from the United States, Japan, China, India and by Europe from Kourou includes an autonomous propulsion unit for putting the satellite into its final geostationary orbit and keeping its station, which tends to drift naturally under the influence of forces of gravitational attraction and must be corrected. The technology for this propulsion was standardised during the 80s, becoming entirely based on liquid propellants[35]. With the exception of Kourou, the other land launch sites are located at less favourable latitudes and the angle of the transfer orbit is higher. The orbit correction is therefore greater and the quantity of propellant on board the satellite more voluminous and heavier. Because it will have greater reserves of propellants for its use in orbit, having used up less to reach its station, a satellite launched from the equator has a longer lifetime for the same volume of propellants. A different compromise could result in reducing the total mass for an equivalent lifetime.

This mechanism for transfer from a "non-active mass" to an "active mass" [36] is identical if the launcher places the satellite in a very energetic orbit, whatever the launch site. The gain in the mass of propellants is all the greater if the launcher is able to substitute itself partially or totally for the satellite's main propulsion unit.

Moreover, the mass of satellites has constantly increased since the start of commercial applications. From hardly more than a metric ton in the 70s, commercial telecommunications satellites have gradually reached an average of 4 metric tons in 2007[37].

---

[32] 19 launches of a total of 75.

[33] Military space has only been significantly developed in Europe by France, Great Britain and, more recently, Italy, Germany and Spain.

[34] The two operational systems, the American GPS and the Russian GLONASS, are controlled by the military.

[35] Propulsion known as unified which only uses a single type of thruster burning a pair of propellants known as fuel and oxidizer. This configuration took over from the previous one combining a main solid rocket motor for the initial circularization and a mono-propellant propulsion system whose thrust was produced by a catalytic decomposition of hydrazine for station keeping.

[36] This terminology implies that the payload is the sole justification for putting the satellite into orbit and that it forms the active part of the target application. The dry structure and the propellants provide functionalities essential for positioning and operating the payload whilst forming a large mass that the launcher must carry to its release orbit.

This development is characterised by :

- A general increase in the mass of all classes[38] of satellite,
- The appearance of very large satellites, the maintaining of a niche market for small satellites and the concentration of the majority in a medium-heavy category between the two,
- The expansion of the "spectrum" as a consequence of the two preceding points.

This is mainly a result of the increase in the number of operators, of the diversity of their commercial positions, their strategies and the segments of the downstream services market in which they operate[39]. The growth in demand from the end customers is mirrored by an increase in the number of repeaters and data processing technologies which increases the density of the data flows. This development has led, on the one hand, to an increase in the number of satellites in geostationary orbit and, on the other, payloads made up of a greater number of repeaters. Similarly, the need for ever increasing electrical power on board is satisfied by larger, and therefore heavier, and more efficient solar generators. The first factor has had a favourable direct effect on the launch market. The others have led to heavier and more voluminous satellites which has led in turn to the development of launchers with higher payload capacity and greater volume under the fairing.

This demand-led trend is however limited by the diversity of the launch offer. The general tendency observed since the start of the activity is one of distinct periods of growth. Though the satellite offer may encourage operators to order heavier satellites, they generally only do so if there are launchers available. Most of them dimension their satellites so that at least two launchers can place them in orbit[40]. Those who have exceeded the limit of 6,000 to 6,200 kg[41] recently are rare. The consequence of this purchasing strategy is to concentrate orders in the 4,000 – 6,000 kg range. It ideally corresponds to the Proton and Zenit / Sea Launch offer of service whose GTO capacity has been raised to this level by successive increments over the last ten years of operation[42].

This observation leads to the following conclusion: Ariane 5 (and Atlas 5[43]) do not currently constitute a sufficiently well-established commercial offer to induce the operators to opt for 6,500 kg and heavier satellites more frequently. Proton and Zenit set the limits for practically the whole of the commercial market. So, at least three launchers[44] satisfy the general demand for either single or dual launches.

Consequently, two important tendencies which are, on the one hand, the need for more powerful payloads and, on the other, prudence in the matter of launch capacities, lead the market towards technological solutions that allow for the carrying of heavier payloads with an equivalent total mass. It is only when this development has been totally exploited that the maximum mass of satellites will increase again.

The duration of this phase is not easy to estimate but it is quite probable that the large majority of satellites will not have a mass greater than 6,000 kg before 2018 – 2020. A few satellites may reach 7 metric tons for very specific needs, in a choice strategy identical to that which won out for the iPStar and ICO GEO satellites. The platforms being developed, including Alphabus in Europe, will be capable of satisfying this requirement but the great majority of their uses will be at around 6 metric tons and even below that figure.

There are two possible technological developments to western platforms[45] in the coming years that will make this possible. For reasons explained above, they will change the situation in the commercial launch market :

---

37 The average mass of telecommunication satellites launched in 2007 was around 3,900 kg. That of satellites ordered in 2007 was around 4,400 kg.

38 Satellites are usually classified by mass categories, using the qualifiers nano, micro, mini, small, medium, heavy and very heavy. Telecommunications satellites come within the last four classes mentioned. The limit values of the categories are not standardised. They vary over time and according to who is talking about them.

39 Fixed services (feeding ground receiver stations that distribute to individuals) and mobile services (land, sea and air), distributing directly to individuals equipped with a receiver antenna.

40 Only an intergovernmental organisation like Intelsat could decide to launch a 4 metric ton satellite at the beginning of the 90s that could only be launched by a single launcher, which in addition was a military system : Titan 3.

41 iPStar (6,505 kg) by Ariane 5GS in 2005, in single launch, and ICO GEO (6,634 kg) launched in 2008 by Atlas 5.

42 It is important to note that, for several years now, the competitiveness of Arianespace's competitors has resulted in a much greater ability to capture the "heavy" satellites. For example, the average mass of commercial satellites launched this year is around 3,500 kg for Ariane, 4,300 kg for Proton, 4,500 kg for Sea Launch, and overall 4,200 kg.

43 A modular launcher whose performance in geostationary transfer orbit comes within the 4,950 – 8,700 kg range on an orbit inclined at 27°.

44 Atlas 5 is relatively rarely chosen by customers; they generally use Ariane, Proton and Zenit.

45 which with a very few rare exceptions form almost the totality of the fleets of private operators. China has started to export telecommunications satellites but in the very specific framework of state markets. It supplies a turnkey satellite on its geostationary orbit and launches it from its territory, e.g. Nigsatcom 1 and Venesat 1. Astrium, in partnership with

- The gradual adoption of a Russian type configuration, with no main propulsion unit and equipped with electrostatic plasma thrusters[46] for station keeping,
- The use of a "unified electric propulsion" once the high powered thrusters, which several engine manufacturers are currently qualifying, have proved their operational viability. This propulsion is not able to replace chemical propulsion in an identical way. The extra speed that it provides can only carry the satellite to its final orbit from a closer transfer orbit[47]. The launcher's upper stage will be used to place it there.

Due to the way it works, a "plasma" propulsion system only consumes a small quantity of gas for an identical lifetime to that made possible by traditional chemical propulsion and contributes to the reduction of a large part of the platform's mass. Therefore, if the total mass is equal, the on-board payload can include a larger number of repeaters. This advantage is even greater with the second option considered, "unified electric propulsion".

Electric propulsion is already used in a very large number of commercial satellites for station keeping. The interest shown in it by industrial concerns and space agencies is clear judging from the large number of developments carried out in the west over the last fifteen years. In the United States, the US Air Force has promoted the emergence of high powered plasma technology in the context of military satellite programmes[48]. Industrial companies, engine manufacturers and satellite builders are ready to introduce it into the commercial market especially as they are the same suppliers as the suppliers of the chemical and electro-chemical[49] thrusters used currently. The iPStar satellite mentioned above, also American made, is equipped with these thrusters, made in Russia. The Astrium Inmarsat 4 and Intelsat 10 satellites were the first examples of the commercial use of this technology, also of Russian origin, and which were qualified to western standards in Europe.

The dual advantage of endowing a satellite of the same size with a higher value by increasing the mass of its working payload and limiting the upper total mass of satellites is a technological breakthrough that will have a major impact on the launch market.

A launcher with insufficient power to place a geostationary satellite configured in this way into a high orbit will be marginalised in a market where most competitors are already capable of it.

<u>What answers can the geostationary orbit launch offer provide ?</u>

The reignition of the launcher's upper stage and direct putting into station of satellites, or their injection into an orbit close to it, are the only appropriate answers to the development of their configuration, for the following reasons:

1. Before the arrival of the Russian Proton and Zenit / Sea Launch launchers on the commercial market, Ariane 4 had established a sort of implicit standardisation of the putting of satellites into geostationary orbit. Ideally positioned near the equator, the launchers fired from the Kourou space port in French Guiana placed the satellites intended for geostationary orbit into an elliptical transfer orbit with a very low inclination angle.
The "Ariane standard" consisted of releasing the satellite when it can achieve by its own means an increase in speed of 1500 m/s to attain its definitive orbit.

To get round the difficulty of launching from the Baïkonour in Khazakstan, at a very high latitude[50], the Soviets originally adopted a compromise in performance between the launcher and the satellite different from that chosen by the other countries. The Russians inherited it. Their telecommunications satellites do not have any main propulsion unit on board and are placed directly into geostationary orbit by the launcher's upper stage. Their mass is lower than that of western, Japanese and Chinese satellites. In this configuration, the launcher supplies the extra power that the satellite itself cannot deliver. To do this, the upper stage must transfer the satellite it is propelling from an inclined orbit to the final equatorial orbit. This operation requires more complex

---

ISRO, the Indian space agency, offers a satellite with a platform made in India. Recently, the Russian NPO PM sold a satellite to Israel.

[46] Preferable to other electric propulsion technologies; it provides the best thrust – electrical yield compromise.

[47] The thrust of a high powered electrical thruster is about one thousand times less than that of a chemical propellant apogee booster. Also, the transfer made under low thrust takes from several weeks to several months, depending on the orbit the launcher has placed it in. The lost earnings of commercial operators are between 3 to 5 million dollars per month of immobilisation of a satellite carrying 50 transponders.

[48] Particularly AEHF (Advanced Extremely High Frequency), very high speed telecommunications satellites. First launch in 2009.

[49] Technology known as "arcjet".

[50] Latitude 45°6 north.

flight mechanics which alternate propelled phases and non propelled or ballistic phases. Consequently its engine must be fired several times. This characteristic is present in the Russian stages from the manufacturers Khrunichev (Breeze stage) and Energuia ("Block DM" stage) which equip the Proton launcher, launched from Baïkonour, and Zenit 3, which since 2008 is launched either from the Sea Launch maritime platform or from Baïkonour. Sea Launch combines the two advantages of the equatorial location of the platform placed off the coast of the Kiribati islands and a reignitable upper stage.

The Americans equipped themselves with a similar stage at the start of the 60s[51] and have continuously improved its performance. The new Lockheed Martin Atlas 5 launcher is fitted with it. Although it is relatively marginalised on the commercial market due to the priority given to institutional missions, it is nevertheless present[52]. The Boeing Delta 4 launcher is also equipped with a reignitable upper stage powered by an engine that is not very different. As for the Japanese, they already have a reignitable stage that the Chinese have also planned for the Long March 5. The Indian GSLV[53] launcher will soon be fitted with a stage powered by an engine derived from a Russian reignitable engine.

Thus the main space powers involved in launches already have this advantage. In less than ten years, others will have caught up and will also enjoy it.

2. The entry of the Proton and Zenit launchers into the market has not changed the situation yet. Up to now, Proton has carried out few missions that required reignition[54] and Zenit has not used its own. However, satellites have continually increased in mass and these launchers have increased their payload capacity which now exceeds 6 metric tons.

But with the predictable change to "all electric" that will consequently increase the number of repeaters for equal mass, Arianespace's competitors already have launchers adapted to this new configuration. In addition, the upper stage reignition capability may well result in the modification of the "1500 m/s standard" that Ariane imposed on the commercial market when it had no rival.

Reignition of the upper stage means the launcher can place two geostationary satellites launched simultaneously directly into their definitive orbits or to carry out more complex missions in which one of the two satellites is released into transfer orbit whilst the second is placed directly into its final orbit. This would enable Arianespace to pair two satellites of different designs, an appreciable advantage as long as satellites do not meet a single standard in terms of propulsion.

As the economic equation of Ariane 5 is based entirely on its ability to launch two satellites at once[55] and therefore share joint costs, the possibility of carrying out missions with profiles that mix two satellites with different configurations is crucial.

Moreover, this type of stage's ability to change orbit planes enables it to disperse several satellites launched simultaneously on different planes. This technical and economic requirement is particularly evident in the case of constellations made up of a large number of satellites which it is economically viable to want to put in place in clusters. Concretely, in Europe, Galileo is the first potential customer.

In conclusion, Ariane 5 fitted with a modern cryogenic upper stage that is reignitable and more powerful than the ECA stage is the only possible answer, in the medium term, to the triple challenge:

- of winning back a large share of the upper segment of commercial satellites,
- of maintaining the attractiveness of dual launches by adapting to the change in the telecommunications satellites market,
- and, in the second half of the next decade, of launching the second generation of Galileo satellites in clusters and perhaps other constellations that may appear on the international market.

[51] "Centaur" stage, powered by the Pratt & Whitney RL10 engine, the world's first "expander" cycle cryogenic engine.
[52] 8 commercial satellites have been launched by Atlas 5 between August 2002 and April 2008.
[53] The GSLV Mk I whose third stage is supplied by Russia will be succeeded by the entirely Indian Mk II version in 2009.
[54] Several satellites have already been won by ILS, the American operator of Proton, thanks to this advantage. A satellite of about 2,500 kg given to Proton – i.e. two and half times its capacity in GTO – could for the same mass be less loaded in propellants and carry a greater number of repeaters, increasing its commercial potential.
[55] Initial technical-economic choice that must be consolidated if Ariane is not to loose its foothold. Unfortunately, the 2008 manifest illustrates this perfectly: the withdrawal of two satellites planned for the last flight of the year forced Arianespace to reduce its activity to 6 flights instead of 7 and put back the launch of two early warning technological demonstrators from the Ministry of Defence (Spirale) – see AFP dated the 6th of October 2008.

The Vega – Ariane 5 synergy:

The small Vega launcher, an Italian initiative, resulted in an optional programme of the European Space Agency, decided on by its Council at ministerial level in 1998 and to which France is the second contributor. It will be marketed by Arianespace. The maiden flight is now planned for the end of 2009[56].

The advent of this launcher has strengthened European sovereignty in terms of access to space. However, the price of a launch, estimated at around 23 million dollars[57] has been the subject of criticisms and the competition from ex-soviet small launchers[58], offered at very low prices, will not help its entry onto the commercial market. The Indian PSLV has also become a serious competitor[59].
Consequently, it will probably be very difficult to get part of Vega's fixed operating costs supported by commercial contracts, as in the case of Ariane.

This means that Vega's future can only be based on a response to the widest possible range of institutional demand in Europe. Since 2000, the number of European institutional payloads, from the ESA or national agencies, launched by non-European launchers has grown continually[60]. This proves that the market has grown and that Europe does not yet have its own means.

If a commercial response is found, and probably on satisfactory economic terms for the customers, the future of the Vega European launcher is not threatened. Today, there is a quite wide consensus on using it and the Council of the ESA at ministerial level in Berlin in November 2005 issued a recommendation to the member states asking them to prefer the use of launchers developed by the Agency, including Vega, as far as possible[61].

However Vega's capacity is limited and, just like Ariane, its reliability will only increase to an acceptable level if it is used as frequently as possible. As the rate also has a direct impact on its cost, the technical-economic conditions of its operation will be better if Vega can develop towards a larger payload capacity and a wider variety of missions.

Even though Italy is the main contributor to Vega[62] and ELV S.p.A[63] is the main contractor and industrial architect, it was not suitable to launch the small Italian Cosmo Skymed military satellites due to lack of sufficient performance. They will be replaced in the middle of the next decade. It would be desirable if Vega can meet this objective by that time. To achieve it, its performance must be stepped up to the current characteristics of this constellation, at the minimum, i.e. 1,700 kg in heliosynchronous orbit[64].
This payload capacity can be achieved by using an upper stage that will replace the current upper stages and will be adapted to the dimensioning of the lower stages[65].

The industrial synergy between Ariane 5 and Vega can be created by using the same upper stage, with some mechanical adaptations[66]. Thus, the development of a new stage would benefit the two launchers and satisfy

---

56 Les Echos, 21st of July 2008.

57 As the Euro-dollar parity has varied a lot since the European currency appeared, and the market is governed by negotiations in dollars – see Les Echos, 19th of June 2007 – the price indicated for informative purposes is in dollars.

58 With the exception of Cosmos and Cyclone, resulting from the reconversion of ballistic strategic missiles : Rockot, Dnepr, Start, Volna, Shtil.

59 On the occasion of the Indian Prime Minister's visit to France in September 2008, EADS signed a long term agreement with ANTRIX, the commercial branch of the ISRO, for the launch of its observation satellites by the PSLV (see Aerospace Daily, 2nd of October 2008).

60 Civil applications: Cluster, Mars Express, GRACE, Cryosat, GIOVE, Venus Express, Demeter, Corot, TerraSAR-X are the main ones. Military applications : Cosmo-Skymed (Italy) and SAR-Lupe (Germany).

61 "on condition that this preference does not present unreasonable disadvantages in terms of costs in accordance with the provisions of point 24, of reliability or of suitability for the mission". Order of preference: launchers developed by the ESA, Soyuz operated at the CSG, other launchers (see the resolution related to the development of the European launchers sector adopted on the 6th of December 2005, § IV, point 23, paragraph c – ESA/C-M/CLXXXV/Res.3(final)).

62 Cosmo Skymed 1, 2 and 3 launched by Delta 2 (Boeing) – The remaining two satellites have not yet been officially assigned, but Delta 2 seems well placed (see the declaration of the President of the ASI related by Aerospace Daily, 7th of July 2008).

63 Limited company under Italian law whose capital is held 70% by Avio and 30% by the Italian Space Agency (ASI).

64 i.e. an incline of 98°. In its initial version, Vega's reference performance is 1,500 kg in polar orbit, 90° inclination, altitude of 700 km according to the Vega's User Manual from Arianespace, edition 3 March 2006.

65 First solid fuel stage (P80), second solid fuel stage (Zephiro 23), third solid fuel stage (Zephiro 9), fourth Ukranian AVUM storable propellants circularization stage.

66 The stage should be loaded with propellants according to the structural characteristics of the lower stage(s).

the great majority of European institutional needs, with the payloads not falling within this coverage being natural candidates for Soyuz as specified in the ESA resolution dated November 2005 mentioned above.

What direction should we take?

In conclusion, given this analysis, we recommend the immediate launching of the development of the cryogenic upper stage powered by the Vinci engine. It will provide Ariane 5 with the extra capacity that will be essential for its operational flexibility and raise its competitiveness to the level of its direct competitors, Proton and Zenit 3 Sea Launch, in the "heavy" and "very heavy" geostationary telecommunications satellites segment.

With a payload of around 12 metric tons, excluding the associated mechanical structures, it will be able to couple all of the satellites on the market without constraints, whatever their order of arrival at the Guiana Space Centre. Its multiple reignition capability will open the way to all forms of complex missions such as institutional satellites and Galileo.

If this stage is also used on Vega, with the necessary adaptations, it will also contribute to strengthening Europe's independence in terms of access to space.

In the immediate future, the crucial point is much more the work timetable than the technical solutions meeting the operational constraints. It is essential that the development of this stage is started without delay so that Ariane 5 is able to make its best offer to its customers. To keep around 50% of telecommunication satellites in the next ten years, it cannot take the risk of abandoning, even momentarily, a part of this segment to its competitors. The Vinci engine has already obtained very encouraging results in the now concluded pre-development phase. The realistic development and in-flight qualification time for a new stage cannot be less than seven or eight years. It coincides well with the requirement to supply a matured engine at the time of the first stage tests and the construction of the appropriate test bench.

Consequently, a favourable decision taken at the ESA Council meeting at ministerial level in November 2008 could not result in a first commercial flight before 2015, at the earliest. The years in between will see considerable changes in the market, its players, its technologies and the requirements of satellite operators. As it is constantly progressing, it will not be the one we know today. At that time, the 8,700 kg payload that has up till now been carried by Ariane 5 ECA, close to its limits in this configuration, will probably be insufficient. Time is against us. Putting the decision to start development off for three years would most likely severely damage the prospects of maintaining Ariane 5 in the commercial market, and ready for all its customers, in the first place the member states of the European Space Agency.