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INTERNATIONAL CONTEXT OF SPACE INDUSTRY

Position paper on policies adopted to foster space industry and support its activities, especially in Europe and Japan.

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The European space industry has for long reached a level of maturity that allows European industrial actors operate seamlessly at all levels (EU, ESA, other international organizations and national) and among all space markets (civil and defense, scientific and commercial). It can be considered as the third or the fourth worldwide with the Chinese and after the US and the Russian ones, depending on the criteria retained (size and independent access to manned spaceflight, or global technological capabilities and scope of applications). It is really a European industry, in the sense that firms, at least the biggest ones, have integrated branches and business units that are located and are operating in different European countries. In almost all space systems sold by a European integrator, there are some sub-systems, components, parts whose conception and production is spread across European countries. It is the result of more than 40 years of consolidation and concentration process, that broadly occurred first at national level (mostly until the 80s) and then at European level.

As compared to the four main players on the world scene, the Japanese industry is lagging a bit behind, in terms of size as well as overall capabilities. Besides some strong technological successes, it has never been a key player in the commercial worlwide markets and has been competed on its domestic market as well. And despite its long lasting efforts it is also still relying on numerous key technologies owned by the USA.

In Europe and in Japan, public policies have played a key role in the emergence and the development of the space industry. As in the USA, these policies have been essentially based on a space agency combined to the realisation of large programmes conducted with the means of procurement policy. However, a range of various other policy tools have also been implemented and other actors have been involved along the history, in a view of adapting the policy to the evolution of the space industry and of the space markets.

To this regard, European history is dominated by the emergence and the long-lasting preeminence of a specific body set up to design and lead the European space policy, ie the European Space Agency (ESA). Accounting for more than 50% of the European space industry's development activities, ESA programmes have also played a key role in the development of key technologies and in the structuration of the European space industry. Thanks to ESA, a series of launchers as well as some 50 satellites have been developed and produced. ESA has also transferred the operation and exploitation of launchers, telecommunications satellites and weather satellites that were developed under its responsability to dedicated operators. But in a recent period, this role has been challenged by the development of other market-oriented forces and by the emergence of new institutional actors in the field.

Japanese space industry history has largely been determined by conflicting interests and changing strategies at high policy decision level and by actions undertaken by the different public bodies in charge of designing and implementing space policy. This has frequently made this latter difficult to understand and to follow. This influence has probably been even more stronger than in the European case. Japanese space industry is still largely dependant from Japanese space budget (around 2 billion $), and has not benefited from defense-related expenditures (until 1998 and the start of Japan's satellite reconnaissance program there was not even indirect defense contribution to Japan's space program). However, the evolution has not been fully imposed by the government, but is rather the result of close interactions and mutual dependance.

A lot of the space companies (at least the bigger ones) are embedded in the wider aerospace and defense industries, and to a far lesser extent to the electronic and telecommunications industries[1]. Due to its history, its technological specificities and its relatively small size as compared to other sectors, the space industry has been dependant on institutional and strategic options adopted in those sectors; especially sectoral restructurations greatly affects the one of the space industry. But from the beginning of the space activities, there have been complex interactions between the space sector and the other sectors of the industry, especially aeronautics, defense, telecommunications, or even transport or scientific and medical instrumentations. Among the diverse forms that those interactions can take, knowledge transfers played a significant but evolving role in the emergence and development of the space sector. Economic studies have extensively proven the existence of such transfers, but have valued them differently, and have shown that specific conditions could foster or inhibate them. Among those factors, firm characteristics and strategies are key points. And again various public policies set up along the history of space activities have also strongly backed up these phenomena.

In this paper, we try to expose those different ways through which public policies has influenced and is still influencing the evolution of the space industry and support its activity, in order to understand the present situation of the respective European and Japanese space industries.

In the first part, we will propose a brief overview of the history of the development of both industries, the context of their development, the main strategies adopted by the nations and generally implemented by space agencies, and the main factors that can explain the respective patterns this development has followed. In each case, different periods will be distinguished.

Then a second part will be devoted to a more analytical understanding of the different types of policy tools adopted by the public authorities, notably procurement policy conducted by space agency and support to R&D.

In a third part we will focus on the complex interactions between the space sector and the other sectors of the industry. Spinins, spinoffs and dual development will be at the heart of the analysis, which will also detail the specific policies adopted in the field.

The analysis of the structure of space industry in Europe and Japan will formed the fourth part, which will exhibit current characteristics of these industries as they result from the broad evolution and implementation of various policies described along the preceding parts. On this basis, some of the main strategies adopted by the different actors in the world market will be explored. Finally, we will draw some lessons from the overall analysis as regards the policy adopted to foster space industry, and try to provide some hints about to which extent they could be applied or adapted to the specific case of Brazil.

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[1] For instance European space industry turnover is roughly equal to 5 to 6% of European aerospace industry turnover (AECMA, 2002).

I The evolution of space industries in Europe and Japan: context, challenges and policy options

A The case of Europe

- *Emergence and set up of basic competencies: from late 50s to 70s*

At the beginning of this first phase, the different countries initiated the first space programmes on a national ground. "Big" European countries, namely UK and then France started to develop some rockets on the basis of military-related scientific background partly issued from German specialists. UK was leading for rockets (V2-based Skylark and then Blue Streak) and then for scientific activities with the creation of the British National Committee for Space Research (BNCSR). France effort became significant in rocket development necessary for nuclear weapon, and resulted in Diamant launcher; CNES (Centre National d'Etudes Spatiales) was also set up. In this field, Germany was a bit lagging behind, because of limitations affecting its development in defense industry. The willingness to develop an independant access to space was right from the beginning the main motivation to support these efforts. The programme were centrally piloted, were driven by a mix of scientific, military and prestige objectives, and mainly involved companies that were active in the defense and aeronautic industry. Other developments concerned the satellites or probes, in which more countries were involved, such as Italy and Germany. Roughly said, the presence of academics and of sectors less related to defense (such as telecom or electronics) was more important in these fields.

However, it appeared quite rapidly that in none of these two main domains, Europe could compete with the US and the Russians. Joining nation's individual efforts at a broader European level was then more and more considered as the relevant solution, and European countries moved towards a European vision that was not the common way of thinking at that time[2]. Space was really one of the first field in which this vision started to become a reality. Due to the duality of the development (satellites mainly for science, launcher both for scientific and defense and independence-related purposes), two bodies were firstly set up at a European level: the ELDO (European Launcher Development Organization) in 1962 for the development of launchers, and the ESRO (European Space Research Organization) in 1964 for the one of the satellites. Through ELDO, France, Italy and Germany joined the efforts of UK for developing a rocket on the basis of UK Blue Streak, but the UK solution was rapidly given up, paving the way for the French industry dominant position in the field of launchers.

The European industry was only emerging at that time, and the ELDO and ESRO programme were crucial in this perspective. Through ESRO and ECSC (European Conference for Satellite Communications), different successful trajectories of satellite development were initiated. By placing contracts, they also contributed to the development of the first space companies and of the alliances (consortia) between them that afterwards led to closer integration. However, national or bi-lateral programmes were still strongly existing in parallel to the achievements of ELDO and ESRO. All in all, it is clear that the first industrial development were then directly and primarily driven by States decision to support industries in either the national programmes and in the European ones.

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[2] History of ESA and its predecessor is based on (Krige J. et al, 2000).

- *Space industries towards maturity: 7O-mid80s*

The European countries decided to replace the two space agencies by a unique one, the European Space Agency that officially came into force in 1975. Doing that was really the result of a willingness to go a step further in the European integration. After its convention, the ESA was not only in charge of the definition and the conduct of the European space policy, but also to strengthen the capacity and the competitiveness of the European space industry. Following the different ESA's councils along the period, the priority was put more on applications and launchers than on science. The ESA launched different large programme in the field of launchers (Ariane), telecommunications (Marots, MARECS, ECS/OTS families, Olympus), meteorology (Meteosat), remote sensing (ERS), microgravity and mannned flight (Skylab, Spacelab), besides the different scientific satellites and the more up-stream technology programmes. Collaboration with US and Russia was also largely expanding during this period.

From the point of view of the development of space industry, this period was the peak of European common integrative effort directly supported by State policy (Schwartz, 1979). No space market was really mature enough to allow for private-only sufficient incentives to foster such a development. Two aspects of the ESA influence on the space industry were intricated. First, by promoting the set up of large consortia able to answer its calls for tenders and then by choosing among them, it contributes to structure these consortia that later on became the large European space companies. Second, the activities for ESA were the opportunity for those consortia to developed technologies and solutions that were afterwards proposed on the subsequent space (mainly institutional) markets. It then opened the road that goes from public support to RD and spacecrafts qualification to "private" exploitation of space industry capacity (see below part II for a more detailed presentation of the underlying policy models). The most proeminent results of this policy was the creation of the Arianespace company (and the industrial structure behind it), and the set up of different consortia in the field of satellite industry, centered around different plateforms or buses. Correspondingly, to some exceptions the consolidation of space industry was mainly at national level, grouping in a few national based firms competences and facilities spread within each country.

- *The development of commercial markets: mid80s-end 90s*

This period was characterized by the growing divide between commercial applications and non-commercial applications on the one hand, and the divide between civil and defense-related applications. The logics behind those different lines of development tended to diverge, and the European space industry had to compromise between different objectives and requirements. In parallel, the central role of the ESA started to be questionned since it was not anymore the main actor in each of the sub-segments of the market. The main commercial applications with the corresponding ground segment (launchers, telecom, meteorology and remote sensing) were mostly driven by actors different from ESA, and in these fields the development of technologies less and less relied on ESA programmes (apart from launchers). Non commercial application basically remained under ESA influence, apart some smaller national programmes. European industry was also engaged in international collaboration, notably with the US for the ISS. On the other end of the spectrum, ESA was not involved in any military programmes because of its civil-only purpose stated by its founding convention,. Therefore, those programmes were conducted primarily under national supervision, sometimes with a view of providing facilities at multilateral level but with a smaller geographical coverage than ESA.

The market was then divided in different sub-segment as regards its openess to competition. Broadly speaking, ESA markets were reserved for European companies, national (infra-Europe) markets were more and more open to all European companies. International institutional (Intelsat, Eumetsat, etc) and morevoer commercial market (telecom) were open to worldwide competition, even when European institution (Eumetsat) and European-based bodies (in telecom) were clients. The commercial markets have grown quite constantly over the whole period, but whereas from 1985 to 1995, European institutional budgets had grown in average by 10% per year, they have remained almost stable in current terms (ie decreasing in real term) after 1995.

In order to support the competition with the US on these markets, the concentration movement of the European industry tended to accelerate and the big internationally-based space companies progressively appeared as commercial market expanded. A growing concern was about productivity, delivery time and production cost. Due to the specificity of its technological content, of its constraints of use and to the small size of production, it was difficult for the space industry to make the same progress in these fields as the one observable in the rest of the industry. But this phenomenon was partly counterbalanced by the rapid growth of telecom and launcher markets, the optimistic forecast about the future development of those market (cf the constellation of satellites) as well as the still expected explosion of market such as earth observation, microgravity or tourism.

In this period also, the process of European integration accelerated. With less and less restrictions to international flows of goods and resources within Europe, the integration/concentration of the European space industry was increasingly favoured. Industrial consolidation started to operate largely across boarders. From the mid80s, EC also launched and then kept on developing initiative to foster cooperation and integration of R&D activities in all sectors of industry (notably the RTD Framework programme), to the exception (among a few others) of space activities in which ESA stayed up-front. Last but not the least, in addition to the emerging industries from Japan, China or others, the fall of Soviet regime transformed the type of competitive behaviour of the Russian industry, which started to sell some competences and facilities, but did not established itself as a competitor on commercial market to the notable exception of launcher market.

- *The new situation*

In the first years of the 2000s the phenomenon appeared in the 90s were in some way amplified, but different events make them developing in a crisis situation. First was the sudden slow down of the satellite telecom market, the main commercial market, which fell from almost 30 satellite a year down to 6 in 2002 after the bankruptcy of the Globalstar and Iridium constellation projects for mobile communications. The blow-out of the "internet bubble" then put the telecom market even more into trouble and uncertainty. One of the main consequence was the fall of the launcher orders, especially for Ariane; and the failure of the new-developed Ariane 5 made the future of the European launcher industry quite uncertain. The fall of telecom market revealed the overcapacity of the European industry that was developed until now in a context of quasi-permanent growth. Neither traditional non commercial civil market, long-term being "future" markets (microgravity, tourism, etc) nor the growing military market were able to provide enough orders to compensate. Therefore, reinforcing the productivity-cost related problems already encountered, the space industry runned into financial losses. The usual actions have then been adopted by the space industry: concentration, jobs cuts, industrial plan for cost reduction and productivity increase, etc. Space market has partially recovered from the 2002-03 crash, but this period has deeply marked the structure and strategies of the space industry, the organisation of space policy and the public support to industry.

The ESA, which role appeared less and less clearly justified in the last decade, also reacted, largely with the "help" of the EC that fully entered in the scene. After a long period of discussion (cf European Commission 2003 White Paper and EC/ESA subsequent Framework Agreement), the EC is now working together with ESA (which remains independant from EC). To some extent, EU level may be the preeminent one in the future, notably because it is not constrained in the same way as ESA as for the defense-related activities (even if defense-related activities are not so much emphasized as in the USA, especially after the 9-11 shock). EU has also a much larger geographical coverage than ESA. However, the full shift of power from ESA to EU is depending on the ratification of the Constitutional Treaty for Europe, not completed so far (Gleason, 2006).

On the world scene, the competition of emerging (China, India for instance) or "re-emerging" countries after troubled period (Russia, Japan) is growing. China is now a main player. And the US have annouced great plan for Moon and Mars exploration without diminishing its efforts in defense-related activities. The US have not made clear the future of the exploitation of ISS, which tie up European resources for maintenance or development of the pressurised Columbus laboratory and the automatic freight transport facility (Automated Transfer Vehicle – ATV). Next ESA/EC summit in 2007 and ESA Council at Ministerial level (2008) will have to take account of all these evolutions.

As a conclusion, it is important to remind here some of the features of the two main markets on which the European space industry is active. On the commercial markets, the competitiveness of European systems (30-40% European market share on commercial satellites, 33-60% European market share on commercial launchers) has boosted the growth of the European space industry between 1991 and 2001. This market is increasingly characterised by higher levels of technology-driven competition, cyclical and volatile effects, changing patterns of global demand, shorter lead times, very high reliability and timeliness requirements. Operational lead production time is reducing (18 to 36 months in average for operational space systems) but full qualification of space technologies in orbit is still a long process, up to 10 years. This is in part due to recent changes in insurance policies and the consolidation of Private Equity Investors as major shareholders in most satellite operators[3]. Both actors push towards the need to have new technology demonstrated prior to its commercial deployment, and tend to link payments not only to deliverables but also to proven operating capabilities. The pressure from the clients has dramatically increased, not only on price, life-long performance but also on delays (Atzei, 1999). They want very rapid pay-back from the exploitation of the space systems. But they also use the space systems until the very end of their lifetime, and then want to replace it the quickiest as possible. Given that the moment when the system will « die » is hardly predictable, and it is difficult for prime to planify their activity (this is why is needed reactivity based on long-term relation with suppliers). More and more, the operators are grouping their demand, thus in a recent period, the calls were on very big deals (with only one « big winner »). The space systems have also a longer life than before. But on the other hand, since the life-cycle of technology is shorter and shorter, it is difficult for suppliers to amortized industrial equipment and to secure experience feedback. Consequently, there is a high level of technical and financial risks, not to mention market uncertainties or the hazard related to the risk of a launch failure.

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[3] Five of six major fixed and mobile satellite service providers in the world have been partly or entirely sold to conventional financial investors, which invested approximately US $12B dollars in private equity transactions in the satellite sector over the last 18 months (Mathurin, Peter, 2006). Noteworthy these transactions have taken place despite the supposed overcapacity, stagnant growth and declining operating margins of the satellite services sector.

The institutional markets are characterized by three major phenomena. There is still a paradoxical uncertainty about the concrete future of large systems such as Galileo, GMES and European launcher, despite the short-term decisions adopted in 2003, the mid-term commitments of 2005 and the corresponding key role taken from now on by the EC. Expenditures on defense-related activities (and to some extent scientific activities) are also unsufficient and scattered across countries. And support to R&D activities is also still lagging behind the US, despite the EC funds in FP7 that will only be really effective in 2007-08. As a consequence, European space industry does not benefit from the same financial backup and mid-term visibility as the US one.

B The case of Japan

- *Emergence of space industry and the role of individuals: 50s-60s*

Due to restriction inherited form World War II (defense related development, including in aerospace, were prohibited until 1952) the defense industry has not played the role it has played in other countries as USA, UK or France; notably it did not provide the technological base and the human capacity on which space activities relied in these countries. However, individual researchers from universities were attracted by the emerging space activities, and notably around Prof Itokawa at University of Tokyo, they started to develop things almost as a craft industry[4]. Prof. Itokawa was at the origin of the first rocket experimented in Japan (actually a very small "pencil" rocket) in the mid 50s. It was not only a researcher passion that motivated these researchers, but also the willingness to allow Japan not to lag behind what was happening in the USA and Soviet Union. They convinced the government that the development of a launching capability independant from the US one was important for Japan. As Suzuki (2005) pointed out, a logic of science expressed by individuals coupled with a logic of independance was the trigger of the emergence of space activities. Regrouped into the ISAS (Institute of Space and Aeronautical Science) at Tokyo University, the team managed to develop not only valid solid-propellant launchers ("Kappa" and "Lambda") but also some scientific satellites (first being "Osumi").

- *The priority on autonomous development of technologies: 70s to 80s*

In the following period, the trend of development of space industry was still largely following a technology push path. However, it somewhat diverged when in the late 60s, the USA realized that Japan could be able to reach their objectives of having at disposal a national-based launching capabilities. In order to avoid such a situation, the USA decided to "offer" to Japan the transfer of liquid propellant launcher technology based on Thor-Delta. There was a strong debate at the highest policy decision level, and despite the opposition of the ISAS, Japan accepted the offer. In this case, some partial autonomy was provided but not based on indigeneous technology.

Japan was aware of the potential of space activities, in terms of future markets and possible spillovers to other sectors. With the high performance launcher now available, they wanted to invest in space applications and then initiated a series of satellites in telecommunications, broadcasting and meteorology, with the strong willingness to catch up with the development of the other industrialized nations. To manage these national project, the NASDA (National Space Development Agency) was created under the growingly influential STA (Science and Technology Agency), but other institutions were involved as leading users: Nippon Telegraph

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[4] Part of the history of Japanese space sector is inspired from Lee (2000) and Tatsukawa (1995).

and Telephon Agency (NTT), Kokusai Denshin Denwa (KDD – International Telecommunications), Nippon Hoso Kyokai (NHK – National broadcating center) and the Meteorological Agency. In parrallel, scientific satellites were still developed under the responsability of the ISAS. But heavy industry and large electronic companies realized that the space business was not mature and that if it was more prestigious, it was also less money-making than their constantly growing other activities. But engaged in an effort to reduce the technological gap with the US and European counterparts, they stayed on the spatial scene and focused on autonomous technological development instead of market development, while letting the public bodies make the largest part of investment. After the sales of ISAS launchers to Yugoslavia and Indonesia, new Japanese laws adopted in the 60s reinforced the civil purpose of any space activities, and this also prevented space companies to target market applications because they were afraid of possible restriction to export.

Progressively, other public bodies also became involved in space satellites development: MITI, through its affiliate agency ANRE (Agency for Natural Resources and Energy) in the case of remote sensing applications, and Ministry of Post and Telecommunications. As a consequence, some sort of industrial specialization emerges between the different field of applications, with the coupling of those public bodies and companies (NASDA-MELCO, MITI-Toshiba, MPT-NEC in commercial applications, ISAS-NEC for scientific satellites). Throughout all this period, the military and commercial arguments in favour of space development were almost not used in the Japanese context (to the benefit of technological catch up and to a lesser extent prestige arguments), contrasting with the situation in Europe. But MITI and MPT started to challenge the technological logic pursued by NASDA and tried to emphasized a more market and user-based approach, while ISAS still tried to emphasize scientific and autonomy seeking rationales. However, NASDA got by far the main part of the Japanese space budget and then its influence was predominant in the construction of Japanese space industry.

In the 80s, the decision was made to start a new launcher programme (H-II) using only domestic technologies. Despite its high cost, it became NASDA and government priority, with the aim of escaping again from US technological domination.

- *The turning point of the US "Super 301" article and its consequences: 90s*

In 1990, a dramatic policy change occured under the pressure of the USA that had been increasing in the late 80s (Lee, 2000). These accused Japan of protecting their industry on domestic market by the means of unfair trade practices (complex and opaque procurement rules, regulation, public financial support to CS-4 satellite projects that they consider as a commercial ones, etc). Based on the Article 301 of US Trade Act (the "Super 301"), they threatened Japan of unilateral retaliation sanction, consisting in increasing tarif on major Japanese export to US (especially cars, electronics, super computers). Obviously, the USA followed not only a pro-competition objective, but also wanted to hinder the development of Japan competition on fast growing or emerging markets (communication, positioning/navigation, remote sensing). Japan then agreed to open up public procurement procedures for non-RD satellites to non-Japanese companies. They also announced that despite the success of the new launcher H-II, they would not enter the commercial launcher market. As a consequence, the Japanese companies almost lost these domestic markets, unable to compete with US firms. But to say it briefly, they preferred this situation, because it allowed maintaining their exporting capabilities on their main business. MITI and lately MPT were also in favour of this decision, because it considered that it would help to focus more on user needs rather than on developing on a national basis something that were already available on the world market at cheaper price. This point of view was shared to some extent by the traditional buyers of domestic satellites such as NTT or NHK.

NASDA then focused on RD satellites still protected from international competition, but for which the Japanese companies did not see any strategical reason to develop their competitiveness. They became even more dependant from public procurement policy, and beside came more and more engaged in collaboration with US companies.

During the 90s, after some successes (first H-II rocket, delivery on time of the Japanese contribution to ISS,…), consecutive failures affected some of the programmes that were left under the main control of Japanese industry (ETS-6, shuttle prototype HYFLEX, H-IIA with two satellites, ADEOS-2, Planet-B, M-V). This put the Japanese space programmes and industry in quite a bad situation, and the financial and economic crisis of Japan from the mid90s made it even worst, with space budget in real terms sharply decreasing.

- *The creation of the JAXA and the consequences of the reorganization of the space administration of 2002/03*

In the early 2000s, a vast reorganization occured in the Japanese administrative organisation at ministry leve, and space activities did not escape from this. In 2002 the two space agencies (ISAS and NASDA) merged together with the National Aerospace Laboratory (NAL) and formed a new-born agency eventually called JAXA (Japanese Aerospace Exploration Agency) under MEXT (Ministry of Education, Culture, Sport, Science and Technology) (Godai et al. 2003). At the same time, the Space Activities Committee, formely an interministerial decision-making entity covering all space activities, reduced its supervision to JAXA, while another body, the CSTP (Council of Science and Technology Policy, headed by the prime minister) was created to supervise all fields of science and technology, including space. It apparently showed the decreasing interest of government for space, since high level decision regarding space was in some way diluted in all decisions concerning all science and technology fields. Despite this apparent simplification, the decision-making process still remainded quite opaque and complex, and one consequence was that the space activities were under the responsability of MEXT bureaucrats with neither experience nor background in space nor market-oriented vision.

The evolution of the administrative reorganisation, combined with diminishing public funds allocated to space, incited the Japanese industry to seek for different sources of funds and support, especially METI and CSTP. Electronics companies such as Mitsubishi Electronics, Toshiba or NEC persuaded themselves that their success on consumer products markets could be re-played on space commercial markets, even if the sudden decline of telecom market has narrowed the window of opportunity to do so. But because of constrainst on public expenditures, they tried to develop some forms of Public-Private Partnerhsip and started to takes some risks in various projects such as Galaxy Express (GX) or Quasi-Zenith Satellite System (QZSS). However, some companies has drawn different conclusions from the present situation: Nissan for instance, considering that space was not a rentable business, has withdrawn from the industry by selling its Nissan motors branch to IHI (Nissan Motors had been one pioneer space industry in Japan).

II Policy tools

A The pillar: space agency and procurement policy

- *The basis of the model*

The space agency is usually under the supervision of very high decision political level and not administrative one. It has its own budget directly allocated by the State, and is usually in charge of designing the broad lines of the space policy and the different programme to be carried out in the different fields. It is also responsible for the design and the implementation of the different aspects of the procurement policy. In this context, procurement policy corresponds to orders, made by the Sate to the industry, of scientific or technological development or (above all) of spacecrafts or any other physical artefact that constitutes the space infrastructure (launchers, satellites, probes, instruments, ground station, etc). In case the outcome is a spacecraft, the space agency will either use it for its own purpose and make it available for other users while still operating it (for instance scientific satellites piloted by the space agency but whose scientific data are available for scientific community), or "forward" it to the relevant body that is in charge of operation and the relations with end user (for instance new version of launchers or new models of applications satellites).

To perform these activities, the space agency relies on "policy-designing" staff, managers, administrative staff, accounters, lawyers and on scientific and technical resources. These are conducting some research on their own, but essentially play a role of: i) support to the space industry (advising, providing test facilities, etc) ii) experts controlling the level of performance/quality of the space industry proposals and deliverables. As compared to the usual categories of public bodies acting in the field of industrial research and sectoral development, the space agency therefore exhibits quite specific features: it is not only a funding agency, it is not really neither a R&D operator nor a producer, it is more than a programme agency and it is also an intermediary between producers and users.

The function of organizing transition from public-based to private-based activities is the last "building" brick of the system relying on agency and procurement. Although it has taken various forms throughout the years and across the countries, the basic philosophy is always the following. First, on the supply side, it is to make space industry develop technological capacity and then produce first prototype or demonstrator of spacecrafts. In parrallel, it consists in supporting (or even creating from scratch) the demand side, for instance by pioneer user, or first client of technologies and spacecraft. Then when space industry has created capacities and has developed technology and/or spacecraft (or part or subsystem of them), it is supposed to be able to compete on markets that are also emerging and maturing on the basis of the demonstration effects provided by the pioneer use made by the agency. The agency can afterwards maintain the dynamics of the process by anticipating the future needs and the future technologies able to match these neeeds, through market escalation and consolidation (Edler et al., 2005).

This specific combination of roles played by the space agency has a strong and specific impact on the emergence and evolution of space industry. Obviously, this impact is all the bigger as its expenditures represent a high share of the space market. Different challenges faced by such an agency are then to be emphasized (see also Cohendet, Lebeau, 1987 and Iorio, 2002). At the emergence of the space industry (and it can also happen later in specific technological fields) there are scarce human resources having the skills and capacity in scientific and technological fields related to space activities. Consequently, there is a trade-off to be found between letting enough resources to the industry to develop, and keeping sufficient resources for "controlling" what industry is proposing to the agency as answers to agency's calls and for supporting the industry. Another challenge is to avoid a tendancy to develop internal programmes and self-funding activities to keep on justify the existence of these internal teams (crowding out effect of financial resources).

As a user of technology and spacerafts, the space agency is naturally prompt to design sepcifications that meet its own needs; but even as an intermediary between producer and user, it is often tempted to orient the specifications towards what it seems the best from its viewpoint (this is especially true when the users are not familiar with space technologies). The space agency is then influencing the direction and path of technological development of the space industry as well as the type and content of possible applications. Potentially, there is a risk that users' actual or potential needs are not enough or not properly taken into account; this could also be reinforced by the culture of the space agency staff (more scientific, technological and engineering oriented that marketing oriented, to put it briefly).

The influence of space agency is also important as regards the modes of management and the industrial "culture". Modes of organisation of activities, system of reporting, time schedules, focus on peculiar performance criteria etc used by space agencies are not necessarily the same as the ones used by other more commercial clients on space markets. Space companies that mainly work for the agency surely tends to comply to its rules and become more and more adapted to them, and possibly less and less adapted to market-drivent requirements.

- *Different ways of implementation*

Apart from NASA, the <u>*ESA*</u> represents the main example of the model detailed above. According to its convention, the purpose of the Agency is to provide for and to promote, for exclusively peaceful purposes, cooperation among European States in space research and technology and their space applications, with a view to their being used for scientific purposes and for operational space applications systems. The essential way to achieve this is through procurement policy that covers all space activities, from science to applications. A related key assigment is elaborating and implementing the industrial policy appropriate to its programme and recommending a coherent industrial policy to the Member States.

In addition to overall objectives (maintain and develop space technologies and meet the requirements of the European space programme and the coordinated national space programmes in a cost-effective manner) the objectives of the industrial policy are:

a. Improve the world-wide competitiveness of European industry by maintaining and developing space technology and by encouraging the rationalisation and development of an industrial structure appropriate to market requirements, making use in the first place of the existing industrial potential of all Member States;

b. Ensure that all Member States participate in an equitable manner, having regard to their financial contribution,

c. Exploit the advantages of free competitive bidding in all cases, except where this would be incompatible with other defined objectives of industrial policy.

85 to 90% of ESA budget being spent on contracts with European industry and as an international organization, ESA has to face the problem of the repartition of contracts throughout the European industry. Right from the begining, two general principles has been adopted and then only slightly modified along history without changing the spirit of it. The

first one is the rule known as the "fair return" rule, which stipulates that the space industry of one given country should be awarded an amount of contracts (weighted according to their technological interest) in proportion to the contribution of this country to the ESA budget (ESA Convention; Van Reeth, 1995). The second one is the distinction between mandatory programmes, ie programmes to which all member countries should be involved in (and correspondingly contributing to the funding budget in proportion ot their GDP) and optional programmes, ie programmes to which countries are involved in depending on their willigness to do so (with a monetary contribution also variable in accordance to their interest). The combination of the two principles ensure that: i) all members countries are involved at least at minima in space activities, ii) there is no free-riding countries iii) countries which want to go further in developing certain field are not held back by the others who do not want to iv) there must be negociation between countries to define the common part (mandatory programme) as well as to make emerge field in which some countries only are interested in.

The most striking feature of the ESA industrial policy, the fair return rule, has also been implicated for long. On the one hand, it has allowed to make emerge competences in different countries all over Europe, and has contributed to diversification as well as some forms of coherence of the national industries (Bach - Lambert, 1992). During the first phases of development of the European space industry, it has been seen as a way to foster long-term competitivity of this industry. But it has always been suspected to play to the detriment of short-term efficiency, when the choice of contractor was not always made on a pure cost-performance basis (which often gave rise complaints from companies from "big" nations, because competitors from "small" ones were preferred in order to ensure fair return).

As European integration improved and non-ESA market grew, the fair return has been more and more attacked, following different lines of arguments. A first one is related to the rigidity of the fair return rule. A "micro-management" of fair return by the State focused on short-term that does not fit well with mid-term and long-term horizon of space R&D and space programmes. And in a context of scarcity of public resources, the States have always tried to push the application of the fair return rule always a bit further, even if some recent adjusments were made. Return constraints per State still render ESA programmes almost unmanageable because of the multiple constraints that coexist at different levels of calculation (all programmes, mandatory ones, etc)[5].

A second critical point is that the return coefficient does not take properly into account the specificity of the different space activities, the objective of the different programme phases, their relative economic importance or their potential impact on the space industry. Numerous suggestions were made to adjust the calculation to one or the other of these elements, but there are very difficult to operationalize, and at large ESA has not managed or even tried to include them.

Another limitation of fair return rules is related to the pernicious effects it may have in a context of restructuration of the European space industry. Internationalisation of European industry makes the control of nationality required by fair return rule implementation of companies more and more difficult to apply and more and more artifical. Mergers and buyouts in a open market area such as Europe are naturally associated to decisions of closing down of units for sake of reductions of duplicated means, or by transfers of activity from one country to the other. But these decisions are largely influenced by the opportunity opened by contracts awarded according to fair return. This disturbs the process of rationalization of the European industry (eg by maintaining duplication and overcapacity), or at least make it very complex and possibly instable, all the more when national space procurement policy

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[5] A new approach should be soon finalized in order to increase the flexibility.

sometimes try to compensate for the companies that were not successful in bidding for ESA contracts. Last but not the least, the fair return rule has always been suspected by the EC to be against the free competition rules set up as early as in the Roma Treaty, and more and more carefully impemented by the Commission.

ESA has been very successful in the transition from public-based to private-based (or at least market-based) applications. The case of Ariane launcher is the most well known one, despite problems ecountered at different points in time (notably in the early 2000s with the initial difficulties of Ariane 5). Research and development is funded and piloted by ESA (and French CNES is this case), then the commercialisation is provided by Arianespace (formally established just after the first successful launch of the first version of the rocket), the same industrial consortia being in charge of both development and production. Between those two phases, the procedure adopted was to set up an intermediate phase between qualification and full commercialisation, neither wholly commercial nor wholly R and D, and during which cost-efficiency are improved by simplification of fabrication methods and rationalisation of management and launch operations. ESA acts as a user for some of the launches of this so-called promotion series. The same model has still being used for the following generation of Ariane, with only slight readjustments such as the reorganization of the industrial consortia under the primership of EADS in 2003. And Arianesapce has the possibility to set up its own marketing strategy, including striking deals with other launch service operators. One other typical pattern of public -supported to market-driven activities has been adopted in the case of applications satellite. Technological development and demonstrator or prototype were under the responsability of ESA, and one the space system proved to be operational it has been transferred to other new or specially established international organisations (public or lately privatised). It was the case for telecom satellites (with OTS, ECS and Marecs) subsequently operated by Eutelsat and Inmarsat and meteorology satellites (Meteosat) operated by Eumetsat.

ESA has always tried to limit its internal resources (staff and equipment) to a level compatible with its role, avoiding the danger of "capturing" the industry resources and of being to big. But the restructuration of the European space industry could lead to a situation in which European calls are only answered by one bidder, implying direct negociations. This may reinforce the role of ESA because it will require strong capacity of negociation and control

As underlined in Part I, the procurement policy of ESA has strongly influenced the development and the early structuration of the European space industry. But since the mid80s, the relation between ESA and the space industry has changed. For various reasons, in neither earth observation nor microgravity applications ESA has been able to reproduce the model evoked before for telecom and weather satellites, not to mention military applications that are by definition out of its scope. The question is to know to which extent the ESA is still adapted to play a leading role in the definition of applications and technologies that will have to meet growing and diversifying market needs (Lebeau, 1994; Bildt, 2003; Smith et al. 2007).

- *National space agencies*

At national level, one can find different variations of the "agency model", with different mix of the functions. Some countries as Swiss or Belgium have a programme agency without technical center (they use the ESA facilities and resources), while others combine a strong programme agency with important technical capacity, such as France with the CNES (Pompidou, 2004; Eurospace, 2006).

CNES is probably the closest one to the agency model described above. Created in 1960, it has shown an apparent stability over the years as compared to its European counterparts. To the difference of ESA, apart form the national dimension, it must be noted that CNES is usually acting as delegate for French Defense Ministry. CNES has mainly used procurement type of policy, and has probably more developed the function of technical center than ESA, following the governmental assignment of developing centres of expertise in technology and in the development and management of space systems. This notably includes taking on the risk of developing certain advanced technologies for the benefit of the industry; providing the scientific community with expert assessments in technical areas and mission analysis; to be capable of running operations on behalf of customers. CNES has also implemented the model of transition from public to market-based activities. The best examples are Ariane (since CNES actually act as space agency under delegation from ESA) and earth observation activities based on SPOT (with Spot-Image). One other difference with ESA is that CNES is shareholder of the companies set up for operation and commercialisation, as Arianespace (32,52%) and Spot Image (41%).

In the other European countries, structures have been evolving, resulting in Italian Space Agency (ASI, born 1988), the British National Space Center (BNSC, born 1985), and German Space Agency (DLR) created in 1989 but coupled in 1997 with German Aerospace Center (DLR). ASI is probably the closest to the agency model. BNSC is essentially a entity set up to coordinate civil space policy and programmes across a range of government funded organisations which jointly owned the BSNC and who are responsible for their own budgets. DARA generates the German space programme and control its implementation on national and ESA level. It is now within DLR, which is essentially a big research center adressing either aeronautics and space technologies. In this sense its ressembles NASA. Is has therefore the capacity to carry out research work on its own and is even working under ESA contracts.

The Japanese case has long been characterized by the coexistence of different bodies and conflicts between them, as it was mentionned in Part I. The overall merger of most of them in the 2003 born *JAXA* has not fully solved the problems (Suzuki, 2005). According to its long-term vision (JAXA, 2005), one of the objectives of JAXA is to contribute to the growth of self-sustainable space industry with world-class technological capability. JAXA intends to conduct research and development of new technologies, which could lead to turning space industry into key industry of Japan. As other countries do to support their space industries, JAXA aims at doing so that Japanese space equipment industry could grow to achieve a certain level of industry size to become a key industry of Japan.

Japanese procurement policy has been characterized by a double transition. The first has been the opening up of Japanese non-R&D satellite market to foreign competitors, as underlined previously. The second one has been from one original approach to another original approach, namely from work-sharing to technology-sharing (Lee, 2000). Work-sharing system was in place from the beginning and especially since 1977 until the early 90s. Japanese government was reluctant to spent huge resources in space development but wanted to keep major companies in the business. Private companies were not so keen on investing to much on their own funds, because of the small size of the Japanese space markets and the low profitability Close consultation between the two parties led to a sharing of activities so that every major company could survive, secure workload, progress along the learning curve and lower manufacturing cost. It was particularly true in satellite business NEC became specialised prime contractor for meteorological satellites, MELCO for communication satellites and Toshiba for broadcasting satellites. As compared to cooperation and specialization in other fields, the specificity of space as regards this organization was that this cooperation to minimize competion lasts from R&D to production and government procurement. As a result of the US competition pressure and in order to improve their competitiveness, a new organization of the relation in the space industry replace the old one, although still backed up by the willingness to keep everyone in the business. All firms started to cooperate on the same projects within each area of the space applications, under the primership of one of them. This was accompanied by companies need to share technologies with each other. The differentiated technological capacity previously acquired through specialisation and through preferred one-to-one relations with US companies, as well as three decades of cooperative relationships formed the basis of these new forms of relations, which lately led to merger between NEC and Toshiba. However, to some extent companies still followed their previous trajectories, with MELCO in communication, NTS in other satellites, and MHI and IHI in rockets and large structure as ISS components.

B The other components of the "space policy-mix"

- *RD support: overview of the various European schemes*

The second main tool used by government to support space industry development is obviously the funding of R&D activities. In theory, the differences with the procurement policy are that i) by definition, only scientific and technological development is funded (not the design and production stages), ii) the governmental body that fund the R&D activity is not the direct user of it ii) the IPR regime is different in the sense that the governmental body is not the owner of the result achieved iii) the topic of the R&D is largely defined by the industry itself within a more or less large perimeter of activities defined by the governmental body. Generally speaking, the level of control over the activities carried out by the industry is then lower, both in term of monitoring of activities (milestones, reporting, cost justification) and in terms of results. However, the differences between procurement policy and RD support may be a bit blurred since development of spacecrafts is very often as such mainly a R&D activity. The influence of agency in the definition of R&D priority and contents is also very important, because of its leading role in space policy, its scientific and technological capacity and its needs as future client or delegate of future clients. Therefore R&D support mainly takes the form of funding of up-stream or advanced technology developments according to plans and in areas precisely defined in advance by the agency.

As in many sectors, European space R&D – the "seed-corn" of future success – is probably inadequately funded (ESPI, 2005). As regards public support to R&D at European level, ESA (and national agencies which role is crucial in this field) has for long largely implement this tool, but the emergence of the EC as major actor is now modifying the picture. For the time being, the main tools used by ESA are the following (ESA, 2006).

The General Studies Technology Programme (GSTP) provides technologies of potential interest for all ESA programmes, bridging the gap to user programmes, developing generic/cross-cutting technologies, elements of scientific experiments and pilot projects. GSP studies are selected from proposals submitted by ESA staff. These proposals may relate to all areas of ESA activity, with the result that ESA staff act as the main "discoverers" and "filters" of new ideas in the European space sector. In the future, it is also supposed to support the emergence of new applications stemming from EC policies. The Basic Technology Research Programme (TRP) provides technologies of potential interest for al the ESA programmes, assuring long term technical capabilities. TRP focuses on research and feasibility demonstration. The Core Technology Programme (CTP) is dedicated to critical development technologies activities of scientific missions, aiming at developing engineering models tested in relevant environment. These first three are part of the mandatory programmes. Development of future technologies in specific fields or mission specific technology elements are either included in dedicated programmes (Artes for satellite telecommunications systems, FLPP for next generation launchers, Aurora for human exploration etc) or covered by the dedicated technology activities to mandatory or optional programmes. It is important to note that when activities are market-oriented, contracts may also be awarded on the basis of co-funding by industry (Georg, 2004). This is the case in some GSTP contracts (up to a maximum of 50% funded by companies), and always in the case in Artes. In those cases, no profit is allowed to company, the initiative and the definition of projects objectives, requirements and work programme is often on the industry side, and the ownership of results frequently also for the industry.

The EC is now a second main source of support to space R&D. However, from a general policy point of view, the action of the EC is larger than this. Together with the ESA, it defines a lot of important policy decision by the mean of the Space Council, bringing together ministers from both ESA and EU Member States, and of cooperation on a more regular basis ensured via a High Level Space Policy Group (with a joint EU/ESA Secretariat). In principle, EC and ESA's domains are complementary: ESA main role is to develop space infrastructure and technologies and to pursue space-based scientific research and space exploration, while EU’s interests in space focus primarily on space applications and the way these can help us to achieve EC policy objectives. The three fields of applications are navigation and positioning (Galileo), observation and geo-spatial information service (GMES: Global Monitoring for Environment and Security) and telecommunications, which are presently at different stages of development. Galileo is well advanced (see below), telecommunications is at a very early stage of discussions in different fora and committees, and GMES is presently in discussion as regards its financing and governance model.

Within EC, Space Policy Unit resided within the DG Research until 2004 and were moved to the DG Enterprise and Industry, which is higher in the EC hierarchy and headed by an EC Vice President. This indicates political will to increase the status of space within the EC, and emphasizes that space is an area that goes beyond research. However, operational responsabilities are a bit scattered. DG Research is funding R&D in the three domains of applications (see below). Research on Galileo application and security needs comes from the DG Transport (through the TEN-T, Tran-European Transport Network initiative) also heading the programme on the EC side. DG Enteprise and Innovation is heading the GMES activities. For some GMES and GEOSS applications, support from DG Information is also available, while Earth observation research, including GMES (and GEOSS), receive funding through DG Environment (but in both case in limited extent and in coordinaton with corresponding budget lines of DG Research). An in-house Space Task Force brings together all EC services interested or involved in space policy and space applications, including policy areas such as environmental, agricultural, telecommunications, transport, and external relations (Euroabstracts, 2006).

As in almost all industrial fields, the EC support to R&D is provided through the so-called Framework Programme for Research and Technological Development (EC FP programme) runned by the Directorate of Research. These are 4 or 5 years succeeding but partly overlapping programmes, including different supporting tools among which the most important is the co-funding of R&D projects run in collaboration between companies, universities and research centres of different EC member (or associate) countries. They cover a large variety of sectors. The FP1 was set up in the 80s and now the FP7 will start in January 2007 and will last 7 years (until end 2013). As underlined in Part I, space sector has only been seriously covered since the start of FP6, but it is the first time in FP7 that space activity will be identified as a budgetary line as such.

In FP6 support to space activities was mainly achieved through the set of programmes labelled "Integrating the European Research Area (ERA)" that covers thematic areas including "Aeronautics and space". The space component consists in R&D projects related to Galileo (development of multisectorial systems, equipment and tools) GMES-Global Monitoring for Environment and Security (stimulation of evolution of satellite-based information services by development of technologies e.g. sensors, data and information models, services for global environment, land-use, desertification, disaster management), and Satellite Telecommunications (integration with the wider area of telecommunications, notably terrestrial systems). The instruments used by in FP6 have been classified into three different groups on the basis of their purpose[6].

The first group comprises the instruments aimed at generating, demonstrating and validating new knowledge through R&D, and is composed of:

- Integrated Project (IP), for ambitious, industry-led and objective driven research dealing with different issues through a “programme approach” focusing on multiple issues, and encompassing various (often multidisciplinary) activities as research, demonstration, training, innovation linked activities;
  - Specific Target Research Projects (STREP) are objective-driven often monodisciplinary research more limited in scope than IPs and usually focussed on a single issue.
  - Networks of Excellence (NoEs) form a second group of tools. They are very complex machinery set up for durable integration of the participant’s research activities. They are university/research centers lead, involving only indirectly industry through steering or scientific committees, governing board etc.
- The third group comprises instruments aimed at supporting research coordination and networking (Coordination Action) or for preparing future actions, disseminating results from previous action or supporting policy (Specific Support Action), through individual meetings, seminars, workshops, working groups, etc.

The future FP7 will also bundle all research-related EU initiatives together under a common roof and play a crucial role in reaching the goals of growth, competitiveness and employment (along with Competitiveness and Innnovation Framework Programme – CIP –, Education and Training programmes, and Structural and Cohesion Funds for regional convergence and competitiveness, that will only marginally concern space activities, except some measures for SMEs).

The broad objectives of FP7 are grouped into four categories: Cooperation, Ideas, People and Capacities, working together to promote and encourage the creation of European poles of (scientific) excellence.

'Cooperation' is the main category and the one essentially concerned with space activities; it supports all types of research activities carried out by different research bodies in transnational cooperation and will aim to gain or consolidate leadership in key scientific and technology areas. "Security and Space" (with for each separate programmes and budgets) will be one of them, covering technologies developed to ensure citizen security with applications

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[6] It is not possible to provide statistics on the repartition of support to space industry according to the instruments presented.

in the civil as well as the defence areas for these two elements[7]. Three domains have been identified: space –based applications at the service of the European Society, exploration of space, RTD for strenghtening space foundations. In addition, transport and environment areas will also contribute to finance space-related activities within "Cooperation".

The FP7 instruments for Cooperation are a mix between the existing FP6 ones and new ones. The bulk of EU research funding in FP7 will go to "*Collaborative Research*", through a range of funding schemes: Collaborative projects (FP6 Strep), Networks of Excellence, Co-ordination/support actions, etc[8]. "*European Technology Platforms*" (ETPs) have already been set up in a number of areas where Europe's competitiveness, economic growth and welfare depend on important research and technological progress in the medium to long term. Their activity will be extended in the future. ETPs bring together various stakeholders, under industrial leadership, to define and implement a strategic research agenda with RTD priorities for the medium to long-term, measures for enhancing networking and clustering of the RTD capacity in Europe, mechanisms to mobilize the private and public intervention (including seeking fundings), education and training strategy and communication. Two ETP are existing in space related fields. The Integral Satcom Initiative (ISI) is an industry-led action forum designed to bring together all aspects related to satellite communications. The European Space Technology Platform (ESTP) aims to create a non-dependent technology portfolio facilitating European strategic independence for the access to and exploration in space, and to support the development of next-generation technologies best serving Europe's ambitions in space-related sectors (Galileo, GMES, security, space exploration, broadband communications, etc.) (ESA, 2006a). The ESTP complements previous coordination and harmonization effort in several strategic areas, along three main pillars on (1) non-dependence, (2) technology spin-in and multiple use, and (3) enabling technologies for EU Applications. Finally, in a limited number of cases, the scale of a research or technological objective and the resources involved justify setting up long-term public-private partnerships or even joint enterprise corresponding to *Joint Technology Initiatives*, a last "Cooperation" tool. Galileo is frequently cited of example of this future tool, and GMES is one the five best placed candidate for adopting this new arrangement.

The importance of EC funding to space R&D is showed in the Figure 1. However, as underlined above, a comprehensive picture of all funds dedicated to space is extremely difficult to draw, and focusing only on budget line labelled ''space''in either FP6 and 7 is misleading.

2002-2006	FP6 *DG Research*	19 113
	of which "Focusing and integrating Community research"	14 682
	of which areonautics and space	**1 182**
	Galileo	109.7
	GMES	106.7
	SatCom	37.5
TEN-T (Tran-European Transport Network) for Galileo *DG Transport*		**680**

2007-2013	FP7 *DG Research*	53 221
	of which "Cooperation"	32 365
	of which space	**1 430**
TEN-T (Tran-European Transport Network) for Galileo DG Transport		**1 000**

Figure 1 (in million euro) (Eurospace 2006a; EC website)

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[7] According to the last declaration from the head of Space Unit, 85% of the funds for space will go to GMES applications.

[8] Apart from "Cooperation", "Ideas" programme, piloted by the new-formed European Research Council, will fund "frontier research" projects presented by researchers on subjects of their choice (bottom-up approach), evaluated on scientific excellence by peer review. "People" seeks to improve the quality of the human potential in European R&D and increase the number of researchers and "Capacities" is for reinforcing research and innovation infrastructures, including SMEs, regional research-driven clusters, etc.

- *Harmonization of technological development*

Another important tool used by the public authorities in charge of space affairs concerns the effort to standardize and harmonize technological development in order to avoid gaps, fill holes in technologies, eliminating overlaps or providing redundancy for strategic components, critical path elements or key pieces and ensure a good level of interoperability. Besides trying to favour this technological coherence through the very scientific and applications programmes, agencies, and especially ESA have launched dedicated actions in the fields of project management, quality management, software or engineering.

More recently in 2004, the European Component Initiative was launched to ensure the timely and unrestricted availability of space-qualified components (from fuses to high-performance microprocessors) for European Industry by creating alternative sources for parts that are subject to export controls. For instance, all technologies/products that can fall under the US ITAR rules are under the scrutiny of ESA[9].

A significant achievement in 2005 was the introduction of a single new End-to-End Space Technology R&D Management Process for all ESA technology programmes. It is user driven and aimed at meeting both the institutional and commercial needs of Europe. A complete analysis was carried out identifying areas of space technology in which Europe may risk being dependent on other countries, to the detriment of its institutional and commercial aspirations[10]. It provides the European space community with as complete an overview as possible at European level of all the envisaged missions, their associated top-level technology requirements (user pull), and the technology requirements related to 'technology push'.

The European Space Technology Harmonisation effort, mandated by the 2001 ESA Ministerial Council in Edimburgh, is designed to achieve better coordinated space technology R&D activities among all European actors, with the 'filling of strategic gaps' and the 'minimising of unnecessary duplications' as major objectives. Based on voluntary participation and two review cycles per year, the process is strongly supported by all stakeholders and recognised by the European Commission White Paper as a leading instrument for space technology in Europe.

The ESTMP (European Space Technology Master Plan) is another key element of the overall ESA driven European effort towards coordination and harmonisation of space technology. After four releases, the first of which was in 2002, the 2005 edition of the ESTMP provides stakeholders with the most comprehensive single source of information on space technology in Europe, reporting on the latest developments and defining roadmaps for future action, and reflecting the new ESA Technology End-to-End Process. In this way, each member state and industry will share the same appreciation of the situation within each field of technology and will be able to decide on where to invest in full knowledge of the facts[11].

- *The development of PPP schemes*

In innovation-related activities, ''public/private partnership'' generally refers to any innovation-based relationship whereby public and private actors jointly devote financial, research, human and infrastructure resources, either directly or in kind (OECD, 1998). A

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[9] One famous example is the Mosfet, a key component of all satellite only produced by one US company. First deliveries of qualified EU-based components are expected during the fourth quarter of 2006.

[10] It led to the creation of a new Technology line known as 'NewPro', based on spinin and dual-used technologies, see Part III

[11] Particular attention is also given to ESA-EC cooperation and to the European Space Technology Platform (ESTP).

more resticted definition, focused on infrastructure development and operation, lead to consider the PPP concept of financing, provision of services, and operation as one in which the initial investment for development (the "D" of R&D) of a given infrastructure is largely or only made by the public sector generally on the basis of technology/know-how available in public bodies. The private sector then manages and increasingly finances the operational phase of the infrastructure, ie deployment, implementation and commercialisation. This second phase is generally operated through a concessionaire with equity assumed by private enterprises, while the infrastructure is generally still owned by public partner, the private one paying public authority back via licenses/royalties. Sharing of fundings and management (with increasing role of private side) is accompanied by agreements on objectives, on sharing of risk and responsabilities for the whole life-cycle of the insfrastructure, and on pooling any resources required by the project.

PPP scheme applies when the private partners can identify clear commercial interest in a mission, but investment and risk are too high to be supported only by private fundings. Public partners should also identify clear social and strategic interest in the same mission, including fulfilling needs and legal role of public authorities. PPP scheme should then enable to generate both types of benefits durabily. In parallel, funding scheme allows to align fundings with the time frame adopted by funding body: long term for development activities, shorter term for deployment and operations. It is also a way to solve the lack of funds related to budgtary constraints faced by any government. Advantages for the private sector due to private financing in the second phase is the access to unlimited availability of capital in the private sector, and the focus on market-driven performance of the management of the activities.

Firms generally see two potential difficulties when engaging in such partnership: concerns about profitability, technology and market risk, and concerns regarding interference from the public sector, since public institutions are subsidizing the endeavor and are regulating the firm and its activity. Public side carefully seeks to avoid any excessive privatisation of benefits, hampering the society to benefit from the mission. One of the consequences is that partners need to formalize all aspects of the future activities and clearly state the sharing of risk. Thus generally, negotiations are about defining stages in which the party – whether private or public sector – best suited to bear each of the risks identified is determined.

Consortia forming the concessionaire could be made up of companies from all kind of sectors, such as for instance financial institutions and insurance groups, service providers, equipment manufacturers and users. They are thus in a position to use financial institutions of all kinds, such as the large public or private Investment Bank, institutional investors, investment banks, etc, and with the major groups providing services or supplying equipment.

Galileo, the European global satellite navigation system, is the largest example of PPP in European space field (ESA, 2006b; Siegel et al. 2003). When fully deployed, the system will consist of a constellation of 30 satellites, together with associated infrastructure on the ground. Although capable of operating autonomously, Galileo has been designed to be compatible and interoperable with both the US global positioning system (GPS) and Russian Glonass systems. But Galileo will make Europe independent from the US military GPS in this strategically important technological field. The total cost is evaluated to be in the range of 3.4 (2004 evaluation) to 3.7 billion euro. To date Galileo is the biggest and first Public-Private Partnership (PPP) attempted within the European Union (EU). In line with the PPP rationale, the reason that the Galileo founders (ESA/EU) decided to use this form of cooperation is that the program offers commercial opportunities for the private sector as well as large social benefits.

After an initial definition stage already completed, the program is divided into the following three phases: development and in-orbit validation, deployment, and commercialization. The system will be developed and built with European public funds, facilitated through a "public-public" partnership between ESA and EC. The second stage, which is principle is of lower risk, will be partly financed with private funds. This will require that partnership turns to a public-private partnership, notably including Galileo's key prime contractors which will hold equity in the resulting enterprise. This organizational structure is novel also because not only the 'private' part of the partnership is comprised of more than one entity, but also the 'public' part.

The development and in-orbit validation phase covers the detailed definition and subsequent manufacture of the various system components: satellites, ground components, user receivers[12]. It is co-funded by the EU and the ESA for total cost of EUR 1.5 billion. It is managed by the GALILEO Joint Undertaking (GJU), a special legal entity with the EC (representing the EU) and the ESA as founding members. The GJU ensures the management of the development phase of the programme, prepares the market for Galileo applications and services, and prepares the management of the deployment and operational phases. ESA, EC and the GJU are actually managing the development phase through EC FP6 and 7 Calls, and the ESA procurement, using the specific EC and ESA rules, respectively.

As for the deployement and commercialisation phase, a concession structure will provide for a clear legal relationship between the public sector and a new private sector company formed to deploy and operate the GALILEO system. The concessionaire will normally be choosen in beginning of 2007. Two thirds of the deployment costs will normally be financed by the concessionaire. For the deployment phase, the Commission will also make provision for partial funding from the Community budget. For the operational phase starting in 2008-2010, gradually decreasing public funding is anticipated until 2015; this will be an advance from the Community budget and not a subsidy, since it may be offset by the operator's revenues. The concessionaire will be choosed on the basis of the EC public service requirements defined by the EC (quality, availability, integrity and continuity of the services, safety requirements, etc.). Until 31 December 2006, this phase is managed by the GJU, and after 1 January 2007, the European GNSS (Global Navigation Satellite System) Supervisory Authority, a Community agency set up by Council Regulation, will take over from the GJU and complete the implementation of this phase. This entails awarding a private organisation exclusive rights to the use of the infrastructure for a period of 20 years. The infrastructure remains in public ownership, as the system is owned by the European GNSS Supervisory Authority, which signs the concession contract and acts as licensing authority.

The deployment phase covers the years 2009 and 2010 and the commercial one effectively commences at the end of 2010, at a time when the entire system should be up and running. Maintenance and replenishment of the infrastructure over 20 years also comes into play. The Galileo Supervisory Authority will regulate and supervise some of the activities of the Galileo PPP, since Galileo will also draw on public funds and impact fields of public relevance.

The Galileo management structure and the PPP are good examples of how a supranational organization (EC), an intergovernmental institution (ESA), and the private sector can work together to complete a mission. One of the most striking feature of Galileo project is that the European Commission (EC) and the European Space Agency (ESA) have agreed to share equity/ownership with European space firms, service providers, and financial institutions.

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[12] Galileo industries GmbH, a European company established in 2000 as a joint venture of leading European space companies, has already been awarded the contract for the first four satellites for an amount of 950 million euro paid in equal shares by ESA and EC.

Japanese cases provide two other contrasting examples of PPP schemes.

The first case, most problematic, is the *QZSS – Quasi-Zenith Satellite System* (Suzuki, 2006; Kallender, 2004). This three-satellites system, of a cost of approx. 100 billion yen, is intended to provide enhanced-accuracy GPS navigation signals and other paid services such as high-data-rate mobile communications. The necessity for the new advanced augmentation system came from the spread of civil uses of GPS services in car navigation (mainly), aviation, marine, etc, Japan being of the leading markets in a lot of these fields. This programme was first discussed in the Keidanren and the Society of Japanese Aeropsace Companies (SJAC), and they lobied MEXT and other related ministries to this end. Finally, the QZSS project was approved in CSTP, thanks to METI's promotion, and MEXT had to support and finance the R&D for this project. Four ministries were involved in the project. The government has agreed to provide 180 billion yen over 10 years to operate the system as a public service, but did not assign that responsibility to any particular ministry. As an intended recipient, a commercial venture called Advanced Space Satellite Business Corporation (ASBC) was established in 2001 under the joint stakes of six major firms (of which MELCO and NTS) plus more than 70 aerospace, broadcasting, telecommunications and automobile companies. In 2003, the four ministries jointly took action for funding for the development of Quasi-Zenith Satellite System (QZSS). But in 2004, the CSTP was not able to ensure interministerial coordination as for the funding follow up. Each ministry maintained its own policy logic for approving the programme but none of them wanted to take the lead and to commit to operating the QZSS system once it is deployed because they feared that the cost would consume funding for other space programs. The ASBC partners were ready to invest their (relatively low, 5 billion-yen, ie $47 million) share for the design and the related infrastructure. But facing the uncertainty about the ministries' decision, the industry consortium has refused to commit its share of the funding.

Whereas the solution could have been provided by either top-down or bottom-up processes, none of the ministries feel they have the formal authority or responsibility to make a decison, and the PM cabinet office did not really push them to find an agreement. The project has then been delayed by this disagreement over funding, setting back the original 2008 launch date until at least Q1 2009. Finally, the JAXA announced that it would fund the first of three QZSS satellites. But a deal has still to be reached on respective funding shares for the second and third QZSS satellites.

Another Japanese example is the *Galaxy Express (GX)* project (Sato et al., 2006). It was initiated by Ishikawajima-Harima Heavy Industry (IHI), which acquired solid booster launch technology from Nissan Motors. The aim was to realize low cost, highly reliable, and environmental friendly rocket system by integrating already established technologies (US and Russian technologies for the 1st stage, existing key components such as avionics, fairing, payload adapters, etc) and LNG (liquid natural gas) technologies. Thus, IHI proposed the new GX project to keep on utilizing its expertise in system engineering for launcher construction[13]. One objective was to avoid long and expensive public base development as Japanese space sector was used to carry out. Commercial business cannot afford such approach anymore and the aim was that the GX development was performed in the most effective way, with minimum development cost, and in a shortest development period. But IHI managers were aware of the limitations of the market size for medium-sized launchers, and thus they invited Lockheed Martin either be major stakeholders, to supply some technologies and to get access to US launching market. They also convince the government to

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[13] IHI was concerned about the future of its technological capability to assemble complex rocket system, because of the uncertainty about the future of the M-V rocket programme for which IHI was the prime contractor. The procurement value of M-V was very low but was important for IHI to keep ahead this technology field.

proceed under the framework of PPP. The project was approved at CSTP level, again with support from METI, and MEXT had to support and finance the R&D for upper stage technology.

Following PPP logic, a new company was set up for handling over the private part. GALEX (Galaxy Express Corporation) was formed in 2001, by seven major Japanese space related industries with Ishikawajima-Harima Heavy Industries Co., Ltd. (IHI) as the main shareholder. GALEX was formed to represent the industries in order to perform GX development and marketing of GX launch services after the development is over. Basically the Japanese Government is responsible for developing necessary new technology, industries are responsible for total system integration development plus adaptation of existing ones as well as the development of GX unique facilities, and GX launch is in charge of services business. The first commercial launches are supposed to start in FY2007-08. About 2/3 each of total development cost is shared by MEXT and METI by granting R&D contracts to GALEX (even if MEXT gradually withdrew its support for GX because of budgetary constraints). The remaining 1/3 of total development cost is secured by the industries, more precisely by banking groups that provides this financial support to GALEX with the guarantee letters issued by major shareholders. GALEX is issuing necessary subcontracts to each shareholder.

III The interactions between space and the other sectors

A Spinin, spinoff, dual development: changing rationales about space's role in technology development

It is first important to precisely define the different type of "knowledge interactions" between space and the other sectors. In a limited and standard sense of the term, the term *spinoff* refers to transfers of knowledge developed in one context (here space sector) to other sector. Knowledge encompasses here various forms, from scientific inventions to technology described in a patent or embodied in a product, a prototype, a production pilot or any device, from industrial methods to blueprints, problem-solving methods, workers' know-how, etc[14]. There is often a combination of knowledge (typically product + patent + process + know-how) which is transmitted, and more or less important modifications are then required of the knowledge itself to be adapted to the the non-space environment; spinoff is thus an innovation process. There could be "internal" spinoff (within the same department or same firm or same group) and "external" transfer (between two different entities).

In a broader sense of the term, *spinoff* (from the space sector) refers to useful and unexpected result (in other sectors) produced in addition to the intended result in the sector of origin. It thus cover a larger scope of phenomena, including not only the ones mentionned above but also creation of standard, norms, management methods (quality, project), modes of organization, network of collaboration, image and marketing references, or even teams of people owning some complementary skills, knowledge and way of working together. In this perspective, space activities can bee seen as creating two types of infrastructure: a "physical" one (launchers site, ISS, satellites system, etc) that can be exploited for applications, and a

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[14] According to some slight variations of the definition, spinoff may only concern cases in which there is the creation of a specific new company hosting and exploiting the knowledge, or cases in which only artefacts or "codified" knowledge (eg scientific models, patent) is transferred and used as such in other context, or when transfers are only between two firms. A synonym may be Technology Transfer depending on how one defines what "technology" is.

"intangible" one, whose exploitation for non-space activities is what is called spinoff.

Conversely, *spinin* (to the space sector) refers to the same phenomenon but in the other way round, with a limited sense or a broader one (ie a useful result obtained in the space sector from developments done in other sectors). *Dual-Use Technology* is a technology used or created in two or more different fields of application (ex: space and defense).

It has been argued that the direction of transfers has progressively shift along the history of space activities. This shift is strongly connected with a change in the rationale for justifying public expenditures in space activities (Cohendet, 2006). As already mentionned, space activities have initially relied to a large extent on technology coming from defense and aeronautics, especially in the field of launchers (Ordway, 2007). This corresponds to a *first spinin phase, roughly in the 50s and part of the 60s*. The main rationale for space activities was related to independance, prestige and competition in a cold war context, and thus use of technologies from defense related activities pursuing more or less the same goals was quite coherent (although the assumed peaceful purpose of space activities was source of paradox and ambiguity). As space sector grew, developed its own technological trajectories and its own "knowledge base", spinoff started to develop and attracted the attention. Then a *second phase (a spinoff phase) could be observed from the 60s to the 80s*. Regardless of their real economic value (see below), spinoff was particularly important because they were contributing to justify space expenditures, beyond the classical argument of independance and prestige. A turning point was the post-Appolo situation, in which US taxpayers and policy-makers started to question the huge amount of resources devoted to space once the competition against the Russian (behind the "new frontier" moto) was considered as won. Spinoff were associated to economic returns for the whole society, and this argument has extensively been used to various extent by different public bodies in charge of space activities, as well as by companies strategy-makers. For instance, it has been prevalent in all the Japanese space policy history as well as in the Japanese companies rationale for investing in space.

The recent period has shown a more balanced view over the actual and desirable direction of transfers. Since the 90s, a phase of "*Spin-in, with less emphasize on spin-off*" can be observed. This is in line with two of the arguments used to justify and defend space expenditures, taking the relay of the spinoff argument not sufficient as such. One is that this should be considered as a business as any other business and attract companies and commercial interest: using no-space genuine technologies may lower the entry cost of companies in the space business. A second is that space activities should tend to reach a better resources/performance and utility ratio, and using less costly and proven terrestrian-based technologies would be welcomed (see below for more details on this point). Indeed, it appears there is a growing concern about using existing terrestrial technologies but also *ground* products or elements of products for space purposes, needing only to *space qualify* them. This had already been the case for some electronic components for a long time, and it is also true for instrumentation dedicated to experiments in life or material sciences. In this respect, the obvious economic advantages of spinning-in are that duplication of effort is avoided, costs are lowered, conception and development cycles are shortened, and the leading-edge technologies may be used by the space programs (Caffrey et al., 2002; Crute, 2003; McDermott, 2002).

Among the various factors that can explain such evolution, the nature of the space technologies and its mode of development are central (Withney, 2000). As reminded by Lionnet (2006), space technologies exhibit such peculiar charcteristics as robustness in extreme physical conditions related to the launch environment (vibration, noise…) and to the space environment (radiations, extreme heat/cold, vacuum), reliability and autonomy (servicing on location is seldom possible and is always expensive), or need of power and mass efficiency (for putting hardware into space, and for operating it).

After the first phase of emergence of the space industry, the second phase was the occasion to develop leading edge technologies that were at the origin of spin-offs in many areas where space and current industrial or even social needs overlaped (miniaturization - size and weight -, energy savings, resistance to hostile environment, information processing, and knowledge of materials at microscopic or atomic level). Space activities had a specific role in integrating and interfacing technologies coming from different origins, and new technologies dealing with the integration requirements were really specifically generated by space activities. These interfacing/integrating technologies become ideal candidates for spinoffs. In addition, lifetime of space products was not so different that average lifetime of products of other sectors, which facilitate the synchronization of developments.

But it is important to note that they were not only "pure" spinoff, ie single direction transfer. In a lot of instance, a carefull attention reveals that one should rather talk about spinin/spinoff processes. The extreme conditions in which spacecraft must operate often lead to an improvement in the performance of the technologies on which they are based. Correspondingly, these extreme conditions require a very detailed and fundamental knowledge of the properties of these technologies and of their real potential for use. For this purpose, specific scientific research work and very often new testing operations are required (based on adapted facilities and procedures), both turning into new sources of future spinoffs. Therefore, technologies imported from other sectors can be first tested (pioneer use for space applications) and/or upgraded and better controlled thanks to their use by the space sector, and then come back for larger or more efficient ground applications.

One could also wonder why the spinoff stream seemed to run dry in the third period. The fade of space novelty (given also the less revolutionary and pionneer programme developed in the space area), an access to space still very expensive as compared to the declines of price of other high-tech, the fact that the lower level of globalization of space industries than other sectors may have slow down the process of circulation of technology could be argued.

But another line of argument is also related to the evolution of the *fit* of space requirements to societal and industrial needs, and the rhythm of innovation. The problem is that at present, needs such as miniaturization is generalized in society and other sectors are ahead of space activities in providing answers (consumer electronics, information technologies). The other trend affecting the potential for spinoffs is the dramatic speed of the innovation cycle in industry in general. The development cycle and lifetime of standard product sharply decrease at a rythm largely superior to the one of the space product and technologies. And when technological development is very rapid, the spinin/spinoff processes becomes very time-consuming. For instance, in microgravity experimentation, time to experiment (especially if there are delays, or not enough continuity), interpret the results and transfer is sometimes too long compared to parallel terrestrial development. Furthermore, some firms also claim that space technologies are really not at the cutting-edge of technological progress anymore. Then the question arises of the possibility of the *innovation cycle* of space activities to be in phase with the *innovation cycles* of the non-space sectors.

Does it mean that space spinoff is not possible anymore? Not at all. Success of adapting policies towards spinoff shows it, as it will be detailed below. Some examples also clearly show that where a *fit* still exists, the combination of different types of knowledge (scientific and technological) for space applications makes firms able to proceed very successfully. Spinoffs from manned space and microgravity activities (especially medical and material science) may give some hints. For instance, the need for medical diagnoses and tele-surgery, which could have significant impact on tele-medecine; the need to monitor experiments in confined, sterilized and fully controlled environments; the need to model and simulate experimental results; the ergonomics of specific medical instruments to match the problem of scarcity of resources (time, room, information systems, etc.) during space activities. There is a growing need for very fast-shared time data acquisition and handling from multiple sources, and for very light, robust, reliable and easy-to-operate experimental devices. This is in line with the growing tendency to use autonomous, reliable and user-friendly designed medical devices for diagnosis and monitoring of patients, sometimes with a capacity of automatic analysis and/or diagnosis (e.g., emergency unit, at-home treatment of patients).

If we now turn to others type of spinoff and spinin, we can see a similar situation. There is strong evidence that, in the first period of space programs, space activities were at the leading-edge of progress in that field (notably by importing methods from defense-related activities, another aspect of the first spinin period mentioned above). But then in parallel to the technology-based spinoff phenomenon, new methods of managing large, complex projects were also sources of spinoff for the rest of the industry. Despite being much more oriented towards project and prototype development than towards mass production, *space methods* were sufficiently ahead to be used out of the *space context* in conception activities (design specifications, design review), in other big projects (specifications for hierarchically-organized consortia), in production activities (quality control/management methods), in day-to-day management (informal skills bout how to interact with teams from other cultures, how to conduct successful meetings and the like), in any project (PERT methods, planning, monitoring and evaluation of human, technical, financial and time resources), etc.

In the second phase, space firms had already learned organization, methods and process management and there were only a few new firms involved. But in parallel, other sectors (automotive and consumer electronics in particular) have dramatically improved their capacity to manage the processes. The space sector has neither been the leader in the evolution of quality management systems towards quality assurance, ISO 9000-type certification and Total Quality Management, nor it is in just-in-time and lean production systems, new Cost and Value management (activity-based management, added-value chain perspective, etc.), process reingineering, concurrent or *overlap* engineering and so on. In other words, mass production industries have been able to turn to smaller series and flexibility of answers to the changes in demand or market conditions, while keeping some advantages of the *old* industrial system (reliability and cost control). At the other extreme, large public space programs (smallest series possible -prototype- and best adaptation to *clients* who themselves define the product they want) have not really been able to respond in a similar manner. This phenomenon was particularly prevalent during the 1980’s, when one of the most important barriers to transfer space knowledge to *terrestrial* products was the lack of ability of space firms to switch from costly prototype performance-optimizing to cheap larger series cost-optimizing ways (Bach et al., 1992). At that time, it seemed that both spinin and spinoff roads were cut.

More recently, the space industry has increasingly tried to learn from methods and organization principles used in other sectors (Ariane commercial series is a case in point), while these latter sectors keep on innovating very fast (for instance, through the possibilities opened by new information systems). Thus a spinin process is observable, even if it is mainly true for commercial space activities. But what about methods used in large public programs? Some recently interviewed firms gave contrasting answers: some seemed to learn a lot from their involvement in ESA programs (especially in terms of collaborating in small complex projects, in terms of ability to contract with other partners (specifications, scheduling and risk forecasting) and in terms of quality management; some others considered space programs as *exotic* when compared to standard industrial methods (lack of flexibility of the projects, bureaucracy, costly way of working). The fact that the first category of firms were mainly new firms (whereas the second were mainly rather well-established firms) suggests that some progress has to occur, hoping that the former firms will not only learn what is considered by the latter ones as "bad industrial habits". This could prevent them from later diversifying even towards space commercial markets.

However, there is a general trend in the industry towards organizing activities as projects, coupled with a process-oriented thinking. Is (or would) it be possible for other sectors to be still inspired by methods or principles developed from space programs? The question is open, but some very big European firms tend to claim that small highly cooperative international research projects, with limited budgets, objectives well defined in advance (such as microgravity experiments), and interaction with scientists, are a source of method learning for other non-space projects of the same type. Another potential source, although more hypothetical, could be the organizational devices and management tools that will be used to couple a large, public international and long-term oriented project of infrastructure (International Space Station is the best example) with small, mainly private and short-term projects of infrastructure utilization. This could constitute a basis for a new model for the organization of large public–private R&D programs, and also for training firms to work in even more complex situations with public–private interactions, long term and short-term perspectives, sharing of resources, and international relationships (Bach et al., 2002).

In this global picture of spinin and spinoff between space and other sector, it is difficult to assess the relative important of dual technology (Giget, 1996). Pure dual development is probably rather seldom, at least for technologies and for product that will be on-board, because of the specificity of the space qualification requirements. It is probably another question as regards the ground segment, but in this domain, it is difficult to draw a precise line between space and non-space sectors. An ambiguity arises with the development of defense-related space applications. It is more and more frequent that space system, product, technology can alternatively be used for non-defense and defense purpose. Could one talk about dual technology in this perspective? If yes, then there is surely a growing tendancy towards dual technology development.

B Overview of the main studies on spinoff

- *Economic aspects*

Many studies have been carried out aiming at looking at different dimension of the economic aspects of spinoff, mainly the spinoff following the "narrow" sense defined above. Most of these studies have tried to identify and evaluated the economic value of these spinoffs, and sometimes also the benefits for the rest of the society. Some of the studies complemented the evaluation-oriented approach by trying to identify different factors of facilitating or hampering spinoffs[15].

Different economic approaches have been used, and the scope of the evaluations also differed. Some studies aimed at evaluating the performance or impact of specific policies towards spinoff (such as dedicated lines of programmes or the creation of Technology Transfer Offices by space agencies). For instance they tried to identifiy the use and economic impact of technologies listed in technology catalogue released by TTOs, or made available on data base,

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[15] For an extensive overview in different countries, see for instance the special issue of Journal of Technology Transfer, issue 27, 2002.

or registred as agencies' patent (DRI, 72; Mathematica 75). Other studies use a list of technologies effectively transferred through TTOs and tried to evaluate the economic benefit of these transfers (Chapman, 1989); other focused on a limited number of these technologies (as Mathtech (1977) which studied the well-known case of pacemakers). Other studies focus on specific technolocal fields and/or specific space activities and programmes, and tried to gather through any mean possible (experts, literature, industrial survey's etc) information on "success stories" and evaluate some of them. Studies of spinoff from life science and microgravity activities are good examples (NOVESPACE, 2000; Seiber, 2001; Hertzfeld, 2002).

In order to avoid the criticism of "only picking the winner", a much broader view was adopted by other studies. Some of these considered a specific type of knowledge originated from space and tried to identify subsequent use of this knowledge. For instance, Schmoch and al. (1991) looked at all patent originated from space activities and identified patent refering to these "space patents", as an "objective" measure of space technology spinoff (then an economic appraisal of the use of those patents was also conducted with more classical tools)[16]. Finally some other studies tried to encompass all transfers regardless of the institutional support provided to the spinoff and whatever channel it tooks. Probably the most comprehensive studies of that type were conducted by the BETA research team that had a unique opportunity, through a series of studies that started at the end of the 1970's, to measure the spin-offs and technological transfers that resulted from the European programs in space (Bach et al., 1992; Bach et al. 2002). This approach was also adapted and applied in the case of one Brazilian space programme (Furtado et al., 2003).

Beyond the refinements and the specificities of each approach and each study, the main results they have in common are quite simple to summarize. First, the existence of spinoff from space activities is undoubteldy ascertained. The importance of the spin-off phenomenon was clear in qualitative as well as in monetary terms, attested by the figures of technological effects in BETA studies or figures provided by other studies (see for instance Hertzfeld, 1992; Bach *et al.*, 1992 or Winthrop et al. 2002). It was true for product technologies as well as production technologies (with a particular emphasis on test facilities for the latter). In some case, the economic value can be very high, but in the spinoff game, there are only a few "nuggets winner" and a lot of "small winners", ie the distribution of gains is very asymetric. In most studies using cost-benefit oriented approach, the ratio benefit/cost is broadly speaking superior to one, which indicate a certain level of rentability of the spinoff operation. However, this should be taken very cautiosly, since the benefits can be distributed between involved actors (space company, "receiver" of spinoff, partners to spinoff operation, space agency, clients, general public…) according to very different patterns. Similarly, cost can be alternatively seen as the cost of space activities generating something to be transfered, the cost of the transfer itself, or the cost of public action supporting transfer (or a combination of elements of these different costs), which also induce different patterns as for rentability. But there is no proof of any link (positive or negative) between the level of public support to spinoff and the level of rentability for any of the actors mentionned above. Another very important conclusion of these studies is that there is absolutely no way to justify the rentability of space programme or its social impact by the *sole argument* of the economic value of spinoff. But indeed, spinoff contributes to the justification of space activities. Understanding this was an important turning point for the search of rationale for space activities two decades ago. To some extent, it also showed the maturity of the industrial

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[16] It seems that no attempt of this type has been conducted on an extensive scale as for space-related scientific or technical publications and subsequent citations.

development of a sector, which had not anymore to demonstrate its economic value by the sole interactions it has with other ones.

More generally, these studies also suggested or confirmed three hypotheses about spinin and spinoff:

- The spin-in and spin-off phenomena may in some instances be interconnected, with a technology spinning in first and later spinning off.
- Technologies are never transferred from another sector and used as such: they are always modified, adapted, enhanced, possibly generating other potential transfers, and also mixed up with other pieces of knowledge in a dynamic way. This confirms that transferred technology is not fixed and defined once and for all, but evolving and adapting.
- There are probably much more spinoff within companies or within groups than between companies. But the first are obviously more difficult to identify and to measure in economic terms; and at least at first sight, the benefit of those spinoff are mainly for these companies that are able to achieve such transfers.

Finally, a last important output from all these economic studies on spinoff was the detailed understanding of the factors that favour or hamper the generation of spinoff, beyond the ones related to the characteristics of the technology in itself (Goehlich, 2005). This is briefly summarized below.

- *Factors facilitating/hampering spinoff*

Specificity of space technologies and some consequences on the existence of spinoff (and spinin) have already been pinpointed. One difficulty that some of these specificites raised is the sometimes too high complexity and sophistication of the products, device or components that are derived from them. To some extent, they are overqualified for most of standard terrestrial. This "overquality" is frequently combined with high cost, caused by the technology itself or by the cost of development to be amortized (including high salarial cost with high level of overhead associated with R&D intensive work necessary for these development). Then either space-born products or more broadly space technology is not adapted for mass production, or they are limited to very narrow applications. In both cases, sufficient level of profitability of spinoff operations is difficult to obtain. In addition, spinoff is more frequent in case of generic technologies (eg microelectronics) as compared to specific technologies. But space technology are very often quite specific and more seldom of a generic nature.

Technological proximity between space sector and "receiving" sector is also a key factor, as well as the diversity of technology portfolio of receiving companies. Generally speaking, there are more spinoff from space to "close" sectors such as defense, aeronautics or telecom than with other sectors. This is also due to the fact that companies working in both fields are a priori more able to generate such internal spinoff. It can be noted that these spinoff are not necessarily the ones that are the most often and largely mediatized; they are probably less spectacular and more "modest" taken one by one than the frequently cited example of teflon, space suit, kidney lithothriper or carbon brakes, to mention but a few "hits" spinoff. But their frequency and pervasive nature make them a very important component of the spinoff landscape, and only deep investigation allow to identify them and show their importance. For instance, the BETA 1988 study on spinoff from ESA bring out results on this issue that clearly confirmed three points. A lot of spinoff is internal to firms. The "generic" space technologies are the ones at the origin of the higher share of the spinoff value (on-board electronics with 31%, production/testing equipment with 20% or power supply and storage with 12%) as compared to "specific" space technologies (thermal control, attitude and orbit control or optics, with 2% or less each). And spinoff to aeronautics and defense were largely dominating the other ones (around 30% for each, far ahead data processing, electronic equipment or even telecom, with around 7-8% each).

Another series of factors influencing the type and the level of spinoff of space companies is the level of responsability and more generally the position of firms in the industrial network or consortia set up for achieving space programmes. It has been shown that this position has an impact on the technological specialization of firms, and consequently on the spinoff capability. For instance, prime will tend to develop integration technologies or project management skills and made spinoff of them; components suppliers will tend to make spinoff at the product or process technlogical level, etc.

The existence of firm's internal policy for identifying and supporting spinoff process is also a key point; but it requires adopting an organizational structure and mode of management favourable to stimulate transfers. Cross-fonctional teams, sharing and exchange of knowledge, organization of formal as well as informal relationships between staff and teams within companies are but a few examples of possible ways. This is mainly true to internal spinoff.

Spinoff between firms corresponds to different situations. It could be a one to one relationship in which space companies supply technology to another non-space companies, or a situation in which one space company tries to enter non-space markets with the help of other companies that will be associated to the spinoff process itself and or to the exploitation of the result of this process. In any case, complementary skills are necessary to perform such spinoff operation. Obviously, scientific and technological knowledge is not enough, and competences in project management, funds seeking, business plan design, production etc are also indispensable. But maybe the key point is often the marketing capabilities and the knowledge about consumers needs and distribution channels in the receiving sector. This especially true when this sector is very specific or "far" from the space one.

As regards spinin, the difficulty of the space qualification step has already been underlined. But the spinin process is very often effective if there is an involvement of the non-space specialized firms in the spinin phase, which means that it is not only a matter of taking a product from the shelf: spinin is associated to renewal of the "club" of space companies. Policies to attract non-space firms in the space business can be designed for this purpose (see below).

Finally, it is obvious that classical factors affecting any transfer are also at stake in the case of space spinoff: availability of relevant type of financing at each step of spinoff or spinin processes, fight against Not Invented Here syndrom on the part of the receiving side, and relevant IPR scheme garanteing exploitation for the mutual benefits of the parties involved.

C Companies strategies

- *Marginal or key role of space in large companies?*

In large companies or groups, the question of strategies regarding spinin and spinoff has to be relied to the one of the relations between space and non-space activities.

The evolution of the scope of activities of the main companies active in the space industry is almost always the same: it starts from a small team within the sector that spinin to space (defense, aeronautics or any sub-division of these activities, such as structure, on-board equipment, propulsion, advanced materials or the like). Then progressively space activities grow and gain autonomy. The team generally becomes a department or a division, then a business unit, finally a branch or a subsidiary, with less and less connections with other part of their mother group (be it as regards technology, production or network of suppliers).

If one look at the evolution of the space industry structure, it appears that it is merely when the division level has been reached that space activities have been subject to merger and acquisition. But in most of the cases of major restructuration, recomposition of space activities were in part an induced effect of recomposition strategically designed as for connected activities, again defense, aeronautics or telecom. The case of EADS and forming companies (for instance, at different steps of the history, Aerospatiale, Matra, MBB, DASA, CASA) clearly showed that Airbus and defense related activities were largely leading the concentration movement. It is only in launchers and telecom satellites activities (and probably recently in navigation and space defense) that space was considered at the highest level of business strategy. Recent examples at stake are Alcatel and Nissan Motors; both firms clearly subordinated their decision as regards space activities to decision concerning their main business activities. It confirms that for the largest companies involved in space business, space activities are seldom the group core business.

Correspondingly, it seems that in large companies, spinoff and spinin have more or less followed the evolution of the position of space activities. Spinin was first, when small space team benefited from its technological environment, possible internal spinoff came after when space activities gain autonomy but kept being strongly connected to other technological development. Space activities as a source of spinoff was strongly advocated at this stage. In the 70s and early 80s, large companies such as Aerospatiale or Dornier largely mediatized spinoff cases, which had a preeminent place in annual reports for instance. Other companies clearly adopted organization and modes of management for fostering spinoff generation and exploitation. In the 80s, as spinin started to come back on the scene, such interactions were still fashionable. When MBB joined Daimler in the mid80s, one argument was the technological proximity between activities as for materials, flow (information, fluids, etc) management, and the possibility to import modes of industrial management in space activities for enhancing the production performance and reduce development and production time.

Then as space division or business unit grew, in most large companies it became less and less interconnected with other business units, and knowledge flows decreased or became channeled through conventional corporate lab or RD-business unit RD type of relations. The logic of business unit autonomisation became prevalent to a logic of technology cross-fertilization. One consequence is that in the recent period, spinin is probably mainly between firms rather than internal to firms, which makes a big difference with the former period.

- *Differenciated strategies: is there a specific role for SMEs ?*

Nowadays, it seems that as regards spinoff and spinin, firms involved in space programs have two winning strategies and a loosing one:

(i) To concentrate on space activities, and try to couple institutional programs and space markets which together may form a profitable business. Many space divisions of big firms are doing this, neglecting more and more spinoff opportunities as not really worthwhile. Some small prime contractors and a limited number of smaller very specialized companies are also following this path. In this context, dual development may be an opportunity, but they are often limited to dual use of space technologies for defense and non-defense related activities. For instance, Alcatel Alenia Space and Thales have developped the Syracuse defense telecom satellite system, which partly based on dual technologies shared with Telecom 2 (at least for plateform). EADS has almost jointly developed Helios (defense) and Spot observation system family. Plateform developped by the UK SSTL are another case at stake.

(ii) To develop from the very beginning dual scientific or technological knowledge. This strategy requires a capacity to forecast future needs of potential users. This is clearly the strategy of most successful firms in terms of spinoffs. However, if knowledge is dual, it does not mean that technology and products are dual. For instance, when a technology or a product should be space-qualified, it will seldom be the same as the terrestrial one. Thus there is an unavoidable divergence of the innovation process at downstream level. Different cases in the instrumentation for medical use are particularly significant illustrations of this spinin/spinoff process at the product level, and some firms even build their strategy on it. This type of spinin/spinoff process (at product level) seems to be more and more prevalent, but it is different from the ones identified in earlier stages of space programmes, which took more time.

(iii) To keep on trying to develop technologies or products with only space requirements in mind, and later on (for instance when space activities are declining in the corresponding field of activities), trying to find possible terrestrial applications, with very few chances of success. This is not really a pro-active strategy, and it can be observed in the case of long-time being space agencies and institutional makets suppliers which heavily depend on those markets.

The capacity of a given firm to successfully implement strategy (ii) obviously depends on its ability to build up a common knowledge base between space activities and non-space activities (scope or variety of scientific and technological competences, teams of open-minded engineers with multidisciplinary culture and experience at scientific and technological levels). This is one component of the strategy. Two other components are crucial.

The first corresponds to the building of necessary knowledge about non-space markets. It is not only a matter of identifying potential uses for products or services derived from technology transfers which is problematic, but it seems to be the knowledge of how the markets are operating, of the formulation of an adequate pricing strategy, of the channels of distribution, of the relevant and leading prescriptors, and of the norms and legal aspects (cf example of spinoff in the medical sector). Finding the relevant market is also an important point. SMEs often claim that they have difficulty targeting markets with sufficient added value to be profitable, but not enough value to attract big firms. This may also allow avoiding situation in which the only receiver is sometimes a well-established firm with existing products in competition with the ones potentially derivable from technology transfers. This firm may freeze the technology transferred by buying it and promoting it only when existing products are on the decline or if the new product is significantly more profitable than the existing one.

The second is building a network of relevant partners covering the different aspects of the transfers (from manufacturers to distributors), knowing how to cooperate with them (contractual arrangements, IPR problems…), knowing where and how to get funds, etc seems to be crucial. In some technological fields, there are examples of networks based on common and stable rules set up by scientists and industrialists which successfully combine research and commercial exploitation adapted to market needs.

Recent studies have shown that in this context the SMEs may have special roles to play (Novespace, 2000; Bramshill, 2003; Morris, 1999; Sylos Labini, 2000). Some are good example of the strategy (ii) evoked above, either through dual development or through continuous and rapid spinin-spinoff loops (this is the case for instance of DAMEC/Innovision or Verhaert). Some others are important means of recent spinin activities. Part of those SMEs are involved in the use of ground–based technologies for onboard equipements or components. Entering the space sector could be as new source of revenues, but they have to face different problems related to the cost of entry in space business, the risk to become space business-dependant, the risk to be "rigidified" by the administrative/management constraints imposed by space activities, the risk that their technologies are taken over by large firms, etc. Others are involved in R&D and production activities, bringing in some capabilities developed in other fields. The role of these spining-in firms has to be put in perspective with the evolution of the suppliers' structure of large companies and the policies adopted by space agencies to attract new comers in space business (see elsewhere in this report). Finally, as spinoff field has been progressively given up by large companies, SMEs are nowadays the ones the most active. Space SMEs, non-space SMEs receptor of spinoff, SMEs facilitating spinoff by offering a range of complementary skills and services are now the building blocks of most of the spinoff occuring between firms. There is also the main target of spinoff policies set up by space agencies.

D Policy towards spinin and spinoff

The evolution of policies towards spinin and spinoff has logically accompanied the evolution of knowledge transfer described earlier. Initially fostering spinoff with the introduction of Technology Transfer offices or department, policies have been completed by various measures in favour of spinin. The policy tools have also evolved, benefiting from an increasing comprehension of the transfer mechanisms as well as the factors influencing them. Europe (and especially ESA) has probably more and earlier developed this type of tools than Japan but a large share of the tools used is common (also with the US).

\- *Technology Transfer Offices*

It has been long after the creation of the NASA Commercial Technology Program in the 60s that in 1990 ESA created is own spinoff programme, know as the TTP (Technology Transfer Programme) runned by the TTPO (Technology Transfer and Promotion Office), a special unit set up in ESA technical center ESTEC. The aim of ESA’s Technology Transfer Programme is basically threefold:

- To identify technologies with potential for non-space applications
- To ascertain the technological needs and requirements of the non-space sector
- To match available technologies with the non-space needs and subsequently provide assistance in the transfer process.

Interesting is that the ESA TTPO has mandated a network of technology broker companies (covering a large number of ESA member countries) to act as main actors of TTP actions. This ESA's Technology Transfer Network (TT Network), which is potentiallly renewable through regular call for tenders, is now composed of more than 10 European and Canadian service companies.

Classical tools have first been used to promote spinoff[17]. An inventory of available space technologies has been made and is regularly up-dated and made available through a on-line data base (Technology Forum website maintained by the TTN). Success stories were first publicized in catalogues (more or less the equivalent of NASA Spinoff) but it is not regularly issued. It rapidly appeared that a simple passive "technology broker" activities mainly on the supply side was not enough. Then action of the demand side has been engaged, with the aim of identifying industry needs. Massive survey was conducted, and then potential matching was identified. Other tools still in the spirit of technology brokerage have also been adopted. For instance, directely connecting people was a next step, that led to the organization of special events.

In parallel, a support to spinoff projects was also brought to candidate companies. The TTPO supports projects that adopt space technologies for non-space applications by providing funding, in partnership with others, for feasibility and pre-market studies. ESA's TTPO expects the parties involved to participate in a co-funding scheme, with a maximum ESA's TTPO contribution of 50%. Proposals for such funding normally include reasonably detailed aspects such as the description of how space technologies will be adapted for non-space uses, the identification of the potential market for the proposed new product or service, and the proposed funding scheme. In a context of scarce resources, the funding support has never been very important. But it has be completed by the possibility to use ESA facilities and expert services, and then by the help in finding the relevant partners bringing their complementary skills. The TTN was particularly mobilized for such help.

The experience of the TTP also showed that a lot of spinoff corresponded to the creation of new companies. Taking into account this need of supporting entrepreneurs and start-up companies transferring space technology into non-space sectors, ESA and EU took a further step and launched ESINET in 2002, the European Space Business Incubators’ Network. ESINET now consists of more than 35 incubators in different European countries, one of the ESINET founding member being the European Space Incubator (ESI) located near ESTEC. Each incubator can provide seed capital, offices, logistics support, professional business services and access to ESA expertise and laboratories; all crucial elements in the start-up process. It is worth to mention that although there are some connections with the EU in supporting spinoff (for instance as regards the ESINET, or when technology transfer can be co-funded by FP programme related to the receiving sector or field of application), there is no specific space spinoff policy on the part of the EU.

In Japan, despite the constant discourse of space actors putting emphasis on the importance of spinoff, Japanese polices towards those spinoff has never been as active and structured as the ESA one, not to mention the US one. Facilitate spinoff of the space-born technology was nevertheless one of the task assigned ot the "Industrial Collaboration Office" created in 2003. Recent actions seem to focus on the question of IPR, in connection with the evolution of Japanese law on public organisation patenting (Law Promoting Technology Transfer from Universities to Industry in 1998 or Intellectual Property Basic Law in 2004). JAXA's Industrial Collaboration Department has recently formed a special team to promote the use of intellectual property and licensing or cross-licensing to lead to further innovation.

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[17] Specific initiative have also been launched such as the Harsh Environement Initiative through which space technologies were transferred and applied to the oil and gas pipeline and mining sectors which operate in remote and harsh environments or Health Care Network (EHCN) officially launched in 2004 in order to develop, promote and commercialise solutions for healthcare and well-being derived from space research and development.

Considering that there is a lot of IP created through its own research and development activities, JAXA is performing an activity through "IP Program" to transfer JAXA’s IP such as patent right, copyright including software programs, remote sensing data, know-how to the aerospace field as well as other industrial fields. The list of JAXA’s IP together with various application ideas is for instance available on the open web-site. "Technology Transfer Program" is to mitigate risks and technical problems of development for the private companies, promoting practical use of JAXA’s IP. Under this program, JAXA helps private companies in RD for commercial products using JAXA’s IP. This program originally started in the former National Aerospace Laboratory (NAL) in 2002. Another measure provides help to JAXA employees incubate venture using JAXA IPs (JAXA venture support program, with assistance for licensing IP, establishing business foundation). In addition, another action of the Industrial Collaboration Department is also to promote the industry’s use of JAXA’s test facilities when not in use for JAXA purposes, for instance by providing the timely and appropriate information on availability.

- *The emergence of policies for attracting non-space companies*

As it has been largely explained elsewhere, there is a growing tendancy to spinin technologies from non-space sectors. ESA has develop different initiatives to foster this phenomenon, and by this means pursuing different goals: lower cost, shorten life-cycle, renew the club of contractors, bring in innovative and performant SMEs, and secure the supply of critical technologies, components or products with European suppliers (either to guarantee independance and avoid US regulations on exports). Thus, these initiatives have overlaping, are multi-form and are runned under different umbrella. Beside the Technology Master Plan and related actions that have already been exposed, a major line of actions is focused on SMEs. Some measures were already implemented in 1998, but the core was established in 1999 together with the set up of a dedicated unit at ESA HQ, the SME unit. Budgeting and financing of the SME Initiative is covered by the General Budget.

There are now a number of specific measures implemented, including some new ones added since the starting phase, but no necessarily formally included under the SME Initiative[18]. The main are the following.

*SMEs’ participation in the definition o*f ESA R&D programmes. The *SME subcontracting clause* encourages established European space companies, bidding as main contractors for ESA technology procurements, to include SMEs in their teams. Some programmes encourage SME to put forward new technologies/concepts that they already possess (*LET-SME* programme fully dedicated to SMEs, *ARCoP* programme for cooperation between SMEs and academic institutions).

Special treatment for SMEs in announcements of opportunity. A call for proposals is made each year, under the TRP, reserved for ‘non-Primes’. About 30% of this budget is reserved exclusively for SMEs, although they may also submit tenders within the remainder of the budget.

Training and technical assistance to SMEs. This consists of a package of courses that are reserved for SMEs, and held at ESTEC. Technical assistance can also be provided through access to specific ESA experts.

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[18] Part of them are similar to what the NASA is doing, two notable exceptions being the US mentor-protegee scheme and the wide use of all type of award system.

Preferential access to ESA facilities and laboratories. This measure facilitates access by SMEs to ESA laboratories and test facilities. Such access is provided at preferential rates, ie, less than full cost.

Improved information and possibility of networking for SMEs. The significant feature of this measure is the establishment of the ‘Industry Space Days’ forum, allowing briefing and meetings between ESA staff, large companies and SMEs. Other networking opportunities exist through the ESA Industry Website.

Improved supply of information. This goes with the creation of a specific “ESA industry homepage" on the ESA website notably including access to a SME data base containing information about expertise and capacities of hundreds European SMEs.

Procurement Actions are also influenced by the SME Initiative, such as *ARTES 5 Programme* in Telecom Programme, *General Study Programme* (in *Aurora* programme, dedicated to Exploration Missions) or *ISS*, which has a budget envelope for SMEs. Note that for supporting SME spinoff, there is a special budget reserved exclusively for SME tenders In addition to the support already available within the ESA TTP[19].

One of the most recent initiative was a joint action between ESA and EC (in FP6) launched in 2005 under the name of SINEQUANET (Space INtelligence, Engineering & QUAlity NETwork), intended to be a mechanism able to organise, structure and deliver access to technical facilities, expert support and training services for SMEs. Networking is thus the essential locus of this initiative, and it has started by extensive survey of expertise and technical capabilities available in Europe, gathering of opportunities for SME in space programmes and workshops.

Beyond support to SMEs, all sources of potential spinin are also targeted through other initiative. One is called the Innovation Triangle Initiative-ITI (launched in 2004). ITI supports the identification, validation and development of so-called disruptive space innovations based on new ideas or concepts, giving preference to innovations coming originally from non-space industrial or research sectors. The submitters of these ideas or concepts are supported by ITI with seed-money (from 50K€ to 150 K€), technical support and networking contacts aiming at combining the creativity, know-how and experience of the Research Community, Space Customers and Industry. ITI is based on a concept stating that collaboration of three different entities is crucial: a customer, a developer and an inventor Three types of contract activities are possible within the ITI, each type of actor being involved either through an individual contract or by being part of a team.:

- Proof of concept (for inventors): fast validation of new ideas and demonstration of its advantages.
- Demonstration of feasibility and use (for developers): component and/or breadboard development up to validation in laboratory
- Internal critical process review (for customers): internal review to identify products, processes or services that are potential candidates for innovation.

Another new initiative called NewPro that was launched in 2005 with three key objectives:

1. To ensure European independence in the critical technological capabilities required for space-based solutions.

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[19] But far from the extent it has taken under the US SBIR/STTR schemes.

2. To enable the use for space applications of multiple-use technologies, development of which is driven mainly from outside the space domain, through systematic spin-in.

3. To prepare the technological base for future civil security programmes and applications.

Conceived to be co-financed with the European Commission, a three-year interim period has been proposed for NewPro's implementation under the GSTP.

This review may give the impression of a quite fragmented and dispersed policy. But all of them are not of the same order of magnitude, and in total, the amount of resources devoted to this support to spinin is not very high. The main challenge is thus the coherence of these policies with the tendancy characterizing space market in general. If there is a sufficient level of coherence, then policy will accompanied and support the movement, but there could not be a driving force alone.

In Japan, NASDA had also launched in the early 2000s a programmme to attract SMEs in space business (Small Business Research Promotion Programme) and established the Small and Medium Business Research Promotion Office as a "bridge" between NASDA and Venture Enterprises. It does not seem that this policy has taken a great emphasis after the creation of JAXA (Uchitomi, 2004). But as spinoff, spinin was also a task assigned to the JAXA Industrial Collaboration Office. This is done mainly through the "Space Open Lab" initiative, whose aim is to facilitate access to the space activities, increase number and variety of players especially from non-space community and nurture promising projects. This is a system of incubation (virtual laboratory using website facilities) towards space oriented business with industry-university-public sector (ex. JAXA) collaboration. Through "Space Open Lab", JAXA is aiming at facilitating borderless collaboration to realize new business by accelerating exchange of information fostering spinin (as well as spinoff of the space technology). Various supports are offered such as technical advice, matching coordination for finding business partners. Additionally, JAXA may share the research cost in case of the selected research programs. Thanks to the "Space Open Lab", projects can be initiated though two ways. One is based on "blank proposal". After exchange of information on the website forum which is organized per theme, interested people form different horizons may be assisted by JAXA coordinators develop collaboration teams for specific space business, so called "unit". Then with non-disclosure agreement with JAXA, unit members may agree to start a detail study for the targeted business model, supported by JAXA's technical coordination. If a research proposal is selected by JAXA, the unit can implement its research as contractual research or joint research with JAXA. Other projects cover specific issue JAXA wants to overcome, based on the concept of "Space R&D venture programs" NASDA originally started in 1999. "Frontier theme" are announced at "Space Open Lab" website and participants can submit any solution proposal anytime, and they can be selected for contracted research or joint research with JAXA.

IV Industrial structures, industrial strategies

A Characteristics of the space industry in Europe: towards the Airbus model of monopoly ?

- *Structure of the European space industry*

According to various ESA and national sources, and depending on the perimeter retained, the turnover of the European space industry varies from 3 to 4 billion €, and it is formed of up to 2 000 companies employing up to 40 000 persons. However, the main yearly survey conducted on the European industry[20] reports that in 2005, the consolidated turnover of the European space industry is roughly equal to 4,5 billion €; it has showed a slight rebound in 2004 after a sharp and sudden fall in 2001-2003, but slowed down again in 2005 (see Figure 2). But it has not recover the 5,5 billion € peak level reached in 2001. According to the same source, total employement is about 28 000 employees and is almost continuously decreasing since the mid90s (when it was about 35 000 employees, that is 20% job-cut in one decade). In terms of size, these figures makes nevertheless the Europe the fourth power worlwide, after the US industry (which accounts for approx 20 billion $ and more than 100 000 employees, ie roughly 4 times as big as the European one) and the Russian and Chinese ones for which data are not fully comparable and reliable.

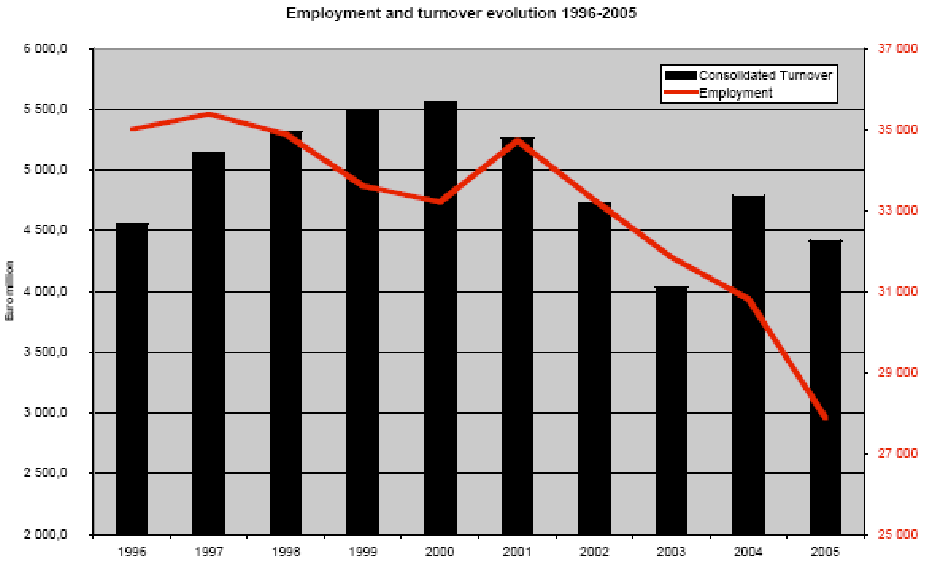

Figure 2 (© Eurospace, 2006)

The European space industry competes with the other large industries on all markets, and especially with the US on all GEO commercial markets, and with US and Russia on launcher market. To the difference with the US, its turnover is since the mid90s almost equally divided between institutional market (civil and defense related) and commercial market, whereas 80 to 90% of the business of US space manufacturing industry is derived from institutional programmes (NASA and DoD). Defense related turnover is especially far below the US level. This make the European space industry much more exposed to business cycle of the commercial market. Institutional market remained more or less stable in the last decade, while the commercial one has suffered from the sharp decline of the early 2000s from which the European space industry has not fully recovered yet.

There are different ways to present the structure of the industry. A first one is to look at the *geographical distribution* (Eurospace, 2006). With around 11 000 employees and turnover of

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[20] These data as well as a lot of other in this section are coming from the 2005 Eurospace annual survey (Eurospace, 2006b). It is the most comprehensive statistical source for the European space activities, for which answers were provided by 88 companies representing 91% of employment data and 94% of turnover. Missing answers were supplemented by publicly available information or using proxies from previous years replies (when available). The survey does not cover the satellite operators revenues (broadcast, telephony etc.), the consumer-end equipment design and manufacturing (satellite dishes, GPS handhelds etc.) and missile activities. Space subsidiaries in large industrial groups are all accounted for separately.

1,9 billion €, the French industry represents 40-45% of the total industry and dominates the European landscape. It has suffered the most from the slow down of space activities of 2001-2003. Germany, Italy and a bit behind UK are following with 0,5 to 0,7 billion € turnover and 3 400-4 400 staff each. A third group is formed of Spain and Belgium, with 0,1 to 0,2 billion € turnover and just below 1 000 staff; the industries from all the other European countries are well below 0,1 billion € turnover and 700 staff.

Size distribution of the companies provides a second approach. From this point of view, it is obvious that two players are dominating the landscape: EADS (European Aeronautic Defense and Space Company) and Alcatel Alenia Space[21], especially since it has integrated part of the space activities of Finmeccanica. Because of the leading role of France in space activities, the head quarters of those two groups are located in France, but both of them have space branches and production units in the three other leading countries (Germany, Italy, UK). This situation favours a good integration of the European industry, as underlined above. They amount together for more than 60% of space industry employment, if all their subsidiaries are summed up, and if we add the two other large groups involved in space (SAFRAN notably through SNECMA, and THALES, both French companies), this proportion goes up to 80%22. At the other end of the spectrum, there are quite a lot SMEs (from 5 to 10% of the total space industry turnover and employment), which are either specialized in very specific components, sub-contractors of other companies for manufacturing, engineering or services activities (especially software-related), or involved in downstream activities (remote sening, telecom, etc) (Bramshill, 2003). In between, co-exist a lot of companies spread across Europe that are for the most part rattached to medium-sized or large groups (Siemens, Sagem, Ericsson, RWE, Fuchs, etc). This situation is at large due to the ESA fair return policy that has ensured the existence of space activities in all member countries, and to the constant restructuration of European space industry. In many companies, space activities are regrouped in specific department. In other instance, it is centralised in division or business units or even externalized in a specialized subsidiary (EADS, Contraves,…). In some cases also, space units perform a share of defense related or telecom activities in a team or department connected to other fields and sometimes also active in these fields (EADS ST, Snecma propulsion solid, etc). In fewer cases, space activities are spread thourought the company without a specific unit (Thales).

A third usual way of describing the structure of the European space industry consists in taking into account the *level of responsability/capability of the companies*. This is inspired by the hierarchical breakdown of work usually put in place for large space programmes23. Obviously, firms are often acting at different levels, and may change level through time. In the following, firms are affected to one category only, and subsidiaries as well as sub-contracted activities are taken into account.

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[21] In 2005, Alcatel and Finmeccanica have their space activities and created two companies. Alcatel Alenia Space (under control of Alcatel) focus on space systems (estimated turnover of €1.8 billion, 7200 staff). Telespazio (under control of Finmeccanica) develop business in operations and satellite services (estimated turnover of €350 million, 1400 staff). In October 2006, the byout of Alcatel space activities by THALES was announced, but has not yet been approved by the DG Competition of the EC.

[22] If these subsidiaries are considered as separate space units, the 10 largest concentrated 64% of the total employment in 2004 (Lionnet, 2006) and the 20 largest space units three-quarter of the total employement in 2005 (Eurospace, 2005).

[23] On the top are the system integrators (often called Prime contractors), responsible for the overall design, integration and delivery of the system (launcher, satellite…) to the client. Then sub-system suppliers are in charge of sub-systems such as antennas, solid booster, solar generator, engine..... Equipment providers are the next category, delivering equipments and parts to be integrated at system and subsystem levels (solar cells, EEE components, valves, mechanical parts, onboard software ...). Finally, all the preceeding categories are surrounded by ground support and service providers which provide support, test and services to the space industry as well as dedicated equipment and software for ground systems.

- System Integrators. They are less than around 10 companies with the corresponding capacity. However, some can be considered as large system integrators who provide complete integration of large spacecraft (>1.5t). They are only 3 left in Europe, as they were nearly 10 some twenty-five years ago; 2 of them are in the satellite area (EADS Astrium, Alcatel Alenia Space) and one in launcher (EADS Space Transportation)[24]. Besides, medium and small system integrators are also to be taken into account, providing complete integration of smaller spacecraft (<1.5t). OHB-System and SSC (Swedish Space Compnay) are dominating this segment with together 2/3 of the corresponding market, which includes also SSTL (Surrey Satellite Technology Ltd) or QinetiQ. They are organized at national or sometimes at international level. System integrators are the main driving forces of the European space industry, with around 55% of employement and of turnover (after exclusion of the share that is subcontracted to lower tier companies). The system integrators are the backbone of the European space sector (Lionnet, 2006). Consequently, they have been the ones the most affected by the recent slow down of commercial markets (with for instance 2400 over the 2460 jobs lost in 2005), especially the large system integrators. Over the last few years, competition between LSIs and SSIs has intensified in the markets for subsystems, payloads, and small satellites in the 300 kg range for scientific and remote-sensing missions. This rises again the question of the compatibility between the fragmentation of suppliers of subsystems, payloads and small satellites and trend of both worlwide and European institutional markets is at stake (Carayanis et al., 2002).
- Subsystem suppliers. There are approximatively as numerous as the prime (14 companies, according to Eurospace sources), and represent around 15% of total employment and of turnover. An important share of them are launcher companies, such as Snecma (from Safran), AVIO Group (still in Finmeccanica group), Dutch Space (now from EADS group), Kongsberg D&A, L'Air Liquide…
- Equipment suppliers. It is difficult to provide a comprehensive list of such actors, given the variety of equipement, devices, parts etc supplied. Probably a bit less than one hundred companies. (79 companies for instance covered by the Eurospace survey), but many more if one includes components manufacturers, materials or manufacturing services. They are the second generator of employment after the prime (with roughly one fifth of the total) but generate comparatively a bit less turnover. These figures seems to indicate a lowest value of the production of these actors as compared to the prime, especially when it is reasonable to consider that their production is less labor-intensive thanks to some (however very limited) automatisation. Companies like Thales ED, Jena Optronik, Galileo Avionica (Finmeccanica group) are among this population.

4. Services and ground support to industry. it is even more difficult to have a precise idea about the number of these actors, probably some tenths (45 companies in Eurospace survey), because they cover a very wide range of activities: ground system and ground station design, development, manufacturing and operations, services to industry (engineering, test, etc.), EGSE, consultancy, engineering, test & support, support to space segment design, development and manufacturing, launch site hardware and services provision, services and operations to non commercial space systems (including raw data sales from EO satellites), etc.

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[24] Actually it makes two groups, all the more since EADS has regrouped all its space activities in Astrium – EADS Company.

They are a lot of overlaps between these different categories. LSI are characterised by a high degree of vertical integration, and would be almost able to build whole systems to the exception of some highly specialized components. There are a quite high degree of duplication of competences between the equipment suppliers and between the equipment suppliers and the system integrators, and system integrators have some ambiguous links with a weak and dispersed down-stream added-value industry.

It is also possible to consider the *segment of market* adressed by firms' activities. This last approach is also difficult since most of the companies are active on different segment and even sometimes change segment, as underlined above. But it is possible to simplify the segmentation and look at the type of activities on which companies focus or get more than 50% of their revenues. If one uses again the Eurospace data source, four segment can be distinguished.

- Launcher segment is formed by companies mainly involved in launch systems design, development and production (25 firms in Eurospace 2005 survey). These firmes have generated a consolidated turnover of 1,1 B€ and employes 6 550 persons. Most of the employment (50-55% of total) is located within companies operating at subsystem level. System integrators employment of 2650 represents 41%, while equipment suppliers have a lesser weight in the segment's employment (6%).
- It is in the satellite segment that one find the most numerous companies (92 companies in Eurospace survey), the highest share of turnover (2,9 B€ in 2005) and the most numerous employees (18 750, that is roughly 2/3 of total employement). To the difference of the launcher segment, the largest share (2/3) of employment is located within companies operating at system integration level, the remaining employment being unevenly split between companies operating at subsystem level (3.6%), companies operating at equipment level (26%) and companies in the service and ground business (3.1%).
- The last main segment, Ground segment, includes companies primarily involved in ground activities (system and/or services). It largely overlaps the "services and ground support to industry" companies mentionned above. The consolidated segment turnover is around 360 M€ and employement amounts to 2 540 (ie less than 10% of the total industry)

It is also worthy to note that there is a relative specialisation of the companies in each segment, and this correspond to the reorganisation of the space activities all over Europe. For instance, according to Eurospace survey, in 2005, satellite activities represent only 5% of the launcher segment turnover, but account for 78% of satellite segment turnover; launcher production and development activities account for 81% of the launcher segment revenues. Ground segment is more diversified: services and ground support is only slightly above half of the turnover ot the companies included in this segment. Companies that have been affected by concentration movement have tended to regroup activities in different branches or business unit centered on one given core segment. Small units in large non-space companies are also often centered on specific core of activities. Smaller ones are either mono-activities, or with a main one complemented by a few other that result either from opportunity or portfolio strategy.

To complete the picture, *Vertical integration* is another typical approach of an industry. Due to longer series of production (which allows for economies of scales and rationalization of production using outsourcing), historical factors (long term stability of industrial consortia), technologies (especially propulsion parts) and to a lesser extent a better visibility over the market forecast, the production of launcher is less vertically integrated than the one of the satellite. It is particularly interesting to note that in the satellite segment the most relevant industry types are system integrators (representing alone 67% of the segment's employment) and equipment suppliers. In contrast, in the launcher segment subsystem suppliers are responsible for most of the segment's employment (53%). For instance, there has been an evolution from A4 to A5: there are less and less components and parts, but they are often more complex and technology-intensive (special alloys, composites, etc). The share of the cooperating sub-contractors has increased, partly caused by the fair return, with ESA members wanting to put more money in Ariane and then receive contracts.

- *Some trends in European space companies' strategies*

Facing the evolution of the competition environment briefly sketched in end of Part I, the European space companies have followed various strategic paths in the recent period. Because of the complexity of the European industrial structure, the close links between industry and public bodies such as space agencies, the frequent subordination of decision regarding space activities to decisions regarding larger fields of activities (aeronautics, defense, telecom), as well as the specific constraints on each firm, it is difficult either to identify one common strategy or to describe all typical cases. However, some general tendancies seem to be clear.

The most obvious strategy is the *concentration* of the European space industry through mergers, acquisition and collaborative agreements, especially at higher level (system integrators and sub-systems developers), as already mentionned. Economic rationales are a first line of justification. The objective is to reach a critical size, and thus generate a number of industrial and financial benefits, making them able to compete with the US counterparts and with future competitors from emerging countries. Notably:

- scale economies
- large internal R&D
- broader access to technologies,
- better negociation capacity vis-à-vis the client
- better capacity of negociation with suppliers
- better access to new capital and sharing risk;
- easier technology transfer
- higher levels of standardisation
- better management training

Companies also tend to carry out some lobbying activities in order to favour concentration on the demand side, especially as regards EU-led space activities and defense-related ones. The aerospace industry would not be able to launch large-scale projects such as Galileo or GMES and profitable endeavors without the economy of scale and market power of EU-led space initiatives. If similar demand concentration were realized as regards EU security space, European industry would also be in favourable position, as international competition would be minimized because of Europe willingness to protect space capabilities vital for Europe's strategic independence in space.

A second strategical path is related to the *search for garantee of supply for key components and equipments* (for instance gyroscopes, electronic components, ammonium perchlorate, etc). Actually, some of them are not designed and produced by the European industry, but generally by the US one. This is currently a key point for the European space industry, reinforced by the regulation on US exports. The space related technologies had from the begining been included in the ones falling under the ITAR (International Traffic in Arms regulations). The effects of these regulation has been especially significative since the return of the control by State's Department and the fact that space technologies were again in the munitions list; from 1996 to 1998, they were ruled by dual-use controls (EAR-Export Administrative Regulations) and under the juridiction of the Department of Commerce). The ITAR cause difficulties for European space industry when the products it wants to use and export include a component or a sub-part coming from US suppliers. According to a lot of European companies, it is complex and takes a long time to get the agreement from the State's Department (often 2-4 months for the simplest technical information up to 20 months or even more for more sensitive parts). Noticeably, in the recent examination of the Alcatel / Finmeccanica agreement giving birth to Alctael Alenia Space, the Competition Directorate of the EC yet stated that "European countries are not listed as countries subject to ITAR prohibitions and that European prime contractors can source satellite subsystems and equipment from US suppliers provided that final customers are not located in one of the black listed countries. The market investigation has indicated that export licences are routinely granted if the final customer is not located in one of these countries". Some prime contractors wait until they have won a contract before launching calls for suppliers of small components or small sub-system, and those suppliers cannot order components in advance since ITAR prevent the export of these without knowing who is the final customer. This put the suppliers under increasing pressure to deliver on time with adequate performance and price level while deadlines are getting shorter in all segment of space business, or exposed them to penalties and loss of future work. The technological advance of some US firms on specific components and the low level quantity of orders makes it difficult to have a dual-supplier policy. Another effects is on the insurance side; due to ITAR regulations, it is sometimes difficult to get detailed technical informations on history of components or subsystem, which is against the requirements imposed by insurance companies for evaluating risk or analyzing failure cause (as well as by major satellite operators). Shortage of insurance funds and increase of insurance premium could result from this situation. This negative effect of ITAR on European space industry has lead this industry to promote ITAR-free offer and/or to develop technologies in the field where the US suppliers held a monopoly. Some clients have been sensible to this argument, for instance on the Chinese market, or Arabsat in 2003, Intelsat in 2000 or Telesat Canada. Thus, ITAR has also a positive effect on European space industry since it can increase their competitiveness in comparison with US suppliers. It is the case either at the level of satellites manufacturer (for instance it has been argued that Alcatel Alenia Space has been able to double its market share of communications satellites from 1998 to 2004 especially thanks to its "ITAR-free" Spacebus plateform) and at the one of components (see the case of Sodern and its new generation of star-tracker for satellite attitude control introduced in 2006).

One can also notice that the launcher may be subject to the MTCR (Missile Technology Control Regime); but this does not seem to add to the problems since they are already subject to ITAR. And in the case of European launcher, none of them has been exported as such, only launch service operated by European companies has been sold to clients. It cam also be mentionned that space technology is still excluded from the WTO agreement.

Integrators seem also to more and more willing to *propose clients an "end-to-end service"* not limited to space segment, and not limited to physical infrastructures. This is true for large integrators but also for some smaller ones such OHB Technologies. They want to provide the overall capacity to connect user to user, that is not only satellite but also ground network and telecom operating services, plus also global engineering (including financial engineering), plus also launching services. This is in line both with the general tendancy towards service supply (answering technology and service needs of the demand), and possibly also with an increasing synergy between the different activities of groups. The consequences are the creation of branches for services, the byout or merger of services companies or the set up of various forms of collaborative agreements between firms offering complementary goods and services.

Another clear trend observable in most integrator and subsystem suppliers is the *rationalization of the production system, and especially of their supplying structure*. It means that they try to reduce the number of direct suppliers, and choose the ones that are not only the best in terms of performance-delay-quality, but also the ones that can offer design capabilities, long-term commitment and reactivity. Generally speaking, they want to develop long-term agreement with their suppliers, which would result in more reactivity, instead of having a complex and rigid industrial hierarchy for each programme. One key aspect of the "make or buy" strategy is to secure double sourcing, because having supplier in monopoly position is very risky. When it concerns very specialized components/parts/technology with very small activity (niche) and thus it is difficult for the integrators to give business to two or more suppliers, at least the integrator wants to « maintain alive » the potentiality of another source. But on the other hand, integrators and subsystem providers want to avoid that suppliers are too dependant from them, ie non dependance should be on the either sides. Among others, this is one of the most important consequences of the evolution towards offering a full user-to-user service to clients. The financing schema between the final clients and integrators becomes more and more complex, and the payment is increasingly related to the in-orbit long-term performance of the system (with incentives, milestones, penalties, etc mechanims). Thus integrators have to ensure that it works with highly reliable suppliers and sub-contractors, and has to enter in long-term relation all along the life of the satellite (after-sales service) and accumulate experiences on recurrent use of the same supplier. Other aspects of the organisation of collaboration between suppliers and integrators and/or subsystem suppliers are also changing, following general trends of the industry. Now more and more the relation between one integrator and one given supplier is through one single interface, whatever the number of programmes for which this supplier is used. This is more simple, and most of all it allows experience feedbacks, long term monitoring of components (incl. in flight), reliability, etc. Some would also like to develop the « plateau technique » approach, with different suppliers working together on the same site (or virtual site) at design/development level. However, this type of approach is also associated to the use of some advanced industrial methods (DTC, Quality Design etc), which are not often mastered by traditional suppliers (and even by bigger firms), and could be part of the suppliers' selection criteria very soon if not yet.

Obviously, *reducing cost* is also a key objective of strategies followed by European space industry, given the well-known specificities and constraints of the space design and manufacturing Delocalization of production being difficult in space business (although the process is already engaged especially towards former-Estearn European countries) generally spkeaking in order to reduce cost, integrators tend to cut jobs (see the example of EADS and Alenia who lost several hundreds of jobs since the crash of 2002-03). This is especially the case when mergers occur. Share of suppliers heavily depend on prime internal workload, except on the one hand for very specialized products (prime being unable to do them) and on the other hand very standard ones (prime not economically competitive with suppliers). As for the rest, integrator could almost do everything. Thus there is a trade-off to find between keeping work inside to maintain jobs as well as competencies and cut-job and externalize to be more flexible and make cost decrease. But mass lay-off surely threatens the maintenance of key competences and skills and continued transfer of know-how and information. With a long-term view, given the very long lifecycle of space projects and their specific features, space industry is particularly sensitive to the transfers of knowledge and know-how between generations of scientists and engineers. But the population of space specialists is ageing. It is estimated that nearly 30% of people employed in the European space sector will be retired within the next 10 years.

In the *launcher market*, EADS (Ariane prime contractor) and Arianespace have to face the supply overcapacity25. This has led these leaders of the European launcher industry to diversify their offer, either through in-house development or through international agreements. The new Ariane 5 family is now apparently secured at least in the medium-term (since the 2003 EGAS agreement); for medium-size launching capacity, the European spaceport in Guiana will also have the ability to operate Russian launcher (Soyuz) in addition to Ariane. For small-size launching capacity, a new launcher able to place multiple payloads into orbit is presently developed (with the Italian Avio, one of the main shareholder of Arianespace, as prime), using advanced low-cost technologies and introducing an optimised synergy with existing production facilities used for Ariane launchers (first launch is planned for 2007).

International agreements have also been signed with two other launching systems: the Japanese H2A (operated by Mitsubishi Heavy Industries) and Sea Launch (operated by Boeing Launch Services). This network of alliances also allows offering clients a back-up service: in case of problem with one of the launchers, client can use another launcher of the allied parties in order to launch its spacecrafts in time. EADS is also the main shareholder of the French-Russian Sertem and Eurockot Launch Services companies, respectively in charge of the commercialization of the medium-size Soyouz launcher and small-size Rockot launcher[26].

In the *satellite market*, it is unlikely that in the short term the process of concentration in the satellite integrator market will lead to the survival of one only company˙ In other words, the current tendancy is not to evolve towards an Airbus-type of structure (Saleh, 2005). This possibility has been discussed in the last two or three years, especially after the joining of most of Alcatel and Finmeccanica space activities in Alactel Alenia Space and Telespazio. But the recent evolution of Alcatel activities in last spring makes it difficult to envisage a merger with EADS. Actually, Alcatel has recently merged with the US Lucent, and the new group is center around telecom equipment. The two firms have decided not to put their senitive business activities in the new entity, and in the case of Alcatel these activities include space ones. Therefore, after some months of intense dicussion notably involving French government, Alcatel and Thales have agreed on an increase of Alcatel participation in Thales capital and to the buyout of Alcatel Alenia Space by Thales (noticeably, the regrouped activities are issued from space activities of Thomson/CSF and Alcatel which have splitted some 25 years ago). EADS unsuccessfully proposed a similar arrangement to Thales. But

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25 From the USA with two new launchers (DELTA 4 and ATLAS 5), and the possibility for Boeing and Lokheed-Martin to launch the highly reliable and low cost Proton and Zenith; Japan (H2A) ; China (Long March); India (GSLV); Russia (Proton), etc

26 Relationship with the Russian launcher industry are not so clear: there are various cooperation agreements between National Agencies (CNES, DLR, ASI) or major industries (EADS, SAFRAN, Arianespace) and the Russian Federation for the use of existing Russian launchers and the development of future launchers as well as agreements between ESA and the Russian Federation.

what were at stake were Thales, a major defense and electronics group in the European industry, and the consequence on space activities was only a side-effect of the battle. Another (partially related) evolution was the reorganisation of EADS space activities in last summer, with the grouping of EADS Space Transportation and Astrium in EADS Astrium.

Therefore, the expression of "Airbus model" for space industry is misleading and cannot be envisaged, since the situation varies greatly varies from one industry to the other: in aeronautics, the different firms that formed Airbus progressively merged to form EADS (to the exception of BAE whose shares have been sold to EADS a few weeks ago) and then Airbus became a subsidiary of EADS. EADS is in charge of Airbus production and is largely vertically integrated down at subsystem or even equipement level. In the case of launcher, there are three major actors that cannot be grouped: CNES (acting on ESA behalf) for the R&D and development phase, EADS as industrial prime contractor and Arianespace (subsidiary of CNES and of the different industrial companies inolved in Ariane production); no one can imagine that all subsystems developers and CNES merge into EADS. In the case of satellite, there is not a common product jointly developed by the main integrators on an equal basis, with production series large enough to generate scale economies justify such a "final" merger[27]. After the "slimming course" inflicted on the big prime in a market taking off again, and the recent fight between the two main integrators, it is not sure the the debate on a supposed overcapacity of the European satellite industry will go on.

B The characteristics of the space industry in Japan

According to SJAC source (SJAC, 2006), the turnover of the Japanese space industry amounts roughly to 1.5 billion euros (1.467 billion euros in 2004, decreasing by 1% in comparison with 2003). This corresponds to approximatively 18% of the turnover of the overall Japanese aerospace industry, a figure that is higher than in Europe. As in the case of Europe, but with less emphasis, the figures have declined in the 2002/03 after a high level in end 90s and early 2000s. However in the Japanese case, the peak was reached in the mid90s, mainly due to software related activities. It is expected that the space sector recover its level with the successful launches of H-IIA rocket and M-V rocket of 2005 and 2006. The Japanese space industry employed 6 to 6,5 thousand staff (6 378 in 2004 with a 10% increase as compared to 2003, despite a long-term decrease trend in the overall aerospace industry).

The major Japanese space firms are now in the field of satellites MELCO (Mitsubishi Electric Company) and NTSpace (formed by the merger of the space units of NEC and Toshiba), and in the field of launchers: MHI (Mitsubishi Heavy Industry) and IHI (Ishikawajima-Harima Heavy Industries, which has bought aerospace activities of Nissan Motors). But none of them can be compared to their European or US counterparts in terms of size. The biggest Japanese player MHI appears only around the 30 rank of the TOP 50 Space News ranking of Space companies, with 2005 space sales of 354 million $ that is less than 2% of its overall sales, and less than 10% of its aerospace sales (Rains, 2006). MHI and IHI appear only at respectively the 22 and 32 position in the Top 100 ranking of aerospace companies annually published by Flight International (Massy-Beresford - Warwick, 2005 and 2006).

The structure of the Japanese space industry is different from the one of the European space industry. Companies acting at integrator, subsystem and equipement levels are less numerous, around ten (Lee, 2000). Beneath them are some eighty subcontractors. Due to their long

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[27] Even if the Alphabus programme is an opportunity of joint work between EADS Astrium and Alcatel Alenia Space/THALES.

relations with NASDA and ISAS (continuing now with JAXA) and to the policy adopted by these governmental bodies, most of these companies have followed a certain specialization path.

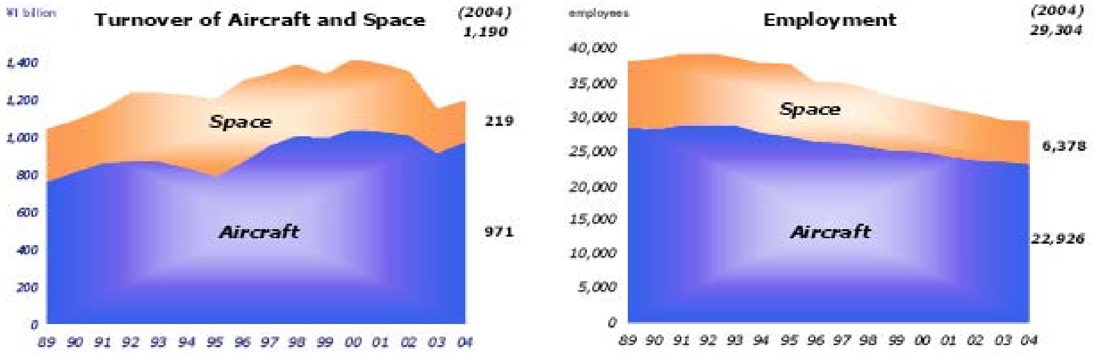

Figure 3 (SJAC, 2006)

In the field of rocket and launchers, MHI is the main integrator, also specialized in turbo-pumps, KHI is leading in rocket firings and solid rocket motors since its buyout of Nissan. In the area of satellite manufacturing, the primary contractors are MELCO, Toshiba and NEC. Following the work-sharing policy adopted in Japanese space policy, these companies were initially specialized in different satellite applications: NEC in scientific applications and in geostationary meteorological satellites, MELCO in communications satellites and Toshiba in broadcasting satellites. Coupled with this specialization pattern, the companies were able to establish links with different US companies: Ford (later merged with Loral Space Systems) with MELCO, General Electric with Toshiba and Hughes (now part of Boeing) with NEC, and the experienced and technologies acquired or developed by Japanese companies through these links allowed them to reinforce their capability in these respective domains. But after the turning point of the end 80s (see Part I), the Japanese space policy changed and so did the form of competition-cooperation between the main Japanese space companies. According to the new "technology-sharing" arrangement, MELCO, NEC and Toshiba jointly develop most of the major applications satellites, together with IHI (solid fuel rocket). The US companies being more and more reluctant to transfer technologies to their Japanese partners, one of the main goal of this new collaborative pattern was to try to "preserve" the Japanese space industry from the US competition, and to mutually reinforce each other through collaboration.

The breakdown of turnover by segment reveals that the industry is mainly involved in satellite segment (58%), ahead of launcher (19%) and ground (16%) segments (2004 figures; software segment, representing 7%, being isolated in SJAC statistics).

In the field of satellite, the Japanese space firms have not yet been successful in competing as prime contractor on the world market, and even on their non-R&D domestic market. The first contract in the world market awarded to a Japonese company was the communication satellite “OPTUS C1” one (launched in June 2003), for MELCO; then followed by the prime award for domestic commercial satellites. However, they have been able to gain an increasing portion of work at subcontractor level.

The failure of Japanese firms to compete as prime contractors is often attributed to weakness in the area of system integration (Berner, 2005). This would be due to past relation with JAXA (and its predecessors), who developed design requirements for most of their satellites. Thus the governmental bodies acted as the prime contractor and system integrator, responsible for acceptance testing and quality assurance. Japanese firms follow JAXA's specifications, and to some extent act more as subcontractors (subsystem and components) than as prime contractors. In addition contracts tend to be of a fixed-price nature, with little dynamic interaction with the companies.

Another commonly underlined feature of the Japanese space industry is their low level of investment. For most of the big companies, space represents only a small share of their overall business and is not so strategically important.

Conversely, it can be noted that Japanese industry has been more successful in penetrating the ground segment and user terminal markets. Receiver systems for Very Small Aperture Terminal – VSAT – satellite communications networks, Direct Broadcast Satellite – DBS – systems, and GPS consumer units are manufactured in large numbers, much more in line with the Japanese strengths in mass production.

In the field of launcher, the Japanese space industry follows the trend towards a diversification of its offer to clients (Pekkanen, 2001). Because of the past failures of the previous Japanese launchers, Japanese operators have for the most part used US or European launchers, but it is now slowly changing with the possibility to use three types of launchers for different weights of payloads: H-IIA, M-V Rocket (the biggest solid propellant rocket in the world, developed by IHI), and Galaxy Express (GX) Rocket, the last being still in development under a PPP arrangements leaded by IHI and JAXA (see above). Following the recent success of H-2A, MHI (Mitsubishi Heavy Industries) starts to play on the world market. It benefits from the transfer of technologies from JAXA to improve reliability and reduce the cost, the privatization of production phase, the primership for commercial launch services, as well as with the back-up agreement signed with Arianespace and Sea Launch (see above). But all in all, the Japanese strategy is as driven by JAXA as it is by the space industry on its own: H-IIA will be maintained and operated as the national-flag rocket system, and the competitiveness of M-V and GX on the global commercial market is still to be proven.

As compared to the European space industry, the trend towards concentration has not been so important in Japan, the major movements being the buyout of Nissan Motors by IHI and the merger between NEC and Toshiba. This is due to the fact that the industry was less scattered, the pressure from international competition was paradoxically less important since Japanese companies were not really part of it, and consequently the size and capacity of the Japanese companies were more or less in line with the size of the markets on which they were active. More broadly, the space activities were not so exposed to massive restructuration of the overall space and defense industry.

V Lessons and conclusions as regards the Brazilian case

The purpose of this last part of the paper is not to provide a full range of strategic recommandations as regards the Brazilian space policy or even as regards the industrial policy part of it. To do so, it would have been required to perform a careful analysis of the history of the Brazilian space sector, of the structure of the Brazilian space industry and of its strenght-weakness-opportunity-threat mix. This is obviously far beyond the scope of this paper.

However, it is possible to draw some basic lessons derived from our detailed examination of how and to which extent public policies contributed to support the development of European and Japanese space industries. This could allow us to propose some thoughts about the conditions in which the various policy tools implemented in both cases could also be implemented in the case of Brazil. But again, policy tools as such are nothing if not justified and backed up by an underlying strategy and policy rationale. These last two elements are obviously missing here.

But before it seems worthwhile to come back to the framing conditions in which these policies were designed and adopted. First, Brazilian space industry has already a long history, and thus it is not really relevant to directly refer to the period of emergence of the space industry. Moreover, the development of European space industry (and to a lesser extent the Japanese one) came along the development of corresponding applications and (with some delay) corresponding markets. This co-construction is not possible anymore, or on small market niche corresponding to narrow applications (not to take about very long-term space project such exploitation of Mars resources or the like). In this perspective, developing further an industry in face of the big primes and myriad of strong suppliers existing on the world market is more about how to find a place on the scene than about creating the whole scene. An intermediate way could nevertheless be to try to create a new and indispensable role on the scene and become the only one able to play this role. But this place should be profitable enough to attract resources; and given the limitations of the space markets, one possibility could be to benefit from dual development between space and non-space activities. This was in part the Canadian strategy in robotics (Amesse et al., 2002). They were able to build up competences, create numerous research centers but also education and teaching, attract students, researchers and practitioneers from the entire world. This was the outcome of a dual strategy of articulating participations to large international programmes (Canadarm, ISS) and Canadian-based competences diffusion programme among SMEs, universities, research centers (STEAR programme). This last programme was not only devoted to enhancing the Canadian capabilities in view of keep on being involved in large programmes, but also to deepening the technological and knowledge base through spinin and spinoff mechanism with selected non-space domains.

Correspondingly, Japanese and European space industries emerged at a time when it was more or less possible to protect its domestic maket in order to develop domestic capabilities (although the Japanese case showed that specific relations of power with the USA make it difficult at some points in time). So it is probably not anymore economically viable to develop a full (at system level) domestic capacity on "standard" space product (such as telecom satellite) exposed to world competition. It also means that a large part of the companies developing space capabilities could probably be potential target for buyout by US or European space companies (as in the case of Equatorial Sistemas partly purchased by EADS Astrium last May).

Another aspect is that at early stage of space industry history, independance and prestige arguments were exacerbated by the cold war context, which does not exist anymore. And Brazil is neither limited (as was Japan) as to develop defense-related space activities, nor forced (as were European countries) to pool resources only on non-defense related space activities because of diplomatic considerations. This leaves room for development of dual knowledge and technology.

Lastly, it will probably be more and more required to justify space expenditures not only by independance and prestige arguments, spinoff achievements or even commercial successes, but also by its social impact at all levels. Rationale for policy has dramatically changed (especially in Europe), and this should be taken into account when deciding about the space policy and consequently about policy to foster space industry.

If we now turn to the different policy tools implemented in Europe and Japan, the first one that comes under scrutiny is the agency/procurement set up. This is something already implemented by Brazil. Experience shows that agency's size and the attraction it exerts towards human resources should not be to the detriment of space industry. There is also the risk of conducting procurement policy in a situation of quasi-bilateral monopoly, that is a one-to-one relation between the agency and the only one consortia economically viable given the size of market affordable for companies. Space agency may want to avoid facing one single system integrator, but may have not sufficient power to garantee by its own activities the financial equilibrium to two system integrators. This situation differs from the US one, where a strategic choice has been made to favour duplication of industrial capacity between the two main integrators (Boeing and Lockheed-Martin), with US institutional funds large enough to do so. Beyond strengthening technological capabilities of companies, it should also not develop behaviour (in terms of modes of management, efficiency criteria, economic and technological dependance, passive attitude of simple subcontractor obeying orders, etc) of space companies that would prevent them from being competitive on the commercial markets. And it should not make space industries specialized to much in fields where afterwards it will be not possible for them to gain commercial markets against worldwide competition. Of course, those simple statements are valid provided that strengthening the capacity of space industry is really a first order objective associated with the ambitious of making them able to flourish on space business. They may be less relevant if the aim is to sustain an industry as for it being able to secure domestic need at a reasonable cost/performance level.

As regards support to R&D, European and Japanese examples show that is seems difficult for space agencies and more generally public bodies in charge of space policy to find a way between two underlying logics. One is to support R&D in view of future needs of the agencies; that was the traditional inclination of ESA and Japanese agencies. The other one is to support R&D in fields where there is a high potential of social and/or "political" benefit (security, life saving, environment preservation, natural disasters prevention or monitoring, etc), as in the case of EC. Surprising is that the simple rationale of funding R&D for enhancing competitivness of space industry is less preeminent (although not absent) as it can be in most of other sectors. To put it in another way, a relevant balance (again depending on high levels of policy decision) is to be found between those different rationales for R&D support, a balance from which also should depend the modalities of support (co-funding, reporting, ownership of results etc).

Harmonization and coordination policy, so important in the European context, are probably less relevant in the Brazilian case, given the lower size of the space companies, their smaller diversity and the corresponding smaller diversity of trajectories of space technologies. The European or Japanese attempt in those fields could be exploited by other space industries, showing them some niches where they are needs that under certain conditions could be fulfilled by non-European or Japanese suppliers. From another perspective, such an approach could be useful when taking into account not only space technologies but also technologies from connected sectors. This could probably favour dual development and spinin and spinoff flows in a fruitful way. This brings about the question of spinin and spinoff policies that has shown some successes, provided again that one does not claim to sustain all space industry development on this sole economic potential. The complexity of these processes and the variety of factors affecting their realization has been extensively discussed earlier. The size of the Brazilian space activities and its (supposely high) level of vertical integration may have two consequences ion that matter. On the one hand, potential spinoff may be concentrated on a few number of actors and related sectors (typically aeronautics and defense), with by now probably more internal spinoff than external ones. This includes also the institutions depending on or coordinated by the Brazilian Space Agency. So promoting spinoff would be about set up inentives mechanisms to foster those specific actors to make spinoff; in the first case this should be coherent with firms policy, in the second case, this could also resemble all attempts made by any Public Research Organizations to valorize and commmercialize their technologies. Experiences from other PROs could be used then. On the other hand, spinin would mean to open the circle of space companies to new comers. This is something that should probably be "negociated" between the present circle and the public space bodies. For instance in Europe, space companies do not unanimeously support the effort of ESA to favour spinin since they have the feeling that it would threaten not only their competitive position but also their very existence (given the supposed overcapacity of the European space industry, at least in some domains).

The last main policy tool used by either Europe and Japan (although differently) is the support to the transition from public-driven activities to private-driven activities, including all forms it has taken from Arianespace model to the more recent PPP scheme. Again the conditions of implementation of PPP have been extensively discussed earlier, the main of which being the mutual and complementary interest as well as strategic coherence, as it seems to be the case in the Galileo project. For instance, the QZSS project was considered in 2002 as a model of government-industry cooperation in an era of tight government budgets. But it shows the limitations of the model when partners do not really agree on the relevance of the project, when commercial forecast are put in question and most of all when policy-making process is characterized by lack of coherence and cohesion. The GX project is illustrative of the tendancy of space actors to develop some forms of public-private co-funding on project initially launched by the industry, with the risk of mainly serving the interest of a few companies. For country like Brazil, PPP in space sector is probably feasible on a small scale (for some applications, or some components or technology), but much more difficult at larger scale, that is for large space infrastructure. The reason is that projects for space infrastructure large enough to attract a large number of partners and huge financial resources are probably already engaged (launchers, space station, navigation and telecom satellite, global monitoring system etc). Thus financial resources may lack, and economic potential for sustainable activity may be too low. The challenge would then probably be to choose a intermediate size fitting more with Brazilian needs and resources (including international ones in cooperative framework), innovative enough to provide competitive advantages for Brazilian industry on specific fields. But elaborating further in this direction would lead to strategic considerations that go beyond the scope of this position paper.

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