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EVALUATION OF FUTURE SPACE MARKETS

Project on The Commercialisation of Space and the Development of Space Infrastructure: The Role of Public and Private Actors

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EVALUATION OF FUTURE SPACE MARKETS

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INTERNATIONAL SPACE UNIVERSITY

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FINAL REPORT

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FOREWORD

This working paper has been produced in the framework of the International Futures Programme's two-year project *The Commercialisation of Space: Development of Space Infrastructure*. The main purpose of the Project is to take stock of the opportunities and challenges facing the space sector, particularly civilian applications, with a view to reaching a better understanding of the issues at stake and of the solutions that could be applied -- both at national and international levels -- in order to ensure that the sector contributes fully to the development of the economy and society at large. The Project is to be carried out in five main phases: (1) Assessment of the future evolution of the sector; (2) Selection and Clustering of Promising Applications; (3) Consideration of Business Models; (4) Improving the Framework Conditions; (5) Conclusion. The work of the two first phases is now available as an OECD publication: *Space 2030: Exploring the Future of Space Applications.* It is to a large extent based on four background papers that were drafted in summer 2003 by outside experts. They are:

- Bouchard, R. (2003), "Commercialisation of Space, Technology Trends".
- Hertzfeld, H. and M. Fouquin (2003), "Economic Conditions and the Space Sector".
- Kane, T. and M. Mowthorpe (2003), "The Space Sector and Geopolitical Developments".
- Macauley, M. and D. Chen (2003), "Space Resources and the Challenge of Energy and the Environment".

The working papers provide a picture of potentially promising space applications over the next 20-30 years on the basis of a "top-down" assessment of some of the key drivers likely to have a major bearing on the supply and demand conditions facing space actors in the future. For the purpose of this assessment, four main drivers of change have been identified: geopolitical developments, socio-economic developments, energy and the environment, and science and technology. Each of these four drivers is the main focus of a separate paper.

In addition, a fifth "bottom-up" paper, focused more specifically on space applications, was used in the analysis:

- Peeters, W. and C. Jolly (2003), "Evaluation of Future Space Markets".

EVALUATION OF FUTURE SPACE MARKETS

FINAL REPORT

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INTRODUCTION

In this report the following approach was followed:

In the first part an analysis is made of the past forecasts, in order to caution for the exactness of such forecasts in a transient sector such as space activities, but also to draw some ‘lessons-learned’ from this in conjunction with the technology developments. In particular, an analysis was made on the different activities which were forecasted to develop and the reasons why this was not the case.

In the second part, the current main commercial sectors (launchers, telecommunications, navigation, earth observation) and their presumed evolutions are looked at. The potential importance of new integrated downstream-integrated applications is stressed.

In the third part, future envisaged commercial sectors are presented, with their rationale. The interactions with markets, technological development constraints and potential regulatory effects, as well as timeframe estimations, are synoptically presented per application area. In particular, relation with Technology Master Plans is analyzed.

In the fourth part one particular future sector has been chosen to illustrate the problems in estimating the financial feasibility and in constructing a viable business plan for such a new sector. Space Tourism has been very well studies and many data are available, also on market analyses. It was therefore considered as a prime candidate in the framework of this study.

As an overall summary of the conclusions, the applications described are lined out in function of an assumed timescale

1. LEARNING FROM THE PAST

1.1 Global Evolutions in the Space Sector

The space sector is a very specific domain and its evolutions are based on a combination of factors and technological developments.

1.1.1 Major Political Factors

A strong political motivation has always been essential for the space sector to evolve. Without strong political will, no technological breakthroughs would have been built on to serve as the backbones of some space programs (e.g. missile technologies used for space launchers).

Three main factors, sometimes combined or not, have historically guided the evolutions of space programs worldwide:

- National prestige (e.g. US-USSR moon race, Chinese human spaceflight program);
- National security (e.g. US space power theory, Indian earth observation programs);
- Strategic independence (e.g. European programs: Ariane and Galileo, Brazilian launcher program).

Those political factors have always been keys to the development of the space industry. Only six weeks after first successful flight in space by the Russian cosmonaut Yury Gargarin, the President Kennedy declared on 25 May 1961: “ I believe that the aim of this nation should be to land a man on the moon and return him safely to earth before the end of the decade”. The direct consequence for the American space industry was the considerable amount of the national budget (nearly one percent of the BNP, see figure 1) spent on the Apollo program, without major criticism or resistance from any party.

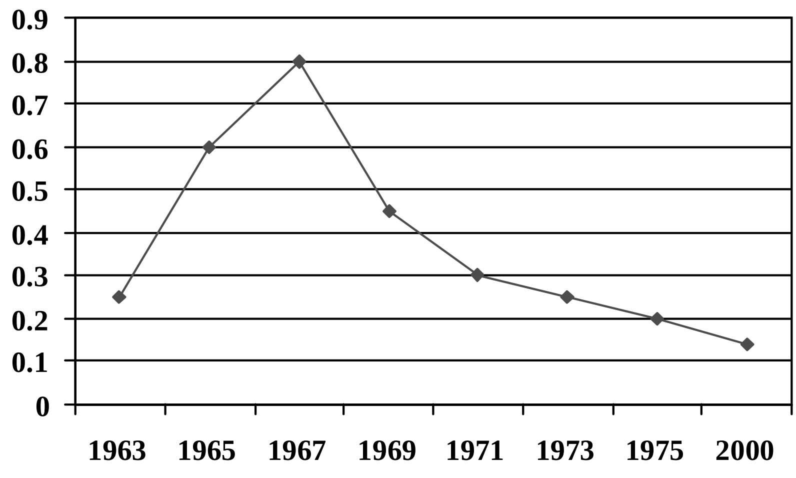

Figure 1 – Effect of the ‘space race’ on the US budget

Other examples based on political factors include:

- The International Space Station (ISS), which had been decided on the 'official' basis of a political desire to cooperate on an international scale, even if the scientific and financial justification have been disputed;
- Irrespective of the market oriented justifications, the Galileo project was started in the frame of a political desire to make Europe independent from the US controlled GPS services, even if the American services are already provided free of charge.

Space activities have followed a near-identical phasing in most of the space-fairing nations:

- Political objectives are set by governments with direct/indirect impacts on the space sector (e.g. US military navigation GPS, human spaceflight programs for prestige);
- Those objectives are executed by governmental/space agencies, together with the related funding. Agencies tend to define the related projects and programs, which are executed under contract by the national space industry;
- The space industry develops a number of products and processes and may urge for the commercialization of some "spin-off" products or specific activities. The wish to establish Public-Private-Partnerships (PPP), commercialize and even privatize some activities tends currently to come more and more from governmental agencies.

The general process is graphically represented in the following figure.[1]

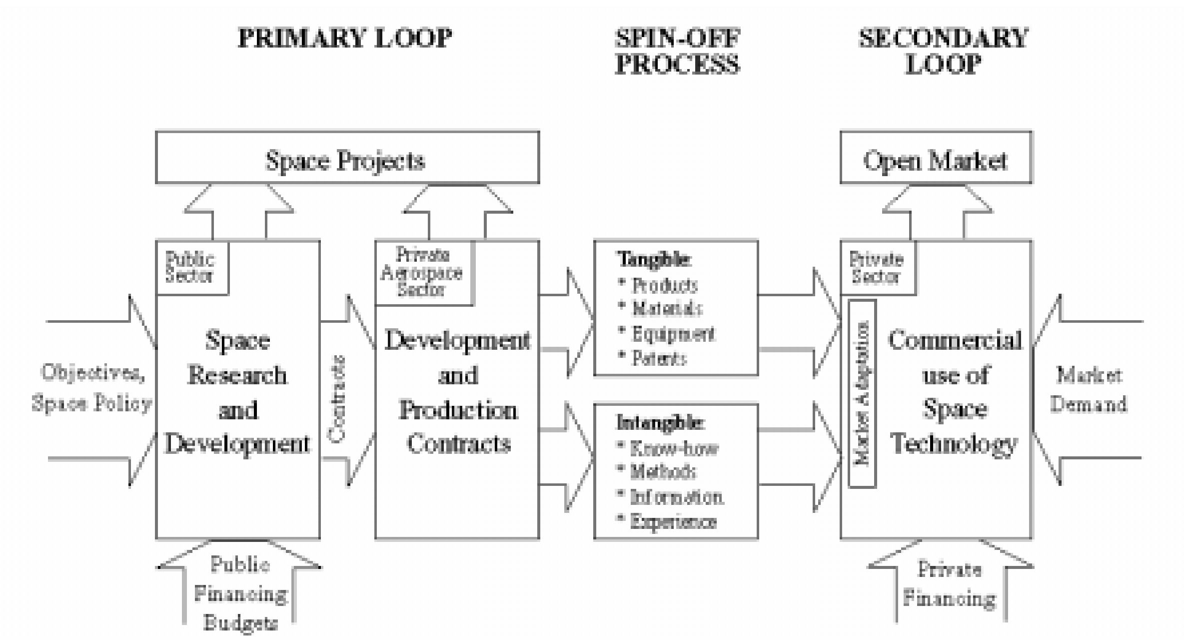

Figure 2 – Schematic spin-off process

Based on what we have seen, the commercialization of some space activities is largely a consequence of the main political factors that generally guide the evolution of the space sector.

Will economic development become one of the leading new factors in the evolution of space activities? For some specific sectors already quite privatized (e.g. space telecommunications), the space segment tends to lose already its uniqueness and become just one market segment of a broader economic sector (e.g. information technology). As we will see in this report, other current space sectors may follow the telecommunications' example and become more and more integrated in other terrestrial commercial

[1] Peeters, W., *Space marketing. A European perspective,* Kluwer, Dordrect (2000) p. 101

activities (e.g. navigation, earth observation). The question is still open for the potential new commercial space activities (e.g. human spaceflight, space-based power) that will look at.

1.1.2 Role of Technology Developments

Aside from political considerations, technology is at the heart of any new space system. However, contrary to general thinking, the space sector is developing nowadays very few new technologies. Indeed, if we consider the percentage of the turnover spent on R&D, as presented in the following figure, we note that at present many other sectors are far more advanced in this respect. [2]

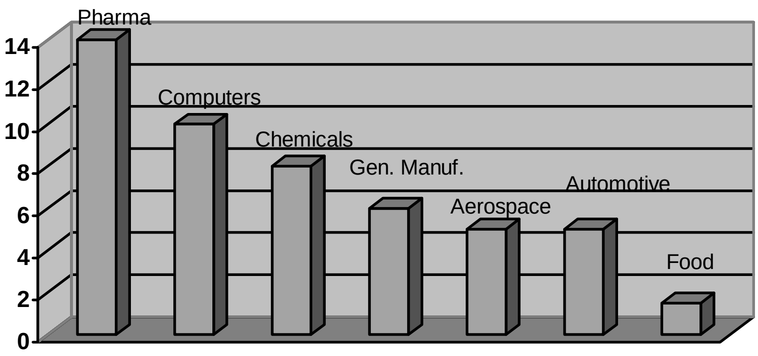

Figure 3 – R&D general turnover in the space sector in comparison with other sectors

This has not always been the case. In the Apollo days, budgets were so readily available that all the needed technologies could be developed without having to worry about the level of budgets needed. Military secrecy reinforced also this situation during the cold war period, allowing large uncontrolled spending in the space sector in the United States, but also in Russia.

There is now a tendency to conduct space programs in a more pragmatic approach. Indeed, the Russian projects tend to use many COTS (Commercial Off The Shelf) items, which are simply protected (e.g. against radiation, by covering them with a layer of material). Typical examples are the use of onboard computers, which were until recently especially developed for the US space programs, whereas the Russian programs simply used commercial CPUs, after protection.

When public budgets became scarcer, the space sector started to look into so-called spin-in processes (see following figure). The Spin-in process is the use of existing technologies from another (non-space) sector in the space sector.

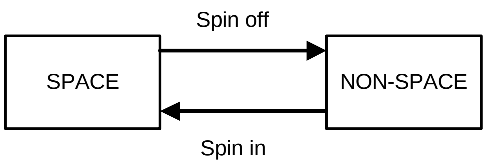

Figure 4 – Schematic of spin-in versus spin-off processes

A recent example of this is the introduction of an established terrestrial technology, the *Bluetooth* technology in satellites. Space exploration programs provide also substantial opportunities for sophisticated applications of robotics and artificial intelligence, used in other sectors.

[2] TROTT, P., *Innovation Management & New Product Development*, Financial Times Publishers, London (1998)

This spin-in effect is not only valid for small space projects. Already in 1984, NASA did an open appeal, listing the different technologies, which were considered as critical for the construction of the International Space Station. It was a major surprise for NASA to find out that more than half of these technologies were already available in other high-tech sectors. The new NASA technology programs, scheduled to be implemented in 2003 (NASA Enterprise ‘Engine’) puts a lot of emphasis on this spin-in aspect. JAXA, the new Japanese space organization, is also stressing the use of spin-in technologies, a very novel approach in the Japanese space sector.[3]

The main difficulty for space engineers, in whatever country they may be, is to identify clearly the existing technologies that may benefit their programs. Advances in computer sciences, quantum mechanics and even biotechnologies, are not easily accessible to non-specialists, as each different sector has its own ‘language’.

As an interesting step, ESA has undertaken the task in coordination with the European Commission and industry, to:

a) Pursue the programmatic coordination and harmonization of technology programmes in Europe and prepare the European Space Technology Master Plan;
b) Define road maps and harmonized implementation schemes for the development of critical technologies, involving industrial funding as necessary.[4]

The European Space Technology Master Plan (ESTMP) is the core of this activity[5]. Some 1600 space activities are already logged in the ESTMP database (updated issue of June 2003). These entries can be sorted by technology domains, funding institutions, and keywords. The decision was made to establish first a standardized technology tree, with technology domains and sub-domains. This also allows for global, worldwide technology mapping, which is of very strong interest for the present OECD harmonization activity.

The rationale and objectives of the ESTMP are to:

- Support a European strategy for Space;
- Achieve “more” at European level by prioritizing and harmonizing European R&D plans and resources;
- Consolidate, expand and innovate European space technology base;
- Observe technology developments in other nations, in order to optimize resources
- Support capability & competivity of European industry.

An interesting academic exercise based on ESTMP-identified technologies was conducted by ISU, with a strong support from ESA. Using the international group of participants from the 2003 ISU Summer Session program in ISU, a preliminary mapping of the main space fairing nations in terms of technology programs was done. This innovative approach, based on public sources, was successful thanks to the participation of students able to read documentation in native languages (e.g. Russian, Japanese, Chinese).[6]

A preliminary top-level conclusion from this mapping effort is presented in the following table, whereby the first column represents the standard technology domains as defined in the original ESA technology tree.

---

[3] MEXT, Aoyama report (Tokyo, March 2002)

[4] ESA, *Resolution of the Edinburgh Ministerial Council Meeting* (November 2001)

[5] Lascar, S., Gugliemi, M., Martinez de Aragon, A., Nati, M., Williams, E. and Maresi, L.: *European Space Technology,* ESA Bulletin 112, November 2002.

[6] TRACKS to Space, ISU *SSP03 Team Project* (ISU, Strasbourg, Aug. 2003)

Technology Domain (ESA system)	China	Japan	Russia	USA
On-board data systems				**XX**
Space systems software				**X**
Spacecraft power		**X**	**X**	**X**
Spacecraft environment				
Space systems control		**X**	**X**	**X**
RF Payload systems	**X**	**X**	**X**	**X**
Electromagnetic technologies				
System verification	**X**			
Mission control	**X**			
Flight dynamics / navigation	**X**			**XX**
Mission analysis / space debris				
Ground stations				
Robotics		**X**		
Instrumentation	**X**	**XX**	**XX**	**XX**
Mechanisms	**X**	**X**	**X**	**X**
Optics	**X**	**XX**	**X**	**XX**
Aerothermodynamics				**X**
Propulsion	**X**	**X**	**X**	**X**
Structures		**X**		**X**
Thermal		**X**		**X**
ECLSS & in situ resources	**X**			**X**
Components		**X**		**X**
Materials processing				**X**
Quality & Safety				
User segment				
Application specific technologies		**X**	**X**	**X**

X : some projects identified
XX : number of projects identified (> 5)
No mention means that no projects were (yet) identified based on public information.

Table 1 – Space technologies developments by non-European countries

Public-funded space research is mainly targeted at non-commercial applications, such as scientific research and planetary missions. Agencies worldwide tend to develop their technological roadmaps accordingly. Projects are designed first, and then the needed technologies are combined in a systematic way. Since public funds are still the essential source of new technologies and patents, the objectives of space research is directed to a number of applications, which not necessarily coincide with the requirements for commercial applications.

One mechanism, which is now currently used by NASA, CNES, and ESA, is the public-private-partnership (PPP) concept whereby commercially oriented technologies are developed and verified - often the most costly part of the development - by the space agencies in order to be later applied in commercial ventures (e.g. under a system of royalties).

Some dual-use technologies may also have, indirectly, a spin-off to civil applications (subject to such elements as military confidentiality and export control regulations). Though the applications resulting from military developments cannot be ensured to be transferable within a short time span (e.g. the 30 years old precise navigation system of the Minuteman rockets is still confidential material).[7]

To provide some examples of drivers for technology R&D, the next ESA table introduces some of the space activities we will be looking at more closely in chapter 2.[8]

Space Sector	**Timing, Mission and Budget Type**	**Drivers for Technology R&D**
Public and Application Services - Weather - Navigation Disaster management	- *'Long-term service guaranteed' approach (> 30 years) necessary* - Public infrastructure financing with delegated exploitation	- Satellite constellations - Advanced ground computation - Often, available services have to be tied together by appropriate 'merging technologies'
Commercial Services - Mobile telecommunications - Multimedia - Broadcasting - Navigation services and traffic management - Global, regional and local applications of Earth observation	- Global financial and insurance arrangements dictate schedule for early return on investment - Public guarantees expected - Typically 3-4 years from kick-off to launch - Constellation build-up over several years - Constellations from a few to several dozens of satellites	- End-to-end turn-key approach - Commercial services will go 'fully digital' - Interface with terrestrial means standards crucial - On-board processing for comms./ nav.& Earth obs. needed for simpler user end - Use of higher frequencies (> 30 GHz) - Continuous services - Ground stations for constellation control
Science and Exploration - Astrophysics - Planetology - Moon/Mars exploration - Earth observation - Human spaceflight	- 10 year cycle typical for large missions - Public funding from R&D budgets - International program setup	- Usually one-of-a-kind - Very demanding developments in all technical fields - Technology-push approach - Mission success oriented - Direct man/machine interactivity
Space Transportation - Future re-usable systems - Small expendable	- 10-20 years of development - Operational flexibility - Guaranteed availability	- Improved cryo-propulsion - Re-usability

[7] The effect of dual-use technologies on commercial space activities is introduced later in this chapter.

[8] ATZEI A. et al., "Future Space Missions and Services - A Road Map for Future Technology Development", *ESA Bulletin*, Number 88, ESA/ESTEC (1996)

launchers		
Man in Space - Space infrastructure - Crew transportation - Logistics, payload support	- 20 year development time - Public funding for development and operation - Indefinite system lifetime	- Design update during lifetime - Maintenance and reconfiguration of elements - Habitability - Very high reliability

Table 2 – Programmatic Aspects of the Space Sector and Major Technology R&D Drivers (1996)

It is very likely that the applications having a minimal dependency on new technologies have the most important chance to spurn profitable commercial products and services in the next two decades. However, one very interesting aspect is that future space activities do not only depend on direct space technologies progress (e.g. propulsion), but also more and more on the integration of breakthroughs in other sectors (e.g. nanotechnologies).

1.1.3 Role of Regulations

A recent study, performed by a broad international working group, came to following conclusions[9]:

- The current regulatory framework for launch activities involves a number of new players having different perspectives;
- There is a general lack of regulation of the international space market and therefore a need to create a better environment and easier access to the market for the private sector;
- Effective licensing procedures for commercial ventures have to be established;
- The need for a balance between the improvement of access for private investors in space and the need for safety standards is of great importance.

A number of international standards relative to space legislation are ratified by states, thereby becoming law. This is in particular the case for the Outer Space Treaty (OST).[10] These treaties all date from the 'pre-commercialization' period and make limited reference to commercialization. This does not mean at all that the Outer Space Treaty is obsolete, and it will be difficult to find at this point in time and under the present political context sufficient consensus between the partners to develop a new treaty.

Proposals have been made to improve the space treaties in order to remedy the situation (e.g. through a dedicated UN Supplementary Protocol to the space treaties), as well as improved contractual practices (e.g. by developing 'Incoterms' for launch contracts). [11]

Only some Western European countries have adopted relevant national legal instruments, which are less focused on commercialization than some of the US legislations, as shown in the following table. German, French and Belgian national space legislations are presently under discussion.

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[9] BOECKSTIEGEL, K.-H., "Legal Framework for Privatising Space Activities", *Proceedings of the Project 2001 Workshop*, Vienna (July 1999).
[10] UN, *Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and other Celestial Bodies* (UN, London/Moscow/Washington, 10 October 1967).
[11] KAYSER, V., "Liability Risk Management for Activities Relating to the Launch of Space Objects", *Doctorate Thesis*, McGill University, Montreal (15 May 2000)

	Space legislation	Date
Sweden	Act on Space Activities	1998
United Kingdom	Act on Space Activities	1986
USA	Commercial Space Launch Activities Act (amended in 1988)	October 30, 1984
	Land Remote Sensing Policy Act	June 14, 1995
	Commercial Space Act	October 28, 1998

Table 3 – National space legislation

Such national legislations are important, as states are still responsible and liable at the international level. However, only an international organization would be able to deal with the rules of trade between States and fully open the way for international commercial cooperation.

The World Trade Organization (WTO) appears to be in the best position to carry out the role of an internationally recognized regulatory body. It was established in 1995 and has 135 Member States. At present, only telecommunication services are expressly mentioned in the WTO texts of 1997, thereby covering 93% of the commercial telecommunication services. Another action taken by the WTO, on the TRIPS Agreement (Trade Related Aspects of Intellectual Property Rights) could equally contribute to the global harmonization of Intellectual Property aspects. [12] It is assumed in general that WTO's area of competence will soon expand.[13]

It is evident that there is a strong need for a solid regulatory framework, also to eliminate the concerns of potential investors in future commercial space activities, which do not like additional risk factors in the environmental conditions.

1.2 Forecasting the Commercial Space Sector: Lessons Learned

Forecasts can often be overly pessimistic or reflecting an optimism bordering on naiveté, especially concerning the space sector. In 1923, Robert Milikin, a Nobel Prize winner in physics, claimed "there is no likelihood man can ever tap the power of the atom." In 1895, Lord Kelvin, President of the Royal Society, said "heavier than air flying machines are impossible."

Optimism and pessimism are normal obstacles to forecasting, but they can be ameliorated through methodological rigor. Accidents, serendipity, and wild cards must also be dealt with to provide sound forecasts, and time horizons clearly play a crucial role. In standard industries, forecasts of the next five years are often predictable and may fall into the realm of market research, while those more than thirty or forty years away are mostly speculation. In the case of the space sector, the nature of the business makes the uncertainty even stronger.

Public-funded space activities are to a certain extent relatively predictable as they are more linked to decisions made over longer-term periods. As an example, the International Space Station has been decided on a multinational level and will put its 'stamp' on public space expenditure for many years to come, due to the complexity of the agreements, which cannot be terminated as easily as a commercial contract.

Aside from public expenditures, the number of commercial space applications is rapidly growing (see next figure). However, how to best estimate the impact of the private sector in the space sector in the long run is a complex exercise.

[12] TRIPS, *Trade-Related Aspects of Intellectual Property Rights.* Full text under http://www.wto.org/wto/intellec/intellec.htm (January 1996)

[13] MALANCZUK, P., "The Relevance of International Economic Law and the World Trade Organization (WTO) for Commercial Outer Space Activities", *Proceedings of the Third ECSL Colloquium*, ESA-SP-442, ESA, Noordwijk (May 1999), 305-316

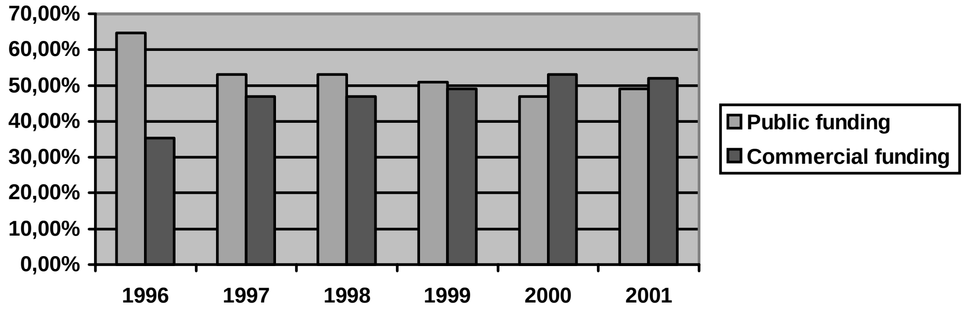

Figure 5 – Increase of commercial space applications (Example of Europe)

Past forecasts may indeed become rapidly obsolete due to changes in the geopolitical and socio-economical conditions. This trend can be illustrated with examples of past forecasts, which have been harmonized for comparison purposes (see the following table).

Ranking	1979 [14]	1991 [15]	2000 [16]
1	Space Communications	Sub-orbital transport	Space Tourism
2	Nuclear Waste Disposal	Space Tourism	Space Solar Power
3	Manufacturing in Space	Space Solar Power	Satellite maintenance
4	Space Solar Power	Manufacturing in space	Sub-orbital transport
5	-	Asteroid Mining	Asteroid mining

Table 4 – Commercial space forecasts (ranked in chronological order)

Only the space telecommunications sector developed quickly as a commercial market (hence was not retained further in the list in the following years). However, a number of projects that were forecasted did not take place, such as the Low-Earth orbit constellations, which were supposed, in 1998, to be developed in the period 2000-2003 (see the following table). Those predicted developments did not take place after the Iridium failure, and affected not only the satellite manufacturing market but also the global launch market.

[14] WOODCOCK, R., On the Economics of Space Utilisation, *Raumfahrtforschung*, 3 (1973), pp. 135 - 146

[15] ASHFORD, D.: The Commercial Demand for Space Stations, *Journal of the Interplanetary Society*, Vol. 44, (1991), pp. 269 - 274

[16] ISBC, *State of the Space Industry, 1999*, Sage Publishers, Bethesda, (1999)

Name	Number satellites	Cost (Billion$)	Operational	Primary Scope	Company
Iridium	66 (LEO)	5	1999	Voice, data, fax	Motorola
Globalstar	56	2.6	2000	Voice, data, fax	Consortium
ICO	10	4.7	2000	Voice, fax	Consortium
Skybridge	48	4.2	2001	Multimedia	Alcatel
Teledisc	288 (LEO)	9	2003	Broadband Internet	Motorola

Table 5 – Planned communication systems (1999)

Other markets have completely disappeared due to different environmental conditions, such as the nuclear waste disposal, and others were initially not even considered seriously by space agencies (e.g. space tourism).

The trend towards commercialization is considerably changing the space sector scenery. New commercial entities tend to promote products that would never have been considered by governmental organizations, because of their unawareness of the potential commercial markets or their unease to get involved in innovative projects.

Space burials represent one example. Since 1996, the company Celestis is selling special burial services, sending into orbit probes with remains of deceased people. The company launches its probes in combination with commercial payloads (in December 1999 a Taurus rocket was used, launching two Earth Observation satellites). Three launches have taken place so far, and the plan is to make two other launches in 2000+. The Payload is in the order of one kilogram, and customers are paying 4,800 $ each ‘burial’ (which is only in the order of one gram of ashes…). A Japanese company called Sekise has entered the market in 1999.

In order to illustrate the difference evolutions between the commercial sector and the public sector, it may be worth mentioning here that ESA performed a study in 1999[17] evaluating a number of potential space candidates, based upon Feasibility, Affordability, Potential benefit and Spin-off’ which led to four remaining candidates:

- Mars exploration;
- Moon exploration;
- Space Solar Power;
- Space Tourism.

The table below gives the financial forecasts for the year 2002, provided by ISBC[18], an independent organization doing research on space business. The same organization had to revise these figures considerably in its 2002 report. [19]

Category	1998	2002 (1998 estimates)	2002 (actual)
Infrastructure	55,471	64,389	46,821
Applications	33,646	56,397	32,497
Use of space data	4,648	13,307	9,513

[17] ESA: *SE&U Study Report*, DLR, Cologne (1999)

[18] ISBC, *State of the Space Industry, 1999,* Sage Publishers, Bethesda, (1999)

[19] ISBC, *State of the Space Industry, 2002,* Sage Publishers, Bethesda (2002)

Support Services	3,827	3,728	3,870
Total	97,593	137,822	***92,702***

Table 6 – Previsions of commercial space turnover in 2002 (US$ millions)

It deserves equal attention to consider the shifts, which have taken place in the past in the commercial sector.[20] By normalizing the figures presented in the following table, and by taking into account the doubling of the activities, the basic commercial activities (i.e. production of satellites and launch services) have rather been stable over the period in absolute terms. On the other hand, the services including space applications tend to strongly develop.

Sector	***1996***	***2001***
Satellite manufacturing	28 %	17 %
Launchers	15 %	9 %
Ground Infrastructure	22 %	22 %
Services	35 %	52 %
Total	45 B$	102 B$

Table 7 – Recent evolutions in commercial space activities

Aside from the political and socio-economic conditions that may clearly affect the assessment and forecasts of commercial space activities, another challenge lies in the difficulty to collect worldwide, and often even nation-wide, valid and comparable statistics.[21]

1.3 Commercial Space Activities and Market Realities

Based on the past forecasts of commercial space activities, it is always prudent to study carefully the different factors that may affect the development of space-related markets. Three elements are important concerning the commercial space developments: the effect of the technology life cycle (TLC), the time-to-market (TTM) factor and the needed support from end-product users, often defined by the dual-use characteristics of space technologies.

1.3.1 Effect of the Technology Life Cycle (TLC)

In marketing terms, we are still used to think in terms of Product Life Cycles (PLC), whereby we start up a new product when the previous one (or preceding version) is reaching a maturity phase. Technologies are developing now much quicker (e.g. microprocessors making 3 year old computers virtually obsolete), which means that a number of steps are taken in the cycle that are different but also must faster. Each step requires a different marketing approach and even a different company structure (see the following table).[22]

[20] Futron Corporation, *Satellite Industry Indicators Survey,* SIA report (2002)

[21] HERTZFELD H., Space Economic Data, Space Policy Institute, Washington D.C. (December 2002)

[22] See POPPER, E. and BUSKIRK, B., Technology Life Cycles in Industrial Markets, *Industrial Marketing Management,* Vol. 21 (1992) pp.23-31

Variable	**Cutting Edge**	**State of the Art**	**Advance**	**Main-stream**	**Mature**	**Decline**
Product	Feasibi-lity	Specialised	Segmen-ted	Standard	Shared	Obsolete
Price	Very High	High	High, price war	Market price	Market price	Dumping price
Distribution	Direct sales	Sales network	Multiple channels	Market channels	Reduced channels	Limited
Promotion	Personal selling	Trade shows	Distrib. Network	Brand Name	Sales Promo	Limited
Technology	> 95%	→		< 5%		

Table 8 – Phases of the Technology Life Cycle

An important aspect is the different type of companies involved in the various phases. In the electronics and biotechnology sectors for example, it is standard that some companies remain in the early cutting edge and SOTA (State Of The Art) phase. They are found in the typical California University Valley environments in order to remain close to the research centers and possibly work together with local high-tech research institutes.

Whenever their products have reached the feasibility stage, they sell the know-how, even in a prototype version and go further in the field they are best in, namely the continuous development of new products. To bring such a prototype into production requires different skills, as well in the field of making products compatible with fabrication chains as in the marketing and financing.

In the space sector this philosophy is not established (yet). Scientists and engineers with very good ideas are trying to bring these ideas themselves on the market. In their attempts to find sources, they face such problems as:

- No experience in preparing a business plan (sometimes technically excellent but unacceptable in terms of market research, profitability analysis and risk assessment);

- Communication problems with bankers. The financial world assumes that each entrepreneur is familiar with Net Present Value concepts and Equity/Debt management (just to quote a few). The developer will still work with such concepts as ROI (often showing payback periods which are far beyond the interest of the financial institutions);

- A natural mistrust in the financing community. As most space projects have no historical precedents, this is an area that is difficult to evaluate for the financial analyst. Moreover, the image of the non-cost-conscious scientist is not improving the atmosphere of trust.

Many of the ingenious projects, also in the space tourism sector, have been stopped in front of this hurdle. Awareness of the TLC, and acceptance of the old saying ‘which business are you in?’ may create a more stable relationship, with space technology developers exploring the first part of the TLC and then leaving the marketing to other companies, themselves earning their (good) living from technology sales and royalties.

An example of this is the space tourism sector, where most developers have not even thought about trying to get in contact with the final market, the tourism sector…

1.3.2 Effect of the Time-To-Market (TTM)

The time required to bring a space-based product to the market can be relatively long, compared to ground based products. There are numerous reasons for this, just to name a few:

- Longer development time due to less use of Off-The-Shelf (OTS) components;
- Time consuming process for precursor missions;
- Long checkout times and transport to launch site;
- Especially when smaller payloads are combined with ‘prime payloads’ (so called ‘piggy-back launches’), timely availability of the launch can pose timing problems and delays.

As we will note later, this is one of the major problems associated with space tourism and a high uncertainty factor in each space tourism business plan. Also projects such as the aforementioned Iridium, which required 6-8 years TTM period have failed largely due to this delay (in the case of Iridium the much faster implemented GSM capability made the product partially obsolete even before it reached the market).

Methods of ‘rapid ramping-up’, essentially oriented towards reducing the time between research and market maturity are not common in the space sector yet.

Indeed, even the commercial space sector is still very technologically oriented (with scientific trained management) and the traditional conflicts between a marketing and a research oriented approach (see the following table) are, in the space sector, most of the time decided in favor of the technological ‘school’.

Marketing Interest	Technology Interest
Concentrate on New Product Development (NPD)	Concentrate on Research
Develop and control specifications	Try out parallel technology
Freeze a design as quickly as possible	Keep options open
Accelerate Time-to-Market (TTM)	Do extensive pre-testing
Rapid Ramp-up (to go in production)	Start a ‘pilot-plant’ first
Enhance Customer Acceptance	Emphasize technology
Keep proprietary rights	Publish results

Table 9 – Internal conflicts influencing Time-To-Market (TTM)

Related to the last point in the table, the relation between space activities and confidentiality is also still playing a big role. Research has shown that the internal security procedures in governmental laboratories are still so dominant that a market-oriented approach is strongly hindered (response times, security clearances for RFQ work, flexible information flow to the customer…).[23]

1.3.3 Governmental Role and Dual-Use Effect

Most space activities still need a ‘carrier’ or a “raison d’être” to come to a future profitable commercial product. Indeed, let us consider some sectors, which are presently showing economic potential:

- Telecommunications is undoubtedly the most important one;
- Earth Observation has a ‘value-chain’ component which is interesting, but still one order of magnitude lower than telecommunications;
- Navigation is developing rapidly and considered as one of the most promising sectors for the next decade.

[23] BUYS, K. and HANNA, J., The Compatibility of the Marketing Concept Within the ‘Classified’ Customer Service Culture of Department of Defense National Testing Laboratories, *Journal of Nonprofit & Public Sector Marketing,* Vol.5(4) (1997), pp. 49-68

If we mention these sectors we cannot avoid talking about ‘dual-use’. The driving force behind many space-related technological advancements was, and to certain extent still is, military objectives The impacts of the dual-use technologies affects the development and use of civilian and commercial space activities (see following table).

Technologies	Civilian Use	Military Use
Remote Sensing (Optical, Radar)	Earth Observation satellites for weather forecasting, mapping, etc.	'Spy' satellites for combat intelligence, arms control verification, etc.
Advanced ballistics and missiles	Space transportation systems (launchers); Sounding rockets (for microgravity experiments)	ICBMs (Intercontinental Ballistic Missiles); Short range surface-to-surface missiles
Biotechnologies	Aerospace medicine; medical research	Biological weapons
Satellite communications	Telephony, Internet, Broadcasting	Military communications

Table 10 – Examples of Dual-Use Technologies

Military U.S. space budgets are larger than the public civil ones and as such the DoD’s space budget is the largest governmental budget in the world. The R&D for market-oriented applications is largely a spin-off of military developments.[24] Indeed, as the military sector develops and operates these systems, they provide end-to-end testing for new technologies. It goes without saying that this is a considerable advantage for the U.S. companies who operate both in the military and the commercial market (an effect which is amplified by the fact that space companies have merged in U.S. to a considerable extent).

If we now consider some US military developments such as:

- The Milstar military telecommunications system (25.3 billion $ from 1983-2002)
- SBIRS Infra-Red early warning satellites (estimated at 22 billion $)
- Navstar/GPS navigation systems (25 billion $ investments in the period 1974-2016)

These coincide remarkably with the present commercial space sectors, including a large presence of American companies.

As described before, the correlation can be easily explained: the considerable investments have provided the sector with equally considerable know-how, also as reliability requirements are higher for military projects as compared to civilian ones. Therefore, when the market opportunities become evident, the related industrial space manufacturers can relatively quickly develop derivates at very competitive prices, requiring less testing (hence reducing the TTM considerably).

It has to be noted here that also this sector is able to invest in the research phase considerably: DARPA, the US military research Agency, has not only considerable budgets (order of 3 billion $ yearly) but also relatively unlimited possibilities to recruit people on short-term notice. This has resulted in unusual developments, which turned out to be important applications, such as the Internet.

The consequences of these observations are evident:

[24] GIGET, M., CHENARD, S. & LE PROUX DE LA RIVIERE, E., Impact of the dual use concept along the value chain of major space applications, *Acta Astronautica*, 38 (1996) pp. 587-603

- Such carrier is only available in case sufficiently large budgets are available, such as the present case for US DoD;

- Developments of this type are consequential, not proactive (in other words, if there is no interest for the application from the prime partner, the development is unlikely to take place);

- For different applications, different development schemes are needed.

In Europe, the so-called Public-Private-Partnership (PPP) has been regarded as a potential solution. Projects such as Galileo have demonstrated a will of the private sector to be involved, but no will to pre-finance.

Furthermore, a public agency is used to work independently and has a contractual procedure tuned to this. Under a PPP concept this has to be adapted to integrate the interest of both parties, as shown in the following table.

ASPECT	TRADITIONAL AGENCY APPROACH	PPP APPROACH
Financing (LCC)	100% Agency financed	Shared financing
Requirements	Agency	Industry, in view of commercial interest
Statement of Work	Agency	Agency (only top level)
Programme of Work	Agency	Industry (mainly)
Contract Conditions	Agency	Tailored

Table 11 – Use of contractual instruments for a PPP approach (Adapted from Benetti, 1999)

We have to mention here that not exclusively military applications need to be a good carrier for space applications. Political motivation on national (e.g. emphasis on environmental protection) or supra-national scale (such as the new transportation infrastructure plans of the European Commission) can have a similar positive impact. Even a global decision, such as the one taken in Johannesburg on Sustainable Development, may lead to a parallel market development.

1.5 Preliminary conclusions from the present experiences

We can at this point draw a number of conclusions that are important for the rest of the study:

- Many of the announced applications with a visionary character have not been realized;
- As this has also an indirect effect on other space activities (such as the launch sector), expected economic growth as forecasted has not been reached;
- The main facilitators for a successful space commercialization approach are:
    - Initial or parallel investments made by public funding (such as the ‘dual-use’ applications);
    - Segmentation in the Technology Life Cycle between different players;
    - Availability of a professional business plan when discussing financing;
- The main impediments are:
    - The considerably long Time-To-Market (TTM) periods;
    - The lack of a track record of success stories, discouraging potential investments;
    - The additional perceived risk of a lacking regulatory, commercially oriented, framework;
- As ‘killer applications’ are not rapidly evolving due to the aforementioned factors, most of the economic growth has to be expected in a more global utilization of existing applications, including the desire for sustainable development.

2. CURRENT COMMERCIAL SECTORS AND THEIR PRESUMED EVOLUTIONS

2.1 Introduction

As mentioned in the previous chapter, many of the commercial space initiatives started out as government-funded research programs in the United States, Russia, Western Europe and the rest of the world. Most of the current commercial actors themselves are often:

- Privatized governmental or intergovernmental bodies (e.g. large satellite operators such as Intelsat, Eutelsat);
- Companies created with commercial purposes, but with some governmental control through shareholding (e.g. Arianespace, Alenia Spazio, EADS, Khrunichev Energia International)
- Private companies but largely dependent on governmental contracts (e.g. most remote sensing companies).

For the past decade, a shift towards making use of those new commercial actors by governments, instead of developing new publicly funded systems, seemed to indicate a wish to encourage the private sector to develop with its own funding new products and applications. However, except for the communications satellites sector, governmental users (e.g. public civilian bodies, defense) are often still the main customers for many commercial products and services.

The following current commercial sectors are briefly presented in the next sections: launchers, telecommunications, earth observation, navigation and military space applications, and we will look at new integrated applications that may drive new commercial ventures.

2.2 Main Sectors and Trends

2.2.1 Launchers

The commercial space launch market is not really "commercial", as stated by 39 international leaders from government and industry of 16 nations and 5 international organizations, meeting in Houston for the first space policy symposium in 2002: "Today's commercial satellite market is not sufficient to sustain current space launch systems or justify industry investment in new systems and technologies. Government support is necessary for the foreseeable future to achieve national objectives in the security, civil, and commercial sectors."[25]

The US Federal Aviation Administration (FAA)'s Commercial Space Transportation Advisory Committee (COMSTAC) prepares every spring since 1993 an annual international commercial space launch forecast, and its latest numbers tend to corroborate the above statement concerning the state of the space launch sector.

This year's report predicts indeed a continuing decline in the average demand of satellites to be launched per year over the period from 2003 through 2012.[26] The COMSTAC averages annual demand

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[25] AIAA, "World Leaders Convene for Space Policy Summit", *Press Release* (October 2002)

[26] FAA/COMSTAC, *2003 Commercial Space Launch Forecasts* (May 2003)

forecasts of 2001 and 2002 reports were 30.5 and 27.3 satellites per year, respectively. This year's average forecast is of 23.3, 15 percent lower than the average forecast of 2002 (see following table).

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Total	Average 2003 to 2012
Satellite Demand	22	18	18	22	24	25	26	27	25	26	233	23.3
Dual Launch Forecast	3	2	4	5	5	5	5	6	6	6	47	4.7
Launch Demand	19	16	14	17	19	20	21	21	19	20	186	18.6

Table 12 – Commercial geosynchronous orbit launch demand forecast

The potential arrival of new cost-effective launchers is currently largely based on governmental investments. The United States and Europe are leading the way in terms of budgets for researching new reusable technologies, but though technological breakthroughs are possible, no commercially viable reusable launcher is foreseen in the near future by experts.[27]

Pending technological progress, the following factors should contribute to the evolution of the commercial space launch sector in the next 15 years:

- International economic conditions (poor conditions tend to depress the economic activities of the launchers industry's customers);
- Continued launcher and satellite industry consolidations worldwide (hence potentially less competition amongst launch providers, but also less satellite to launch);
- Increased satellite lifetime (less replenishment satellites);
- International regulatory environment (promoting or discouraging competition);
- And the development of new applications, requiring new satellites on orbit.

2.2.2 Telecommunications

The telecommunications sector has faced some difficulties in the past three years, as mentioned in chapter 1 of this study. Those difficulties are mainly due to the reduction in demand for wireless satellite constellation development, to the proliferation of new actors in the field, and to the continuation of a trend in larger commercial communication satellites lasting longer on their on-orbit stay times. The numerous applications using communications satellites make however this sector the only real 'commercial' space sector so far (see the following table).

	Communications Infrastructures	Fixed Communication Service to End User	Mobile Communication Service to End User
Telephone	International trunking Domestic trunking	Primary telephone service via satellite	Mobile business oriented service via satellite (roamer Service) In-flight telephony
Television and radio	Relay of cables and Broadcast signals	Direct-to-home television/ Interactive television Direct radio multicasting / caching	Direct radio In-flight TV
Data	Internet backbone Global "fiber-like" networks providing backbone services	Broadband Internet connection Wireless networks (VSAT) Asset management	Messaging and asset management In-flight fax/internet

Table 13 – Major telecommunications applications

[27] Futuraspace LLC: *Future Trends in Human Spaceflight: A Global Survey* (May 2002)

The space industry is marked by stiff competition among commercial firms to secure orbital locations for satellites and to secure the use of radio frequencies to exploit a global market for goods and services provided by those satellites. Two key factors should affect positively satellites' telecommunications future developments and lead the way for new integrated services.

❑ Essential communicating tools for the 'Information society'

The past decade has seen a new technological revolution take place, with the information society becoming a reality. Personal computers, cellular phones, PDA's (Personal Digital Assistants), satellite television, DVDs have all become daily products in developed countries. The Information Technologies (IT) already a key factor in space activities, offer the opportunity of new applications and new domains of use that draw on the telecommunications sector, as the provider of essential satellites links. The space component of the telecommunications business is already a multi-billion dollar industry, although it is only a small percentage of the total communications sector.

Those new "infocom" applications include: multimedia for education (e.g. tele-education), large data distribution (e.g. public libraries), medical applications (telemedicine), and satellite radio communications.

"The convergence of telecommunications and information technologies will continue to fuel commercial growth for advanced infocom products and services for a global mobile community. The inherent "look down" advantages of space-based capabilities will continue to provide an effective means for delivering services and gathering information on regional or global basis."[28] These infocom products and services are described in more details in the section 2.3.

❑ The increasing need for broadband Internet

The present scale of development of the Internet - and especially interactive multimedia applications - is causing problems of overload on the terrestrial networks run by the telecommunications operators. Three main reasons tend to advocate for the use of satellite communications:

- The continued increase in the number of Internet users, especially in Europe and Asia;
- The proliferation of memory-intensive applications such as graphics and images requiring lines fast enough to ensure acceptable response times;
- and the comparatively slow development of the high-speed terrestrial infrastructure.

It seems clear that "the information highways do exist but more often than not, we still have to travel along small country roads to get to them", especially in remote areas where phone lines, when they exist, are the only communicating means available.[29]

The "digital divide" is a key problem, as a large part of Earth's population, including in developed countries, may never have access to terrestrial broadband Internet. Communications satellites have a major role to fulfill, by providing up in the sky the "missing links" for these highways by creating new itineraries for Internet users. Though currently some companies tend to defer any large "broadband" projects because of the weak market and the lack of available financing, the increasing need for broadband access in developed countries in Europe and Asia notably, should benefit the space telecommunications sector in the next decade.

As we will see in the next sections, the telecommunications sector will have a major role in helping develop new integrated space-related services.

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[28] OBERG Jim, *Space Power Theory*, USAF, Department of Astronautics (March 1999), p. 22.

[29] DUPAS Alain, *L'âge des satellites*, Hachette (1997)

2.2.3 Earth Observation

Historically, the earth observation commercial market predictions have been overly optimistic, with worldwide expectations of exponential growth that were always to begin in just ‘2-3 years’. It was thought that being able to monitor agricultural fields for example on a world-wide scale, and to accurately predict the world harvest for different crops, would revolutionize the agricultural (precision farming), industrial (food industry) and trading (commodity markets) sectors. However, recently the European Space Agency has noted an annual growth rate of only 1.4% for the European earth observation industry between 1997 and 2000 – a decline when inflation is considered.[30]

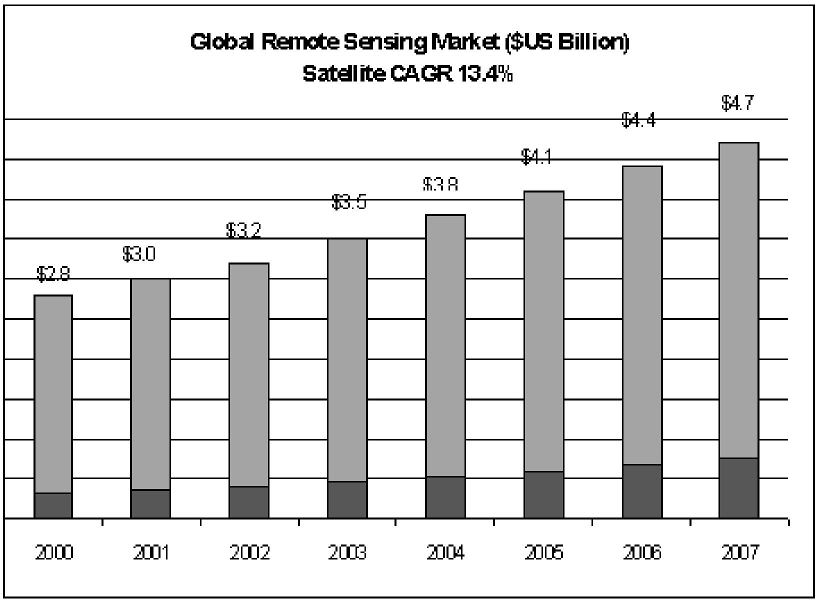


Figure 6 – Global earth observation market (Frost & Sullivan 2001)

As shown in the above figure, Frost and Sullivan projected in 2001 a global demand for the overall commercial earth observation market (including both satellite and aerial photography) to grow from $3.2 billion in 2002 to $4.7 billion in 2007, a Compound Annual Growth Rate (CAGR) of 7.7 percent. Satellite’s share of this market was expected to expand from just over 11 percent in 2000 to 16 percent in 2007 (darker column), creating annual demand growth of 13 percent for the satellite industry, the EO public and private community.

The precise level of maturity and types of services offered by commercial earth observation based geo-information companies is not always very clear for potential customers in governments and industry, whether that may be in Europe or the United States (see table 11).

[30] ST-PIERRE M., Canadian Space Agency, “The Future of Earth Observation”, *Presentation at the Earth Observation Applications, Industry Days* (12 June 2003)

Sector	Applications	Customers
Agriculture / Forestry	Precision Farming Agricultural Statistics Forest Certification	involved with planning, management & control of crop resources (incl. developing countries) Private sector: agribusiness industry including commodities, insurance)
Surveillance / Monitoring for Security (Land & Ocean)	Environment Research (pollution, global warming…)	Administrations / scientific organizations
Defense / Diplomacy	Treaty verification (e.g. Kyoto protocol)	Governments, military

Table 14 – Examples of earth observation applications

In response, ESA has drafted a portfolio of marketable products and services based on ESA data, which includes only services where sales have already been made or where the service is available and ready for market.[31] However, no real estimates of what users are actually prepared to pay for what type of services have been made so far. Analyses are often cost-based (e.g. how much an image costs) than demand-based, even in the more developed American market. The demand itself is shifting increasingly from basic pictures to value-added products and services which prices are harder to estimate since they are based on precise user requirements (e.g. full Geographic Information Systems 'GIS' integrating ground and space data).

The figure in the next page shows earth observation revenues by market segment in 2001 in the United States, according to a large Remote Sensing Industry Analysis conducted by the American Society of Photogrammetry and Remote Sensing (ASPRS), started in 1999 under a NASA contract.[32]

Earth observation is still a sensitive domain, especially in the current renewed international tensions following the 9-11 events and the Irak war. The main customers for earth observation derives data should still remain governmental agencies; especially the ones dealing with security aspects in the broadest sense (e.g. defense, natural disaster relief efforts), while the private sector demand (e.g. oil and gas industry) is likely to remain cyclical.

Therefore, the strong public good element to earth observation should offset somehow the lack of enthusiasm from the private sector. Enhanced monitoring capabilities are essential for early warning of environmental changes, regardless of whether those changes are natural or human induced. Remote sensing is certainly a key contributor to the ability to monitor, and therefore oversee, how human activities are interfacing with the various types of environments on which they locally depend.

[31] ESA, *Earth Observation Market Development Summary Report*, *European EO Services: Activities, Achievements, Issues And Future Prospects*, Industry Workshop, ESA-ESRIN, Frascati, Italy (10-12 October 2002)

[32] PLASKER J., Executive Director ASPRS, *Highlights - The 10-Year Remote Sensing Industry Analysis*, Presentation (November 14, 2002), See http://www.asprs.org

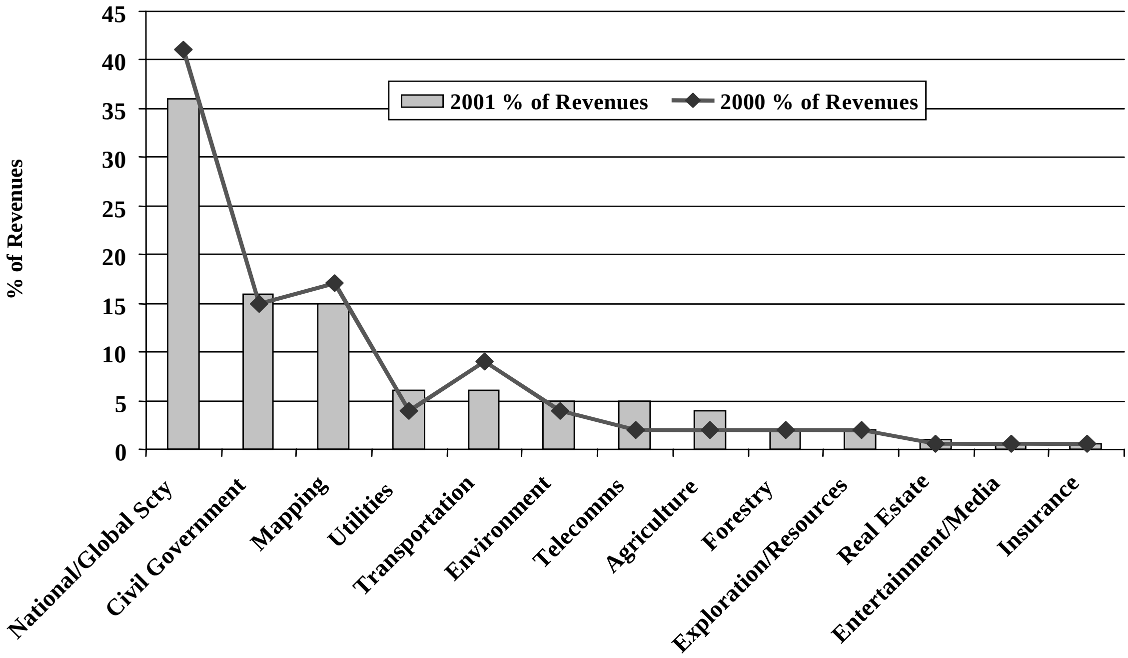


Figure 7 – Earth observation revenues by market segment 2000 and 2001 in the United States

Starting in 1999, NASA and the United States Department of Agriculture (USDA) met representatives from four major agricultural grower associations (corn, cotton, soybean, wheat) representing 115,000 farmers to craft a draft national strategy to help farmers improve their planting, fertilizing and harvesting methods. "The overriding goal of this unprecedented meeting is to spend less and grow more," said then David Brannon, program manager of NASA's Commercial Remote Sensing Program (CRSP). "By bringing remote sensing technology and variable-rate precision farming technology together, we will be able to provide farmers with information about crops and their condition."[33] This tends to show that public agencies still have an important role to play in informing and even convincing potential users of the benefits of earth observation applications (see figure below).

(courtesy of NASA)

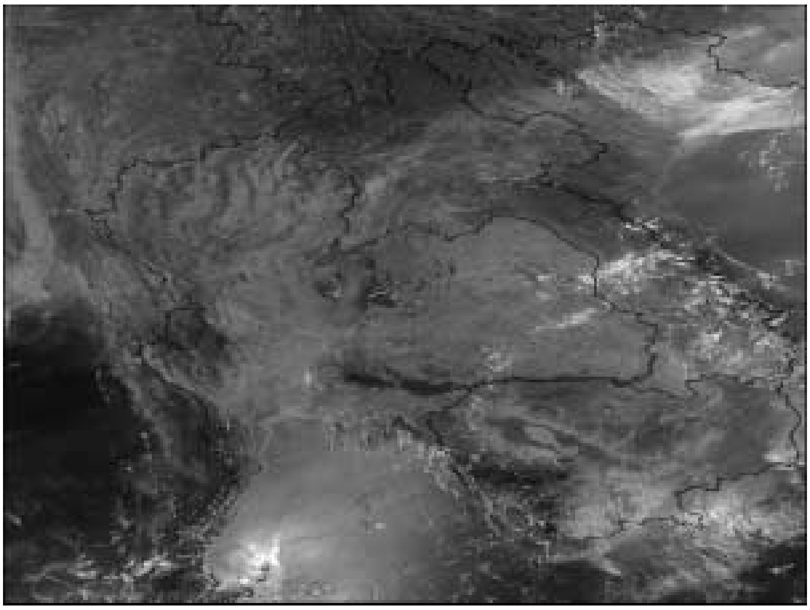
Figure 8 – Monitoring of agricultural fields on the American-Mexican border

Follow some short- and long-term factors that are likely to influence public support for furthering earth observation in the future:

[33] NASA, Stennis Space Center, "Workshop Focuses on Remote Sensing Applications to Improve U.S. Agricultural Practices", *Press Release* (19 Aug. 1999)

- Renewable vs. non-renewable resources (fossil fuels);
- Clean drinking water;
- Arable, fertile land;
- Trans-boundary air and water pollution, nuclear pollution;
- Climate change, ozone depletion / greenhouse gas emissions;
- Sustainable forests (tropical deforestation);
- Sustainable seas (fisheries depletion);
- Natural disasters (fires, floods, earthquakes…);
- Humanitarian crisis (population migration, refugees…);
- Wars, armed conflicts;
- UN operations;
- Disarmament agreements.

The increasing usefulness of obtaining satellite imagery in time of crisis should also drive governmental usage (see following picture).



(courtesy of NASA - Terra satellite)

Figure 9 – Fires in South East Asia (April 5th, 2002)

Though the commercial earth observation satellites performances are increasing, four main issues should impact the commercial industry development in the next decade:

- Focus on limited national/regional markets due to captive markets;
- Customer acceptance of earth observation based information;
- Development of adequate supply capabilities according to user requirements;
- And still high costs of imagery, limiting the customer base.

The key challenge for remote sensing industry is the seamless integration of their data into larger Geographic Information Systems 'GIS' products and services. As we will see in section 2.3, earth observation products and services could potentially become commercially viable, when they become partially integrated in infocom products and services.

2.2.4 Navigation

Many analysts see the navigation sector as the future profitable market, after the telecommunications sector. Sales of GPS equipment and services are already expected to exceed $16 billion by 2003. The annual turnover associated with an entire navigation system and its very diverse integrated applications (e.g. traffic-management tools, in-car systems, hand-held receivers) is estimated to be as high as €15 billion in 2001 and €150 billion by 2020.[34]

Other services identified by PricewaterhouseCoopers, which was contracted by the European Commission to conduct a market study, include: the aviation, the oil and gas industry, the police and fire services, the vehicle route guidance, and marine, mining & other sectors (see following table).[35]

	Personal Communications and Location-Based Services	**Aviation**	**Oil and Gas**
Revenues in 2020	≈ € 280 millions	≈ € 110 millions	≈ € 50 millions
Assumptions	3bn users world-wide 90% GNSS enabled 50% Galileo chipsets €0.35 royalty / chipset	€360m ground-based navigation costs 50% savings from Galileo usage 50% of realized savings captured by Galileo Operating Company	20,000 units €10,000 per unit per annum to service provider 25% to Galileo Operating Company

Table 15 – Most promising sectors for the Galileo Navigation system

The deployment cost (2006-2008) should reach €2 billion, with an average annual operating cost of €135 millions per annum. The replenishment cost (2008-27) for the constellation should reach €1.8 billion. The development phase should be fully funded by the European Commission and the European Space Agency, whereas the deployment phase is expected to be funded partly by the public sector (up to 33%) and partly by a private consortium. The establishment of a PPP should in theory facilitate equity and debt.

However, "the development and operations costs of a complex system such as Galileo represent a major commitment and a real challenge for Europe and its industry. According to most studies, important revenues will come from the downstream services; however, public funding remains essential to the system's launch and operation over many years. A private consortium could, in time, operate the system, but many questions remain open."[36] The key issue is whether additional space segment providers such as Galileo are viable, since the American GPS is already a free service, and whether the market will be large enough for both contenders.

As we will see in section 2.3, the commercial navigation sector might actually develop as it is being integrated with other terrestrial products and services.

2.2.5 Space Military Market

Defense budgets are forecasted to promote space military applications over the next few years in major developed countries. Though, at a first approach, this seems a purely public sector the considerable amounts involved may lead to proactive business plans from the space industry.

[34] European Commission, European Space Agency: *Business In Satellite Navigation: An Overview of Market Developments and Emerging Applications* (5 March 2003)

[35] POULTER T., *Galileo - The Commercial Structure and the Commercial Structure and Revenue Opportunity,* Presentation by PricewaterhouseCoopers (2002)

[36] JOLLY C ., *Europe's Challenges in Developing its Own Satellite Navigation System*, Paper presented at 8th Annual ISU Symposium, Strasbourg, France (May 2003)

❑ **Military market *per se***

The larger defense market is in the United States, where the "space power" theory was born. "Space is not simply a place from which information is acquired and transmitted or through which objects pass. It is a medium much the same as air, land or sea. In the coming period, the United States will conduct operations to, from, in and through space in support of its national interests both on earth and in space. As with national capabilities in the air, on land and at sea, the United States must have the capabilities to defend its space assets against hostile acts and to negate the hostile use of space against American interests."[37]

Many military space programs are currently being funded in navigation, remote sensing and telecommunications (see table below).[38] Aside from those, the 'National Missile Defense' should also be noted as this initiative, developed to protect the US from limited attack from long-range ballistic missiles, should consist of ground-based radar, space sensor systems, surface-to-air interceptor missiles and airborne laser technology to locate and shoot down warheads.

FUNCTION	CURRENT SYSTEMS	PLANNED SYSTEMS
Missile warning and tracking	• Defense Support Program (DSP)	• Space-Based Infrared System (SBIRS High) • Space Tracking and Surveillance System (STSS, former SBIRS Low)
Intelligence, Surveillance and Reconnaissance	National Reconnaissance Office (NRO) satellites	• NRO satellites • DOD's Space-based Radar
Communications *Wideband/ high capacity systems*	• Defense Satellite Communications System (DSCS) • Global Broadcasting Service (GBS)	• Wideband Gapfiller Satellite (WGS) • Advanced Wideband System (AWS)
Protected systems (antijam, survivable)	Milstar	• Advanced Extremely High Frequency (AEHF) • Advanced Polar System
Narrowband systems	Ultra High Frequency Follow-On satellite communications system (UFO)	Mobile User Objective System (MUOS)
Navigation, Positioning, Timing	Global Positioning System (GPS)	Next Generation GPS
Weather / Environment	Defense Meteorological Satellite Program (DMSP)	National Polar-orbiting Operational Environmental Satellite System (NPOESS)

Table 16 – Current and Planned US Military Satellite Systems

In this context, besides the US DOD efforts, one should note also recent plans to build up a European space military capacity.[39] It is clear however that in the next decade, American firms in almost every sector of the space economy should largely benefit more from the US DOD contracts, than their European counterparts from the European authorities.

[37] HAYS P., "What is Spacepower and Does it Constitute a Revolution in Military Affairs?", *Journal of Military and Strategic Studies* (Fall 2002)

[38] GAO, *Military Space Operations: Common Problems and Their Effects on Satellite and Related Acquisitions*, Report GAO-03-825R, Washington, D.C (2 June 2003)

[39] ASSEMBLY OF THE WESTERN EUROPEAN UNION, *European defence-related space activities and the development of launcher autonomy*, Document A/1822 (4 June 2003)

As seen in chapter 1, defense funding for large space projects always gives a definite advantage for future commercial ventures using tested military technologies. In Europe, the defense budgets tend to stagnate, which leads some analysts to worry that future commercial applications will be largely based on American technologies, hence limiting international competition in the long run. This situation might be offset by the development of more commercial applications directed at commercial users, but defense budgets will still have their importance in helping develop new technologies. In South-East Asia, the Indian sub-continent and South America, defense efforts in developing advanced missiles' and satellites' technologies may impact the commercial space sector in the long run, however their developments are at a lower scale compared with the United States, Europe, and Japan.

As an interesting point in the defense market, cost is not the primary driver in the design of military systems and this is an advantage many industrial actors tend to take advantage of. In the commercial world, relatively small differences in user equipment or service costs can determine which of two competing systems is ultimately successful in the marketplace. In the acquisition of military systems, performance plays a more important role. This fact already triggered the interest of aerospace commercial firms decades ago.

Also, where there is insufficient commercial demand for a class of component or subsystem that the military needs, aggressive measures are usually taken by the public sector to ensure the continued existence of a reasonable pool of both suppliers and R&D technical expertise. Some new commercial entities may then find military niche markets in the future space sector (e.g. for the satellite mobile applications: broadband high-power amplifiers and high-gain antennas with unusual characteristics).

Based on budget predictions, the military space market might be growing a bit in the next decade, but the important factor for commercial firms lies in its continuity, giving them some assurance in their business planning.

- **Military as a customer of commercial space products and services**

Because of the large cost differential between commercial- and military-developed equipments, there is a strong incentive for the military to make greater use of commercial products and services, including off-the-shelf (COTS) equipments. As any governmental body, the military tend to use more and more commercial space products.

Although military variants of commercial systems would appear to offer a middle course of action between military-unique and commercial off-the-shelf systems, military variants tend to represent a reduced compromise between these two extremes. Except for limited ruggedization in some cases, there is little that can be done on an after-production basis. Other modifications require the cooperation of the original equipment manufacturers, hence limiting the commercial competition. Therefore, in space-related products as in ground equipments, prices tend to be much higher for modified commercial equipments, and may approach those of military-unique systems.

There is also inherent divergence between military needs and what the commercial world is providing and likely to provide in the near future.[40] Primary reasons for this divergence include:

- Different priorities for commercial and military system users;
- Requirement for ruggedization of the military systems (e.g. satellites able to support attacks), when many commercial types of equipment provide inadequate security.

In summary, the defense sector may influence the developments of future space applications, through:

[40] GAO, *Defense Space Activities: Organizational Changes Initiated, but Further Management Actions Needed*, Report GAO-03-379, Washington, D.C (18 April 2003)

- Its actions on the commercial space sector as a customer;
- Its joint ventures involving government subsidies for research carried out by industry, and guaranteed minimum buys of products meeting specified performance requirements;
- The military research funding: the defense departments often promote research in areas that are of particular importance to the military, and where the commercial world will unlikely take the initiative on its own (e.g. because the market is primarily military, or because the risks are too high), hence helping develop new technologies;
- Its active participation in standards working groups and other forums nationally; regionally and internationally. It is noticeable that especially in Europe, it is not taboo anymore to see officers taking part actively in industry meetings to discuss future space systems.

2.3 Towards New Telecom-Derived Integrated Services

Though in the last decade we have seen a clear evolution from government to commercial business activities, some still consider that the current ‘real’ space business is merely an offshoot of the global telecommunications industry. Indeed, the great majority of the revenue generated by all commercial space activities comes mainly from two sources: providing telecommunications directly, and serving the telecommunications industry (e.g. satellite operators, satellite manufacturers, launch vehicle, ground support equipment providers). All other commercial space sectors are either limited (e.g. earth observation), or already more and more interlinked with telecom (e.g. navigation). As we will see in this section, integrated services and products generically called ‘infocom’ may drive further development of the current space sector.

2.3.1 General Principles

The main current space applications (telecommunications, remote sensing, navigation) are reaching a level of technological maturity. Space-related technologies are indeed no longer regarded as novelties, and are used more and more by the general public (e.g. satellite dishes on rooftops to access broadcast movie channels, foreign television channels, high speed connections to the Internet, satellite weather maps on the evening news, GPS receivers for campers…).

The technological maturity of the systems should be followed in the next decade by the ubiquitous use of their induced commercial applications. They would filter down through all levels of society, being integrated in many different aspects of daily life (e.g. telephones and televisions have become two technologies so pervasive in today’s home as to be regarded as simply another piece of furniture). Space utility has yet to reach that phase, though the premises of such uses can be already seen today by looking at the prototypes being developed to integrate space-based communications and locations services for the general public.

The need to communicate will remain and will be an important driver for the rest of the applications, but the added demand for localization and mapping is already creating new integrated appliances using space technologies. It can be estimated that navigation as an ‘identified market’ is likely to disappear, as navigation technology becomes embedded in larger systems, while the key challenge for the remote sensing industry is the seamless integration of their data into larger Geographic Information Systems (GIS) products and services.

The space industry and the information technology (IT) industry are both facing the same infocom revolution. The IT industry consists of many companies that provide systems (i.e. computing hardware, software, networking equipment) and/or consulting to manage transactions and internal communications for individuals, business, industries, and governments. In the coming decade, “the IT industry will be dominated by creation of full-services networks which provide voice data, and video services. One of the hard tasks facing the IT industry is breaking the inertia of conservative clients from conventional industries (e.g. petrochemical, steel etc.) The concept is remarkably simple, but it represents a dramatic change in how telecommunications services are provided. Companies will no longer be able to build businesses by providing a single type of service, but they will need to provide comprehensive packages supporting all three types of service […] As full service networks are deployed, competition for customers will focus on the last link – the bit of wire, cable or radio frequency transmission that connects the subscriber to the network. This will increase the choice available to consumers while increasing competitive pressure on service providers."[41] And those service providers include of course current satellite operators.

Space technologies may become then not only essential for telecom infrastructure purposes (e.g. helping counteract the 'digital divide'), but may also provide content for the infocom products and services (e.g. imbedded satellite imagery and localization tools in car transmitters). One of the big challenges for the space industry is then the speedy integration of new developments in microelectronic, microcomputer and micro-mechanic technologies with the space-related technologies.

2.3.2 New Markets

- **Regional markets**

As we noted in Chapter 1, a steady growth can be noted from the services we are used to in the western society but which will have a considerable boom in the emerging countries. Just to give one example: let us look at a forecast of mobile phones in a country like China (see figure in the next page), then we note very substantial markets which can be accessed but which will need certain changes in regulations. As space-related products should be integrated more and more in standard appliances for businesses and the general public, the emerging national and regional markets in Asia should provide an important source of growth in the next decade.

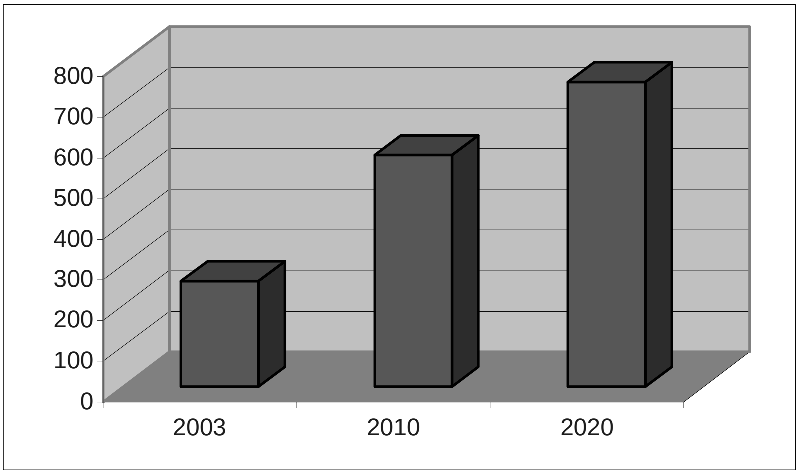


Figure 10 – Recent forecast of growth in mobile phones in China

In Europe, recent institutional programs promote space-based systems and their integrated applications in order to tap in the developing infocom markets. The Global Monitoring for Environment and Security (GMES) program is an European Union–ESA program, which seeks to exploit better Europe's existing and planned space- and land-based Earth observation systems (e.g. Envisat) to help develop European technologies and know-how to create new commercial applications. The Galileo navigation system should also spur many indigenous commercial downstream activities. There is a clear political will on European institutions' part to participate in developing the European infocom markets.

[41] HOUSEL T., SKOPEC E., Global Telecommunications Revolution: The Business Perspective, McGraw-Hill Irwin (2001) p. 60

- **General Infocom products and services**

Space markets tend to become more and more integrated with the terrestrial economy, rather than distinct from it. Space products and services are not anymore standalone products and services, but are providing inputs to other commercial goods. Satellite communications represent now already a telecommunications service more than a space business, whereas satellite remote sensing is increasingly considered an input to larger Geographic Information Systems.

The market for integrated navigation and GIS data is growing rapidly

- Telematics, wireless communications are more and more using location/position data;
- Knowing "where something is" is becoming as important as knowing what time it is.

As we have mentioned already, the key challenge for developing the remote sensing industry is the seamless integration of their data into 'GIS' products and services. GIS is a set of processes executed on geographically referenced data as well as non-spatial data, which aid in the process of decision-making. However GIS includes different components (software and often hardware tools) that allow different types of data to be consistently collected, analyzed, and displayed within a spatial framework. The space data (e.g. space imagery, location) becomes just one the component of the overall system. This service is of increasing value to farmers and ranchers, fisherman and miners, city planners and scientists.

Some infocom with implications for the space industry, either as infrastructure or content provider, are presented in the following table.

Applications	Description	Development Status	Users
Secure digital payments	Payments using digital highways (Internet, voice)	Efforts have been ongoing for a decade, but national regulations on encryption tend to slow down international standardization, hence slowing down digital commerce	- Individuals - Companies - Governments
Geographic Information Systems	Set of processes executed on geographically referenced data as well as non-spatial data, which aid in the process of decision making	One of the fastest growing field of applications	- Companies (e.g. agriculture, utilities, energy…) - Scientists - Governments (e.g. civil infrastucture)
Desktop videoconferencing	Computer mediated interactive communications, including voice, motion video, and data information. It includes videoconferencing and groupware tools.	Also one of the fastest growing field of applications	- Individuals - Companies - Governments - Private virtual organizations - Telecommuting workforce (location-independent workforce)
Virtual reality	Human computer interface in which the computer creates a sensory immersing environment that interactively responds to and is controlled by the behavior of the user.	First applications were in the military, slowly being integrated in the civilian sector. Communicating in three-dimensional virtual space will profoundly change the nature of human and business interactions in the next 20 years. Currently, experimental phases.	- Private virtual organizations - Telecommuting workforce (location-independent workforce)

Table 17 – New infocom applications with a space component (as infrastructure/content provider)

❑ Mobile applications

As seen previously in the description of the navigation sector (section 2.2.4), the estimated revenues for the Europe system Galileo should be driven principally by personal location-based services and route guidance for cars and light commercial vehicles. The personal location-based services are forecasted to take off as users increase their reliance on the new navigation-related technologies.

Four factors are driving the expansion of satellite based transmission systems and mobile applications:

- Provision of services to areas without adequate telecommunications (85% of the land mass);
- Increased convenience for consumers who will be able to carry one phone anywhere and bypass local networks;
- The prospects of dramatically reduced costs with expected satellite communications charges;
- Expended bandwidth with data rates on the order of several mbps and up to support voice, data, video and multimedia services.

Two demographics tend to be the main drivers for mobile infocoms products and services:

- ‘Global roamers’, ‘elites’, and ‘outposts’ (high income, high usage per capita);
- Rural/developing region (low income, low usage per capita).

The development of this ‘mobility market’ clearly follows advances in the IT industry, as more and more “product developments will allow information devices to be ubiquitous, wearable, and in continuous contact with one another. We expect to see a multitude of diverse, powerful, inexpensive sensors and other devices capable of (limited-distance) wireless communication; these devices will provide a vastly increased coupling between the physical world and the cyber world, allowing information systems to react much more comprehensively to changes in their environment and vice versa.”[42]

Also, current trends in terrestrial traditional markets, such as car manufacturing, may help the development of specific mobile infocom products and services. For example, transportation markets are developing in emerging countries (e.g. China) whilst new high-tech upgrades to western products are made continuously every year (e.g. mandatory air bags in cars, when ten years ago it was still a novelty). Already PDA applications with GPS receivers and mapping software, connected to cars cigarette lighter for power, can be purchased.

Finally, the role of a “killer application” for those new mobile applications should be mentioned. A killer application is usually associated with the introduction of a technology. Overtime, it is often replaced by multiple applications, with smaller market shares, as the technology diffuses. As an example, telephone service started with a single killer application (voice), and much later added other applications such as fax, voice mail, and call forwarding. However, the infrastructure has gone through several systems-wide upgrades that enabled these new services, which are clearly not killer applications. Wireless telephone service started with the same single killer applications (voice) and has added additional applications such as Short Message Services and digital image capture and transmission.

In the case of the integration of space-related systems in terrestrial products, no real killer application is foreseen yet, though technological breakthroughs are always possible. Future applications, unclear at present,

[42] RAND, *The Global Course of the Information Revolution Recurring Themes and Regional Variations*, Santa Monica, California (2003)

are the wild cards that will determine the fine details of the ubiquitous use of space-related technologies in everyday life.

2.4 Preliminary Conclusions from the Current Evolutions

Based on the brief presentations of the current commercial space sectors in this section (see the two following summary tables), it is interesting to note that the trends for their future developments have a tendency to indicate that their specificities will gain value only by being integrated in larger terrestrial systems. The new infocom products and services might become the new drivers for the current commercial space sector.

	Private Sector Demand	**Public Demand (Civil Sector)**	**Public Demand (Military Sector)**
Telecommunications	*Strong* Companies and individuals tend to rely more and more on satellites telecommuni-cations as supplement to ground cables, and for specific entertainment applications (e.g. television per satellite…)	*Strong* *Governments, regional and local administrations*	*Medium* *The historical sole reliance on military systems tends to be more and more put in question by the use of commercial systems*
Earth Observation	*Medium* Often subsidized customers: Agriculture (in USA principally), utilities… The costs of images and the persistent lack of visibility of related systems (GIS) tend to complicate the development of a private market.	*Strong* Governments, regional and local administrations, scientists are the main customers. (e.g. infrastructure, environment, archaeologists …)	*Strong* Commercial imagery tends to complement the military systems.
Navigation	*Small / Medium* As commercial navigation applications are being developed for specific companies' purposes (e.g. packages location, trucks fleet location), they still need to prove their usefulness. Combination telecom/navigation phones potential new market.	*Medium* Governments, regional and local administrations,	*Strong* Though the US military utilize the military GPS, other militaries worldwide use the civilian US GPS and its related applications.

Table 18 – Public, private and military demands for existing commercial space services

The phased development of new applications in different regions of the world is quite clear:

- Industrialized countries tend to make use of the current commercial space markets (e.g. telecom), and will probably be the main engines for creating new markets for the infocom products and services;
- Current telecom operators are closely looking at emerging countries, such as China and India. The next decade should see an increased demand for infocom products and services;

- Under-developed countries do not really benefit from any of these markets, the use of satellite dishes for communicating being still a luxury few can afford in major parts of Asia, Africa and South America.

EXISTING SPACE MARKETS			
	Telecommunications	**Earth Observation**	**Navigation**
Benefits	More extensive and mobile telecom applications in more places (reducing the digital divide)	Brings to the general public, companies and governments the ability to map clearly oceans, cities, agriculture fields for scientific, public good and commercial decision-making	Brings to the general public, companies and governments the ability to locate people, vehicles and packages anywhere in the world
Economic potential *	XXX	XX	XXX
Existing assessment of market demand	Yes	Yes	Yes
Existing private ventures	Yes	Yes	Yes
Potential Return on Investment	XXX	XX	XXX
Public-Private Partnership possibility	XXX	XXX	XXX
Technical feasibility	XXX	XXX	XXX
Needed Technological Developments	Ongoing	Ongoing	Ongoing
Frequency of launch opportunities	Not necessary	Not necessary	Not necessary
Legal and regulatory constraints	- Market liberalization with the WTO for landing rights (Restricted markets: e.g. China) - National licenses and tariffs	- Some captive governmental markets with no international competition - Security aspects (e.g. political & legal restrictions on private companies concerning the selling of certain imagery)	- Liability issues (e.g. safety of life services and air transportation) - Privacy issues - Liberalization of transmitters (e.g. National licenses) - Security aspects (e.g. governmental signal denial to 3rd party / terrorists jamming)

X: small probability, XX: medium probability, XXX: high probability

* The economic development of the earth observations and navigation applications depend largely in their integration with the telecommunications applications.

Table 19 – Summary: Existing Commercial Space Markets

3. FUTURE ENVISAGED COMMERCIAL SECTORS

As mentioned in chapter 1 of this report, it is difficult to forecast the development of new space-related activities. However, based on current technological research and development advances, the evolution of some commercial sectors can be hinted at. The signs that their evolution is feasible are presented below.

3.1 Introduction

3.1.1 Cycles of Space Activities

Space activities, as any technological programs tend to follow cycles. It had been theorized that major space development follow cycles of more or less 15 years (see following table). [43]

Cycles	Dates	Events
Pre-space age "-1"	1926-1942	First rockets (from Goddard to the V2)
Pre-space age "0"	1943-1957	Military race for intercontinental ballistic missiles, first satellite on orbit (Sputnik)
Cycle 1	1958-1972	Space race (from Sputnik to the end of the Apollo era), beginning of military applications
Cycle 2	1973-1986	First space stations (Skylab, Salyut) and shuttles (US space shuttle, Buran), development of military applications, beginning of civilian applications, emergence of new actors (Europe, Japan, China)
Cycle 3	1987-2002	Second generation of space stations (Mir, ISS), stronger role of space applications in militaries, strong development of civilian and commercial applications
Cycle 4	2003-2018	Ubiquitous use of civilian and military space applications in the information society ('infocom'), new generation of space-related technological advances prompted by integration of breakthroughs in micro-electronics, computers, and materials sciences
Cycle 5	2018-2033	Potential development of new space activities coming of age.

Table 20 – Cycles of space activities

Space activities follow the "S" innovation curve pattern, utilized to analyze the evolution of technological activities and most human activities (see the figure next page). Such curve patterns can be drawn based on the exponential number of Western hemisphere explorations, or the air transportation developments. Sometimes, the plateau of an "S" curve can be the take off platform for another one, as it was the case for universities in Europe, the Renaissance ones, expanding on the plateau reached at the end of the Middle Ages.

[43] Adaptation of lecture notes from Alain DUPAS, « DESS Analyse des systèmes stratégiques », University of Versailles, 1998.

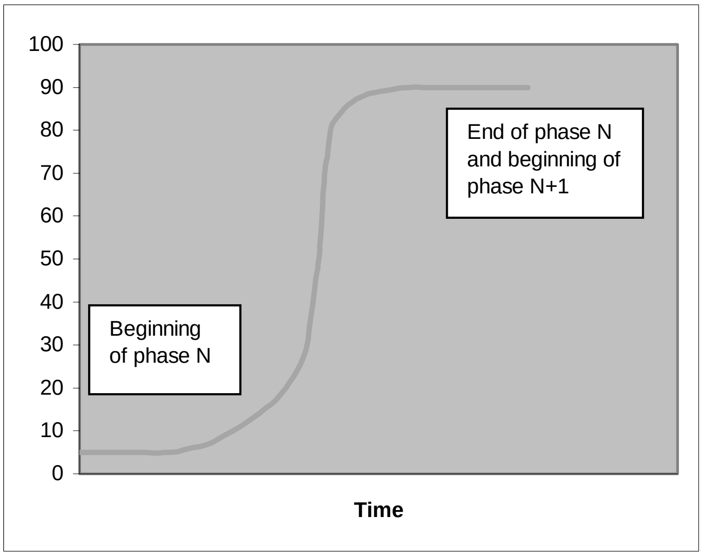


Figure 11- Typical "S" curve

As mentioned in chapter 2, we are already seeing the rise of the 4th wave of space activity concerning the ubiquitous use of civilian and military space applications in the information society (e.g. GPS), as satellites become part of the global information infrastructure. Aside from governmental agencies' demand, new products and services dubbed 'infocom' might be driving the developments of the commercial telecommunications, navigation and earth observation sectors.

A key problem is to forecast what could be the next "S" curve for the 5th wave of space activities. The ever-increasing incorporation of space technologies in people's daily life shouldn't occult indeed the potential development of other future space commercial sectors. Those developments could occur at the end of the phase 4 (2003-2018), or most probably in the phase 5 (2018-2033), if those activities are to build on new space and non-space technologies.

3.1.2 Telecom-Derived Integrated Applications vs. Space Exploration Applications

Currently as the space industry continues to evolve, it is growing into two distinct industries: a commercial space industry which, as it grows and integrates different applications, is becoming a subset of the world's larger telecommunications sector; and a second one that is fueled so far solely by government contracts and focus on human spaceflight and space exploration. The two are growing apart at a rapid pace and are becoming quite distinct entities. The government-funded human spaceflight and space exploration sector might be the source of future new commercial applications.

Public support is strongest in areas with tangible benefits to society such as meteorology, earth observation for environment and defense applications notably, and advanced research and technology. Scientific objectives are also at the core of many space programs.[44] Some areas of the human spaceflight and space exploration sector might provide some interest to the private sector.[45]

Private proponents of future space markets and governments, notably the United States, have conducted a number of studies trying to estimate the commercial feasibility of innovative space endeavors. NASA's "Commercial Space Transportation Study"(CSTS) identified in 1994 the following possible sectors:

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[44] For example, "Science" is the only mandatory programme in ESA, for which Member States have the obligation to contribute financially, whereas the other agency's programmes (e.g. launchers, earth observation, human spaceflight) are all optional.

[45] For information on the legal implications of new commercial space activities, see: Van TRAA-ENGELMANN, *Commercial utilization of Outer Space*, Kluwers Academic Publishers (1993)

- Space manufacturing
- Asteroid detection/negation
- Space rescue
- Fast package delivery
- Space servicing and transfer
- Hazardous waste disposal
- Space tourism
- Ultra high speed civil transport
- Entertainment (digital movie satellites, orbiting movie studio, space athletic events, artificial space phenomena, multiuse LEO business parks
- Space debris management
- Space medical facilities
- Space settlements
- Space utilities markets (extraterrestrial resources such as lunar liquid oxygen, helium-3 (He3)
- Space burial

The main rationale for such a revolutionary study from a space agency, at the time, is stated in the report's introduction:

"The perception held worldwide by government and industry [is] that

(1) Significant untapped markets exist or could be created if the costs for access to space could be reduced by an order of magnitude or more,
(2) A new launch system can provide this order of magnitude reduction in launch costs, and,
(3) A reduction of that magnitude will cause the equivalent of a space industrial revolution with a tremendous increase in users and traffic. This conjecture is often stated but has never been proved."[46]

More recently, the U.S. Department of Commerce, Office of Space Commercialization co-sponsored a workshop in November 2001, administered by the U.S. Chamber of Commerce, titled "Market Opportunities in Space: The Near-Term Roadmap", in collaboration with the Space Transportation Association and the Space Enterprise Council.[47]

The rest of the world is still a bit shy in trying to forecast potential new space-related commercial activities, though some recent studies in Europe notably, tend to show that discussions on future space activities are not entirely in the realms of science fiction anymore. Based on current technological research and development programs and existing preliminary studies, the following paragraphs describe some sectors that could be candidates for future commercial space activities. It is important to note however that technological breakthroughs (e.g. reducing the costs of access to space), could facilitate the development of those activities, but in the end, and as for any current commercial space sector, only strong political support would help those sectors face the many hurdles that await them (e.g. private financing, regulatory, legal issues).

[46] NASA, Commercial Space Transportation Study (CSTS), Final Report (May 1994)
[47] The long awaited proceedings can be found in the following report: U.S. Department of Commerce, Office of Space Commercialization, *Market Opportunities in Space: The Near-Term Roadmap*, Prepared by DFI International (December 2002)

3.2 The Different Sectors

3.2.1 Suborbital Market

The first new emerging commercial space sector that is clearly the most promising is the suborbital market. Suborbital commerce should in theory help lay the commercial, legal, regulatory, and technical foundation upon which later orbital space businesses, including a full blown space tourism industry, would be built (the space tourism market will be presented in more details in chapter 4 of this report).

Space tourism has already started evolving through a number of stages beginning with ground theme parks, space camps, and zero gravity flights. Progress to suborbital trips with a brief experience of weightlessness will probably follow as a natural further development. Suborbital initiatives are seen to benefit from a greater reliance on existing technologies, shorter development time, and lower start-up costs, when compared to future orbital alternatives.

One of the drawn conclusions of the Office of Space Commercialization workshop organized in the United States in 2001 was that the rapid development of suborbital RLV's and spaceports could facilitate the growth of potentially lucrative markets, primarily adventure travel but also cargo delivery and other transportation-based services.[48] Emerging or potential suborbital markets identified in the report include military surveillance, commercial and civil earth imagery, fast package delivery, high-speed passenger transportation, media, advertising, sponsorship, and space tourism.

On its part, Futron Corporation released in 2002 a 20-year forecast for the orbital and suborbital space tourism markets. According to the report, the commercial space travel industry could generate revenues in excess of US $1 billion annually by 2021.[49] The survey was confined to individuals in the United States that could potentially afford these high price space travel experience. Futron's forecast for suborbital space travel projects that by 2021, over 15,000 passengers could be flying annually, representing revenues in excess of US $ 700 million.

The international transfer of data, goods, and people through suborbital transportation systems seems promising. However, the recent end of the supersonic Concorde flights, due to a limited and volatile market should not be ignored.

SUBORBITAL MARKET			
	Suborbital Space Tourism	**Fast Delivery Packages & People**	**Advertising**
Benefits	New adventure travels, creation of a customer base for space tourism	New services targeted mostly at businesses	New high tech support to advertise products and services
Economic potential	XXX	XX	X
Existing assessment of market demand	Market studies based on adventure tourism	N/A	N/A
Existing private ventures	Yes	No	Yes
Potential Return on Investment	XXX	XX	-
Public-Private Partnership	XXX	XX	XX

[48] U.S. Department of Commerce, Office of Space Commercialization, *Trends in Space Commerce* (2001)
[49] FUTRON, *Orbital Space Travel & Destinations with Suborbital Space Travel* (October 2002)

possibility			
Technical feasibility	XXX	XX	XXX
Needed Technological Developments	Limited	Essential	Not necessary
Frequency of launch opportunities	Essential	Essential	Not necessary
Legal and regulatory constraints	- Liability issues - Protection of passengers	- Trade Practices: Export/Import, Customs, Tariffs, Immigration - Protection of passengers	- Possible liability issues - Contractual arrangements with space agencies

X: small probability, XX: medium probability, XXX: high probability

Table 21 – Summary: Suborbital markets

3.2.2 Orbital Industrialization

In this study, the terms 'orbital industrialization' cover two specific activities in orbit: space manufacturing and on-orbit servicing.

- **Space manufacturing**

Space manufacturing could allow theoretically industries to produce new products or existing products more economically. The space environment offers a combination of physical properties not duplicable on Earth: absence of vibration, lack of convection, unlimited heating and cooling, lack of atmospheric attenuation, near perfect vacuum, unfiltered sunlight, sterile environment, and most importantly, no interference from gravity.

This microgravity environment allows certain enzymes to separate more readily than in a gravity-influenced environment, or some chemical elements to mix that cannot be mixed on Earth. Any orbital industrialization activities presuppose the existence of a space station on Earth's orbit, or in any future adequate location, to conduct commercial activities.

Already many scientific experiments have been conducted in the International Space Station and previous orbital facilities (e.g. Salyut, Mir, Shuttle) to promote the future industrial utilization of the unique conditions of microgravity.[50] The idea is to test and manufacture products on space stations or free flying automated space platforms with compartments and laboratories leased or purchased by industry. The industrial sectors that could benefit from on-orbit facilities include: biotechnology, pharmaceuticals, and materials research sectors.

Some examples of products:

- Large electronic crystals for semiconductors and electro-optical materials, with greater purity and reduced defects achievable only in space;
- Improved existing metal alloys, with higher resistance;
- New alloys and composites, by permitting particles of vastly different density to remain in uniform suspension until solidification;
- Improved glass, bubble-free to improve laser technologies, which would itself advance the telecommunications industry;
- New lightweight and heat resistant ceramics.

[50] HARR M., KOHLI R., Commercial Utilization of Space: An International Comparison of Framework Conditions, Batelle Memorial Institute, Columbus Ohio (1990)

However, the uncertainty surrounding the realistic demand for space products is the biggest obstacle faced by space manufacturing projects. The absence of proven marketable products after more then 20 years of experimenting seems a bit discouraging at first sight. The risks involved in market entry are simply too high for most private firms, as the financial payoff from space projects is difficult to project with on long return on investment. Follow some of the main constraints and obstacles:

The launch costs;

The lack of flight opportunities, especially after the Challenger accident in 1986 and the Columbia accident in 2003;

- The time-to-market issues prevent companies from proceeding past the early stage of exploratory research;
- The intellectual property rights that are difficult to fully protect on current space carriers;
- The Earth-bound technologies boosted by recent developments in computing, may already provide good enough substitutes for space-made products.

The industrial exploratory research is often funded, at least partially, by space agencies. The European Space Agency's Microgravity Applications Programme (MAP) was initiated for example in 1999 to prepare for future applied research on board the ISS with direct industrial participation. The main research fields covered are physical sciences and biotechnology. Some projects such as "Precision Measurement of Diffusion Coefficients Related to Oil Recovery" or "Crystal Growth for Biological macro-molecules" involve European industrial actors (oil industry, pharmaceutical companies) and universities.[51]

Therefore, though no return on investment seems guarantied so far, experiments in space with private involvement are continuing.[52] Public funding keeps being essential, and the emergence of a potential market can be envisaged only in the future, as many space agencies still intend to support efforts by academic researchers and private industries to explore further the potential of microgravity. The 'public good' element for this research is obvious, as many space agencies (e.g. NASA, ESA, NASDA) have ongoing human spaceflight and space exploration programs, and wish to offset some of their costs in the long run, by creating public-private partnerships with industries.

The following picture could emerge for potential commercial markets in microgravity:

- In the next ten years, taking into account the main current costs factors (e.g. launch) and orbital facilities, limited markets are likely to emerge only for products with high value-to-weight-ratio, such as electronic devices, specialty glasses, alloys, and pharmaceuticals products. A limited size market for the results of medical research could develop to meet the space agencies' increasing demand for life support systems and medical care of astronauts, as future human missions to the moon and/or Mars can be foreseen;
- In the next twenty years, if a cheaper access to space becomes possible, the use of microgravity research results, as improvements of products and processes on Earth, may trigger more commercial activities;
- Only in the longer term, larger commercial markets for space-manufactured products could develop.

[51] ESA, *The International Space Station European Users Guide*, UIC-ESA-UM-0001 (2001)

[52] Companies such as SpaceHab in the United States or IntoSpace in Europe try to make a profit by offering their services mainly to the space agencies.

- **On-Orbit Servicing**

There is a potential on-orbit servicing market, but it still needs to be more researched. Ever since the 1980s, technical feasibility studies using different type of spacecrafts have been done on paper in the United States, Europe and Japan. Micro-, small- and large servicing platforms have been envisaged.[53] However, few business plans have been drafted so far, due to the market uncertainty and high development costs.

In fact, “the design of any servicer spacecraft should be driven by the form and function of the spacecraft which it will service.”[54] There is not therefore one single on-orbit servicing market, but potentially several niches, depending on what type of space platform needs to be serviced (e.g. commercial satellites, commercial unmanned scientific platforms, space stations, reusable launchers in the long term).

The main on-orbit services are presented in the following table.[55]

Service Class	Type of Service
Motion	Re-orbiting De-orbiting Salvage
Manipulation	Maintenance Repair Retrofit Docked inspection
Observation	Remote inspection

Table 22 – Definition of on-orbit services

The need to re-think the commercial satellites design is one of the major obstacles the on-orbit servicing developers face. If the space platforms are simply not serviceable on orbit, there won’t be any market. Satellite operators may choose to continue replacing instead of upgrading on orbit their fleet. The example of the Hubble telescope, serviced twice by the space shuttle (so far) is a good example: the servicing improved immensely the efficiency of this publicly financed telescope, but with very high costs (shuttle mission).

Currently, the new generation of satellites continues to yield economies of scale:

- Higher power (10+kW)
- More transponders (60+)
- Longer life (15+ yrs.)
- Lower operating costs (Automated TT&C)

The potential anticipated needs for servicing commercial satellites include:

- Replenishment of consumables and degradables (propellant, batteries, solar array);
- Replacement of failed functionality (payload and bus electronics and mechanical components);
- Enhancement of the mission through insertion of new technology.

[53] For a good overview of the different servicing missions and designs: WALTZ D., *Supplement to On-Orbit Servicing Of Space Systems*, Krieger Publishing (1998)
[54] DAVINIC N. et al., *Cost-Benefit Analysis of On-Orbit Satellite Servicing*, Journal of Reducing Space Mission Cost, Kluwer Academic Publishers (1998)
[55] KREISEL J., *OOS: A Challenge*, Presentation at the 1st bilateral workshop on "On-Orbit Servicing of Spacecraft (OOS)" (November 2002)

Therefore, the potential benefits of servicing comprise: extended satellite life, enhanced performance, enhanced mission flexibility, and reduced life cycle costs.

There are still many technological (e.g. docking maneuvers, extensive fault detection, isolation, and diagnostic capabilities on the serviceable platform) and regulatory uncertainties concerning this market. Governments are bound to be involved in the research and development phases, as some space agencies and the US Air Force already are. Future public-private partnerships could be established when the technologies are mature enough to test the marketability of on orbit servicing operations.

	ORBITAL INDUSTRIALIZATION	
	Space Manufacturing	**On-orbit servicing**
Benefits	New pharmaceutical products, new alloys, societal benefits to advance medical research	Extended satellite life, enhanced performance, enhanced mission flexibility
Economic potential	XX	X
Existing assessment of market demand	Yes	Yes
Existing private ventures	Yes	No
Public-Private Partnership possibility	X	X
Technical feasibility	XX	XX
Needed Technological Developments	Necessary	Essential
Frequency of launch opportunities	Essential	Essential
Legal and regulatory constraints	<u>Liability</u>: Uncertainty associated with legal third-party or product liability exposure related to commercial entities can inhibit commercial activity. <u>Tangible Property Rights</u>: Mechanisms or processes establishing the property rights for hardware, payloads, and systems that are provided by commercial entities on space stations are inadequate. Governments should define property rights in space in a way that is compatible with terrestrial practice. <u>Intellectual Property Rights</u>: Currently there are inadequate processes to address infringement of international intellectual property rights. Enforceable international conventions relating to intellectual property rights should apply.	Liability issues Insurance

X: small probability, XX: medium probability, XXX: high probability

Table 23 – Summary: Orbital Industrialization Markets

It should be noted that space debris management, though probably not a commercial market in the next decades mostly due to the high costs of developing the adequate technologies, is becoming an important and costly issue governments need to address. “Deliberations are currently being conducted at the national and international levels intended to implement appropriate and affordable measures to minimize the potential risk and financial loss that space debris may cause to orbital space assets."[56]

3.2.3 Extraterrestrial Industrialization (Moon, Asteroids)

Aside from exploration considerations, some space enthusiasts intend to encourage mining on extraterrestrial bodies, such as the moon and asteroids. Though no business cases are really credible yet due to launch costs considerations and current technical limitations, some academic and materials experts are looking at possible commercial ventures in the space-mining sector.

The capability to extract and utilize space resources in time, particularly from the Moon, Mars, and near-Earth asteroids, would provide an alternative to transporting certain products from Earth into space and would also provide our planet with new resources.

This technology area includes exploring for resources; mining and refining raw materials; processing, manufacturing, and storing materials derived from raw resources; transporting materials to their point of use; and identifying potential uses or customers. Technology development in this area would focus on extraction, processing, and storage, although advances in other areas, such as power, automation and robotics, and space transportation, will also be required for many applications.

The Colorado School of Mines (CSM), which has many research institutes in the fields of energy, environment, materials and minerals, founded in 1989 a Center for Space Mining. One of the research professors explained, "Space mining is 10 to 20 years, or even further out. However, somebody has to start thinking about these things now."[57] Their workshops tend to bring together space enthusiasts and minerals experts.

Other space-mining proponents, such as Apollo 17 astronaut Harrison Schmitt, lobby for mining the moon for helium 3, a rare element not found on Earth, which could be used for energy consumption on Earth, but could also be turned into rocket fuel onsite to facilitate exploration of the solar system. The *in-situ* production of propellant from extraterrestrial resources could significantly increase the performance and lower the costs of planetary exploration missions that require the return of people or hardware to Earth.

Extraterrestrial resources could also be used for shielding or constructing human habitats. Surface materials, such as the lunar regolith, might be much cheaper than materials delivered from Earth, particularly for applications that require large masses of material (such as radiation shielding for lunar surface habitats). If in-space transportation for bulk material from the Moon or nearby asteroids became cost effective, it could also enable and accelerate the development of new generations of government and commercial in-space capabilities that require large masses of material, such as large space stations, or hotels or power stations, beyond low Earth orbit.

Aside from basic costs considerations for such enterprises, potential regulatory barriers in the international space law framework do exist (e.g. ownership of property on the moon), and would need to be clearly addressed in any business scenario.

EXTRATERRESTRIAL INDUSTRIALIZATION		
	Moon Mining	**Asteroid Mining**
Benefits	New materials for Earth-based industries, gives commercial incentive for ongoing planetary	New materials for Earth-based industries, gives added commercial incentive for

[56] BRISIBE T., *The Impact Of Orbital Debris On Commercial Space Systems,* Presentation to the IISL-01-IISL.4.04, American Institute of Aeronautics and Astronautics (2001)
[57] DAVID L., "Business Sees Cash Among the Constellations", *Space News* (9 January 2000)

	exploration	scientific exploration
Economic potential	X	X
Existing assessment of market demand	N/A	N/A
Existing private ventures	No	No
Public-Private Partnership possibility	XX	XX
Technical feasibility	XX	X
Needed Technological Developments	Important	Important
Frequency of launch opportunities	Regular	Not necessary
Legal and regulatory constraints	- Liability issues - Private property issues	- Liability issues - Private property issues

X: small probability, XX: medium probability, XXX: high probability

Table 24 – Summary: Extraterrestrial industrialization markets

3.2.4 Space-Generated Power

Studies concerning space-generated power are underway, building on recent experiments of satellite laser technologies. Recent studies indicate that collection and transmission of power from space could become an economically viable means of exploiting solar power within the next couple of decades.[58]

Technological advances still need to be made to allow space-generated power to compete with current Earth-based alternatives. However, some current researches focus on providing power for in-space activities. These platforms would grab hold of the flood of energy flowing from the Sun and then drive it to Earth via laser or microwave beam. On earth it would be converted to electricity and fed into power grids to be tapped by terrestrial customers.

In 2001, a special study group of the American National Research Council (NRC) reviewed NASA's current efforts in space solar power. The group concentrated solely on the NASA Space-to-space power (SSP) Exploratory Research and Technology (SERT) program.[59] The NASA program has developed a set of integrated roadmaps containing goals, lists of technology challenges and objectives, and a schedule of milestones that guide technology investment.

In that report, “a top recommendation is that industry experts, academia, and officials from other government agencies [than NASA] - such as the Department of Energy, Defense Department, and the National Reconnaissance Organization - should be engaged in charting SSP activities, along with NASA. The panel said that significant breakthroughs are required to achieve the final goal of space-generated power cranking out cost-competitive terrestrial power. [However] the ultimate success of the terrestrial power application of powering-beaming satellites critically depends on "dramatic reductions" in the cost of transportation from Earth to geosynchronous orbit.” [60]

[58] MANKINS J., "Power from Space: A Major New Energy Option?", *Proceedings of the 17th Congress of the World Energy Council*, Paper 4.1.16, Houston, Texas (18 September 1998)

[59] NATIONAL RESEARCH COUNCIL (NRC), *Laying the Foundation for Space Solar Power - An Assessment of NASA's Space Solar Power Investment Strategy,* NRC report (2001).

[60] DAVID L ., "Bright Future for Solar Power Satellites", *Space News* (17 October 2003)

Many technologies for space-generated (and other space missions) are not currently on the critical path for any near-term NASA, ESA or NASDA missions.[61] In the case of the solar power generation components (i.e. photovoltaics), programs are currently under way in the US Air Force to develop high-efficiency, high-specific-power solar cells However, little funding is available that can be leveraged by SSP to develop these technologies.

A commercial – and more importantly a profitable – utilization of such technologies cannot be foreseen in the next decade, or even the next one, as technological advances are still needed to test the system. Theoretically, the economic potential does exist, but space-generated power is still a long way from being practical.

SPACE GENERATED POWER	
Benefits	New source of unlimited power
Economic potential	XX
Existing assessment of market demand	No
Existing private ventures	No
Public-Private Partnership possibility	XX
Technical feasibility	XX
Needed Technological Developments	Important
Frequency of launch opportunities	Not essential
Legal and regulatory constraints	- Mainly many liability issues - Security issues (e.g. distortion of beams as weapons)

X: small probability, XX: medium probability, XXX: high probability

Table 25 – Summary: Space-generated power market

[61] MACAULEY M., DAVIS J., *An Economic Assessment of Space Solar Power as a Source of Electricity for Space-Based Activities*, Resources for the Future, Discussion Paper 01–46, Washington D.C. (October 2001)

3.3 Preliminary Conclusions from the Current Evolutions

The potential commercial space sectors described in the preceding sections could indeed be plausible, if the different caveats presented in chapter 1 are well taken into account, in particular the current launch costs barrier.

The promising commercial applications we looked at are all capable of being developed but in the long term. Governments and private actors may support more actively research and developments funds to those sectors if they can find an advantage in their induced commercial and societal benefits.

It is also clear that the different applications are interconnected. Progress in one application, especially in its underlying technologies (e.g. materials, propulsion) may have implications for the others. Based on the main technology domains identified by ESA in its *European Space Technology Master Plan*, a general summary table of desired technologies is drafted below for the main potential commercial applications presented in this chapter. Breakthroughs in each identified areas could enhance the feasibility and profitability of those sectors, though the main ‘wildcard’ would be the development of cheaper space transportation. However, even a reduced space access cost would have limited effect in the short term, as the different commercial space applications would still have to develop their own specific technologies, procedures and client base.

Technology Domain (ESA system)	Space Tourism	Fast Delivery	Adverti-sing	Space manufact.	On-orbit servicing	Moon mining	Asteroid mining	Solar Power
On-board data systems				X	XX			X
Space systems software				X	X	X	XX	X
Spacecraft power				X		X	XX	
Spacecraft environment	X				X		X	X
Space systems control					XX	X	XX	X
RF Payload systems								
Electromagnetic technologies				X	X			XX
System verification	X			X	X	X	X	X
Mission control		X			XX	XX	XX	X
Flight dynamics / navigation					XX	XX	XX	
Mission analysis / space debris	X				X	X	X	X
Ground stations				X	X			XX
Robotics				X	XX	XX	XX	
Instrumentation				XX	X	X	X	
Mechanisms							X	

Optics								X
Aerothermodynamics					X		X	
Propulsion		X		X	X	X	XX	
Structures					X	X	XX	
Thermal								X
ECLSS & in situ resources	X							
Components	X					X	X	
Materials processing				X		XX	XX	
Quality & Safety	XX			X	X	X	XX	
User segment	XX	X	X	X	X	X	X	X
Application specific technologies	X	X		X	XX	XX	XX	XX

X : Technological progress desirable
XX : Considerable technological progress needed.

Table 26 – Technology advances necessary for new commercial space applications

An estimated time scale for markets to develop, based on current projections, is presented in the next table. If transportation costs were to dramatically decrease, the most obvious and supported market in this study, which is the suborbital market, could expand faster and prepare the economic and regulatory environment for the well documented space tourism sector.

	Promising Applications	Time Scale for market development *
Suborbital Market	- Suborbital Space Tourism - Fast Delivery Packages & People - Advertising	10 years 15 years Current
Orbital Market	- Orbital space tourism - Orbital manufacturing - On-orbit servicing - Space-generated power	20 years 15 years 20 years 25 years
Extraterrestrial Market	- Moon mining - Asteroids mining	25 years 25 years

* if specific transportation, technical and regulatory hurdles are circumvented.

Table 27 – Time scale for future "space exploration - human spaceflight" applications

4. CASE STUDY: SPACE TOURISM

From all the mentioned future applications, space tourism is certainly the one, which is the most generally accepted. Moreover, it has the distinct advantage of having been studied extensively from various viewpoints, also in view of market demand. Though its developments seem so near, it is also clear that there is a strong reluctance in the traditional financing market to invest in new space products and services.

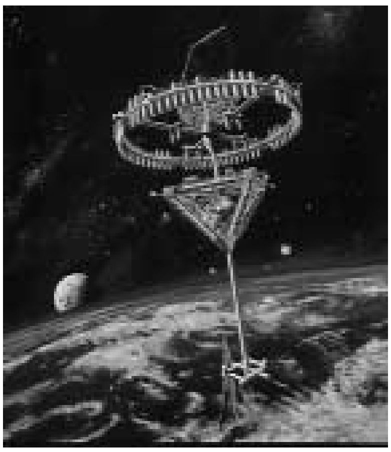
4.1 Introduction

It is inherent to human nature to conquer new frontiers, in order to make progress, even if this raises skepticism and criticism. Some enthusiasts have baptized the conquest of space as the 'Final Frontier', (but certainly there will be other frontiers to be conquered after this one, even if they are less tangible now). The idea originally stems from the famous book from Von Braun called 'Space Frontier', where it was clearly put that the conquest of space is the main challenge in our present times.

From the moment that people became aware of the existence of other planets and celestial objects, they started to dream on how to reach them (e.g. Daedalus, Icarus, Jules Verne).

W. Von Braun, who conceived theoretically circular towns, developed a space hotel model in 1952. The rings were rotating in order to provide artificial gravity in the outside circles. More recently, this idea has been further developed in many conceptual studies, such as the Hotel Berlin, the WAT&G concept and even the Celestial Hilton hotels. The design, which is the most often found in literature, is the concept of the Shimizu Corporation of 1989.[62] It is a circular design .The rotation is foreseen at some 3 rpm, providing for an artificial gravity of approximately 0.7g.

In the outer ring, as shown in the figure below, 64 guestrooms are foreseen of 7 meters in length and 4 meters diameter each. It has to be noted that the Shimizu industrial consortium is still looking at financing the development of this idea.



[62] MATSUMOTO, S. et al., Feasibility of Space Tourism. *Proceedings of the 17th Symposium on Space Technology and Science.* (Tokyo, 1990), pp. 2301-2308

(Courtesy : Shimitzu Corp.)

Figure 12 – Shimizu Space Hotel project (1989)

This Japanese corporation was targeting to put the hotel in operation around 2020. Taking into account a forecasted mass of 7,500 tons, this will put a high challenge on present upload capacities (approximately 30 tons for the Shuttle) and makes also the target date rather optimistic. Here we reach the first point of reality check. The present launch capacity and launch prizes make such projects unfeasible at this point in time. Unless this problem is basically solved, such projects will remain in the conceptual phase.

4.2 The present launching cost problem

The X-33 project, which was abandoned after $1.3 billion of investments were made, illustrated once more the considerable risks associated with projects of this nature, especially when the development of new technologies is undertaken,

This virtually excludes a private investment in such a multipurpose Reusable Launch Vehicle (RLV), whereas, from the public investment perspective, the 3rd generation RLV's, in accordance with NASA's roadmap is not expected under an optimistic scenario before 2025.[63]

The targets for this generation of launchers, indeed is to be 10,000x safer and 100x cheaper than the present Space Shuttle. This will bring thus upload costs in an order of magnitude, which is presently considered as compatible with realistic space tourism ticket prices of $100,000 per trip (a figure which is assumed to support a viable market). Assuming this figure, a simple analysis, as the one presented in annex, shows that upload costs of $500/Kg need to be reached.

In the absence of such an orbital RLV for the next few decades, it looks therefore that only two realistic possibilities are open in the near future for space tourism:

1. Use of existing vehicles, only charging the operational costs to the space tourist;
2. Development of relatively cheap suborbital vehicles for the single purpose to offer short duration zero-gravity stays to space tourists, probably making use of existing, even off-the-shelf, technologies.

The first market will remain a very exclusive one. Using the US Shuttle or the Russian Soyuz system will only be possible for ticket prices in the order of $10+ millions, but also only after extensive and demanding training periods. Indeed, a crash-course providing only the basic skills and safety training is considered in the Russian cosmonaut-training center to take as a minimum 4 months.

It is evident that the high price and such demanding requirements will strongly limit the number of candidates, so that we can hardly talk about a market but rather about a byproduct of an existing system.

In a recent study, called ASCENT and made by FUTRON on behalf of NASA, a detailed 20-year market forecast and rationale for the launch market was undertaken in order to figure out key driving system requirements for new RLVs. In this study the number of paying passengers in the category described above is estimated around 10 in 2013 and around 50 in 2021.

This leaves us with the only viable option for the next few decades, namely the development of a dedicated, operational low-cost vehicle, for short duration, suborbital flights.

63 WEBBER, D, The ASCENT Study, *Paper presented at the 53rd International Astronautical Congress* (WSC, Houston, 2002)

It is generally assumed that the X-prize competition[64] for which now some 20 competitors have registered,[65] may represent this breakthrough. Some of these projects are simply based upon modified military fighters, such as the MIG-31[66] or a compilation of off-the-shelf motors and booster rockets,

4.3 Economics of space tourism

4.3.1 The Pricing Aspect

A major element of space tourism is the *price* of a space tourism trip, and how many people will be prepared to pay such price. Also here we see a tendency to come to more realistic approaches over time.

First surveys were made based upon telephone interviews (which are evidently non-committing) and came up with figures in the range of more than 10% of the population (in industrialized countries) willing to pay one year's salary for one space trip.

Abitsch[67] adapted these figures, introducing the factor of real commitments and came up with ticket price / number of buyers relations resulting in a 400,000 yearly customers for a $100,000 ticket price.

The billionaire Richard Branson (Virgin Group) established a company 'Virgin Galactic Airways' in April 1999, targeting at a 200,000 people market willing to pay up $100,000 for a trip.[68] Evidently, as his own money is at stake, he is more conservative in his assumptions.

A recent approach[69] uses the income of people worldwide and assumes that only 0.56% of them are interested in a space trip (taking into account physical fitness and adventure tourism interest. The more conservative market potential of over 40,000 people willing (and able) to pay a $100,000$ ticket price is reached by this approach.

It has to be noted that the author bases this $100,000 target upon a so-called X-Prize reference scenario. Cost simulations lead to an investment cost of less than $100 million for this type of project with a yearly passenger number of less than 250 people ($100,000 per ticket) in order to obtain an acceptable IRR (Internal Rate of Return) of 17.6%.

Evidently this often-quoted $100,000 ticket price has a direct relation to the launch cost problem, as it will require reducing launch costs with not less than two orders of magnitude (as demonstrated in a simple model, see appendix 1).

[64] A 10 million prize is awarded to the competitor who can demonstrate that his vehicle, which shall be privately financed, is able to fly twice in two weeks with 3 people, reaching each time a minimum altitude of 100 Km. Economic viability needs to be demonstrated insofar that lees than 10% of the first-flight propellant mass may be replaced between the two flights.

[65] See: www.xprize.org, St. Louis, USA

[66] INDEN, W., Tourist Space Flights. A Vision for 2020 and its Challenges for Today. *Proceedings of the International Symposium on Impact of Space Technology Innovation on Economic Development* (Shangai, April 2001), pp. 222-233

[67] ABITZSCH, S., Global Market Scenario of a Space Tourist Enterprise. *Paper presented at the International Symposium on Space Tourism,* Bremen (20-22 March 1997)

[68] BERGER, B., Billionaire Shops for Space Tourism Vehicle. *Space News,* (May 10th, 1999) p. 6

[69] EILINGSFELD, F, and SCHAETZLER, D., Developing Viable Financing Models for Space Tourism, *Paper presented at the 53rd Astrronautical Congress,* WSC, Houston (2002)

4.3.2 The Market Demand

The author Collins has no doubts about the considerable demand for space tourism products and services (using the parallelism with aeronautical progress from zero in 1900 to 1.5 billion passengers in 2000). [70] In his macroeconomic perspective, space tourism will become an integral part of economic growth in the next decades.

So, even if the market potential for space tourism has constantly been corrected for more realism over the last few years, there is still a sufficiently big margin to conclude that there is room for a viable and profitable venture at such ticket prices.

In fact, without evaluating in depth the absolute figures, one can safely assume that for 'ticket price' in the order of 100,000 $, there is a demand that probably will not be satisfied by the offer (with, as a consequence, that initial prices will continue to be 'market prices' such as the ones paid by Denis Tito.

A paramount aspect, which has been much overlooked, is the regulatory one. This will not only influence the fact if the product can be effectively sold, but also the certification will considerably influence the TTM (Time To Market) and, hence, the project pre-financing.

4.3.3 Physical Distribution

Under this heading we need to consider a number of different elements. There are the aspects of bringing the flight opportunity to the client (which is not so critical, as long as a commercial airport can be used as a close hub) but there are also the important aspects of training and physical qualification.

For simple flights, with a few minutes of zero-gravity, it is assumed that some 75% of the population will qualify. It shall be noted here that a design project made by students of the International Space University foresees the use of Virtual Reality tools to simulate the experience in a less demanding environment.[71]

The training needed will remain an essential factor. Many of the flight opportunities will require very extensive preparation periods of several months, requiring the potential candidates to invest a substantial period of time. This will be a second obstacle, which, after the price, will strongly reduce the number of potential candidates.

A paramount aspect, which has been much overlooked, is the regulatory one. This will not only influence the fact if the product can be effectively sold, but also the certification will considerably influence the TTM (Time To Market) and, hence, the project pre-financing. In view of the importance, this regulatory aspect will be treated in a separate paragraph.

4.4 A potential catalyst: the tourism sector

The strongest promoters of space tourism may eventually be the tourism industry itself, which is constantly looking for new products, especially in the adventure market sector.

The yearly market volume for tourism is presently in the order of $3400 Billion. In order to evaluate the importance of tourism, we should not forget that tourism generates 10.2 % of the world gross national product, and accounts for 10.9 % of all consumers spending. With these figures (source: World Tourism Organization, 1999) it means that tourism is the world's largest industry in terms of gross output, providing employment to 8% of the total world work-base.

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[70] COLLINS, P., Meeting the needs of the new millennium: passenger travel and world economic growth. *Space Policy 18/3* (Aug. 2002) pp. 183-198.

[71] ISU, Virtual EVA, A ground option for Space Tourism. *MSS02 Team Project report*, ISU, Illkirch (2002)

Presently, some $110 Billion are spent on adventure recreation in the U.S. alone, with some examples quoted as:

- $20,000 to sail to the Arctic;
- $70,000 to climb the Mount Everest;
- $150,000 for a sight seeing tour around the world aboard a small executive jet;
- $350,000 for an exclusive world trip on board of the Queen Elisabeth II.[72]

One illustration, relevant to our space tourism case, can be shown in this context as follows.

Zeghram expeditions, a leading adventure tourism promoter, launched an on-line booking for a suborbital flight at a price of $98,000. Although no exact technical specifications or deadlines were specified, it is reported that 41 persons confirmed their bookings and 3000 reservations were made.[73] This illustrates both the effect of promotion as well as the feasibility of such $100,000-ticket market.

On the other hand, even if one can dispute the fact if the project was meant to be a real business case or just a publicity stunt, the claim of the Hilton chain to create hotels on the Moon and Mars in the future, can be taken as early indications of interest from the tourism sector.

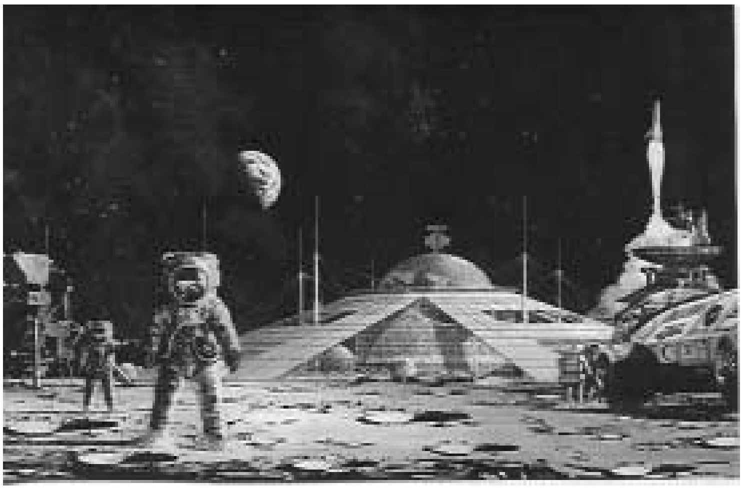

Figure 13 – Hotel Project from Hilton (published in Space News)

4.4 Regulatory Framework aspects

The Hilton example, even being an extreme one, can provide us already with flair on potential regulatory issues.

Indeed the patent request gave raise to a legal discussion on the applicability of the Outer Space Treaty text, which clearly puts emphasis on 'national appropriation' and leaves a legal backdoor for 'private appropriation'. On the other hand the concept of 'free access to all areas, stations, installations, equipment and space vehicles on the Moon and other celestial bodies', which has also been imbedded in the Treaty, weakens any 'property rights'. In strict application, any visitor walking into the hotel should be given free access, according to this principle.

[72] ISU, *Space Tourism: From Dream to Reality*, Team Project SSP Chili (2000)

[73] RUGG, K., Spaceports do tourism? *Space Business International* (4/2000), pp.56-62

There are many more issues to be considered before full space tourism commercialization can be envisaged. Already the following (non-exhaustive) list, which has been collected in the NASA/STA study [74], is impressive enough:

Near-term Regulatory Issues:

- Experimental flight regulations
- Spaceport regulations
- Waiver of liability
- Space traffic management.

Near-term policy issues:

- Use of government assets
- Privatization of zero-gravity flights
- Authority to license re-entry vehicle

Longer-term issues:

- Certification of commercial transport systems operations
- Property rights (claims registration)
- Environmental issues (overland supersonic flights)
- Orbital debris removal

It can only be hoped that these elements are tackled timely by the legal experts, to avoid a later bottleneck in the implementation once the financial and technical problems are solved, a fact which is becoming more and more realistic.

On the certification aspect, ISU students recently completed a study[75] that clearly demonstrated the complexity of this issue. Due to the lack of standards (an area which has raised a lot of interest by the FAA), it is difficult to predict how the certification process will have to be done in detail (e.g. how many planes will need to be crash tested?) but clearly, here also, the influence of the TTM on the business plan has been considerably underestimated until now.

4.5 Conclusion

Space tourism is rapidly evolving from dream to reality. Real are, nowadays, the space trips using government-owned and registered vehicles such as the US Shuttle and the Russian Soyuz system. However, only a limited number of wealthy clients should benefit from this possibility for a considerable time..

A more realistic and broader market is emerging in the form of suborbital flights. Once a dedicated vehicle will be developed, it is assumed that a sufficiently large part of the population will be ready to pay the targeted $100,000 ticket price. Over the recent years, the number of persons ready to pay such prize has been revised and corrected. However, with a product, which has a viable market potential, based upon 250 passengers a year, it is reasonable to assume that there will be no lack of potential customers.

The approximately $100 million, assumed to be needed for dedicated development of this nature, may therefore evolve from a viable business plan, e.g. as the result of the X-prize competition.

[74] O'NEIL, D. et al., *General Public Space Travel and Tourism.* NP-1998-3-11-MSFC, (NASA, March 1998), p.12
[75] ISU, *Navigation Systems for Future Space Vehicles,* MSS03 report (2003)

If we look at this specific case and compare it with the lessons learnt (see chapter 1), we come to a similar analysis:

- There are strong elements in favor of a good business plan for space tourism, such as:
    - A strong demand curve;
    - Existing technological knowledge for limited suborbital flights.

- An end-user sector, with sufficient purchasing power (the tourism sector) can be identified.

- However, there are a number of drawbacks still, namely:

    - Business plans are too strongly technological oriented and need professional help;
    - The regulatory framework is still very unknown;
    - As a consequence, the TTM is very hard to define (hence also any profitability approach).

CONCLUSION

The term "commercial space," except for telecommunications satellites, was for many years not very credible. The current developments in the space sector tend to show two main trends concerning commercial applications:

In the next ten years, the already-started ubiquitous use of civilian and military space applications should expand in the information society though new ‘infocom’ products and services. This trend is supported by the development of new generations of space-related technological advances, prompted by the integration of breakthroughs in microelectronics, computers, and materials sciences.

In the next fifteen years, taking advantages of the technological developments, in particular in the space transportation sector, new space exploration and human spaceflight-related applications could begin their infancy period in orbit.

We may have then two parallel families of commercial space applications:

1- Infocom products and services, with space-based components providing infrastructure (satellite link) or content (e.g. imagery, navigation signals), fully integrated in terrestrial appliances;
2- New suborbital and orbital space-based activities, in particular the space tourism market.

Some technological advances are still needed, as well as an evolution of the legal framework. For developing infocom activities, the main technological challenge lies in integrating smoothly the space segment specificities in the terrestrial applications (e.g. upgraded antennas, large uplink and downlink bandwidths). In the case of space exploration and human spaceflight-related applications, specific technologies need to be developed.

As seen throughout this study, the main hurdles for new commercial activities are often based on the lack of cheap transportation to and from space, especially for the space tourism activities. However, even if cheaper launchers - for the end-customer - are developed more rapidly than envisioned by specialists (circa 2025), thanks to technological breakthroughs in propulsion notably, high investments to create actual orbital infrastructures for industry or tourism purposes still will need to be made.

The public sector still has an important to play on fostering the technological and regulatory development of future commercial space activities. The role of space defense applications and governmental research and development may also be essential for the next decades. Many activities could take place though the form of PPPs, as expensive technologies still need to be tested (e.g. on-orbit servicing), and governments have large societal responsibilities (e.g. space debris management).

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APPENDIX 1 - COST SIMULATION MODEL FOR SPACE TOURISM LAUNCH COSTS

One ROI (Return On Investment) model could run as follows:

$G \times P = (TC + MC + PE + FC + DC) \times (1 + R)$ **(Eq.1)**

Whereby:

G = Total of yearly number of Passengers
P = Price per ticket
TC = Transport Cost per year
MC = Maintenance Costs per Year
PE = Personnel Expenses
FC = Fixed Costs per year (Insurance, Administration, Ground facilities)
DC = Depreciation Cost per year
R = Margin for Risk and Profit (example 0.08).

Each element can be further expressed as:

TC = (LC/PC) x WT x (G + I)
MC = 0.15 x TCC (assuming 15 % yearly maintenance)
FC = 0.15 x TCC (assuming a 15% insurance cost, certainly higher in the initial phase)
DC = TCC / t

With:

LC = Cost per launch (example Shuttle 110 million $)
PC = Payload Capacity per launch (example: Shuttle 29.5 tonnes)
WT = Weight per passenger, including food and other supplies (typically 100 kg per person)
G = number of Guests per launch
I = number of Instructors per launch (including replacement crew for Space Hotels
TCC = Total Construction Cost (for Hotels: Assembly complete in orbit)
t = expected lifetime

It is evident from this model that TC, the transport cost per year, will be a determining factor. If we make for instance a very simple assessment by putting all other costs equal to the transport costs; we could in a first instance simplify ***Eq. 1*** as

$G \times P = 2 \times (LC/PC \times W \times (G + I))$ **(Eq. 2)**

Or, with

W = 100
I = 0.2G (20% professional crew)

$G \times P = 2 \times (LC/PC \times 100 \times 1.2G)$ ***(Eq. 3)***

Resulting in

$P = 240 \times (LC/PC)$ ***(Eq. 4)***

Eq. 4 would indicate that LC/PC needs to be in the range of 410 $/kg, to come to acceptable prices for a 100,000 $ ticket.