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COMMERCIALISATION OF SPACE AND ITS EVOLUTION

WILL NEW WAYS TO SHARE RISKS AND BENEFITS OPEN UP A MUCH LARGER SPACE MARKET?

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Foreword

The main purpose of this report is to investigate if new models for sharing risks and benefits may lead to more space activities.

Also included in the study are ongoing activities to reduce the cost of access to space and other efforts to make space more affordable such that there will be more space related activities.

Examples of such work are the privately funded launcher development by rich entrepreneurs in the US and the increased capabilities of smaller satellites developed by universities and small companies.

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Executive Summary

The prime goal of this study was to investigate new ways and present new role models for the development of space systems.

If Governments could be smarter, take more risks, and change some of their policies, commercial space could grow faster and would become more affordable and therefore more useful. The first seven chapters deals with the development of commercial space activities organized by sector, including a chapter on Space Tourism.

The main recommendations of the study are:

1. Governments should stimulate demand by being "smart customers" and give industry flexibility both in implementation and in getting additional revenues.

2. Governments should invite industry and make serious efforts to really reduce the cost of access to space.

3. The current challenge with Galileo is analyzed and a way forward is proposed based upon an adaptation of the way Europe has developed its meteorological satellites and established Eumetsat.

4. The most daring proposal is found in Chapters 8 and 10. Assuming prices of launchers can be brought significantly down if sufficient number of same type of launchers are used every year, it is proposed to develop a system for fully automated assembly in orbit of future medium to heavy mass spacecraft, using multiple launchers, one for each individual subassembly.

Finally in chapter 10, the benefits and risks of the proposed actions are analyzed.

Governments may gain twice if the proposed actions are implemented. They will pay less for the space derived services they need, and they will help foster a globally competitive industry. By far the most critical element is to truly reduce the cost of access to space.

Contrary to general belief, commercial space business is already the major space activity, in particular when space based applications are included as space business. The capabilities in the private sector are such that any space activity which governments wishes to do, can also be done by the private sector. This is due to the fact that over several decades Space Agencies and other Government Agencies have contracted out the major portion of its space mission to industrial companies.

The major hindrance to more space activities and to more space business is the relative high cost of access to space and of the spacecrafts or satellites themselves.

A part of this study has therefore been devoted to ongoing activities to make space more accessible and more affordable. Of special interest to reduce cost of access to space is the new entrepreneurial companies in the US, developing with mainly private funding new launchers.

Also mentioned in the report is space tourism, initially sub-orbital tourism. If the current development in sub-orbital tourism leads to also orbital tourism it will have a major impact of both the cost of access to space and the volume of space business.

In particular, the cost of manned space missions could be significantly reduced both for Governments and wealthy individuals if the entrepreneurs succeed with their ambitious plans. Also the likely development of mini satellites is

analysed with their potential for becoming much more capable.

There seems to be a substantial difference of mentality in the private sector between the US and Europe in the willingness to take risks in developing commercial space ventures.

In the US private sector invested several billion USD in the so-called satellite constellations for the Iridium and Globalstar networks. Now wealthy entrepreneurs are investing in the development of new launchers as well as in space tourism. In Europe such high risk individuals or companies are not visible in space ventures, with the exemption of Sir Richard Branson with his Virgin Galactic sub-orbital space tourism company.

This study gives several examples of new and different ways of sharing the risks and benefits of space missions compared to the traditional practice.

This has opened both for more commercial space activities and helped create new space companies.

A key part to foster such paradigm shift is that the customer, and in particular government or space agency customers, may buy data or information or a particular service based upon competitive bidding, and where the supplier is free to design the means to produce the customers requirements and also to use the government contract as an "anchor contract" to develop a system to produce the desired data, information or service, and keep for himself the additional revenues for selling more data, information or services to other customers, using the same system.

In the US, the government agency, National Geospatial Intelligence Agency (NGA), now procures, through the Clearview programme, optical pictures with very high resolution, fresh, newly captured, information (40 cm ground resolution and 30 minutes after a pass) for various US government agencies needs, including both civilian and military use. This has led to the creation of new entrepreneurial companies, DigitalGlobe and GeoEye, who have designed, built and launched optical earth observation satellites which they now operate using commercial ground stations and commercial data transmission to reach the end-users.

These companies have their risks reduced by being guaranteed a certain minimum sale of such pictures, however the companies have all technical risks including launch and satellite failure. They basically make their profit from selling the remaining capacity for taking imagery to other commercial users.

Both in Europe and recently also in the US, the military needs for secure, encrypted satellite communication is now met by commercial companies who combine the secure military satellite payload with the standard commercial transponders using a common geostationary communication satellite (i.e. Skynet 5 and HispaSat).
Another example is ground station services for telemetry, tracking and control (TT&C) and data reception is now being opened for global competitive commercial tendering, allowing any satellite owner or potential satellite owner to have its satellites being ground serviced from a globally competitive industry with no need to make the investment for their own dedicated ground station.
The chapter on commercial launchers details the historic background of launcher development and the strength of Ariane 4 and 5 in the global market for launch of communication satellites to geostationary orbit. An analysis of the potential of the new commercially under development launchers, like the Falcon family from SpaceX is given with its possible impact on the European launch industry. It is recommended that Europe establish a road map for bringing up a Euro-Russian family of globally competitive low cost launchers.

A possible paradigm shift for both commercial and institutional space is analyzed. Such change caused by a combination of very much reduced cost of access to space for small to medium sized payloads to Low Earth Orbit (LEO) combined with the use of practical commercial components, who have proved their reliability in space, making small to medium sized satellites far more capable than today.

The author proposes an alternative approach for complex and large spacecraft, either for Earth orbit or for planetary missions.

His idea is to develop a system for in-orbit assembly of complex and large spacecraft such that the most cost effective launchers may be used to LEO, and getting also economics of scale by standardized solar cells power system and also standardized satellite bus to which the specialized and dedicated payloads will be mated fully automatically in orbit.

Finally in the last chapter on lessons learned, commercial space and role of Governments, an analysis of risks and benefits for the various proposals is given. This chapter also includes a section of an alternative for Galileo based upon following the well proven model of how European Member States organized its meteorological satellites by setting up Eumetsat and tasking ESA for the development and launching of the satellites needed.

1. Capabilities in the private sector

It is interesting to note, and normally not even people working in space activities reflect on this that both in the US and in Europe, the private sector has equal capabilities to pursue advanced space missions as any of their governments. This is because the consistent policy developed over decades has been that Governments and/or Space Agencies missions are contracted out and executed by private companies. Thereby these private companies gained know-how, insight and technological expertise and capabilities to develop complete space systems independently.

It was for this very reason that commercial satellite communication or "Satcom" developed into a large competitive business which today dominates commercial space with around $60 billions annual sales out of total $180 billions total annual space activities[1].

As an interesting example, consider the following: If Microsoft Corp., for whatever reason (Public Relation, wish of its Founder and Major owner) wanted to put a man on the moon before China, India and the US Government, they have the financial resources, the organizational know how, to task existing industry to do such "man on the moon" project on their behalf. Also the Founder of Microsoft, Bill Gates, could easily afford, through The Bill and Melinda Gates Foundation, both to help eradicate key deceases and fund such a "man on the moon again" project. (His personal wealth is more than $50 billions).

On a more realistic level, there exists now Launch Ranges (like Sea Launch), Commercial Ground Stations and industrial companies able to perform any commercial space mission without the need to use assets owned by Space Agencies or Governments. (It should be noted that nonetheless permissions from Governments to do space missions in most cases would be needed for logistics reasons).

[1] Source 2005 figures from the US Space Foundation 14.11.2006

2. Development of commercial satellite communication

The first demonstration of telecommunication via a satellite was the NASA passive satellite Echo, launched already in 1960, to be followed by the relay satellites Telstar and Relay from 1962. However, it was the use of the geostationary orbit with first the Syncom satellite which demonstrated live TV signal transmission over the Pacific from Tokyo, Japan to the US during the 1964 summer Olympics, that satellite communication was born as a business. Soon thereafter satellite communication (Satcom) was being developed for trans-oceanic telephony.

The technology was first developed by NASA, however it was the major telephone (monopoly) companies; Comsat in the US was established in 1962 and Intelsat established in Europe in 1964, that made Satcom for telephony into a major business. With the proliferation of fiber optical cables crossing the vast ocean distances over the Pacific and the Atlantic, Satcom for telephony lost its strength for commercial trans oceanic traffic.

It was the Direct-to-home TV (DTV) market that really caused the Satcom industry to become by far the most important commercial space business and thus providing the largest market for both the satellite launcher companies and the satellite manufacturers. Typically every year around 6-10 large communication satellites are procured, manufactured and launched at a cost of around ($200M-$300M) for the satellite and ($60M-$100M) for the launch.

Consequently Satcom became the most important driver for European space companies. Arianespace became the launch service provider of choice with its Ariane 4 launcher (typical with 60-80% of global market share), and both Alcatel and Astrium proved that they could compete with the 3 key US competitors, Hughes (now Boeing), Locheed-Martin and Space Systems/Loral. Today Thales Alenia Space (after the merger Alcatel Alenia Space with part of Thales) is the global leader when measured as order book (at end 2006) for new satellites.

European companies did equally well in the Satcom services business. After privatization of most national telephone companies in Europe and elsewhere, a consolidation and privatization of the Satcom services companies followed with Eutelsat, Intelsat and Inmarsat becoming listed on major stock exchanges, and recently to be purchased by a combination of US and European Private Equity Funds. Today the 10 largest Satcom services companies are:

Rank	Company	Location	2005 Revenue in million $	Satellites in Orbit	Satellites on Order
1	SES Global	Luxembourg	1480	30	6
2	Intelsat Ltd	Bermuda/USA	1170	28	1
3	Eutelsat	France	885	22	3
4	PanAmSat Holding	US	861	24	1
5	Telesat Canada	Canada	407,3	6	2
6	JSAT Corp	Japan	373	9	3
7	New Skies Satellites	Netherlands	240,5	5	1
8	SingTel Optus	Australia/ Singapore	165	5	2
9	Star One	Brazil	164,5	4	2
10	Space Communications Corp	Japan	153,7	4	1

Source : de Selding P.: "Top Fixed Satellite Service Operators" Space News 26/6/2006

It is worth noting that both the largest and the #3 operator are European based.

3. Satellite communication constellations

One of the most interesting examples to learn from, as regards new initiatives for enlarged commercial space activities, is the so-called global constellations for satellite communication. The first initiative was led by the US communication company Motorola, Inc. who proposed 77 satellites in 7 orbital planes providing full global coverage, including the poles and the oceans. This was followed by a less expensive proposal from Globalstar with 48 satellites in 4 planes with a "bent-pipe" architecture using and dependant upon the terrestrial network for coverage globally over land. However, the most advanced proposal came from Microsoft and Mr. McCaw (a pioneer in US cell phone systems), proposing an internet in the sky structure with internet routers in each satellite and with broadband transmission rates.

The system called Teledesic was initially proposed with around 900 satellites, later reduced to a proposal of 495 satellites. In Europe Alcatel Space proposed Skybridge, a constellation with 64 satellites for high bandwidth Internet traffic. These 4 competing constellations would create a new and large market for launchers, both for the initial configurations and the replenishing of single satellites after their individual failures, as well as for satellite manufacturing.

All these proposals were based upon using private capital with minimum government support envisaged or asked for. Two of these systems were actually built and launched; Iridium, with finally 66 satellites in 6 orbital planes with 6 in-orbit spares for a total of 72 satellites, and Globalstar with 48 satellites plus 4 in-orbit spares. Both systems are operational.

What is truly remarkable is the private sector willingness to invest in high-risk space ventures and the rapid pace in designing, manufacturing and launching and get in operation such large and complex systems.

However, Iridium soon went bankrupt, Teledesic and Skybridge were never developed, a main reason for this was the very rapid globalization of digital cell phones becoming available in most countries and in the most remote of places. This caused the market for the globally travelling business people to be taken over by ordinary cell phones.
After its bankruptcy, Iridium was taken over by a new company, also privately financed. With a guaranteed minimum business from the US Department of Defence which also financed the development of an encrypted, secure Iridium phone to provide global secure communication with a small handset, Iridium has survived.

As an example of the speed the private sector may work at, the author will go through the Iridium development in some detail. It might be interesting for a reader to compare this with the Galileo project. (Iridium was both more expensive and has more than twice as many satellites).
The concept for Iridium was basically ready in 1988, Motorola established the company Iridium Inc. in 1991, and after using $5 billions and building an advanced assembly line type automated factory for producing the satellites and launching 66+6 satellites the system was fully operational in September 1998. This technical achievement was not to be followed financially, already after 12 months the company went into chapter 11(the first stage of US bankruptcy law), and after another year it went bankrupt in August 2000. With new ownership the services were re-established in 2001.

Teledesic and Skybridge gave up before any satellite was built and also Globalstar had to go through a Chapter 11 debt restructuring. It is worth

mentioning that after the financial restructuring where most of the debt was not to be served both the Iridium and Globalstar will finance their next generation of satellite constellation from their ongoing operations. Thales Alenia Space has already received a contract for 48 new satellites for Globalstar.
The Iridium satellites have shown a remarkable long life and the company claims there is enough in-orbit spares to keep the system going until 2020 without building any new satellites (most likely with a reduced configuration if no more satellites added).

It is interesting to note that the Iridium satellites marginal cost was only around 5MUSD each, achieved by automated assembly line manufacturing (marginal cost meaning the additional cost of making one extra satellite).

Conclusions

There are at least the following lessons to be learned from these constellations:

- **If private sector sees a space based commercial opportunity, it is able and willing to invest very large amounts.**

- **The ability to have a very rapid pace to develop, take risks, launch and operate a multi billion USD very complex infrastructure both in space and on the ground.**

- **Be aware of alternative solutions to reach the market, space may not be the only alternative and space may be risky.**

4. Development of commercial Earth observation

It is fascinating to observe how space-based Earth observation over the years have changed from black and white secret photo reconnaissance missions, recovered from space in capsules, by the Soviet Union and the US, to commercial Earth observation with satellites with capabilities of 40 cm ground resolution in panchromatic and around 1meter resolution in full colour directly downloaded and transmitted to Earth.

Partly the same incredible speed of improving the performance and ease of use of amateur and professional cameras is now taking place in optical satellites, making them much less expensive and easier to operate.

The US Government has opened for commercial optical Earth observation by guaranteeing a market through the NGA[2] Clear View programme creating both a new business model and a market resulting in some new entrepreneurial companies.

The US risk sharing model is easy to understand: The US Government guarantees minimum revenue for several years subject to delivery of useful pictures (data) and ensuring priority of data access. It also may pay for part of the technical development.

The supplier bears all technical risks, including launch failure and in orbit failure of the satellite (both of these may be insured, however at a high price).
The supplier gets all additional income from other customers.

There can be US Government imposed restrictions ("shutter control") on the commercial sale of high resolution pictures (sometimes reflected on the freshness on the pictures).

[2] NGA: National Geospacial-Intelligence Agency

From a European perspective, one of the interesting commercial developments of Earth observation is the success of Spot Image, a subsidiary of CNES, dedicated to Earth observation, imaging and a value added service provider. The company has grown and for many years been a leader in commercial optical data with even US government agencies among its largest customers.

The chosen method of risk sharing implied a high risk for CNES which developed for its own account the SPOT satellites and launched them into orbit and then transferred the operation of the SPOT satellites to Spot Image for a royalty fee.

Another interesting European case of technological development is the use of Information Technology (IT), which has made Earth observation satellites less expensive as demonstrated by Surrey Satellite Technology (SSTL) Ltd from the UK. By being involved in both UK and ESA advanced satellite technology development projects, SSTL as an offspring from Surrey University, became a global leader for the development and the manufacturing of small satellites.

These small satellites over the years became more and more capable, in particular as regard to optical resolution, on-board memory storage and rate of data transmission to Earth ground stations.

This has resulted in a business for SSTL for affordable, highly capable optical Earth observation satellites with typical 3 meter resolution and costing around 5-10 Meuro. SSTL provides also launcher selection, support to the launch and a significant offer for training and support to the customer. SSTL has made looking at your neighbours from space affordable and practical for many nations.

Examples of customers are countries like, Algeria and Nigeria, the city of Beijing and the German company RapidEye which is focusing on the agricultural market with a constellation of 5 satellites.

When looking back 10 years from now, the authors personal intuition is that the most dramatic event in commercial Earth observation proved to be the competition between the two giant software companies Microsoft and Google and their respective Virtual Earth and Google Earth programmes. This competition has already opened-up a new market for the new entrepreneurial companies GeoEye and DigitalGlobe (both companies established due to the new US policy of opening Earth observation commercially) as well as for companies like Spot Image.

It is worth noticing that what has made Google Earth and Virtual Earth possible as a free service from internet is the tremendous improvement in IT, in particular the cost of storage and transmission. The unit cost of computing, measured in current currency, has been reduced by a factor of 50 million from 1964 to 2004!

Conclusion

Commercial Earth Observation revolution is already happening with the most important impact being the rapid spread of web-based Earth observation imagery portals. It has not been a bonanza for the large space companies because the more agile, flexible and less risk adverse entrepreneurial companies have been the winners for affordable Earth observation.

5. Development of commercial Satellite Ground Station Services

An interesting example of how government policies open up for commercialization of space is the rapid commercialization of Satellite Ground Services, a key element of all space infrastructures. From the beginning of Space Age, Governments and Space Agencies owned and operated the large ground stations with their large tracking antennas to provide two-way communication between the spacecrafts and the mission control centres. During the mid 1990´ the US Congress decided that US Federal Agencies like NASA and NOAA should purchase whenever possible, both telecommunication services and Ground Station Services for support of their satellites. This was confirmed by the Commercial Space Act of 1998.

A decade after this US Congress decision, the result is very visible. Commercial Ground Station Services are now available through competitive suppliers and costs have been dramatically reduced due to both competition and improved technology as well as lower costs for both terrestrial and space data transmission making economy of scale gains by collocating multiple antennas at same site with automated operations.

The result of such change is that a Government or a private company can launch, support and control its satellites without any investment in, or own dedicated Ground Stations.

In particular for Polar Orbiting Satellites, the orbit of choice for most Earth observation satellites, the change is dramatic and can be illustrated with an interesting example from SvalSat, Svalbard Satellite Station at Longyearbyen, Norway.
This station was developed from scratch starting in 1996. However, in less than 10 years it has become now the world largest Ground Station for Polar Orbiting Satellites. More than $100M have been invested, almost all coming from the institutional satellite owners like NASA, NOAA and Eumetsat and lately both Iridium and Galileo have decided to install an antenna park at SvalSat.
It was the combination of the US opening Ground Station Services for commercial companies plus the ideal location at 78 degrees north that made SvalSat possible.
SvalSat can have radio contact with all 14 orbits of a typical polar orbiting satellite, allowing one contact during each orbit by the use of only one ground station with each contact lasting from 6 to 17 minutes.

In 2003 in order to save costs the two major users of SvalSat, NASA and NOAA, agreed to pay for transmission services an amount which made it possible to install two independent sub sea fiber optical cables between mainland Norway and Longyearbyen of total cable length around 2900km for the two cables. The project cost of around $50M was paid back over only 4 years compared to alternative transmission methods. It is interesting to observe that to meet the space needs of data transmission a solution with a technology that normally is not appreciated by space agencies was selected.

Because of the demand for fresh data with twice per orbit data dumps a sister Ground Station is now fully operational in Antartica at the Norwegian Troll Station at 67 degrees South, permitting the "pole-to-pole" concept with twice per orbit data downloading. Again this investment in Antartica became possible due to US Government decisions on purchasing "fresh" data for imagery from private sector companies.

6. Space Tourism

Commercial space tourism currently is only available from Russia through the US-based company Space Adventures with the so-called taxi flights to the ISS at a cost of around $23M-$25M for a 7-10 day trip including training (which may last several months). It is reported that there is a long waiting list of individuals willing to pay such amounts for becoming an astronaut. Until now only 5 individuals have paid these amounts and been tourists in space, all of them being self made entrepreneurs becoming rich by establishing IT/internet/software/ biotech companies.

By winning the Anzari X-Price, Burt Rutan financially backed by Microsoft co-founder Paul Allen proved that suborbital flights using the Space-Ship 1 rocket plane are feasible. A European entrepreneur Sir Richard Branson have seen the potential for space tourism and has established the company Virgin Galactic which has teamed for the development of the Space-Ship 2 vehicle and the White Knight 2 mother airplane with Paul Allen and Burt Rutan and their company Scaled Composites. Test flights are planned during 2008-09 and first tourists flights will start in early 2009. This will open Space Tourism for a much larger market. Current pricing is around $200.000 for an approximate 2 1/2 hours ride, of which a few minutes in zero gravity to the dark sky at around 100 km above Earth.

Sir Richard Branson states that this might lead to suborbital travel permitting travelling from London to Singapore in about 30 minutes (for passenger and very high value goods).
Virgin Galactic will apparently be facing competition from another entrepreneurial start up, a US company called Benson Space Company. According to Virgin Galactic web site, the first 1000 priority space tourists have already been sold out. To secure such priority, payment of the full price of $200 000 was needed.
Currently US legislation will allow for commercial sub-orbital Space Tourism business to be conducted from commercial US spaceports planned and under construction. In Europe the Swedish Government through the 100% owned government company Rymdaksjebolaget AB (Swedish Space Company Ltd) has signed an agreement with Virgin Galactic to investigate the possible development of a space tourism spaceport in Kiruna to become available no sooner than 2010.

It will be more than interesting to see if space tourism actually becomes a new business and as such a driver for very much reduced cost of access to space and opening up for commercial ballistic flights. However, Orbital Space Tourism is a very much more challenging task than Virgin Galactic Space-Ship 2 as it requires launchers and manned spacecraft of a very different nature.

Nevertheless, the US company Bigelow Aerospace is developing habitable, inflatable spacecraft, with one already being tested in orbit based upon technology from NASA.

Both SpaceX and Kistler are developing reusable launchers with stated goals of being able to offer manned transport both to the ISS and to these Bigelow “Space Hotels”. Mr. Bigelow recently gave a press conference stated that their initial market is Governmental, countries that wish to have its own astronauts and unable to secure this by other means. NASA has awarded contracts to SpaceX and Kistler for a total of $500 M as part of their COTS (Commercial Orbital Transportation Services) to stimulate the development of commercial launchers.

Conclusion

A few years ago, most people associated with serious space activities working with space for Governments and in Space Agencies would laugh and consider ridicule the idea of Orbital Space Tourism organized by private companies.

However, after Burt Rutan and Paul Allen success with Space- ship 1 and Sir Richard Branson willingness to invest his own money in Virgin Galactic as well as the successful launch of a pressurized Bigelow module, some of them have changed their minds on the viability of such endeavours.

It is highly likely that suborbital space tourism will become a reality in less than 3 years from now.

Orbital Space Tourism as a commercial activity might actually happen, and if so it will have an enormous impact of cost of going to space both for humans and for spacecraft.

7. Space transportation, commercialization of launchers

The rockets to launch satellites into orbit were initially adapted Inter Continental Ballistic Missiles (ICBM), developed by Soviet and the US, based on the German V-2`s. In the beginning of the Space Age they were the only countries to have this capability.

It is interesting to revisit how a growing commercial space business in satellite communication led Europe to develop the Ariane family of launchers. Until 1965 Europe was depending upon using US rockets to launch its satellites. When Europe around 1973 wanted to launch a communication satellite for commercial business on a US launcher, the US Government requested Europe to guarantee that this European satellite called Symphonie would not compete for business with US communication satellites, and to be considered as an experimental satellite.

Europe, led by France, could not accept this, and in 1964 ELDO (European Launcher Development Organization) was established, later to be merged with ESRO (European Space Research Organization) and ESA was created.

ELDO and later CNES, through an arrangement and some funding from ESA, developed the Ariane family of launchers. Ariane 1 was launched in December 1979 and Ariane 4 was available and tested when the US policy of using only the Space Shuttle to launch all US satellites, governmental or private, totally failed with the loss of the Challenger Space Shuttle in 1986.
Ariane 4 dominated the commercial launcher business with a market share of 60-80% for the launch to Geostationary Transfer Orbit of communication satellites, the main launcher market.
The next generation of heavy launchers Ariane 5, and Atlas 5 and Delta 4 were all developed by government funding with the argument of having guaranteed independent access to space for respectively Europe and the US and to serve the commercial markets.

At the same time both Soviet and Chinese rockets had been made available both for launching commercial and institutional spacecraft. It is worth mentioning that it was the major western launch companies Boeing, Lockheed-Martin and Arianespace who brought the Soviet/Russian/Ukrainian launchers to the market with the following joint venture or alliances as follows:
Boeing with the Sea Launch company using the Ukrainian Zenith rocket, Lockheed-Martin with ILS (International Launch Services) using the Russian Proton and Arianespace with Starsem using Soyuz. It was these companies who had to ask their Governments for support in order to continue the guaranteed access to space, in effect an indirect subsidy to allow the commercial satellite communication companies to continue to be able to use Western launchers.

In Europe this led to the ESA program, EGAS (European Guaranteed Access to Space) and in the US it was decided to fund two complete independent family of launchers through the EELV (Evolved Expendable Launch Vehicles), the Atlas and Delta (with the Atlas 5 first stage depending upon a Russian rocket motor).

Recently, in order to save costs, the US Government approved that Boeing and Lockheed –Martin merged their respective launcher organizations for Atlas and Delta into their 50/50 owned company ULA (United Launch Alliance) which for the time being have a monopoly for US Government launches of heavy spacecraft.

This is the background from which the US new entrepreneurial companies started developing new launchers.

The major hindrance for more use of space and increased space activities is the high cost of access to space.

This is due to the challenge of reaching the necessary orbital speed of around 7,2 km/sec for a spacecraft to enter a stable orbit. Many attempts and almost equally many failures have until now not really reduced the cost of access to space. However, some intriguing efforts are now ongoing in the US, where privately funded enterprises challenge both their Government efforts and the established launcher companies.

As an example, the case of SpaceX is looked at in some detail including a visit in February 2007 by the author to this entrepreneurial company located in El Segundo, Los Angeles.
SpaceX is entirely funded by Elon Musk (a small portion owned by his brother), a software entrepreneur who sold his company, Pay-Pal, when he was in his low thirties and with several hundred $ millions available, he decided he would use his time, energy and some of his money to make space access affordable trough the development of a completely new family of very competitive launchers.
SpaceX is privately developing a family of launchers with the following main specifications and prices

	FALCON 1	**FALCON 9**	**FALCON 9 Heavy**
First launch	Q3 2007 (Two demo launches occurred, first failed, second partially Successful)	Q2 2008	2010 Estimated
Number of launches on current manifest	5	6	0
Customers on manifest	US Gov., Malaysia SpaceDev, MDA Corp (Canada), Swedish Space Corp	US Gov, MDA Corp (Canada),NASA Demo-1, NASA Demo-2, NASA Demo-3	
Performance to LEO	500kg (200km sun-synchronous)	8 000kg (700km, 60 degree incl.)	27 500kg
Price to LEO	$ 7M	$ 35M	$ 90M
Performance to GTO (185x35788)km	nil	5 000kg	12 000kg
Prices to GTO as a Function of satellite mass		<3500kg $ 35M 3500-4500kg $ 45M 4500-5000kg $ 55M	5000-5500kg $55M 5500-6500kg $ 65M 6500-11500kg $ 90M

It is likely that the SpaceX designers must have had access to the best practice and all the legacy of all previously US designed launchers. It has clear roots in the Saturn moon rocket, using kerosene and liquid oxygen and several identical rocket motors in parallel and very strong emphasis on reliability. The author visited its main assembly hall located in the same building as its head office. In the hall was the first produced tank for the Falcon-9 and also a full size mock-up or model of the Dragon spacecraft. SpaceX have decided to be completely independent of supplies or services from any of their competitors. SpaceX therefore have in-house capabilities for the design and manufacturing of all critical elements, this includes complete stir-welding equipment for the large tank. Moreover if demands outstrip the capacity of their current two assembly halls they will contract out manufacturing work.

It is worth to mention the following policies of SpaceX.

- SpaceX was founded without any direct government support, and until Mike Griffin was appointed NASA administrator, there was no likely NASA business.
- SpaceX has refused to accept direct US government funding to develop the Falcon family of launchers. This is because it wishes to be free with its pricing policy and believe in its competitiveness with any other comparable launcher.
- DARPA (Department of Defense Advance Research Project Agency) has supported SpaceX by purchasing an unspecified number of (up to a maximum of $100M) demonstration launchers, the first of which failed while the second test and development launch took place March 20th 2007 (Without a payload).
  This launch was considered successful enough so that the next launch (fall 2007) will be for a satellite with a paying customer.
- SpaceX competed for the NASA COTS (Commercial Orbital Transportation System) and was rewarded with a USD 278 million contract as one of the two winners (the other winner Rocket Plane Kistler).
- The NASA COTS contract with SpaceX is not for the development of the Falcon family; it is for the partly funding (approximately 1/3 according to SpaceX) of the Dragon spacecraft, an Apollo like re-entry capsule designed to take cargo and crew to the ISS and for the purchase of 3 demonstration launchers.
- SpaceX is also a 10% investor in Surrey Satellite Technologies Ltd, its purpose, according to the management, is to gain detailed insight into the requirements for the launching of modern small satellites like the ones SSTL is developing.
- SpaceX business plan does not depend on making the Falcon-9 reusable or refurbishable. It will land in water using a heat shield and a parachute and will be recovered. SpaceX states that the main purpose of this recovery is to increase the reliability by being able to inspect in detail the mechanical structure after a launch. Only if economical and practical will parts of the Falcon 9 be refurbished.

SpaceX is now speeding up the development of Falcon 9 in order to be able to support NASA with crew and cargo transport to the ISS competing for post COTS contract in 2010. The target is to qualify the Falcon 9 for human flight in time to fill part of the gap between the retirement of the US Space Shuttle at the end of 2010 and the ARES/Orion successor to be ready at the earliest in 2014.

There is a substantial business opportunity for SpaceX if this company is able to qualify the Falcon 9 and Dragon in time to support the ISS with cargo and crew transportation. It should be noted that to be qualified for human flight is a much more challenging task than cargo flights.
However, if Falcon 9/Dragon could be qualified for human flights, another opportunity is to transport paying astronauts to the planned Bigelow “Space Hotel”.

What will happen if one or both of the US COTS selected companies succeed?
It will mean that for the first time since the retirement of Delta 2, the US will have an affordable and globally competitive launcher.

With Falcon-1 capable of launching 570 kg to Low Earth Orbit for less than 7 MUSD, space will become affordable and possible for more players.
It also means that Russian, Chinese and India launchers will have a US competitor.

For Europe, it will probably have initially a modest effect on the dual-satellite Ariane 5 launcher for its traditional heavy communication satellites to Geostationary Transfer Orbit (GTO). It is possible the Falcon 9 will compete with Soyuz from Kourou for satellites to GEO weighing less than 5 tons. According to current price information, the Falcon 9 with a GTO capacity of 3.5 tons has a list price of $25M. (Soyuz from Kourou initially will have a maximum weight to GTO of 3 000 kg (Soyuz 2-1b), while a standard Falcon 9 will have 5000 kg).

For European launchers the main impact will be for the European small launcher Vega. This launcher already faces competition from launchers from the low cost economies of Russia, China and India. Vega now may face one or two more competitors with significantly lower production costs. For a satellite to LEO weighing less than 550 kg, the SpaceX Falcon 1 is hard to compete against. The Vega will have a capacity of around 1500 kg to LEO so it fits into a class between the Falcon 1 and Falcon 9.
If the so called Falcon 9 Heavy will be developed, this launcher will compete head-on with the US Evolved Expendable Launch Vehicles (EELV) launchers, Delta 4 and Atlas 5, and the Ariane 5. According to SpaceX the Falcon 9 Heavy may be available at the earliest in 2010 with a capacity to GTO of more than 12 tons.

The following tables are giving some key information on launchers from various countries available on the market. Prices are very difficult to obtain, parts of the market is supported by converted strategic missiles, using them for launching satellites instead of destroying them as agreed by the US and Russia, so production costs are not very meaningful.
Only the market for launching communication satellites to Geostationary Transfer Orbit (GTO) is in some way commercial, although development in most cases was paid for by Governments.

Small Launchers					
Name	**Capability* to LEO kg**	**Country**	**Origin/launch organization**	**Price information millions US$**	**Remarks**
Pegasus XL	190 - 440	US	Air launch Orbital Sciences	20-25	190 kg to 800 km SSO
Taurus 2110	740 - 1 250	US	Orbital Sciences	30-50	First stage from Peacekeeper
DNEPR-I	400 - 3 700	Russia Ukraine	ISC Kosmotras	10-15	Converted strategic missile
Minotaur 4	1 750	US	Orbital Sciences		Converted strategic missile
Rockot	1 340 - 1 850	Russia	SS19 Eurockot	15-20	Converted strategic missile
Cosmos 3M	1 500	Russia		15	
Vega	1 500 – 2 300	Europe	Arianespace	20	Target price
Falcon 1	570 - 670	US	Commercial SpaceX	7	

Medium Launchers

Name	Capability to LEO (800KM) Kg	Country	Origin/launch organization	Price information millions US$	Remarks
Delta 2	2 700 - 6 100	US	No longer available for commercial market	60-80	2 185 kg to GTO
Soyuz 2 – 1a	4 350 – 7 480	Russia	Arianespace	40-50	2 780 kg to GTO
PSLV	1 200 – 3 650	India	ISRO	20-25	
Falcon 9	8 000	US	Commercial SpaceX	35	See also p. 23

Heavy Launchers

Name	Capability to GTO in Tons	Country	Origin/launch organization	Price information millions US$	Remarks
Long March CZ-3B	5.1	China	Great Wall	Not known	
GSLV	2.2	India	ISRO	40-50	
H-IIA	2-3.8	Japan	JAXA Mitsubishi	80-100	
Proton M/Breeze	5.5-6	Russia	ILS	Negotiable	
Zenith 3 SL	6. 1	Russia Ukraine	Sea Launch	90-110	
Atlas 5	4.1-8.2	US EELV	ULA	Negotiable	
Delta 4	3.9-10.8	US EELV	ULA	140-170M	
Ariane 5 ECA	9.6-10.5	European	Arianespace	100-160M	Dual payload

Source: Wikipidia, free encyclopedia and International Reference Guide to Space Launch Systems AIAA, Fourth Edition, 2004.

* Capabilities to LEO depending on orbit from 200km LEO to 800km SSO (Sun Synchronous Orbit).

Conclusion

Thanks to European institutional investments in launchers with the Ariane family, and now also the forthcoming Vega and Soyuz from Kourou, Europe has secured its guaranteed access to space with a choice of launchers depending on the requirements. More than securing access to space, initially Ariane 4 and now Ariane 5 became globally competitive over several decades in the most important business, the launching of communication satellites to their Geostationary Transfer Orbit (GTO) where they became the global market leaders.

The author believes it would be risky for Europe to rest on its laurels in the belief that the current strong market situation will last and that the new entrepreneurial efforts in the US will all fail.

What neither Europe nor the US so far has achieved is to really reduce the cost of access to space.

The author believes that it would be good government policy to create more space activities and also be an insurance against the new launchers designed to be globally competitive if the future European launcher policy also would focus on the following:

- To really reduce the cost of access to space due to smart design, efficient manufacturing and low cost launch campaigns.
- To ensure that new launchers be globally competitive for their class and without need for subsidies nor for future support.

A pragmatic attitude should be selected if low cost is achieved through reusability, partly reusability or partly refurnishable or simply by developing a launcher with low manufacturing cost using state of the art manufacturing and cost effective subsystems . What is more important is to find the lowest cost both to governments for their initial funding and afterwards for each launch. If Europe could combine the strength of the capabilities in Russian launcher companies with those in the ESA member states, there should be no doubt that Europe can combine a good business case and reduce cost of access to space. It is therefore recommended to establish a road map for bringing up a Euro-Russian family of globally competitive low cost launchers.

What, at the end may be more important for Europe, is the fact that cheaper access to space will bring more space activities and an increased space market both for smaller and highly capable satellites and the applications derived from such satellites.

8. Could dramatic changes happen to commercial space?

Space business has developed, in a way, like most businesses with normal growth, not really any major changes but ups and downs following the mix of demand from commercial space, military space and government institutional market.
Could this change?

If the new US entrepreneurial launcher companies really succeed in bringing launch costs significantly lower, this could have a major effect. There will be more satellites, in particular more nations looking at their neighbours from space because it will become affordable and competitive compared to other ways of observations and it will also potentially open new markets.

The smaller satellites to use these new low cost launchers will definitely become more capable because they will use newer generation of computers and sensors with much more in-orbit storage and higher data transmission rates. Except for Surrey Satellite Technology, Europe is not really prepared for such a possible challenge. Europe is even less prepared for Space Tourism (except the fact that the largest investor in Space Tourism, Virgin Galactic is owned by a European entrepreneur, Sir Richard Branson, also owner of Virgin Airlines).

Europe with its dominant position in commercial space business, both in launch services and in satellite manufacturing, has a lot to loose if smaller satellites become more capable and can be cheaply launched.

European governments may be faced with two choices to avoid this situation:

1. **Support the established large space companies with their network of subcontractors which may be losing business and market share because of a new generation of entrepreneurial companies with smaller satellites and cheaper launchers.**
2. **Support the customers by supporting the solution which gives the best value for money with acceptable risks.**

As a general comment, we feel that Government industrial policy should be more focused on fostering change instead of preventing it. By supporting the customer and accepting change, the long term prospects will be better, even if at short term there will be some pain for the established industrial base.

In the US a very real choice for the US Government may be how to provide crew and cargo transport to the ISS after the shuttle retires in 2010. The NASA COTS programme finances alternative entrepreneurial companies to possibly take over such transport to the ISS.

A recent study by a US Engineering consulting firm SpaceWorks Engineering shows a win-win situation where US Government might save as much as $8 billions and creating a commercial business to support ISS of around USD6.5billion when comparing COTS to using current US government available launchers.
Could similar dramatic changes which happened to the computer industry, also take place in commercial space activities?

The computer industry for many years followed two laws:

1. Grosch law saying that if you doubled the manufacturing cost of

a computer, you would increase the performance with a factor of 4, implying that the largest and most expensive computers would have the lowest cost of per unit computing.
2. Moore law saying that the time to double the number of transistors on a chip (an integrated circuit or a microprocessor) would be between 18 and 24 months.

Most companies used a combination of these two laws and kept manufacturing cost constant and increased performance at a rate of doubling every second year. However, only Moore law survived and is still valid, and made Grosch law today completely irrelevant.

Between 1988 and 1990 the market price for a typical high performance 32 bit computer fell by a factor of 10, and in a few years the global industry was completely changed as most computer companies had disappeared. The modern IT world thus started with a revolution, computers became so cheap and still very useful that they became a mass market and were sold in millions instead of in thousands as before. Today microprocessors are ubiquitous and are included in almost any device.

Could a similar revolution (although on a more moderate scale) happen with space?
Suppose cost of access to space is reduced by a factor of 10, and a 500 kg satellite could be put into low earth orbit for 3 MUSD, could that be the first start of changing commercial space?

The author believes strongly that the cost of access to space for small payloads will be significantly reduced. However, even more important, the small satellites will become far more capable and affordable. A visit to the recognized global leader in small satellites, Surrey Satellite Technology Ltd. (SSTL) in the UK in April 2007, and a meeting with this company chairman and founder Sir Martin Sweeting, convinced the author that there is a tremendous future potential in using more advanced microprocessors, more on-board memory storage and new sensors in order to make really useful small satellites. Not quite the same pace of progress as with computers and microprocessors, however sufficient to have a major impact on the cost of future satellites, both for more scientific use and for application satellites.

The author believes that a third pillar, besides low cost launchers and more capable and affordable satellites, needs to be developed and perfected before a substantial increase in capabilities and even more impressive reduction in the cost for future space missions can be achieved. The idea is not new, and is based upon the same concept that was first sketched and then implemented for the Apollo moon landing architecture.

Suppose that fully automatic assembly of space system subassemblies could routinely and reliably be performed in orbit (for example assisted by Galileo+GPS very accurate positioning). This third pillar, together with lower cost of access to space and far more capable small satellites could really start a dramatic change and increase commercial space activities.

Several organizations, including space agencies and the new entrepreneurial space companies are now designing the systems which will allow for fully automated assembly in orbit. There is an important similarity here with modern computers, The development cost is high while the manufacturing cost is marginal. (To develop a high end competitive microprocessor today, including its manufacturing plant, costs several billion USD, while the manufacturing cost of each microprocessor is much less than 100$ (less than 1$ for the mass market)).

What is needed initially for automated assembly in space is to supply fuel or fuel tanks to a spacecraft in orbit, this is already in development, with the first application to extend the life of geostationary communication satellites where the new company, Orbital

Recovery with ConExpress has this as its business plan. If also the solar panels, and /or the large antennas for either communication or radar satellites, or even a complete ion-engine with its fuel and solar cells, could be put into orbit on separate launchers and mated fully automatically to its target spacecraft, than we have the beginning of a "LEGO" type space systems (LEGO is the trademark of a Danish toy company famous for its plastic building blocks and the way they are combined into objects by pushing the blocks together).

For the planetary and other complex orbits, also the engine and its fuel could be mated to the mother spacecraft in low-earth orbit.

With such an architecture even large highly capable long lasting spacecraft may be placed into any orbit, even planetary missions, at a much reduced cost compared to current architecture where the complex ESA, NASA and NOAA advanced Earth observation satellites all have a cost of more than $ one billion including launch.

Such architecture is scalable. SpaceX, just as an example, may be able to put 20 tons into LEO for around $50M with its Falcon 9 Heavy launcher, planned to be available before 2012, assuming a very realistic discount when you order 50 launchers. 1000 tons of spacecraft, fuel, return fuel, rocket engines, human habitat modules etc could be assembled in orbit at a launch cost of less than $3 billions. Compare that with the cost of developing the next Saturn V, the ARES?

In order to make such a third pillar happen, Space Agencies and Governments should simply accept that lower cost of access to space for medium weight class spacecraft will take place and become available in the market. Also it should be taken for granted that those spacecraft will become far more capable just by following the general technological development (with some distance time wise to the commercial market).

Conclusion

Governments should therefore task their Space Agencies to develop this third pillar and make the mating technology available to all competing space industrial companies.

The governments will be the biggest winners if modern space systems would be made with interoperable space subassemblies to be fully automatically connected together in orbit. If the successor to the ISS could be manned Bigelow structures in orbit, the savings to Governments compared to supporting ISS could be enormous.

9. Lessons learned, commercial space and role of Governments

Space, contrary to what most people believe, is mainly a commercial business driven activity. This is even more so for Europe because military space which is a very large portion of US space activity has only a modest impact in Europe. Commercial space is totally dominated by applications made possible by infrastructure in space.

Most of such applications are based upon combining the space infrastructure with equipment on the ground, like end user terminals for navigation, satellite telephones and TV reception. By far the most important and largest element of today's commercial space is satellite communication and broadcast, providing telephone, internet, broadband and TV to any spot on earth, stationary or mobile.

European companies have been very successful in every part of these segments; they have dominated the launching of these large satellites to their geostationary orbit. European satellite builders are competitive in a global market place with typical a market share of around 40% of the global market. Finally European owned or controlled companies now dominate the largest part of the satellite communication business, the service providers with no. 1 and no. 3 of the largest companies being European.

Government policies have been important to reach this success. Governments, mainly through ESA have supported the development of both the launchers (Ariane family) and the advanced technologies needed for the satellites themselves. However, even more important, Governments have facilitated at a very early stage the establishment of service providers and allowed these service providers to be privatized and listed on major stock exchanges and by such policies becoming global leaders with active participation in the consolidation phase.

By looking for lessons learned and comparing US and European policies to stimulate commercial space, the following observations can be made:

a) The US policy of transferring to the private sector its needs for telecommunication and ground station services and also optical high resolution Earth observation data has been very successful and has created new industries championed by new entrepreneurial companies.

b) Government policies should in particular stimulate the demand for space based applications and if necessary, governments themselves should be the initial customer. Such policies are in the beginning of revolutionizing Earth observation with commercial companies bringing their own satellites into orbit and the competition between Google and Microsoft provides an additionally large market on top of the various agencies of the US government.

c) European governments must be very aware of this trend in the US and increase its focus on stimulating the market. Because the largest investments by European governments in space applications is currently focused on the Galileo navigation system programme and GMES, we find it is relevant to give brief comments on whether these government programmes will really foster more commercial space activities.

d) The public-private partnership (PPP) model for Galileo was the first major effort in Europe to implement a new model for sharing of risks and benefits for a major space project.

The European Union (EU) wished to have a European, civilian controlled Positioning, Navigational and Timing (PNT) system to complement and to be interoperable with the US military controlled GPS. EU and Member States decided upon a model where European industry was invited and encouraged to form competing consortia to bid for the so called position "Galileo concessionaire" who would take over from ESA a proven and tested design including 4 Galileo satellites in orbit (the result of the EU/ESA co-funded IOV (In Orbit Validation) phase for Galileo) and then complete the 30 satellite Galileo constellation and operate it for 20 years.

This financing model for Galileo and the Galileo project itself are now facing major difficulties, including several years delay, cost overruns and political infighting for roles and locations of Galileo infrastructure and hosting of Galileo main offices among Member States funding Galileo. Also the shareholders of European Satellite Navigation Industries (ESNI) are fighting among themselves to secure the roles they wish to have. The fact that the two competing consortia were allowed to merge and to put forward one consolidated proposal has eliminated competition. This merged consortium, now called ESNI, has decided to use a bank loan to partially finance the implementation of the full Galileo system.

The banks are not willing to take any risks and therefore ESNI have asked EU or its Member States to give a guarantee for a minimum future revenue stream to come from the Guaranteed Public Regulated Service supposed to be the key feature of Galileo compared to the free use of GPS.

However, with the delays for making Galileo fully operational, the difference between the free GPS and the planned more accurate Galileo will be reduced due to a new generation of GPS satellites after the Galileo specifications became known to the US.

We believe that it might be necessary to rethink and adjust the original public-private partnership model. We see at least the three following models for Galileo:

1. **ESA completes the full Galileo System under a contract from EC and hands it over to a Eumetsat like organization controlled by Galileo Member States.**

2. **ESA completes the full Galileo System under a contract from EC and when finished hands it over to a consortium/ concessionaire which in the meantime have been set up by the EC/EU.**

3. **The European Union will guarantee a minimum purchase of services for a number of years sufficient for the original public private partnership model to be accepted by industry.**

We believe in the current situation that the best value for European tax-payers money, and also to limit the delays is to adapt the Eumetsat model. This is the way Europe has chosen to operate the European meteorological satellites.

ESA manages on behalf of EU and the EU/ESA Member States the fixed price contract for the Galileo IOV (In-Orbit Validation) phase. This will include 4 Galileo satellites tested in their proper orbits and demonstrating the proof of concept for the complete Galileo system including the basic Ground System Network in order to operate the Galileo constellation. Member States could simply task ESA to complete the Galileo constellation. ESA would then, based upon competitive bidding, following mutually agreed EU-ESA industrial policy rules, purchase the needed number of additional copies of the already contracted 4 Galileo satellites and launch them into their proper orbits. ESA would also complete the associated Ground System Network necessary to operate the complete constellation.

In parallel with this ESA part, Member States will establish a Eumetsat like organization, GalileoSat, who will consolidate the situation, operate the system to be taken over from ESA. After a few years of operational experience GalileoSat may invite competing consortia to take over the Galileo operation, much in the same way as originally foreseen, including always having in-orbit spare satellites and replenishing failed satellites with new ones. Planning of next generation Galileo constellation and next generation satellites also to be organized by GalileoSat (not industry, not ESA in order to be user driven).

Also parallel to these efforts, GalileoSat and its Member States should encourage industry and academia and others to identify such high value services based upon the unique Guaranteed Regulated Navigational Signal that a future revenue stream for such a service is both understood and is likely to happen. If no such service is to be found it would be clear that like in the US, the GalileoSat organization will have to be funded by its Member States.

The author believes that most probably such high value services will come from combining the Guaranteed Position, Navigation and Timing signals with other smart technologies like for example advanced communication systems, probably embedded into smart devices using state-of the art IT. (One possible such application may be fully automatic operation of first cargo trains, without drivers, and later passenger trains).
It is even possible 10-15 years from now to have a convoy of trucks driving on the autobahn where only the first truck has a driver and all the others are following using trusted guaranteed Galileo signals combined with sensors and smart boxes in each vehicle and in constant touch with the "AutobahnSatAuthority" regulating semi-automatic truck traffic.

e) The European GMES, Global Monitoring for Environment and Security, we believe is a balanced development of government funding of the space and ground infrastructure and applications development. We also commend the development of the most important early services element, and believe this is a good model for development of commercial space based services. European governments are orchestrating a structure whereby government agencies are customers, and encouraging private sector companies, including SME´s to compete for services needed by governments.

10. Analysis of risks and benefits of proposed actions

Governments should stimulate demand by being "smart customers" and give industry flexibility both in implementation and in getting additional revenues.

By buying services/data/information there is a clear definition of who has which risks and who gets the benefits.
Industry is free to make all technical decisions and select a solution which can deliver the customers requirements at a better understood risk and with better known revenue and profit potential.

Such a policy will also result in a globally more competitive industry, helping industry in particular for the fully commercial space market.
Customers, institutional and commercial, will benefit from lower prices and share in the benefits of either reuse of system or reuse of information and economies of scale.

The customers will themselves determine their actual needs and if this can be delivered from existing or moderately improved existing systems, they will benefit.

Governments will benefit twice, first as smart customers paying for their needs only, and second they will help create a more competitive space industry. A good proof of this is military space contracting in the US, where the Government takes all the risks. And US industry with its "fat" cost plus military business becomes unable to compete commercially and globally (example US launcher industry).

Governments should invite industry and make serious efforts to really reduce the cost of access to space.

Benefits from reduced cost of access to space.

The main benefit will be to create increased space business because there will be more space activities, resulting very likely in a total net growth (As an example, when prices of computers significantly decreased by several orders of magnitude, the total computer market exploded and therefore total IT-investments including computer sales increased).

Another benefit will be to have a commercially competitive launch industry also for medium sized payloads, and which does not depend on future government support.

Governments must be willing to take some risks now, in order to reap the rewards in the future.

The prevailing culture in most space agencies and in the large space companies is to avoid failures and therefore try to eliminate any possible cause of a launch or satellite failure. Because both launching and satellites are so expensive it is fully understandable that this no risk culture prevails.

Governments could save meaningful amounts by tasking their Space Agencies and ESA to take more risks now and develop the LEGO type architecture for assembly in orbit as mentioned in chapter 8. For medium to large missions such architecture could lead to substantial future savings and also shorten the time from concept to a functional spacecraft in its orbit.

A beginning could be to seriously study the feasibility of developing the docking or mating system to allow a spacecraft to be launched as three separate subassemblies like for example:

- Solar panel module with its associated docking mechanism. No in orbit manoeuvring is foreseen and needed, only a low cost satellite stabilization system during docking plus a communication system to inform the ground system of its precise orbit (using GPS and/or Galileo).
- Fuel tanks and rocket engines for in orbit position keeping and for the ability to find and dock with the solar panels already in orbit. These two docked pieces will constitute what is normally called the satellite bus. Typically this unit will include the star tracker and reaction wheels for three axes stability and attitude control and for manoeuvring.
- The actual payload with its standard docking part and which the already mated satellite bus will also find and dock to. Note that also this unit does not need in orbit manoeuvring, just the same standard low cost stabilization and communication system.

Such a scheme was actually discussed between CNES and RKK-Energia in 2002, and both NASA and DARPA in the US are working on similar concepts.

The future large satellites for Eumetsat and next generation advanced Earth observation could then be based upon such three subassemblies to be fully automatically mated in orbit. Two of the units will be standardized and only the payload part will be unique to each mission. Such LEGO type architecture would allow the development of next generation modules to be independently decided. When there is little to be gained, the standardized modules for the bus including the solar panels could last several generations of payloads where most likely the technological development in components and sensors will be more valuable.

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Mission Statement of ESPI

ESPI's mission is to carry out studies and research to provide decision-makers with an independent view on mid- to long term issues relevant to the governance of space.

Through its activities, ESPI contributes to facilitating the decision-making process, increasing awareness on space technologies and applications with the user communities, opinion leaders and the public at large, and supporting students and researchers in their space-related work.

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