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UNDERSTANDING THE SPACE ECONOMY

Competition, cooperation and commerce

A STUDY PRODUCED FOR

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Executive Summary

Space is already crucial to the process and progress of our globalised economy. In the absence of continuing investment in space technology and space-based services, the outlook for growth in the developed world -- and even more so in the developing world -- would be bleak.

Yet even now it is still unusual to think in terms of a 'space economy'. We have become familiar with space exploration, space technology and even space tourism, but the idea that the supply and demand of space-related goods and services forms a distinct economic system is new. This is partly because data reporting systems have not broken out the downstream as well as the upstream value that stems from the space sector. But it is also linked to the daunting nature of space as a business environment, both physically and financially.

After five decades of the space age, satellites remain expensive, launches remain expensive, and returning information is only slightly less expensive. The price of entry is high and the cost of developing infrastructure from scratch essentially prohibitive. As such, the space economy does not conform to the classic free market model. Instead, it is a hybrid economy, one in which the public sector must do much of the work that makes a role for the private sector possible.

Experience shows that only governments can afford to develop the tools and let the contracts that enable entrepreneurs to become established. Experience also shows that the rewards for doing so are not just better delivery of the benefits from the space economy to consumers but also the creation of new jobs, new businesses and new skills. In addition, the links between space and the wider economy mean that a country that plays a central role in space is well positioned on the high ground of global competitiveness.

However, this hybrid nature means that taking the space economy into the next phase of its evolution will demand another surge of public commitment. Governments must continue to play the role of developer in the sector alongside that of customer and regulator, with the public sector contract the precursor to private sector funding.

The six leading players that we look at in this study have a range of experiences between them in the relationship between the public and private sectors in the development of space.

- The **United States**, the most market-orientated, has found it difficult to meet a stated goal of transitioning away from the predominant role of the public sector in space activities. The government remains the largest consumer of space products and well as a significant supplier of services and hardware. However, the American experience also shows how much of the value of the space economy, as distinct from spending on space, remains dispersed and unmeasured in other sectors from defence to consumer electronics. In addition, as the pioneer of space development, Washington's need to take proliferation issues seriously has led other countries to develop their own space expertise, with implications for competition in the space economy.

- During the 1990s, **Russia's** annual space budget was five times lower than in the final years of the Soviet Union. During the current decade, it has rebounded tenfold to reach more than one billion dollars. The goal now is to raise Russia's share of the global space market from below 10% to above 20% by 2015. In pursuit of this, the government is consolidating the space sector in order to integrate supply chains, improve quality control, and make Russian companies more attractive as international partners. There still remain barriers to progress but Russia is able to build on a record of successful partnerships with American and European companies in the global launch market as it moves into other space services.

- **Europe** is keen to integrate the private sector into its space activities as far as possible. Some governments are now using private companies to handle low-level defence traffic via satellite, or teaming up with the private sector to produce both commercial- and military-grade imagery from the same satellite network. Others have changed its laws to set out clearly the relationship between privacy and the commercial sale of data gathered by satellite. In most cases, the private sector is contributing its ability to deliver data to a customer base in the form of an attractive service, while government is providing much of the infrastructure in which that service depends. Both European Union and the European Space Agency see the future as moving the private sector into a greater role on the infrastructure side. However, the Galileo navigation system, the intended showpiece of Europe's effort to develop space applications using a public-private partnership, has simply proved too ambitious to fit the model.

- **Japan's** ability to blend overseas technology into its government-nurtured space sector proved so successful in the 1970s and 1980s that it had become the subject of a US trade complaint by 1990. When the country's subsequent fiscal crisis cut space budgets, the private sector urged the use of public-private partnerships to maintain the country's autonomous capabilities. Resistance from the civil service to that idea resulted in politicians and the space industry joining forces to produce legislation that broadens the ability of the Japanese government to support commercial space development.

- Until very recently, **India** has had the purest form of public sector space programme, with the government as both the provider and the user of space applications work. Almost all the country's space spending has been tied closely to its socio-economic development, with prestige or defence playing a surprisingly minimal role. Now, however, India is developing international partnerships in planetary exploration and making its launch services commercially through a government-owned corporation.

- **China** is also moving strongly into the market for space hardware and services. With much of the commercial launch market closed by western export regimes, China is now using its space resources to build its regional leadership profile and, most recently, to court developing countries with large reserves of natural resources. It has already built and launched a communications satellite for Nigeria and will do the same for Venezuela this year. If it develops a trend of subsidised sales to emerging market nations, this could lead not only to serious trade friction with the United States but also to concerns about political influence.

All these countries recognise that space offers a combination of political and economic opportunities at the domestic, regional and global level. They also appreciate the extent to which the development of space-based services still needs serious government investment.

In recent years, opportunities have begun to grow for channelling that investment through private sector enterprises. This has strengthened rather than weakened the reasons why the government's role is so crucial. Nurturing these new enterprises, which at present are focused on delivering better services to the downstream consumers in the space economy, will be the foundation of leadership not only in the space sector but also in the wider global economy over the coming decades.

Section 1: Understanding the Space Economy

Introduction

Space makes the global economy what it is: universal, dynamic and productive. Remove the space dimension and the world would loose much of the growth that it has experienced in the last 50 years. Looking forward, without continuing investment in space technology and space-based services, the prospects for maintaining economic growth over the next half-century -- even the prospects of holding on to the current standard of living in the developed world -- would be bleak. In addition, and perhaps more importantly, efforts to raise the living conditions of more than half the world's population to a viable level would be severely hampered without the contribution of the space economy and the services that it makes possible.

A groundbreaking OECD study published last year described the space economy as comprising

> "a long value-added chain, starting with research and development actors and manufacturers of space hardware (e.g. launch vehicles, satellites, ground stations) and ending with the providers of space-enabled products (e.g. navigation equipment, satellite phones) and services (e.g. satellite-based meteorological services or direct-to-home video services) to final users." [1]

This is a much wider definition than a purely industrial (or 'upstream') view, embracing the capacity of the space economy to create new products whose ultimate customer may have little appreciation of the role played by space technology.

Taking this economic approach to the benefits of space technology underlines the extent to which commercial considerations may now drive further development; winning a large share of a world market expected to be worth over one trillion dollars by 2020 offers an obvious return. But such an approach does not include the indirect and less quantifiable gains derived from leading the space economy. These go beyond the crucial contributions towards national security to encompass the benefits of "soft power", Joe Nye's instructive term for leadership through positive example. Leading the development of the potential of space-based services can mean leading international efforts to alleviate poverty, to protect the environment, to head off the

[1] *The Space Economy at a Glance 2007*, OECD, Paris 2007, p.17.

effects of climate change, and to spread positive cultural messages. Closer to home, leading rather than following in space generates new jobs, creates new businesses and fosters new skills.

Growth comes from combining the impact of technologies.

Much of the new growth in the space economy is being driven by emerging technologies, and combinations of technologies, coupled with new ways of doing business. In particular, the fusion of space-based services with information technology and terrestrial networks is creating novel "systems of systems" that have the potential to combine the nineteenth century impact of railway development with the world-altering effect of telecommunications and computing in the twentieth century.

As in the initial period of these earlier technologies, quantifying all of these effects -- technological, economic, commercial and political -- and especially the role played by the 'hidden' space economy lying down stream from the launch and orbital infrastructure is hard if not impossible. Yet, despite the methodological problems, there is an emerging consensus that they are significant. Adopting this expanded view of commercial space activity is to grasp the point that holding a central role in the space economy is to command the high ground of global competitiveness. The breadth of impact that ranges from telecommunications, navigation and broadcasting to weather forecasting and earth observation work marks out space as distinctive and significant. To ensure a place at the heart of this activity rather than on its periphery -- to ensure the ability to influence and shape events -- is the crux of twenty first century economic power.

The Space Economy as a Public-Private Hybrid

Space is now a hybrid market.

In the half-century since Sputnik 1, space has moved from being a totally public sector preserve to a hybrid that mixes public and private actors. While private sector players are still a minority, their number has grown rapidly over the last two decades and will undoubtedly grow further over the next ten years. However, given the continuing importance of space for security and military affairs, the balance between public and private usage is unlikely to change significantly in the short to medium term. At the same time, as more earth observation applications are developed, a further set of public or quasi-public sector players will enter the space marketplace.

Access to space, a central aspect of the space economy, remains a largely public sector concern, with most launch vehicles now in use having been developed with government funds. Yet the emergence of commercial organisations to market and sell launches on behalf of hardware manufacturers has added to this hybrid nature. It also remains the case that, because so many space activities were originated for strategic and military purposes, much of the space technology now in use has dual-use potential, resulting in a significant government regulatory presence in the marketplace.

THE SPACE ECONOMY AND THE JET ENGINE

There is some similarity here with commercial aviation up until the 1950s, when the civil-military linkage became less direct and airliner design was driven primarily by commercial requirements. The immediate post-1945 world saw the early stages of an international industry in which the airlines were a mix of publicly and privately owned organisations; the hardware was developed on the back of military research or directly funded by the state; and aviation in general had a high national security content.

Commercial aviation in the 1940s was only beginning to have its wider socio-economic impact and was still some way from the age of mass travel and the space-time shrinkage that would come with the jet airliner. In turn, the demand for mass air travel would help to drive deregulation and airline industry liberalisation. The arrival of the jet, democratising travel and propelling civil aviation to the fore, was the turning point. In some respects, space is still awaiting its own version of the jet engine -- a means of dramatically reducing the cost of access to space that swings the impetus towards deregulation and a smaller role for government. This would encourage a wider range of players to enter the market as equipment suppliers and service providers.

A truly free-market space economy is decades away.

Even in the absence of a sharp reduction in the 'pound to orbit' cost, however, it is probable that, as proved to be the case with the Internet, space technologies will break away from their defence-sector origins and stem instead from truly market-driven responses to commercial opportunities. The key uncertainty is the timeframe. At present, a truly free-market space economy appears decades away for two main reasons: the continuing role of government actors will take a substantial amount of time to 'wither away', while the capital markets (as opposed to a few very wealthy individuals) will remain reluctant to provide complete support for new developments when so much government-subsidised activity continues.

In the meantime, the provision of space infrastructure and much of its operation will continue to be a matter for national governments, regional political entities such as the European Union, and multilateral agencies with an interest in space-based solutions to a range of global problems.

Market Regulation and Access to Space

While certain key aspects, such as the allocation of orbital slots and frequencies, are regulated by international agreements and the work of long-standing multilateral bodies such as the International Telecommunication Union, the space market is effectively shaped by those actors who control access to orbit and who can afford the investment needed to create, develop and sustain space-based infrastructure.

Compared to ten or twenty years ago, the contemporary space economy is notable for the number of states or groupings of states that now have autonomous access to space. But the United States, through the sheer scale and scope of its space operations (public and private) and by dint of a technological lead that, while shrinking, is not yet threatened, will remain able to shape the space market if not unilaterally then certainly from a position of strength.

This aspect of market 'regulation' -- *de facto* rather than *de jure* -- has implications for all space market actors so long as actions are limited simply by capability rather than regulated by international agreements with transparent benefits for all. Much of the space infrastructure is far from robust, so that while increased resilience in the future may come from orbital redundancy or quick-launch replacement, actions that, for example, leave debris in a well-trafficked orbital plane, threaten the entire space user community.

Over time, it is possible that space will see the development of a code of conduct similar to maritime law and the system of convention and regulation that governs use of the seas. However, at present the situation is more analogous to the nineteenth century, when sea-lanes were largely controlled by British naval power that was, for the most part, exercised with the aim of ensuring stability (or, from another perspective, stasis) in the international community. As such, the maritime convention model is not yet appropriate as a guide to market regulation or, in this context, to constrain the kind of unilateral action that might threaten access to space and the unimpeded operation of space assets on which so many now depend.

The widespread importance of the space economy can also make regulation difficult.

It is certainly the case that the value of space as a general asset for all mankind, for national governments and for business actors raises the cost of non-compliance with whatever regulatory structures there may be. However, that value inevitably drives more players to enter the market and so complicates the negotiating environment for creating the regulatory structure needed if space is to operate as a genuinely commercial environment. Such dependence also increases the temptation to nullify space assets in time of conflict, and so also increases efforts to protect those assets on a unilateral basis.

In general, an increasing dependence on space is common to most of the players in the space economy -- whether public (military and civil) or private, especially in the financial, energy and telecommunications sectors. In the longer term, alternative technologies may mitigate this risk and consequently reduce space dependence, as advances in fibre optics have already done for some forms of telecommunications. But in many areas (location and navigation, and comprehensive approaches to understanding weather, climate change and earth resource management) there is simply no alternative to space-based assets.

Public Actors Must Still Lead

The consequence of the hybrid nature of this 'pre-regulated' market is that taking the space economy into the next phase of its evolution will demand another surge in public commitment to space technology, as well as a public role in pioneering novel space markets. While this may entail a degree of international collaboration, it will remain better to lead rather than follow -- in the construction of regulatory regimes and the setting of standards, as much as in the development of new technology.

Public sector commitment to space remains vital for moving the space economy forward.

Public actors therefore have a vital role in building the modern space economy by creating a suitable environment for the space industry and service providers. This entails the basic function of maintaining access to space, especially investing in new technologies to drive down the cost to orbit and establishing an appropriate regulatory regime that balances public and private requirements as well as national and international interests. The approach of routine space tourism is already offering the opportunity to encourage entrepreneurial activity even as safety standards are codified and upheld; the work already undertaken by the Federal Aviation Authority (FAA) in this area has shown that such a balance is achievable for new technologies in the sector.

Indeed, a key challenge for furthering the new space economy will be to ensure firm grounding for a positive relationship between government and the private sector. This may be easier said than done. If governments continue to bear the majority of the costs of research and development (R&D) and the demonstrations of new technology, this should lead seamlessly to private investors addressing market risk and generating viable economic returns from space. However, neither the demand nor the supply systems in the space economy are fully mature. Instead, to a significant degree, supply continues to arrive before demand, leaving the onus on the space sector to coral customers on a sustainable basis -- a task that proved beyond early pioneers such as Iridium. This model in which government-sponsored technical progress produces technologies that then look for commercial application is unlikely to change markedly within the next decade. Given the length of time usually involved in proving the commercial attractiveness of a market and obtaining a payback, government agencies will inevitably continue to partner the private sector well into the product cycle.

The government's role as partner may sit uneasily beside that of government as purchaser and government as market regulator. So long as government wears all three hats, the space economy will not be functioning as a free market. But without this degree of government involvement there is a real probability that it will not grow at all.

Government as First User

The government contract still needs to precede private sector funding.

The public sector remains, and will remain for some time, the primary user of space-based services and data. Private actors may also make use of them and indeed may create a very lucrative secondary market, as has happened with satellite navigation technology. But as the first, and often the most reliable and durable customer, only governments can stimulate wider market uptake and enable service providers to attract private investment. The government contract needs to precede private sector funding, rather than the other way around, in almost cases other than those in which an individual chooses to commit personal resources to pioneering a new niche in space-based services.

THE 'GREEN' SPACE ECONOMY

The role of government as first user is particularly important in the growing area of earth observation and monitoring. Space-based systems have a unique role in monitoring climate change and helping policy-makers to formulate appropriate responses. Equally, satellites enable governments and other actors to track the immediate consequences of terrestrial disasters that may become more frequent and intense over the next decade.

This has a purely scientific and humanitarian dimension, but disasters cost money as well as lives and can have a lasting effect on national and regional economies. Weather-related events caused damage worth some 750 billion dollars during the 1990s alone. More capable metrological satellites and early-warning networks will help to reduce both the human and the economic costs of natural disasters. Better day-to-day and conventional long-range weather forecasting will have a comparable impact on economic activity throughout the world. Such activity is increasingly based on international efforts to spread the cost and widen the impact of space-based monitoring, as with Europe's Global Monitoring for Environment and Security (GMES) programme.

THE 'HIDDEN' SPACE ECONOMY

The ubiquity of space-based services is often taken for granted. Few people know or care whether their phone calls are directed through terrestrial lines or bounced via satellite. Global broadcasting is an equally routine event, although those with access to direct to home satellite broadcasting will at least notice their personal receiving dish. These are part of the 'downstream' market that can be thought of as the 'hidden' space economy because its users and consumers are at best only vaguely aware of the central part played by space-related technology.

Today a number of key activities could not operate without space systems. But like water, transport and other vital infrastructure, they have become "so embedded in our modern societies that their benefits go largely unnoticed, except when systems fail to function as expected."[2] Interruption of space-based services, perhaps even only for minutes, suddenly becomes a rare, and hence alarming, inconvenience for many people.

Downstream services are the hinterland of the space economy.

Downstream is where space has the most direct and indirect impact on national economies and the global economy. This is the hinterland of the space economy, where space feeds growth and drives competitiveness. In some respects it is still an undeveloped market, and this is where much of the struggle to command the global heights of the space economy will be fought out over the next 20 years.

The Space Economy: From Prestige to Necessity

In the 1950s, the space race helped to define the characteristics of the Cold War between two superpowers; space 'firsts' counted as victories on the road to proving one political and economic system superior to the other. Today, thirty countries have national space budgets and more than fifty own satellites in orbit. Over 80% of total global spending on space is still generated by the United States, followed at a very considerable distance by the EU and Japan. But the renewed interest of Russia and the rapidly growing commitments of China and India mark a new space contest.

[2] *The Space Economy at a Glance 2007*, OECD, Paris 2007, p.69.

There is still a strong political and security motivation at work in driving space budgets. But there is also a growing recognition that even more is now at stake in investing in space technologies and in nurturing space-based services. Space today is no longer about playing to an audience of non-aligned countries. A strong presence in the space economy is as important as having a modern transport infrastructure and information highways. Operating technology in space has moved on from being a prestige-proving ground to become a twentieth century necessity.

For a new generation of aspirants, space is still about garnering respect and demonstrating a level of achievement. But the space economy is not about prestige. It is fundamentally about hard-nosed, pragmatic solutions to hugely complex problems; grafting out long-term and hard won returns and rather than quick and easy profits. The benefits from space should be global but the returns will go to those countries that support sustained investment in developing the space economy.

Section 2: Major National Contributors to the Space Economy

The United States

The United States continues to be the home of the latest developments in space technology and space exploration. Rovers on Mars, the shuttle and the burgeoning International Space Station, and the latest reconnaissance satellites, as well as the Apollo moon landings, come instantly to mind when thinking about space. Leadership in space remains a stated national policy, as it has been for five decades, and the sheer scale of American space activities means that its leadership remains unquestioned.

Yet one area where the United States has proved less successful in meeting a stated policy goal in space is in transitioning away from the predominant role of the public sector in space activities. Initial efforts to encourage private sector participation in the 1980s met with little success, so that satellite-based communications services remain the only area where the private sector has made its mark without continuing government support. This has some bearing on the space economy in the United States, as it can be difficult to find clear-cut boundaries between the roles of the public and private sectors.

Defining the US Space Economy in Traditional Economic Terms

While the areas to which space-related activity makes a significant contribution can be easily listed, the space economy itself continues to escape easy categorisation. It does not fit comfortably into the customary economic model in which consumer demand met by supply in a relatively stable system where price allocates the goods and services. Instead, the space economy is shaped by a large government component, part civil and part military, that operates by performing R&D, manufacturing its own space hardware, and even operating its own services. At the same time, the US government is also a consumer of space goods and services, ordering the very same R&D, hardware, and services from private firms. And, depending on the good or the service, government agencies may range from procuring 'off the shelf' to setting set extremely precise and specialised specifications for their purchases. On top of all of these complications, the US government exercises a strong regulatory regime over the availability of space goods and services, ranging from licensing launch vehicles to severe restrictions on exports.

The manufacturing of space hardware in the United States is oligopolistic, with a few large firms supplying most of the equipment. This is also characteristic of space firms in most other nations, although unlike the United States, many foreign space firms have a significant portion of their equity in the hands of their respective governments. In the United States, these firms tend to have the government as their largest customer, with defence programmes the primary component of their sales and space being only a relatively small part of their portfolio. Space services such as telecommunications, remote sensing, and navigation include many more companies. Finally, the way in which many retailers handle sales of consumer electronics that receive satellite signals, such as GPS and TV receivers, makes the sales revenue they generate indistinguishable from that of other consumer products.

GAUGING THE SCOPE OF THE SPACE ECONOMY

The government remains the largest consumer of space products.

This complex public/private system has evolved from a multi-facetted government programme that was originally developed as a Cold War technological race with the former Soviet Union. Today, with mature space systems and different government priorities, the commercial space sector is emerging and growing in the United States. Some aspects of the space economy are now relatively competitive and prices do matter. But, since most space services have dual uses (civilian and military), and the government remains the largest consumer of space products, applying traditional economic analysis to this sector remains difficult. In particular, it is almost impossible, using the economic statistics available, to estimate clearly the demand, supply and market-clearing prices for most space-based equipment.

The market for goods and services stemming from space assets is also hard to assess accurately for two major reasons:

- A high proportion of sales remain dependent on government budgets.
- Many consumer products such as cell phones that are not purchased for their space-related components also include valuable space-based information such as a GPS signal. The inclusion or exclusion of those types of equipment will have a large effect on the bottom-line total for the space economy.

That being said, it is possible to provide rough estimates of today's economic space activity in the United States. It is also possible to highlight trends in commercial space activities that have been developing with some consistency over the past 15 years and which are likely to continue to evolve in a similar fashion over the next decade.

Demand and Supply for Space Goods and Services

Demand for space goods and services can be divided into several components.

Using the space environment
The most important aspect concerns how the space environment is used. There must be something of measurable economic value to do in space; otherwise the analysis is outside of economics and must move into the realm of geopolitical and military applications (i.e. public goods). Fortunately, there is a growing list of space-based economic applications in areas such as telecommunications and remote sensing, together with miscellaneous services ranging from industrial R&D to launching the remains of loved ones into space. These will soon be joined soon by private human spaceflight as it moves beyond the handful of individuals who have already travelled into space with the Russians.

Derived demand
Derived demand for space activities includes the manufacture of launch vehicles and the provision of a variety of launch-related services ranging from vehicle integration (preparing the payload for launch) and spaceport activities to insurance and financing services. In addition, there are ground station equipment, software support, and satellite operations and control facilities that would not exist if there were no economic uses for space assets. At the consumer end, examples of products that are derived from the uses of space include the demand for satellite broadcasting receivers and decoders, satellite radios, and navigation (GPS) equipment.

Government as customer
In addition to the government as a manufacturer and provider of equipment and services for its own use, there is a growing trend for the government to purchase 'off the shelf' space products ranging from transponders on telecommunications satellites to launch services and data analysis.

The supply-side of space services is concentrated on the firms that manufacture space equipment, provide space services and operations, and market those services to end consumers. From these space-specific economic activities come additions to existing product and service distribution as well as sales activities for space services. In particular, there are the wholesale and retail establishments that ship and market both consumer and capital equipment that make direct use of space information.

SUPPLY CREATING DEMAND

Neither the demand nor the supply systems in the space economy is fully mature. They are characterised by rapid change in manufacturing and processing plants, cost structures, distribution methods and even service options and products. Behind many of these changes are the government-funded investments made in research work. The distribution of R&D funding (the choices made among life sciences, earth observations, climate change, propulsion technologies, and other sectors) often drives the development of future commercial goods and services. In effect, in the space sector there is a significant element of the supply of new goods and services creating demand; this technology push effect precedes the generation of new consumer interest.

Neither the demand nor the supply side of the space economy is fully mature.

Trends in United States Space Economic Activity

The United States continues to take the lead in developing new transportation vehicles, particularly with respect to very heavy lift vehicles in support of NASA's space exploration programme. These vehicles in the Ares series, when built, are not expected to have a major effect on commercial space capabilities. At the same time, more than one entrepreneur is investing in launch vehicles whose design is optimised for commercial use. Over the next five to ten years at least one or two of these private efforts are likely to succeed and will provide a valuable test of the commercial viability of privately developed space vehicles.

Security of all types

One space application that will continue to grow in importance is monitoring for security of all types: environmental, resources, health, climate, and defence. Some of these applications have commercial value but most will be bought and used by governments. The United States will continue to expand its satellite capabilities in support of homeland security and military activities as well as for industrial uses. Since this is a shared capability, the combination of end users and specialised data production is likely to continue and expand, as will the complex ties between public and private sector activity; for example, larger telecommunications companies have proposed the use of their satellite platforms for selected dedicated defence instruments, as well as being part of government communications networks.

Imagery

Space imagery and navigation services, combined with other information tools such as Google Earth and Microsoft's Virtual Earth, will begin to grow more rapidly as consumer services based on those capabilities are popularised. Still to be determined is the profitability and contribution to the economy that may result from the adoption of these capabilities for products that businesses and consumers are willing to purchase such as advertising, special value-added analytic reports and surveys, and gaming.

Commercial opportunities for all types of space activities will continue the rapid expansion which started about 20 years ago and will become an even larger share of all space economic endeavours. Since many other nations are becoming active in building and operating various types of communications and remote sensing satellites, the US share of revenues from these activities will diminish even as actual total sales revenues continue to rise. The rate of increase will depend on unpredictable parameters such as the depth of the current economic downturn and government policies toward export controls on space technology and components.

The US share of the global space economy will decline even as total US sales revenues rise.

Contradictory trends

As this growth continues, two contradictory trends will emerge in the space sector. One is the development of duplication in the provision of space-based goods and services as nations develop independent and often domestically captive markets. The other is the increase in mergers between private companies that provide consumer space services as a result of the expenses involved in establishing competing systems and the possibilities of great profits through economies of scale. In this respect, the recently approved merger of satellite radio providers Sirius and XM represents a significant development.

How these trends will affect the price of space goods and services and the overall marketplace remains open to question, since one trend will encourage competition while the other will discourage it. Policies such as free trade in space goods and services and the overall economic and geopolitical climate will heavily influence the direction of globalisation in space commercial products.

Profiling the Space Economy in the United States

A recent, widely inclusive estimate of the value of global economic space activity puts the figure at about 250 billion dollars annually.[3] With the largest and most comprehensive degree of space activity of any nation, the United States accounts for well over half of the world's space-related economic investment and commercial revenue.

[3] *The Space Report 2008*, The Space Foundation, Washington DC, 2008.

Yet for many reasons a measurement of the actual size of the commercial space sector in the United States does not exist. These include:

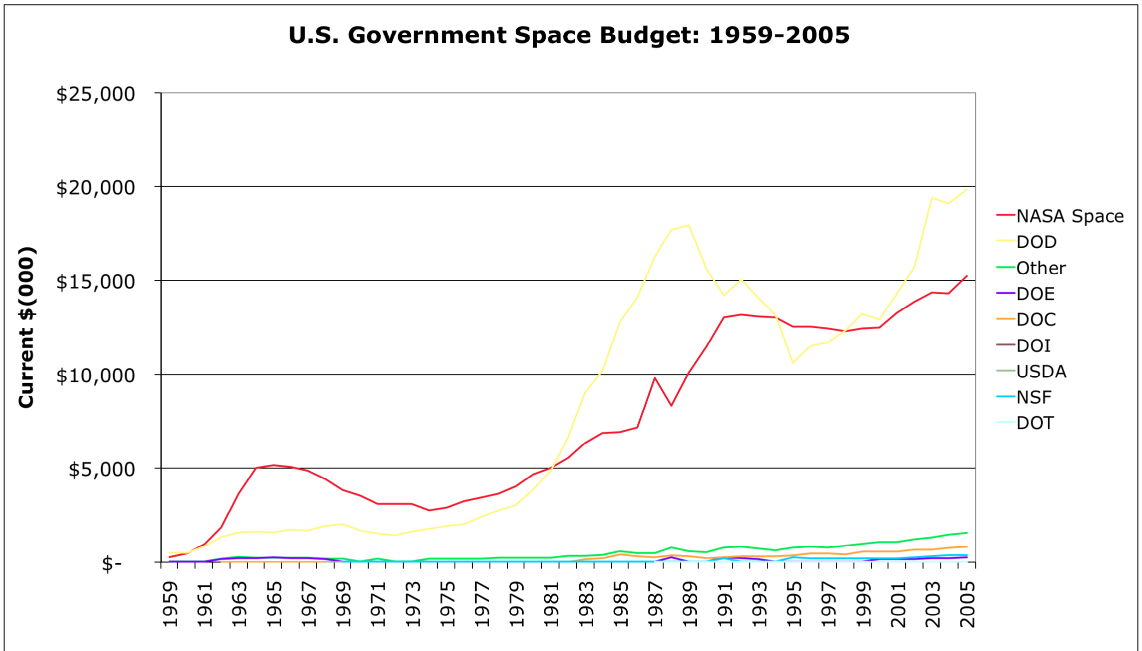
- multinational space firms with global markets that do not report out either space R&D or sales by country;
- government contracts that are often considered as 'commercial' sales and therefore double counted (once in government spending and again in industry sales);
- firms offering space services and applications that are huge conglomerates and do not separate reported data by space/non-space categories; and
- the existence of privately-owned firms that have no requirement to make their corporate financial information available to the public.

Compounding the situation is the lack of a "space" sector in the industrial coding used by governments in economic data reports.

However, despite these constraints, it is possible to attempt to develop a first-order estimate of the measurable space economy in the United States. The components are:

- annual government expenditures by agency;
- studies and surveys that have analysed direct, indirect, and multiplier effects of reported commercial investments in space activities; and
- other data sources which show trends and growth in space activity in the and validate the order of magnitude of the estimates.

The figure below details the investments made by the US government in space activities from 1959 to 2005. The equivalent 2007 budget authority for space is approximately 43 billion dollars, showing modest growth from 2005 in all major agencies. Not included in the chart or the updates are expenditures on space and space-related programmes funded by the National Reconnaissance Office or the Missile Defense Agency. Estimates place these at approximately 19 billion dollars but the government does not release the amount devoted to classified space activities.



Source: Aeronautics and Space Report of the President FY 2005

Government space investment has increased each year since 1995 but when adjusted for inflation the increases have been modest. Even with NASA's new initiative for exploration and the increasing reliance of the Department of Defense on satellite assets for command and control of military actions, federal spending on space has not expanded rapidly. However, given the budget deficit and other spending pressures on the government, even small increases in space funding are significant as a sign of the importance of these assets to the government and the economy. Over the next five years, when it is unlikely that the underlying pressures on government spending will subside, it is also unlikely that US government space funding will experience significant cuts.

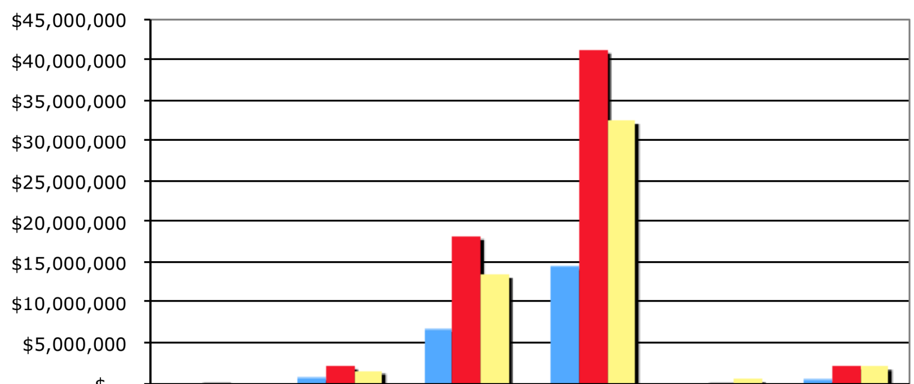
One recent attempt to measure the size of the commercial part of the US space economic activity is the study released this spring by the FAA on space transportation and its impacts. The study estimates that direct sales of all space-related industries for 2006 were approximately 23.2 billion dollars.[4] That generated another 65 billion dollars in indirect (supporting industries) sales, and another 51 billion in induced effects (additional non-space expenditures by those receiving income from space businesses -- the traditional economic

[4] *The Economic Impact of Commercial Space Transportation on the US Economy*, Federal Aviation Administration, April 2008.

multiplier). The total of 139.3 billion dollars is divided among the various industry groups, and it is evident that over 60% of the commercial impact lies in satellite services, mainly in the direct-to-home (DTH) satellite broadcasting market.

Combining these estimates with the figure for government spending produces a first-order approximation of 180 billion dollars for the current annual value of the space economy in the United States.[5] However, it should be noted straight away that this figure captures spending rather than value, which must be substantially higher, and even then only part of the relevant spending. Perhaps the greatest implication to be drawn from it concerns the need for data collection systems to improved so that it is possible to come closer to determining the higher figure. In the meantime, the first-order figure should definitely be viewed as conservative.

Economic Impact of Commercial Space by Sector in the United States: 2006

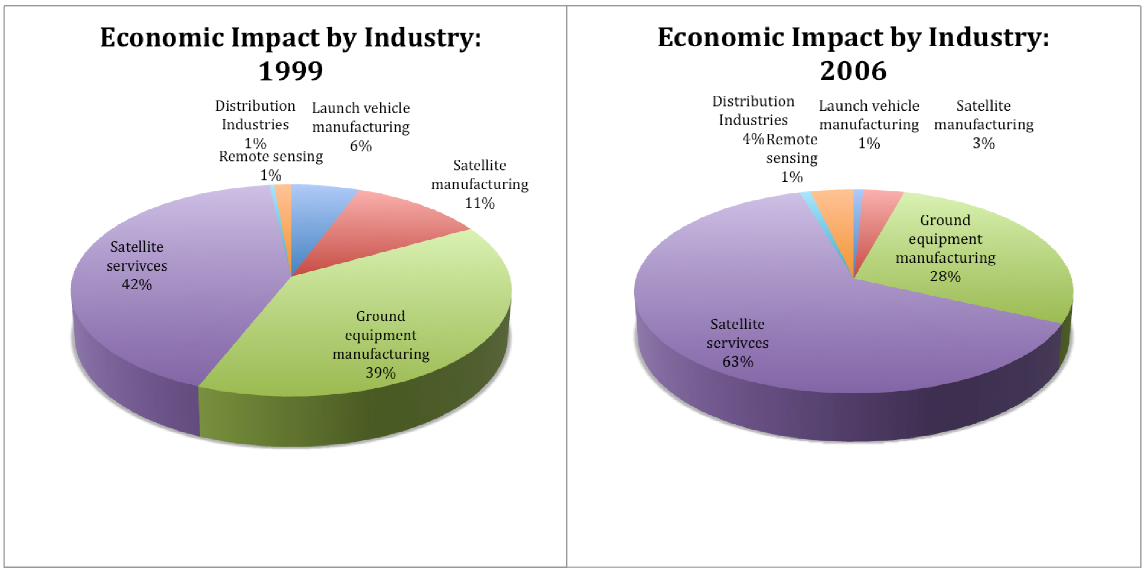


	Launch vehicle manufacturing	Satellite manufacturing	Ground equipment manufacturing	Satellite Services	Remote Sensing	Distribution industries
Direct	$199,195	$847,992	$6,898,385	$14,530,871	$126,804	$637,662
Indirect	$527,028	$2,240,455	$18,226,019	$41,267,679	$509,190	$2,261,410
Induced	$440,500	$1,662,453	$13,523,993	$32,579,181	$628,429	$2,154,781

Source: FAA, 2006

[5] It is important to recognise the assumptions and problems with this estimate, from the difference between government budget authority numbers and actual spending in any given year to the likely double counting of government funding and commercial sales back to the government. However, some inconsistencies may tend to balance since this estimate does not include the budgets for classified government programmes. Note also that these numbers reflect money spent, not the actual value to the user of the information. Although the price paid by a private customer may actually reflect the relative value of the information to that customer, there is no equivalent data on the value to the government of such space-derived information.

The FAA study estimates that commercial space spending creates some 730,000 jobs outside government. It also shows the dramatic change in the distribution of commercial space activity in the economy. As the figure below shows, over the years between 1999 and 2006 there has been a relative decline in three areas in the United States: the manufacturing of launch vehicles, the manufacturing of satellites, and the manufacturing of ground equipment.[6] The decline in launch vehicle manufacturing likely reflects the economic slowdown in the early 2000s, as today the sector is showing signs of recovery as a result of investment from NASA and DOD as well as new entrepreneurial efforts.



But the relative decline in building satellites and ground equipment in the US does mark a significant change. One reason for this is increased competition from other countries. For years, US companies enjoyed unchallenged global leadership in the quality and capability of satellites and receiving equipment. That leadership has steadily been eroding as a result of the increased technical abilities around the world coupled with national interests pushing other countries to develop a autonomous and indigenous independent manufacturing capability.

Impact of ITAR

Adding to the incentives for other countries to develop an autonomous space sector has been the International Traffic in Arms Regime (ITAR), the US government's export control regime, which can make it very difficult, expensive, and time-consuming for other nations to purchase US manufactured satellites and components.

[6] Interim studies have shown a wide degree of variation in these trends.

ITAR appears to encourage other countries to develop substitutes for US technology.

European efforts to produce replacements for components developed in the United States have been ongoing since export restrictions relating to satellites were tightened at the start of this decade. As a result, at least one European company has been able to produce a satellite that can be sold to a Chinese-owned telecoms satellite owner and launched by a Chinese Long March vehicle without the need for export clearances from the US government. Although some European companies have said that they will not attempt to sidestep ITAR by using particular components, in the spring of 2008 nine European countries that are backing a joint microsatellite programme appeared ready to sanction an 'ITAR-free' version that could sold without US approval.

While it is difficult to separate out the direct effect of ITAR-related concerns as a direct stimulus for the growth of space manufacturing abroad, the trend of greater value from the satellite market moving away from the US is evident in the statistics. In 2007 the United States had exports of spacecraft, missiles, rockets and parts that were just over 2 billion dollars and imports that were just under 1 billion dollars.[7] These figures include both civil and military hardware. Reflecting the above trends in foreign capabilities, the 2:1 ratio of exports to imports for space hardware represents a significant decline from the 3:1 ratio that existed in the mid-1990s. Similar data for the trade of space services are not reported in the same data series.

The Outlook for the United States in the Space Economy

The United States remains the world leader in both investments in R&D and in the production and sales of space equipment and services. Even though its relative share is decreasing, the absolute growth of the space economy worldwide and in the United Sates is robust and is projected to continue. The two categories of commercial services that have accounted for the majority of growth are direct- to-home (DTH) broadcasting and the global positioning and navigation sector. This growth is likely to continue but the rate of increase may slow due to market saturation.

There are currently no other commercial space applications that can be projected to become large revenue sources for the industry in the United States over the next five to ten years. The space tourism industry has yet to develop and its success can only be measured once paying customers are flown successfully with any degree of regularity.

[7] AIA data, as reported in *The Space Report 2008*, page 16.

Applications such as remote sensing, which have important uses and many customers, have not accounted for a large share of revenues from the commercial sector. One reason they may be undervalued is that the data provided from space becomes far more valuable when combined with other information prior to being sold commercially, with such sales not being attributed to space in economic reporting.

Almost all of the development of these space applications and capabilities can be traced to efforts, both governmental and commercial, in the United States. And, although there appears to be no slowdown in the US development of space applications, the commercial lead is shifting to other nations. The two primary reasons for this are:

- the recognition from other nations that space investments can stimulate their domestic economies; and
- the US focus on space investments and space policy from a geopolitical perspective more than an economic growth perspective.

HIDDEN VALUE

Much of the value of the space economy remains undocumented.

The conclusion from this survey of the US space economy is that the United States receives more value from its space investments than is measured by any existing economic study. The estimate of 180 billion dollars for the size of the US space economy captures only the top level of economic benefits.

The additional value can be found in a variety of areas including:

- Services and applications that provide information to the public such as the vast improvements in weather forecasts, environmental monitoring, disaster management tools and the management of resources and energy. The public benefits can add up to hundreds of millions of dollars each year but go largely unmeasured.
- Internal government uses of information that are transferred among agencies but for which there is no specific transfer of funds and therefore no price or value equivalent.
- The value of commercial space services to military and security operations. While it is possible to measure monetary expenditure on purchases by government agencies, the value-added and the efficiencies created by

space systems used for command, control, communications, and intelligence are extremely valuable yet remain unmeasured.

- Spin-off technologies that leverage government R&D into additional value-added for firms and industries. sThere are many examples that range from new products originating from space research (e.g. new lubricants, non-invasive medical imaging instruments, insulating materials, composites, etc.) to less obvious process-related technologies such as better clean room procedures, improved robotics, and new production software and systems.

- The development of a new communications infrastructure that has improved the quality of life in the United States and radically changed the way in which people are connected and interconnected. Space components have become an integral part of the communications networks (voice, video, data) that shape modern life and these networks now depend on the effective operation of satellite systems.

Having made space-related services an indispensable part of its increased productivity and connected lifestyle, the United States may now be looking at a prolonged period in which the hardware used in providing those services is increasing sourced from outside the country. While the hidden value that is still provided by space-related services may well make the diminution of the US lead less noticeable, the clear intention of other countries to help their companies compete in the global space economy means that work is needed if the United States is to continue selling twice as much as it buys in the global space marketplace.

Russia

The structure of the Soviet space programme was based from the start on the development of a large military-industrial complex. This did not mean that it was monolithic -- indeed, competition between different design bureaus and their political sponsors hampered Soviet efforts to retain an early lead over the US civil space programme. However, since the collapse of the Soviet Union, even as Russian links with US and European space activities have increased, Russia's space industry has experienced chaotic times characterised by budget shortfalls and hesitant strategies. Only recently has a new effort to increase Russia's economic and political influence in the global aerospace arena led to a reorganisation of the sector in an effort to capitalise on what is still a unique set of capabilities.

Surviving Through the 1990s

While space activity was primarily a matter of national prestige in the Soviet Union during the Cold War years, Russia has been striving for more than 15 years to place a value on its space capabilities since the collapse of the USSR. During the 1990s, the annual public investment in the space sector was five times lower than the average budget devoted to space during the last years of the Soviet regime. The first and most obvious consequence of this situation has been the large-scale reorganisation of the space sector, which has had both institutional and economic consequences.

Russia's new federal space agency, known as Roskosmos or RKA, was established in 1992 as a relatively lightweight political structure compared to Glavkosmos, its Soviet predecessor. Over time, however, it has developed into a much more significant actor than the purely bureaucratic body initially envisaged. RKA is now the dominant actor in the institutional landscape, having won a lengthy battle for political authority with the country's leading space company, NPO Energia. This was partly a result of RKA's success in boosting export earnings during the 1990s. In 1993, the space manufacturing and services sector earned 40 million dollars from work done for other countries; by the end of the decade, that figure had risen to 880 million. Much of the increase came from RKA efforts to establish lucrative cooperation agreements with other governments.

As a result, RKA was rechristened Rosaviakosmos and given additional responsibility for 350 companies in the aviation sector in the hope of developing closer links between the country's air and space programmes. However, the different dynamics between the two sectors, which is by no means unique to Russia, meant that the experiment was not a complete success (leaving President Putin to try a similar strategy in 2006-7) and the agency reverted to previous name and role in 2004.

Ministry input

RKA has progressively increased its links with the defence ministry, which is the other key player in the Russian space sector. It not only controls military space policy but, through the military space forces (VKS), it manages and operates the country's launch complexes and space infrastructure. Cooperation has been a necessity for the ministry, given the increasing number of dual-use programmes as well as the enduring shortage of federal funds for civilian and military space activities (annual budget allocations tend to be greater than the money that is actually made available for spending).

Civil and military space links are close.

The ministry of communications has also played a significant role as a user institution. Relatively autonomous, this ministry has developed its own space telecommunications programmes using funds that are independent of the federal space budget. It is also in charge of domestic and international negotiations about frequency allocations, a role that is likely to grow in importance.

The industrial sector

As indicated by their names, modern Russian aerospace firms still have their roots firmly in the old Soviet organisational structure. Some retain the designation KB or OKB in their title, indicating their origins as either a general or specialised design bureau, although during a communist-era bout of consolidation during the 1970s many of these were swept up into NPOs (science-production associations). NPOs proved relatively successful in following the 'conversion' model imposed during the final Soviet years, transitioning from their defence industry role to civilian-oriented activities. Since then, however, shrinking investments and associated budgets, coupled with the attempts to introduce 'western style' commercial best practices, have had an unsettling effect.

The sector has survived for two main reasons:

- The integration inherent in the old Soviet system enabled the NPOs to exert considerable control over the complete production chain and use strategic reserves to maintain the production processes.

- Active efforts to engage with western governments and companies interested in closer technical cooperation developed after the Clinton administration decided to inject capital into the Russian space sector as a non-proliferation measure.

The space sector was an important source of hard currency in the 1990s.

The development of joint ventures with both American and European partners during the 1990s helped Russia to extract hard currency value from its relatively cheap and reliable indigenous space technology at a time when such a financial contribution was particularly crucial. The main areas for cooperation were the marketing of launch vehicles through linkages with Lockheed Martin (International Launch Services), Boeing (SeaLaunch) and Arianespace (Starem), and the construction and supply of the International Space Station (ISS).

In the field of manned space flight, traditional intergovernmental agreements were used to sustain industrial capacity. NASA paid to send seven of its astronauts to the Mir space station, while ad hoc industrial contracts were used in applications programmes and areas such as rocket engine technology. Further attempts at commercialisation have included the marketing of decommissioned ballistic missiles to launch small satellites for less than 20 million dollars.

These international links saw the sector through the bleakest period, and for those firms that have survived, private investment and genuinely commercial sales now make up a substantial part of their income.

The Putin Years

The RKA budget has grown by a factor of ten since 2000 to reach approximately a billion dollars.

After Russia's financial crisis of 1998, the general economic recovery -- partially based on dramatic achievements in the exploitation of huge oil and gas reserves -- has also improved the situation of the Russian space sector. The RKA budget has grown by a factor of ten since 2000, reaching approximately one billion dollars in 2006. This makes it comparable to the budget for the European Space Agency (ESA) when the lower local costs in Russia are taken into account.

A long-term outline for the federal space programme, drafted by the RKA under Director Anatoli Perminov and covering the period from 2006 to 2015, received presidential approval in the autumn of 2005 and subsequently won backing in the Duma. It calls for total spending of almost 20 billion dollars during the period, representing a doubling of the current annual budget, together with as much as a quarter of a billion dollars for specific R&D projects.

The ten-year plan envisages some 70 active civil satellites in operation by 2015, backed by new launch vehicles and benefiting from a upgrading of the northern launch site at Plesetsk, which is currently reserved for military launches. This revitalisation of the civil sector has begun with renewal of the Global Navigation Satellite System (GLONASS). This was decaying badly early in the decade, with the number of fully operational satellites in single figures, but the possibility of linking it with Europe's Galileo system (even though this frequently discussed idea has only an outside chance of being realised) has made it a target for investment. By the end of last year, there were 18 satellites in service and the full constellation of 24 is due to be in place by the end of 2009.

In 2006, President Putin set up a new Military-Industrial Commission (VPK). Its central aim is to overhaul procurement procedures but it also has the task of pushing the transfer of technology developed for the military into the civil sector and encouraging dual-use development projects. RKA stands to be a significant beneficiary of the policy, with the GLONASS modernisation being an early example of efforts to expand civil benefits from space technology. Putin specifically hailed it as a vehicle for economic as well as technological innovation, pointing to its role in exploiting natural resources as well as assisting in urban planning -- both of which are priorities at the federal level.

Russia is keen to increase its competitiveness in the global space economy.

Although the direct integration of GLONASS with the US GPS system and Galileo remains unlikely at present, other countries, notably India, are interested in working together with Russia on the programme. This represents an increasingly important strand of Russian thinking, which is to get its space technology accepted in the international marketplace. The space industry is likely to get a boost from the substantial effort now being put into increasing Russian arms exports, especially in the aviation sector, while government efforts to raise the profile of Russian technology in general should help RKA extend its international links and contacts.

Consolidation and National Champions

As part of the general goal of having space technology play a greater role in civil infrastructure and economic growth, as well as becoming more competitive internationally, the idea of consolidation within the sector is once more on the political agenda. It is widely accepted that with more than 110 companies in the aerospace sector employing about 250,000 people, there is room for greater efficiency through the building up of a just few very large organisations. The model here is clearly Lockheed Martin or Boeing in the United States, or EADS in Europe, and Russia already has a small group of leading companies around which consolidation could take place. These include Energia (spacecraft), Khrunichev (launch vehicles) and Energomash (propulsion systems).

Current thinking calls for much of the sector to be reorganised by 2015 into three or four large holding companies. This looks ambitious, as does the interim goal of 6-10 such groupings by 2010. But momentum is definitely moving in the direction of greater consolidation, and the economic logic of greater streamlining within the sector is inescapable. There is also an assumption that the companies that managed to survive and grow through the very lean times of the 1990s and early 2000s have management experience that can only benefit the rest of the sector.

The intention under Putin, which seems likely to continue under the new tandem leadership of President Medvedev and Prime Minister Putin, is make more funds available to these companies through RKA in order to restructure and develop their activities. The ultimate aim, first mooted in 2006, is to double Russia's share of the global space market from around 10% to above 20% by 2015. This is more a goal than a target, at least at present, but the underlying rationale is to push up the extent to which the output of the Russian space sector, which for so long existed as the sole supplier to a government that was its only customer, can compete in world markets.

RESTRUCTURING

At the most basic level, this will entail an overhaul of product lines and the incorporation of current technology. More importantly, it also has to mean a significance increase in quality control procedures. Commercial launches from Russia continue to suffer from equipment failures, notably in the 'Breeze' upper stage of the heavy-lift Proton launcher, that have been laid at the door of poor production practices.

Corporate governance practices are improving in Russian space companies.

This would also mean a change in the legal status of the enterprises that the government is hoping to herd into these large holding groups. Today, more than 80% of companies in the space sector are "united federal companies" (or FGUP), meaning that their production tools belong to the Russian state. Under the current restructuring proposals, these FGUPs would be transformed into regular companies that are fully owned by shareholders and would have a more recognisable approach to corporate government. This transformation is likely to take place in several phases, but it should make Russian space companies more attractive to potential international partners.

This reorganisation is also likely to see a greater emphasis on the speed with which space-related technology is being moved into and applied to the civil sector. This primarily means civil-orientated space applications work, but could also mean developing spin-offs with direct benefits for individuals in other areas: Energia, for example, has already been moving into medical technology. The current plans call for increasing the relative share of civilian-oriented production from 20% to 30% within the overall space sector.

Key Actors in the Contemporary Russian Space Sector

A list of so-called 'strategic companies' in the space sector was first drawn up in August 2004. At that stage, the move was part of a much wider effort to limit foreign ownership of enterprises in sectors with particular significance for Russia's economic and physical security. However, these leading companies are each likely to act as a nucleus for one of the new holding companies. They include: Energia, Khrunichev, TsSKB-Progress, NPO Energomash, and NPO PM.

The government regards space as a strategic sector, limiting foreign investment.

1. Energia

Energia is one of the key industrial players in the Russian aerospace sector, with an announced net profit of some 22 million dollars in 2006. It dominates the manned space flight programme, having produced most of the Salyut series of space stations as well as Mir, the Russian flagship in space from 1986 to 2001. Its work on the International Space Station has given it the most experience of any company in collaborating with American public and private sector partners, as well as making it, until recently, a rival power centre to the RKA, the official Russian space agency. As the production of modules for the ISS slowed down, Energia worked hard to develop links with the European Space Agency, notably in the initial design work on a new manned spacecraft known as Kliper that would ferry crews to and from low earth orbit. Energia also developed the Yamal series of geostationary communications satellites, originally under a contract from Gazprom.

One of the first enterprises in the sector to undergo a partial privatisation in the mid-1990s, Energia is currently the only major aerospace company with a stock exchange listing and its market capitalisation is around 330 million dollars. The Russian government holds 38.2% of its shares, while its management owns 30% -- another reason why the company has a reputation of putting its own interests above those of the government on occasion. Energia will undoubtedly remain at the forefront of the sector and be closely involved in efforts to expand into the global space economy. While its political stock has fallen slightly as that of RKA has risen, and its ability to influence policy has lessened, this in itself may give it further impetus to developing international ties.

2. Khrunichev

Khrunichev leads the launch sector with its Proton and Rockot vehicles. Itself the product of a major merger with a design bureau in the early 1990s, in 2004 the Putin administration began to fold several other enterprises into Khrunichev including the Isayev engine factory, the Mechanics Institute of Voronezh, and Polet of Omsk, which builds the GLONASS navigation satellites. This has increased the company's workforce to 35,000 people and broadened its base, but the principal reason was to bring engine and launch vehicle production more closely together. The move, which came after Khrunichev lost an international launch contract because of a shortage of engines for its boosters caused by another Russian company using the Isayev plant, was something of a dry run for later consolidation and has proved successful. Priority access to Isayev has enabled Khrunichev to build up inventory and serve its military customers while still competing aggressively for global business.

Indeed, International Launch Services (ILS) the company set up in 1993 with the help of Lockheed Martin to introduce a Russian launch option to western customers (and ease US government concerns about technology transfer issues), has proved extremely successful. In May 2008, Khrunichev completed the acquisition of the shares in ILS previously held by Lockheed Martin, so that it now holds 83% of the company while Energia (which contributes a stage to the Proton) holding the remaining 17%. With full control of a well-established launch company that has more than 20 launches on its order books worth approximately two billion dollars, Russia is well positioned to increase its share of the global launch market and utilise the resulting profits for reinvestment.

Russian companies now fully control the former US-Russian joint venture set up to market Russian launch vehicles in the West.

Long confined to the drawing board by funding problems, work at Khrunichev is now advancing on the Angara family of launch vehicles, which will be able to operate from launch sites in the north and east of Russia (as opposed to the Proton, which can only be flown from the launch complex at Baikonur that Russia now rents uneasily from Kazakhstan). Designed with multiple booster options to offer a large number of launch configurations, the Angara should ensure Russia's commercial competitiveness throughout the coming decade.

3. TsSKB-Progress

The TsSKB-Progress enterprise, created when the TsSKB design bureau was brought together with the Progress production plant in Samara, produces the Soyuz medium-weight launch vehicle. Derived originally from the first Soviet ICBM, the Soyuz is the most reliable launch vehicle in the world and the mainstay of the Russian manned programme. Although the Soyuz is too small for the largest communications satellites, a deal brokered by ESA and backed by France has led to a new launching pad being built at the Arianespace launch complex in French Guyana from which the Soyuz will fly commercial launches catering mainly to constellations of satellites -- Globalstar has been the main customer so far. A Franco-Russian company, Starsem, handles the marketing side.

TsSKB-Progress, which also works on a number of scientific missions, remains a FGUP but is likely to take on several other companies as part of the current restructuring effort.

4. NPO Energomash

With roots going back to the start of the Russian space programme, Energomash is the country's main innovator in propulsion technology. The RD series of engines, which use a turbo-pump fuel feed system and are recoverable, is used by several Russian launch vehicles. Under a contract worth 500 million dollars, the RD-180 is also used by Lockheed Martin in its Atlas V heavy launch vehicle, with Pratt & Whitney setting up a special facility in Florida to manufacture these engines for use in launching government payloads following US concerns about security of supply. The RD-191, now completing testing, will be the main engine for the Angara vehicles. There are indications that Energomash may soon absorb the second leading engine enterprise, KBKhA, as part of the consolidation process.

5 NPO PM

NPO PM, based in Krasnoyarsk, is Russia's leading builder of communications and navigation satellites. Its efforts to modernise the Soviet fleet during the 1990s were desperately under-funded but under the Putin administration it was allowed to partner with European companies. This has led not only to an updating of Russia's own Express series of telecommunications satellites but also a growing amount of work for western customers such as Eutelsat. In 2006, PM made a major move towards full joint stock status when the government grouped it together with several other companies from the satellite sector to give it full control over design, production, and in-orbit propulsion systems. The aim was to improve quality control and increase its attractiveness as an international partner.

NPO PM has pioneered links with European satellite companies.

What Next?

The trend in Russia is to group together complementary activities in traditional key sectors -- launch vehicles, propulsion systems, and applications satellites. The aim is to consolidate the production chain, streamline manufacturing, raise economies of scale, shorten the time required to produce new models, and enhance quality control -- all factors which will help Russia's international competitiveness. Restructuring that also emphasises corporate governance issues will assist in attracting western partners as well as customers. It is also possible to envisage a further government step in which the space sector is integrated further into the wider aerospace sector, creating mega-companies along the lines of Boeing or EADS in which space technology is a small but significant part of a larger whole.

However, the Russian aerospace industry has been engaged in a genuine integration process for the last four years and has now reached a stage where the long-term objectives and strategies that stimulated the process are looking a little fuzzy. Enduring institutional, industrial and even personal rivalries and competing strategies have blurred the original intensions and, in the absence of strong leadership driving the process from the above, momentum may slow as some of the smaller enterprises resist absorption.

One step that might help to keep the process moving would be requiring greater fiscal transparency from the major companies, which they in turn could apply to their suppliers. Another would be a broad government strategy for increasing the role of international cooperation across the sector. At present, this is primarily a broad aspiration supplemented by the occasional ad hoc intervention, and companies in the space sector still find their efforts to work with foreign companies held up by inefficient bureaucracies or straightforward corruption. NPO Energomash, which is selling engines to Lockheed Martin, had its export licence suspended for several months last year before being approached for a bribe by a defence ministry official to have it reinstated.

Russia is also using its new oil wealth to invest in western aerospace companies.

At the same time, the investment traffic is not all one way. In August 2006, Vnechtorgbank, the Russian state bank, bought 5.02% of EADS in a move that President Putin described as taking a 'blocking minority' stake. The main motivation seems to have been to secure involvement in the governance of the Airbus programme, but the move also showed a new degree of political confidence based on a strengthening position in the commercial aerospace market. With a bulging Reserve Fund, made up of income from oil and gas sales, Russia's ability to buy takes in western companies as part of an active sovereign wealth fund strategy over the next decade can only enhance its global competitiveness.

Europe

Europe is not new to space -- the French space agency was established as early as 1961 -- and it has long experience of tensions between national programmes and regional collaboration, as well as between the development of autonomous capabilities and reliance on cooperation with the United States and the Soviet Union/Russia. Even so, in the 1960s intra-European cooperation in space activities provided an unthreatening underpinning to the wider integration then gathering pace. The early realisation that, without autonomous access to space, Europe was destined to remain a second order power led to the work of the European Launcher Development Organisation.

This laid the groundwork for the Ariane family of launch vehicles, whose development was continued by the European Space Agency (ESA) when it was established in 1975. Since 1980, Arianespace, a commercial undertaking that is closely tied to ESA, has marketed Ariane launches. CNES, the French national space agency, and EADS each hold a stake of some 30%, with other companies involved in manufacturing the launchers holding the rest. ESA remains crucial to the success of Arianespace, for example by underwriting some of the commercial risks involved in developing the Ariane V heavy launch vehicle.

The same appreciation of the need for autonomy -- driven, as with access to space, largely by France – has led Europe to develop its own series of applications satellites in order to have independent access to space-based sources of data. After a period in which some European countries, notably the United Kingdom, felt that French enthusiasm for space spending had become slightly self-serving, recent years have seen a new interest in space among smaller European countries. But, even as it expands, European space activity remains a complex layering of national, multinational and EU-directed programmes.

National Budgets and Programmes

Traditionally, national efforts have preceded European collective endeavours in space. An overview of Europe's current resources reveals that this history has had a lasting effect on its multinational space architecture, one borne out by a relatively uneven distribution of investments and resources. Out of almost 28,000 people working in the space sector in Europe, around 11,000 are employed in France either by CNES or by the leading space industries located there.

France also accounts for almost 35% of the current European space spending, with 1.4 billion euros devoted to civilian space activities.

The next two leading contributors, Italy and Germany, represent 20% and 18.6% respectively. To emphasise the differences in levels of investment, the United Kingdom and Spain, ranking fourth and fifth, contribute 8.2% and 5%. Since 2000, the French share has been falling marginally, while the relative contributions from Italy, Germany and the United Kingdom have grown very slightly, but the gap between first and fifth remains substantial.

France also has the largest military space budget in Europe, having invested an average of 400 million euros annually over the last decade. The United Kingdom (285 million euros), Germany (129 million euros) and Italy (87 million euros) came next in spending in 2006.

National Financing of Space Applications Programmes

European policy makers strongly support earth observation programmes.

Earth observation satellites are firmly inside the comfort zone of European policy makers. They have clear civilian uses, they prevent reliance on other countries for vital information and data, and they can provide work for skilled technicians in a range of companies across the continent. They also demonstrate the extent to which national programmes still provide the building blocks from which international cooperation can be constructed.

DEVELOPING EARTH OBSERVATION PROGRAMMES

Pléiades

CNES has followed the technical and commercial success of its SPOT satellite series (**S**atellite **P**our l'**O**bservation de la **T**erre) with the new Pléiades programme. This consists of a pair of satellites carrying an optical system with a ground resolution of less than one metre, meaning that objects this size or larger can identified from the data set back. The first is due for launch in 2009, with the second following 18 months later. The programme also has a dedicated ground support segment for receiving, processing, and archiving data.

The development of Pléiades demonstrates the trends towards bi-lateral cooperation and dual-use projects. Originally, France had begun studies on a successor to SPOT at the same time that the Italian Space Agency was beginning to develop the Cosmo-Skymed programme, a constellation of small radar satellites that would cover the Mediterranean. Spotting the potential synergy between optical and radar imaging, the two countries agreed to bi-lateral cooperation on complementary development of the two national programmes in 2001.

However, from the outset the Pléiades system has been conceived with a dual-use objective, marking a significant break with the SPOT series. As a result of its intelligence role, the security classification issues surrounding its development have been significant, limiting cooperation opportunities for other countries in what is decidedly a French-led project. The commercial operations of Pléiades will continue to be handled by Spot Image, the French firm set up in 1982 to commercialise the original SPOT imagery, but it remains to be seen how the dual-use aspect of the project will impact commercial users.

The four satellites in the Cosmo-Skymed constellation will be used for maritime surveillance and tracking work by the Italian defence ministry, while the system's 3-D terrain modelling system also has a duel-use function. The first satellites are already in orbit and the system is expected to be fully operational by the end of 2009.

SEOSAT

In 2006, the Spanish government authorised the SEOSAT programme (Spanish Earth Observation satellite) to be financed as a contribution to ESA's environmental monitoring effort. SEOSAT, with a ground resolution of 2.5 metres, will also have a dual-use role: the Spanish defence establishment will have access to an autonomous information collection system even as the satellite slots into existing international environmental monitoring projects. Launch is due in 2010.

SVEA

At the end of 2005, the Swedish government began to investigate the possibility of developing an earth observation system for civil and security purposes using small satellites. The goal is to allow Sweden to respond to national and international crises with high performance capabilities, as well having imagery to share with other governments. As a result, the Swedish Space Corporation, along with the private firm SAAB Space (and in collaboration with Nanospace, a subsidiary of the University of Upsalla), has initiated a dual-use satellite project called SVEA that will be available to the armed forces as well as other customers involved in crisis management situations. The SVEA programme is now waiting for the official go-ahead.

MOSAIC

In 1996, Surrey Satellite Technology Ltd (SSTL), a British firm established in 1985 by the University of Surrey, proposed an Earth observation constellation based on small, low-cost satellites that offered medium-level ground resolution. Started in 2000 with active support from the UK government, the MOSAIC programme (Micro Satellite Applications in Collaboration) allowed SSTL to develop a class of earth observation satellites designed primarily for civilian disaster monitoring work.

SSTL's first four government customers -- Algeria, Nigeria, Turkey and China -- have come together to form the Disaster Management Constellation consortium, whose members agree to devote 5% of the operational time of their national satellites to support a coordinated disaster monitoring service. A new business unit coordinated by SSTL called DMC Imaging International was formed in November 2005. Its goal is to provide rapid imagery when needed, for both commercial and humanitarian users, while adhering to the principles of the DMC consortium.

At the same time, SSTL launched a new series of satellites, DMC+4, with a ground resolution of four meters and yet still small enough to be inexpensive to launch; China and the United Kingdom were among the first customers. It also provided the satellite platforms for a five-satellite constellation being put together with Germany and Canada for agricultural monitoring. In April 2008, SSTL completed its journey from academic spin-off to the commercial big-time when EADS Astrium bought the 80% of the company that was owned by the University of Surrey. It will be interesting to see if the access to additional capital sharpens or dulls the company's reputation for innovation.

TerraSAR-X

The other significantly innovative national project is the TerraSAR-X radar satellite, which has been developed under the public-private partnership (PPP) model. DLR, the German space agency, using funds provided by the ministry responsible for education and research, provided three-quarters of the 130 million euros needed for development, construction and deployment costs, with EADS Astrium supplying the rest. The satellite, launched into polar orbit by a converted Russian ICBM in June 2007, uses radar to offer ground resolution of up to one metre regardless of weather conditions. Infoterra, a wholly owned subsidiary of Astrium, has been offering commercial access to its images since the start of 2008. This is the first commercial access to high-resolution radar images and has already proved successful with institutional and business users. A twin satellite due for launch in 2009 will fly in tandem with the first, increasing the depth of coverage available, while a second-generation satellite, TerraSAR-X-2, has already been commissioned for launch in 2012.

The innovative aspects of the TerraSAR-X project lie not only in the PPP aspect and the public access to high-resolution radar technology that had previously been the province of government agencies, but also in the effort that has been put into maximizing the commercial potential of the data produced. Infoterra has developed what it calls a

'Direct Access Service' that provides customers with their own workstation terminal through which they can order and receive data and images and then manipulate and process them to maximize the value which can be extracted. At the same time, the federal government has adopted a new piece of legislation which sets out clearly what services may be provided by non-military German satellites (and commercial satellites operated by German citizens) and a transparent process for governing the sale of high resolution data. The aim of the legislation, which came into force in December 2007 just in time to govern Infoterra's first sales, is as much to encourage the commercial market for such data as it is to safeguard the country's security interests.

Germany has produced new legislation to cover the sale of high- resolution images.

FINANCING MILITARY COMMUNICATIONS SATELLITES

The trend at the national level in Europe is clearly towards giving military space systems a commercial dimension where possible. The most progress has been made in Germany and the United Kingdom, which have been encouraging the private sector to provide operational services for which the military would be privileged customers. While not covering the most sensitive communications, the sheer amount of less sensitive data, especially video, now generated by military services deployed around the world has justified this transition.

Some countries are migrating less sensitive military communications to networks run by the private sector

Germany

Germany is buying two new SatCom BW military communications satellites that are due for launch by 2009. To do this, the government has contracted with a specially established company, Milsat Services, of which EADS Astrium owns 74.9% and ND-Satcom, the ground services division of SES, holds 25.1%. Milsat has a ten-year contract to run the project, managing construction and deployment as well as providing fixed and portable terminals and a central network management facility, with the German armed forces as its direct customer. However, as well as running the SatCom BW satellites, which will be fully compatible with NATO systems, one of the tasks for Milsat will be to run as much lower-level military communications as possible over open commercial networks, for example by using Intelsat satellites.

United Kingdom

The United Kingdom has financed the latest upgrade of its Skynet family of military communications satellites through a Private Finance Initiative (PFI) with Paradigm Secure Communications, an EADS subsidiary. Under the agreement, the system is fully dedicated to government agencies in times of crisis but, as the managing organisation, Paradigm can commercialise unused capacity for the rest of the time. The deal, concluded in 2004, has enabled Paradigm to position itself as the leading service provider for military communications satellites in the EU, and it now holds service contracts with the armed forces in Portugal and the Netherlands. The key idea underpinning the PFI is that the government customer does not own the network assets but merely contracts for access under an agreed set of rules. (This is in contrast the situation in Germany, where the government will actually take ownership of the two Satcom BW satellites once they are in orbit.) This approach need not be limited to one country, with the close ties among European allies making it possible for more than one to share a similar arrangement on a network.

Both Germany's PPP model and the UK's PFI approach are likely to be taken up for future telecommunications satellite projects in Europe. For example, the French and Italian defence ministers signed a letter of intent to go ahead with the Athena-Fidus military communications satellite project, which will provide data rates of between 2 and 3Mbps when operational in 2012. A key part of the project is that capacity will also be available to civilian agencies and commercial customers through low-cost terminals. In addition, it is less exclusive than some other French-initiated projects, and Belgium is already interested in participating.

The European Space Agency and Multinational Space Policy

ESA has managed to retain an identity and membership distinct from that of the EU.

Created in 1975 and completing parliamentary ratification by its member countries in 1980, ESA has managed to retain a multi-national structure (now up to 17 member states) that is distinct from membership in the European Union. States that belong to ESA need not be part of the EU (allowing in Norway, for example) while members of the EU need not belong to ESA -- although several of the newer EU countries, such as Slovenia, would like to join but face a long qualification period. While its members are keen to protect this independent status, it does create a situation in which ESA's policy and programmes have to coexist alongside national and EU-sponsored space activities.

Two key organisational aspects have kept ESA popular with its members.

1. Optional and compulsory programmes.

Member states make contributions to ESA in relation to the size of their GDP. Only about 25% of the agency's projects and activities require all members to take part and they are usually ones devoted to scientific and research work, where every member has institutes capable of contributing. With the exception of about 5% devoted to work for countries outside Europe, the remaining 70% of activities are optional. These include the large applications programmes, work related to the ISS, and development of the Ariane family. This system provides sufficient flexibility to maintain a collective interest in the agency among its members, as it allows the five largest contributors -- France, Germany, Italy, the UK and Spain, who between them contribute most of ESA's budget (2.9 billion euros in 2006) -- to work at their own pace without being held back by other members who might feel that they were supporting projects from which they derived little direct benefit.

2. The 'just return' principle.
This principle guarantees that each ESA member state will benefit from an 'industrial return' in proportion to the level of their national contribution. This return takes the form of contracts for work to be done in that country. Although often criticised for inducing some rigidity in the functioning of the agency and encouraging some degree of duplication of industrial capabilities in Europe, this principle has also guaranteed a sustained interest for space from smaller countries with emerging space industry capabilities. It has also led to national specialisations that have helped to strengthen the commercial competitiveness of Europe as a whole.

ESA today continues to cooperate with its partners in the ISS and conducts a sophisticated programme of robotic planetary exploration both on its own and in cooperation with the United States and Russia. It also co-manages two important 'flagship' application programmes, GMES and Galileo, which are discussed below. However, it does not look likely to be a major global player in the specific development of new commercial application programmes and the sale of related services over the next decade. That role seems mostly likely to be played by the EU itself.

The EU will have a larger role in developing commercial applications programmes over the next decade.

The European Commission as a New Space Actor

The EU, through the European Commission (EC), has come relatively late to a major interest in space activities. For several decades, these were largely regarded as part of Europe's R&D work. As a result, the main budget instrument used by the EC has been the successive five-year framework programmes for supporting R&D work. In this respect, it is interesting to see the continuous annual increase in spending on space technology and operations research since the start of the Fifth Framework in 1997. From only a few million euros in 1997, the space research budget has risen to more than 200 millions annually, a level guaranteed by the Seventh Framework programme until 2013. A developing recognition of the ability of space-related operations to contribute to the security of Europe's citizens in the face of natural disasters and malicious intent has played a large part in this increase.

Besides the research framework, the Directorate Generals (DG) within the EC (similar to cabinet-level departments in the US federal system) also have an interest in space, notably the DG responsible for energy and transport and the DG with responsibility for the environment. These DGs have supplied funds from their own budgets to support Europe's two flagship projects, GMES and Galileo, which the EU is co-financing with ESA.

GLOBAL MONITORING FOR ENVIRONMENT AND SECURITY (GMES)

The GMES project was first broached by national space agencies and the EC as far back as 1998, when they acknowledged a shared need for a European space monitoring capability. Since then, the scope of the project has expanded to include the development of useful space-based monitoring techniques for civil security, including missions dealing with operational forecasting, hazards mitigation, damage assessment and rescue operations, as well as agricultural issues, food-provision concerns and health-related issues. Beyond the humanitarian dimension, GMES is expected to have a more direct security role, contributing in particular to the verification of some arms control treaties, for example those related to chemical weapons.

GMES has been run by the EC as a three-stage programme, with the initial period from 2001 to 2003 followed by a 'capacity build-up' period lasting until 2009, when the first part of the five-satellite constellation is due to become operational. An executive group drawn from interested (and supporting) DGs within the EC has day-to-day responsibility for the project, with the national space agencies and ESA represented on a relatively low-profile advisory council. The financing for the core services that GMES will provide, i.e. the primary services that are of public interest, is coming completely from public funds via the budgets of national space agencies and the Sixth and Seventh Frameworks for research work administered by the EC.

The private sector role lies in working with downstream

The EC will have primary responsibility for maintaining the GMES system once it is operational. However, there is an expectation that the private sector will be invited to participate once the system is fully deployed. Its likely role will be in furnishing downstream services that can be easily categorised by locality or issue. This definition of downstream services implies, of course, the existence of a user/customer base that is ready to pay for such services. Several market studies are underway to assess potential business cases in a range of areas from maritime/coastal monitoring and surveillance to urban planning, and environment monitoring and protection-related activities and services. At present, with few detailed results available, the EC remains optimistic that demand will be substantial enough to attract serious private sector involvement.

This enthusiasm underlines a notable aspect of GMAS. Although its deployment is publicly funded, cost-effectiveness is being given equal attention alongside technological development. The subsequent involvement of the private sector is both dependent on a streamlined project in which costs are closely controlled, and also symptomatic of the need for public sector involvement to offset operational costs to some degree as soon as is practical. In other words, while the project could not exist without public financing, this should no longer be equated with bloated budgets and costly overruns that result from prioritising national political interests over fiscal prudence. The commercial requirements now inherent at the user end of data and imagery programmes are increasingly feeding back into tighter controls and project management at the development and deployment stages.

THE GALILEO SATELLITE NAVIGATION SYSTEM

Galileo was always intended to be a public-private partnership.

The Galileo programme is a joint initiative undertaken by ESA and the EC to create Europe's own satellite navigation and positioning system. Galileo is the largest industrial project ever organised on a European scale, the first piece of infrastructure entirely owned by the EU, and was also intended to be a shining example of the PPP model in large-scale action. Indeed, private sector participation was originally considered the *sine qua non* of the project.

A study for the EC completed at the end of 2001 by outside experts clearly suggested that allowing the private sector to charge user fees, along the lines of the toll model already deployed in Europe for some transport infrastructure, was the appropriate solution for making possible the deployment and operation of the Galileo system. The study identified a range of markets for Galileo and estimated that the system would generate revenues for the operator that would rise from a minimum of 66 million euros in 2010 to 500 million in 2020.

However, instead of being overwhelmed by bidders ready to compete for the concession to build and operate Galileo, when it called for tenders in 2003 the EC found that the main European space companies had formed a single consortium that was less than enthusiastic about the financing approach. Negotiations took longer than expected, with the consortium worried that the requirement to offer a basic service for free, when the US GPS system already offered an extensive free service, would limit the scope for collecting fees, while national governments contested issues such as the location of the main ground control centre. The consortium was already worried when it signed a contract at the start of 2006 to produce four initial satellites, and subsequently chose not to proceed further on the grounds that the project could not be profitable enough to justify the investment.

Having already spent 1.5 billion euros, the EC had little choice but to pledge a further 2 billion euros to provide the full financing of the 30-satellite constellation, which it did late in 2007. Given the importance of the project to Europe's aerospace sector, this was not at all unexpected. However, it was somewhat surprising that there was so little protest at the fact that the leading companies would now get the same amount of work without having to put up the majority of project financing, as had been required in the original Galileo proposal.

Although the development and deployment phase of Galileo is now the full responsibility of the EC, the operating phase of the programme still needs to be defined not only in terms of funding but also in terms of management, especially in consideration of the dual-use nature of the data that it can provide. The national examples discussed above suggest that a private sector role in operating Galileo should be possible, albeit under a fixed contract system rather than relying wholly on user fees. At the same time as that debate takes place, the reasons why the EC now finds itself in this position with regard to Galileo, and what this may mean for the relationship between public and private financing of other major space projects, will have implications for how the European approach to the space economy develops over the next decade.

Japan

A country whose geography makes it a natural user of space-based services, Japan pursued a government-assisted effort to develop applications satellites until the programme was halted by a trade dispute with the United States. After an unsuccessful experience with the public-private partnership model, the Basic Law for Space Activities of 2008 has restored a greater role for public investment.

Developing a Catch-up Strategy

Space research work began in Japan's universities as early as the mid-1950s and by the 1960s there was already interest from the country's aerospace sector in developing space technology that could be applied to commercial activities. This led the government to establish the National Space Development Agency (NASDA) in 1969. One of its prime aims was to facilitate the introduction of US-originated technology into Japanese space applications programmes in order to shorten the time needed to reach global technological standards, and so hasten Japan's entry into the commercial market.

The country's first series of launch vehicles, based on the US Thor-Delta design, enjoyed a 100% success rate. For application satellites, NASDA worked in partnership with NTT on developing telecommunication satellites (the CS series) and with broadcaster NHK on broadcasting satellites (the BS series), as well as with the National Meteorological Agency on the GMS series of weather satellites.

This blend of domestic industry, overseas technology and user input proved very successful in the 1970s and 1980s.

- It improved the country's technological base. The Japanese space industry enjoyed considerable support from US companies as its satellite sector was being developed but NASDA was careful to channel increasing resources into developing domestic technologies.

- The incremental approach provided a steady introduction of services. Although Japan is relatively small compared to other space-faring countries, its mountainous landscape and over 6,000 inhabited islands offered a profitable base for operators of satellite-based communications, broadcasting and meteorological services.

- With a demand for services and supported by government-sponsored contracts, the space industry enjoyed steady increases in both its revenues and its technical expertise. NASDA was able to coordinate a system whereby contracts were distributed between the country's three satellite companies, Mitsubishi Electric (Melco), NEC, and Toshiba. The role of prime contractor rotated between them on a project-by-project basis so that each would be able to gain a full range of experience.

IMPACT OF US RRADE ROW

As relations between the US and Japan worsened amid tensions over trade policies, NASDA's strategy ran into serious difficulties in the late 1980s. The Reagan and Bush administrations asserted that Japan unfairly protected its industry through opaque public procurement protocols, regulations, and business customs, so making it difficult for US companies to penetrate the Japanese market. There were particular complaints about consumer electronics and supercomputers, as well as car sales. To avert American threats to invoke unilateral sanctions against Japan under Article 301 of the US Trade Act, in 1990 the Japanese government agreed, among other measures, to open up the public procurement process for all types of satellites, other than those built purely for R&D missions, to international bidders.

By forcing Japan to open up its space market, the US helped service providers but hurt manufacturers.

This agreement had an extremely damaging impact on the Japanese satellite industry, which was much less competitive than US companies whose 'off the shelf' models enjoyed economies of scale. Unsurprisingly, in the following years almost all of the non-R&D satellites bought by both public sector and commercial operators came from US manufacturers. However, the companies affected remained quiet and uncomplaining, largely because all three of them were keen to continue their sales of consumer electronics and supercomputers in the US market.

NASDA was now left to focus purely on R&D satellites, the only area in which it could place non-competitive contracts with Japanese companies. At the same time, the industry was content to scale back its efforts, having concluded that the space business was no longer commercially profitable. Both sides accepted that the country's initial strategy of improving its technological competitiveness through developing application satellites was no longer an option.

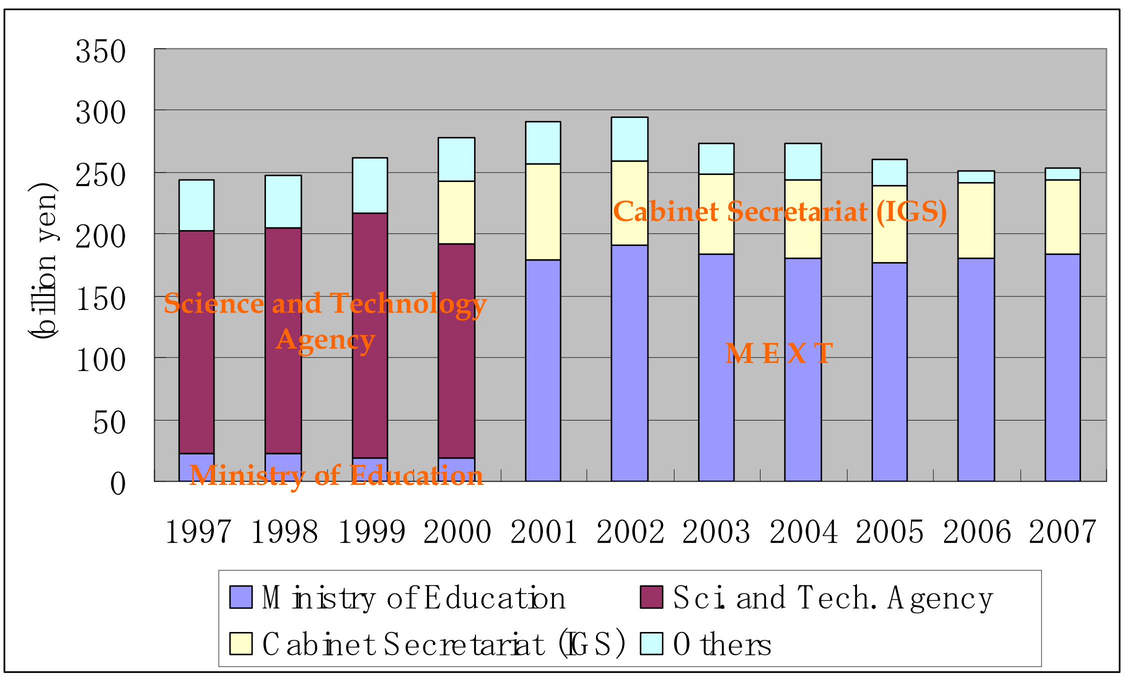
Administrative Reform and Budgetary Constraints

The agreement with the United States was not the only factor to change Japanese space strategy in the 1990s. The other major problem was a bureaucratic reorganisation begun in the wake of a severe budget deficit that had almost left the government bankrupt. In 1996, Prime Minister Ryutaro Hashimoto began to rationalise government ministries in an attempt to reduce the number of civil servants. Implementing the reforms took more than five years due to strong opposition in the bureaucracy, but as a part of the process the Ministry of Education merged with the Science and Technology Agency to create a new Ministry of Education, Culture, Sports, Science and Technology (MEXT).

The reorganisation also affected smaller agencies, including NASDA and the separate Institute of Space and Astronautical Sciences (ISAS), which had responsibility for funding space science work. Amid a rush to greater efficiency, having two space agencies was considered unnecessary and NASDA and ISAS were merged into the Japan Aerospace Exploration Agency (JAXA), which became operational in 2003. As its name implies, the emphasis of the new agency was on research and exploration rather than applications programmes.

At the same time that JAXA came into existence, Japan's space budget began to fall off from its peak in 2002. Although the space budget of MEXT, which funds JAXA, has remained relatively constant since then at some 180 billion yen (about 1.08 billion euros), the overall trend is in decline.

JAPANESE SPACE BUDGET 1997-2007



Source: Society of Japan Aerospace Companies

By this time, the lack of funding was less the result of budgetary constraints than of a reduced political interest in space. There were many greater demands on the government's attention, including deployment of Self-Defence Forces to Iraq, overhauling the country's pension system, and the postal service reform. In addition, there were three high profile space failures in 2003: the ADEOS-2 earth observation satellite, which stopped working after less than a year in orbit, the Planet-B spacecraft which failed to go into orbit around Mars, and the H-2A launch vehicle that had to be destroyed during launch with the loss of two expensive government intelligence satellites. As a result, the Japanese government began to question whether its funds for space development were being used efficiently, and drew the convenient conclusion that NASDA and now JAXA had been over-funded rather than under-funded.

Trying the Public Private Partnership Model

The reduction in government spending after 2002 forced a private sector response.

Although it had earlier accepted the need to open up the satellite market to US firms, the Japanese aerospace sector was alarmed by this downturn in government spending, which was now its leading source of space-related work. The leading companies realised that they would have to take the initiative if they wanted to compete in the global space market.

QUASI-ZENITH SATELLITE SYSTEM (QZSS)

In this context, the private sector proposed the Quasi-Zenith Satellite System (QZSS). This constellation would always have one satellite in place close to the zenith over Japan and so be able to serve customers in cars, built-up urban areas or mountainous countryside who would otherwise experience poor service when using mobile broadband networks. It would also offer a great improvement in the accuracy of positioning and navigation services. The programme was first discussed at the start of the decade among space manufacturers in the Society of Japanese Aerospace Companies, which then lobbied MEXT, the Ministry of Economics, Trade and Industry (METI) and other government bodies for support. However, the government response was that the constraints of the 1990 agreement with the United States still prevented it from directly supporting the development of such a venture.

This led the industry to explore a public-private partnership (PPP) model under which the private sector would develop, build and operate the satellite system, with the government simply taking the role of customer, albeit a customer with whom a large, long-term contact was agreed in advance. The fees paid by the government would be sufficient to cover the cost of deploying and running the system, and the operator would be free to generate profits by selling other satellite services to a range of private sector customers.

Although this sounded a simple solution to an essentially legal problem of defining the nature of government involvement, in fact it proved unsustainable. In a surprisingly similar outcome to that of Europe's Galileo, Advanced Space Business Corporation (ASBC), the industry group including Melco and NEC Toshiba Space Business Corporation that had initially attempted to develop QZSS under the PPP model, finally handed the project back to the government in early 2006. It is now considered an engineering test programme under the responsibility of MEXT.

There were two main reasons for the inability to make the PPP work in this case.

Ministries failing to commit support

Although the industry successfully persuaded the government to approve the programme, there was no coherent strategic mechanism for coordinating and securing support from the four individual ministries expected to provide funding. In 2004, ASBC needed the ministries to commit to making use of the system once it became operational before it began spending its own resources on development work. But the ministries could not agree on how to apportion usage and costs between themselves. There were two sets of problems. The lesser was that, although all four ministries were generally in favour of the programme, they argued that it was difficult to justify spending public money for a programme initiated by the private sector. The two main customers for QZSS services, the Ministry of Land, Infrastructure, and Transport (MLIT) and the Ministry of Internal Affairs and Communications (MIC), also argued that their budgets were under too much pressure to commit funds going forward.

The QZSS project failed as a public-private partnership because of a lack of bureaucratic coordination and political support.

More importantly, there were deeper divisions between the four, with little means of mediating between them. Being responsible for technological and developmental issues, MEXT was willing to offer considerable support for developing the project, while METI was also a strong supporter, although able to offer only a limited financial contribution. MIC was prepared to support only the development of communications-related aspects of the system. Crucially, MLIT, which was expected to the major government user of QZSS, had been extremely sceptical about space since an H-2 launcher carrying the ministry's expensive Multi-functional Transportation Satellite failed in 1998. As a result, MLIT took a very strong position that it would not financially commit until the programme was fully operative.

Although the idea of the government only playing the role of customer is the ideal of the PPP model, the service supplier usually needs a commitment from its customer that it will purchases services from the completed system. In the absence of such a clear commitment, ASBC chose not to proceed.

Insufficient political support

The possibility that the ministries might be reluctant to make long-term commitments had been carefully considered by the aerospace sector, but there was an expectation that the industry's long-standing friends in the ruling Liberal Democratic Party (LDP) would bring them into line. To be sure, ASBC lobbied the LDP very hard to coordinate the different ministries, and indeed a cabinet committee was formed, unsuccessfully, to do just that. However, the Ministry of Finance, with fresh memories of the recent budget deficit, refused to give the MLIT the money it said was needed before it could guarantee its role on QZSS. In this instance, politicians were not able to contradict the advice of their leading civil servants and their own espoused principle of fiscal discipline in order to increase spending for QZSS.

This 'failure' meant the end of QZSS as a PPP project. The Diet was not able to increase ministry budgets for QZSS, forcing the private sector to give up a business plan that depended on government taking an 'anchor tenancy'. However, having stated its enthusiastic support for the project, whose preliminary stages had already received some support from MEXT, it would have been difficult for the government to terminate the programme as a whole. Thus, QZSS will be continued as smaller R&D programme to 'verify' the technology that has been developed during the last couple of years, but it will not be used to provide the services to government that were originally expected.

GALAXY EXPRESS (GX)

At the same time that QZSS was struggling, a private sector launch vehicle project started by Ishikawajima-Harima Heavy Industry (IHI) was also in trouble. IHI had been alarmed by the merger of ISAS and NASDA because the scientific agency had been the only customer for the relatively small M-5 launcher, for which IHI was the prime contractor. Although sales of the M-5 were, inevitably, very low, it was important to IHI to maintain its capability to assemble a complex launch system. Thus, IHI proposed a new medium-class launch vehicle project, Galaxy Express (GX), which would continue to utilise its expertise in system engineering for launcher construction. Realising that this slice of the launch market is now quite small, IHI invited Lockheed Martin to be a major shareholder and technology

A bureaucratic power play also damaged the commercial prospects of a PPP launch vehicle project.

partner in the new enterprise in the hope of gaining access to the American market, where NASA's long-time medium launch vehicle of choice was being phased out.

IHI was able to secure existing Lockheed Martin hardware for the GX first stage, thereby reducing costs in an effort to remain commercially competitive. However, it then learned that the government would only play a role if the project were to be integrated with a new programme at JAXA to develop the world's first rocket engine to use liquid natural gas (LNG) as a fuel. This was a straightforward power play. The launch vehicle researchers and engineers at JAXA were about to loose their only project with the transfer of responsibility for the H-2A heavy lift vehicle to Mitsubishi Heavy Industry. Without the H-2A, these JAXA employees had no other programme to work on and their job security was in danger. IHI had little choice but to link the GX to progress on the new engine, which was more than three times over budget and two years late by the end of 2006. This effectively ended the GX as a commercial proposition, marking the demise of another attempt at a public-private partnership.

The Basic Law for Space Activities 2008

One consequence of the untimely ending of the commercial hopes of the QZSS and GX projects has been a shared frustration between industry leaders and politicians at the extent to which bureaucrats were taking major decisions affecting space policy. The two sides found an opportunity to make common cause in the use of space for security purposes. This had become a high-profile issue since North Korea fired a ballistic missile over Japanese territory in 1998, an act that spurred the government to develop two pairs of reconnaissance satellites known in Japan as Information Gathering Satellites. (The second IGS pair were the satellites destroyed in the H-2A launch failure in 2003.)

Japan has been rethinking its policy on the 'non-military' use of space.

It had taken the unheralded missile over-flight to prompt Japan to make its first move into the security aspects of space technology. In 1969, in what was essentially a pre-emptive move, a Diet resolution stated that all Japan's space activities should be conducted for exclusively peaceful purposes, which was widely interpreted as meaning the 'non-military' use of space. Because of this resolution, Japan's defence authority was not able to develop, own or operate space systems, being limited to the use of commercial space assets or public assets that did not exceed commercially available specifications. This policy also applied to the IGS series of satellites, which are operated out of the cabinet office and were limited in capacity to a resolution of one metre, the highest commercially available.

In 2005, a sense of grievance over the fate of QZSS and concern over the limitation placed on IGS led the LDP to establish a study group on the legal and political issues surrounding Japanese space activities. This duly identified a key problem as being the sizable role played by bureaucrats rather than politicians in determining space policy. The study group issued a report in 2006 that urged new legislation that would create a ministerial post with responsibility for space, establish a new government forum for space-using ministries, and change the interpretation of the 1969 Diet resolution. The report was widely accepted not only within the LDP but also by its coalition partner, Komeito, and the largest opposition party, the Democratic Party of Japan (DPJ). In 2007, the coalition government submitted a draft bill for a Basic Law for Space Activities to the Diet, which was passed in May 2008.

THREE KEY ELEMENTS

The Basic Law has three key elements.

Organisational structure

The legislation sets up a new decision-making structure for space. It starts by creating the post of minister for space and establishing a forum of user ministries, the Space Development Strategy Headquarters, that will also feature input from industry and academia. It will have significant authority over spending. The minister for space will not be in charge of a department as such but will instead be based in the cabinet office and coordinate the space-related activities in different ministries. The forum will be the final decision-making body for the allocation of budgets, having negotiated with the Ministry of Finance on behalf of the user ministries.

Military option

The 2008 Act states that space development in Japan shall follow the Outer Space Treaty and other international agreements and "be conducted on the basis of the concept of pacifism in the Constitution." This indicates that the traditional interpretation of the 1969 phrase 'exclusively peaceful purpose' as meaning 'non-military' need no longer apply. Since 1992, Japan has loosened its restriction on sending its Self-Defence Force overseas in support of UN peacekeeping operations and disaster relief operations. Deployment across the world requires extensive space infrastructure, but the military was severally limited to its use of space-based assets under the 1969 Diet resolution. The new Basic Law now gives the military authorisation to become directly involved in the development, procurement and operation of space systems.

The military can now participate in the development, procurement and operation of space systems.

Strengthening competitiveness

The Basic Law also urges the government and industry to work together to step up efforts to strengthen industrial capabilities and autonomous business competence in the space sector. For the first time in space-related legislation in Japan, the concept of promoting 'competitiveness' appears explicitly in Article 4 of the Basic Law. Moreover, Article 16 directs the government to "take into account procurement items and services from private entities and the efficiency of using private entities' capability for progressing private space business activities." This statement is specifically designed to provide the legal foundation for the government to play its part in the public- private partnership approach to developing space capabilities.

The 2008 Basic Law should increase use of the public-private partnership model.

Anticipating passage of the Basic Law, JAXA is already altering its R&D-oriented approach and is looking to provide Japan's space industry with more opportunities to strengthen its competitiveness in developing application satellites. User ministries, including MLIT, MIC, the Ministry of Foreign Affairs and now the defence ministry, are launching pilot projects for using space infrastructures for improving government services. As a result of the legislation, which comes into effect in 2009, more programmes for space applications work developed under the PPP model can be expected.

Shifting Demand for Space-Based Services

Japan's island geography and mountainous terrain led NASDA to begin its application work with communications and broadcasting satellites. However, it did so in the 1970s and 1980s, when terrestrial networks were not highly developed. Given the subsequent rollout of fibre optic and multi-channel cable TV networks, the demand for commercial satellite-based communications services within Japan is falling.

In terms of remote sensing satellites, there is still consistent demand for meteorological data, as weather-related concerns are deeply engrained in everyday life, but the demand for space-based imagery has not yet grown much beyond researchers in the natural sciences who work on environmental change and land use. This is partly because NASDA/JAXA has been constrained from providing images to commercial customers under the terms of the 1990 agreement with the United States. While there are several commercial imagery providers such as Japan Spaceimaging, their main customer is the defence ministry.

However, the Basic Law for Space Activities may turn this situation around. The ministerial forum that will manage space-related government spending can now make some of the money that MEXT had previously channelled into JAXA available to other ministries to increase their budget for purchasing space-based services. In addition, local administrations at the prefectural and municipal levels are increasing their use of space-based services. For example, the Prefecture of Iwate, in the north of the country, is using space imagery to track illegal waste-dumpers because this turns out to be much cheaper than CCTV monitoring or aerial photography. Many local governments are facing financial constraints and would be happy to use space-based services if they can reduce costs.

Will Japan be a Leading Space Power in the Next Decade?

China's successful use of space applications work in regional diplomacy has also renewed Japan's political interest in space.

One of the motivations for LDP politicians to strengthen and broaden Japan's ability to operate in space has been the development of the Chinese space programme. Although impressed by the technology inherent in China's manned activities, the real concern has been China's use of space in its relations with other Asian countries. In 2005, the Chinese government completed its establishment of the Asia-Pacific Space Cooperation Organization (APSCO), having already set up an organisation for Asia-Pacific Multilateral Cooperation in Space Technology and Applications (AP-MCSTA) in the 1990s for developing small satellite technology and user-oriented applications. Both have attracted a great deal of attention from developing countries in the region, with AP-MCSTA now having 13 members.

For many years, Japan was the regional space leader, having established the Asia-Pacific Regional Space Agency Forum (APRSAF) in 1993. However, APRSAF focuses only on technical issues between national space agencies, with no coordination of space strategy or policy on a regional basis. Recently, and in the light of China's success with its own organisations, there has been dissatisfaction within the LDP that APRSAF was not supporting the key needs of developing countries for the transfer of technology and the chance to work together on hardware development. However, this leadership role may prove difficult to win back.

BUDGET CONSTRAINTS

Despite the new range of possibilities that it introduces, it is unlikely that the Japanese space budget will increase markedly as a result of the Basic Law. The financial constraints on the government remain considerable, even as it faces demands for greater spending on health and pensions as a result of the country's aging population. It would be very difficult to justify a sizeable increase in the space budget at present, even given the new political commitment to use space for strategic purposes.

Any significant increase is also made harder by Japan's experience with the International Space Station (ISS). Although a faithful partner with the United States from the beginning, Japan found itself pushed aside when the decision was made to bring Russia into the project and its subsequent experience was of constantly finding the station redesigned and its role redefined with little or no consultation. Only in May 2008 was Kibo, the science module built by Japan for the ISS, finally attached to the station, two decades after work on it began. Although JAXA is still hoping to be involved in international projects that continue the exploration of the moon and Mars, Japanese spending is likely to be concentrated on research and applications work in the coming years.

Since the definition of a global space power is still linked so closely to the size of a government's space budget, it seems unlikely that over the next few years Japan will be regarded as a leading global space player who shapes international regimes and pioneers new technologies. However, Japan will continue to invest in space with the aim of improving its industrial competitiveness and this will increasingly make it a commercial force to be reckoned with.

India

India's approach to space has not been defined by military competition, national prestige or a desire to stimulate scientific and technological development. Instead, Indian space policy has primarily been driven by the need for an applications programme that would contribute to improving socio-economic conditions in the country.

Setting Indian Space Policy

A key to understanding India's attitude towards space activity lies in the role of Vikram Sarabhai, who established the Indian Space Research Organisation (ISRO) in 1972. To a degree unique to India, Sarabhai is regarded not only as the father of its space programme but also the spiritual leader of the Indian space community for his explicit linkage of space research to the needs of the country. A key quote of his, now prominently displayed on the ISRO website, is still widely cited by Indian space scientists, engineers and policy-makers.

> "There are some who question the relevance of space activities in a developing nation. To us, there is no ambiguity of purpose. We do not have the fantasy of competing with the economically advanced nations in the exploration of the moon or the planets or manned spaceflight. But we are convinced that if we are to play a meaningful role nationally, and in the community of nations, we must be second to none in the application of advanced technologies to the real problems of man and society. "

The first ISRO Director, Satish Dhawan, entrenched the primacy of civilian applications work. Although a specialist in launch vehicle technology, clearly a dual-use area, he strongly rejected military intervention in space activities. His stance influenced a string of subsequent ISRO Directors that included Abdul Kalam, later to become the President of India. The strength of the mentor-student relationship within the Indian space community has enabled the handing down of the founding concept, with no loss of intensity over the decades, that the space programme should be driven by domestic needs rather than international competition, either civil or military.

Since 1979, ISRO has launched two main series of satellites.

- There are now three generations in the INSAT (Indian National Satellite) series. Their prime task is to send broadcast signals to more than 1,100 transmitters that provide the country's terrestrial television broadcast system. They also link radio networks together, provide voice and data communications for business, and support tele-medicine services. In addition, they are an integral part of the country's emergency response network, gathering meteorological data, relaying cyclone warnings, and providing emergency communications support during disasters.

- India has already flown ten IRS (Indian Remote Sensing) satellites for Earth observation. Data and imagery from the IRS satellites are used for determining the availability of ground water, monitoring agricultural crops and advising coastal fishermen on promising zones for fishing, as well as urban planning, rural development, and land management programmes.

- In addition, ISRO operates two Cartosat satellites for mapping work and Edusat, designed for educational broadcasting, launched in 2004.

At the same time, it has developed the Satellite Launch Vehicle (SLV) family to orbit these satellites. The two most important members are:

- the Polar Satellite Launch Vehicle (PSLV), which can carry sizable earth resources satellites into the polar orbits from which they are most effective, and

- the Geosynchronous Satellite Launch Vehicle (GSLV) which uses a new cryogenic third stage, produced indigenously as a result of export restrictions on Indian access to US technology, to carry satellites up to 2.5 tons to the main orbit used by communications satellites.

Administratively, the ISRO is supervised by the Department of Space. The existence of a government department exclusively dedicated to space means that ISRO does not initiate its own programmes but carries out an agenda set by the department, which formulates space policy in conjunction with ministries that use space-based services. The result is a space agency that, both by inclination and by political design, is heavily focused on space applications work.

India is heavily focused on space applications work by inclination and political design.

Unique Industrial Structure

Unlike other major spacefaring nations, India has not developed a wide industrial base for space activities. Most industrial contracts go to companies with an effective monopoly on competence in a particular technology. For example, Hindustan Aeronautics is the major ISRO contractor for the manufacture and assembly of satellites and launch vehicles, while Sarat Electronics holds the same position for satellite communications equipment. These companies heavily depend on government contracts rather than private sector work. In fact, the central role played by ISRO in providing space-based services means that there is very little commercial space activity in the Indian aerospace sector. Instead, the industrial structure is largely based on a monopoly-monopsony relationship.

MAJOR SPACE INDUSTRY PLAYERS IN INDIA

Companies	Main Activities
Hindustan Aeronautics.	Manufacture & assembly of advanced components and structures for India's satellites and Satellite Launch Vehicle (SLV) family
Bharat Electronics	Telemetry systems, S-band transmitters, C-band transponders, and other satellite communication equipment including receivers, uplink stations and terminals
Anup Engineering	Current projects, include producing structures for the PSLV and GSLV vehicles, INSAT, IRS
Hyderabad Batteries	Contractor & manufacturer for space-qualified nickel cadmium cells and silver zinc batteries for SLV
Electronics Corporation of India	Satellite earth station equipment & antennas, real time computer systems, S-band direct reception system for satellite television
Helios Antennas & Electronics	Satellite antenna systems
Karthik Engineering	Satellite ground station antennas manufacturing
Prabhakar Products	Satellite ground station antennas for Edusat system, communications antennas for ISRO

Source: http://www.bharat-rakshak.com/SPACE/space-industry.html

While India takes space seriously, government spending is not extensive in global terms because the cost of labour and materials for domestically built equipment is relatively low. However, the budget for the ISRO has been rising significantly in recent years -- up 24% in 2004-05, and 35% in 2006-07 – to reach 40 billion rupees (just under one billion US dollars) in 2008-09. The increases are largely to fund a new generation of communications satellites together with an upgraded launch vehicle (the GSLV III) and development of India's first lunar probe, Chandrayaan-1. In total, ISRO now directly employs about 16,000 people at its research centres and launch sites.

THE ROLE OF ANTRIX CORPORATION

In 1992, ISRO and the Department of Space set up a commercial arm, Antrix Corporation, with the aim of selling space services to foreign customers. These include launching satellites, supplying data and imagery, and leasing transponders on INSAT satellites. After a slow start, Antrix has made some progress in imagery sales and transponder leasing, as well as arranging for microsatellites and nanosatellites from a range of countries to piggyback on SLA flights. A major breakthrough came in 2007 with the dedicated launch of an Italian astronomy satellite by a PSLV, followed by another dedicated commercial PSLV launch carrying an Israeli radar satellite in early 2008.

As Antrix is owned by the Department of Space, less information is available about its revenues and intentions than would usually be the case for a commercial company. However, it would apparently like to win between two and three commercial launches a year using the PSLV and GSLV. The main selling points will be low cost and proven reliability, although one of the reasons that Antrix is only now making progress with commercial launches is that the GSLV, which will handle the lucrative heavy launches to geostationary orbit, is still establishing a sustained track record. At present, the returns from Antrix are still relatively small but, if the marketing is effective and production can keep pace with demand from the Indian government as well as foreign clients, the GSLV has the potential to prove a significant player in the global launch market.

In European terms, Antrix acts as a combination of Arianespace and Spot Image. However, the crucial difference is that the European commercial space-based service companies were established to provide opportunities for hardware manufacturers to develop and advance their technological skills and thus strengthen their industrial capability. By contrast, Antrix is essentially a sideline of the Indian government space programme, selling services already developed and deployed by ISRO and the Department of Space. In other words, its products are heavily subsidised.

Government efforts to market space services have so far been limited but could raise trade issues if, as appears possible, they are stepped up.

As long as Indian commercial activities are not disrupting global markets and impinging upon the commercial interests of other countries, they will not raise serious competitive issues. At present, this remains the case. India is not seriously targeting the global commercial satellite-based services market through Antrix because the primary objective of its space activities is still focused on socio-economic development. However, were Antrix to step up its efforts there are likely to be repercussions that could have some echoes of the Japanese experience at the end of the 1980s.

Although India has concentrated on developing space applications for its domestic requirements, other countries in the region have similar needs. Afghanistan, Bangladesh, Bhutan, Maldives, Nepal, Pakistan and Sri Lanka face similar socio-economic problems. Although there is no dedicated regional institution through which India can formalise its lead in space technology, ISRO and the Indian government take full advantage of the opportunities provided by space-based data and infrastructure to offer leadership in managing various issues across South Asia. These include:

- improving food security through water management, drought mitigation, crop monitoring and fisheries forecasting;
- developing infrastructure through transport analysis, land use mapping, and VSAT communications networks;
- bridging inequalities in access to services though tele-medicine and tele-education services;
- coordinating regional disaster management and response efforts though cyclone warnings, flood damage assessments, and landslide zoning; and
- monitoring environmental change in forests, coastal zones, mining sites, urban sprawl and atmospheric pollution.

Linking space with leadership in South Asia.

Providing services in these areas on a government-to-government basis -- especially as climate change becomes a very real issue in South Asia -- offers useful political benefits and a boost to India’s role in the region.

Economic Benefits from Space Activities

Having invested so much in space applications, India has endeavoured to keep track of the resulting benefits.

Public broadcasting

Satellites have increased the area of the country able to receive India’s public broadcasting service from 14% in 1983 to 78% in 2005, with the population coverage growing from 26% to 90% in that time.[8] The capital cost and annual operating expenses of running all government

[8] K. Kasturirangan, "India's Space Enterprise: A Case Study in Strategic Thinking and Planning", Deliberation at Australian National University, 2006 http://rspas.anu.edu.au/papers/narayanan/2006oration.pdf

broadcast services through terrestrial technology would be some seven times greater than the current equivalent costs for the satellite-based approach. This estimate, albeit coming from a leading figure in the Indian space community, illustrates that space-based broadcasting has a huge advantage over terrestrial service for countries like India with a large surface area. That increase in coverage also raises demand for consumer electronics, starting with radio and television receivers.

Telecommunications

India's geography also favours the use of communications satellites, which can provide considerable saving over the use of fibre optics. The cost of connecting 393 remote areas, currently served by INSAT, by fibre optic cable would be more than twice the comparable costs for satellite technology. Space-based connections with islands in the Indian Ocean have integrated them with the mainland and helped to boost trade and tourism.

Weather services

Meteorological services provided by the INSAT system have had a significant impact. A comparative study of cyclones that hit Andhra Pradesh in 1977 (before INSAT) and 1990 (after INSAT), shows that, even though the two cyclones were similar in scale, tracking the 1990 cyclone through INSAT imaging and the success of preparatory steps taken by the government meant that only 817 lives were lost compared with 10,000 in 1977. Such results have helped to sustain both political and popular support for space spending.

Remote sensing

Direct and indirect benefits from remote sensing activities can be summarised as follows:

DIRECT RETURNS IN MILLION RUPEES (AND US DOLLARS)

Returns from sale of Satellite Data and Value Added Products by NDC	**1,600 (32 million)**
Returns from ANTRIX through access fees and royalty	600 (12 million)
Opportunity cost (Cost of foreign satellite data equivalent to IRS data used)	~ 5,000 (100 million)
Cost saving due to value addition	~ 12,000 (240 million)
Cost saving due to mapping using RS data	~ 11,000 (220 million)

INDIRECT BENEFITS IN MILLION RUPEES (US DOLLARS)

Programme	Nature of Benefit	Potential Long-term Benefit
National Drinking Water Technology Mission	Cost saving due to increased success rate	5,000-8,000 (100-160 million)
Urban Area Perspective/ Development/Amenities Plan for Cities	Cost saving in mapping	16,000-20,000 (320-400 million)
Forest Working Plan	Cost saving in mapping	11,860 (237.2 million)
Potential Fishing Zone Advisories	Cost saving due to fewer trips to places not recommended by PFZ advisories	16,350 (327 million)
Wasteland Mapping: Solid Land Reclamation	Productivity gain	24,690 (493.8 million)
Integrated Mission for Sustainable Development: Horticultural Development in Land With and Without Shrub	Gross income	13,000-26,000 (260-520 million)
Bio-prospecting for Medicinal Herbs	Value of Indian life saving drugs	800 (16 million

Source: K. Kasturirangan (2006)
http://rspas.anu.edu.au/papers/narayanan/2006oration.pdf

Finally, technology transfer and spin-off were the other sources of economic benefit from space activities. Space technology is widely contributing to development of a robust industrial and technological base for high-tech industries, while the impact on human resource development is impressive. By 2005, ISRO had generated 165 patents, 10 trademarks and 17 copyrights.

Space work is helping the high-tech sector by strengthening its human resource base.

A New Place for Science

Since Indian space activities are mainly focused on application programmes, the importance of space science has often been downplayed. However, India has proved able to run a successful, if small-scale, science programme by attaching experiment packages to applications satellites. The country has built only one satellite dedicated purely to space science but has been able to contribute to research work in X-ray astronomy and gamma ray bursts. However, the status of research work has been changing recently.

Implication of Chandrayaan-1

In 2003, four years after initially proposed by the Indian Academy of Sciences, ISRO announced a mission to put a satellite into lunar orbit. Chandrayaan-1 will carry out remote sensing work using a range of optical, infrared, X-ray and radar instrumentation. In keeping with the traditions of the Indian space programme, the mission, which is currently due to launch in July 2008, is being presented as the next step in the development of India's remote sensing capabilities. It will produce a three-dimensional map of the lunar surface and search for deposits of particular minerals, both tasks that have clear terrestrial applications.

India is now actively cultivating international partnerships.

In 2005, ESA signed an agreement to contribute three instruments to Chandrayaan-1; the following year NASA signed on to provide a further two. In both cases, the heads of the agencies came to India to sign the agreement, representing useful political capital for the Indian government. In November 2007, while the Indian prime minister was visiting Moscow, ISRO signed an agreement with RKA, the Russian space agency, to work together on Chandrayaan-2, a lunar surface rover due for launch in 2012. These agreements have served as international acknowledgement of India's technological achievements in space, and as such have helped to justify the 85 million dollars that India is spending on Chandrayaan-1.

Manned spaceflight?

At the end of 2006, ISRO head Gopalan Madhavan Nair surprised much of India by endorsing a plan that would launch a manned mission in 2014-15 and land an Indian on the moon by 2020. Even given the step represented by Chandrayaan-1, this was a huge move away from the traditional socio-economic needs approach to space. Yet the fact that Nair was able to win general support for the idea from the President, the Prime Minister, most (if not all) of the senior ISRO management, and much of the popular press suggests that attitudes are changing.

Several points support an indigenous human spaceflight option.

- India is already working on many of the necessary components. The new version of the GSLV, once it is man-rated, should offer access to earth orbit; India has already experimented with returning a capsule from orbit; and the Chandrayaan missions will provide experience with working at lunar distances.

- The challenges facing India today are different from those of four decades ago. Growth is strong, as many of the benefits from the first space applications programmes have fed through into raising productivity. A more pressing problem now is retaining the country's brightest scientific graduates in a public sector programme (and, indeed, within India itself). A new space challenge could help achieve this, as has been the case with Chandrayaan-1.

- There will be significant benefits, including new commercial opportunities, for India's aerospace industry from a programme that would require the national spending on space to double.

Nair argues that the country can now afford this degree of investment and that it is indeed the next logical step; but he has taken care to keep as close as possible to the traditional rationale for space expenditure. ISRO, like most national space agencies, executes rather than determines government space policy and it is not clear how deep the political support may be for such an increase in space spending, given the substantial increases that ISRO has recently received. A key factor in the future of the manned spaceflight proposal is likely to be the extent to which India continues the outward-looking trend seen in the lunar probe project.

A more outward-looking space programme has implications for India's place in the global space economy.

Whether portrayed as a contest or race to the moon with China (with India hoping for an Apollo-like come-from-behind win) or as an opportunity to cooperate as an equal partner with the world's leading space powers, a shift away from applications for the domestic market would also have implications for India's international competitiveness in the global space economy. An internationally orientated space would encourage India's space sector to become much more commercially active, seeking new markets overseas. Unless it does so with private capital and an absence of excessive subsidy, however, the result could be a series of trade tensions that run counter to other international ties that may develop through cooperation.

However, it is also worth noting that, more than most countries, India has predicated its space policy on the need to assure autonomous capabilities in space. There remains some domestic suspicion, with roots going back to the colonial experience and India's pioneering role in the non-aligned movement, about the idea of collaboration.

A Space Race in Asia?

There has been considerable speculation that India's interest in an ambitious manned space programme is linked to a need to equal or surpass Chinese achievements. The timing of the proposal and the history of Indo-China relations would suggest that this perspective makes sense. However, if India has serious ambitions to compete with China, whose manned programme was well known long before the flight of Yang Liwei in 2003, it would have started a similar programme a decade ago. Yet there was little discussion of doing so among the Indian space community until recently, when the rationale was presented primarily in domestic terms.

It also makes little sense to talk of Asia racing to the moon. The decisions in Japan, China, and India to launch lunar probes were taken independently from each other.

- In the case of India, a key factor was the increasing influence of scientists who were not satisfied with application-oriented programmes and wanted more of the space budget.

- For Japan, a crucial factor was bureaucratic politics following the integration of NASDA and ISIS into JAXA.

- For China, a high-profile demonstration of technological capability and providing a useful symbol of national achievement were clearly factors but neither was aimed specifically at the other two countries.

Instead, these are three programmes developing along similar lines while primarily fulfilling domestic policy rather than foreign policy objectives. As such, neither competition nor cooperation looks set to be defining issues for any of them. This leaves the private sector in each country to forge links with the global marketplace without significant government encouragement but always facing the possibility of being reined in on the grounds of technology transfer concerns or other national security issues. Once again, the hybrid nature of national space economies leaves the public sector with very much the largest role.

China

Chinese space activities tend be more opaque than those of most countries. Policy-setting and decision-making lines are not always clear between civil space officials and their military counterparts, while budgets and future plans are rarely made public in great detail. As a result, analysts in the West offer a range of interpretations for those aspects of Chinese space activity that do become visible. In terms of the space economy, however, significant questions clearly surround China's commercial capabilities and intentions and the extent to which relations between China as a supplier of services and western customers may be damaged by political responses to Chinese actions.

Developing a Political Rationale for Space

In 1970, China became the fourth country to launch its own satellite. The launch was primarily to demonstrate the advances in its ICBM programme following the withdrawal of Soviet technical support a decade earlier; the development of nuclear weapons had much greater priority than space activities. The Cultural Revolution also damaged much of the science and engineering research community that in other countries had been able to win government support for space applications work. Once its effects had passed, the 1979 policy shift under Deng Xiaoping towards a more open economy produced new, more lucrative jobs for elite software technicians and engineers and led to a gradual migration towards other areas, notably the telecoms sector, during the 1980s.

Interest in space among the country's senior policy-makers revived only at the start of the 1990s, when Jiang Zemin, himself an engineer, became leader of the Chinese Communist Party (CCP). Needing to overcome the impact of the Tiananmen Square protests and facing the increasingly unequal divisions of wealth between social classes, between coastal and inland regions, and between rural and urban communities, he turned to nationalism rather than ideology as a means of bringing society together. An early focus of this policy was antagonism towards Japan but it also included national celebration of the return of Hong Kong and the selection of Beijing to host the 2008 Olympic Games. Under Jiang, China also aligned itself more closely with the global economy by joining the World Trade Organisation in 2001 and becoming a full member five years later. Linking national pride with greater acceptance of China as a leading member of the international community became two strands of the same policy.

In this context, a revitalised space programme made political sense. In addition, the availability of a substantial amount of Russian technology at affordable prices in the difficult first years of the post-Soviet period, together with improvements to the Long March family of launch vehicles, had reduced the challenges of manned spaceflight so long as work was conducted at a slow and steady pace. Set up in 1992, the programme proceeded on this basis until 1999, when the newly named Shenzhou project received the final approval to go for orbit. In October 2003, Yang Liwei became the first person launched into space from China. Yang was presented less as an ideological champion of communism and much more as embodying the traditional national virtues of a modest family man. The audience was the Chinese public rather than the international community, with his most important post-flight visit being to Hong Kong as part of Beijing's efforts to foster closer identification with the mainland.

China has kept its manned space programme at a slow and steady pace.

ORGANISATION

With the Shenzhou programme fully sanctioned, the State Council issued a White Paper on Space Activities in 2000. This was the first public statement of China's approach to its goals in space. It embodied a slightly uneasy twin-track approach that aimed to develop benefits for all mankind while protecting China's own national interests.

There was a new effort to put a degree of day-to-day distance between the civil and military space communities involved in the space sector. The China National Space Agency (CNSA), which manages civil space activities including Shenzhou, and the China Aerospace Science and Technology Corporation (CASTC), which manufactures much of the country's space hardware, are both under the oversight of the Committee on Science and Technology Industry for National Defense (COSTIND). Yet, while these two key organisations are strongly influenced by the political leadership, they are relatively autonomous from the defence community. The China Academy of Sciences (CAS) and the various technological institutions that support the applications aspects of China's space activities enjoyed a degree of insulation from national political objectives, enabling them to focus on less spectacular but often more useful projects.

NEW EMPHASIS ON APPLICATIONS

The remarkable change in the 2000 White Paper is its new emphasis on application programmes. While China's geography means that space-based services have an obvious utility, another factor involving technology transfer issues appears to have been behind the shift. After 1986, a year in which the United States and Europe had suffered catastrophic failures of their primary launch systems, China offered its Long March vehicles to launch western-built satellites on a commercial basis. An informal and temporary agreement with the US administration enabled Beijing to price launches at up to 30% below standard industry pricing and it won some custom. At the same time, a new degree of cooperation began to develop, both with satellite builders in Europe and with American manufacturers such as Hughes and Loral whose satellites would use Long March launchers.

China's new emphasis on space applications in 2000 coincided with tighter US export restrictions on space technology.

All sides acknowledged the importance of technology transfer guidelines. However, when in 1996 a new version of the Long March series failed spectacularly during launch, killing six, injuring many more and destroying a top-of-the-line satellite built by Hughes for Intelsat, commercial confidence was badly damaged. A subsequent political row in 1998 over the participation of US companies in the accident review process led Washington to place new restrictions on China's ability to launch satellites that contain specific US components. As a result, and facing the possibility of greater restrictions on access to western technology and networks, such as its long-time use of US Landsat data, renewed emphasis on indigenous development of space-based applications became important.

Responding to New Demand for Space-Based Applications

The inherent tension between autonomous development and international collaboration -- and the attempt to plot a middle course that embraces both -- has been evident in the development of China's space applications programmes over the last decade.

THE 2006 WHITE PAPER

The State Council published a second White Paper in October 2006 that reaffirmed the significance of space applications, although this time also stressing the importance of the manned programme. In contrast with what was widely seen as a surprisingly bellicose update of US national space policy, made public just days earlier, the White Paper took pains to emphasise the civilian and peaceful nature of China's space activities. In terms of applications programmes, it identified the main issue now facing the CNSA and the CAS (which has particular responsibility for remote sensing work) as being the need to better integrate the work of designers, manufacturers, operators and the user community in order to make systems more efficient and more effective.

The need for autonomous capabilities was still stressed but the paper placed a new emphasis on the importance of fundamental research and innovation so that China could move up to a leadership role in space technology. A long-term collaborative programme with Brazil on remote sensing technology (which has now put three satellites into orbit) and work with Canada on synthetic aperture radar represented a welcome mid-point between fully autonomous development, likely to be lengthy and expensive, and dependence on western technology to which access could not be guaranteed. The emphasis in the White Paper on China's acceptance into the World Meteorological Organisation and the International Maritime Satellite Organisation on the strength of its space work was there to underline that investing in space continues to play a useful role in raising China's profile as a contributing member of the international community.

REMOTE SENSING

Public sector demand is currently outstripping the supply of individuals with strong skills in interpreting satellite data.

Since the 1970s, China has used remote sensing data, mostly from foreign sources, in a range of areas that include meteorology, mining, agriculture, forestry, water conservancy, oceanography, seismology and urban planning. The users of these services are overwhelming based in public agencies and ministries, as there is not yet much commercial demand for space imagery. This governmental need for environmental imagery is strong and growing, mostly recently as result of the earthquake in Sichuan in May 2008, and is driving great investment in technological capacity. However, one area where China may be experiencing problems is in extracting maximum value from space-based imagery and data. CAS officials have noted a shortage of individuals with high levels of interpretative skills to meet the needs of the wide range of government agencies now depending on space applications work. As interpretation skills and technology are regarded as falling into the dual-use category, Western countries are wary about providing training and technical assistance. The State Council is increasing investment in this area but results will take time.

COMMUNICATIONS

China began to use satellite-based networks in the mid-1980s for broadcast and two-way communications with remote areas. There are more than thirty service providers of VSAT (Very Small Aperture Terminal) communication services. However, most users of satellite communications are telecoms operators, regional authorities, and central government ministries with responsibilities ranging from transport and energy to water and public health. Broadcasting demand is centred on state media, primarily CCTV (China Central TV). There are some other approved service providers but it is difficult to see a private sector service provider becoming a major commercial force by operating outside state control.

The government has been using satellite broadcasts to provide tele-education for secondary schools in China for some time, and more recently for supporting the international network of Confucius House Chinese language programmes.

NAVIGATION AND LOCATION SERVICES

In common with the rest of the world, China uses the US GPS network in the delivery of a wide range of public services. However it is more uncomfortable than most in this dependency, particularly as Washington reserves the right to restrict access to the signal in exceptional circumstances. This has led Beijing to develop its own positioning system, the Beidou network, which -- unlike GPS or Galileo but like Europe's EGNOS -- uses a small number of geostationary satellites to provide hemispheric rather than global coverage. Some of the ground elements of Beidou were developed in partnership with a Canadian company but it soon became apparent that the accuracy of the system would fall unacceptably below the expected standards of an upgraded GPS system and Galileo.

China sees satellite navigation and location services as a focus for international cooperation.

As a result, a new system to supersede Beidou was announced in 2006 that will use a larger constellation in a lower orbit to offer free service in China. Like GPS, this new system will provide a more accurate signal for the military services that operate it. A test satellite has already been launched, but the care with which China has stressed compatibility with Galileo signals suggests that it would like to see close ties between the two systems.

Championing the Developing World in the Space Economy

China's approach to international cooperation is a complicated one as it encompasses a desire to link space projects to political leadership aspirations.

LEADERSHIP GOALS

China regards itself as leading the community of developing countries in both space policy and space applications. In the main multilateral organisations, not least the United Nations, China argues that the development of space should be undertaken for the equal benefit of all nations, although with particular emphasis on the needs of developing countries. While this rhetoric is understood as having been crafted for its diplomatic surroundings, it does carry the implication that China is willing to provide technical know-how and space-based services to developing countries so as to fill a gap that has resulted from a less than generous provision of support by the other space-faring powers.

From China's perspective, in the Twenty First century developing countries are increasingly disadvantaged by their lack of participation in a space economy that is enabling its active members to pull ahead. In global terms, the difference between moving up and remaining stranded in a continual 'developing' status lies in the degree to which a country is integrated into the global economy, and space applications can go a long way towards supplying that linkage. China argues that, in contrast to the United States and Europe, it is enthusiastic about making those applications available.

China has taken the role of championing the rights of the developing world to see benefits from space technology.

PURSUING A REGIONAL LEADERSHIP ROLE

As early as 1992, China signed an agreement with Pakistan and Thailand to establish a regional organisation for sharing the benefits of space applications technology. This was AP-MCSTA (Asia Pacific Multilateral Cooperation in Space Technology and Applications), which subsequently attracted Iran among a dozen members ranging from South Korea to Bangladesh. The objective of AP-MCSTA was to promote multilateral cooperation in space applications, but it was clear that China was the country with the experience and data to distribute. In fact, the main activity under the AP-MCSTA umbrella has training government officials from member countries in how to apply this data to key areas that promote economic development such as resource management, infrastructure development and disaster planning.

In perhaps its most active initiative, China has used AP-MCSTA to coordinate cooperation between Iran, South Korea, Mongolia, Pakistan, Thailand and Bangladesh in developing a network of microsatellites for communications and remote sensing work. Having developed experience with microsatellites in the early 1990s by sending students to study with the university group that would later be spun off as Surrey Satellite Technology, China has been able to pass that experience to others on its own terms through AP-MCSTA.

However, China has so far been frustrated in its original aim of turning AP-MCSTA into a much more structured organisation for coordinating and integrating most aspects of regional space activity. This is largely because of the existence of another regional grouping, the Asia-Pacific Regional Space Agency Forum that Japan also set up in 1992. Instead, in 2005 China led the formation of the Asia Pacific Space Cooperation Organisation (APSCO). Its eight initial members also belonged to AP-MCSTA with the exception of Peru, which China hopes will be the first of several South American countries to join. Turkey became a full member in 2006 and Argentina has observer status. Beijing continues to woo Brasilia, although the extent of space cooperation between the two countries makes Brazil's participation less crucial. The organisation has not yet developed a track record, and it may be that its value to China lies as much in heading a regional organisation that does not feature Japan as in channelling launch contracts to its Long March vehicles, whose commercial prospects are still clouded by US export regulations.

SPACE AND NATURAL RESOURCES

China is using space to develop ties to countries with large oil

China has gone to considerable lengths in its use of space to develop international ties, first to its regional neighbours and subsequently to the wider Asia Pacific region. Now it is using a similar strategy to develop bilateral ties with a series of countries with substantial supplies of oil.

Brazil

China's collaboration with Brazil on space applications work goes back to the early 1990s, with the first jointly-developed earth resources satellite being launched in 1999. Following the launch of its successor in 2003, the governments signed new agreements on the development and construction of a new generation of satellites and on cooperation in the use of data. A visit to INPE, the National Institute for Space Research, was a high point of President Hu Jintao's visit to Brazil in 2004, when the agreements were signed. Although the relationship with Brazil predates China's recent interest in global oil resources, it is notable that the current head of Brazil's space agency, appointed in March 2008, worked on the original cooperation agreement with China and has indicated his intention to strengthen collaboration.

Nigeria and Venezuela

In 2004, China won the contract to build and launch Nigeria's first communications satellite. The satellite was built entirely in China, although some of the communications package came from Europe, and was successfully launched by a Long March vehicle in May 2007. Both the satellite and the launch were purchased by Nigeria under commercial contracts but it is thought that a degree of subsidy was involved beyond a guarantee of replacement in case of failure and an agreement to train Nigerian engineers. In 2005, China signed a similar contract to build and launch a communications satellite for Venezuela and will also supply ground stations. Launch of the Venezuelan satellite is due before the end of 2008.

Implications for the Space Economy

The contracts with Nigeria and Venezuela, as well as the renewed enthusiasm for cooperation with Brazil, show that China is now both willing and able to use its space expertise to further ties with countries that have key natural resources. This holds an implication for the space economy as much as for global energy supplies.

MARKET DISTORTION

If China is prepared unilaterally to offer discounted pricing for launch services and now satellites, either covertly or by rolling several elements into one package, it risks a distortion of the market. At present, this has not happened to a significant extent. Nigeria complained bitterly that no western company had taken its satellite tender seriously, while the strained relations between Washington and Caracas would have dissuaded most US companies from bidding for the contract in Venezuela. Moreover, the political risk aspects in both cases would mostly likely have been prohibitive for almost any company lacking direct government backing.

Trade row

However, if China offers subsidised space access to a resource-rich country that does not pose such problems for western companies, a row may very well develop over unfair trade practices. Revenues from satellite construction work are already threatened by the new enthusiasm for microsatellites, making US manufacturers -- who now lack Europe's links with the Chinese space sector -- to protest to Washington through groups such as the Satellite Industry Association. Cause for complaint may be less evident in cases where China provides services to developing countries that would not otherwise be able to afford them, in line with its UN statements, but this would still leave western suppliers aggrieved if it happened in more than one or two instances. Washington may also be more likely to listen to the industry if China appears to be favouring countries that are ambivalent about relations with the West.

Should they become more prevalent, subsidised deals with developing countries risk market distortion and trade disputes.

MARKET RISK

In addition to the possibility that China may choose to distort the market aspect of the global space economy for political reasons, it remains possible that western responses to Beijing's actions in other areas may impact companies seeking to conduct commercial relations with China's space sector. This happened a decade ago, following the 1996 Long March accident inquiry, when concerns about technology transfer issues led Congress to move responsibility for licensing the export of US satellite technology from the Department of Commerce, which instinctively favoured granting licences, to the Department of State, which did not.

At present, the risk of this happening is not high, although neither is it totally negligible. Beijing's response to disturbances in Tibet in the spring of 2008 has not had major repercussions for the Olympics, for example, and it would most probably take a combination of two or more factors to produce a significant ban on American or European space sector companies doing business with China. However, it is possible to envisage that, in a period of bad bilateral relations perhaps triggered by an aggressive Chinese pursuit of natural resources, an espionage scandal, or a significant human rights incident, or even an incursion of some kind might lead western politicians to look at sanctions. Focusing on high technology areas, and particularly space, could offer a relatively low-impact/high-profile response.

The 2007 anti-satellite test

One incident that might have triggered such a response was China's destruction of one of its own weather satellites in January 2007, in a test that had some resemblance to one carried out by the United States in 1985. Instead, the international community gave Beijing a free pass on the grounds that:

- The test was conducted by elements within the military as a response to the issuance of the new US National Space Policy document a few months before and the civilian leadership had no warning that it was to be undertaken. The foreign affairs ministry certainly appeared convincingly embarrassed, as it had been campaigning for a new international agreement to lessen the risk of orbital damage from space debris.

- There was relatively little scope for finessing sanctions to fit this particular event. US policy has already closed much of the global launch market to China, leaving only the option of a larger gesture.

- Although creating considerable space debris in a well-used orbital plane, the test broke no international laws or treaties, as the means used to destroy the satellite was not itself based in space.

As a result, the muted international response was shaped largely by an acceptance that the best restraint on such tests in the future will be China's growing self-interest in protecting the space environment that is now important for its economic development.

Section 3: Demand in the Space Economy

Introduction

Space is a major force in the global economy, with satellite-based services already acting as a critical enabler for many key activities. Indeed, the efficiency and resilience of space-based networks now underpins both the process and the progress of globalisation.

The benefits of the space economy are delivered in several ways:

- directly, through the satellite construction and satellite services sectors;
- indirectly, through the end-use of satellite services in other businesses; and
- through the transfer of technology and expertise into other sectors.

American and European companies still dominate the space market, with the United States remaining the pre-eminent space-faring nation. But competitive pressure is increasing from emerging economies such as India and China, as well as from a revitalised Japan and a resurgent Russia. These countries are investing heavily in developing their technological base through civil and military space projects.

Governments and other public bodies remain the most important source of investment in space infrastructure. The challenge now is to harness the efforts of the private sector to those of the public sector in research, technology development, knowledge transfers and the generation of skills in order to create a strong basis for further economic growth and to exploit emerging space markets.

The Direct Impact of the Space Economy

Although space and commerce have been combined for decades, the concept of the space economy is a relatively new one and few economic impact studies have been attempted. As mentioned earlier, the challenge lies in defining terms with sufficient precision to collect comparable national data (where available) and conduct econometric analysis.

- Upstream industrial data (the manufacture of launchers and satellites, and some aspects of ground facilities) is often subsumed into reporting from the larger aerospace and electronics sectors.

- The limitations of international statistical classifications have historically led to underestimates of the size of both the aerospace sector and its space sub-sector.

- There is a total absence of data on value-added per employee that would enable cross-national analysis of the competitiveness of the sector.

- Finally, there are the general complexities of the interactions involved in such a study, for example in tracing spin-off effects and the lags between stimulus and effects.

Space offers significant returns on investment.

However, one illustration of the downstream impact of space investments comes from a Euroconsult study that put European investment in telecommunications satellites at five billion euros in 2002 and the resulting output at 100 billion euros -- a multiplier of 20. Generalised studies of R&D multipliers suggest that for every dollar invested in research, societal returns will be between 30% and 70%. Given the high levels of national investment in space (in the United States, space accounts for some 17% of the national total for civilian, publicly funded R&D), space can be expected to realise at least the minimum multiplier and is likely to be closer to the top end of the range. (By contrast, defence-specific R&D is believed to be towards the bottom.)

RESULTS FROM THE UNITED STATES AND UNITED KINGDOM

In 2008, the Federal Aviation Administration (FAA) issued the fourth in series of reports on the economic impact of commercial space transportation on the US economy. In 2006, Oxford Economic Forecasting (OEF) produced a report commissioned by the British National Space Centre (BNSC) that assessed the role played by the UK space industry in the wider British economy. These reports, the first made public and the second proprietary, give some indication of the direct value of space investments in two national economies.

FAA report

The FAA study found that the US space sector was responsible for 98 billion dollars in economic activity in 2004 and supported, directly or indirectly, over half a million jobs. It found that all major sectors of the US economy received additional stimulus from space-related investment. However, by way of comparison, the civil aviation industry generated ten times as much direct and indirect output.

BNSC report

The OEF analysis for BNSC indicated that the UK enjoyed space-related manufacturing revenues of slightly more than 10 billion dollars in 2005. This was concentrated almost entirely in the development and production of telecommunications and other satellites. The report estimates that the UK downstream space industry is at least five times as large as the upstream manufacturing segment, which directly contributed around 4.8 billion dollars to the UK's GDP. This makes it one of the UK's most productive industries, reflecting the high proportion of skilled employees and the fact that R&D in the sector is six times as intensive as the figure for the UK economy as a whole.

Estimates of the indirect and induced impact led OEF to conclude that the total contribution made to UK GDP by the space-manufacturing sector was over 10 billion dollars. When all of the multipliers are taken into consideration, that contribution rises to at least 14 billion dollars or 0.44% of UK GDP. In addition, the report values the 'spill-over' effects of space R&D as worth more than 3 billon dollars a year to UK GDP.

This data does not include the value of downstream activity, such as having several leading satellite user organisations including Inmarsat headquartered in the UK. However, the study concludes that this value is considerable and would include some 14 billion dollars resulting from improved navigation around the UK road system and 4-6 billion dollars saved from improved weather forecasting. Not all of this output is from space alone but a large proportion can only be realised through space-based equipment.

THE SCOPE OF THE NEW SPACE ECONOMY

The space economy continues to develop new products and services.

At the heart of the new space economy is the fact that the space industry is enabling an ever-expanding range of products and services that are changing the way in which people live their daily lives. Many of these have emerged only in the last few years. ABI Research, a technology market research firm, reports that global revenue from GPS equipment and integrated chipsets grew from approximately 37.5 billion dollars in 2005 to 56.2 billion dollars in 2007, with much of that increase coming from demand for in-vehicle navigation devices. These accounted for approximately 60% of all GPS equipment revenue in 2006 and are increasingly becoming essential features of both public and private sector transportation.

Discovery of new uses and applications for space products and services shows no sign of slowing down. Starting from a strong base in the communications and media sectors, demand has expanded into virtually every economic area, from transportation to healthcare to financial services to entertainment. Moreover, the combination of positioning services with other technologies is opening new commercial opportunities. As users -- government, commercial and individual -- become increasingly comfortable with these new technological options, the period between the appearance of a new service on the market and significant take-up will lessen, moving towards the point where technology will address specific market demand rather than needing skilful marketing to generate initial consumer interest.

Access to Space and Space Infrastructure

LAUNCH SERVICES

A dozen countries (including the EU) now have an autonomous capability to launch satellites into orbit. Almost all launch vehicles now in use have been developed with public funds, usually because their prime role has been to carry government payloads. However, while the number of actors has risen, the number of launches carried out around the world has fallen since the late 1990s. There are several reasons for this decline, including the increased reliability and longevity of satellites and the availability of heavy launch vehicles able to carry two or more satellites at once. But a key factor has been the aftermath of the financial crisis that hit global telecommunications operators in 2001. Russian and Chinese launchers gained market share during the years after 2001 only through offering low prices and overall revenues in the sector have declined along with the number of launches. However, the cyclical nature of the satellite market, with the need for renewals and the development of new models, together with the growing number of national space users, should stimulate demand for launches over the next five years, with the slight upturn seen from 2006 being sustained.

SATELLITES

According to the recent OECD report on the space economy, after the slum of 2001 worldwide satellite industry revenues remained steady from 2002 to 2005 at around 35 billion dollars.[9] However, within that figure it is notable that the proportion generated by ground equipment rose while the amount directly contributed by satellite building declined. It took an increase from the manufacturing segment in 2006 to bring overall revenues back to the levels of 2000. This recovery is likely to continue given the industry's cyclical nature: a 2005 study estimated that the 937 satellites then operating had a replacement value ranging from 170 to 230 billion dollars. However, the growing number of players in the market is diluting the spread of

The increasing number of players in the sector is diluting the spread of overall revenue.

[9] OECD, The Space Economy at a Glance, 2007

overall revenues. The share of global revenues enjoyed by US firms fell between 2002 and 2006 and European space-related manufacturing also saw sales fall during the period. Both sides of the Atlantic have seen an upturn in conditions since 2006.

More than two-thirds of the satellites currently operating in orbit are communication satellites, most of which are in geostationary orbit. Slots in this orbital plane are allocated by the International Telecommunication Union on a country basis in one of the few examples of multilateral regulation in the space economy. The development of smaller and more affordable satellites will inevitably contribute to increased crowding and space debris in busy orbits over the next decades, an effect that may curb some aspects of space-based economic growth.

The Markets for Space-Based Services

SECTORAL OVERVIEW

Revenues from space-related services are not easy to gauge on either a national or an international basis but estimates range between 52.2 billion and 77.2 billion dollars for global revenues in 2005. According to the US Satellite Industry Association, revenues from the world satellite services industry (primarily telecommunications and earth observation) were 83% higher in 2005 than five years earlier and will continue to rise.

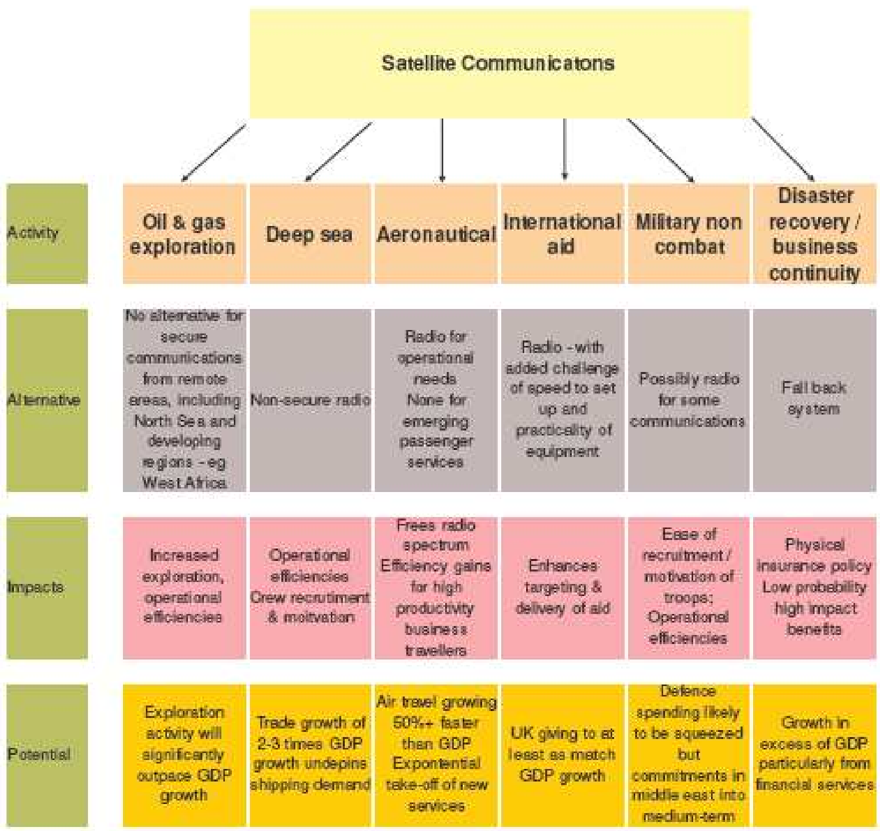
Revenues from space-based services will remain underestimated in the absence of better data.

Telecommunications services, in particular direct-to-home (DTH) broadcast services, are leading growth in the sector and were worth 48.5 billion dollars in 2006. Other space-related services, notably imagery and navigation, are not yet as significant. However, the trend towards greater patronage of commercial services by military users will drive greater growth in these areas. Revenues will also increase as a new generation of satellites powerful enough to provide a wide range of services to mobile users comes on stream. It is also likely that, as suggested by the recent work done for BNSC, revenue estimates for space-related services will continue to be generally underestimated in the absence of improvements in the way that data is collected and broken out.

The space science sector is almost entirely publicly funded, either at a national or multilateral level, but remains a key driver for investments in innovative R&D and a key mission area for space agencies as it includes manned activities. It can have a high public profile and is usually popular with national taxpayers.

TELECOMMUNICATIONS

Satellite communications are especially important where construction of affordable land-based communications is prohibitively expensive, either because of geographic barriers or a dispersed customer base. This has particular relevance not only for the developing world but also for vital industries such as the hydrocarbons sector and shipping that operate in remote locations yet need to be fully integrated into the global communications infrastructure for voice and data. Satellite communication is already a key aspect of the operational control of aircraft, and space-based networks are increasingly providing telephony and Internet services for airline passengers. Larger companies are also using space-based communications networks as part of the disaster recovery and business continuity plans that are now being required by financial regulators.



Source: OEF study for BNSC, 2006

Fibre optic networks that use wavelength division multiplexing technology have already superseded satellites for carrying much of the world's routine intercontinental and transoceanic voice and data traffic. Similarly, the unexpectedly quick growth of mobile telephony over terrestrial networks severely damaged the commercial prospects of Iridium and Globalstar, the first constellations of small satellites in low earth orbit that were designed to offer mobile voice services across most of the planet. However, the satellite sector has seen a new resurgence driven by DTH broadcasting and broadband Internet access, where space-based systems can deliver more bandwidth to rural communities. The spread of mobile services as the first form of telephony to be widely available in many developing areas is likely to be supplemented by satellite-based broadband service for terminals at village level, as carrying high-speed data is not a priority for these networks.

DTH is currently the most important aspect of the space-based telecommunications market. More powerful satellites that carry a larger number of transponders and can benefit from advances in video compression technology have radically improved the competitiveness and value of broadcasting from space. Cross-border broadcasting to reach a large audience with an economy of scale is much easier by satellite than by fibre optic networks. Interactive television, which demands a return channel to link the viewer with the broadcaster, is also well suited to satellite-based systems. Satellites already provide Internet access on this basis to rural areas, although in some cases these services have required significant government subsidies or support. Broadband services, both to the home and then to mobile users, are likely to become an important factor in the space market over the next decade.

NAVIGATION AND POSITIONING

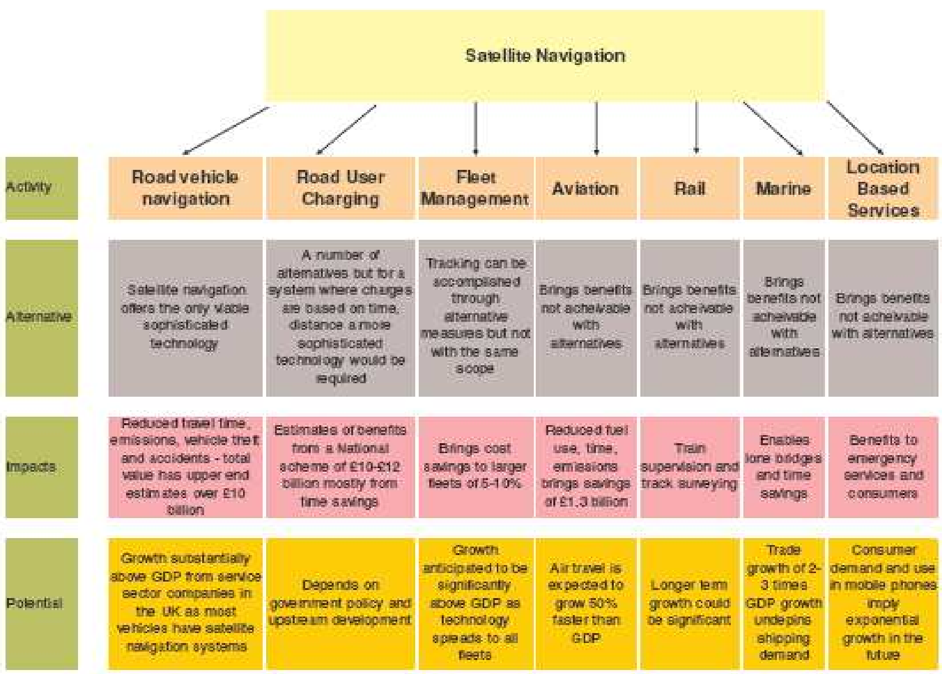
Navigation and positioning services are already central to the space economy.

The importance of satellite-based navigation and location services to growth in the space economy is hard to overstate. Usage is becoming so widespread that they are already being described as the 'fifth utility' after water, gas, electricity, and telecommunications. Within the sector, growth is being led by in-car services. These can help a driver plan a journey, pinpoint a current location on the road, or assist an owner to track a stolen car. At present, the industry is still at the stage of marketing a range of service of associated services in the hope that some attract interest, such as placing location devices in children's shoes.

Signal providers

The Global Positioning System, developed and operated by the US Department of Defense, has made a degraded version of its military signal fully available for worldwide use in commercially available receivers since 1993, as the result of a specific policy decision taken during the Reagan administration. GPS remains the *de facto* global standard for navigation signals. Russia is in the process of rebuilding its GLONASS navigation network -- itself a military system adapted for civilian use -- and has invited India to be a partner in the modernisation process. However, GLONASS is still largely regarded outside Russia as a possible supplement to GPS signals rather than as a standalone system.

Europe is offering the European Geostationary Navigation Overlay Service (EGNOS), based on three geostationary satellites, as a precursor to Galileo, its own navigation and positioning satellite constellation and the first to be constructed as a civil system from the outset. Galileo is designed to offer tiered levels of accuracy, with the highest being sold on a subscription basis. However, uncertainty about the sustainability of this model in light of an expected third-generation upgrade to the GPS system was one of the reasons why the public-private partnership model that originally underpinned Galileo has foundered.



Source: OEF study for BNSC, 2006

Transportation benefits
The transportation sector is the main beneficiary of enhanced navigation and positioning services, which is why European transport ministries have strongly championed Galileo.

- Satellite-based services can lessen commuting times through better traffic management, resulting in less environmental damage and social stress, as well as underpin toll and road-pricing schemes and raise the efficiency of commercial fleet operations.

- Greater accuracy for the aviation sector will enable airlines to fly more direct routes between locations and land in closer proximity, saving time and fuel. Trials of EGNOS in Spain in early 2008 proved promising and the prospect of reducing both fuel use and carbon emissions has heightened industry enthusiasm.

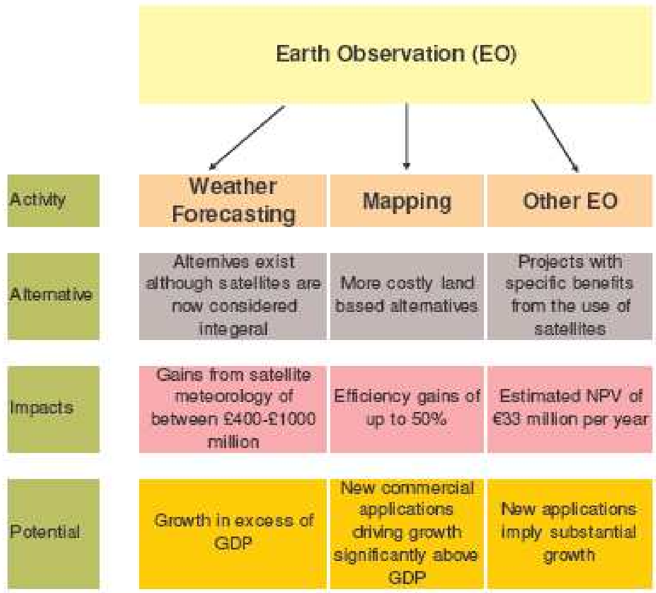
Civil aviation is likely to drive much of the integration of space-based positioning and communications services.

Other services derived from linking locational systems with the latest generation of mobile communications are already being examined in the billing, advertising, gaming, and personal security industries. However, the civil aviation sector is likely to drive much of the integration of space-based positioning and communications services. During the next two decades, a global network comparable in scope to the Internet could be at the core of a 'gate-to-gate' aviation system. This would enable new levels of automated control, increasing flight safety; improve passenger satisfaction through access to wider entertainment and communications options; and increase logistical support for airline operations, including full in-flight diagnostics fault reporting and better scheduling of flight connectivity. This system should also facilitate the better integration of unmanned aerial vehicles (UAVs) into controlled airspace.

EARTH OBSERVATION AND REMOTE SENSING

Satellite-based observations play a unique role in understanding the planet. The use of high-resolution satellite imagery, together with infrared, X-ray and radar sensors, offers unmatched coverage, continuity and quality of data. Satellites help scientists understand the processes that govern the state of the Earth, revealing, for example, accurate information on the state of the ozone layer, the clearing of the world's rainforests, and the melting of the Greenland ice cap. Earth observation has revolutionised environmental forecasting and contributed to improved disaster response.

The priority now for users is to ensure stable support for the development and use of observation technologies and systems in order to deliver the best possible environmental science and operational services to policy-makers as well as commercial users. The direct economic return from this activity is hard to gauge, although the EU has estimated that its own global monitoring programme (GMES) could yield a yearly economic value, once fully operational, of between 5 and 28 billion euros by contributing to the early identification and efficient resolution of environmental problems.



Source: OEF study for BNSC, 2006

WEATHER FORECASTING

Weather affects all aspects of economic activity, from delays in transportation services to lost agricultural production and fluctuating demand for electricity, as well as the ever-present risk of extensive loss of life and damage to property and infrastructure from severe weather conditions. Over more than four decades, observational data from meteorological satellites has contributed to improvements in the accuracy, scope and timeliness of weather forecasts. Over the next decade, this contribution will increase as advances in imagery technologies and interpretation techniques are coupled with a new generation of small satellites to enhance the extent and quality of coverage available from space.

DISASTER MONITORING

Monitoring from space is now a crucial component in tracking, monitoring and assessing natural hazards including tsunamis, earthquakes and volcanic episodes in addition to severe weather phenomena. Mitigating the impact of these disasters involves integrating data from various Earth observation systems for use in predictive modelling and then using satellites to transmit accurate and actionable information as quickly as possible. The use of satellites to provide advance information about tropical cyclones doubled the warning time now available to most authorities from 24 hours in 1990 to 48 hours in 1999. For tornados in the United States, where extra minutes can be vital in getting populations into storm shelters, localised warning times also doubled over that period to 17 minutes.

The benefits from Europe's GMES system may also prove significant in this area. Warnings provided by GMES services could reduce the costs of flood damage by 1.5% and from forest fires by 1%, through a combination of improved risk assessment and detailed monitoring. This would produce an average annual economic benefit of around 145 million euros, an appreciable return on development and deployment costs.

CLIMATE CHANGE

Over three-quarters of natural disasters are weather-related; during the 1990s, natural disasters killed half a million people and caused damage totalling 750 billion dollars. The Intergovernmental Panel on Climate Change (IPCC) has concluded that climate change will increase the frequency and severity of weather-related emergencies. To mitigate the impact of subsequent disasters, it is vital to establish effective early warning systems. Much of this response is best achieved -- and, in many cases, can only be achieved -- through the use of space-based systems.

AGRICULTURE, LAND USE AND FISHERIES

Satellites such the US Landsat series have long been used to monitor agricultural production and support land management efforts. Remote sensing is actively used to identify soil properties by spectral signature, to evaluate crop productivity, and to forecast yields. For example, the agricultural benefits of improved El Niño forecasts that are derived solely from data returned by meteorological satellites are estimated to be worth some 500 million dollars a year on average. Furthermore, EU estimates suggest that the economic benefit of satellite-based forestry management could soon be worth between one and four billion euros a year. In addition, space-based communications systems enable farmers to make the most informed decisions regarding the timing of planting and harvesting, as well as providing current information about the use of pesticides and fertilizers. The role of satellite data in water management issues, including cross-border water-related disputes, is likely to become a key area for space-based services in the next two decades.

Space-based systems are also increasingly important for marine production through the management of fish stocks and the prevention of illegal fishing. Remote sensing technologies allow a more frequent and detailed coverage of the oceans, especially of their remoter parts. The European Envisat, for example, is being used to measure such variables as sea surface temperature, waves and wind variations, and factors that determine oil slick trajectories. Satellites also supplement other devices, such as remotely operated vehicles and free-drifting data collection floats, in mapping the three-dimensional nature of the ocean environment.

SPACE TOURISM

Orbital space tourism is currently available only through Russian space infrastructure via an exclusive arrangement with Space Adventures, a US-based company. A round-trip flight to the International Space Station (ISS) lasting 7-10 days has a list price of 25 million dollars, which includes several months of training. Five individuals have flown under this arrangement so far since 2001, with a sixth due to fly in 2008 and apparently a long waiting list. Space Adventures announced in June 2008 that Google co-founder Sergey Brin has put down a deposit of five million dollars to fly in 2011 on what will be the first privately chartered Soyuz flight. Two paying passengers will fly to the ISS with a Russian pilot on a mission that is not part of official station operations and is completely financed by Space Adventures.

Burt Rutan's company Scaled Composites used financial backing from Microsoft co-founder Paul Allen to prove with its reusable SpaceShip One that quick turn-around sub-orbital flights are feasible, thereby winning the Ansari X-Prize. Richard Branson's Virgin Atlantic company had seen at least the promotional aspects of space tourism as long ago as 1997, when it trade-marked the name Virgin Galactic, and has stepped in with the money to commercialise Rutan's design. A small fleet of a slightly larger model, SpaceShip Two, will be able to carry six passengers on flights lasting two and a half hours that offer several minutes in space. Test flights are planned for 2009 and the first paying passengers could fly by the end of 2010. Full-price tickets are likely to cost around 225,000 dollars per person but deposits totalling 30 million dollars have already been taken.

Space tourism will make only a slight contribution to the overall space economy in the next ten years.

In addition to Scaled Composites, recently acquired by Northup Grumman, other beneficiaries from the Virgin investment include Las Cruces in southern New Mexico, which is building an operating headquarters for the company, and Kiruna in northern Sweden, from where Virgin will launch flights through the Aurora Borealis. Its training facility for passengers is housed at a former naval base in Pennsylvania. Despite this, however, space tourism will make only a marginal financial contribution to the overall space economy in the next ten years. Yet the publicity that will undoubtedly surround the first commercial sub-orbital flights offers the opportunity to raise wider awareness of how space-based services are widely used in everyday life.

Future Relations Between the Public and Private Sectors in the Space Economy

Historically, space markets have been pioneered by government-funded infrastructure development and first usage. Once established on the back of proven technology and demand, the private sector has moved in. This was the case in telecommunications, where commercial customers and service providers have come to dominate the market. This pattern is now evident in newer space markets, especially Earth observation and monitoring services, but the level of early government involvement in development and sustained public sector participation as a customer has proved crucial to the initial development of market segments.

Clear View

In a typical example, the US government opened up the optical observation sector by guaranteeing an initial market for earth resource monitoring with the Clear View programme. This guaranteed minimum revenues for several years to the commercial sector in return for delivery of pictures and data, and also contributed towards development costs. However, this still left the service provider to bear all technical risks, including launch failure and in-orbit satellite failure, and generate its profits from the sales to other customers.

Spot Image

France's Spot Image has similar origins as a publicly funded service and is now a market leader in the supply of commercial optical data. CNES, the French national space agency, developed and launched the SPOT satellites and assumed the high initial operating risk. Once operational, the system was subsequently transferred on a royalty fee basis to Spot Image for commercial exploitation.

Google and Microsoft

Competition between Google Earth and Microsoft's Virtual Earth programme is currently generating new revenue streams and stimulating further commercial opportunities. Supply data has already opened up a new market for established companies such as GeoEye (formed from the combination of Oribimaging and Space Imaging in 2006) and DigitalGlobe, whose first satellite was launched in 2001. These services have made rapid progress through linking space-based observation with Internet-based services and enhanced data storage technology.

SUCCESS AND FAILURE

Europe's experience with public-private partnerships has been mixed.

Skynet

In recent years, governments have been looking for ways of reducing the financial impact of large infrastructure investments. The UK has been a major innovator in the use of public-private partnerships to fund such programmes in several areas, including the defence sector. A leading example is Skynet, a large-scale defence satellite communications system developed and run by a private sector company, Paradigm. Services on Skynet are also available to other UK government departments and to other agencies and organisations that require secure communications. They are also available to approved defence and other governmental users from overseas countries and multinational organisations, primarily NATO.

The Paradigm team is led by Paradigm Secure Communications, which was formed by EADS Astrium and includes Logica, General Dynamics Decision Systems, Cogent DSN, Serco, Cable & Wireless and Stratos. Paradigm Secure Communications contracts with Paradigm Services for full service delivery and EADS Astrium for the dedicated satellites and ground systems. UK government support provided some 10 million pounds over two years towards development costs and co-funded with industry a technology demonstration programme to limit risk and show that performance targets could be met.

The total service contracts are worth 2.5 billion pounds over 15 years, which include a billion pounds to cover the cost of the satellites from Astrium, which will have UK content in excess of 70%. Experience with the Skynet programme helped Astrium to go on to win a large construction contract with Inmarsat. Meanwhile, the annual potential for third party and export opportunities for secure satcom services is estimated at 30 million pounds.

Galileo

On the other hand, attempts to establish a commercially sustainable business model for the Galileo navigational and positioning system have so far failed. As a result, the EU and ESA have little choice but to assume responsibility for the system at least until it becomes fully operational before there may be a chance of attracting private sector participation.

Europe has found it difficult to make the public-private partnership model work for Galileo.

Galileo was Europe's first serious attempt to implement the public-private partnership model for sharing the risks and benefits of a major space project. The EU wanted a European-controlled civilian navigation and positioning system to complement and enhance the GPS system. Competing European industrial consortia would bid for the position of "Galileo concessionaire" with the winner taking over from ESA a proven system design and four satellites already in orbit.

The successful bidder would then build out the 30-satellite constellation and operate it for 20 years.

With development costs rising and deployment targets slipping, this model has proved over-ambitious -- although avoidable in-fighting amongst the member states over allocating work and financial contributions has certainly not helped. In the final analysis, private capital was simply not prepared to fund the risks involved. These risks were not so much technical as financial, centring on doubt that there would be a sufficiently large market for the fee-based services that Galileo needs to sell in order to pay back its costs and produce a return on investments.

Here one can detect long memories of the painful example of Iridium, the global satellite phone service pioneered by Motorola in the late 1980s and 1990s. This required the development and deployment of a whole new infrastructure of satellites and ground stations, only to be overtaken by fast growth and falling costs in the terrestrial mobile sector. Several leading financial companies had invested in Iridium, which raised the subsequent level of scepticism, and the financial community has also been substantially more cautious about the telecoms sector since the downturn of 2001.

The consortium that won the Galileo contract was forced to request a guaranteed income stream from the sponsoring governments. When one was not forthcoming, largely as a result of internal politics within the European Commission, the private sector side withdrew from the project. The EU is now set to fund the 3.5 billion dollars required to complete development and put the network in place by using money diverted from sectors that are expected to use the system, notably transport and agriculture.

The private sector needed guarantees of government usage that were not forthcoming.

The political supporters of Galileo highlighted the technological gains from developing the system and the economic benefits it will produce; its critics described it as simply another European prestige project. However, the simple fact is that with deployment and operating costs expected to be 20 billion dollars over the lifetime of the contract for the private sector operator, breaking even was always going to be difficult even before costs rose by almost 50% during the development phase. With a cautious capital market, uncertainty about demand, and disharmony within the sponsoring organisations, it is not surprising that only a guaranteed revenue stream could ensure private sector participation along the lines originally envisaged. Lacking the unity of purpose and commitment that the UK government was able to provide for Skynet, Galileo's public sector sponsors found that the project was simply too ambitious in scope and scale to fit into the public-private partnership model.

FUTURE DRIVERS OF DEMAND

Governments can make a major contribution to the space economy by supporting efforts to lower the cost to orbit.

The space economy has developed on the back of a mix of demand from civil, military, commercial and institutional users. Whether the composition of this mix will change markedly depends first and foremost on cutting the cost of reaching orbit. Developments in this area may flow from a more competitive, entrepreneurial approach to existing launcher technology or from exploiting the opportunities afforded by a new generation of small satellites operating individually or in groups. Other emerging drivers for a new market for space include introduction of the next generations of computers and sensors linked to more in-orbit storage and higher data transmission rates. The combination of both of these developments could encourage the emergence of a new set of space service providers and clients. Government policy should be focused on fostering these changes: it should certainly not obstruct the development of new markets through over-regulation and a stultifying concern for security.

Looking further ahead, if and when new launch technologies reduce current costs by a factor of ten, so that a 500 kg satellite can be placed into low earth orbit for less than three million dollars, the economics of space will experience the equivalent of the jet engine revolution in civil aviation. Sustainable private sector ventures will be possible and the role of the public sector should shrink to become one of regulation and leading edge research, as with air transport today. Larger space undertakings whose goal is scientific research would still require government sponsorship, probably on a collaborative basis, but a shorthand distinction is likely to see the private sector operating in low earth and geosynchronous orbits with government-funded missions engaged in planetary exploration.

Funding the New Space Economy: National or International Investment?

Over the next decade, and probably longer, the burden of supporting the space economy will fall to governments. This is a reflection of market failure, in so far as the private sector has proved unwilling to invest in space-related ventures with long-term and uncertain returns. The public policy dilemma, however, may not be whether to invest in the space economy, but rather how much can and should be undertaken as a global collaborative endeavour?

Clearly, some aspects of space operations and the space economy demand international cooperation. Wavelength and orbital slot allocations require diplomatic engagement and the oversight of international bodies. There is a case for developing a more robust regime on space debris, while renewed interest in the active militarisation of space may also generate demands for a new multilateral agreement. Having a stake in the outcome enhances the ability of a country to shape the direction of international regimes. Stakes are earned and leveraged by the degree of investment and engagement.

Collaborating with other states or groups of states in developing new technology, perhaps new launchers or large space-based assemblies, offers the potential to share costs amongst several partners. An international partnership may also speed the creation of a wider user community and the involvement of private capital across a number of countries. On the other hand, as the experience of collaboration on the ISS and in other large technology projects has shown, internationalisation can increase costs and generate competition for the "best" aspects of the project that results in friction over leadership and access.

A national programme may be easier to manage effectively: there is certainly less potential conflict over the division of costs and benefits. However, the increased absolute costs must be evaluated against the likely benefits, often over a very long period. Certain infrastructure programmes by their nature will inevitably attract 'free loaders' able to capitalise to a degree on the investment of others -- although this may not be an issue if, as in the case of GPS, the benefits to the sponsoring country far outweigh notional losses through freeloader exploitation. Equally, national control of key technologies or of a novel service may in any case be a relatively short-term advantage. The Soviet-American duopoly in launch vehicle technology barely lasted a decade. Indeed, Washington's attempts to control access to US launchers stimulated European development work in this area to the commercial detriment of American launch services. European-based telecommunications and media companies now have a strong presence in a sector pioneered by US companies.

It may prove difficult to hold on to a technological lead, making international work more attractive.

THE CASE FOR COOPERATION

There is a better case for determined and strategically informed national involvement in international programmes. The crux is to lay early claim to leadership and a consequent ability to determine the terms under which the programme is managed and benefits distributed. There may still be a need to accept compromises in areas such as technological transfer issues and national representation in management positions, but it is vital to ensure that long-term commitments to fundamental research and early technology demonstration are maintained. This may imply a hard-nosed attitude to priorities and the rationale for investment, and it certainly suggests a more economically and commercially informed approach to long-term planning. It is likely to demand curtailing politically sensitive but unproductive areas and eschewing the idea of national prestige. But only by fully embracing the range and scope of the new space economy can such long-term undertakings ensure a sustaining rationale that will survive changes of government and shifts in the political landscape.

There is undoubtedly a competitive element associated with space, with some advantages, albeit fleeting, going to the first mover. Yet the real power goes to those prepared and able to make a generous commitment of national resources -- tangible and intangible -- to a continuous cycle of investment in space.

The key to leadership is a generous commitment of national resources to a continuous cycle of investment in space.

Newton's Universe: Space as a Harsh Marketplace

Space is a harsh market place. Success or failure can be measured in microns and a payload costing half a billion dollars can disappear literally in a flash. Failure on station has no call-out repair service. Running a railway across the baking deserts and high mountain ranges of the Americas was easy compared to building the infrastructure for space. The nearest one can get to the space environment on earth is the offshore oil industry, and oil riggers do not have to contend with a vacuum, total extremes of temperature, or solar flares that can disable crucial systems.

Any understanding of the space economy has to grasp this reality. Moreover, the laws here are those written by Isaac Newton rather than Adam Smith. The physical forces at work shape the space economy more than do those of the market. Hauling a payload into orbit means having to overcome gravity and, at current levels of technology, that effectively makes the entry costs to the space business very high indeed. There are opportunities at the margin to reduce these costs to some extent, but not so much as to turn space into another simple transport service. Once on station, flexibility and adjustment are at present only options for the latest military reconnaissance satellite. Even then, they come at the price of reduced longevity.

Since Sputnik, the private sector has made some progress in exploiting space for commercial returns; but it takes nerve and proof of market before the private investor is comfortable with the risks involved. The private sector may use the infrastructure of space if given support and encouragement but is unlikely to construct it unaided. Together with the ongoing importance of space for defence and security, this means a continuing role for national governments in promoting space technology and pioneering services.

Although the space economy plays a crucial role in the globalised economy, the revenues are far from immediate and are usually hard to distinguish as being space-related as they are often at their most substantial a long way downstream from the orbiting satellite. But the returns on investment are there for the economies of those governments willing to sustain the cost and risks of leadership in space.