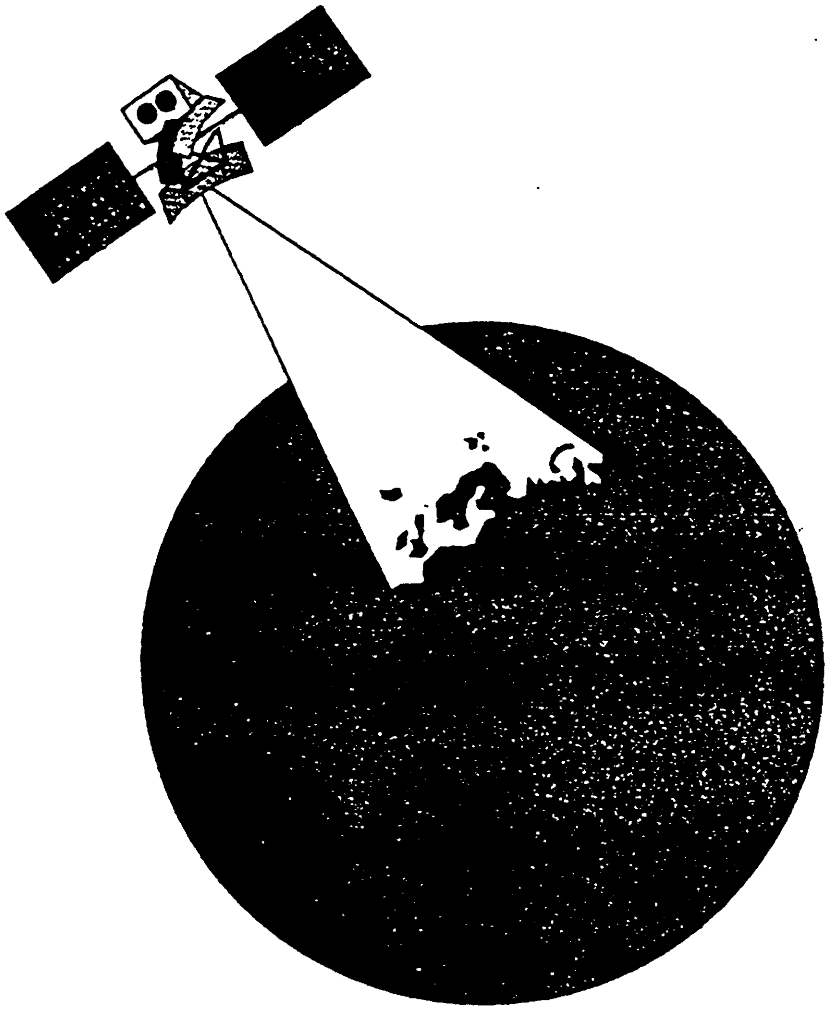
KPMG Consortium

An Economic Assessment of European Satellite Orbit and Spectrum Resources

Final Report



European Commission

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KPMG Consortium : 30 November 1993

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1 Introduction

KPMG, and its Consortium members, have been retained to undertake an economic assessment of the way in which geostationary orbit and spectrum resources (GSOSR) are allocated and used in International Telecommunications Union's (ITU) Region 1 (covering Europe, the former Soviet Union and Africa). The objectives of this study are as follows :

- to develop a set of principles, based in particular on economic theory relating to resource management, that will facilitate the optimal allocation of scarce orbit and spectrum resources,

- based on these principles and as far as possible incorporating the main technical, legal, political and other considerations, to develop principles for managing the allocation and utilisation of orbit and spectrum resources.

In particular, the principles that are developed will need to take into account the current and potential requirements not only of Europe but also of the developing countries (LDCs), especially in Africa.

Currently there are few or no explicit economic regulations impacting the allocation or assignment of GSOSR at the international or national levels in Europe. This does not mean, however, that there are no resulting economic impacts. Indeed the technical and administrative regulations tend to interfere with and distort market forces, thus leading to economic inefficiencies developing in the market.

In this report there is discussion of the key issues emerging from interviews conducted with a range of operators, regulators and representative bodies involved in the satellite communications industry, as well as input from our economic, legal and technical experts. The structure of the remainder of this report will be as follows:

- **Review of literature.** Chapter 2 presents a review of the literature that deals with the regulation of the GSOSR and of analogous resources.

- **Technological trends.** Chapter 3 considers the technological context of the use to which GSOSR is put. This provides an essential backdrop to later considerations of regulatory and economic issues.

- **Overview of the existing regulatory situation.** Chapter 4 places the rest of the analysis in the context of the ITU and national level regulations that currently impact the allocation and use of GSOSR.

- **Shortcomings of existing regulations.** Chapter 5 assesses the problems associated with the existing regulations and regulatory structures from an economic perspective.

- **Options for regulatory change.** Chapter 6 describes the options for regulatory changes which formed the basis of our interview programme.

- **Synthesis of key points from the US and European interviews.** Chapter 7 discusses the main points raised as a result of the interview programme. The views from the US and Europe are presented separately because there is an interesting difference in emphasis that reflects different regulatory, geo-political and economic conditions.

- **Regulatory scenarios.** Based on the analysis in the preceding sections, in Chapter 8 we develop four scenarios of regulatory change and analyse their potential economic and welfare effects. We include an assessment of the practical difficulties associated with introducing change.

- **Model overview.** Chapter 9 outlines the methodology developed to analyse the quantitative scale of economic impact associated with each scenario. It describes how the model has been estimated, the parameters that can be varied when analysing the regulatory scenarios and the resulting outputs.

- **Model results and implications.** Chapter 10 presents the full assessment of the quantitative and qualitative implications of regulatory changes.

- **Policy implications.** The final chapter summarises the consequences of the analysis for the future formulation of policy towards the regulation of GSOSR.

2 Review of Literature and Regulatory Systems in Analogous Industries

2.1 Review of Economic Analysis of the Satellite Industry and its Regulation

2.1.1 Introduction

A survey of the literature on satellite economics was carried out with the objective of identifying previous work on the economic valuation and allocation of orbit/frequency resources and other methodologies that might be applied to this topic. The research accessed the following sources of information:

- telecommunications, satellite and economic policy journals,
- books and government publications,
- other consultancy studies,
- articles in the trade press.

A full bibliography is provided in Appendix 1. However, a review such as this one can only scratch the surface of the literature, highlighting the main issues and previous work relevant to this study.

The following sections highlight some of the specific points arising from this survey relating to modelling of satellite markets in general, specific methodologies, possible policy and regulatory scenarios and issues. A wide range of relevant literature exists, dealing explicitly with the satellite industry or with other sectors and situations that can be viewed as analogous. However, coverage of economic theory and its practical application to satellite issues is relatively recent. To a great extent this reflects the development of the industry itself, which has only recently begun to take into account economic theory and market forces, having previously been driven primarily by technical and political factors.

2.1.2 Background

A number of issues were identified that apply to almost any modelling approach.

One of the key problems lies in the definition of the "product" that is being modelled. Satellite orbit slots and frequencies can be regarded as multidimensional. Each observed point comprises a combination of an orbit position and a frequency. However, the orbit and frequency resources have no value in isolation. They only have value when combined to provide what may be referred to as a "transmission opportunity" in space. As such it is appropriate to regard the orbit and frequency resource from which transmissions can take place as a single unit.

Levin (1988) suggests that the appropriate market, that can be considered as a proxy for the orbit and frequency resource, is for "transponders in orbit". He argues that the orbit slots themselves are not a marketable end product. An orbit slot per se has no value until there is a satellite in it. Even then, the marketable end product is not the satellite itself but the services that it supports. Snow (1988) in his economic assessment of Intelsat, developed a cost function using circuits as the output variable. Circuits are suitable when considering predominantly telephone services. Given the range of services (TV as well as telephony) that are considered in this analysis, circuits would not be an appropriate unit of examination for the current study.

Transponders, or a standardised 'transponder equivalent', would seem, therefore, to be the most practical proxy for the orbit and frequency transmission opportunity. Consideration must be given, however, to the services delivered via the transponders, especially when transponders delivering different services are not easily substitutable for each other. It would seem that in the short to medium term transponders are likely to become more service specific. Technological developments will permit greater efficiency in the use of both the orbit and frequency resource for specific applications. Technological change will also improve the quality of transmission that is possible for a given service application. In the longer term, integration of services in digital multimedia transmissions is likely to reverse the trend and increase the substitutability of transponders.

2.1.3 Alternative modelling methodologies

Snow (1990) highlights a number of difficulties with using economic analysis in the area of satellite regulation as follows:

- political and econometric difficulties with marginal costs and demand sensitive pricing,
- external price effects (externalities),
- missing or inaccurate data,
- political and socio-cultural considerations,
- the difficulty of arriving at a single indicator of social welfare.

Levin (1988) in a slightly different context, sets out the modelling problem. He emphasises the difference between the existing system of regulation which allocates GSOSR according to technical and administrative criteria and one determined by economic theory. The former has a rigid, tightly packed allotment plan while the latter envisages a loosely packed plan with transferability of assignments. This can be shown to be more efficient:

> *"The task is simply to estimate and compare the economic losses in foregone outputs due to the vacancies left for flexibility, and the greater net value that results from transferring assignments from lower to higher valued uses and users."*

Thus Levin stresses the centrality of both flexibility and transferability of the right to use GSOSR to an economically efficient regulatory system.

Snow (1988) used a number of quantitative techniques to investigate specific aspects of Intelsat's operations. These comprised:

- development of a cost function (based on an assumed functional form) for a hypothetical Intelsat signatory, to evaluate whether Intelsat is a natural monopoly,
- utility analysis to assess the potential loss in welfare arising from loss in potential connections (the network effect) as new entrants divert customers from Intelsat,
- probability analysis, to assess the implications for satellite replacement and breakdown coverage of new entrants.

The analysis found that Intelsat benefited from efficiencies of multiple product output (EMPO). This lead to a recommendation for a shift in Intelsat's pricing policy away from average cost pricing and towards more demand sensitive pricing mechanisms, in order to sustain the benefits from these efficiencies, which can be eroded by competition from smaller new entrants.

Snow (1990) identified a number of possible general methodologies for evaluating Intelsat as follows:

- *functionalist theory*, which emphasises the development of international cooperation in the context of the institutional framework in which it takes place,
- *cooperation and social economy*, the former views political and economic cooperation as superior to the market place while the latter envisions state involvement as necessary in cases of market failure,
- *political economy of deregulation*, which explicitly takes political considerations into account,
- *collective or public goods model*, which views the frequency spectrum as a public good (due to indivisibility and non-excludability),
- *neoclassical economics*, the optimisation of key economic variables, such as consumer welfare, subject to constraints.

In our discussions with Professor Snow it has been agreed that for the purposes of this study the neoclassical approach is the most appropriate method of analysis as it provides quantified estimates of welfare gains associated with different regulatory options. It is an approach which is based on well accepted economic principles and conforms well with the objectives of this study. The considerations associated with the other methodologies should be borne very firmly in mind when considering in practice how regulatory modifications might be formulated, implemented and monitored.

In the summary of his article, Frieden (1992) promises to explore "how international competition can enhance consumer welfare." The analysis was qualitative, discussing the implications of the following different types of market entry behaviour:

- *provocateur/trendsetter*, the pioneer, visibly challenging the status quo,
- *low profiler*, a later entrant, after policy battles have been concluded,
- *innovator*, customer oriented, providing new or improved services to different markets,
- *regional marketer/niche player*, focusing on a specific region or service,
- *opportunist/extortionist*, exploits the current regulatory framework (eg for LDCs).

While this type of analysis may be of general interest, and can be used, as Frieden does, to categorise recent market developments in satellites, from the point of view of policy analysis the focus is too much at the micro level and there is little potential for carrying out a quantitative assessment of policy options.

Macauley (1989) focused on the value of particular orbit slots by estimating the welfare costs of locational and operating inefficiencies that arise as a result of the current "first come first served" orbital assignment mechanism. This was done by modelling the value of orbit locations and combining this with a model that estimates the impact of substituting for more efficient technologies. The analysis drew on models of monocentric spatial locations that are used in land economics to show how land values (and therefore the capital intensity of land use) increase the closer you get to the central business district. Macauley argued that if producers faced incentives to use the "prime" orbit locations more efficiently, then welfare gains may accrue. Based on the analysis of two regions, Central/South America and the Caribbean, and the Pacific Rim, she found potential cost savings of $30 to $40m. While these are small compared to the size of the world telecommunications sector, "they are large compared with the telecommunications sector in a developing country or with the budget for communication satellite R&D in the US". Again, this type of approach is useful for looking at specific issues (such as the value of a particular orbit slot). However, it is difficult to extend it to address more general, multi-dimensional, regulatory changes.

2.1.4 Policy and regulatory scenarios

General

A wide range of policy options and scenarios were identified. Although the general thrust was for a deregulation of the market, there was considerable difference in focus. Verhoef (1992) set out the current thinking of the Commission. Snow (1988, 1992) was particularly concerned with the implications of diluting Intelsat's monopoly position.

More general deregulation scenarios were investigated by Levin (1988). He looked at recent developments in the satellite industry and through a number of case studies highlighted the ways in which market forces are being introduced "through the back door". He proposes three possible mechanisms for increasing the market orientation and flexibility of the existing regulatory framework, with specific reference to the potential benefit to LDCs, as follows:

- *bond posting*, users from developed countries would post a bond for use of LDC allotments, to be forfeited if they do not vacate the slot within a specified period,
- *leasing out* of frequencies and orbit slots. This would require a more flexible definition of orbit/spectrum rights. The current, narrowly defined, system means that there are few alternative uses for particular allocations,
- *economic coordination*, the equalisation of incumbents and new entrants through cross payments and penalties.

Levin (1991) subsequently argued that it may be possible to establish a market to trade in rights to use orbital slots and associated frequencies.

Scarcity of orbit and spectrum

The existence of scarcity of orbit slots and spectrum, and the extent to which this may be an artificial result of the current regulatory framework, is a subject of considerable debate. Elsewhere (see Section 7) we report the views obtained in the US and Europe as part of the interview programme. However, scarcity is also addressed in the literature. As with the interview programme, the views expressed are mixed. In particular, there is considerable debate as to whether new technology will alleviate the problem or whether new uses for orbit and spectrum will continue to develop and exacerbate the problem. What is generally agreed is that one of the main causes of scarcity lies with the current regulatory system, at both national and international level. As indicated below, however, there are wide differences of opinion over what needs to be done.

Even if the general scarcity such as that experienced in the US during the late 1970s and early 1980s has been relieved, demand can still exceed supply in particular geographical locations/orbit slots/frequency bands (see, for example, the competing claims by potential LEO operators). Those who believe that scarcity is a function of inappropriate regulation argue that the shortages are more apparent than real and would disappear if the resources were priced and allocated according to economic principles.

The Congressional Budget Office (CBO) (1992) reviews the current position in the US. It notes that while technological advances are increasing capacity, they also lead to new services that compete for orbit and spectrum, such as digital audio radio and improved television broadcasts. It also notes that most of the desirable frequencies between 3KHz and 300 GHz have already been allocated to specific uses, and those below 2 GHz that have the best technical characteristics are already tightly packed. Motorola (1991) estimates that by the year 2000 an additional 317 MHz of spectrum will be required for wireless communications and the CBO refers to one study that calculated the cost to the US economy of delays in allocating frequencies to cellular phone services at $86 billion.

Also in the US, an article in Business Week (1990) argues that spectrum overcrowding is still increasing, as new wider technologies such as cellular phones and pagers increase in popularity. The article views the current overcrowding as being due to a combination of pressure from entrenched interests and an inflexible regulatory system. It reports the ITU as stating that during the 1980s alone as many new frequency assignments were recorded as in the previous 80 years. In the US, there were 500,000 applications for cellular radio licences between 1984 and 1988 alone (Benzani and Kalman, 1992).

Matheson (1993) argues on the side of technology increasing capacity. He believes that the flexibility of the spectrum, the new, more efficient technologies currently coming on line, and shifts in the way that spectrum is used (for example the use of fibre optic cable for bulk voice transmissions and the reduced demand for military applications as a result of the peace dividend) all mean that scarcity "is not inevitable and could actually ease in the future". In order to take advantage of these developments, the allocation process will need to become more flexible and market oriented. Gilder (1991) also argues that, if allowed, technological innovation will overcome any spectrum scarcity, citing the example of Motorola's LAN that operates at 18 GHz. He argues that auctioning spectrum that is currently not allocated "would end, overnight, the notion that spectrum is a scarce natural resource".

The situation outside the US is also unclear. At an international level, Intelsat (1992) argues that according to its forecasts there will be a spectrum shortage in the Atlantic Ocean Region after 2008. Intelsat appears to believe that this is at least partly a result of inflexible regulation, as its proposals to alleviate the situation comprise:

- elimination of some Radio Regulation footnote constraints in the C band,
- increased flexibility as regards planned BSS and FSS spectrum in the Ku band,
- systems combining fixed and mobile applications (such as SNG) being accommodated in the higher frequencies of the Ka band.

The consultants Booz Allen (Collins, 1992) hold the opposite view. They found that, for the UK, the supply of spectrum "can reasonably be expected to exceed the demand on all reasonable forecasts over the next two decades". This is primarily expected to result from technological improvements, and Collins uses this to argue that as there is no real scarcity, at least in Europe, spectrum auctions are unnecessary.

In Europe, the ERO (1993) is studying the usage of spectrum under the Detailed Spectrum Investigation programme. It has found that "there is no shortage of spectrum bands above 3.4

GHz". Below this band, "where competition in the provision of public telecommunications has been introduced, in highly populated areas, there does appear to be problems in ensuring that spectrum is available for new networks in key geographical areas where radio systems are required to link major conurbations. Means must therefore be found to ensure that sufficient radio capacity is available to enable new entrants in the telecommunications business to compete effectively and fairly with established PTOs." However, the ERO's recommendations focus on the traditional technical approach to allocation, via increased frequency sharing, particularly between civil and defence users, and improved co-ordination within Europe. Little attention is given to economic or market based allocation mechanisms except to note that the costs of improved spectrum management should be reflected in licence fees and charges.

In their summary of the economics of frequency allocation, Benzani and Kalman (1992) suggest that scarcity is present in particular bands and geographical areas and that this is set to increase, attributable to three factors:

- rapid technical progress that has dramatically reduced the cost of radio equipment and terminals while improving their performance. While it is becoming cheaper for existing services to be sent over the spectrum rather than terrestrially, technical progress is also developing new satellite applications. The author indicate that over one third of major new IT applications for the year 2000 are expected to use the spectrum in some way,

- rapidly expanding demand for radiocommunication services. For example, the number of subscribers to cellular radio systems grew by an average of over 20% a year between 1986 and 1991,

- deregulation in telecommunications services markets, allowing increased private competition to established PTO monopoly. Without accompanying liberalisation in the upstream markets (eg. in the regulation of orbit and frequency) this has led to considerable bottlenecks. The authors argue strongly (and this is echoed elsewhere in the literature) that the existing regulatory procedures serve to stifle innovation and therefore waste resources.

Alternative Allocation and Assignment Mechanisms

In the context of the US regulatory framework, the NTIA (1991) discussed alternative market-based spectrum allocation/assignment systems. The report discussed a number of options, including:

- competitive bidding through some sort of auction process. This could be by way of a "Vickrey Auction" where the highest bidder wins but pays the second highest price,

- setting of fees. This would be "less appealing" to the NTIA than the market based approach. The level of fees could be set in a number of ways:

    - to cover administrative costs,
    - to equal "shadow prices" reflecting willingness to pay,
    - to encourage efficient use of the spectrum,

- as a percentage of gross revenue.

There have recently been some significant moves towards economic pricing mechanisms that set charges closer to the "true" cost to society (or "opportunity cost") of using the orbit/frequency resource, most notably in New Zealand, Australia and the US. In practical terms, however, implementation of such mechanisms has so far been extremely limited. The main basis for setting charges remains the fixed licence fee approach. In addition, in a number of countries the fee charged is not even related to administration costs. Coopers and Lybrand (1993) highlight the main arguments for the market pricing approach:

- it would lead to more efficient use of spectrum through encouraging:
  - applications to shift to other delivery mechanisms,
  - use of more efficient technology;
- it would generate income to governments that could be used to further promote efficient spectrum use.

In addition, NERA's (1988) report for the Government of New Zealand argued that a market based allocation system:

- decentralises decisions on the use of spectrum to the users, who have the best information,
- encourages transfer of spectrum to higher value uses, promoting flexibility.

The report also recognises that where negotiating costs are high, these benefits could be reduced. However, the report of the German Expert Committee looking at spectrum reform notes that (in Europe at least) the need for international co-operation and co-ordination limits the scope for using market pricing.

CBO (1992) compares the two main allocation mechanisms currently used in the US with auctions in terms of efficiency, fairness and revenue. Their table is reproduced below.

Licence Assignment Methods Compared

Method	Efficiency	Fairness	Revenues
Comparative Hearing	Might not assign the licence directly to the user who values it most. Secondary markets allow licence sales to the users who value them most. Consumes substantial private resources in licence-seeking activity and inflicts high administrative and delay costs on society.	Can ensure a specific distribution of licences. Legal and administrative costs of the process give larger financial interests an advantage.	Revenues limited to licence application fees. Total FCC fees for 1991 were $46.6 million, including renewals and fees for lotteries. New licence fees range from $35 to $70,000. Comparative hearing fee for a new applicant for land-mobile services was $6,760 in 1991.
Lottery	A random process unlikely to assign the licence directly to the user who values it most. Secondary markets allow licence sales to the users who value them most. Less prone to delay than hearings, less prompt than auctions.	Allows all applicants equal opportunity if they can pay the application fee. By awarding licences to applicants who do not intend to provide services, grants lottery winners a windfall not shared by the public.	Lottery revenues are included in totals noted above. Fees for specific lotteries can be substantial. The digital electronic message service lottery, the 220-222 MHz filing of 1991, drew 60,000 applicants and total fees of $4.4 million.
Auction	Is likely to assign the licence directly to the user who values it most. Should assign licences more quickly and at a lower cost to society than alternatives.	Gives taxpayers a share of spectrum rents. Can be structured to accommodate small bidders.	CBO estimates an auction of 50 MHz of spectrum for two additional land-mobile licences could generate between $1.3 billion and $5.7 billion in fiscal years 1993 through 1995.

Source: Congressional Budget Office

CBO (1992) estimated that auctioning two licences, each of 25 MHz, to advanced land mobile services could raise $1.3 billion to $5.7 billion. The report summarises the main arguments for and against spectrum auctions as follows:

For:

- economic efficiency: the licence goes to the user who values it most. They can be administratively easier, have lower transaction costs and be quicker than other options,

- fairness: licences often bestow monopolistic powers to the holders. Auctions allow the Government to cream off monopoly profit, reducing the level of windfall gains.

Against:

- public goods: auctioning may inhibit the provision of essential services such as public safety and defence,

- focus on revenue: using auctions merely to generate revenue can act against economic efficiency as Government has an incentive to limit competition in order to increase the value of the licence being auctioned and therefore its revenue take,

- market failure in the telecommunications sector: the existence of widespread market failure means that conventional economics assumptions break down, which could negate the potential benefits.

The recent focus on auctions as a means of allocation/assignment has led to considerable interest and literature on the subject, although little of this is backed up by empirical analysis. NERA (1988) recommended a system of tradeable spectrum property rights "wherever there is good reason to consider that the result and efficiency gains will be significantly greater than any potential increase in administration, transaction and enforcement costs". In particular, they recommended that for New Zealand, spectrum should be distributed by (Vickrey) sealed bid auctions, with a hand over period of up to three years in cases where there are existing users. During that time existing users were to pay annual licence fees that could either cover administration costs or reflect the opportunity cost of the spectrum. However, Coopers & Lybrand (1993) note that the system has failed to achieve expected levels of revenue. In a large part this can be attributed to political pressure from incumbents, which extended their rights from three years to 20 and achieved annual licence fees at a more favourable (ie lower) rate than had originally been intended.

In the US new legislation provides for the reassignment of some frequencies currently reserved for Federal Government use. This is to be done through competitive bidding, as the procedures currently used (lotteries and comparative hearings) "can be expensive and time consuming, can strain the limited resources of the Federal Communications Commission, and can result in an inefficient distribution of spectrum and an unjustified windfall to speculators" (US Government, 1993a).

The costs and benefits of auctions are also discussed in Macauley (1984), Hazlett (1992), Collins (1992) and US Government (1993b) among others.

LDCs

Levin (1990) explicitly models the costs of being a latecomer to the industry. Although this analysis was in the context of the LDCs, it could also be applied to new entrants in a deregulated market. He modelled a cost function (where output was defined in terms of "transponder years") and found that latecomers were handicapped by less convenient frequencies, higher power requirements, a need for new equipment (losing out on economies of scale), high R&D costs and increased cost of coordination with existing operators.

Jussawalla and Tehranian (1993) argue that LDCs can benefit from their latecomer status, by "leapfrogging" the developed world in accessing the most advanced technology (see also Abramovitz (1986)) developed in the West. They cite among others the examples of India, Brazil and Mexico, which are using satellite technology to improve domestic telecommunications, as well as AsiaSat, which "provides a host of developing nations with advanced satellite technology at an affordable price." The latter in particular is an example of investments made by developed countries to enable them to access LDC markets. This is part of a growing trend made possible in part by falling costs of technology and by the increasingly global nature of communications markets. Such developments are in line with modern economic theories of investment which suggest that new investment will take place so long as its market value exceeds its cost.

2.1.5 Conclusions

The general conclusions from the survey are as follows:

- the original terms of reference for this study emphasised the innovative nature of the task. This is reflected in the sparsity of the literature in this area. Little work has been carried out on the economic evaluation of orbit/spectrum, although a number of studies have focused on specific aspects. The techniques used also tend to vary considerably, generally being developed to address specific problems (such as market entry when there is a natural monopoly, or the value of a particular orbit slot),

- very little quantitative analysis was identified. This is true even of the most recent literature. The modelling approaches adopted a variety of methodologies, including comparative utility analysis, probability analysis, estimation of cost functions and more pragmatic market forecasting. None of these are considered to be directly applicable to the current problem, although similar techniques might be applied in specific areas such as preparing market forecasts. Other sources that promised to investigate the impact on consumer welfare of market deregulation were largely qualitative, describing alternative "models" and discussing their likely implications for the industry,

- all the literature emphasised the rapid change in technology that characterises the industry. The main developments are described in Section 3 below. However, a key implication for modelling purposes is the need for careful specification of the baseline case against which alternative policy scenarios will be evaluated,

- the satellite industry is extremely complex. In addition to the technological change highlighted above, there are market failures, such as the high level of concentration in the provision of transponder capacity, the participation of competitors (the PTOs) as shareholders in the main providers of transponder capacity, and the degree of technical regulation and government ownership. This is reflected in the wide range of possible deregulatory scenarios that have been covered in the literature. In order to ensure that the results of this study are properly focused, the scenarios to be considered will need to: be clearly specified; avoid complex combinations of regulatory change (which are difficult to model and for which it will be hard to disentangle the welfare effects); be relevant to the current policy debate; and be limited to a manageable number. A number of general possibilities are identified in the literature. However, the final specification will need to take cognisance of the existing regulatory initiatives being promoted by the Commission and other such as the European Radiocommunications Office (ERO),

Overall, the analysis of the literature suggests that the approach adopted will need to be based on sound economic concepts, straightforward to model and bear in mind likely data limitations.

2.2 National Satellite Regulations - Some Examples

2.2.1 Introduction

This section briefly reviews the current system of regulation at national level for a sample of countries, focusing on access to the space segment for the provision of satellite services. More detail on the international regulatory framework for provision of space segment is provided in Section 4 and on regulation of particular services (radio, telecoms, etc) in Section 2.3.

Western Europe

- CIT Research (1992) describe the regulatory situation in Europe. Their summary table is reproduced below. Overall, Germany, France and the UK are viewed as being the most liberal, with the Netherlands "not far behind". In other countries the PTO has monopoly rights to the provision of satellite services;

- selection of operators is most commonly on a first come first served basis, although methods vary according to type of service. For most member states, the process by which decisions are made is not in the public domain;

National Regulations for Satellite Communications

	Receive Only Terminals	One-way Services	Two-way Services
Germany	PL	PD	PD
France	PL	PL	PL
UK	P-	PL	PL
Italy	M	M	M
Spain	PL	M[1]	M[1]
Portugal	PL	M[2]	M[2]
Sweden	PL	PL	PL
Norway	PL	M	M
Denmark	PL	M	M
Finland	PL	M	M
Netherlands	PL	PL[3]	PL[3]
Belgium	PL	M[4]	M[4]
Luxembourg	PL	M	M
Switzerland	PL	M	M
Austria	M	M	M
Greece	PL	M	M
Ireland	PL	M[5]	M

M Monopoly of telecommunications organisation
P- Private supply without licensing, type approval or coordination
PD Private supply subject to a declaration to the national regulatory authority
PL Private supply subject to licensing, type approval or coordination

Notes:

1 Legislation is pending that will grant licences on the basis of an administrative authorisation.

2 Satellite links are not permitted for private installations. However, if CPRM is not able to provide leased circuits that offer the same standard of service, exceptions to this rule are made.

3 Anyone can now apply for a licence for fixed services but this is subject to interim rules and will not become law until 1993.

4 Exclusive rights are due to expire at the end of 1992. The licensing procedure will then consist of a declaration to the Belgian NRA.

5 Telecom Eireann has exclusive rights in the provision of national services and is licensed to provide international services. However, competition in the provision of national or international services is not precluded by legislation.

Source : Reproduced from Communications and Information Technology (CIT) Research Ltd

- UK: there is increasing deregulation in telecommunications markets. Seven companies (Specialised Satellite Service Operators (SSSOs)) have been licensed to provide satellite communications services (in addition to BT and Mercury). Licences were granted for 12 years. While the licensee may make its own arrangements for accessing "separate systems", Intelsat and Eutelsat space segment can only be accessed via BT, the Signatory. The SSSO licence was replaced with a broader Satellite Class licence in 1991, which allows any operator to provide any kind of satellite link not connected to the PSTN. Two licences permitting limited international telecommunications were issued in 1992;

- Germany: relatively deregulated. Germany allows a private company to install, operate and own a two-way VSAT network. Licences to provide satellite services are obtained from the Ministry. Space segment capacity can now be obtained from other (ie, foreign) Signatories than DBP Telekom. Four EC Member States -- Germany, the UK, France and the Netherlands -- now permit Eutelsat space segment to be provided in their territories by the signatories of all four countries. By April 1992 there were 26 operators licensed to provide one and two way satellite communications services. "Private voice" links and connections to the PSTN are evaluated on a case by case basis as to whether they threaten the DBT monopoly. Twelve such licences had been granted by April 1992;

- Luxembourg: at least in the case of SES-Astra, international satellite broadcasting is encouraged, but telecommunications services remain a PTT monopoly. Private uplinking of voice, data and video is subject to prior approval. Luxembourg PTT owns the uplinks to Intelsat, Eutelsat, PANAMSAT and DFS-KOPERNIKUS;

- France: there is a move to relating costs of telecommunications services to the actual cost of service provision. France opposed the liberalisation of the market for terminal equipment. Previously only France Telecom was allowed to provide uplink services on voice, data or video, although it could licence private operators (it did this for VSAT services). Subsequently the Directorate for General Regulation has issued 10-year licences to a number of operators to provide two way VSAT services.

USA

- generally regarded the most liberal (regulatory system) in the world. There is an elaborate consultation process. FCC (responsible for commercial services) undertakes extensive public notice and comment proceedings to determine allocations and assignments under a public interest standard and has private sector advisory committees on specific issues.

- licences to provide certain services (radio paging, cellular) are allocated either by comparative hearings or lotteries. Current legislation allowing reassignment of some federal spectrum to commercial use, stipulates auctions.

- licensing systems are very open. Domestic earth station licences are only necessary if owners wish to ensure protection from interference. Domestic uplink authorisation is routine, based on technical characteristics. However, foreign ownership of certain types of licences (eg radio) is restricted;

New Zealand

- broad property rights to spectrum are allowed. 20 year licences are sold by auction, although revenues from those auctions that have taken place (broadcasting and mobile communications) were lower than expected. Incumbents have 20 year grandfather rights and low administration fees. Some spectrum remains reserved for non-commercial uses, eg, aeronautical, navigation, astronomy. The regulator consults widely with broadcasters, network operators and telecommunications service providers;

- as a result of the 1989 Radiocommunications Act:

  - Government can create nationwide property (known as "management") rights for spectrum;
  - these can be transferred to private ownership;
  - licences are tradeable, technically specific but not purpose specific;
  - existing systems are "grandfathered";
  - licensing is via sealed-bid, second price public tender;
  - no specific due diligence provisions, but existing anti-trust legislation may be invoked to prevent "hoarding";

- all types of antennae (television and data receive-only, interactive VSATs and major uplinks) can be privately owned and operated for both domestic and international services, with no foreign ownership restrictions.

Australia

- 1992 Radiocommunications Act introduces a radical market system, creating new property rights over spectrum and providing for auctions of concessions on parts of the spectrum;

- the regulator consults with user groups, manufacturers associations and manufacturers themselves and other Commonwealth Government departments;

- prior to 1992 based on the 1991 Telecommunications Act, any person or company (there are no foreign ownership restrictions) could own a receive only or two way earth station and operate a domestic or international service, provided that they comply with the Service Providers Class Licence. Licence fees were based on the usage of transponders by that service.

Canada

- some licences are awarded on a first come first served basis. Where the number of licences needs to be limited, an "administrative comparative" approach is used which comprises a public invitation to tender. Selection criteria are developed on a case by case basis and tenders are evaluated by the regulator. The regulator consults widely with the industry, user groups, manufacturers, the public and within government;

- Telesat Canada is the monopoly operator of the domestic space segment, Teleglobe Canada has a monopoly on overseas satellite services. There is competition between service suppliers for domestic satellite communications;

- no licence is needed for receive only earth stations for television or data, but no protection from interference is provided. Two way VSATs must be licensed (only available to Canadian citizens or companies incorporated in Canada) and services must conform to published technical and safety standards.

Japan

- licences are awarded on a first come first served basis. Charges are designed to cover administration costs;

- TVRO (and reportedly data receive only) earth stations can be owned and operated by any individual. Users of satellite networks are not allowed to own their earth stations. Companies need a licence to own and operate an earth station;

- all types of domestic service are generally liberalised but international services are restricted to licensed international carriers;

- the regulator holds consultations with the Radio Regulatory Council, a "group of experts".

2.2.2 Current developments and future trends

The OECD's Committee for Information, Computer and Communications Policy has an ongoing research programme into the economics of frequency allocation. An Issues Paper (OECD 1992) highlights the key policy issues for its member countries, and notes that "while there is general agreement that the practice of "first come first served" cannot be sustained ... there is little consensus on what allocatory methods should replace it".

The paper demonstrates that economic theory is beginning to have a greater role in the satellite communications policy debate and provides an indication of the direction of current thinking. However, it also illustrates the wide divergence that exists between different countries on a range of fundamental issues, which suggests that there is a long way to go before such policies are widely accepted and implemented. OECD members generally agree that:

- the spectrum has considerable market value,

- spectrum management should be separated from the operation of services provided over it,

- nations should co-ordinate spectrum management policies,
- the spectrum plans should be reviewed regularly, with open consultation.

However, there is only partial agreement as to whether:

- spectrum management should be administered on a cost recovery basis,
- the price of spectrum should reflect true market value,
- policies should cover spectrum allocation and its recovery.

Other areas that are still under discussion include:

- incumbents should be compensated if required to give up or shift spectrum use,
- spectrum should be assigned by competitive bidding,
- licences should be tradeable,
- licences should have renewable time limits.

2.3 Review of Analogous Regulatory Environments

2.3.1 Introduction

In this section we outline the regulatory frameworks in place for a number of industries in which a variety of methods are used to allocate scarce resources. In some industries pricing is used in order to reach a market equilibrium whereas in others the price mechanism is not used at all. There is a number of approaches to allocating resources, some of which have differing objectives, ranging from economic efficiency through to equity. Ownership and transferability of ownership of rights to produce, or rights of access to a service are also important. For example, a government may own a resource and then allocate it for free on a first come first served basis (like the National Health Service in the UK or motorways in Germany), or it may give the resource to the highest bidder (as in the franchise monopolies for regional terrestrial television in the UK). In broad terms the approaches include:

- no regulation - the market is left to its own devices. If the market is freely competitive and there is no market failure then the outcome gives rise to a market clearing price which is economically efficient. No consideration is given to equity,
- regulation - this can range from regulation of the structure of the market (number of players) through to the conduct of the players (pricing principles) in the market or a combination of both.

We now consider some of the regulatory frameworks in operation in a variety of industries.

2.3.2 Roads

In the UK and Germany, most roads are publicly owned and typically prices are not charged for road use. There are some restrictions on the types of vehicles allowed on certain roads, however. Depending on demand for use, congestion results on some roads. Clearly, this is costly to road users in terms of time wasted and also maintenance costs are high. Some argue, particularly in heavily congested areas such as city centres, that the pricing mechanism ought to be introduced or, in some cases, that cars should be prohibited.

2.3.3 Independent Radio

The Radio Authority regulates Independent Radio (IR) on AM and FM in the UK. IR is composed of Independent Local Radio (ILR) and Independent National Radio (INR). Licences to broadcast are awarded as follows:

- **ILR** - licences are advertised by the Radio Authority. Applicants submit an application which contains details of programming, technical specifications including population coverage and a business plan. The licence for each locality is awarded on the basis of the proposed programming and technical competence. No cash bid for the licence is charged but an annual payment to the Treasury is required. Licence duration is 8 years, and

- **INR** - as for ILR except coverage is national and the licence is awarded to the highest bidder.

In both cases the companies that own the rights to broadcast can be taken over (if they are tradeable companies), ie. ownership can be transferred on the stock exchange. However, once the right to broadcast is given, it is owned by the incumbent for eight years. There are restrictions on the number of ILRs and INRs one company can own.

In France in the mid-80s, there were virtually no restrictions on radio licences. For a time, there was a period where there was lots of overlaying (and hence interference) of local stations. The industry is now regulated and the problems have been alleviated. Nevertheless, there is as a consequence a large number of radio stations.

2.3.4 Terrestrial Television

In the UK, the Independent Television Commission (ITC) awards regional franchises to companies to provide regional television broadcasting (Channel 3). Once awarded, the duration of the franchises is ten years - essentially a monopoly in regional television. Take-overs are allowed after the first year of operation. There are two stages to the process: a strict quality threshold is to be crossed firstly, followed by a cash bid. The franchises are awarded to the highest bidder. A percentage of revenue is paid as a fee in addition to the cash bid. There are restrictions on the number of C3 franchises one company can own and on cross-media (newspapers, for example) ownership.

Channel 5 (one station with national coverage) licences have been advertised (same lines as C3), although the ITC is currently reconsidering Channel 5 and no franchise has been awarded as yet. Little interest was shown in C5 owing to the high costs associated with ownership of the right to broadcast. The main cost to the broadcaster was the cost of re-tuning video recorders. Furthermore, consumers would have had to purchase special aerials to receive the channel. Given the competition from existing terrestrial television and the growing penetration of many satellite channels, C5 was perceived to be a high risk venture. The ITC has thus put the concept on hold and is rumoured to be investigating the availability of alternative frequencies with no technical cost penalties for the broadcaster.

In France, Canal Plus was given a monopoly right to supply pay terrestrial television in exchange for certain obligations to invest in French films.

2.3.5 Cable TV

Cable TV licences applications in the UK are awarded on an area basis which is defined in terms of thousands of population. Applications are judged on the basis of quality, household coverage, financial backing and business plan. No cash bid is required. Once the licence is awarded, the successful company has a monopoly on cabling in the area.

2.3.6 Airport Landing Slots

Peak and off-peak pricing is used to charge for European airport landing slots, with the peak price being around three times the off-peak price. However, the right to these slots is largely determined by *grandfather rights*, that is those who have historically enjoyed the right, continue to do so, with transfers happening only when companies are taken over. Airports have a scheduling committee (comprising the airlines) which deals with re-scheduling twice a year. If a slot becomes available then who ever asks for it gets it. Priority is given, however, to grandfather rights. The right to take-off and land is independent of the origin and destination of the flight. There is no trading of airport landing slots. This contrasts with the US where landing slots are traded.

2.3.7 Airline Routes

Airline routes between countries are regulated by bilateral agreements, so called airline services agreements (ASAs). The ASAs are agreed by governments in relation to number of seats/flights per week. A government will nominate one or more airline for a route subject to airworthiness, quality and so on. Once set, these routes last indefinitely. In order to have the right to fly an existing route, a company would have to take over the incumbent. Within countries routes are determined according to individual domestic policy. ASAs specify:

- the airlines to fly on the route,
- the capacity each airline will offer,
- the capacity third party airlines will offer.

Domestic routes were deregulated in the US in the late 1970s and in the UK during the 1980s. The UK negotiated a relatively liberal ASA with Benelux and limited pro-competitive agreements with Germany and Switzerland. At that time, those countries which were most hostile to deregulation were Denmark, Italy, Portugal, Spain and Greece. Council regulation (EEC) No 3976/87 exempts certain air transport practices from the application of EC competition law (ground handling services, computer reservation systems, joint planning/co-ordination of capacity, revenue sharing, tariff consultations and slot allocations at airports). The long-term aim of the EC, however, is open competition in airline transport services. Member states are in the process of deregulating the industry.

Note that whilst one of the aims of airline regulation, to curb the abuse of market power, is applicable in the US and the UK; in other countries this typically has not been the case. Indeed, the regulatory regime in operation has aimed to protect the finances of the domestic (typically state-owned) airline rather than the interests of the consumer. Ironically, despite deregulation, owing to the high fixed costs, uncertain running costs and the "grandfather" approach to slot allocation, deregulation has not in general led to a sustained competitive environment in the relevant air transport markets. These areas are under review by the Commission.

2.3.8 Utilities

In the UK, the utilities (gas, electricity, telecommunications and water industries) are privatised. Where feasible and desirable competition has been introduced (eg in generation of electricity and non-local telephone calls) and where there are natural monopoly characteristics, conduct regulation (of prices and quality of service) prevails.

Whilst the characteristics of the industries do differ, there is a number of common features within the regulatory regimes:

- price control and quality of service regulation are used to curb monopoly power and protect consumers - where possible competitive market behaviour is mimicked,
- the utilities are obliged to supply all who have a reasonable demand for the service,
- licences to supply the services are for long periods (25 years), and
- regulators aim for tariffs that are related to costs.

2.3.9 Radiocommunications

In the UK, the Radiocommunications Agency (RA) is responsible for most civil radio matters. It seeks to ensure that the radio frequency spectrum is used in ways which maximises its contribution to social and economic welfare, while having regard to the safety of life factors. Licences are charged for on an annual renewable basis, and are designed to cover the administrative cost of radio regulation, rather than the actual cost incurred in issuing a particular licence.

2.3.10 Summary of Relevant Issue

The above discussion has indicated a wide variety of market and non-market mechanisms which are used in resource allocation in a range of industries. Issues raised in this discussion which are relevant to considering regulatory options applicable to the regulation of GSOSR include:

- what sort of mechanism should be used to assign orbits and frequencies? If price is used, should it be set with rights to the resource determined on a first-come-first-served basis, or should rights be determined via some bidding process?

- to what extent, and in what manner should the behaviour of holders of the rights to use orbit and spectrum resources be regulated?

- what should be the duration of spectrum and orbit rights?

- once a right to use GSOSR is conferred, should it be transferable?

The regulatory scenarios developed in this study represent approaches to introducing some notion of economic efficiency into the management of GSOSR. They are intended to suggest alternatives to the existing first-come-first-served and "equitable" planned basis for resource management.

3 Technology Trends

3.1 Introduction

This summary is intended as an introduction to the history and development of satellite technologies. It places particular emphasis on the impact of these technologies on the key physical resources used in satellite communications; the orbital slots into which satellites are placed, and the radio frequencies (and associated bandwidths) by means of which they communicate. However, it is important to note the link between the two, since a communications satellite is inextricably linked with a set of radio frequencies, and can thus be regarded as a single resource.

The key technologies and the trends in those technologies (both current and future) are discussed, focusing on satellite orbits, signal processing techniques, intelligent satellites and broadband services. The effects of these technologies on the orbit and frequency resources will also be assessed. A fuller discussion of these issues is to be found in Appendix 2.

3.2 History

The worldwide satellite communications infrastructure was originally developed by Intelsat during the 1960s, and provided a limited number of telephony and TV channels. Communication was entirely between PTOs (the signatories to Intelsat), with national distribution by the relevant PTO. Satellites increased in number and sophistication during the 1970s, and spectrum efficiency was improved by the use of "dual polarisation". It became possible to lease a transponder from Intelsat and this allowed private networks to be created, though country distribution was still typically carried out by the PTOs.

The 1980s saw an exponential rise in the use of satellites and the range of services supported, notably for domestic US applications but also internationally. Data services were developed, and earth stations were increasingly located on customers' premises. The rise of regional systems, such as Eutelsat and Arabsat, increased pressure on both orbital slots and the radio spectrum. Inmarsat became operational in 1982, and now offers a range of mobile communication services.

Satellite TV broadcast direct to home (TV-DTH) services and business/VSAT services also proliferated during the mid to late 1980s.

The 1990s are likely to see the rise of low- and mid-earth orbit (LEO and MEO) satellites, which will decrease the pressure on orbital slots in the geosynchronous orbit, but which will only serve to increase the pressure on the RF spectrum.

3.3 Resources

There are two physical resources which limit the worldwide capacity for satellite communications. These are :

- the potential orbits for satellites
- the frequencies used to communicate with the satellites, the available range of which is limited by technology (the techniques for exploiting higher and higher

frequencies require constant development) and physics (only certain frequency ranges penetrate the earth's ionosphere).

The dominant orbit for communications satellites has always been the geosynchronous orbit (GSO), a unique ring located some 35,000km above the Equator. This orbit allows a satellite to remain apparently motionless relative to any point on the Earth's surface. Technological constraints have meant that satellites in this orbit cannot be placed less than 2° apart, thus severely limiting the potential number of orbital slots. This is particularly the case in popular positions, such as those best suited to serving the US and Western Europe.

This situation may soon be eased by the growing trend towards the use of LEO and MEO orbits, in which the coverage of a single GEO satellite is provided by a constellation of many satellites (which, since they are not geosynchronous, are best suited to polar and near-polar coverage).

Although the pressure on the orbit resource will be eased by the use of LEO/MEO satellites, this will not affect the problem of the crowded RF spectrum. Satellite communications uses the microwave frequencies, from 0.9 Ghz upwards. However, not all frequencies above 0.9 Ghz are available, since the earth's ionosphere is impenetrable at many frequencies. There are a number of windows, and these windows (bands) are named and divided between civil and military satellite communications. The bands used in civil satellite communications are:

- L band (1 - 2 Ghz), which is used for mobile services;
- S band (2 - 4 GHz), which is used for mobile services and for telemetric control of the satellite itself
- C band (4 - 6 GHz), which is used for general telecommunications services;
- Ku band (10 - 14 GHz), which is used for both general and broadcast telecommunications services;
- Ka band (20 - 30 GHz), which is used for general telecommunications services.

Exploitation of higher frequencies is the subject of research. As frequencies increase, so the signals are increasingly subject to fade, so that the exploitation of higher frequencies is highly dependent on the development of fade countermeasures (FCMs).

The allocation of frequency bands to services is carried out by World Administrative Radio Conferences (WARC). WARC '92 allocated bandwidth to LEO/MEO mobile satellite services (such as Motorola's proposed Iridium system) and to satellite sound broadcasting.

RF signals must be modulated if they are to carry data. The two principal modulation schemes currently in use are variations on Phase Shift Keying (PSK):

- Binary PSK (BPSK) offers the best resilience to phase noise but is not as spectrally efficient, as it offers lower transmission speeds, as other schemes. Quadraphase PSK (QPSK) offers double the spectral efficiency of BPSK but is more sensitive to phase variations and additive noise. Consequently, it is more difficult and expensive to implement.

More spectrally-efficient modulation schemes are now being developed, in particular for use in broadband transmission and for mobile communication with LEO/MEO satellites.

Older, analogue technology (both on board satellites and in earth stations) does not make efficient use of the portion of the spectrum allocated for a particular transponder. This is being addressed by means of Digital Signal Processing (DSP) techniques which will allow better performance and a degree of flexibility in changes between modulation schemes.

Finally, a large proportion of the RF spectrum has been allocated to users who do not make full use of it; in particular the blocks set aside for military use are not always efficiently used.

3.4 Technologies

The principal satellite communications services and selected key characteristics, are as follows:

- Telephony services, which are likely to become more prevalent because of a number of technical advances:

  - DSP techniques and VLSI implementation will reduce the cost of the earth stations;

  - digital compression techniques reduce the bandwidth required from what was once 64 kb/s to (currently) 16 kb/s, with a potential reduction to 2.4 kb/s for mobile communications;

  - digital speech interpolation (DSI) further reduces the bandwidth required for the transmission of speech by removing the redundancy, the gaps, from the speech.

  Taken together, these factors have the potential to make satellite telephony a viable option. The proposed LEO/MEO personal telephony networks, such as Motorola's Iridium, will all use a handheld earth station. This is in contrast to the current telephony networks, which require a much bulkier earth station, so that their mobility is limited.

- the well-developed terrestrial telephony infrastructure in developed countries clearly limits the potential of satellite telephony, so that its principal application in those countries is in rural development. Another potential use of satellite telephony is in links with areas where the terrestrial infrastructure is far less developed, such as links with Eastern Europe or Africa. However, these limited uses meant that Europe and Japan, with their limited rural development opportunities, were opposed to the allocation of bands to LEO/MEO satellite telephony systems at WARC '92,

- Direct to home (DTH) -- or Direct Broadcast Satellite (DBS) -- television services, which currently generate more than half of European satellite communications revenue. These services have seen a phenomenal growth since the beginning of the 1980s, and although some observers hold that their dominance is set to decline (to about a third of the total European revenues), they will still grow significantly over the next ten years,

- the Multiplexed Analogue Component (MAC) system has been introduced experimentally as a replacement for the older PAL system. There are two European variations of the system, D-MAC and D2-MAC (which uses half the bandwidth of D-MAC, with some sacrifice of picture quality). Although D- and D2-MAC have some digital characteristics (notably digital sound and digital data), they do not offer digital TV, as the signal is still transmitted using FM. Although "pure" digital television is not yet available via satellites, SES-Astra is planning to introduce a 180-channel television satellite, using digital compression techniques, during the mid-1990s,

- although pure digital TV via satellite is likely to be commercially available by 2000, it is debatable what impact it will have; since most TV transmissions are either to cable heads (for distribution via cable) or direct to home, existing standards (PAL, D-MAC) will be preserved for a significant time to come, and it is likely that initial users of digital TV will be limited to specialised uses, such as satellite news gathering (SNG), video conferencing, distance learning and business television,

- the introduction of digital radio broadcasting, using the Digital Audio Broadcasting (DAB) standard, is likely to be slowed by the same problem of existing standards. Thus the digitisation of television and radio broadcasting is unlikely to have a significant effect on relieving pressure on the RF spectrum over the next ten years,

- data; business services have been available since the early 1980s, using Very Small Aperture Terminals (VSATs) for both one-way and two-way data communications. Although the resources dedicated to business services comprise a small proportion of the total at the moment, this sector is poised to experience the greatest growth over the next ten years,

- broadband services, currently under development, are an important target. They will allow the integration of telephony, TV and data into a single, digital service, thus achieving the emerging objective of multi-service support by a single transponder,

- broadband services will require support for the ATM and SDH protocols, which will require significant development in the areas of modulation and coding.

The evolution of new satellite services has been supported by a number of technological developments:

- earth stations have undergone major advances, particularly the RF portion. However, in bands above Ku band, there has been very little development, which clearly needs to be redressed if the higher frequency bands are to be exploited in the future,

- Circuit Multiplication Equipment (CME), which allows a greater number of circuits to be carried within the same bandwidth by means of compression techniques,

- Access Schemes, which allow multiple users to access the same satellite transponder, in particular the development of co-ordination and networking techniques for constellations of LEO/MEO satellites.

3.5 Future Trends

There are a number of technological trends which will have an influence on orbit and frequency resources, principally in the following areas:

- digital signal processing (DSP) makes efficient use of the RF spectrum allocated, thus making available significantly greater potential bandwidth at a stroke,

- the use of LEO/MEO satellites will greatly reduce the pressure on the orbits resource, but will only serve to increase pressure on the RF spectrum,

- new modulation techniques currently under development will considerably improve spectral efficiency, in terms of the bandwidth required to carry a certain throughput of data,

- on-board processing (OBP) will allow satellites to exist in a higher interference environment, so that they can be placed in closer orbits (allowing GEO satellites, for example, to be placed closer than 2° apart), thus increasing the potential number of satellites and therefore the pressure on the RF spectrum,

- inter-satellite links (ISLs) will allow communication between satellites, thereby reducing the number of satellites necessary and so easing the pressure on the RF spectrum. ISLs, which will also rely on developments in OBP, are likely to have most impact on LEO and MEO satellites.

The main technological development is, of course, digitisation of transmission for RF services (*e.g.*: DAB and digital HDTV) leading to a convergence of telecommunications, broadcasting and other services. Such convergence would be supported by means of broadband ATM/SDH protocols, though the full bandwidth required to support ATM is not expected to be available for at least ten years.

This convergence calls into question the concepts of separate service categories applied in current regulatory frameworks. Often technology evolution and market-led developments combine to demolish these artificial barriers, the classic example being the use of the FSS bands for DTH satellite TV broadcasting and the consequent convergence of the FSS and BSS service types.

There are some limitations to this convergence. Satellite transponders that come into service over the next ten years will offer increasing OBP capabilities, so that increasingly complex personal telephony and business/data services can be supported with ease. However, the use of such sophisticated transponders is not justified for TV-DTH and DBS services, and so they are likely to remain separate, leading (in the short/medium term only) to specialised transponders; some specialised for TV, others for integrated (broadband) services. In the longer term, with increased market penetration of digital TV services and sets and their consequent integration with personal telephony and business/data services, the use of sophisticated transponders for TV will become justified since the TV signal will require only a fraction of the (integrated) bandwidth.

Therefore, the convergence of TV and, to a lesser extent (due to the lower capital investment in equipment) radio with other satellite services is likely to be well behind the technical capability, and is not likely in the next ten years.

3.6 Summary

It can be seen that there is increasing pressure on both orbit and frequency resources. Although exploitation of LEO/MEO orbits will decrease the orbital slot pressure, the problem of scarcity of RF spectrum is not going to go away; it can, however, be eased by suitable application of technology such as:

- DSP techniques which will allow efficient use of the RF spectrum,
- allocated digital compression which will increase the number of circuits that can be carried within a certain physical bandwidth,
- new modulation techniques which will further increase spectral efficiency, making broadband technologies such as ATM and SDH feasible.

Against such technological developments can be set the growing importance and acceptance of standards. This is likely to slow down the introduction of innovative technology. The convergence of satellite services, using broadband technologies and the digitisation of TV and radio, may eventually greatly simplify the Radio Regulations by removing the distinctions between services. However, this is a long term aim, since it is unlikely that broadcast TV will converge in the next ten years. Until it does, the best that can be hoped for is the convergence into two types of service; TV and the rest. The one exception to this is the "occasional" user of TV, such as SNG, which will go digital in the short term (since there is no existing standards base which must be supported), and so can converge with the other digital services.

In addition there is the development of LEO and MEO systems which whilst relieving pressure on orbit slots, is unlikely to relieve pressure on the spectrum.

Increasing pressure on GSOR is being affected by a number of technological factors. Most of the pertinent new technologies are expected to be in use in the late 1990s-2000.

4 Existing Regulatory Environment for Assigning GSOSR

4.1 Introduction

The existing system for regulatory access to, and use of, GSOSR involves procedures which are predominantly administrative and technical in nature, rather than economic. Just because there is no economic rationale behind the regulations, however, does not mean there is an absence of economic effect. Indeed, the lack of consideration of economic factors not surprisingly leads to economic inefficiencies and market distortions. The nature of the economic inefficiencies are considered later in this report, as are optional modifications to the existing regulatory system that should improve the economic efficiency of accessing and using GSOSR. Before covering such issues it is important to outline the nature of, and key issues associated with the current regulatory regime.

Consistent with basic principles of public international law, the assignment of internationally allocated bands to specific systems is a role played by national administrations. Generally speaking, the main constraint on accessing GSOSR is not the availability of orbital "parking slots" in the GSO, but rather the requirement that national assignment of internationally allocated bands of satellite spectrum shall not interfere with the operation of previously implemented or registered systems. An overview of regulatory institutions and procedures affecting the use of GSOSR is given in Figure 4.1. Each of the regulatory procedures identified in Figure 4.1 is elaborated on in this section.

Most observers have generally concluded that the available GSOSR is steadily diminishing in concert with growing demand, and it is hypothesized that prospective deregulation of European satellite communications portends a new explosion of pent-up demand for access to such resources. The economics of GSOSR access are influenced at least as much by regulation as by the laws of physics. But very few existing legal arrangements or policy trends, such as sub-regional systems planning, suggest specific possibilities for a European approach to relieving pressure on GSOSR. In the absence of extremely favourable impacts of relevant technological developments, existing pressure on GSOSR is likely to become worse before it gets better.

In the following sections there is more detailed examination of the main regulatory issues impacting access to, and use of, the GSOSR. Section 4.2 examines legal and policy matters limiting the supply of GSOSR to Europe. Existing "supply-side" constraints are examined at the level of public international law of satellite communications as well as from the standpoint of national and Community law and policy. Section 4.3 looks at the European GSOSR "demand-side" issues from the standpoint of public international law as well as from the standpoint of national and European Community law. Section 4.4 provides concluding remarks.

Figure 4.1 Regulation of GSOSR - An overview

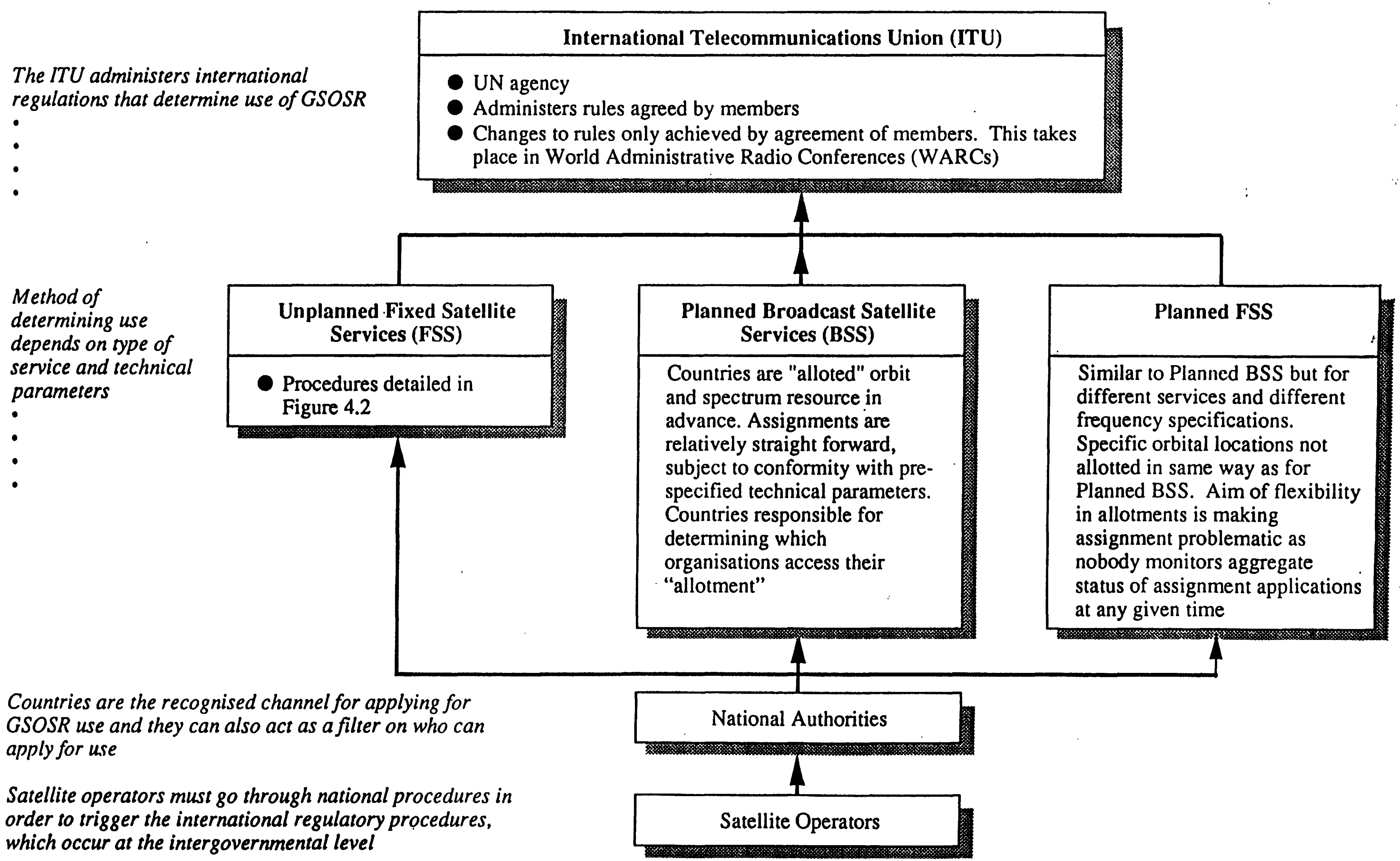

Figure 4.2 Summary of GSOSR Procedures

Unplanned FSS

STEP 1

A proposal is formulated at national level for provision of new space segment (ie: access to the resources required to provide satellite services). The technical and administrative criteria specified by the ITU are included in the proposal.

In some countries the proposal may only be initiated by a limited range of organisations, such as the TO. In other countries a broader range of commercial organisations can initiate proposals.

STEP 2

Proposals are submitted to national authorities who may just pass them on to the ITU (IFRB) or undertake an initial evaluation of the proposal against national criteria.

STEP 3

On receipt at the ITU the proposal is "advance published". It is then circulated to all other national regulatory bodies for "coordination". The coordination procedure essentially allows countries to review the proposed new satellite service against their own existing or intended uses of GSOSR. This review covers only the issue of radio frequency interference with existing satellite or terrestrial systems, or those already proposed to the ITU. If a satellite system under the jurisdiction of a country has been given "advance publication" but does not exist it will be included in the review. The date of "advance publication" provisionally provides protection against interference from systems subsequently going through the ITU procedures.

Figure 4.2 Summary of GSOSR Procedures (Continued)

Unplanned FSS

STEP 4

Objections to the proposal are made by national authorities on the basis of prior recorded or registered assignments with which the proposal might interfere

STEP 5

Negotiations commence between the national authorities sponsoring the proposal (with representation from the organisation initiating the proposal) and each of the national authorities raising objections. This process of negotiation can take several years

STEP 6

If negotiations are successfully concluded then the system's "assignment" may be registered with an ITU institution known as the International Frequency and Radio Bureau (IFRB) in its "Master Registry". Protection against interference from other systems then becomes unconditional. The period from "advance publication" to registration can be up to six years

STEP 7

Some implementation of the system must take place within three years of registration. Partial implementation is sufficient to secure the entire resource specified in the registration for the specified lifetime of the system. It is possible to extend the right to use the resource following the life expectancy period by re-notifying an assignment with a technical specification similar to that of the previous assignment.

4.2 The supply side

4.2.1 The ITU GSOSR Regime

The primary legal regime governing GSOSR is the treaty-based ITU regime, which is legislated by competent international Administrative Radio Conference and administered under the auspices of the IFRB. The extremely complicated details of this regime have previously been documented for the Commission in some detail[1]. For present purposes it is best to provide a summary of the principle characteristics of the regime. The main sub-regimes of interest are those governing the Unplanned FSS, the Planned BSS, and the flexibly Planned FSS.

4.2.2 Unplanned FSS

A step by step guide to gaining access to GSOSR covered by the unplanned FSS regime is summarised in Figure 4.2.

Under applicable ITU Radio Regulations, a country is free to coordinate an assignment of spectrum for implementation of a satellite network making use of the entire allocated band from a particular orbital location or set of locations. The only serious constraint on registering such an assignment is successful coordination with other countries whose spectrum use might be affected by the new assignment.

A country may publish its intention to implement an assignment as much as six years prior to an intended first use of the assignment. All other administrations which may be affected by the proposed assignment are then notified of this "advance publication", and potentially affected administrations may request coordination, which the proposing administration thereby becomes obliged to undertake.

After an interim period of coordination with affected national administrations, with a view to resolving any issues of spectrum interference in respect of prior notified or registered assignments, the proposing country may notify its intended use for registration in the IFRB's Master Registry. The country then has an additional three years to implement the new system.

Protection from interfering systems commences provisionally once a newly proposed assignment has been advance published to IFRB. Unconditional protection commences once, having coordinated a new system, a country has the assignment registered in the IFRB's Master Registry. Hence a national assignment of GSOSR is actually protectable for a period of nine years prior to bringing a system into use. Moreover, in order to protect the assignment once these nine years have elapsed, it is unnecessary to bring into use the full system which was

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[1] See, for example, Sociéte Européenne des Satellites, *Review of the Fixed Satellite Service in Europe* (CEC Contract 45031 Final Report, 1991); especially Chapter 3. Possibly the best detailed review of the overall ITU GSOSR regime, as it has evolved up to and including the landmark WARC-ORB 88 Conference, is provided in Milton L Smith, *International Regulation of Satellite Communication* (Kluwer Academic Publishers, Dordrecht, The Netherlands, 1990).

originally coordinated and notified. A nominal implementation of spectrum assigned to the space segment use will suffice to protect the entire assignment.

Once a registered assignment is implemented, it survives at least for the lifetime of the satellite, and may be extended indefinitely thereafter so long as the technical parameters of the system remain substantially consistent with the registered assignment. Accordingly, there is ultimately no firm limit to the duration of a successfully coordinated national assignment in the Unplanned FSS.

Although modified in certain interesting respects by the 1988 WARC-ORB Conference, the basic ITU regime governing GSOSR access for implementing ("Unplanned") FSS remains substantially the same as the customary "first-come, first served" regime which had evolved up to that point. This regime is explicitly intended to result in efficient use of GSOSR, and is structured to accommodate all users based on the substantive principle of technical non-interference and the procedural norm of voluntary coordination. It is believed that no satellite system has ever failed to be accommodated based on the operation of the classical Unplanned FSS regime.

Consistent with basic principles of public international law, the assignment of internationally allocated FSS bands to specific systems is a role played by national administrations. This does not, however, preclude collaborative international systems - such as the major ISOs, operating in accordance with appropriate intergovernmental agreements - from being coordinated within the framework of the Unplanned FSS.

Generally speaking, and particularly under the Unplanned FSS regime, the main constraint on allocating GSOSR is not the availability of orbital "parking slots" in the GSO, but rather the requirement that national assignment of internationally allocated bands of satellite spectrum shall not interfere with the operation of previously implemented or registered systems. In this regard it must be noted that there is no firm limit to the duration of a successfully coordinated national assignment in the Unplanned FSS.

WARC-ORB 88 introduced various "simplified procedures" into the Unplanned FSS regime, among which at least two are noteworthy for present purposes. First, express provision was made for the device of using multilateral meetings for coordination of proposed systems. Second, simplified coordination of an entire satellite network has been introduced based on the concept of a "typical" earth station.

4.2.3 Planned BSS

The Planned BSS regime legislated by WARC 1977 in effect allocated particular bands of spectrum for the exclusive use of each Region 1 administration. Subject to some exceptions generally not pertinent to Europe, under this regime each country was allotted a specific BSS orbital position from which to serve its national territory using pre-specified bands.

Under the BSS Plan applicable to Europe, a national assignment reflecting an intended use of a BSS allotment must be notified to the IFRB at least three months (and up to three years) prior to bringing a system into use. The assignment will be registered unless it fails to conform with the Plan. Since the right to make a conforming BSS assignment is protected in advance under the 1977 Plan, registration of such an assignment is relatively straightforward.

Subject to the standard norm of non-interference with prior notified or registered uses, under so-called "Plan modification" procedures provided for in the 1977 Plan, it is possible to coordinate uses of BSS spectrum which deviate from the rigid orbit/spectrum allotments nominally provided for each country. However, a minimum of flexibility is provided for in Region 1, and all countries which might be affected by a BSS Plan modification must accede, through coordination, to any specific proposal which differs from the 1977 national allotments.

The 1977 BSS Plan had a nominal lifetime of fifteen years (from 1979), and has yet to be terminated by a competent subsequent WARC. It is unclear the extent to which any such WARC might extend the duration of protection afforded to assignments made in accordance with the 1977 Plan.

As is well known, rapid advances in satellite technology - both space segment (eg. medium-power FSS) and earth segment (ie. low-cost, highly sensitive but physically small TVROs) - have made the technical assumptions of the WARC 77 BSS planning parameters obsolescent, with the result that few systems are likely to be implemented. This is especially significant for Europe in that GSOSR have been reserved for every European country. As a result, GSOSR which might be used for European FSS has been wastefully reserved to non-existent BSS at the level of public international law.

4.2.4 Planned FSS

The 1988 WARC set aside 800 MHz of FSS spectrum with a view to assuring every country the ability to implement domestic FSS. Prior unplanned FSS assignments within this band, which antedated the coming into being of the Planned FSS regime, are effectively "grandfathered" for the twenty-year duration of the Plan.

Although the Planned FSS, like the Planned BSS, involved vesting in advance national rights to make assignments, there were significant departures from the rigid allotment approach reflected in the 1977 BSS Plan. Flexibility has been introduced into the allotments made in the FSS planned band on the basis of two principles. First, systems may be implemented in accordance with more generalised technical parameters. Second, instead of allotting a specific orbital location to each country, the Planned FSS regime allots a nominal orbital location within a 20° "predetermined arc" of the geostationary orbit; assignments may be made involving any orbital "slot" within plus or minus 20° of the nominal position designated in the Plan.

With a view to expediting coordination issues which might arise as between intended assignments in accordance with the FSS Plan and prior Unplanned FSS assignments in the Planned FSS band, the 1988 WARC provided for so-called "improved procedures" including a new mechanism of multilateral planning meetings ("MPM"). However MPM participation is voluntary, and the efficacy of this approach remains unclear. In the absence of an MPM solution to a proposed Planned FSS assignment, the more customary coordination procedure available under the Unplanned FSS will apply.

Like the WARC 77 BSS regime, the WARC-ORB 88 regime for the planned FSS reflects the concerns of GSOSR "have-not" countries that global planning is necessary in order to guarantee every country an equitable reservation of GSOSR. However the planning principles elaborated for the Planned FSS are quite flexible when compared with the rigid allotments previously arrived at for the BSS.

4.2.5 ITU Allocations to Specific Service Categories

Bandwidth reserved for the Planned BSS and Planned FSS in ITU Region 1, including Europe, is very substantial; and by virtue of these two allotment plans is generally unavailable for use in Unplanned FSS, the only category of GSOSR naturally suited to pan-European applications.

The allocations for Region 1 C- and Ku-band downlinks are illustrative. In the C-band, 300 MHz of a total of 1100 MHz for FSS downlinks is allocated to Planned FSS. In the Ku-band, which is considered the most commercially versatile and attractive FSS band, 500 MHz of a total of 1250 MHz for FSS downlinks is allocated to Planned FSS. Hence over a third of total FSS downlinking resource in these two key bands is tied up in Planned domestic FSS allotments.

Moreover, an additional 800 MHz of Ku-band spectrum is allocated to BSS downlinks in Region 1, preempting the use of the resource for FSS applications. In other words, in Region 1 Ku-band, some 1300 MHz are tied up in the combination of Planned FSS and Planned BSS domestic allotments for downlinks; with only 750 MHz of Ku-band spectrum available for Unplanned FSS downlinks.

Although some 3500 MHz of additional Region 1 FSS spectrum is allocated to downlinks in the Ku-band (with none allocated to planned bands), the use of the Ku-band for commercial applications is at an early stage globally.

4.2.6 National and Community Law and Policy Affecting the Supply of GSOSR

Under public international law as well as Community law, the sole authorities competent to licence or otherwise authorise access to GSOSR (consistent with applicable ITU regimes) are sovereign countries, acting individually or in combination.

One significant effect of this basic rule is that strategies for exploitation of GSOSR develop primarily at the national level. Although cooperation in sub-regional systems such as Eutelsat may, at a given stage for a given group of national players, best satisfy national goals for accessing GSOSR, the new empirical trend in Europe appears to be toward an evolution of competing national systems typically characterised by pan-European, or nearly pan-European, coverage areas. The proliferation of such national systems may tend to strain further the supply of GSOSR available for European applications.

The strain will be greater if access to bands otherwise available for pan-European service remains restricted under the Region 1 ITU Plans for the BSS in particular, and, to a lesser extent, the Planned FSS. As compared with North America, the European continent is comprised politically by many ITU-sovereign states. For this reason the recent global tendency to lock up satellite bands in nationally "equitable" GSOSR Plans tends to reduce, in a dramatic way, flexible supply of GSOSR for pan-European applications.

In the current climate of sovereign states being uniquely competent to licence satellites for European service, it can be expected that at least some EC Member States may be reluctant to surrender fundamental "satellite sovereignty" in the interest of relieving pressures on the supply of GSOSR. This will apply in particular to Member States already advanced in their use of GSOSR, and intending to launch additional space segment facilities.

In such an environment, other Members States, whose material stakes in GSOSR are constituted mainly by their inclusion in the ITU FSS and BSS Plans, may also be reluctant to abandon those regimes.

4.3 The demand side

4.3.1 Sub-regional FSS Arrangements Under the ITU Regime

It may be hypothesized that European regional arrangements for providing pan-European service on a "common user" basis, institutionalised supranationally, could serve as a vehicle for relieving demand for GSOSR necessary to satisfy current or foreseeable satellite service requirements. The Eutelsat system is an expression of sub-regional satellite system implementation under the classical ITU regime for the Unplanned FSS.

The WARC-ORB 88 regime for the Planned FSS also makes provision for sub-regional systems. Under a special scheme interested countries choose a nominal orbital position allotted to one of them under the Plan. The associated national allotment is suspended for the life of the sub-regional system. Coordination then proceeds consistent with the requirement of non-interference of national allotments covered by the Plan. However the specific provisions for coordinating sub-regional systems contained in the WARC-ORB 88 FSS Plan are somewhat unclear as to obligations of non-interference owed to "existing systems" in the Planned FSS band which may not have been implemented.

It is unclear the extent to which implementation of sub-regional systems such as Eutelsat - arising under the classical Unplanned FSS regime - tends to relieve demand for GSOSR. In part that would depend on the GSOSR requirements of the particular sub-regional system(s). What seems more likely is the prospect that implementation of a sub-regional system under the Planned FSS regime will tend, at least marginally, to relieve demand for GSOSR by substituting a sub-regional scheme for a national one. On the other hand, it must be remembered that an operative presupposition of the WARC-ORB 88 FSS Plan was to provide domestic national service. Coordination of protection from non-interfering signals may therefore be problematical outside the national territory of the country whose allotted orbital slot is chosen.

It is well to keep in mind the apparent European trend toward national systems geared to sub-regional service. Although such a trend would seem to raise demand for access to GSOSR, it is generally consistent with Community competition policy in the telecommunications sector, and the satellite communications sector in particular. Experience with the sub-regional Eutelsat regime has, by contrast, led to major competition concerns which are not endemic to the constitution of sub-regional systems. Yet an at least arguable case remains that one positive feature of the Eutelsat system is its ability to relieve demand for GSOSR on the part of constituent member countries.

4.3.2 National and Community Law and policy affecting demand for GSOSR

Consistent with the Community law doctrine of exclusive or special rights (embodied in Article 90 EEC), an EU Member State which has authorised at least one satellite system becomes subject to the claim that it must authorise others (although this notion remains untested in the sparse body of Community case law concerned with the satellite sector). For present purposes the salient fact is that no EU Member State currently exhibits a liberal policy toward licensing of commercial "separate systems" (ie. separate from the ISOs) other than systems owned and operated by the dominant national TO or a surrogate linked with the national government.

As is well known, EU Member States have entered into various ISO intergovernmental covenants which discourage commercial competition with the respective ISOs, particularly in the area of "reserved service" (ie. voice telephony); and these so-called "economic harm" provisions are under increased scrutiny in the context of the Community's deregulatory agenda for the satellite sector.

The trend toward growing competition with Eutelsat and the other ISOs in Europe appears to be fairly ineluctable, and this trend may signal a significant increase in European demand for GSOSR, particularly if accompanied by parallel deregulation of national licensing of separate systems consistent with Articles 86 and 90 EEC. Based on a preliminary comparative overview of the European and North American satellite communications marketplaces, it seems empirically demonstrable that legal barriers to entry into provision of European space segment enable a limited number of dominant players to maintain artificially high prices. Accordingly liberalisation of European space segment licensing could stimulate unprecedented demands for GSOSR access under current international legal assumptions.

The European Commission's deregulatory agenda on space segment access will in any event bring prices closer to costs by mandating direct access to ISO space segment and/or by removing customary barriers to entry into space segment provision. Traditional EC Member State sovereign prerogatives to licence space segment may erode as national separate systems increasingly come into being. This would be concurrent with the ongoing devolution of ISO exclusive rights to provide access to space segment for most European applications. A combination of these trends will likely provoke new demands for access to GSOSR on the part of would-be space segment providers.

The effects of impending EC deregulation of the satellite services sector generally on demand for GSOSR may be dramatic, independent of the space segment licensing issues. The proliferation of services such as VSAT, and the foreseeable development of applications such as long-distance trunk bypass, are examples. Today the major share of European space segment capacity is devoted to carrying television signals. In the future, at least for an intermediate phase concomitant with near-term deregulatory trends in the telecommunications sector, it seems entirely likely that overall European demand for access to space segment will grow.

4.4 Conclusions

Under the existing public international regime, European access to GSOSR can be expected to become more not less problematic over time. The Unplanned FSS regime covers the majority of spectrum resource but substantial spectrum has been tied up in the BSS Plan, and the flexibility of the less rigid Planned FSS regime remains in doubt.

The assignment of GSOSR to specific satellite systems remains, in the current climate of European law, fundamentally a national prerogative. Both this legal reality, and the anti-competitive covenants contained in ISO Conventions to which European countries including the EU Member States are party, have tended to reduce access to GSOSR by European users. It is important to recognise that such legal limitations on GSOSR access have tended to constrain European demand for use of GSOSR at an artificially low level.

Both the classically Unplanned and Planned FSS regimes permit accommodation of sub-regional systems, but the effect of institutionalised sub-regional scenarios on the supply of GSOSR is not entirely clear. Here it is well to keep in mind the apparent European trend toward national systems geared to pan-European service. Such separate systems can function as effective substitutes for a European ISO such as Eutelsat, and will presumably compete along lines more consistent with Community competition policy for the telecommunications sector. However their proliferation may add substantially to European demand for GSOSR.

At the level of public international law, including the ITU Radio Regulation, and subject to spectrum non-interference, there is no bar to national licensing of FSS space segment serving territories outside national jurisdiction. In Europe, this is illustrated by, inter alia, the SES/Astra system's pan-European coverage. Elsewhere, US policy on private separate systems has for some time permitted the implementation of commercial space segment linking US and non-US points (eg. Panamsat, Orion). The recent use of the Pacific island nation of Tonga as a commercial satellite "flag of convenience" illustrates that, from a purely legal point of view, there is no ultimate requirement that the territory of the licensing country, or its nationals, be key to the business plan of the pertinent operator.

Empirically, the European sub-regional experience with national space segment provision has customarily evolved with substantial emphasis on national systems serving primarily domestic coverage areas. Prior to Astra, the sub-regional collective solution was the supranational arrangement represented by Eutelsat. But, at least from the standpoint of the Radio Regulations, the possibility of national licensing of pan-European coverage was always available, subject to the usual norm of non-interference with prior recorded systems. So why, until perhaps recently, was the trend not in the direction of multiple pan-European systems comporting under different European flags?

Several factors no doubt played a role. First and foremost, all European countries historically reserved satellite communications to favoured "national champions" --ie. incumbent PTOs; and, customarily, the PTOs were oriented to provision of domestic-only telecommunications services of all sorts (with international service provided on a mutual correspondent basis). In respect of satellite broadcasting, both the issue of respective national languages, as well as the matter of mutual respect for national "cultural sovereignty", no doubt played a role. In addition, national industrial policies of the major European countries compelled the establishment of an independent national identity in the space sector generally, and satellite communications in particular; but this by itself would not necessarily deter national operators from addressing pan-European services markets.

The most profound reason why nationally authorised European space segment providers did not, until recently, gear their commercial planning to pan-European services markets was, indeed, the rigid compartmentalisation of European satellite services markets along national lines, with rights to serve respective markets reserved to national PTOs. Hence the convenience of the Eutelsat sub-regional ISO model, which reserved Continental space segment access to national signatory (PTO) middlemen, on a territory-by-territory basis. An associated reason, alluded to elsewhere in this report, was the disincentive to introduce the possibility of substitutes to monopoly terrestrial infrastructure controlled by respective national monopolies, much less to do so on a cross-border basis (a norm of "mutual non-aggression").

Since satellite telecommunications service provision in Europe has been -- and substantially remains -- reserved to respective national TOs, there has been little evident interest on part of private commercial interests to become licensed for European space segment provision. Even in the current climate of services liberalisation, and even assuming a "separate system" space segment license might be forthcoming from one or another European country, lingering uncertainty about the pace and scope of liberalisation of two-way satellite services continues to undermine the logic of massive capital investment in private satellite systems intended to address markets other than broadcasting (which has already achieved a relatively advanced state of deregulation in Europe).

Moreover, assuming national licensing of private separate systems geared to commercial telecom service provision were to be forthcoming at this stage, there would still be the palpable threat of an effective commercial response from the dominant incumbent operators. The enforcement of basic competition rules applicable to the sector will likely be crucial to stimulating market entry at any stage.

Achievement of the goal of more efficient access to existing European space segment can be expected to stimulate growing demand for GSOSR. And it seems clear that the Community's deregulatory project directed to competitive provision of innovative satellite services will be the most important stimulus to overall market growth of the European satellite communications sector. A potential explosion of pent-up demand for new satellite services anticipated to be introduced in accordance with impending deregulation of the European satellite sector could make the level of demand for GSOSR unsatisfiable.

The ITU experience with "equitable planning" of access to GSOSR suggests little basis for optimism that a similar approach would result in greater efficiencies at the European sub-regional or Community level.

In contrast to Europe, North America appears to enjoy less strain on GSOSR access even in the face of a much more highly evolved, deregulated satellite communications marketplace. In part this is because fewer protected national GSOSR allotments have been tied up in the North American sub-region by international GSOSR planning regimes. One lesson for Europe may be to explore an undoing of the WARC 77 BSS regime at least insofar as that regime applies to a definable sub-region comprised of interested Administrations. In part North America may exhibit a more flexible environment because a centralised and highly sophisticated GSOSR management function has been assumed by a single government body: the US FCC.

The possibility of dramatic advances in satellite communications technology may provide the most comforting basis for optimism that pressure on GSOSR access may be avoidable in the future. A separate school of thought holds that telecommunications technology extrinsic to the satellite sector, such as universal optical cabling, holds the key.

The legal conundrum of GSOSR access is so complex that it invites basic rethinking. One compelling notion is that no regime for access will remain perennially viable so long as basic rights to exploit satellite orbital and spectrum resources are obtainable gratis by national administrations and their chosen operating entities.

5 Shortcomings of Existing Regulations

5.1 Introduction

This section examines the perceived shortcomings of the existing regulatory system. The following discussion has evolved from interviews conducted with various leading figures in the industry and from subsequent analysis and consideration by the team of experts working on the project.

5.2 Shortcomings with the Existing System

The main problems in Europe related to the existing regulatory system can be summarised as follows:

- the creation of artificial scarcity,
- distorted competition, leading to economic inefficiencies.

5.2.1 Artificial Scarcity

The finite nature of the GSOSR means that the issue of scarcity is of particular interest. The key questions include :

- what is scarcity? An economic argument is that this occurs when there is excess demand at the prevailing price. There are also technical issues relating to the finite though re-usable physical capacity of the GSOSR,
- whether scarcity currently exists. Our interview programme and discussions with our technical advisers suggest that the overall answer is uncertain, although there may be particular problems in certain frequency bands and/or specific orbital slots,
- whether scarcity is "real" (ie. physical) or "artificial" (caused by the regulatory framework). With a free market, prices would move to adjust demand and supply. To the extent that the current regulatory framework prevents this, while simultaneously allowing "paper satellites" (satellites which exist only on paper but which can tie-up orbit and frequency resources for up to nine years), scarcity can be regarded as artificial.

The GSOSR constitutes a reusable resource of finite proportions at any given time and under contemporaneous technological conditions. Existing regulatory conditions tend to create various forms of artificial scarcity by tying up resources for predominantly unproductive uses. There are various ways in which such artificial scarcity can be caused by the existing regulatory system, and each will be elaborated on further below. In summary the main contributing factors are:

- the ITU Radio Regulations and associated coordination procedures which lead to the creation of "paper satellites",

- the ITU planned band regimes which can allocate resource to services, such as BSS, that do not develop,

- the principle of sovereignty of national rights over the assignment of GSOSR, which results in significant fragmentation of GSO management in the ITU Region and in Europe in particular,

- technical constraints, such as de minimis parameters that effectively fix minimum spacing between geo-stationary orbital locations to 3°.

"Paper Satellites"

The ITU procedures for regulating satellite space segment permit the overfilling of national assignments to use GSOSR. The current procedures allow nine years between the beginning of the procedure and the deadline for using the assigned resource. This includes six years for completion of the coordination procedures and a further three years for the implementation of a successful assignment. Renotification of a similar assignment effectively grants the use of the resource in perpetuity.

In effect there is no basis for assuring an expeditious process of assignment through coordination or into implementation. This means that satellites which may only ever exist on paper can still tie up assigned resource for a nine year period.

For satellites which are launched there is no procedure for ensuring that the stated proposed level of use is realised. If, therefore, the actual use of spectrum is of a far reduced scale than was originally assigned, there is no legal basis for remedial action. Under-utilisation could continue at least for the originally stated lifetime of a satellite system, which could be 10 - 15 years or more.

With this regulatory system applying to a finite though reusable resource it is not surprising that countries wish to cover their most optimistic needs. Other countries will be adopting the same approach, leading to the opportunistic creation of "paper satellites". These contribute to the creation of artificial scarcity of the resource.

The extent to which 'paper satellites' occupy available orbit and spectrum resources is difficult to determine definitively. The difficulty revolves around the definition and identification of 'paper satellites'. For a 'paper satellite' to be making inefficient use of geo-stationary orbit and frequency resources it would have to be :

- filed and coordinated with no intention of utilisation except in exceptional circumstances,

- filed and coordinated significantly in advance of the date at which the resource is expected to be utilised because of fears over scarcity,

- filed and coordinated with exaggerated frequency requirements, as a blocking mechanism to competition or in advance of their being utilised because of a genuine fear over the future availability of the resource in the future,

- in use, but not utilising the range of frequencies specified in the registration process.

It is not possible to determine without detailed examination of each case whether any particular IFRB filing can be categorised by any of the "Paper Satellite" definitions above. We have, however, conducted research which used the list of IFRB registrations and assessed the following:

- whether a satellite is in operation,

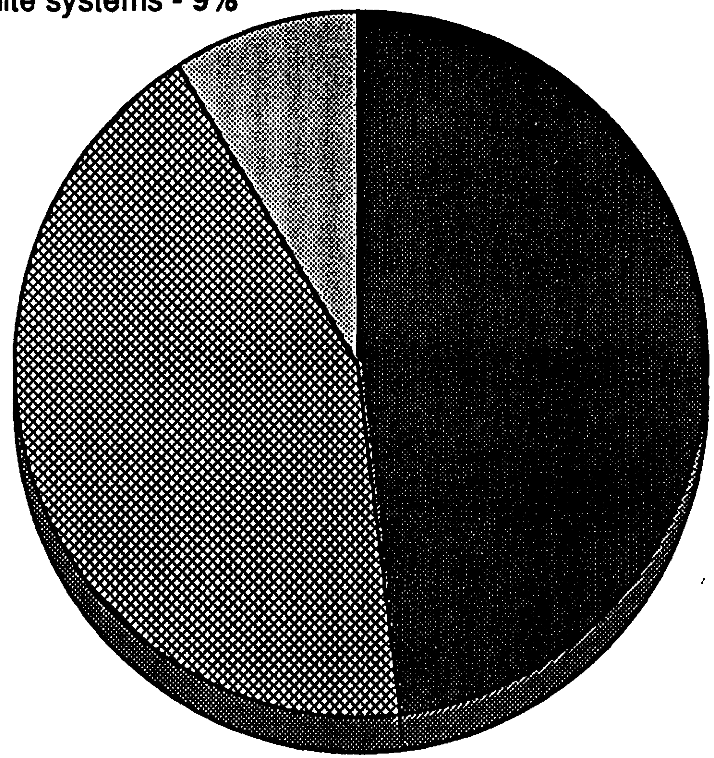
- if not in operation, whether a contract has been entered into with a satellite manufacturer for a system,

- the residual, which will contain all satellites which, for some unspecified reason, at the time of investigation only appear on paper.

It is true, of course, that filings may not have progressed to fully fledged satellites for very good reasons. The most obvious reason is the very time consuming process of international coordination with Administrations whose spectrum use, or intended use, are affected by the proposed system. Commercial plans may have failed or been modified in the light of changed conditions. The same sorts of reasons might apply to satellites that are in use but which are not utilising the full range of spectrum indicated in the IFRB registration.

Nevertheless, whatever the legitimacy of the reasons for 'paper satellites', the result is the same; namely, the inefficient use of geo-stationary orbit and frequency resources. Figure 5.1 indicates that only a relatively small proportion of satellites fall into the residual category described above. In practice, however, a major problem exists because this does not cover the issue of over-specification of frequencies on satellites that exist but which only use a proportion of the spectrum for which they have filed. It has been pointed out in our interviews, for instance by an official in a European TO responsible for filings to the IFRB, that in certain bands of the spectrum it is 'virtually impossible' to coordinate new satellites based, inter alia, on the necessity of coordinating with prior recorded but not yet implemented systems. The example given was for new European FSS in the Ku band. It was also pointed out that Arabsat and Turksat have been and are experiencing serious difficulties in coordinating new systems.

Figure 5.1 Status of IFRB filings and the issue of paper satellites*



* End 1992 figures for TV, telephony, business and mobile services only

G.7970

The conclusion can be drawn, therefore, that paper satellites constitute a problem which is having a significant impact on the ability to launch new satellites, especially amongst new entrants to the market. It is clear that the provisions of the existing regulatory regime, which protect non-implemented systems over a considerable period, encourage overfilling. The solution, however, is not straightforward. Currently overfilings are closely but not exclusively associated with national interests and the national orientation of the assignment process. There is, however, also an interest for any commercial operator to cover comprehensively its future options. There is little or no extra cost in doing this and it can protect future expected growth requirements from scarcity problems as well as protect 'hot bird' type locations from competitive intrusion.

One method of reducing the paper satellite problem would be to apply due diligence - use it or lose it -criteria to proposed assignments. However, if such due diligence were to be applied at a sub-regional level rather than at the ITU level, there would be a danger that any ensuing efficiency improvements would quickly be absorbed by countries or organisations outside the jurisdiction of the sub-regional body. A sub-regional solution could only succeed if this danger were effectively addressed. One approach might be to pool protected but un-utilised GSOSR at sub-regional level.

Planned Bands

The planned bands, in some ways, can be regarded as institutionalised "paper satellites". The pertinent WARC agreements effectively tie up allocations of frequency resource to uses with an uncertain economic future. This has certainly proven to be the case with the BSS band, where the inflexibility of the allotment plan clearly introduces a form of artificial scarcity.

Eutelsat, Astra and France Telecom are all understood to be pursuing complex avenues for exploiting the planned BSS band (both BSS and FSS). Hispasat is an example of where new space segment has been co-ordinated in accordance with BSS "plan modification" procedures. "Plan modification" is, however, a procedure that has not been widely tested. Ad hoc plan modification has the potential for reducing the inflexibility of the BSS plan, but it does not remove the problem.

As a reaction to "paper satellites" and the rigidity associated with the planned bands, there is evidence of organisations looking to interpret regulations so as to broaden their commercial options. Some commentators have pointed to the onus on rights holders to prove interference if new operators make use of resources in ways which do not strictly conform with the detail or spirit of the regulation. Proving interference can be a difficult task, particularly when planned allotments or assignments have never been implemented. There is a growing tendency, therefore, for regulations that contribute to artificial scarcity to be circumvented where possible. This potentially undermines the effectiveness of the planning regime, but in a manner that introduces some greater flexibility into the use of the resource. An argument can be put forward that such developments encourage a review of rigidly planned assignments. The alternative may be for a greater degree of anarchy to affect the industry.

National Rights

The fact that national interests are closely linked to the assignment process contributes to the "paper satellite" problem. Because there are so many national interests in Europe, and indeed in Region 1, there are more likely to be competing national demands for available resource than, for instance, in North America. The process described above, whereby overfilling takes place to secure even very optimistic potential national uses of the resource is, therefore, very likely to take place. Sovereign national rights to assign spectrum use are fundamental to the proliferation of "paper satellites" and to the artificial increase in the scarcity of the resource. The legitimate concern of national security should always be borne in mind. There are, however, accepted frequency bands allocated to military users and this should allay concerns from this source.

Technical Constraints

Some conventional technical parameters can also contribute to problems of artificial scarcity. Problematic technical conventions include 3° minimum spacing between orbital locations as an indicator of spacing appropriate to avoid problems of interference. This limit can be too restrictive where the dish size is such that relatively low power transmission is possible. For high powered transponders and small receiving dishes it may well be necessary to have more than 3° spacing to avoid interference. The crucial issue is interference. This is recognised by experts at France Telecom who are developing ideas about 'self compatibility' whereby an assignment would be disallowed if an identical adjacent assignment in the orbital arc would result in interference patterns.

Technical regulations are having to be re-evaluated as technology develops. The interference problems associated with digital transmission, for example, are less pronounced than with analogue transmissions. It is also possible to transmit a wider variety of service applications on the same frequencies using digital transmissions.

5.2.2 Distortions to Competition

In aggregate the current regulatory regime tends to distort competitive forces, raise barriers to entry and encourage monopolistic tendencies in the market. A number of shortcomings in the existing regulatory system contribute to these tendencies including:

- existing administrative procedures,
- non tradeability combined with assignments effectively given in perpetuity,
- different national rules covering frequency allocations and orbital assignments,
- the exclusivity of direct access to ISO space segment enjoyed by ISO signatories,
- continued distortions in the supply of services using GSOSR, related to the regulation/liberalisation of and user service markets,
- the artificial scarcity issues discussed above.

These points are elaborated on below.

Administrative Procedures

The general nature and complexity of the administrative procedures, and the coordination procedures in particular, represent a barrier to entry in Europe and Region 1. The time it takes to coordinate with so many countries and the associated costs inhibit entry to the market by new competitors. According to national experts, co-ordination of a new Ku band FSS satellite may entail co-ordination with as many as a dozen countries, and a single bilateral co-ordination may take up to a year.

In Perpetuity and Non Tradeability

Limitations on transferability, the assignment of resources in perpetuity without any ability to transfer the ownership of the organisations or the rights to use the resources will tend to insulate organisations from market forces. This situation is typical of most EU Member States. Inability to trade the right to use GSOSR places significant constraint on attaching a value to the resource that reflects the economic value that can be generated from its use. In this respect GSOSR differs significantly from analogous situations such as land and property markets where market forces are usually more pronounced.

The National Role in Allocation and Assignment

Both allocation of bands and assignment to specific uses are normally and exclusively the sovereign prerogatives of national administrations. As to allocation, each country is free to develop any scheme which is not in conflict with prior international allocations legislated at the ITU level.

In Europe, national assignment of rights to use allocated spectrum for implementation of new civilian space segment facilities typically follows a customary model which presupposes that such rights vest presumptively, typically to an incumbent national TO. Hence there is no well-developed selection procedure, or "licensing process", for granting rights to implement new space segment; in general it appears that there is no such process in place at all.

The most notable example of a European space segment operator other than an incumbent TO (or a TO-owned ISO) is, of course, Luxembourg's SES. This example, however, does not reflect a transition to a competitive selection procedure. Rather, it evidences the establishment of an alternative national "champion" whose ownership is held substantially by, and whose proceeds accrue substantially for the benefit of, the national government.

At least one significant exception to this general picture is the possibility of a licence to provide a broadcast satellite service in the UK, pursuant of the 1990 Broadcasting Act (the Marco Polo precedent). In addition, there is at least some anecdotal evidence that perhaps a few independent entities have applied at the national level (eg, in Germany) to construct and operate so-called "separate systems" independent of dominant incumbents linked with the national government concerned. However the identities of such applicants, and the procedural environment in which their proposals may have been entertained, each remains unclear.

We are not aware of any EU Member State (other than the UK) having established a formal licensing process which invites proposals for the provision of space segment independent of both the ISOs and the dominant national incumbents. This regulatory environment, in which exclusive or special rights to provide spacesegment vest at national level, is open to challenge under Articles 90 and 86 EEC. Consistent with the general competition rules contained in the EEC Treaty, alternative national selection procedures would have to reflect objective, transparent and non-discriminatory criteria for deciding among proposals.

By and large, it seems clear that the standard European model for national assignment of rights to implement new space segment resources tends to insulate dominant national players from the competitive pressures of an open marketplace.

Signatory Rights

The exclusivity exercised by signatories over the access to ISO space segment, such as Eutelsat transponders for telecommunications traffic, also represents an important distortion that impacts upon the market for GSOSR. The signatories have effectively created geographical monopolies over the use of Eutelsat satellites delivering communication services to their territories. There are signs that this monopoly power is being reduced by competition emerging between signatories. Nevertheless, the extent of competition is still restricted to the signatories, with the consequence of oligolopolistic if not monopolistic market structures developing. The remaining issue is of direct access to ISO space segment by end users. An association of end users said that it was now possible for its members to gain direct access to Intelsat services, but that there were still restrictions on access to Eutelsat services which had to be rented via the national signatory organisation - which was usually the TO. It was said that some national signatories, such as BT, were becoming more expansionary in their marketing practices by offering access to space segments to customers outside their national territory.

Service Liberalisation

The restrictions over the supply of services to end users also have an impact on the market for GSOSR (see Figure 5.2). The TOs continue to have dominant control of both space segment and service provision. With TOs investing heavily in terrestrial networks - especially fibre - it would not seem in their interests to permit rapid opening up of the GSOSR to potential competitors in their core businesses. However, there is a strong trend in European telecommunications markets towards liberalisation, opening up previously sacrosanct markets to competition, and the relaxing of the state's grip on the sector through privatisation.

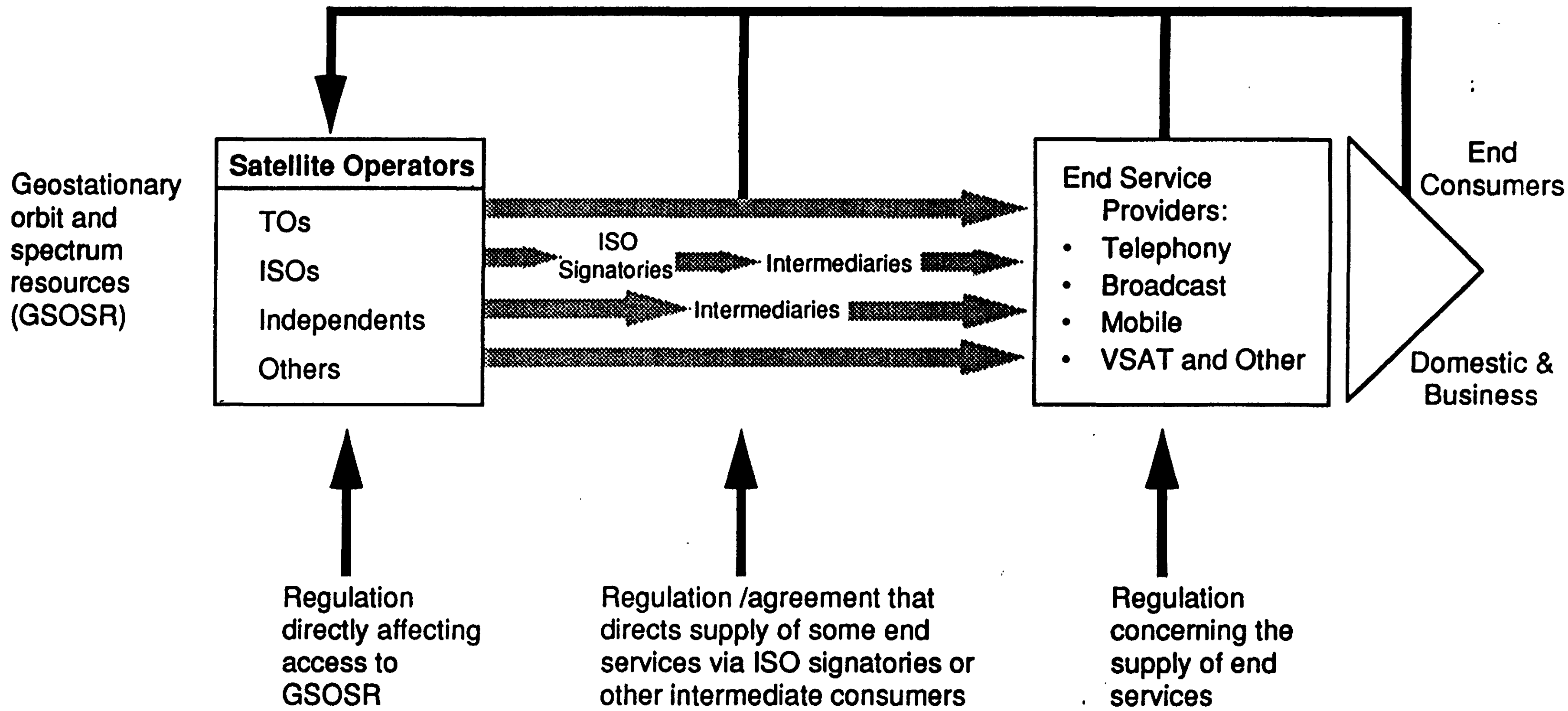
Artificial Scarcity

The artificial scarcity issues discussed above also contribute to the distortions in the market for GSOSR resources. The creation of such scarcity can increase costs of entry by making the administrative procedure more complex and protracted. This can prevent competition from developing, reduce the incidence of innovation and increase the price of existing services.

5.2.3 Summary

The shortcomings of the existing regulatory system manifest themselves in the form of both artificial scarcity and distortions to competition. The consequences for Europe can be regarded as:

Figure 5.2 Satellite industry supply chain



Regulations impacting demand in intermediate and downstream markets will have feedback impact on demand for GSOSR

G.7970

- high barriers to entry limiting competition, and inflexibility in the market, leading to high prices for transponders relative to what would be the case under more competitive market conditions,

- monopolistic tendencies of incumbent operators resulting in high profitability,

- few competitors for pan-European or national services, but many operators providing geographically fragmented and/or application specific services and so not exploiting the full economic potential of the resources being used,

- a regulatory system that leads to the filing of "paper satellites", raising the cost of coordination, preventing market entry and creating artificial scarcity.

The current administrative and technically driven regulations are, therefore, contributing to a highly fragmented and economically inefficient satellite sector in Europe. The inefficiencies are also tending to hold back innovation and reduce the general dynamism of the sector. If the current situation continues there is a long term threat to the survival of the European satellite industry in the face of increasing pressure from terrestrial based substitute services.

Figure 5.3 summarises the shortcomings of the existing regulatory regime.

Figure 5.3a Existing regulations - summary of shortcomings

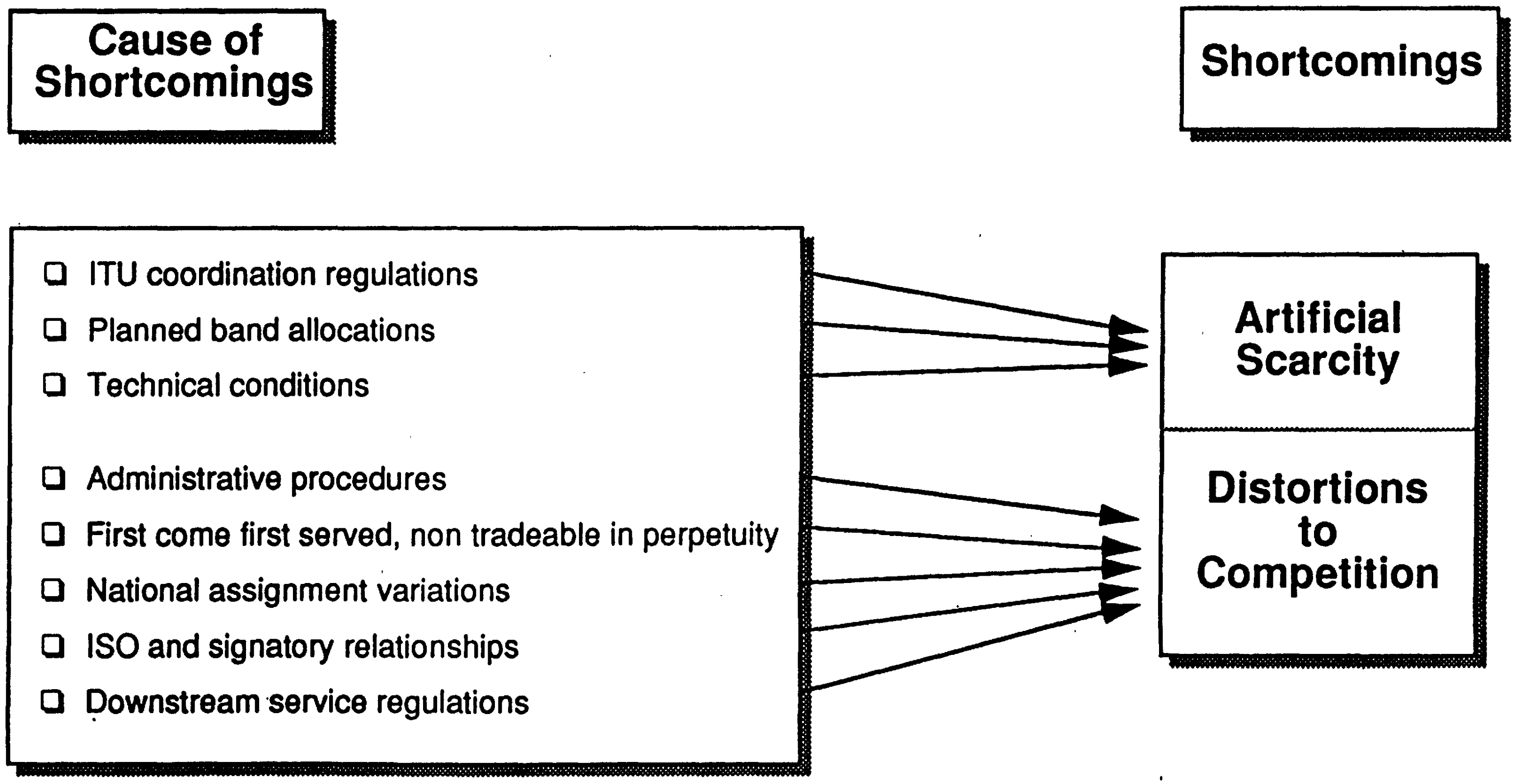


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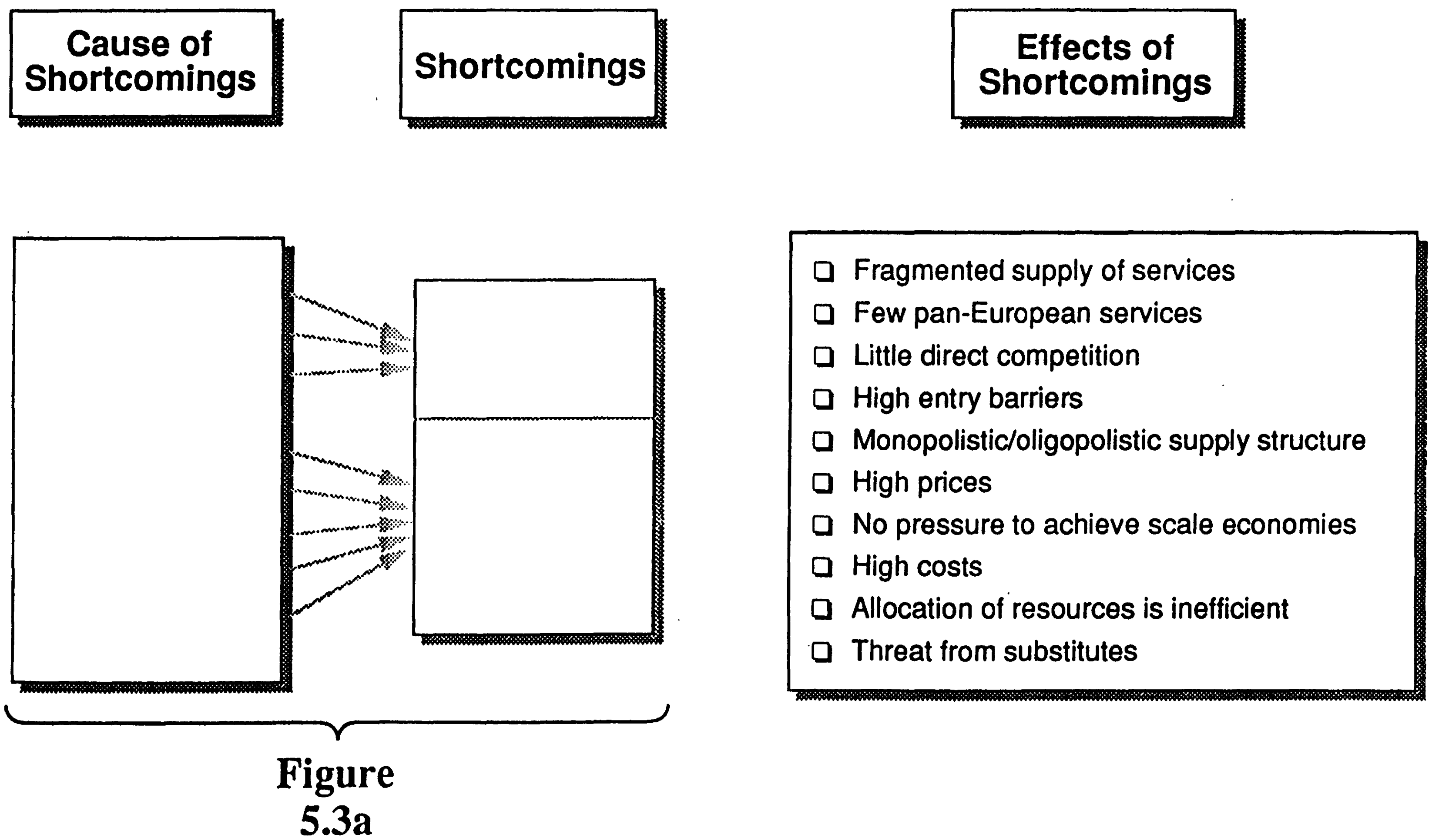
Figure 5.3b Existing regulations - summary of shortcomings



6 The Optional Regulatory Components

6.1 Introduction

We have broken down the key regulatory tasks into six broad areas which were developed by the team in consultation with the Commission. We have used this breakdown as the basis for the interview programme and subsequent qualitative analysis, and ultimately for the modelling work. The purpose of this section is to describe these components, both alone and in combination. The six areas are as follows:

- recoup spectrum
- institutional change
- procedural change
- changes in terms and conditions
- technical policies
- competition policy

These are illustrated in Figure 6.1 below. These components were widely discussed during the interview programme. In addition to the likely impact on the satellite industry, there was also discussion of the main constraints likely to be encountered in implementing each component. These are described in more detail in Section 8 below. It should be noted that for the purposes of the modelling (described below) it was assumed that these constraints would not be binding. The model is therefore based on an "ideal world", where the regulatory options are successfully implemented immediately.

6.2 Recoup Spectrum

Significant parts of the GSOSR are allocated to specific uses. For geo-stationary resources this allocation process takes place at both the international and national levels. Our analysis focuses particularly on two areas:

- military allocations/assignments
- the BSS spectrum

There are strong economic arguments against setting aside spectrum for specific uses. In particular, if the amount set aside does not conform to the level of demand, there will be inefficiency, either through excess demand for the allocated band or because the band is underutilised. While in the past there may have been political or technical reasons for justifying such a policy, these are becoming less important with the development of digital technologies, which reduce the differentiation between signals of different services.

Military

Military users are allocated a significant amount of spectrum, both at the international level (eg, NATO) and at the national level. This has traditionally been granted at no cost to the military on the strength of national security arguments. Recent political changes, notably the end of the

Cold War, have strengthened the arguments for releasing military spectrum to civilian use as part of the "peace dividend".

Discussions are already taking place at both national and international levels and there are a number of examples of increased flexibility on the part of the military. The ERO (1993) proposes that managers of military spectrum should meet with the ERC and CEPT administrations to discuss if and how civilian users can gain greater access to spectrum reserved for military usage. In the United States there is pressure to transfer 200 MHz of spectrum from government (including, probably, military) to civil use. However, resistance from the military to such moves can be expected. For example, Intelsat reported that at a conference in Geneva in 1979 it was agreed to transfer part of the military C band allocation to civilian FSS. In practice, the military continued to use this spectrum for radar, which made it impossible to use for other services.

In addition, it is not certain that if military frequencies were released they would automatically go to satellite uses. Military allocations in the low C band in particular would be subject to strong demand from terrestrial services such as cellular.

A recent report from the ERO, the Detailed Spectrum Investigation covering 3,400 MHz to 105 GHz, investigates this issue in more detail. It concludes that the greatest potential for recouping or sharing spectrum currently allocated to military users exists in the 7 - 8 GHz and 20/30 GHz bands. This is an area of great sensitivity, however, and change is likely to be slow.

BSS spectrum

WARC-77 provided for national allocations of GSOSR for BSS in Regions 1 and 3. A similar but more flexible plan was adopted for Region 2 in 1982. In practice these allocations have generally not been exploited to their full potential. In Europe, the main provider of 'direct to home' broadcast services is Astra, and it does so using FSS spectrum. In the USA the BSS bands are only now beginning to be implemented.

It is argued that the BSS allocation has exacerbated the scarcity in the GSOSR. The allocated bands are generally suitable for the provision of FSS services. The WARC-77 plan was nominally for 15 years from 1979. Although this is nominally due to elapse in 1994, the Plan has yet to be terminated by a competent WARC and is unlikely to be addressed before 1997. Strong resistance to the termination of the BSS plan is anticipated from LDCs, who are likely to view this as an erosion of their property rights.

A possible alternative might be to free up the BSS spectrum at a sub-regional level. This is a complicated political, legal and technical question. The basic rule is that no country's BSS allotment may be "trespassed" (interfered with). However, a sub-regional European arrangement could probably be designed to avoid trespassing the allotments of the rest of Region 1. The prospects for such an arrangement would be increased if there were a regional coordinating institution (see 6.3 below).

6.3 Institutional Change

This section deals with the reorganisation of institutional responsibilities for allocation and assignment of GSOSR. At present, allocation is carried out both at the international level (through the ITU Radio Regulations which are negotiated at periodic WARCs) and, consistent with these allocations, at the national level. Assignment to particular uses is carried out at the national level. As a matter of public international law it would be possible to carry out allocation and assignment at a sub-regional level, such as within Europe, so long as this remained consistent with ITU rules and no third country's rights were violated.

In principle it should therefore be possible to establish a European agency for managing and coordinating GSOSR. Such a body might be envisaged to have responsibilities at any of the following levels:

- a "full service" coordinator, operating as the focal point between its members and the ITU and dealing in particular with both allocation and assignment, issues of coordination; interference; monitoring competition, due diligence, homologation/type approval of equipment, etc. It would have full authority to represent its members at international fora such as WARCs,

- a "partial service" coordinator, dealing mainly with spectrum allocation and some assignment for selected pan-European services. General space segment licensing, as well as coordination and interference, would continue to be handled at individual country level. The organisation would represent its members at international fora,

- a "minimalist" coordinator, responsible for the allocation of Europe-wide bands for specific services. All other duties would continue to be carried out at the national level. This could be viewed as a first step towards a regulator with wider responsibilities.

The following points would also need to be taken into account:

- allocation at a sub-regional level could be considered a de minimis scenario consistent with current trends in telecommunications (for example in GSM, DECT and ERMES),

- assignment at sub-regional level would require a consensus of EU Member States under the EEC Treaty. While it is unclear whether such an arrangement would in itself improve the efficiency of GSOSR utilisation, it is likely that it would lead to a significant reduction in costs and improvement in the speed of start up of space segment providers. Again it is important to stress that the success of such a body would be dependent upon the economic principles guiding its actions and the effectiveness of policies meant to implement the principles,

- the key issue will be political. In particular, the existence and responsibilities of any European coordinating organisation will depend on the extent to which member countries are prepared to delegate sovereignty in this area.

6.4 Procedural Change

In Europe, national assignments generally involve the granting of exclusive rights, within the meaning of Article 90 EEC. Under the current regime the fundamental international principle for assignment at national level is "first come first served". Typically, a potential player will apply to its national regulator for an assignment. The regulator will check for potential interference and then file the proposal with the IFRB. The approval of the assignment is determined administratively based on the purely technical criteria of non-interference.

The lack of transparency at national level and the limited influence of market forces create considerable inefficiency. This has led in particular to the presence of "paper satellites", where there is a successful registration but the satellite is either not launched or occupies a slot but is not fully operational. The fact that the slot is virtually costless while at the same time has considerable economic value to the incumbent creates a strong incentive for "warehousing" of the resource, either for some future use or to prevent competition. This phenomenon makes a considerable contribution to the perception of scarcity of GSOSR.

There is a number of alternative allocation and assignment mechanisms. To a greater or lesser extent, these attempt to move towards the market solution. Economic theory suggests that those mechanisms that are closest to the licensee paying the market price for the resource will be the most likely to promote efficient use of GSOSR. In particular, with an explicit cost of not using the resource, whether it be in terms of interest charges on capital or foregone income from alternative uses of resources, the likelihood of warehousing and the problem of "paper satellites" is considerably diminished.

We have identified the following alternative mechanisms, listed in increasing order of market orientation:

- *first come first served:* like planned regimes, a non-market solution. Applicants are automatically granted a licence with charges set at nominal levels, not related to either the cost of administration or the value of the licence,

- *non-interference:* the current international norm. Licences are still granted on a first come first served basis but subject to the proviso that the service will not interfere with existing licensees,

- *national procedural norms:* in addition to non-interference, as a matter of national law applicants may be required to meet a range of other criteria before being granted a licence. Such criteria are often an initial hurdle prior to use of an additional selection procedure (such as comparative hearings or lotteries). These might include ownership, availability of sufficient financial resources for launch, economic criteria (demonstration of a market for the service) or quality of service. While this makes some progress towards increasing transparency and filtering out non-serious applicants, there is a risk of challenge in the courts,

- *technical planning:* allocation of bands to specific services, determined by purely technical criteria (mainly non-interference). Assignment of licences to provide these services would be on a first come first served plus non-interference basis.

This is analogous to the WARC/Radio Regulations process. Lack of consideration of markets means that this is unlikely to reach an economically efficient solution. The digitalisation of satellite transmission suggests that the basis for technical allocation is diminishing,

- *economic/market planning:* allocation of bands to particular services according to an assessment of current or future demand. This requires the regulator to second guess the market as regards the likely level of demand for specific services. As suggested by the experience with BSS, this is unlikely to lead to the most efficient outcome. At best, the regulator can only reach the market solution, and the likelihood of achieving that is extremely low. On the other hand, such an arrangement might be an acceptable "second best" solution if it is believed that there is a significant degree of market failure (see discussion on public goods in Appendix 4), which would prevent the optimal solution being reached under free market conditions,

- *comparative hearings:* where there are competing bidders for a licence. This involves holding a "beauty parade" to allow the regulator to come to an informed decision as to the "most appropriate" proposal. This approach has been used frequently in the US. Apart from the uncertainty of reaching the most efficient solution, this option is expensive and time consuming for all parties concerned,

- *lotteries:* when there are competing demands for the resource, this involves assignment through lotteries, with the winner being selected at random. This can lead to efficient allocation of resources if licences are subsequently tradeable. The US experience has been that lotteries lead to private auctions of licences once they have been officially allocated. The final user thus pays the economic value (with the concomitant incentive to use the resource efficiently), however the lottery winner receives this as a windfall gain. This leads to speculative lottery applications,

- *auctions:* where there are competing bids, licences are auctioned so that the government receives the economic value for the resource and the winning bidder has an incentive to use the resource efficiently. This can lead to smaller firms with less access to capital being at a disadvantage in the bidding process. In the US the "200 Mhz Bill" provides for the auctioning of the spectrum that is reallocated to the private sector. However, the aim is explicitly to raise revenue rather than promote efficiency. There is a wide range of arguments both for and against the use of auctions for assignment of spectrum. It is recognised that while in theory auctions have the potential to reach the optimal market solution, the degree of competition in the industry is of critical importance. This issue is addressed further in KPMG (1993)[2].

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2 Licensing and declaration procedures for mobile communications in the member states of the EC - report prepared by KPMG and Stanbrook & Hooper for the EC Commission, August 1993.

Apart from the auctions option, there is a number of alternatives for setting charges for licences. The most common current approach is to set nominal fees that are unrelated to either the cost of providing the licence or its true value as determined by the market. One alternative option might be to set fees to at least cover administration costs, which would reduce the pressure on the government budget. However, compared with the total cost of establishing a new service, these are likely to be relatively low, with little impact on market behaviour. Another route might be to charge user fees that are at least partly related to demand for the service. While not going the whole way, this would help to encourage efficiency. This type of arrangement is often considered as part of the economic planning approach.

6.5 Changes in Terms and Conditions

The following components cover specific terms and conditions of space segment licences. These can be used to promote market behaviour (eg by allowing tradeability) or to compensate for its absence (setting due diligence hurdles to prevent warehousing).

- *property rights:* current licences are highly specific as regards the particular use to which an allocation or assignment can be put. One option might be to introduce a degree of flexibility, granting broader property rights over the spectrum. This might involve granting the right to use the spectrum for any service (subject to non-interference) or for a broadly defined set of services such as "business" or "mobile". This is in line with the idea of technological convergence towards digital signals, and with the view of the GSOSR as a homogeneous product ("black space"). Allowing licence holders to have broad rights to spectrum will enable them to change the service provided in line with shifts in the market or (with tradeability) to sell the licence to someone else who can make better use of the assignment. This increases the likelihood of efficient utilisation of the resource,

- *due diligence ("use it or lose it"):* the Radio Regulations effectively set a limit of nine years, from the first filing, for an operator to get up and running. This is generally viewed as sufficient given the long lead times in satellite launch. However, the existence of "paper satellites" suggests that the system is being manipulated in an inefficient manner. Due diligence is required to prevent warehousing of GSOSR (as indicated above this primarily occurs because they are essentially free) and to prevent the "deep pockets" phenomenon, where incumbents or competitors (such as terrestrial providers) buy up the resource to limit competition. At the national level due diligence requires that the licence holder demonstrates use of the resource. For example, the FCC requires that the licence holder makes "meaningful progress" toward system implementation. However, it is often difficult to judge how much progress is "meaningful" and regulatory decisions can be open to legal challenge,

- *duration of licences:* under public international law there is effectively no limit to the duration of an assignment. Licences to provide space segment may vary by country. There are both advantages and disadvantages to setting a fixed duration on licences:

- setting a deadline for the implementation of the service helps to prevent warehousing,

- without tradeability of licences fixed duration licences make it easier to clear out inefficient or inappropriate incumbents,

- the long lead time for launching a satellite and changes in technology that extend satellite lifetimes make it difficult to determine the optimum duration,

- towards the end of the licence period the current holder is likely to stop investing or even disinvest due to the risk of losing the licence,

- putting the licence out to tender periodically increases the uncertainty to the applicant and raises the administrative cost to all parties.

From an economic point of view, however, providing that licences are transferable then letting them in perpetuity has a greater potential for reaching the market solution than setting fixed period licences. In the US licences have a fixed term but there is "reasonable expectation of renewal." This serves to send the right messages about due diligence while minimising the disinvestment problem. It could be argued that if there were tradeability of licences, then there is no need to have a fixed duration, and licences could be let in perpetuity. Warehousing and deep pockets could be addressed through enforcement of competition rules. However, bestowing dominion in perpetuity over a limited resource such as GSOSR raises complex legal questions,

- *tradeability:* should ownership of GSOSR licences be freely tradeable? While GSOSR cannot be "owned", nevertheless, should the right to utilise a particular assignment be considered tradeable as a commercial asset? As indicated above, there are strong arguments for at least making sure that the companies owning satellite systems are themselves freely tradeable. This can be viewed as a key prerequisite for the introduction of market forces and the resulting improvements in efficiency of resource utilisation in the satellite industry. With reasonably efficient capital markets, a company that is not operating efficiently or profitably could be bought out by another that can operate at lower cost. Without tradeability there is no incentive to give up licences. Unprofitable systems are switched off in anticipation of future uses rather than being transferred to alternative users. Other potential users are forced to apply for their own licence and launch an entirely new system,

- *pioneers' preference:* this is a system whereby "innovative" proposals for utilising GSOSR are given preferential treatment over "me too" applications. This can be through priority licensing and even through setting aside spectrum for "innovation". The aim of such a system is to promote innovation by giving the new idea a commercial advantage. This is particularly important for smaller firms who may not otherwise be able to develop their good ideas. Pioneers' preference has been adopted in the US where the openness of the licensing procedures means that innovative ideas are revealed to potential competitors before the benefits can be achieved. However:

- it puts the regulator in the position of having to judge what is a "good idea" and what is not. In the US this is readily open to legal challenge,

- setting aside spectrum for good ideas may create scarcity elsewhere,

- intellectual property can be protected in other ways, for example, through patents and copyright.

6.6 Technical Policies

The rapid pace of technical progress in the satellite industry means that while the GSOSR is a fixed resource, its effective capacity is constantly being increased. However, there is a cost to operators of using the resource efficiently. Incumbents will be reluctant to invest in new equipment before the physical lifetime of their existing satellites expires, while new entrants will be reluctant to bear the total cost of developing new technology (this is one aspect of the "free rider" problem in economics - all users benefit from the introduction of new technology but the cost will be borne by the investor, not the incumbents).

In the satellite production industry and in satellite operation there are significant economies of scale. This creates a strong incentive to build/purchase satellites using tried and tested technology rather than incurring the high cost of new research or using new systems and equipment. This effect is again likely to hold back the introduction of new technology.

Technical policy can be used to encourage the efficient use of GSOSR. This might be done through an administrative process as in the US or through some kind of phased introduction of new technical norms. Compensation arrangements could be used to ease the transition to the new technical regime, with new entrants paying incumbents to move early or incumbents paying potential new entrants or the regulator to retain their rights for longer than some cut off date. There are three issues of particular relevance to Europe:

- *orbital spacing:* while there is no explicit limit on how close together satellites can be situated without interfering, 3° is generally seen as an appropriate rule of thumb. In the US, a severe shortage of GSOSR in the past (the "spectrum wars") led the FCC to develop a 2° spacing rule, after technical study and discussion with the industry. The 2° solution involves positioning satellites using dissimilar bands and geographically dissimilar coverage areas in adjacent slots. Although this had the effect of increasing orbit capacity, there was a trade-off. In order to minimise interference, satellite specifications had to be controlled in a very precise manner which, it is argued, may have limited innovation. In addition, 2° spacing imposes a minimum size on the ground stations. However, the market demand is for relatively small antennas (at least for TV). This is reinforced by local planning regulations which make it difficult to use larger antennas. At a European level 2° spacing would also require a high level of cooperation between national authorities. In any event this policy alone would not address the issue of scarcity of spectrum. It should be noted that with improving technology (particularly digitalisation) spacing of less than 2° could become feasible,

- *frequency sharing and reuse:* there is already a number of technical options for frequency sharing and reuse, and with greater use of digitisation, cross polarisation and modulation techniques, these are increasing. A key issue is the need for international coordination with neighbouring countries. There is potential for frequency reuse between Europe and Africa, for example. This would need international agreement and coordination,

- *European fine tuning:* the issue to be addressed would be to what extent do other internationally established technical parameters for relevant services permit local fine tuning to improve the efficiency of GSOSR utilisation.

6.7 Competition Policy

As noted above in the discussion of warehousing, "paper satellites" and the "deep pockets" phenomenon, there is a key role for competition policy in promoting a more efficient utilisation of GSOSR. The main question is the extent to which competition rules are invoked in order to maintain a competitive market structure. Three particular issues might be relevant:

- *ISO anticompetitive covenants:* The covenants provide protection to operators against 'economic harm' caused by any new proposed assignment. Although the substantive criteria for coordinating "no economic harm" are relaxing, procedural requirements remain burdensome to new entrants. These treaty clauses probably violate Articles 85 and 86 EEC,

- *maintenance of exclusive and special rights:* Member States granting exclusive rights to an incumbent or other space segment provider are vulnerable under Articles 86 and 90 EEC. It could be argued that special rights are inherent to the granting of any GSOSR assignment. On the other hand, the better view is that special rights apply within the meaning of Article 90 only if Member State discretion to licence entrants has not been exercised in an objective, transparent and non-discriminatory manner,

- *"hot birds":* owner-operators of "hot bird" locations, such as SES/Astra, may be vulnerable to an Article 86 claim that they dominate a specific service market. The question is whether they abuse their dominant position, eg, by charging an "excessive" price or unfairly excluding potential competitors from the market. If, and only if, this is the case, possible remedies might include enforced price adjustment or allowing a new entrant access to the incumbent's assignment or space segment capacity (eg force the owner to open up a transponder to a competitor). Three points should be noted, however:

    - any recourse to competition rules would probably be subject to protracted legal challenge,

- there is no rule which in any way prohibits the establishment of additional "hot bird" locations. The key constraints are availability of suitable GSOSR and the ability to offer compelling services (eg. popular television programming),

- by virtue of a dominant market position "artificial" barriers to entry could be maintained in the long run. The key issue, nevertheless, is whether the operator is abusing its monopoly power.

7 Regulatory Components - Respondents' Views

7.1 Introduction

This section summarises the main points raised during the interview programme of satellite regulators, operators, service providers and research organisations in Europe and the United States. The interviews were carried out during June and July 1993. In addition to discussing general points and issues relating to the satellite industry, there was considerable discussion of the regulatory options described in Chapter 6. Such discussion continued in a workshop organised by KPMG and the Commission and attended by leading figures in the industry in October 1993. The main points raised in the workshop are to be found in Appendix 3.

In general there were substantial differences in emphasis between the views of the European and US interviewees. In particular, the US respondents were much more familiar with the regulatory options concerning procedures, terms and conditions and certain technical policies such as pioneers preference. This was partly because many of the options are already in place in the US. The US respondents in public sector organisations also had a greater market orientation, with strong views on the need to minimise regulatory interference and maximise competition as being the best way to promote economic efficiency of GSOSR utilisation and to improve welfare.

A key aspect of the US interviews was the general belief that scarcity of GSOSR is no longer a problem (although it still exists in particular niches/frequencies). The "spectrum wars" of a few years ago are no longer viewed as a big issue. This was due primarily to a combination of technological progress and competition from terrestrial systems, particularly optical cable. Remaining scarcity is viewed as being due to the regulatory framework.

In Europe there was more concern about issues of scarcity, the fragmented nature of the industry and, with a few notable exceptions, the general difficulty of introducing new services on a pan-European basis. An important issue is clearly the appropriate geographic level at which GSO regulation should apply. Should it remain at the national and ITU levels or is there scope to stimulate the market through the introduction of regional or sub-regional regulatory regimes? This is a reflection of the fact that regulations with an economic rationale are practically non-existent in Europe. It was, however, very difficult for most respondents to quantify the likely impact any regulatory change would have on future market conditions. The remainder of this section therefore differentiates between the US and European responses.

7.2 Recoup Spectrum

Summary	
European View	**US View**
• military trying to maintain use • some small amounts of spectrum may be released, limited market impact • BSS would release more frequencies that could improve efficiency of existing satellites - could reduce numbers of orbital locations and costs • planned bands very rigid and inefficient, causes scarcity	• reallocation from under-used or obsolete purposes is desirable/efficient • the problem with TV-DTH is in the market (competition/ copyright) not access

European view

The problem with military use of spectrum in Europe is in some ways more acute than in North America because military authorities in different countries do not always use the same frequencies. This tends to heighten the problem of scarcity. Overall, however, recouping of military bands was regarded as a relatively minor issue compared to other sources of inefficiencies and market distortion.

The reforms affecting Central and Eastern Europe, and the decline in the threat of hostilities between NATO and the former Warsaw Pact had led to hopes for a peace dividend impacting spectrum allocation. The ERO Report on the Detailed Spectrum Investigations (1993) has identified 7/8GHz and 20/30GHz as parts of the spectrum currently tied up by military usage which could be released or, more likely, shared with civilian applications.

There is a counter argument put forward by military interests that, contrary to popular belief, there will be greater demand for spectrum from military users in the future. This is because higher technology defence systems tend to be more intensive users of radio communications. Such systems are also sensitive to interference. The greater dependence on such systems, which in some ways is a consequence of the peace dividend tending to reduce the numbers of personnel in the armed forces, is increasing rather than decreasing military demand for spectrum.

Progress towards releasing spectrum currently allocated to military uses is regarded by operators in Europe as being slow at best. One operator cited the difficulty of gaining access to the 14.6-14.8 Ghz spectrum.

Another factor to consider is the attitude of the Russian military authorities to the release of spectrum reserved for military users which is now increasingly underutilised. The outcome of this issue is currently uncertain[3].

The tying up of resources in planned bands - particularly the BSS which has not been implemented - is acknowledged as being technically and economically inefficient. The general release of BSS bands to other uses would therefore reduce the artificial scarcity affecting the spectrum. One multi-national organisation pointed to the expected increase in demand for spectrum for the supply of HDTV services across Europe. This, it was thought, might be accommodated by means of realisation of the BSS band.

The existence of planned bands is being called into question by some commentators. In particular it is the rigidity of the allocations which causes greatest concern. It was pointed out in European interviews as well as in the US that technological developments - and in particular trends towards digitalisation - are undermining to some extent the need to allocate bands to particular services.

An issue which needs to be considered, however, is whether allocation of bands to very specific services, such as VSAT for instance, is justifiable in terms of the facilitation of pan-European services. A basic problem is the doubt that a commonly available band for uplinking is available on a pan-European basis. The 14.6-14.8 Ghz part of the spectrum has also been suggested as a possible means of introducing VSAT services, however, one operator felt it would be inappropriate to allocate any further spectrum for the use of a service with uncertain future demand. It may not be desirable, for reasons of inflexibility, to set aside parts of the spectrum for specific services, but it will be important to ensure that when real demand arises for spectrum to provide such services that sufficient bandwidth is allocated to ensure that competition can take place. It may be necessary to make such an allocation on a contingency basis. Making provision for competition would also have the benefit of encouraging scale economies to be reaped in the terminals and service equipment associated with new services.

A view exists that there is an artificial distinction between the FSS and BSS planned bands. One operator would like to gain access to as much spectrum as possible from each orbital location. This would include BSS, FSS and the FSS planned bands. Having such access it is felt will allow more optimum use of each satellite and so free up orbital locations by reducing the need for so many satellites for any given level of demand.

It is also felt that the problem of inefficient allocation of spectrum to services is not confined to the BSS. It is also a problem applicable to the FSS. The technical specifications associated with the planned bands make it very difficult for operators to optimise the delivery of their services from any given orbital location. It is acknowledged that it is possible to circumvent the technical specification of the planned bands but only on an ad hoc basis and at significant administrative cost. Applications to change the technical parameters are, for instance, being used by a number of operators to gain access to BSS spectrum for non-BSS applications.

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3 Other authorities are also opposed to reforming the military spectrum. At WARC-92, Russia, the US and some Asian countries rejected the ITU allocation at 1.5 Ghz for DAB.

In general, therefore, the operators talked to were very aware of the failings of planned regimes. The theme was for much greater flexibility either at the ITU or sub-regional European level in the allocation of spectrum for specific application uses. A dissenting note was struck by one respondent who suggested that use of BSS applications in the FSS planned bands was preventing the development of FSS services because of interference problems. This point seems to reinforce the contention that the existing regulations relating to the planned bands are not managing the development of services in the way that was originally intended. Their future should be reviewed as a matter of urgency by the next WARC. As one operator summed it up "There is no scarcity of Ku band in Europe it is the regulatory procedures which are causing the mess". The uncertainty concerning the interpretation of existing regulations represents, in the view of the operator, a significant barrier to new entry.

US view

As a general principle it is not efficient to have any sort of band allocation. To do so involves the regulator second guessing the market, in which case the best possible outcome (from an efficiency point of view) would be the market solution. In practice it is extremely unlikely that the regulator can achieve this. The current band allocations, particularly for the BSS, were viewed as being major causes of scarcity in the GSOSR.

In the short to medium term the shift to digitalisation and other new technology will both significantly increase the capacity of GSOSR and result in digitalisation of signals for different services. It therefore makes even less sense in the future to allocate separate bands to different services.

In terms of recouping military allocations, the Emerging Technologies Act of 1993 provides for the transfer of 200 Mhz of spectrum from Federal Government use to commercial uses (it is therefore known as the "200 Mhz Bill"). While the Bill does not specify where the spectrum should come from, it is likely that at least some will be from military applications, as these make up about 80% of the Federal spectrum (which in turn is about 50% of the whole).

Related legislation, incorporated in the new US Budget Reconciliation Act, also provides for the auctioning of the licences for this 200 Mhz, although the purpose is explicitly to raise revenue rather than promote efficiency. Some scepticism was expressed regarding the spectrum that would be released. Although current users are to be compensated for moving, this would be at the technical cost to them rather than the economic value. It was therefore viewed as being likely that only the least useful frequencies would be given up.

More generally, strong resistance from the military was predicted to any proposed changes in Europe. It is always difficult to counter the emotive argument of "national security".

Another issue was that military frequencies tend to concentrate on the lower C bands where there would be strong demand from terrestrial cellular users. "This will come down to a fight between terrestrial and satellite mobile and the satellites will lose."

The reasons why DTH included in the BSS band remains largely unimplemented include the following:

- strong competition from terrestrial providers, particularly the large, vertically integrated cable companies which limits the likely demand,
- difficulties in accessing programming for copyright reasons. Legislation was recently passed to force cable companies to allow broader access to programming under their control.

The key constraint to the development of DTH therefore lies in the service market. Access to the GSOSR itself was not seen as a problem.

The LDCs were viewed as the main obstacle to releasing the BSS bands. The LDC argument that this was a matter of their "inalienable rights" was seen as legally weak. The fact that LDCs could hold up the reallocation of prime commercial spectrum when they themselves would not be in a position to use it for many years was viewed by one respondent as "a disgrace".

The option of sub-regional recouping of the BSS spectrum was generally viewed favourably as a quicker solution than changing the Radio Regulations. However, there was some scepticism over the likelihood of individual countries giving up their rights.

7.3 Institutional Change

Summary	
European View	**US View**
• might increase the coverage area (CEPT, EC) • would tend towards US price and competition levels, but Europe has higher cost base • would reduce numbers of coordinations and time for coordinations and so reduce costs and barriers to entry • Member States doubt impact and state practical reasons why it would not happen • must cover service introduction and liberalisation	• good idea but can member countries agree? • European licensing good for European operators • more openness and more regulation lead to more litigation • a single European voice could come to dominate future WARCs

European view

Amongst organisations interviewed in Europe there was a contrast between the views expressed by certain Member State regulators or TO representatives and by non-nationally oriented operators and supra-national regulatory bodies. The former, in particular, were suspicious of the European Commission's possible ambitions as a pan-European regulator. Various points were raised to argue why existing national responsibility should remain, including:

- coordination will still have to take place vis a vis non-EU users of the GSOSR and so the creation of a European body would only have a very limited impact on coordination problems and procedures,
- even when access to the GSOSR is restricted to organisations such as national TOs there is ample opportunity for competition at a European level because there are so many TOs able to access the resource. In any case there may be countries willing to host private or quasi-private concerns wishing to exploit the resource (such as Luxembourg with Astra),
- there is no commercially viable future for satellite based communications services (with a few possible exceptions such as VSAT), and there are no or only few restrictions on the provision of broadcast services on a pan-European basis. This negates the need for a European regulatory body,

- it is accepted legally that it is nation states that have rights over assignments to GSOSR within ITU conventions. The principle of subsidiarity means that countries should continue to exercise these rights.

Whilst these points have credence, they do not fully acknowledge the significant inefficiencies that result from the fragmentation of the market in Europe. For each of these points it is possible to present a counter view as follows:

- any reduction in the number of satellites with which new satellites would have to be coordinated will represent a benefit in terms of time and cost savings. As some 80% of satellites in Region 1 belong to European operators it would seem that rationalising coordination procedures at the sub-regional level would yield the potential of significant benefits,

- there are undoubtedly various routes open to organisations wishing to coordinate an assignment but this does not detract from the fact that the national assignment process encourages the fragmentation of satellite service provision in Europe. The logic of national satellites serving national coverage areas is no longer compelling. It would therefore seem appropriate for assignments to be the responsibility of a regional or sub-regional body. The current wide range of national assignment procedures and requirements itself represents unnecessary complexity and a deterrent to entry,

- the point, raised by one European regulator, that satellites had a limited future outside broadcasting, would become a self fulfilling prophecy if it were to justify not improving the regulatory conditions covering access to GSOSR in Europe. It is clear that unless the industry can evolve towards a more optimum structure (ie. one where competition stimulates efficiency of resource allocation and assignment, reduces costs and prices, and thus stimulates demand and provides the prospect of operators benefitting from scale economies) then its future vis a vis terrestrial substitutes such as fibre will indeed be limited,

- it is the case that nations have jurisdiction over assignments within ITU conventions. There is no reason, however, why resources should not be 'pooled' if a common benefit would result. With satellites increasingly being regarded as providers of services to wide geographical areas not confined to national boundaries, it would seem appropriate if regulation would be applicable to a similarly 'wide' area. It may be that Region 1 of the ITU is an appropriate level and it is the case that the larger the area covered by the regulatory body, the greater the potential benefit. Significant benefits would be likely if the CEPT countries cooperated, or even if cooperation was based around a nucleus of European Union states. The principle of subsidiarity does not necessarily support the contention that the regulation of satellites should be at a national level in Europe.

It was emphasised by some respondents that unless there was effective liberalisation of telecommunications service markets then there would continue to be limited competition in and use of GSOSR. Unless the introduction of services such as VSAT, and international private circuits could be freely marketed there would continue to be major impediments to the commercial development of GSOSR on a pan-European basis. One European operator said the deregulation of end user services may not 'work' unless there is European level licensing of satellite services - 'there is a need for both'. The same operator acknowledged, however, the problems associated with assignment that had to take into consideration 'local' terrestrial interference issues. Another, however, said it was not in favour of a 'Euro FCC' - especially one that would continue the inflexible system of band allocations to specific services.

An international organisation emphasised the problems associated with implementing any change. It was pointed out that any changes only in Europe would impact non-European countries. Maghreb countries, for instance, would be impacted by spillover of signals from new European satellites. Such countries have traditionally objected to reforms that would mean changes to existing international treaties. In contrast to this conservatism, however, it was noted that some African countries were interested in options of selling or leasing their rights to GSOSR. Some developing countries, such as Tonga, were realising the economic potential of their rights to GSOSR even though no formal framework existed for leasing or selling its rights to orbit and frequency resources. Such ad hoc developments have the potential of undermining the international regulatory procedures and associated institutions. It was acknowledged, however, that an 'economic' path to reforming GSOSR had not really been explored. It offered the potential of yielding financial benefits to countries that otherwise would be able to make little use of their national rights of access to GSOSR. This may represent a catalyst for generating more general reform of the GSOSR regulatory system - especially if practical benefits could be demonstrated for developing countries as well as European countries.

There remain, however, two views on this issue. The first maintains that equity of right over access is supreme and immutable. The second regards national rights as being something that could be traded or leased to gain financial or other negotiated economic benefit. Any change in the fundamentals of the way GSOSR is allocated/assigned, however, it was pointed out would be "a long way off" - certainly into the next century.

US view

In the US assignments to the GSOSR are controlled by the nation-wide agency the Federal Communications Commission.

Overall the concept of having a European agency responsible for allocation, assignment, etc, was seen as being indispensable to the long term development of the European satellite industry. The need for such an organisation was viewed as "self evident"; "Europe is crazy not to have it." However, there was considerable doubt as to whether the member countries could agree to give up the degree of sovereignty necessary to make it work - "just look at trade."

Pan-European bands were not thought to be efficient on the argument that setting aside spectrum for any service by administrative fiat would create artificial scarcity. However, having a single contact/licensing point and Europe-wide type approval was viewed as very good for operators and service providers serving the European market.

One interviewee emphasised the downside of having more open regulation - a concomitant increase in litigation. Indeed, the high risk of legal challenge to regulatory decisions was raised by many of the respondents.

Several US regulators identified a potential disadvantage to the US of having a single European negotiator in international satellite affairs. A unified block vote at international fora such as WARC would make it much harder for the US to achieve its own objectives. The experience of WARC-92 was cited, when Europe initially stuck together. However, the inflexibility of the European negotiating team made it easy for the US to get around this by negotiating side deals with other countries, while Europe was unable to shift its position. A Europe speaking with a single voice could come to dominate future WARCs.

7.4 Procedural Change

Summary	
European View	**US View**
• interference control is essential, it is possibly the only relevant technical criterion • economic planning is as problematic as technical planning • auctioning must be combined with suitable terms and conditions	• many economists favour auctions - provided for in the "200 MHz" bill • lotteries with transferability lead to private auctions • only need selection procedures where there are competing demands • setting restrictive criteria can discriminate against small, innovative firms

European view

In general, thoughts concerning the relative economic efficiency of procedures to assign GSOSR were less well developed in Europe than in the US. This reflects the relative lack of exposure to procedures other than the traditional, largely administrative procedures, that characterise the ITU and national authorities.

Many organisations in Europe recognise the need to introduce greater levels of competition into the area, but most have not developed definite views on how this should be achieved. One European operator acknowledged that the introduction of 'economic principles' would decrease costs but was not sure how this could be achieved. It was widely recognised, however, that technical considerations should not be the only ones determining allocation and assignment. Some respondents argued that there should be explicit consideration of the market or economic prospects for services prior to assignment. Others, however, doubted whether market assessments or economic planning could predict with sufficient accuracy the future of new and potentially volatile service markets. This led to a reaffirmation of the need for flexibility to be built into the regulatory system. Some respondents thought that decisions should best be left to the market but others doubted whether market forces would cope with the technological complexities inherent in this area.

A national regulator favoured a "middle ground" approach between free market lotteries or auctions and technically orientated administrative procedures. This approach involved inviting multiple applicants and drawing up a shortlist on non-economic grounds according to criteria such as industrial policy, national interest and public interest. Economic and financial criteria would then be applied to decide amongst the shortlist. Those criteria would include "consumer benefit" and "general economic interest".

The examples of failures and potential shortcomings of auction and lottery systems were known, but amongst some there was relatively little detailed understanding of the various forms auctions or lotteries could take. It was stressed by those who had considered the issue in greater depth that the success of auctioning was dependent upon the terms and conditions attached to the pre-qualification, bidding, monitoring and enforcement procedures. The main concern was that auctioning, like any other form of assignment, could lead to a failed or inefficient use of GSOSR which was then tying up resource for long periods if not in perpetuity.

Another view came from a European operator. This operator thought auctions would work but that "there was no need" for them. They were regarded as suitable for commercial applications but pointed out the need to reserve orbital and frequency resources for 'non-market applications'.

US view

The point was emphasised that selection procedures are only necessary where there are competing demands for the spectrum. This suggests that the regulator needs a degree of flexibility. In rural areas where demand for certain terrestrial services is likely to be low, there would be little point in having strict due diligence and trying to enforce competition. In urban areas the opposite may hold.

The FCC noted that its "philosophy is to promote competition, including in different media, by encouraging new technology and services, to give customers a choice." In the past the FCC has used two assignment mechanisms, comparative hearings and lotteries. Comparative hearings are viewed as expensive and time consuming "beauty parades", where competing bidders must testify to convince the FCC that their option is best for the public interest. These are only really feasible with two or three bidders.

The alternative option of lotteries is used where there are a large number of bidders. This was particularly the case for terrestrial cellular licences. The experience with lotteries was not generally viewed favourably. The cost of entry is relatively low, while the potential profits to the winners are enormous. This led to the development of "application mills" that (for a relatively small fee) put in standard applications "by the carload". The tradeability of licences meant that there were private auctions subsequent to the lottery process. From the economists' viewpoint, these did have the benefit that the final user paid the economic value for the licence and therefore had an incentive to use the resource efficiently. However, the prospect of high windfall profits encouraged speculative applications from bidders that had no intention of operating, while denying potential revenue to government.

As indicated above, government is moving towards auctions. The concept of auctions was generally viewed favourably by most respondents, in particular by economists and, to a lesser extent, by lawyers. However, not all interviewees supported auctions. In particular, those with a technical background tended to argue against them on the grounds that GSOSR should not be treated as a commodity.

It should also be noted that the FCC licensed two operators in each cellular market to promote competition. An FCC official felt that "there is no question that society is better off" as a result of this policy. Costs for terrestrial cellular hardware and services have fallen dramatically, with one reported offer pricing the handset as low as $19.95 plus three months free use. On the other hand, gaps in service have developed where market potential is low even in certain urban areas. The FCC was reported to be reclaiming and reletting licences for these.

The FCC normally reviews licence applications with respect to various criteria, including technical, economic (proof of markets), legal (US ownership) and financial standards. The need to prove access to sufficient capital for constructing and launching a new satellite system was viewed as a potential constraint to innovation. For many companies the ability to raise financing is dependent on having a licence. The FCC has introduced a degree of flexibility. For example, there can be a two part approval process, where provisional approval is given conditional on financing, allowing the licensee to then raise capital and gain final approval.

7.5 Terms and Conditions

Summary	
European View	**US View**
• licensing would need to be treated sensitively - trade-off between market forces and investment certainty	• fixed duration licences can lead to disinvestment at end of term • tradeability is essential
• due diligence would be essential	• due diligence helps prevent "warehousing" and "deep pocket" problems
• transferability favoured by private sector, novel concept to others	• pioneer's preference is a good idea but impossible to implement

European view

The procedures followed in the assignment process and the terms and conditions attached to these procedures need to be assessed in conjunction with one another. Auctioning, for instance, is only likely to succeed if the right terms and conditions are attached to the process. An example cited in the interviews related to the duration of licences. If licences are for too short a period then investment could well be discouraged. If, however, the licence is in perpetuity with no tradeability then market forces are frozen out.

The issue of tradeability was not a familiar one to those in Europe who were not in the private sector. For those in the private sector the possibility of trading licences as an asset and of trading companies with such an asset was regarded as normal. Tradeability would, of course, have the effect of attaching a market value to the asset.

Appropriate due diligence was also widely regarded as sensible amongst the European respondents. This due diligence should cover both the bidding process and subsequent monitoring to ensure the resource assigned was being used as intended. In the bidding process it was felt important that:

- financial resources were demonstrable of a scale that matched the scale of investment,
- market growth estimates were sensible and conformed with independent assessments,
- quality and technical dimensions of the project were taken into consideration where necessary, for instance to ensure there would be no interference problems.

In the subsequent implementation phase it would be important to ensure that the terms and conditions of the licence were transparent and adhered to, and that there was some suitable recourse if agreements were contravened. As one European operator put it - "Use it or lose it - we need it". In applying this principle it would, according to one regulator, also be important to take the following points into consideration :

- there is currently a requirement to notify the expected launch date and 'period of life' of satellites in filings to the IFRB. Under a system of due diligence it would be important to review the credibility of these claims, rather than just accept them,

- it would also be necessary to reduce the nine years which operators currently have to implement their filings. It is an open question as to what is an appropriate period over which to monitor the implementation of stated plans. Nine years was regarded as 'too long' and one year as 'too short'.

In order for due diligence to be most effective it would need to be introduced globally. Any regional or sub-regional level due diligence would have to pay particular attention to the drift of operators outside the regulators areas of jurisdiction.

US view

Duration

Fixed duration licences were generally not favoured, due to the problem with disinvestment as the licence gets close to expiry. While US licences have a fixed duration, which varies according to the service, there is a high expectation of renewal. Economists were generally in favour of granting licences in perpetuity, providing that they were tradeable.

Tradeability

Tradeability was viewed as essential for creating a market. This could either be through allowing the licence itself to be traded or through the sale and purchase of the company holding it.

Tradeability does have a perceived disadvantage (when licences are effectively free, eg with lotteries) of facilitating private auctions. This encourages numerous speculative applications by organisations and individuals that have no intention of operating. As a result the administrative cost of running the lotteries increases, while it becomes more difficult (and costly) for genuine players to obtain a licence. The FCC initially tried to get around this by insisting on a three year non-trading period for licence holders. This did not prove effective, as companies got around it, by, for example, letting management contracts. It was argued that with auctions this problem would not arise as there would be little incentive for speculative bids.

Due diligence

The aim of due diligence is to protect against warehousing of GSOSR and the "deep pockets" effect. The FCC generally requires that licence holders make "meaningful progress" in implementing their proposals. In the past the FCC has not made much use of this condition, however there have been a number of cases recently where licences have been revoked. This has resulted in considerable litigation, as licences are generally viewed as assets. Again, there is the problem that the regulator has to judge what progress is "meaningful". This is complicated by the long lead times inherent in the satellite industry[4].

The point was made that if licences are traded at their market values there is little incentive for holding a licence and not using it. There may be a situation where a company wishes to hoard spectrum in anticipation of future technical developments. In a market situation this would be a normal commercial risk. In the current situation there is no risk because the licences are free.

The "deep pockets" problem can be addressed by using competition rules rather than specific due diligence requirements. Companies buying up and holding on to large parts of the spectrum could be viewed as operating anticompetitively. On the other hand, the point was made that due diligence conditions help to send the correct signals to the industry. It may therefore be worthwhile to have them even if they would not be needed in practice.

Pioneers' preference

Pioneers' preference is an FCC policy, with the blessing of the Commerce Department's NTIA. However, the universal reaction from interviewees, including those from these two organisations, was that although the principle of promoting innovation in this way was a good idea, it is impossible to implement in practice. Reactions ranged from "politically palatable but inefficient" and "you don't have it for restaurants so why have it for satellite services?" to "hopeless", "a regulatory nightmare", and "creates more headaches and litigation than it is worth."

There was considerable scepticism over the ability of a regulator to judge what is a true innovation and what is merely a copycat application, and setting aside spectrum for "good ideas" was viewed as counterproductive, likely to create scarcity elsewhere.

The key issue here is the need to stimulate innovation. This leads to an additional protection of intellectual property. The US licensing system is very open - applicants are often in the position of divulging their technological innovations, which can be viewed by any interested party. However, several respondents argued that innovation could be stimulated in other ways, such as:

- patents and copyright,
- having less open licensing procedures where proprietary technology is not revealed to the public,

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[4] An alternative approach, which is less likely to lead to litigation, might be to require applicants to submit a detailed build/use plan, then give the regulator the right to waive it.

- FCC granting temporary experimental licences.

It was also noted that in practice an innovative company that gets a six month lead in a new technology is generally able to maintain that advantage through continued innovation.

7.6 Technical Policies

Summary	
European View	**US View**
• spacing is application dependent • digitalisation will dramatically increase capacity and reduce interference • self compatibility	• 2° spacing feasible but needs uniform specifications and large antennas - there is a cost attached • obvious benefits from frequency sharing/ reuse

European view

Changes to existing technical conventions were not in general regarded as having a major impact on the issue of scarcity or economic efficiency. A number of interviewees pointed out that reducing orbital spacing was not necessarily a sensible way of addressing scarcity problems. For some applications, especially those in small diameter receivers, it would be necessary to have greater than 3° spacing in order to avoid problems of interference.

It was also stressed that the increasing introduction of digital services will increase the capacity of the GSOSR by:

- making it possible to combine services transmitted in any given band,
- reducing the problem of interference that would characterise an equivalent analogue signal.

One potentially major technical policy, however, did emerge from our interview programme. This is known as 'self compatibility' testing and it is being developed as a way of reducing unnecessary scarcity and bureaucratic technical procedures. The principle is being developed by staff at France Telecom and it involves a new approach to testing for unacceptable interference. The test for a proposed satellite application would be acceptable if it did not interfere with a hypothetical clone of itself in adjacent locations. It is acknowledged that this approach may not function well in an analogue environment such as current generation VSAT or FMTV. It would, however, be particularly appropriate in a digital environment. This concept is being developed for submission to the CEPT working party on the issue.

US view

The FCC introduced 2° spacing in response to a perceived scarcity of orbit slots. It commissioned a study which concluded that 2° spacing was technically feasible. This was agreed with the industry before being implemented. In practice it seems to work in the US, although the following should be noted:

- coordination requires that satellites must use similar technologies and systems to work effectively. This has led to "cookie cutter" satellites, all very similar. While this has the disadvantage that it may stifle innovation, it has also promoted economies of scale in the satellite construction industry, allowing the US to dominate the world market[5],

- 2° spacing puts a minimum size requirement on the earth stations, which has a cost implication for customers.

In general, while closer spacing can increase orbit capacity, it should not be imposed unless there is genuine scarcity.

The benefits from frequency sharing and reuse were viewed as "obvious". Frequency reuse is already well developed in the US. It was questioned whether there was a need to regulate for it, however, except on an international basis, as operators have a commercial incentive to avoid interference. It must be borne in mind that unlike the US, Europe is an inherently international region. It was thought that in most cases there is a sufficient buffer between Europe and Africa to permit frequency sharing and reuse. However, care needs to be taken to avoid infringing African rights to GSOSR access.

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5 However, although the US dominates the world market for satellite construction, many of the components on the satellites are sourced outside the US. Europe has 50% of the world market for communications satellite components, for example.

7.7 Competition Policy

Summary	
European View	**US View**
• ISO anti-competitive covenants increasingly not invoked, but still procedural and psychological barrier • signatories have conflict of interest - potential market distortion • "hot birds" should be eroded by technological developments and by reducing regulatory impediments to competition	• the best defence against abuse of "hot birds" is competition • Astra should not be punished for doing a good job

European view

There were three main issues raised with regard to competition policy. Firstly the anti-competitive rights held by Eutelsat were said to be irrelevant because they were not invoked. It is argued by competitors to Eutelsat, however, that the requirement to coordinate with Eutelsat, and to provide Eutelsat with information, however innocuous, about future commercial intentions places Eutelsat in an advantageous competitive position. The existence of such covenants also increases the uncertainty faced by potential market entrants and so represents at least a procedural and therefore a psychological barrier to entry. As the anti-competitive covenants have not been revoked it remains a potential threat to competitors.

Secondly, and more importantly, the exclusivity rights of Eutelsat's signatories over access to its transponders in their national territories represents a major distortion to competition impacting the use of GSOSR. This arrangement severely limits Eutelsat's ability to impact end user prices. Signatory mark ups vary widely and reflect strong monopolistic power. There is conflict between the signatories as suppliers of satellite services in their own right and as providers of substitute terrestrial services. High mark ups will discourage use of satellite services compared to similar services offered through other media. This may be consistent with strategic decisions to invest heavily in terrestrial networks but it tends to distort the operation of market forces in the GSOSR.

It is also in the interests of TOs to protect their positions as much as possible in markets being threatened by liberalisation. One potential threat would be from geo-stationary satellite services which could provide competitive communications services over wide areas of Europe comparatively quickly. It is not in the interests of the TOs to encourage liberalisation of the GSOSR at the same time as they are facing increasing threats to their terrestrial services.

Thirdly, "hot birds" in Europe were not generally regarded as abusing a dominant position. It is recognised that Astra, Europe's dominant "hot bird" operator (with the largest number of ground stations aligned to its satellites), had exploited the distorted European regulatory environment in a very effective manner. It was felt that technological developments such as double antennae dishes could allow effective competition to Astra. It was also noted that removing regulatory constraints would also facilitate greater competition with the Astra "hot bird" location.

Competition policy is a sensitive issue because it is acknowledged that the EC has the necessary institutions to enforce open and fair competitive practices. It is also sensitive because it is acknowledged that liberal market conditions would have to be applied throughout the supply chain of satellite services for it to be effective at the GSOSR level. Without consistency of application throughout the vertical structure of the industry, market signals would tend to be distorted by regulatory "bottlenecks" or "asymmetrics".

US view

The US survey concentrated on the "hot bird" issue and Astra's perceived dominant position within Europe. Respondents were strongly against regulating for competition unless Astra was clearly abusing its position. "Why punish Astra for being good at what it does?...Using legislation to force access to Astra's capacity is totally absurd."

The best defence against the abuse of "hot bird" positions is to promote competition. It is not very expensive to realign satellite dishes, and if a competitor were to arise offering better programming then it would be relatively simple for audiences to switch.

8 Implications of Regulatory Scenarios

8.1 Introduction

One of the key findings arising from the interview programme is that the likely impact of the individual regulatory components described in Chapter 6 will be relatively small. In order to have a significant effect they must be implemented in combination. We have therefore developed four scenarios utilising various combinations and levels of these components. The first scenario involves the most radical changes, and the greatest amount of market liberalisation. Scenarios two and three involve progressively less radical change, with scenario four representing relatively minor modifications of the existing regulatory regime. It is not our present aim to evaluate the actual likelihood of any of these scenarios although practical difficulties in their implementation are considered in Section 8.6.

The remainder of this section briefly describes the scenarios and provides a preliminary qualitative indication of the likely impact on the transponder market and on the satellite industry. This was based on the interview programme and on discussions with the industry experts within the team. Figure 8.1 summarises the potential remedies to shortcomings of the existing regulatory environment.

In looking more generally at the satellite industry, the following are considered:

- impact on innovation and scope of services provided,
- impact on competition between existing (satellite and terrestrial) suppliers and their possible reactions,
- impact on market entry and exit,
- impact on industry structure.

The issue of sustainability of the current incumbents was also considered, where "sustainability" is defined as the ability to produce at the lowest average cost possible in the long run. This has been a problem in other industries where incumbents had to face a reduction in demand because of the entry of smaller independent operators who specialised in niche markets. The current literature[6] does not consider this to be a significant issue in the European satellite industry. It should be noted, however, that this research assumes that Eutelsat is free to set prices at market levels.

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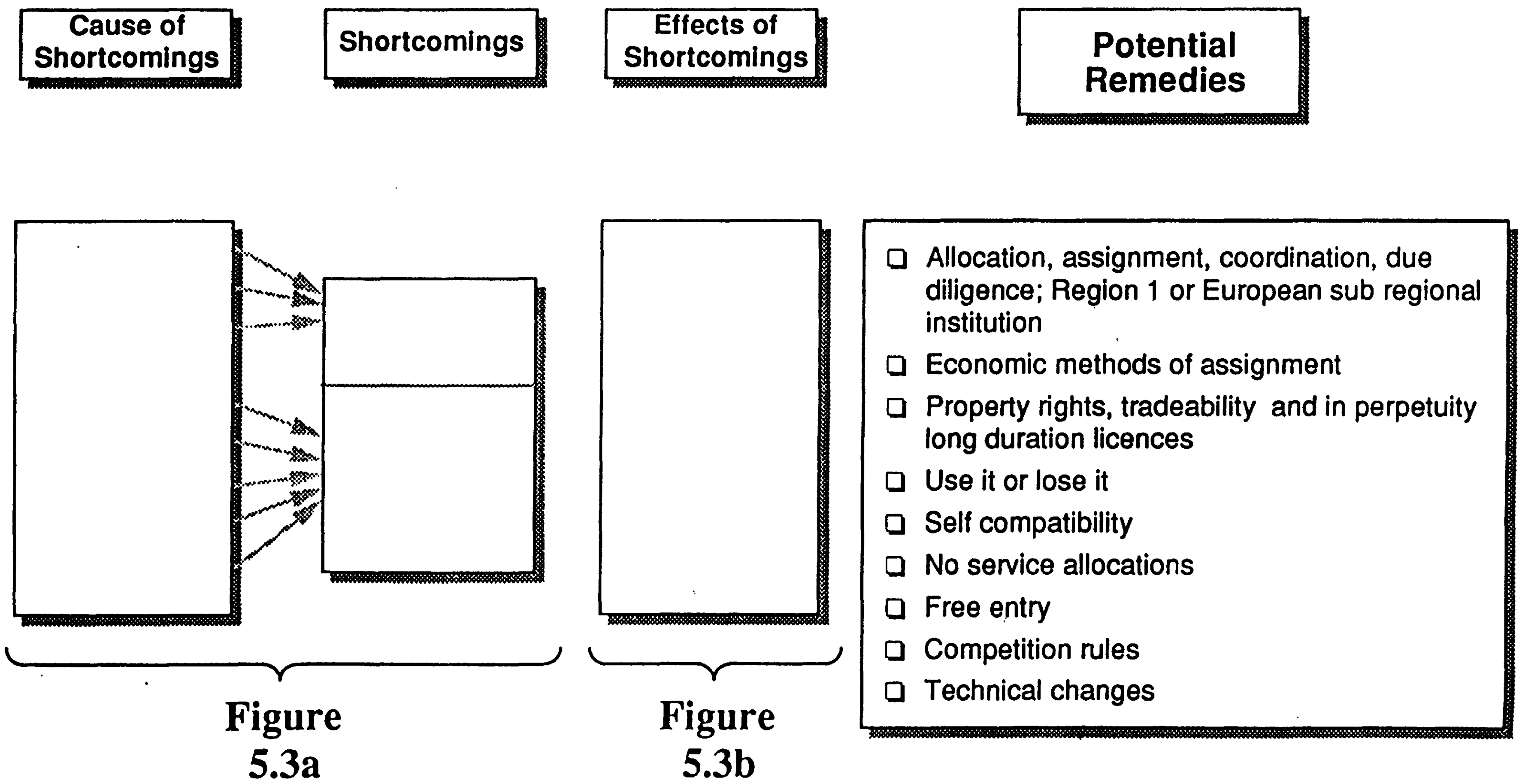
6 The Optimal Structure of the European Satellite Operations Industry - a report submitted to ESA - Roller and Waverman, INSEAD 1991

Figure 8.1 Existing regulations - summary of shortcomings



In looking at the impact on the transponder market the following are considered:

- supply of GSOSR,
- supply of transponders,
- price of transponders,
- demand for transponders,
- costs of launch and service provision,
- economic welfare.

Tables 8.1 and 8.2 below summarise the four scenarios, to allow them to be compared easily. In Table 8.1 we have indicated at what level (national, European or international) the four main regulatory responsibilities would be handled. These responsibilities comprise allocation, assignment, coordination and legislation. Table 8.2 compares the four scenarios across the six regulatory components described in Chapter 6.

Table 8.1 : Comparison of Scenarios - Level of Responsibility

	Scenario 1 Market approach - worldwide	**Scenario 2 Market approach - Europe**	**Scenario 3 Partial markets**	**Scenario 4 Minimal Institution/ Allocation Reforms**
Allocation	ITU/Region 1	ITU/Europe	ITU/Europe	ITU/Europe/national
Assignment	Region 1	Europe	national	national
Coordination	Region 1/international	Europe/international	national/international	national/international
Legislation	ITU/Region 1	ITU/Europe	ITU/Europe	ITU/national

Table 8.2 : Comparison of Scenarios - Regulatory Components

	Scenario 1 Market approach - Worldwide/Region 1	Scenario 2 Market approach - Europe	Scenario 3 Partial markets	Scenario 4 Minimal institution/allocation reforms
Institutional change	assignment, coordination, competition/due diligence, international negotiation at Region 1 level. (ITU functions move from national to Regional level)	assignment, coordination, competition/due diligence, international negotiation at European level. (ITU functions move from national to European level)	pan-European allocation; rigorous competition; common ITU delegation; in Europe 'partial service' coordinators; assignment, due diligence remain at national level	pan-European band allocation for specific services
Procedural change	assignment by tenders, auctions or lotteries	assignment by tenders, auctions or lotteries	entry criteria plus assignment by tenders, lotteries or comparative hearings	assignment by economic administration
Terms and conditions	• broad based property rights • licences issued in perpetuity or with high expectation of renewal • full tradeability • strict due diligence • no pioneer's preference • use it or lose it	• broad based property rights • licences issued in perpetuity or with high expectation of renewal • full tradeability • strict due diligence • no pioneer's preference • use it or lose it	• licences initially service specific • licences issued with high expectation of renewal • full tradeability • strict due diligence • no pioneer's preference • use it or lose it	• service specific • duration service specific • not tradeable • no pioneer's preference • use it or lose it
Competition policy	• free entry to operator and service markets • EC/national competition rules rigorously enforced • no ISO non-competition covenants	• free entry to operator and service markets • EC/national competition rules rigorously enforced • no ISO non-competition covenants	• entry to service markets initially limited • EC/national competition rules rigorously enforced • ISO barriers to entry phased out	• competition enforcement as present • no change in treatment of "hot birds" • ISO barriers to entry phased out
Technical policies	• no limitation on spacing • no limitation on frequency sharing/reuse	• no limitation on spacing • no limitation on frequency sharing/reuse	• no limitation on spacing • no limitation on frequency sharing/reuse	• no limitation on spacing • frequency sharing/reuse unchanged
Recoup spectrum	satellite allocations recouped at World/Regional levels plus grandfathering	satellite allocations recouped at European level plus grandfathering	satellite allocations recouped at European level plus grandfathering	increased flexibility in BSS. New pan-European allocations
Likely welfare and market impact	————————————> Most change Most liberal market impact	————————————>	————————————>	————————————> Little change Little market liberalisation

8.2 Scenario 1 : Market Approach - Worldwide

Description of scenario

This scenario is designed to be the most market oriented. It is actually closer to a pure market approach than the current US regulatory framework, particularly in the use of auctions for assignment of licences. It also assumes that the market principles described below are applied generally at the ITU level to the whole of Region 1 (Europe, including the CIS, Africa and the Middle East). The main components of Scenario 1 are:

- establishment of a "full service" coordinator with responsibility for spectrum assignment, dealing with coordination, monitoring competition and due diligence for the whole of ITU Region 1. It would also liaise with international standards bodies such as CCITT to sponsor industry cooperation, such as development of common standards and would be responsible to inform the industry about current and future availability of orbits,

- band allocation is assumed to be minimised at ITU level. All ITU allotments within the planned band (BSS, FSS) are assumed to be abolished, with suitable arrangements for compensating governments that lose out. "Grandfather rights" of incumbents operating in these planned bands would be maintained, but newcomers would be able to buy them out,

- assignment (ie. the determination of use of a specific combination of orbit and frequency resource) would be carried out through tenders, auctions or (possibly) lotteries. With tradeability of licences, this will ensure that the market value is reached,

- licences to use GSOSR to operate satellite systems and to provide satellite services would:

  - be freely tradeable with no additional restrictions other than notification requirements,

  - incorporate a broad definition of property rights ("exclusive, unrestricted easement subject to non-interference"). Licences would not be restricted to providing a particular service, although there could be geographic coverage limitations as an option,

  - be offered either in perpetuity or given a long term (10 - 20 years) with a high expectation of renewal,

- there are assumed to be due diligence provisions at the ITU and/or regional level, with periodic examinations to ensure progress. For example, pre-launch time limited to five years and reviewed regularly as technological developments enable a shorter construction period, post-launch requirement for a specified proportion of the assigned spectrum to be utilised for three consecutive years. Assignments failing the test would be subject to mandatory re-auction. A sub-regional regulator would have a degree of flexibility in applying this. For example, licence holders where there had been no competition for licences would be given more leeway than those serving prime markets,

- newcomers would be able to negotiate with incumbents with recourse to the regulator only as a final arbiter if they cannot agree. Potentially, this could be a significant barrier to entry unless the regulator has considerable power to impose fines/other measures soon after disagreement arises. The regulator would act as a facilitator for frequency sharing and reuse and other efficiency promoting arrangements and would coordinate with interests outside ITU Region 1,

- ISO non-competition covenants would be abolished to remove barriers to new entrants. EC style competition laws would ensure distortive barriers to entry are not raised,

- countries, especially LDCs, could be encouraged to lease access to GSOSR over which they have acquired rights to commercial users, and a tax could be levied on auction revenue in Region 1 to fund satellite based communications developments in LDCs.

Industry dynamics

With both costs of entry and barriers to entry falling, the potential for greater competition is enhanced significantly. This would stimulate more competitive practices amongst users of GSOSR and have a knock on effect with the services such as broadcasting and telephony that deliver services via satellite but which face entry costs that are not expected to be as high as for satellite operators.

Increased competition would put considerable pressure on prices and would force operators to improve their efficiency and reduce their costs by expanding their scale of operation.

The increased opportunity for space segment provision, pressures for increased efficiency, falling transponder costs and a reduction in the barriers to entry should encourage innovation and the provision of new services. However, the use of auctions for licences may limit access by smaller firms that may not be able to raise sufficient capital to pay the market value. This is a result of imperfections in capital markets rather than in the market for GSOSR. It could be argued that if an innovation were good enough it could be sold to a larger company that had the resources to exploit it.

In addition, for operators paying the full economic value for licences, this would lead to an increase in initial start-up costs. The extent to which costs are passed on to service providers will depend on market conditions. We have assumed a relatively high level of space segment competition, such that operators are required to bear the increased licence costs.[7]

This option is likely to meet strong resistance from existing space segment suppliers (particularly the TOs). However, the widespread lowering of barriers to entry, the introduction of due

[7] see KPMG (1993), ibid, for further discussion of auctions

diligence, the independence of the regulator and the fact that the fastest growth is likely to be in services where the TOs are least strong, all suggest that this resistance may diminish in the long term. Existing suppliers will either have to increase efficiency of operation (having equipment in situ and established markets they will have an initial competitive advantage) or exit the satellite industry altogether. Exits from the sector may be facilitated if incumbents with grandfather rights can financially gain from selling their licences.

Possible market impacts

There would be a significant increase in the supply of GSOSR resources through:

- freeing up of previously allocated bandwidth, particularly the BSS and Planned FSS allocations. To the extent that military bandwidth is recouped it is more likely to be applied to terrestrial services,

- increasing the efficiency of utilisation of the GSOSR resources. Operators paying the full economic cost for the resource would be under pressure to make the best use of it. Tradeability of licences would allow them to go to the companies that were able to make the best use of them and broad property rights would facilitate switching of services to meet shifts in demand and accommodate new services. Licence holders would have an incentive to invest in more efficient new technology in the knowledge that they would be able to operate it for long enough to be viable,

- the combination of due diligence, the upward delegation of national assignment rights in Europe and increased trading of licences should largely remove the "paper satellites" problem. Satellite operators would face the true costs of not utilising their resource, while periodic review by the regulator should prevent anticompetitive behaviour by terrestrial service providers.

Overall, it is likely that the considerable increase in market flexibility combined with the increase in availability of GSOSR will facilitate greater supply of transponders equivalents. This should enhance drastically the potential for entry in the industry and should therefore lead to increased competitive measures and lower prices.

Falling prices would stimulate demand for transponders from two services in particular: broadcasting (including TV and SNG) and data services. Telephony will continue to be dominated by terrestrial delivery mechanisms.

Tradeability will help to promote continuity of service as unprofitable incumbents could be bought out by more efficient providers. This would promote a continuity of demand for space segment.

As indicated above, equipment costs are likely to fall somewhat as a result of economies of scale and because of increased competition. The likely impact on the cost of providing satellite services is uncertain. There is a number of competing effects:

- competition in the operator industry combined with increased supply of GSOSR should reduce transponder costs to service providers, particularly from economies of scale,

- new operators of pan-European services will benefit from the reduced administrative burden and increased flexibility of the new system,

- operators may benefit from economies of scope, ie, from offering more than one service,

- international coordination would be easier without "paper satellites",

- terrestrial substitutes will be under pressure to reduce costs to compete with satellite providers.

These factors should lead to a very significant reduction in costs, benefiting the most efficient operators. This effect could however be moderated by:

- increased licence costs for new operators, although for practical purposes licences would become more tradeable,

- the need to use GSOSR more efficiently which may increase equipment costs to the extent that it requires new technology.

Overall the impact on welfare is likely to be positive and significant. Over the medium to long term, as the markets become established, prices should come down substantially. This will reduce the costs to service providers, while increased competition will ensure that these savings are passed on to consumers. For end consumers rather than just intermediate consumers to benefit there is a need for competition to prevail throughout the supply chain. The lower cost framework will encourage the development of new services, and with the reduction in barriers to entry it will be easier for these to get to market. A knock on effect that is likely to be significant (but which is not measured by our model) would be the increase in welfare arising from falling prices of terrestrial substitutes as competition in their markets increases and their traditional stranglehold on the satellite operation and services industries diminishes.

In addition, to the extent that it is believed that welfare would be higher if government were to receive the economic value of licences than if private companies did, welfare would be increased more if assignment were by auction than by lottery.[8]

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[8] This is based on the equity argument that government spending of these funds would create more social benefit than a private company distributing its profits.

8.3 Scenario 2 : Market Approach - Europe

Description of scenario

This scenario is essentially the same as Scenario 1 but with the important difference that the minimisation of band allocation, the scrapping of ITU allotment plans and the assignment, coordination, monitoring and due diligence functions are carried out at a European, rather than a world, level. Discussions with our advisory team and the responses from the interview programme suggest that this could have a considerable impact on the industry.

This scenario represents the combination of the removal, from national to European level, of allocation, assignment and international coordination functions, with the implementation of strict due diligence to clear out "paper satellites" in Europe. With no change in the regulatory situation outside Europe, the likely response from non-European players would be to fill the gap by filing their own "paper satellites". (This assumes that no pan-European mechanism is installed to prevent such behaviour.) Under these circumstances it is possible that European operators could be worse off than at present, with the loss of their own "paper satellites" but no long term increase in the availability of GSOSR in Europe. Therefore, it may be crucial for the European countries involved in establishing the new sub-regional regime to decide, from the outset, to deposit into a common resource pool those rights over GSOSR which they already hold but are not actually exploiting.

An alternative, however, may be that with the increased tradeability of licences in Europe, countries outside the region would probably be encouraged to lease or otherwise trade their assignment rights to European operators. This could potentially increase the GSOSR available (at the market price) to existing and new operators. The downside would arise from the financial transfer out of Europe of the cost of these rights (which the third party countries had essentially obtained for nothing). However, this might be one way of transferring resources to the LDCs.

Overall, it is extremely difficult to judge what the likely impact on the satellite industry and on the market for GSOSR would be without further information on the likelihood of the above alternatives. Our analysis and modelling results proceed, however, on the basis that an effective solution can be found to the threat of non-European paper satellites absorbing efficiencies initiated by regulatory change in Europe.

The main components of this scenario are as follows :

- a "full service" coordinator for Europe responsible for assignment, coordination, due diligence, and possibly representing CEPT or EU administrations at international negotiations,
- minimal band allocation at European level, with abolition of ITU allotment plans within Europe (maintaining "grandfather rights" of operating incumbents),
- assignment of licences through tenders, auctions or lotteries (with tradeability),
- licences to operate systems and provide services would :
  - be freely tradeable,

  - incorporate broad property rights,
  - be offered in perpetuity or with high expectation of renewal,

- strict due diligence would be enforced at European level, with no "grandfather rights" for paper satellites,

- no restriction on orbital spacing, subject to non-interference,

- ISO non-competition covenants would be abolished and EC style competition regulations would be vigorously enforced.

Industry dynamics

The effect on the satellite industry of scenario two would be similar to that described under scenario one, except the impact would be smaller as only Europe rather than the whole of Region 1 would be affected. The potential threat of other Region 1 operators absorbing the efficiencies generated in Europe is assumed not to materialise. The methodology and policies that should be employed in order to ensure that it does not occur, however, require further investigation.

Possible market impacts

As described under Scenario 1, there would be expected benefits from increased economies of scale. However, these economies may not be as great as in the US, as the technical pressures for having similar satellites would probably be weaker. This, combined with the generally higher cost base in Europe, suggests that prices and costs would not be as low as current US levels.

8.4 Scenario 3 : Partial Markets

Description of scenario

The crucial differences between Scenarios 2 and 3 are as follows :

- in Scenario 3 the European coordinating authority has more limited responsibilities (described more fully below) than in Scenario 2,

- market conditions are promoted in a more partial fashion through national authorities.

In more detail the characteristics of Scenario 3 can be described as follows :

- establishment of a "partial service" coordinator dealing primarily with pan-European allocation and representing Europe (CEPT or EU) at international negotiations as described in Scenario 2. It would also deal with sub-regional competition policy which would be vigorously enforced in order to minimise "paper satellites". Assignment and international coordination functions would remain at national level,

- band allocation within the Radio Regulation satellite frequencies would be progressively removed at a European level, starting with the BSS bands. Incumbents' rights would be preserved in perpetuity, provided that they were actually operating,

- national level assignment criteria and mechanisms would be common across Europe and would be objective, transparent and non-discriminatory. Entry criteria would assess the applications for assignments against the specifications of the service,

- there would be a significant increase in the flexibility of licence provisions, as follows:

    - tradeability would be allowed but service-specificity would gradually be phased out along with rigid European allocations,

    - licences would be for a limited period, which could depend on the particular service, but they would be easily renewable.

    - there would be strict due diligence carried out at national level to deal with "paper satellites",

- ISO covenants would be phased out, to reduce entry barriers, and EC competition law would be vigorously enforced,

- no restriction on orbital spacing, subject to non-interference.

There would need to be common procedures adopted at the national level which, within the EC, may be defined in a harmonising directive. These procedures would cover assignment applications and procedures, due diligence, licence terms and tradeability issues.

Industry dynamics

Under this option the level of competition, and therefore the likelihood of innovation, is initially administratively determined. However, vigorous enforcement of EC competition rules ensures the abolition of special or exclusive rights to provide space segment at national level. This would mean a substantial opening of entry opportunities into satellite operation. But, this would by itself do nothing to alleviate the paper satellite problem.

Over time the development of private auctions of licences should increase the level of competition. However there is a considerable political risk. Politicians instinctively see private auctions as "unfair" and will strive to prevent them. Incumbents are also likely to expend considerable effort on political lobbying in order to protect their position. Given the high level of involvement of national regulators this lobbying has a good chance of success. Private auctions may promote warehousing by existing suppliers and providers of competing services (the "deep pockets" effect). Although this would be addressed by due diligence, it would be carried out at national level, which will again be open to lobbying by incumbents and holders of "paper satellites" to protect their positions.

Overall there is likely to be some limited increase in the level of competition in the industry and therefore some pressure on current operators to increase efficiency and reduce costs. The inflexibility of licences and the introduction of due diligence suggests that there could be some exit, however.

In addition, this regulatory framework could act against smaller innovative companies who may be unable to surmount the barriers to entry. This could be addressed by setting appropriate selection criteria for licences.

Possible market impacts

There would be some increase in GSOSR through the following:

- removal of BSS and phasing out of other allocations. This will be limited by the need to coordinate with other countries,
- once licences begin trading there will be pressure for increased efficiency of GSOSR utilisation. However, this will be constrained by the continued limitations on property rights associated with the licences,
- the limited introduction of market forces and to some extent the use of application criteria, but more importantly the introduction of strict due diligence, will reduce "paper satellites". The speed at which this occurs will depend to some extent on the degree of grandfathering allowed and the actual level of competition enforcement.

To the extent that there is currently a constraint on the use of GSOSR there is likely to be some increase in the supply of transponder equivalents in response to the relaxation of this constraint. However, the relatively limited degree of market forces initially allowed under this option suggests that the price of transponders will not fall significantly, at least over the short to medium term. This is due to the limited scope for competition and for economies of scale.

Some interviewees suggested that the large price reductions experienced in the US were due to the impact of economies of scale and to competition from terrestrial service providers rather than any regulatory change. However, this could not have taken place without a relatively liberal regulatory framework in the satellite market and in the markets for services which by reducing barriers to entry increased the threat of competition and therefore forced incumbents to reduce prices and costs. It is possible that in Europe deregulation of the satellite industry without accompanying deregulation in general telecommunication service markets could substantially limit the potential welfare gain.

There would be some increase in the demand for transponders as market rigidities are relaxed. This will be driven in particular by reduced application costs for licence holders and a reduction in the restrictive practices of the TOs. However, this process is again likely to be gradual. To the extent that there is increased competition in the operator market the costs to service providers should also fall.

The limited increase in competition in the market and the sub-regional nature of the arrangements will limit the potential for welfare gains. Although the development of a secondary market should ensure that part of the potential gain is realised through the producer surplus of the lottery winners, it could be argued that this is a less beneficial outcome than if it had been realised by government.

8.5 Scenario 4 : Institutional and Allocation Reforms

Description of scenario

This scenario represents a minimal change to the current situation, with some deregulation in the institutional framework and in allocation. This could be viewed as an initial step towards a more fully deregulated industry. There is little introduction of market forces in this option and the implications for welfare are consequently relatively small.

The key components of this option are as follows:

- minimalist European regulation focusing on Europe-wide allocation of spectrum for services such as VSAT and SNG,
- coordination and assignment continue at national level as currently,
- granting of licences for these specific services would be determined on the basis of economic, administrative and technical criteria at the national level. Prices would be set administratively, but would aim to approximate the market outcome (eg Ramsey pricing),
- some increase in flexibility of use of BSS bands, but only if this is an outcome of a WARC,
- no restriction on orbital spacing, subject to non-interference,
- ISO barriers to be phased out to reduce barriers to entry; general EC competition rules obviously remain applicable, with an uncertain level of enforcement.

Industry dynamics

There is likely to be little impact on competition, either between service providers, operators or between satellite and terrestrial providers of communication services. However, this will depend to a great extent on national licensing policies which determine the level of competition in these markets. To the extent that licensing authorities continue to be influenced by their TOs, the scope for increased competition in either operator or service markets will remain limited. There may be some scope for increased competition in VSAT services, as a result of any pan-European allocation. This will depend as much on demand for these services as on availability of European VSAT bands. Moreover, it remains unclear whether a dedicated VSAT band would represent, in any sense, an optimal allocation of GSOSR.

Some new space segment providers are likely to supply pan-European coverage, particularly in data services where demand is believed to be strong. The continuation of high barriers to entry and monopoly profits suggest that there will be little impact on exits from the market. The

EC). As a practical matter, in the absence of a special treaty making provision for resolution of conflicts of laws (inter alia), this seems problematic.

The complete abolition of ISO non-competition covenants is a relatively credible prospect, although this is in any event unlikely to be achieved completely overnight.

"Leasing" access to GSOSR is a plausible prospect independent of Scenario 1.

Finally, there would still be inter-Regional coordination and planning issues in respect of GSOSR utilisation, no matter what happens at the ITU Region 1 level.

Scenario 2

The main hurdle, once again, is political. If pressure on usable GSOSR in Europe is indeed growing and the massive economic inefficiencies of the current regime become more widely acknowledged, it is conceivable a scenario such as this becomes, in principle at least, a function of the common self-interest of the countries concerned.

As with Scenario 1, it is possible to imagine a mechanism for delegating authority by special treaty or an equivalent instrument. But, as with Scenario 1, it would be insufficient to achieve such consensus solely within the framework of the EEC Treaty, since many European countries are not party to this instrument, and it is assumed at least all CEPT members would have to be involved.

Our interviews revealed that international coordination of new European space segment often involves coordination with Region 1 administrations outside Europe (eg. Arabsat). Accordingly it cannot be expected that Regional "paper satellite" problem would be comprehensively addressed by this Scenario.

In order to protect existing European claims on GSOSR on a collective basis, it might be possible for the countries involved to assign their respective rights (including existing "paper" rights) to the new European collective. But the political challenge remains daunting.

Scenario 3

This scenario may be seen to advance current trends over the foreseeable future. But some aspects seem quite problematical.

It is hard to envision general abolition of specific satellite service band allocations at a sub-Regional level. This could engender serious technical coordination problems at the Regional and inter-Regional levels.

The protection of incumbents' rights is suspect to the extent that, empirically, the incumbents happen to be mainly dominant TOs and other dominant players. Existing competition rules would tend to require a levelling of the existing playing field before the Scenario could implement in-perpetuity space segment licences.

Scenario 4

absence of any significant regulatory change may in fact spur further entry in the industry which would increase on average the costs for operation for the whole industry. With no increase in competitive pressure there will also be little pressure for innovation.

Overall, existing suppliers, particularly the TOs, should be able to block competition successfully, with the possible exception of the new Pan-European services.

Possible market impacts

The impact on the supply of GSOSR under this option is uncertain. On the one hand, any increase in the flexibility of use of BSS should increase spectrum availability, and in theory closer orbit spacing could increase the supply of orbit slots. On the other hand, allocating bands to European services is likely to have the opposite effect.

Setting prices closer to market values will provide an incentive to utilise spectrum more efficiently. The impact on resource availability will depend on the degree of grandfathering allowed (ie whether existing "paper satellites" are allowed to continue), the extent to which due diligence is applied and the amount of competition allowed by the regulators.

To the extent that there is an increase in supply of GSOSR and that there is currently a constraint on transponders, the supply of transponders is likely to increase marginally. Without a significant increase in competition among operators and with limited prospects for economies of scale there is unlikely to be any significant impact on transponder prices.

Given that licences are currently virtually free, any move towards economic pricing will increase their cost to operators, and indirectly, to service providers. Otherwise there will be little impact on the costs of providing space segment. Concerning pan-Eropean service specific allocations, demand for transponder capacity to provide VSAT services is likely to be relatively low as this is an efficient user of capacity. The demand by SNG providers is likely to be variable, depending to some extent on the occurrence of major events such as the Olympics.

Overall, any increase in welfare benefit arising from this option is likely to be marginal and may be negative, depending on the impact of increased band allocation and the effect of the limited deregulation on costs.

8.6 Principal Practical Difficulties to Realising Scenarios

Scenario 1

The main hurdle is the political difficulty of such a radical shift of sovereign national powers and responsibilites throughout Region 1 or indeed the world, to a body designed to administer Regional GSOSR management. Although it is possible to conceive of a legal mechanism for delegating such powers by general consensus (eg. under a new Region-wide Treaty), such consensus is difficult to imagine being achieved in a short term timeframe.

Enforcement of a special competition policy at the ITU Regional level would require complex coordination/cooperation arrangements with national and other sub-regional bodies (especially the

This Scenario conforms most closely with current trends. The minimalist provisions of this scenario would not be without significant practical difficulties relating to political, administrative and legal impediments to change.

9 Overview of The Model

9.1 Introduction

The ultimate aim of the modelling exercise is to evaluate the economic impact in quantitative terms of a number of possible regulatory scenarios that have been discussed during the programme of interviews. The regulatory scenarios are concerned with potential changes in the regulation of GSOSR. We have focused on the demand and supply of transponder equivalents as a proxy for GSOSR.

We have developed a model which is based on current and forecast demand and supply of transponder equivalents in Region 1. The model is underpinned by classical microeconomic theory in which certain assumptions regarding the behaviour of producers and consumers hold, and that the results of this behaviour can be represented by smooth and well-defined curves representing willingness to pay (by consumers) and willingness to supply (by producers). In constructing the model, we have collated data from a number of sources and these are described below.

The remainder of this chapter is set out as follows:

- we set out in detail the structure and assumptions of the demand and supply sides of the model,
- the result of the interaction of demand and supply is described along with the outputs from the model. In addition, the base case scenario and the capabilities of the model are discussed,
- model limitations are set out,
- a list of data sources is given.

9.2 Structure and assumptions of the model

The model is based on the interaction of supply and demand of transponder equivalents. Demand for transponder equivalents is derived from the demand for the ultimate services that they provide, which we have categorised as television channels, telephony services, data services and mobile communications. The demand for transponder equivalents ultimately leads to a demand for operating satellites, which translates to a demand for orbit slots and frequencies. The supply side is similarly structured. All transponder equivalents referred to are in terms of 36 MHz equivalents.

The following points illustrate the basic structure of the model and the key set of assumptions on which the analysis rests:

Demand Structure:

- the demand for satellite services broken down into tv, telephony, data and mobile,

- we assume that economic signals are transmitted throughout the industry effectively. We assume for instance that benefits resulting from regulatory changes affecting GSOSR can be transmitted to end users of satellite services and not absorbed by intermediate suppliers,

- a technical parameter is applied to translate demand for services into demand for 36 Mhz transponder equivalents. In order to take into account improvements in satellite capacity arising from technical progress, an index of technological change is applied to future demands. This takes into account technological developments such as digital compression,

- demand forecasts for transponder equivalents and estimates of the demand growth in the 1993-2000 period. By making assumptions about the price elasticity of demand[9] we obtain demand curves for each year,

- given the demand for transponder equivalents and the state of technology (ie, the number of transponder equivalents per satellite), we obtain demand for satellites.

Supply Structure:

- the current and planned number of GSO satellites is the main variable underpinning the supply side,

- from the current and planned number of satellites we estimate the growth path of transponder equivalents over the forecast period, taking into account expected technological trends that impact on the number of transponders carried on each satellite and on the capacity of individual transponders,

- a cost function for the supply of satellites is derived. The producers' cost function used in the model is a cubic function. This type of cost function was estimated by Snow[10] in his case study of Intelsat and is a good approximation of the function used by INSEAD in their case study of Eutelsat[11]. It is a well-defined cost function and its shape is a good characterisation of the satellite

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[9] This measures the responsiveness of demand to price. A good is said to be very elastic if when price falls significantly, demand increases significantly. Conversely, a good is very inelastic if when price falls significantly demand does not increase by very much. See Appendix 4.

[10] The Intelsat system : an economic assessment - Snow, 1988

[11] Roller and Waverman (1991), ibid

industry, ie. it accords with previous research which suggests that there are increasing returns to scale up to a certain level of output[12],

- operators are assumed to be the ultimate suppliers of transponder equivalents. The price mark-ups of signatories to these operators are included in the supply side of the model,

- given the expected demand for transponders, and therefore satellites, the model calculates how many new satellites are launched each year if operators are free to maximise their profits, and

- the above steps yield the supply of transponder equivalents in each year and the cost associated with that supply.

The effects of deregulation are modelled as a "move" of the industry towards the fully competitive outcome: this outcome would imply a significantly lower price and significantly higher demand (and supply) of transponders. This is economically the most efficient outcome, since the benefits for both producers and consumers are maximised. The industry is assumed to move closer to the fully competitive outcome the more effective the deregulatory package is in terms of increasing competition and facilitating more efficient production.

A full non-technical list of the basic assumptions concerning the structure of the model is provided in Appendix 5. Readers are likely to get a better feel of the quantitative results after reading the relevant parts, even if they are not familiar with economic principles.

9.3 Outputs and capabilities of the model

Model Outputs

The demand and supply sides of the model interact. It is assumed that the operators are profit maximisers and, reflecting the degree of monopoly power in the market, price is always above marginal cost and is set by the suppliers. The profit maximising number of new satellites is calculated in the model and the associated price, average cost and marginal cost are calculated for each year. The outputs of the model are:

- the number of new satellites being launched and put into operation in any year,

- the associated number of existing and new transponder equivalents, ie. the total number of transponder equivalents in the market,

- the cost per satellite and the price of transponder equivalents,

- industry revenue (turnover), cost and profit for any given year,

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[12] Snow, ibid

- profitability (profits divided by revenue and multiplied by 100) and mark-up (price minus average cost, divided by average cost and multiplied by 100),
- consumer, producer surplus and total welfare for any given price and cost per satellite.

Welfare Changes

As indicated above, our key welfare measure is provided by changes in the sum of consumers' and producers' surpluses. To investigate the implications of regulatory change, we model its likely impact on the supply and demand of satellite transponders and calculate the resulting impact on economic welfare relative to the base case. This allows us to arrive at a quantification of the net welfare impact of regulatory change. The quantitative measure of the impact of regulatory change, as calculated in the model, is illustrated in Figure 9.1. Regulatory changes will give rise to changes in welfare if they impact on :

- technology,
- profits,
- the costs of transponder equivalents, or
- the price of transponder equivalents.

In the satellite operation industry, however, unless the final market for satellite services is competitive, increases in consumers' surplus will translate into increased profits to satellite service suppliers. In order that *final* consumers benefit from regulatory changes in the market for GSOSR, competition also needs to be injected into the market for satellite services.

Initial simulations - the base case

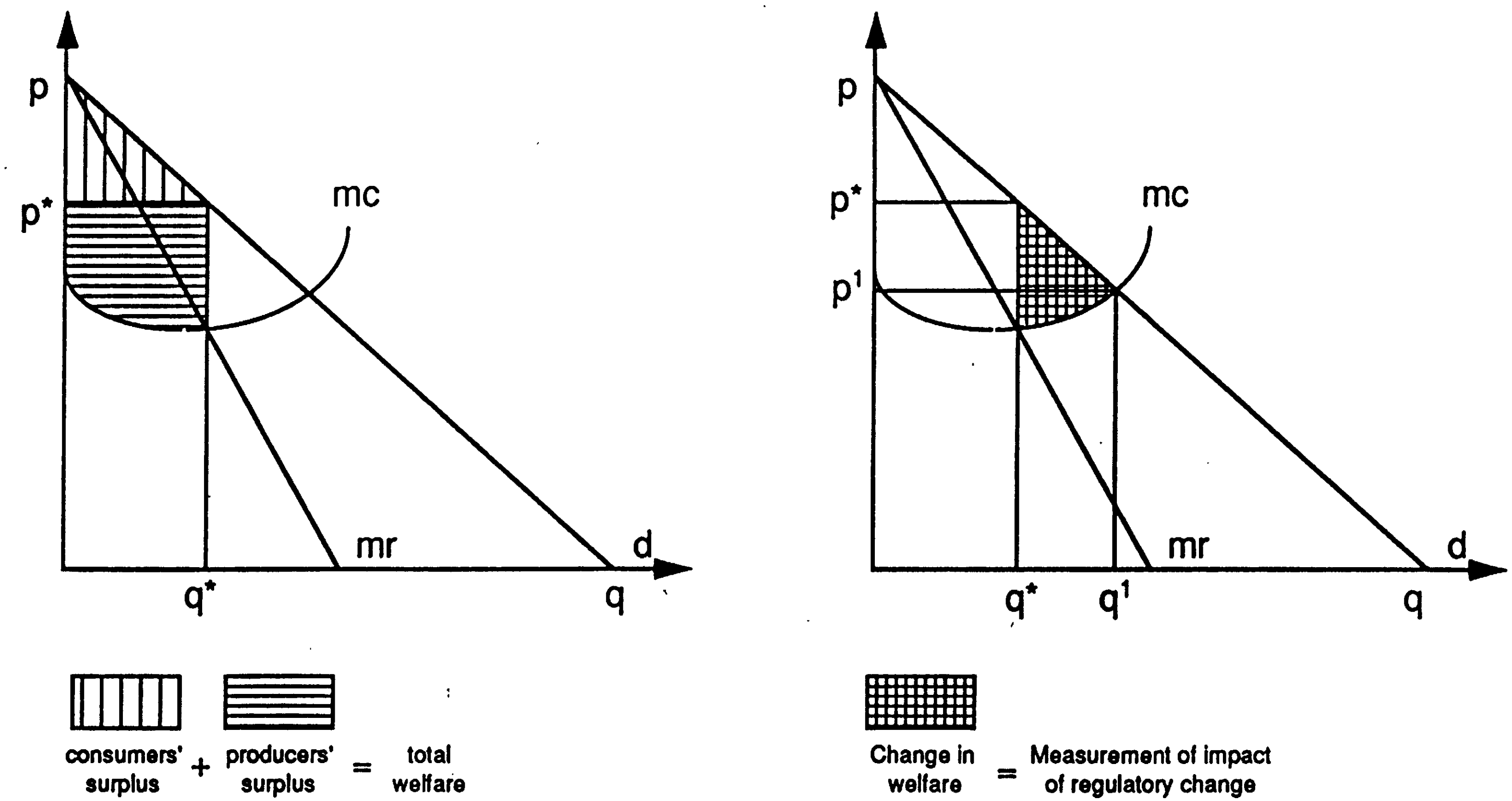
Prior to using the model to investigate the implications of the four scenarios described in Chapter 8, we need to develop a base case against which to compare them. The formulation of the base case is discussed more fully in the following chapter.

9.4 Model Limitations

In the previous Chapters of the report we presented and discussed in detail the capabilities and limitations of the model. It is important to note however the following general points:

- the model provides an overview of the satellite operation industry in Region 1 and Europe for the final users. The quantitative results of the modelling exercise represent the whole industry rather than any one particular operator (either satellite operator or TO acting as an ISO signatory). It follows for example, that the revenue figures would represent the revenue of all independent satellite operators (eg Astra, TV-Sat, TDF, etc) and the revenue of the TOs derived from ISO satellite operations, rather than simply the revenue of Eutelsat and Intelsat,

Figure 9.1 Measuring welfare and regulatory change



G.7970

- the model assumes that regulations work as they are intended. The practical difficulties associated with the definition of the detailed provisions of regulations and the effective implementation of the regulatory regime are issues that would have to be addressed by subsequent work.

9.5 Interpretation of the Results

Prior to introducing the results, it is important to note a few points concerning the interpretation of the results. These have been discussed in detail, as appropriate, in the previous Chapters of the report but we present here in brief a summary of the main points:

- the estimated number of new satellites launched each year has been "smoothed out" (using a three year moving average) over time. This has been done so as to get a good indication of the annual average number of planned satellites by smoothing out differing (time of year) launch dates,

- the transponders available on different satellites are considered to be perfect substitutes for each other after appropriate technical transformations (see Appendix 5). This is not a restrictive assumption as long as each satellite has at least another satellite which can offer similar services or that could potentially offer the same services at a very small cost,

- the results are indicative, that is, they order the impact of regulatory changes, rather than providing exact predictions of the variables of interest,

- the profits in the model include signatory mark ups,

- the forecasts up to 1996 and the implications of welfare change assume smooth developments in technology. Any radical change in the capabilities of existing or new satellites launched could have a significant impact on the industry and can only be modelled in subsequent work,

- welfare is defined as the unweighed sum of consumers and producers surplus. This is an accepted welfare measure amongst economists and means that consumers and producers/operators are of the "same importance", have the same weight/political salience, and are equally deserving,

- welfare estimates are "long term" estimates, ie. estimates of the average annual welfare gain achievable after 5-10 years following all the workings through of deregulation,

- a range of welfare estimates for the regulatory scenarios is given. The values depend on the degree of competition amongst the operators and the extent of consolidation that occurs, following regulatory change, and

- when modelling the industry and the effects of deregulation a distinction is made between Europe and the whole of Region 1. Since our aim is to evaluate the impact of regulatory change, this distinction should reflect largely whether operators are regulated by a European or a Region 1 regulator, rather than whether their satellites cover partly some area outside the primary jurisdiction of regulation (ie. the jurisdiction in which GSOSR is assigned).

10 Model Results

10.1 Introduction

The purpose of this Chapter is to set out in detail the orbit and frequency resources modelling exercise and present in quantitative terms the welfare impact of the regulatory scenarios. As a general rule, the greater the economic efficiency of the market/regulatory mechanisms that allocate GSOSR to users, the greater the potential welfare gain associated with any scenario. A full description of the basic assumptions used in the final version of the model and a list of the parameters taken as given from outside the model can be found in Appendix 5. The aim of this Chapter is to provide a concrete quantitative framework for the application of the above rule. It covers the following:

- **1992, "Base Case" and "Alternative Case" forecasts** - the quantitative results for 1992 (for Europe and for Region 1), including the underlying assumptions, and our forecast of the development of the industry in the "Base Case" (when operators respond to expected demand), and in the "Alternative Case" (when operators proceed with their plans),

- **quantifying the impact of deregulation** - a short description of the four scenarios, how they translate into changes in the model, the quantitative results of the model under each regulatory scenario and an evaluation of the advantages and practicalities of each one,

- **model sensitivities and potential** - a discussion of the sensitivities and potential of the model,

- **conclusions** - from the modelling exercise.

10.2 Modelling the Satellite Operation Industry

In this section we set out how we have used the economic model to analyse quantitatively the satellite industry in Region 1 and Europe in 1992. The model is used to derive forecasts about the development of the industry up to the year 1996. Given the uncertainties surrounding the possibility of technological and structural changes in the industry we have not at this stage forecast developments beyond 1996. The model could of course be used to derive such forecasts when a more definite view is established about the likely changes in the variables driving demand and supply in the satellite industry. It must be noted that the regulatory changes tested are assumed to be in place and fully effective as from 1992. The analysis, therefore, is indicative of what industry conditions would have been like over the 1992-1996 period had these regulatory scenarios been in effect.

10.2.1 The quantitative results for Region 1

Start Year: 1992

The quantitative model results for the Region 1 satellite operations industry in 1992 are presented in the second column of Table 10.1. According to our data sources the net number of new satellites launched (ie additions of satellites minus retirements) in 1992 was seven, bringing the total number of satellites in Region 1 to 39.

The average price per Ku transponder was estimated at ECU 2.6 m and the price per "average" transponder at ECU 1.1 m. Note that if operators restricted utilisation of the existing satellites to 80%, we estimate that the price per Ku transponder would increase to ECU 3.1 m. The estimated market size for the Region 1 industry is around ECU 1.5 bn. Our cost results suggest that the total cost of operating the 39 satellites was around ECU 1.1 bn, leading to profits of ECU 373 m, a profitability (profits/revenue) of 24.4% and a mark-up (price minus average cost, divided by average cost) of 32.3%.

The last two rows describe the current situation in terms of available welfare. The first row (Consumer Surplus) represents the benefit to consumers and the second row (Total Welfare) the benefit for society, ie consumer and producer surpluses, for the given prices and costs.

The 1993-96 Forecasts: the "Base Case"

The basic modelling assumptions for the forecasting results are the same as the assumptions made to derive the 1992 results. Demand for transponders is assumed to grow at 11% per year for 1993 and 1994, growing to 12% in 1995 and 1996 (these are based on current expectations according to two independent sources[13]). In the "Base Case", operators are assumed to respond to the growth in demand.

The results of the forecasting exercise are presented in the last four columns of Table 10.1. Net additions of satellites are between four and five a year. This implies a gradual growth in the total stock of satellites which reaches 57 by the year 1996.

The number of operators is forecast to increase significantly over the forecast period, especially in Region 1 (with the addition of Amos, Turksat, Arabsat, Asiasat, etc). The cost per satellite therefore increases also over the forecast period, as the growth in the number of operators and the lower growth in demand imply a reduced number of satellites operated by each operator. This implies losses in efficiency (ie average costs increase) and leads also to reduced profitability and mark-up throughout the forecast period. Profits are also reduced in 1993/1994 compared to 1992, but as demand accelerates in 1995/1996 they exceed the 1992 level. Profitability and mark-up are also on an upwards trend after 1994.

[13] The sources used are

- Neven, D. Roller, L.-H. and Waverman, L. "The European Satellite Industry: Prospects for Liberalisation", working paper (now published as CEPR discussion paper # 813 and in Economic Policy, #17, October 1993) and

- a summary of forecasts derived by Hyperion Consultants for the Booz-Allen 1992 report "Prospects and Policy for Europe-Wide Specialised Satellite Services" and the Euroconsult 1991/92 report "World Space Industry Survey".

TABLE 10.1

THE BASE CASE AND FORECASTS FOR THE REGION 1 SATELLITE INDUSTRY

	1992	1993	1994	1995	1996
Growth in demand for transp./yr (%)		11.0	11.0	12.0	12.0
New Sats Launched	7.0	4.0	4.0	5.0	5.0
End of period Sats	39.0	43.0	47.0	52.0	57.0
Additions of Transponders	330.0	125.0	128.0	153.0	174.0
End of period Transponders	1341.0	1466.0	1594.0	1747.0	1921.0
Average # of all transponders/satell.	34.4	34.1	33.9	33.6	33.7
Average # of Ku transponders/satell.	15.0	15.0	15.0	15.0	15.0
Price/Transponder (all tr., ECU m)	1.1	1.2	1.2	1.2	1.2
Price/Transponder (Ku tr., ECU m)	2.6	2.7	2.7	2.7	2.6
Price/Transponder (Ku tr., ECU m) (Utilisation at 80%)	3.1	3.1	3.1	3.1	3.1
Average Cost/satellite (ECU m)	29.7	33.1	32.9	32.3	31.9
Revenue/year (ECU m)	1528.0	1748.7	1907.2	2058.9	2236.0
Cost/year (ECU m)	1154.8	1419.0	1548.9	1671.6	1809.8
TOTAL PROFITS (ECU m)	373.2	329.7	358.3	387.2	426.2
GROSS PROFITABILITY (%)	24.4	18.9	18.8	18.8	19.1
MARK–UP (%)	32.3	23.2	23.1	23.2	23.6
Consumer Surplus (ECU m)	655.7	692.6	765.6	859.2	952.0
Total Welfare (ECU m)	1028.9	1022.2	1123.8	1246.4	1378.2

The "Alternative Case": Operators proceed with their plans in Region 1

Our "Base Case" forecast is derived under the demand growth forecast by two independent sources. The number of **planned** satellites however significantly exceeds the expected demand growth, as can be seen in the first two rows of Table 10.2 (in 1996 the planned number of new satellites is almost the same as the forecast so 1996 is omitted from Table 10.2). In the "Alternative Case" we therefore examine what would happen to the industry profits if operators proceeded with their plans and demand grew according to our independent forecasts.

The very significant divergence of expected demand for satellites and plans led us to consider for Region 1 two scenarios, "pessimistic", where prices fall significantly and "optimistic" where operators manage to avoid price falls by restricting utilisation of the new satellites launched.

In the first scenario (*pessimistic*), the excess capacity resulting from the number of satellites launched exceeding the expected demand, leads to more price competition amongst operators as they try to attract customers in order to fully utilise their capacity. Operators therefore manage to utilise all their capacity and although this leads to lower (average) costs because of efficiency gains it also leads to larger reductions in price. In such a case profits are reduced drastically because the reduction in prices for services offered from the new satellites launched drives prices down for the whole market. Operators would therefore be loss making in all three years (with losses ranging from ECU 21 m to ECU 647 m), and are expected to face an annual reduction in profits in the order of ECU 657 m, on average, compared to the "Base Case" (when launched satellites equal the expected demand).

This is quite a pessimistic scenario, and it would be reasonable to expect that in the face of such significant losses operators would realise that a price war would hurt them all significantly. They would prefer therefore to maintain prices (and costs) at the current level by restricting utilisation of the new satellites launched to meet expected demand. In that case the new satellites would be utilised at between 45.6% and 55.4%, and operators would have to absorb the extra fixed costs of the launched but not utilised satellites/transponders. This would lead again to a reduction in profits compared to the "Base Case", but the reduction would be much smaller than in the "pessimistic" scenario, as shown in the lower part of Table 10.2. Operators would face a reduction in profits of the order of ECU 281 m a year, compared to ECU 657 m in the pessimistic scenario. Note also that in this scenario the industry is profit making in all three years, unlike the results obtained in the "pessimistic" scenario.

Those two scenarios describe the "extreme" cases but in both cases the magnitude of the potential loss is relatively large because the difference between expected demand and the plans of operators would affect profits from both existing and new satellites launched.

TABLE 10.2

THE EFFECTS ON THE REGION 1 SATELLITE INDUSTRY OF OPERATORS PROCEEDING WITH THEIR PLANS

		1993	1994	1995	
Planned new satellites (Net,MA) *		8.0	9.0	8.0	
Expected demand for new satellites		4.0	4.0	5.0	
UTILISATION OF NEW SATS (%)		50.2	45.6	55.4	
Average utilisation 1993–95				50.4	
Planned end of period satellites		47	56	65	
Pessimistic scenario REDUCTION IN COSTS & PRICES					
TOTAL PROFITS IF OPERATORS PROCEED WITH PLANS (ECU m)		−227.6	−646.7	−20.8	
TOTAL PROFITS IF OPERATORS RESPOND TO EXPEC. DEMAND (ECU m)−Base Case		329.7	358.3	387.2	
REDUCTION IN PROFITS IF OPERATORS PROCEED WITH PLANS (ECU m)		−557.3	−1005.0	−408.0	
AVERAGE REDUCTION/YR (ECU m)				−656.7	
Optimistic Scenario NO REDUCTION IN COSTS OR PRICES					
TOTAL PROFITS IF OPERATORS PROCEED WITH PLANS (ECU m)		196.1	61.9	−24.8	
TOTAL PROFITS IF OPERATORS RESPOND TO EXPEC. DEMAND (ECU m)−Base Case		329.7	358.3	387.2	
REDUCTION IN PROFITS IF OPERATORS PROCEED WITH PLANS (ECU m)		−133.6	−296.4	−412.0	
AVERAGE REDUCTION/YR (ECU m)				−280.7	

In practice, it is conceivable that some price competition would occur initially. This could drive the small/inefficient operators out of the industry which would then leave the largest operators restricting utilisation in order to maintain prices. Since a number of operators would have left the industry, utilisation of new satellites under an "optimistic" scenario would therefore not fall to the levels predicted earlier (45%-55%). Given the current structure of the industry, however, and the significant divergence between plans and forecasts we still estimate that significant underutilisation of new satellites would occur.

10.2.2 The quantitative results for Europe

1992 and "Base Case" forecasts for 1993-96

The results for 1992 and the "Base Case" forecasts for 1993-96 for the European industry are presented in Table 10.3. The basic assumptions underlying the modelling and forecasting exercise are the same as for Region 1. Recall that in the "Base Case" operators launch a number of satellites sufficient to meet expected demand, as forecasted independently.

Starting with the 1992 results, there is a net addition of seven satellites in Europe in 1992, bringing the total to 33. The price per Ku transponder in Europe (ECU 2.7 m) is higher than in Region 1 and the average cost is marginally lower. Note again that if utilisation was 80%, the price would rise to ECU 3.3 m per Ku transponder. Revenue and costs are both lower but profits are higher, reflecting the fact that most of the rest of Region 1 operators would probably make losses in a commercial environment.

The profitability and mark-up are higher in Europe alone, as expected, since they now incorporate the mark-ups of PTTs. The benefits for consumers and society as a whole are slightly smaller, in line with the relatively smaller market size.

When undertaking the forecasting exercise we assume that demand grows in Europe alone at the same rate as in Region 1 in 1993 and 1994, but then levels off at 10% per year, reflecting the relative maturity of the European market. This leads to three to four net additions of satellites per year in Europe alone (compared with four to five in Region 1).

The movement in prices and costs is very similar for Europe alone and Region 1 as a whole and the rationale behind these movements is largely the same. Average costs in Europe alone exceed those for Region 1 over the forecast period, however, mainly because we expect further entry in Europe (Italsat, Hispasat) compared to Region 1. This means more fragmentation in terms of costs and therefore less efficient operation.

Profits, profitability and the mark-up are again higher in Europe compared to Region 1 for the forecast period. However, the movement of these variables in the two areas is very similar.

TABLE 10.3

THE BASE CASE AND FORECASTS FOR THE EUROPEAN SATELLITE INDUSTRY

	1992	1993	1994	1995	1996
Growth in demand for transp./yr (%)		11.0	11.0	10.0	10.0
New Sats Launched	7.0	3.0	3.0	4.0	4.0
End of period Sats	33.0	36.0	39.0	43.0	47.0
Additions of Transponders	312.0	116.0	117.0	131.0	143.0
End of period Transponders	1210.0	1326.0	1443.0	1574.0	1717.0
Average # of all transponders/satell.	36.7	36.8	37.0	36.6	36.5
Average # of Ku transponders/satell.	15.0	15.0	15.0	15.0	15.0
Price/Transponder (all tr., ECU m)	1.1	1.2	1.2	1.2	1.2
Price/Transponder (Ku tr., ECU m)	2.7	2.9	2.9	2.8	2.8
Price/Transponder (Ku tr., ECU m) (Utilisation at 80%)	3.2	3.3	3.3	3.3	3.3
Average Cost/satellite (ECU m)	29.3	34.0	33.8	33.6	33.4
Revenue/year (ECU m)	1359.6	1590.9	1727.7	1864.9	2012.5
Cost/year (ECU m)	973.5	1242.8	1353.1	1465.2	1583.8
TOTAL PROFITS (ECU m)	386.1	348.1	374.6	399.7	428.7
GROSS PROFITABILITY (%)	28.4	21.9	21.7	21.4	21.3
MARK-UP (%)	39.7	28.0	27.7	27.3	27.1
Consumer Surplus (ECU m)	574.1	583.1	644.3	712.8	781.1
Total Welfare (ECU m)	960.2	931.2	1019.0	1112.6	1209.8

The "Alternative Case" Operators proceed with their plans in Europe

Under the alternative case, the net number of new satellites that operators plan to launch in Europe alone does not exceed significantly the expected demand growth, as can be seen in the first two rows of Table 10.4. In fact in 1995 the two figures are the same, and slightly stronger demand growth in 1993 and 1994 would also bring the expected number of new satellites closer to plans. The potentially negative effects of operators proceeding with their plans are therefore much less pronounced in Europe alone compared to Region 1, and we therefore consider in the "Alternative Case" only one scenario for Europe.

In this scenario we assume that there is no price war because the overcapacity is relatively small compared to Region 1, so that operators maintain price (and costs) at their original levels by restricting the utilisation of the new satellites (this corresponds therefore to the "optimistic" scenario for Region 1). Operators still have to absorb the extra fixed cost of the new satellites that are not being utilised so that their profits are lower by around ECU 89 m a year, on average (see last row of Table 10.4). This result suggests that since the plans of European operators approximate much more closely the expected demand growth, the potential for losses is considerably reduced.

It should be noted that demand forecasts and the planned number of new satellites cannot be predicted with certainty. In the analysis of the alternative case therefore we are not providing a precise and accurate estimate of the implications for the satellite industry of an overestimation of demand. Rather we aim to show the upper limit for the potential losses as a function of the size of the overestimation.

10.3 Quantifying the Effects of Deregulation : The Scenarios

10.3.1 Introduction

In this section we set out the key results of the modelling exercise: the potential impact that regulatory changes could have upon the industry. In presenting the results, the impact is always set out as a change in welfare[14] *relative* to the "Base Case". A range of welfare changes is given, which depends on the degree of consolidation in the industry. The welfare gains or losses are "long run" annual averages. Prior to setting out the results, we first present a recap on the nature of the scenarios investigated and how the various regulatory changes are translated into economic effects. We then explain in general terms the nature of the quantitative information provided and proceed with the presentation of the quantitative effects of deregulation for each of the four scenarios.

14 Changes in prices, costs, number of satellites and number of transponders are also given.

TABLE 10.4

THE EFFECTS ON THE EUROPEAN SATELLITE INDUSTRY OF OPERATORS PROCEEDING WITH THEIR PLANS

		1993	1994	1995	
Planned new satellites (Net,MA) *		5.0	5.0	4.0	
Expected demand for new satellites		3.0	3.0	4.0	
UTILISATION (%)		66.4	69.0		
Average utilisation 1993–95			67.7		
Planned end of period satellites		38	43		
NO REDUCTION IN COSTS OR PRICES					
TOTAL PROFITS IF OPERATORS PROCEED WITH PLANS (ECU m)		283.5	260.5		
TOTAL PROFITS IF OPERATORS RESPOND TO EXPECTED DEMAND (ECU m) (Base Case)		348.1	374.6		
REDUCTION IN PROFITS IF OPERATORS PROCEED WITH PLANS (ECU m)		−64.6	−114.1		
AVERAGE REDUCTION/YR (ECU m)			−89.3		

* MA denotes a 3–year Moving Average

The four scenarios

The scenarios are concerned with changes to key aspects of the present procedures for the allocation and assignment of orbit and frequency resources. In some cases the changes assumed aim to ensure the correct working of the market (eg competition policy or tradeable licences) and in other cases the changes are expected to have a direct impact on the resource available (eg recouping spectrum or no limits on spacing). Scenario 1 is the most market orientated and Scenario 4 the least, with limited change over present procedures. Each scenario is summarised below:

- **Scenario 1 : market approach - worldwide** - this entails the recouping of spectrum and institutional changes at the worldwide level; the establishment of a full service coordinator at Region 1 level (responsible for assignment, coordination, competition and due diligence) and the minimisation of ITU band allocation, licences with broad based property rights issued long term or in perpetuity to be allocated via auctions, tenders or lotteries; no restrictions on orbital spacing (subject to non-interference), ISO non-competition covenants and the planned band phased out, and LDCs encouraged to lease their rights to GSOSR resources,

- **Scenario 2 : market approach - Europe** - as for scenario 1 but the recouping of spectrum and institutional changes are at the European level,

- **Scenario 3 : partial markets** - this entails the establishment of a "partial service" co-ordinator at the pan-European level. Assignments would remain national, but would work according to a common set of criteria and procedures with entry criteria, service specific licences that are tradeable, and the progressive removal of European level band allocation and service specific licences, and

- **Scenario 4 : institution/allocation reforms** - under this scenario there is assumed to be minimal European regulation for Europe-wide service specific allocations, coordination and assignment continue at the national level, licences are determined administratively and there is the possibility of increased flexibility in the BSS, but only if it is the outcome of WARC.

10.3.2 Translating regulatory changes into economic effects

In order to evaluate the effects of deregulation on the satellite operation industry using the economic model we must determine the economic effects of the various dimensions of regulatory change. The various dimensions of change considered have been discussed in detail above and are as follows:

- institutional change,
- procedural change,
- terms and conditions,
- competition policies,
- recoup spectrum, and
- technical policies.

Each dimension of regulatory change will have an economic impact on the industry through one or both of the following routes:

- **increase in competitive behaviour**, by establishing a "level playing field" (ie equal treatment of competitors/no exclusive rights) through:
    - lowering pecuniary barriers to entry (lower coordination and notification costs, shorter application procedures, etc), and
    - lowering non-pecuniary barriers to entry (full tradeability of licences, "use it or lose it", etc),
- **more efficient production**, by facilitating or reducing the obstacles for consolidation of the industry in order to take advantage of economies of scale.

The two routes are not independent since the absence of competitive forces can allow the profitable operation of an industry at very inefficient levels. The absence of such forces leads to relatively higher prices than would exist otherwise. Inefficient operators with relatively high costs can therefore survive and often make significant profits. Although consolidation could lead to lower costs and higher profits for the whole industry, in the case of the satellite industry the legislative environment does not facilitate such a development. There is therefore a continuation of inefficient operation and, somewhat paradoxically, the profitable operation of relatively small operators attracts more players in the market. This makes the industry even more inefficient.

It is therefore of crucial importance to introduce deregulation which allows as much as possible the development of competitive forces. This, combined with a relaxation of constraints for consolidation, would then lead to more efficient production. The recent wave of privatisations in the UK and elsewhere, *combined with the introduction of competitive forces or where they are absent, proxied by regulation*, serves as the most obvious example.

The possible economic effects on the satellite industry of all the regulatory measures already identified are summarised in Table 10.5.

It is important to note at this stage that the effectiveness of deregulation is not so much a function of any *individual* regulatory measure implemented but depends largely on the *coordination and simultaneous operation* of the various dimensions of regulatory change. It would therefore be misleading to provide a detailed evaluation of the economic effect of each component of regulatory change based on some mechanical formula, since the effectiveness of each component will depend largely on "the regulatory package" of which it is a part.

For the same reason, when the quantitative effects of deregulation are evaluated, we consider the effectiveness of each scenario already identified as a "regulatory package", rather than as a sum of the effectiveness of each specific measure that forms part of the "package".

TABLE 10.5

ECONOMIC EFFECTS OF REGULATORY MEASURES

EFFECT ON INDUSTRY/ECONOMIC VARIABLES		Increased Competition/ Lower Prices		More Efficient Production/ Lower Average Costs
ROUTE OF OPERATION		Lower Pecuniary Barriers to Entry	Lower Non–Pecuniary Barriers to Entry	Exploiting Economies of Scale
MEASURE				
Institutional Change	*Allocation*	YES	YES	YES
	Coordination	YES	–	YES
	Due Dilligence	–	YES	–
	International negotiation	–	–	YES
Procedural Change	*Tenders or Auctions*	NO	NO	YES
	Lotteries	–	YES	NO
Terms and Conditions	*Broad based property rights*	–	YES	YES
	Licences issued in perpetuity or high expectation of renewal	–	YES	YES
	Full tradeability	–	YES	YES
	Strict due dilligence	–	YES	YES
	No Pioneer's preference	–	YES	–
	Use it or lose it	–	YES	YES
Competition policy	*Free entry to operator and service markets*	YES	YES	–
	EC/National competition rules	–	YES	–
	No ISO non–competition covenants	–	YES	–
Recoup Spectrum		YES	YES	YES
Technical Policies	*No limitation on spacing*	–	YES	YES
	No limitation on frequency sharing or reuse	–	YES	YES

10.3.3 The quantitative information provided

The quantitative effects of deregulation for all four Scenarios are presented in a single table, Table 10.6, to ease comparison. In the upper part of the table, in the first column of each Scenario we present the "Base Case" values over a five year period for price, cost and quantity under the assumption of no regulatory change - the status quo. The second column of each scenario gives the values for the same variables when deregulation is implemented and the third one provides the percentage changes.

In the lower part of the table, we present the extra gain to consumers, producers and society as a result of deregulation, compared with the "Base Case" (no regulatory change). In some of the alternatives considered the industry as a whole could be loss making as a result of large falls in prices not accompanied by equivalent reduction in costs. In these cases it will therefore be necessary for the governments/regulatory authorities to introduce a mechanism which would cover the shortfall in revenue for the industry by transferring part of the gain of consumers back to the operators. The maximum amount of such a transfer is given in the last row of the table.

The range of possible outcomes, even within each scenario, is quite large, depending on:

- how significant the effect of any regulatory change is, and
- whether it affects the competitive environment, the efficiency of production or both.

Within any scenario, if the effectiveness of any regulatory change in terms of increasing competition is relatively small, the fall in price will also be small, other things being equal. This would then deliver relatively high prices and is indicated in the "Limited regulatory impact" price/transponder row. If regulation is effective however then the price will fall by more and this is presented in the "Significant regulatory impact" price/transponder row.

A similar argument holds for the effectiveness of any regulatory change in terms of facilitating efficient production. If the policies are not effective, costs/satellite will not fall by much (the "Limited regulatory impact" row). If they are, then it is possible to obtain much more significant gains in efficiency (the "Significant regulatory impact" row).

As far as the number of transponders is concerned, the "significant regulatory impact" row presents the number of transponders that would be demanded if regulation had a large effect on competitiveness and led to a significant fall in price. Equivalently, when the effect of deregulation is small, the number of transponders demanded would only be likely to reach the level given in the "Limited regulatory impact" row.

TABLE 10.6

THE EFFECTS OF DEREGULATION IN THE SATELLITE INDUSTRY

ALL VARIABLES AND CHANGES ARE AVERAGED OVER A PERIOD OF FIVE YEARS.
THE EFFECTS OF REGULATORY CHANGES ARE COMPARED WITH THE BASE CASE ie NO REGULATORY CHANGE (COLUMN 92-96, Status Quo)

	SCENARIOS											
	92-96 Status Quo	1 - FULL LIBERALISATION Market approach in Region 1		92-96 Status Quo	2 - EUROPE Market approach in Europe		92-96 Status Quo	3 - PARTIAL MARKETS Limited Market Approach in Europe		92-96 Status Quo	4 - MINIMAL CHANGE Institutional and Allocation Reforms in Europe	
			% change			% change			% change			% change
COLUMN NUMBER	1	2	3	4	5	6	7	8	9	10	11	12
PRICE/TRANSPONDER (ECU m)	2.70			2.80			2.80			2.80		
Limited regulatory impact		1.50	-44.4		2.10	-25.0		2.50	-10.7		2.60	-7.1
Significant regulatory impact		0.90	-66.7		1.80	-35.7		2.30	-17.9		2.80	0.0
COST/SATELLITE (ECU m)	32.00			32.80			32.80			32.80		
Limited regulatory impact		21.90	-31.6		25.40	-22.6		32.80	0.0		33.90	3.4
Significant regulatory impact		13.50	-57.8		16.30	-50.3		18.20	-44.5		32.80	0.0
NUMBER OF TRANSPONDERS	1614.00			1454.00			1454.00			1454.00		
Significant regulatory impact		2951.00	82.8		2182.00	50.1		1832.00	26.0		1600.00	10.0
Limited regulatory impact		2496.00	54.6		1935.00	33.1		1702.00	17.1			
CONSUMERS GAIN (ECU m)												
max *		1856.80			829.40			388.00			138.10	
min		1100.30			508.50			243.00			0.00	
PRODUCERS GAIN (ECU m)												
max		172.50			353.50			400.90			-106.60	
min		-483.60			-299.30			-199.00			-152.00	
SOCIETY GAINS (ECU m)												
max		1373.20			1015.60			788.90			31.00	
min		701.20			438.40			44.50			-13.90	
REQUIRED TRANSFER (ECU m) (only if operation is loss making)												
max		260.50			20.60			0.00			0.00	
min		0.00			0.00			0.00			0.00	

* "max" denotes the maximum amount of gain achievable in the Scenario considered.
"min" denotes the minimum amount of gain achievable in the Scenario considered.

The gain for consumers will be greater the larger the fall in price; the "max" row, giving the monetary values of the maximum possible consumer gain, corresponds therefore to the "Significant regulatory impact" price. The producers gain on the other hand will be greater the larger the fall in costs and the smaller the fall in price. The "max" row for producers' gains corresponds therefore to a combination of the "Limited regulatory impact" price and the "Significant regulatory impact" cost.

The society gain is simply the sum of the gain of producers and of consumers. It will be greatest ("max"), under the largest fall in both prices and costs. Note that this would provide also the "max" gain for consumers but not for producers; it follows that the "max" society gain is smaller than the sum of "max" consumer surplus and "max" producers' surplus. Similarly, the "min" society gain is larger than the sum of the "min" consumer gain and the "min" producer gain.

It is possible when society reaches the maximum gain for the industry to be loss making. Such an outcome would therefore only be realised if governments and/or regulatory authorities were willing and able to introduce a mechanism which would cover the losses of the operators, either by transferring some of the consumers' gain (which would be at a maximum) to the operators or by using some other mechanism (the general Europe wide tax system, direct cost reduction, etc).

10.3.4 The quantitative effects of deregulation : Scenario 1

Basic description and assumptions

Scenario 1 is the full liberalisation scenario and implies that maximum progress is made in terms of establishing a competitive environment and an industry structure allowing the most efficient operation possible. In terms of the analysis of Table 10.5, it is assumed that regulatory changes are implemented in all areas, from recouping spectrum, through institutional/procedural/technical and administrative structures to competition policy.

This is the most radical change envisaged and we therefore model this scenario as representing a move of the satellite operations industry to, or very near, a "perfectly" competitive outcome.

The effects of deregulation

The quantitative effects of the Scenario 1 deregulation measures are presented in columns 2 and 3 of Table 10.6. The status quo figures are presented in column 1.

Under the assumption of perfectly competitive markets we estimate that the price would fall by nearly 67%. Even in the case where the impact of deregulation on the competitiveness of the industry is weaker, we estimate that in Scenario 1 prices would fall by nearly 45%. This would have a very significant effect on the quantity of transponders demanded which we estimate would increase by between 54.6% and 82.8%.

The reductions in costs are also significant but somewhat smaller in magnitude. Under the assumption of full gains in efficiency the industry would be operating near the maximum level of efficiency possible (ie almost at the minimum cost per satellite taking nearly full advantage of economies of scale) and the cost per satellite would be reduced by nearly 58%. This would involve significant consolidation in the industry with a possible major reduction in the number of players. If the full efficiency gains are not realised, we estimate that the cost per satellite would fall by around 32%.

The welfare effects are very significant. Society as a whole could gain annually between ECU 701 m and ECU 1,373 m. This is not evenly distributed however since consumers stand to gain significantly, even with a relatively small decrease in price, whereas operators face the possibility of a significant reduction in profits.

In the extreme case of "perfectly" competitive markets which would result in the largest fall in price, operators would be making losses. In that case it would be necessary for the governments or regulatory authorities to establish a mechanism which would cover these losses. We estimate that in Scenario 1, the required transfer could be up to ECU 260 m a year.

In the more realistic case where regulation implies that the industry moves close to, but not at, the "perfectly competitive" market outcome, operators could also benefit from deregulation, with extra profits of around ECU 172 m a year. This would only be possible however if there were full efficiency gains in the industry, resulting in a reduction of the cost per satellite of around 57%.

10.3.5 The quantitative effects of deregulation : Scenario 2 (Europe)

Basic description and assumptions

In Scenario 2, full deregulation is assumed to occur in the European industry only. This does not translate however into a movement at, or very near, a perfectly competitive outcome for Europe only, since there will still be a need for coordination at a Region 1 level. This means that barriers to entry will continue to exist. Furthermore, there is the possibility that Region 1 operators will frustrate the development of effective competition in the European industry and costs of coordinating with non-European, Region 1, or indeed operators from other ITU regions would remain at existing levels. Under this scenario, we assume that the European countries covered by the regulatory change (those currently members of CEPT) would be able to benefit from relief of resource constraints resulting from regulatory change. This would mean perhaps some form of pooling of GSOSR that prevented organisations that did not participate in the regulatory reform, from capturing any resource that becomes available. Achieving such protection of European resources is, however, a complex legal issue which would require further detailed investigation and analysis.

For these reasons we model Scenario 2 as a movement of the European industry, to approximately midway between the status quo and the "perfectly" competitive outcome, represented by Scenario 1.

The effects of deregulation

The quantitative effects on the satellite industry if Scenario 2 was implemented are presented in columns 5 and 6 of Table 10.6. Note that the status quo has also changed since we are only considering Europe.

The price fall expected under this scenario is between 25% and 36%, reflecting the weaker effect of the Scenario 2 regulatory measures on competitiveness. The demand for transponders would similarly increase by less than in Scenario 1; we estimate an increase of between 33% and 50%. Because of the current fragmentation of the industry the reduction in costs resulting from increased efficiency can still be very significant and could reach 50%.

The potential gains for society from the implementation of the Scenario 2 measures are still substantial, ranging from ECU 438 m to ECU 1,015 m. The gains are now also more evenly distributed, with operators standing to gain up to ECU 353 m a year from deregulation, if they are encouraged to achieve the maximum efficiency possible.

In the case where prices fall substantially (by 35.7%) but there is only a relatively moderate reduction in costs (22.6%) the industry would be loss making. In that case, there would be again a need to transfer part of the consumers' gain to operators in order to cover the shortfall in revenue. The magnitude of the transfer however, around ECU 20 m a year, would be significantly lower than in Scenario 1.

10.3.6 The quantitative effects of deregulation : Scenario 3

Basic description and assumptions

In Scenario 3 the regulatory measures implemented cover Europe but their effectiveness in terms of increasing competitiveness and efficient production are reduced significantly compared to Scenario 2. This is because the service allocations are carried out only at the European level by a "partial service" coordinator and therefore certain barriers to entry and issues of national fragmentation remain. The crucial issue affecting the impact of regulatory change will be the extent to which the national level regulatory responsibilities will be implemented consistently and effectively. The more effective and consistent the implementation the more homogeneous will be the operation of the GSOSR market in Europe. It would be as if a single regulatory environment was in place.

The Scenario 3 regulatory changes are therefore assumed to result in only a partial competitive market outcome, implying that the European satellite industry moves again midway between the status quo and the Scenario 2 outcome. We have also included as the extreme case under this scenario the possibility of no efficiency gain.

The effects of deregulation

The quantitative implications of Scenario 3 for the European satellite industry are presented in columns 8 and 9 of Table 10.6. Note that the status quo figures (column 7) are again those prevailing in Europe (column 4).

The fall in price under this scenario ranges between 17.9% and 10.7%, the latter occurring if the remaining barriers to entry mean that the competitive pressures are not very significant. The increase in demand for transponders would range from 17.1% to 26.0%.

If deregulation has no effect on the ability of operators to improve their efficiency then costs would not fall at all. It is possible again however to have a relatively large reduction in costs (up to 44.5%), like in Scenario 2, if the full gains in efficiency are realised.

If we assume that deregulation will result in lower prices, costs or both, then the gain for society as a whole is in the range of ECU 44.5m to ECU 789m. Like in Scenario 2, this gain could be fairly evenly distributed, with a potential maximum gain for consumers of ECU 388m and for producers of ECU 401m.

By considering the extreme case of no change in costs we can in this case evaluate also separately the welfare effect of achieving the maximum change in competitiveness with no change in efficiency (ie. no reduction in costs per satellite).

In this case consumers would gain up to ECU 243m a year but producers would lose up to ECU 199m a year. This would in fact result in the minimum gain for society in Scenario 3 of around ECU 44.5 m/year.

The key implication of these results is that deregulation should aim at establishing a competitive market and at facilitating the movement towards a more efficient operation for the industry as a whole. Otherwise the regulatory authorities run the risk of redistributing welfare from operators to consumers, without really affecting the overall gain for society.

10.3.7 The quantitative effects of deregulation : Scenario 4

Basic description and assumptions

Scenario 4 assumes minimal change in the current regulatory framework. There would be only tentative moves towards increased efficiency in the allocative mechanisms, some reduction in the barriers to entry and a small increase in the level of competition. The scenario could therefore be seen as a description of a first stage before moving towards fuller deregulation described by Scenarios 2 or 3.

Scenario 4 is therefore represented as a very modest move towards competitive markets. In fact costs might increase as a result of further fragmentation of the industry, following the absence of any substantial regulatory change.

The effects of deregulation

The quantitative effects of Scenario 4 are presented in columns 11 and 12 of Table 10.6. Since there is only a minimal change in competitiveness in this scenario, price falls by around 7.1%. This leads to a very limited increase in the demand for transponders (10%).

If the number of operators in the industry remains the same as in the "Base Case", there would be no opportunity to take advantage of economies of scale and the cost per satellite would remain the same. The absence of any substantial regulatory change can also be taken as a signal by potential entrants that the authorities do not intend to intervene in the market at all. This could therefore attract them in the market and thus increase the fragmentation and the average cost per satellite. We estimate that in such a case costs could go up by 3.4%.

The very limited changes in prices and costs imply that the potential for welfare gains is reduced drastically. Consumers stand to gain a maximum of ECU 138m a year whereas producers will loose between ECU 107m and ECU 152m a year. It is therefore possible under this scenario for deregulation to be associated with a welfare loss of ECU 13.9m a year, whereas any potential gain would be extremely limited.

10.3.8 Key differences between the scenarios

The key differentiating factors, from the point of view of the likely impacts on welfare, are two-fold:

- the level at which deregulation takes place - whether national, Europe, Region 1 or worldwide,
- the degree to which market forces are introduced.

These issues are described in more detail in Chapter 8.

Scenario 1 has both the broadest coverage and the most market oriented regulation. In particular, allocation is carried out at the international (ITU) level, assignment and coordination at European level. In terms of market orientation, assignment is by tenders, auctions or lotteries and licences are let in perpetuity, are tradeable and have broad based property rights. In addition, existing band allocations are recouped at world level. A priori, therefore, one would expect the welfare gain to be greatest for this scenario.

Scenario 2 has the same market orientation as Scenario 1, but the coverage, both of allocation in general and of the recouping of band allocations, is limited to Europe. Potential welfare gains will be more limited than in Scenario 1 but still significant.

Scenario 3 retains the more limited geographical coverage of Scenario 2 and also involves a more limited introduction of market forces. Although it envisages tradeable licences and the introduction of tenders or lotteries over time, property rights remain service specific (at least initially) and time limited.

Scenario 4 involves the least deregulation, with geographical coverage remaining at national level and only limited recouping of planned bands. Licence terms and conditions remain very much as at present, although the introduction of economic factors into assignment procedures is envisaged. This scenario is therefore likely to generate the most limited welfare gains.

10.4 Model Sensitivities and Potential

10.4.1 Sensitivities

We have already analysed a range of possible outcomes within each scenario of regulatory change in order to reflect the possibility that regulatory change could have a range of impacts on either or both the competitiveness and efficiency of the industry.

Furthermore, the model can be used to examine the effects of gradual changes in the parameters taken from outside the model on the "Base Case" results and on the impact of regulatory change. We could therefore examine for example:

- the effect of changes in the competition from terrestrial services, modelled as a change in the elasticity of demand and/or a reduction in the level of demand,
- the effect of more optimistic or more pessimistic demand growth predictions,
- the effect of changes in technology and in some or all of the components of costs, including the possibility of reductions in launching/construction costs,
- the effect of changes in the expected lifespan of a satellite, and
- the effect of changes in the number of transponders per satellite.

10.4.2 Model potential

The model can also be used as it currently stands or by appropriate extensions to:

- forecast beyond 1996,
- assess the desired degree of consolidation in the industry as a function of the effectiveness of deregulation and, depending on data availability, the cost efficiency of the different operators,
- examine the provision of more than one or distinct services,
- examine the potential effects of significant technological change,
- model alternative regulatory scenarios,
- estimate the timing and assess the transition to the chosen deregulated environment,
- assess the potential welfare effects of deregulation on the interaction between satellite and substitute/competing services, and
- examine mechanisms for transferring some of the gain of consumers to operators and/or other means of covering operators' losses if deregulation implies that the industry could be loss making.

10.5 Conclusions

The aim of this Chapter was to evaluate quantitatively the potential gains for consumers, operators and society as a whole from the implementation of a new regulatory framework for the assignment of GSOSR in the European and Region 1 satellite operations industry. The key conclusions that emerge from the above analysis are the following:

- the potential benefits to producers and consumers from deregulation are very significant and could realistically exceed 1000 million ECUs a year; this is true for the maximum gain achievable for society in two out of the four scenarios considered (in the third scenario the maximum achievable gain could approach 800 million ECUs a year),

- the above figures assume that benefits from deregulation can and will be passed on to final consumers. It assumes also that deregulation will facilitate or in any case will not prevent consolidation in the industry so that operators also realise a significant gain; this will enable the achievement of the maximum "society gain" possible by more efficient production. It will also facilitate the implementation of regulatory change, since it should reduce opposition by the established large operators in the industry,

- the above figure excludes the benefits from deregulation resulting in the "competing" terrestrial industries and the possibility of further feedback through increasing demand for satellite services.

The overall results therefore support strongly the case for deregulation along the lines of Scenarios 1-3. Although a precise figure for the cost of implementing the regulatory package and setting-up and running the relevant regulatory authority can only be determined from subsequent work, the potential gains seem significant enough to justify such costs. Furthermore, unlike deregulation and privatisation in monopoly markets in a number of sectors in European countries where a single incumbent stood to loose significantly from the implementation of deregulation, the European satellite operation industry seems to offer significant potential benefits for most or all of the current incumbents because of currently unexploited economies of scale.

Scenario 4, although attractive because of its gradual nature, seems to offer very little potential for welfare gains. If not accompanied by explicit statements that the authorities are determined to proceed with further deregulation, it could also lead to welfare losses through more inefficient production. It seems to be therefore a very risky option. The choice between all the scenarios however will depend largely on a detailed cost analysis of implementing them, which should include tangible and non tangible/pecuniary and non-pecuniary costs and can only be determined with precision in subsequent research.

11 Policy Implications

The preceding analysis provides compelling evidence that the existing system of regulating GSOSR requires significant reform. Introducing more economic considerations into the regulation of GSOSR would yield significant economic benefits to the geographic areas covered by the reforms. The main issues, therefore, are:

- how should the reforms be introduced and implemented?

- precisely what regulatory reforms should and could be introduced?

The international benefits of introducing such reform needs to be communicated effectively at an international level. Consideration should be given to explaining the analysis contained in this report and the principles that are necessary to the realisation of potential benefits.

11.1 How to introduce the reforms

It is clear that the greater the geographic area covered by the reforms the greater will be the overall improvement in the economic efficiency of the resulting regulatory environment. The optimum solution, therefore, would be for reform to take place at the level of the ITU, encompassing Regions 1, 2 and 3. Such regulatory reform would be very difficult to introduce as it would involve extensive multilateral negotiations, changes to UN conventions and fundamental reform of the structure and responsibilities of the ITU.

The ultimate aim for policy makers in Europe should be the initiation of change at the ITU level. European policy makers, however, should not be constrained by the likely slow progress in achieving change at the ITU level. There is an opportunity in Europe to provide a model for changes which should take place at a wider level. It is very important, therefore, that there is a clear understanding of the principles that are behind changes in the regulation of the GSOSR that would yield, if implemented effectively, a more efficient market for geo-stationary satellite services.

These principles would be as follows:

- that as much of the GSOSR as is possible is subject to free market conditions. Care should be taken to ensure that any GSOSR reserved for non market applications is not allowed to distort the operation of market forces outside the reserved area. If GSOSR is reserved for economic development purposes in developing countries for example, it should be completely separate from the GSOSR operating under market conditions,

- there should be ease of entry to, and exit from, the market: this will ensure that inefficient operators could be replaced by efficient operators. The realistic threat of entry to markets should act as an important incentive for existing operators to maintain their competitiveness,

- there should be no barriers to entry for the operation of services except for the absolute minimum of regulation required to ensure the technical integrity of the services being offered: this would mean no restrictions on the type of organisations allowed to provide satellite services, or on the geographical coverage of these services,

- the existing principles of EC competition policy should apply, so prohibiting practices such as predatory pricing, cross-subsidisation, abuse of a dominant position, exclusivity agreements with distributors or major customers.

These principles, which require formal elaboration, should become enshrined in the articles of association of any European agency responsible for the regulation of GSOSR. Again the broader the territorial coverage of such an agency the greater its potential beneficial impact. If an agency could be established to cover the CEPT countries this would benefit the broad European market. If progress proves too slow at this level then the agency should, at least as an interim measure, be established to cover the EU Member States. It would be preferable to introduce an effective agency, implementing the right kind of regulatory reforms to a smaller area than it would to compromise on the fundamental principles of reform for the sake of wider coverage.

11.2 Which regulatory reforms should be introduced

The preceding analysis identified a number of areas in which regulation should be modified in order to get the benefits of greater efficiency in the allocation and use of the GSOSR. The following regulatory principles would be crucial to achieving greater market orientation and the associated improvements in economic efficiency:

- ensure that the regulatory regime applies to all operators delivering space segment services to the geographical area covered by the agency. This would be important to ensure regulations were not circumvented by operators basing themselves outside the area of jurisdiction of the new agency. There is a role for the agency to initiate a pooling of resources currently under the control of participating countries. It would also have a role in reducing inefficiencies that are a legacy of historical decisions and the existing regulations. In this sense it would be helpful to apply due diligence criteria discussed below on a retrospective basis,

- in perpetuity rights of use combined with transferability of the right to use, or long duration licences combined with a high expectation of renewal and transferability of licences. These measures would allow flexibility in use of the GSOSR. Use should be more responsive to changes in patterns of demand with such a provision. The decision as to whether there should be in perpetuity tradeable rights or long duration licences depends on whether regulators wish to retain the possibility of intervention in the future. It should not be necessary, if due diligence regulations are effective, to have such a review. It would however be important to define carefully the "property rights" associated with the right to use the GSOSR,

- basic qualifying characteristics of those applying to use, to ensure they have the minimum technological, management and financial resources to implement plans. There are benefits to screening potential users against criteria judged to be essential for the successful commercial development of GSOSR. The criteria should be explicitly established, transparent and objective. This screening would reduce the possibility of projects failing and continuing to tie up potentially scarce resources,

- due diligence during the period leading up to and following the placing of a satellite in space - use it as intended or lose it. There needs to be active monitoring to ensure that operators are using the resources as indicated. Clearly, careful further consideration should be given to how such due diligence should work in practice. There needs to be implementable powers, however, that can withdraw the right to use GSOSR if there is unacceptable under-utilisation of the resource or unreasonable time delays in it becoming productively used,

- introduce an economic method of determining who uses which GSOSR. New licences should involve open selection methods with certain prequalification criteria to ensure the capabilities of the applicants. Access to the GSOSR should be determined by tendering. Again further work is required to specify the details of what method of tendering should be adopted. There should be some basic screening to ensure the credentials of bidders. Price, other things being equal, should be the final arbitrator, but whether it is a simple highest price plus due diligence, or some more complex variant of this formula is subject to further review.

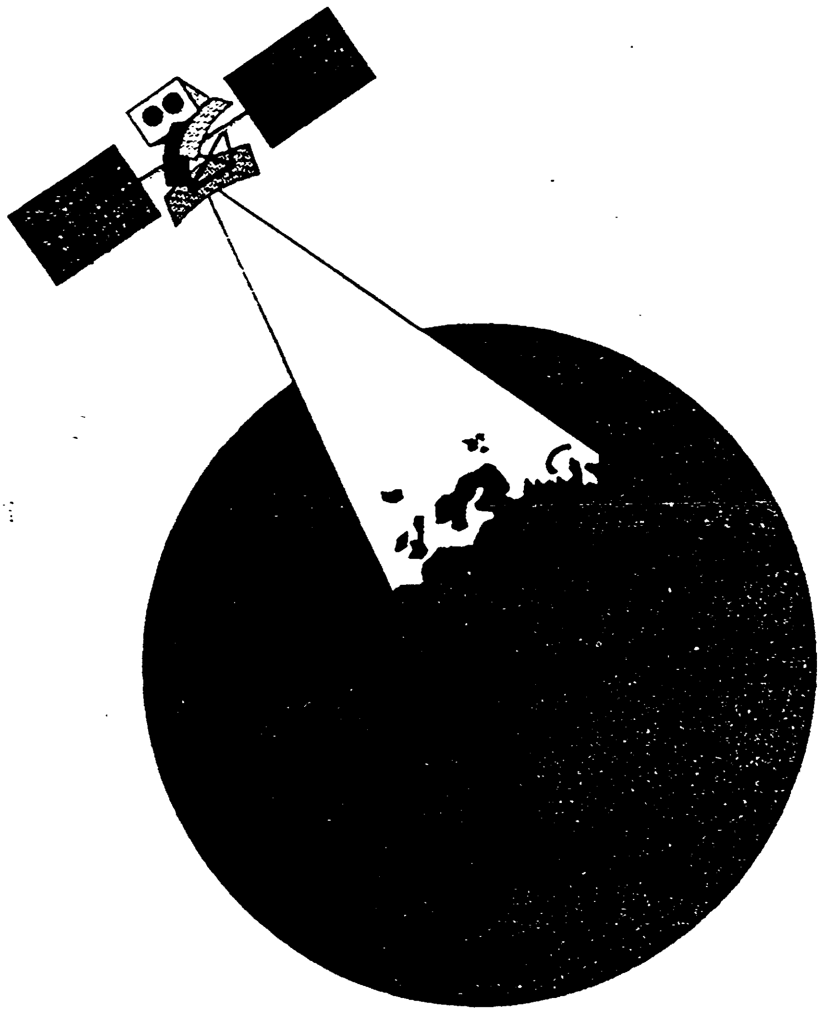
The coordination agency should either administer these regulations directly, or it should coordinate their uniform introduction and implementation across all participating states. The precise structure and responsibilities of different regulatory agencies should be addressed as a matter of urgency. This will, however, to a certain extent depend on which solution is most palatable politically. There is a need for an agency to be established that can drive the process forward. Such an agency should represent the interest of a critical mass of European countries in the first instance and it may form the core of a body with wider regulatory responsibilities.

Action is required because the satellite communications industry and its consumers are suffering from the economic inefficiencies that exist under the current regulatory system. The benefits of greater efficiency could potentially spread to a very wide range of consumers both inside and outside Europe. Such stimulation of the industry would also provide it with a greater chance of competing effectively with terrestrial substitutes - thus spreading the benefits of competition even further through society.

KPMG Consortium

An Economic Assessment of European Satellite Orbit and Spectrum Resources

Final Report - Executive Summary



European Commission

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The KPMG Consortium

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Organisations Consulted

The following organisations were consulted in the cause of this study. We would like to express our thanks for their cooperation and assistance.

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- Bundesministerium fur Post und Telekommunications, Germany
- Comsat
- Congressional Budget Office, USA
- Directorate for General Regulation (DRG), Ministry of Post and Telecommunication, France
- European Broadcast Union (EBU)
- European Space Agency (ESA)
- European Radiocommunications Office (ERO)
- Eutelsat
- Federal Communications Commission (FCC)
- France Telecom
- Hispasat
- Intelsat
- Interational Telecommunications Union (ITU)
- Leventhal, Senter and Lermen
- National Telecommunications and Information Administration (NTIA)
- Organisation for Economic Cooperation and Development (OECD)
- Orion
- Paris Telecom
- Radiocommunications Agency, UK
- Resources for the Future
- Senate Commerce Committee, USA
- SES - Astra
- Sutherland, Asbill and Brennan
- Teleport Europe

For further details of this study please do not hesitate to contact Hans Schoof of DGXIII of the European Commission (Tel: +32 2 296 8610) or Vicky Pryce, KPMG's partner in charge of Strategy, Economics and Marketing in London (Tel: +44 71 236 8000).

EXECUTIVE SUMMARY

E1 Introduction

The KPMG Consortium has been retained to undertake an economic assessment of the way in which geostationary orbit and spectrum resources (GSOSR) are allocated and used in the International Telecommunications Union's (ITU) Region 1, particularly the European sub-region. The objectives of this study are as follows :

- to develop a set of principles, based in particular on economic theory relating to resource management, that will facilitate the optimal allocation of scarce orbit and spectrum resources;

- based on these principles and as far as possible incorporating the main technical, legal, political and other considerations, to develop principles for managing the allocation and utilisation of orbit and spectrum resources.

Currently there are few or no explicit economic regulations impacting the allocation or assignment of GSOSR at the international or national levels in Europe. This does not mean, however, that there are no resulting economic impacts. Indeed the technical and administrative regulations tend to interfere with and distort market forces, thus leading to economic inefficiencies developing in the market.

E2 Review of the literature and analogous regulatory systems

Economic analysis and regulation of the satellite industry

A wide range of relevant literature exists, dealing explicitly with the satellite industry or with other sectors and situations that can be viewed as analogous. However, coverage of economic theory and its practical application to satellite issues is relatively recent. To a great extent this reflects the development of the industry itself, which has only recently begun to take into account economic theory and market forces, having previously been driven by technical and political factors. Key conclusions are as follows:

- the innovative nature of this study is reflected in the sparsity of the literature. Little work has been carried out on the economic evaluation of orbit/spectrum, although a number of studies have focused on specific aspects of the issue. The techniques used also tend to vary considerably, generally being developed to address specific problems rather than the more general analysis needed for this study;

- very little quantitative analysis was identified even in the most recent literature. Modelling approaches adopted a variety of methodologies, including comparative utility analysis, probability analysis, estimation of cost functions and more pragmatic market forecasting. None of these are considered to be directly applicable to the current problem;

- all the literature emphasised the rapid change in technology that characterises the industry. A key implication of this for modelling purposes is the need for careful specification of the baseline case against which alternative policy scenarios will be evaluated;

- the satellite industry is extremely complex. In addition to rapid technological change there are market failures, such as : the participation of competitors (the PTOs) as shareholders in the main providers of transponder capacity; and the degree of technical regulation and government involvement.

Overall, the analysis of the literature suggests that the approach adopted will need to be based on sound economic concepts, straightforward to model and bearing in mind likely data limitations.

The review also highlighted two areas of particular interest to the rest of the study:

- **scarcity of orbit and spectrum:** there is considerable debate as to the existence of scarcity, its causes and whether it will be a problem in future. While it is generally agreed that the constraints of the 1970s and early 1980s have been alleviated (partly because of a switch to fibre optics, at least in the US), demand can still exceed supply in particular geographical locations, orbit slots or frequency bands. Some commentators argue that technological progress will increase capacity to such an extent that scarcity will not be an issue in the foreseeable future. Others, however, note the rapid growth in demand for telecommunications services, and the explosion of new services that use the airwaves, arguing that this will continue to put pressure on resources. Those who believe that scarcity is primarily a function of inappropriate regulation would argue that this is more apparent than real and could be eliminated by a more appropriate pricing policy;

- **alternative allocation mechanisms:** there is considerable policy debate over alternatives. In particular, there has been considerable interest in the use of auctions and tenders, although this issue is controversial. The main arguments in favour of auctions are that they improve economic efficiency and, by allowing Government to cream off monopoly profit, are fairer than current mechanisms. Those against auctions argue that creating a market for orbit and spectrum may prevent essential services from being provided; provide Government with an incentive to promote monopoly in order to maximise revenue gains; and cannot achieve an efficient solution given the existence of market failure elsewhere in the telecommunications industry.

Examples of national satellite regulations

A review of national satellite regulation regimes throughout the world suggests that most of them continue to operate on a non-market orientated basis. However, in recent years the trend towards increasing deregulation in the telecommunications sector has begun to spread to the satellite industry. A small but significant number of countries has adopted relatively liberal regimes, although in most cases these are still at a very early stage. These countries include:

- the US, which has been described as "the most relaxed in the world". Award of licences to provide telecommunication services generally is either by comparative hearings or lottery. Award of licences to implement new space segment is generally a case-by-case procedure. Comparative hearings are used when less than all applicantions for use of GSOSR can be awarded. Current legislation to reassign some Federal spectrum to commercial use provides for the use of auctions, but it is unclear whether this mechanism will be applied in the context of licensing of new space segments;

- New Zealand, where licences provide broad property rights to spectrum (they are tradeable, technically specific but not purpose specific) and are awarded by auction. Australia is adopting a similar approach;

- the UK, which has issued broad Satellite Class licences to provide services not connected to the PSTN, as well as two licences permitting international telecommunications. Under the 1990 Broadcasting Act, new space segment may be implemented by licencees other than the incumbent PTO (BT);

- Germany, which allows private provision of two way networks, private voice transmissions and connections to the PSTN (depending on the likely threat to the PTO monopoly);

- by and large, European countries still reserve provision of space segment to a favoured incumbent PTO or other national "champion". Four EC Member States - the UK, France, Germany and the Netherlands - now permit access to Eutelsat space segment via any of the signatories of their four countries.

Analogous regulatory environments

We reviewed the regulatory frameworks in place for a number of industries, including roads, independent radio, terrestrial and cable television, airport landing slots and airline routes. There is a number of approaches to allocating resources, some of which have differing objectives, ranging from economic efficiency through to equity. In some industries pricing is used in order to reach a market equilibrium whereas in others the price mechanism is not used at all. Ownership and transferability of ownership of rights to produce, or rights of access to a service are also important. For example, a government may own a resource and then allocate it for free on a first come first served basis (like the National Health Service in the UK or motorways in Germany), or it may give the resource to the highest bidder (as in the franchise monopolies for regional terrestrial television in the UK). Issues which are relevant to the regulation of GSOSR include:

- what sort of mechanism should be used to assign orbits and frequencies? If price is used, should it be set and the resource assigned on a first-come-first-served basis, or should it be assigned via some bidding process?

- should the behaviour of the "owners" of the rights to use orbit and spectrum rights be regulated?

- what should be the duration of spectrum and orbit rights?

- once rights over an orbit or frequency are conferred, should they be transferable?

All these issues are relevant to the development of regulatory scenarios for orbit and frequency. It is important to stress the difference between regulation that impacts upon the structure of the market, and that which influences the conduct of competitors in the market. The regulatory scenarios for orbit and frequency resources described below reflect both these forms of regulation.

E3 Technology trends

Technology is a critical factor in the current and future development of the satellite industry, and the likely technical developments will need to be taken into account both in developing any model of the future of the industry and in developing possible regulatory scenarios.

There are two physical resources which limit the worldwide capacity for satellite communications. These are :

- the potential orbits for satellites;
- the frequencies used to communicate with the satellites, the available range of which is limited by technology (the techniques for exploiting higher and higher frequencies require constant development) and physics (only certain frequency ranges penetrate the earth's ionosphere).

The dominant orbit for communications satellites has always been the geosynchronous orbit (GSO), a ring located some 35,000km above the Equator. This unique orbit allows a satellite to remain apparently motionless relative to any point on the Earth's surface. Technological constraints have meant that satellites situated in the GSO cannot be placed less than 2° apart, thus severely limiting the potential number of orbital slots. This is particularly the case in popular positions, such as those best suited to serving the US and Western Europe.

The spectrum is also crowded. Satellite communications use the microwave frequencies, from 0.9 Ghz upwards. However, not all frequencies above 0.9 Ghz are available, since the earth's ionosphere is impenetrable at many frequencies. There are a number of windows, and these windows (bands) are shared by civil and military satellite communications. As frequencies increase, so the signals are increasingly subject to fade, so that the exploitation of higher frequencies is highly dependent on the development of fade countermeasures (FCMs).

In fact geostationary satellites may be co-located in the GSO, but the main constraint on GSOSR is the problem of potentially interfering frequencies from overlapping transmissions (downlinks or uplinks). This constraint is most alternated for the use of the most effective bands (typically, Ku) from the most popular ranges of orbital arc.

There is increasing pressure on both orbit and frequency resources. This is being addressed by a number of technological means both in isolation and in concert. Most of these technologies are expected to be in operational use in the late 1990s-2000. For example:

- DSP techniques which will allow efficient use of the radio spectrum;
- allocated digital compression will increase the number of circuits that can be carried within a certain physical bandwidth;
- new modulation techniques will further increase spectral efficiency, making broadband technologies such as ATM and SDH feasible;

- the development of LEO and MEO systems. However, whilst this may relieve pressure on geostationary orbit slots, it does nothing to relieve pressure on the spectrum.

Against such technological developments can be set the growing importance and acceptance of standards. This is likely to slow down the introduction of innovative technology. The convergence of satellite services, using broadband technologies and the digitisation of TV and radio, may eventually greatly simplify the Radio Regulations by removing the distinctions between services. However, this is a long term tendency, since it is unlikely that broadcast TV will converge in the next ten years. Until it does, the best that can be hoped for is the convergence of two types of service: TV and the rest. The one exception to this is likely to be the specialised user of TV, such as SNG, which is likely to go digital in the short term (since there is no existing standards base which must be supported), and so can converge with the other digital services.

E4 Existing regulatory environment for assigning GSOSR

Particularly in the ITU Region 1 and the European sub-region, the existing regulatory system for access to, and use of, GSOSR predominantly involves procedures which are administrative and technical in nature rather than economic. Just because there is no economic rationale behind the regulations, however, does not mean there is an absence of economic effect. Indeed, the lack of consideration of economic factors not surprisingly leads to economic inefficiencies and market distortions. Some of the key issues related to the current regulatory system are as follows:

- European access to GSOSR can be expected to become more problematic over time. The Unplanned FSS regime covers the majority of spectrum resource but substantial spectrum has been tied up in the BSS Plan, and the flexibility of the less rigid Planned FSS regime remains in doubt;

- assignment of GSOSR to specific satellite systems remains a national prerogative. Both this and the anti-competitive covenants contained in ISO Conventions have tended to reduce access to GSOSR by European users. These legal limitations on GSOSR access have tended to constrain European demand for use of GSOSR at an artificially low level;

- the Unplanned and Planned FSS regimes permit accommodation of sub-regional systems, but the effect of institutionalised sub-regional scenarios on the supply of GSOSR is not entirely clear. The apparent European trend toward national systems geared to pan-European service should be borne in mind. Such separate systems can function as effective substitutes for a European ISO, and will presumably compete along lines more consistent with Community competition policy for the telecommunications sector. However their proliferation may add substantially to European demand for GSOSR;

- more efficient access to existing European space segment can be expected to stimulate demand for GSOSR. A potential explosion of demand for new satellite services, anticipated to be introduced in accordance with impending deregulation of the European satellite sector, could make the level of demand for GSOSR unsatisfiable;

- the ITU experience with "equitable planning" of access to GSOSR suggests little basis for optimism that a similar approach would result in greater efficiencies at the European sub-regional or Community level;

- North America appears to enjoy less strain on GSOSR access even in the face of a much more highly evolved, deregulated satellite communications marketplace. In part this is because fewer protected national allotments have been tied up by international GSOSR planning regimes. One lesson for Europe may be to explore an undoing of the WARC 77 BSS regime. In part North America may exhibit a more flexible environment because a centralised and highly sophisticated GSOSR management function has been assumed by a single government body, the FCC.

The legal conundrum of GSOSR access is so complex that it invites basic rethinking. One compelling notion is that no regime for access will remain perennially viable so long as basic rights to exploit satellite orbital and spectrum resources are obtainable gratis by national administrations and their chosen operating entities. The shortcomings of the existing regulatory system manifest themselves in the form of both artificial scarcity and distortions to competition. The consequences for Europe can be regarded as:

- high barriers to entry limiting competition, and inflexibility in the market, leading to high prices for transponders relative to what would be the case under more competitive market conditions;

- monopolistic tendencies of incumbent operators resulting in high profitability;

- few competitors for pan-European or national services, but many operators providing geographically fragmented and/or application specific services and so not exploiting the full economic potential of the resources being used;

- a regulatory system that leads to regulatory protection of unimplemented ("paper") satellites, raising the cost of coordination, preventing market entry and creating artificial scarcity.

The application of ITU regulations at the national level in Europe can lead to fragmentation because of the geo-political structure of the continent.

The current administrative and technically driven regulations are, therefore, contributing to a highly fragmented and economically inefficient satellite sector in Europe. The inefficiencies are also tending to hold back innovation and reduce the general dynamism of the sector. If the current situation continues there is a long term threat to the survival of the European satellite industry in the face of increasing pressure from terrestrial based substitute services. European industry is already threatened by the economies of scale available to US manufacturers, who supply a relatively robust domestic satellite market.

E5 The key regulatory components

We have broken down key regulatory factors into six broad areas, which we have used as the basis for an interview programme and subsequent qualitative analysis, and ultimately for the modelling work. The six areas are as follows:

- **recoup spectrum** : significant parts of the spectrum are allocated to specific uses. To the extent that these resources are used inefficiently, there is an argument for releasing some or all of these for wider commercial use. Our analysis focuses particularly on two areas :

  - military allocations/assignments,
  - the BSS spectrum;

- **institutional change** : at present, allocation is carried out both at the international level and, consistent with these allocations, at the national level. As a matter of public international law it would be possible to carry out allocation and assignment at a sub-regional level, such as within Europe, so long as this remained consistent with ITU rules and no third country's rights were prejudiced;

- **procedural change** : the lack of transparency in assignment at national level and the limited influence of market forces create considerable inefficiency. There is a number of alternative allocation and assignment mechanisms. Economic theory suggests that those mechanisms that are closest to the licensee paying the market price for the resource will be the most likely to promote efficient use of GSOSR. In particular, with an explicit cost of not using the resource, whether it be in terms of interest charges on capital or foregone income from alternative uses of resources, the likelihood of hoarding or 'warehousing' and the problem of "paper satellites" are considerably diminished. The main mechanisms available, listed in increasing order of market orientation are :

  - *preemptive rights:* dominant incumbent "champions" obtain rights in GSOSR on an exclusive or nearly exclusive basis,

  - *first come first served:* currently the norm for coordinating spectrum use at international level, but typically not a factor in spectrum assignments at the national level in Europe,

  - *non-interference:* assignments are subject to the proviso that the service will not interfere with existing assignments (a fairly universal norm),

  - *national procedural norms:* applicants may be required to meet a range of criteria (technical, financial, etc),

  - *technical planning:* allocation of bands to specific services, determined by purely technical criteria,

- *economic/market planning:* allocation of bands to particular services according to an assessment of current or future demand,

- *comparative hearings:* a "beauty parade" to allow the regulator to come to an informed decision as to the "most appropriate" proposal,

- *lotteries:* with the winner selected at random,

- *auctions:* where the government receives the economic value for the resource and the winning bidder has an incentive to use the resource efficiently;

• changes in terms and conditions of space segment licences include the following elements:

- *property rights:* current licences are highly specific as regards the particular use to which an assignment can be put. One option might be to introduce a degree of flexibility, granting broader property rights over the spectrum, for example, to use the spectrum for any service,

- *due diligence ("use it or lose it"):* to prevent warehousing of GSOSR and the "deep pockets" phenomenon, where incumbents or competitors buy up the resource to limit competition. At the national level, due diligence requires that the licence holder demonstrates use of the resource,

- *duration of licences:* under public international law there is effectively no limit to the duration of an assignment. From an economic point of view, providing licences that are transferable then letting them in perpetuity has a greater potential for reaching the market solution than setting fixed period licences,

- *tradeability:* there are strong arguments for at least making sure that satellite systems are themselves freely tradeable. Without tradeability there is no incentive to give up licences and every incentive to hoard them.

- *pioneers' preference:* a system whereby "innovative" proposals for utilising GSOSR be given preferential treatment over "me too" applications. The aim is to promote innovation by giving the new idea a commercial advantage, particularly important for smaller firms who may not otherwise be able to develop their good ideas;

• technical policies used to encourage the technically efficient use of GSOSR. There are three issues of particular relevance to Europe:

- *orbital spacing:* while there is no explicit limit on how close together satellites can be situated without interfering, 3° is generally seen as an appropriate rule of thumb. In the US, a shortage of GSOSR led the FCC to impose a 2° spacing rule, after technical study and discussion with the industry,

- *frequency sharing and reuse:* there is already a number of technical options for frequency sharing and reuse, and with greater use of digitisation, cross polarisation and modulation techniques, these are increasing,

- *European "fine tuning":* the extent to which other internationally established technical parameters for relevant services permit local fine tuning to improve the efficiency of GSOSR utilisation;

- **competition policy** the key point here is the extent to which competition rules are invoked in order to maintain a competitive market structure. Three particular issues are relevant:

  - *ISO anticompetitive covenants:* provide protection to operators against 'economic harm' caused by any new proposed assignment,

  - *maintenance of exclusive and special rights:* Member States granting exclusive rights to an incumbent or other preferred national space segment provider are vulnerable under Articles 86 and 90 EEC,

  - *"hot birds":* owner-operators of satellite systems occupying uniquely valuble "hot bird" locations may be subject to an Article 86 claim that they dominate a specific service market. The question is whether they abuse their dominant position, eg, by charging an "excessive" price or unfairly excluding potential competitors from the market.

These regulatory components were discussed as part of an interview programme with satellite regulators, operators, service providers and research organisations in Europe and the United States.

In general there were substantial differences in emphasis between the views of the European and US interviewees. In particular, the US respondents were much more familiar with the regulatory options, concerning procedures, terms and conditions and certain technical policies such as pioneer's preference. This was partly because many of the options are already in place in the US. The US respondents in public sector organisations also had a greater market orientation, with strong views on the need to minimise regulatory interference and maximise competition as being the best way to promote economic efficiency of GSOSR utilisation and to improve welfare.

A key aspect of the US interviews was the general belief that scarcity of GSOSR for domestic use is no longer a problem (although it still exists in particular niches/frequencies). The "spectrum wars" of the late 1970s/early 1980s are no longer viewed as a big issue. This was due primarily to a combination of technological progress and competition from terrestrial systems, particularly optical cables. Remaining scarcity is viewed as artificial, being due to the regulatory framework which is inflexible and slow to adjust. This makes it difficult for GSOSR resources to shift to new uses or those with the greatest economic value.

In Europe there was more concern about issues of scarcity, the fragmented nature of the industry and, with a few notable exceptions, the general difficulty of introducing new services on a pan-European basis. An important issue is clearly the appropriate geographic level at which GSOSR regulation should apply. Should it remain at the national and ITU levels or is there scope to stimulate the market through the introduction of regional or sub-regional regulatory regimes? This is a reflection of the fact that regulations with an economic rationale are practically non-existent in Europe.

E6 The regulatory scenarios

We have developed four regulatory scenarios for evaluation, both qualitatively, through discussion with the satellite industry, and quantitatively, through modelling. These are summarised in Tables E1 and E2 below. Table E1 indicates at what level four principal regulatory responsibilities impacting GSOSR -- allocation, assignment, coordination and legislation (radio regulation) -- are carried out. Table E2 compares the scenarios across the six regulatory components and highlights the likely ordering and relative magnitude of the market and welfare impacts.

E7 The model and results

The ultimate aim of the modelling exercise is to evaluate the economic impact in quantitative terms of a number of the regulatory scenarios described above. We have developed a model which is based on current and forecast demand and supply of transponder equivalents in Region 1. The model is underpinned by classical microeconomic theory in which certain assumptions regarding the behaviour of producers and consumers hold, and that the results of this behaviour can be represented by smooth and well-defined curves representing willingness to pay (by consumers) and willingness to supply (by producers). It is based on the interaction of supply and demand of transponder equivalents.

The following points illustrate the basic structure of the model and the key set of assumptions on which the analysis rests:

Demand Structure:

- the demand for satellite services is broken down into tv, telephony, data and mobile;

- there are no monopolistic restrictions on which organisations can provide the end user services on which demand for GSOSR depends;

- a technical parameter is applied to translate demand for services into demand for 36 Mhz transponder equivalents. In order to take into account improvements in satellite capacity arising from technical progress, an index of technological change is applied to future demands;

- demand forecasts for transponder equivalents and estimates of the demand growth in the 1993-2000 period. By making assumptions about the price elasticity of demand we obtain demand curves for each year;

- given the demand for transponder equivalents and the state of technology (ie, the number of transponder equivalents per satellite), we obtain demand for satellites.

Supply Structure:

- the current and planned number of GSO satellites is the main variable underpinning the supply side;

- from the current and planned number of satellites we estimate the growth path of transponder equivalents over the forecast period, taking into account expected technological trends;

- a cost function for the supply of satellites is derived;

- operators are assumed to be the ultimate suppliers of transponder equivalents. The price mark-ups of ISO signatories are included in the supply side of the model.

Given the expected demand for transponders, and therefore satellites, the model calculates how many new satellites are sent up each year if operators are free to maximise their profits. This will yield the supply of transponder equivalents in each year and the cost associated with that supply.

To investigate the implications of regulatory change, we model its likely impact on the supply and demand of satellite transponders and calculate the resulting impact on economic welfare relative to the base (no change) case. This allows us to arrive at a quantification of the net welfare impact of regulatory change.

Table E1 : Comparison of Scenarios - Level of Responsibility

	Scenario 1 **Market approach - worldwide**	**Scenario 2** **Market approach - Europe**	**Scenario 3** **Partial markets**	**Scenario 4** **Minimal Institution/ Allocation Reforms**
Allocation	ITU/Region 1	ITU/Europe	ITU/Europe	ITU/Europe/national
Assignment	Region 1	Europe	national	national
Coordination	Region 1/international	Europe/international	national/international	national/international
Legislation	ITU/Region 1	ITU/Europe	ITU/Europe	ITU/national

Ta... E2 : Comparison of Scenarios - Regulatory Components

	Scenario 1 Market approach - Worldwide/Region 1	Scenario 2 Market approach - Europe	Scenario 3 Partial markets	Scenario 4 Minimal institution/allocation reforms
Institutional change	assignment, coordination, competition/due diligence, international negotiation at Region 1 level. (ITU functions move from national to Regional level)	assignment, coordination, competition/due diligence, international negotiation at European level. (ITU functions move from national to European level)	pan-European allocation; rigorous competition; common ITU delegation; in Europe 'partial service' coordinators; assignment, due diligence remain at national level	pan-European band allocation for specific services
Procedural change	assignment by tenders, auctions or lotteries	assignment by tenders, auctions or lotteries	entry criteria plus assignment by tenders, lotteries or comparative hearings	assignment by economic administration
Terms and conditions	• broad based property rights • licences issued in perpetuity or with high expectation of renewal • full tradeability • strict due diligence • no pioneer's preference • use it or lose it	• broad based property rights • licences issued in perpetuity or with high expectation of renewal • full tradeability • strict due diligence • no pioneer's preference • use it or lose it	• licences initially service specific • licences issued with high expectation of renewal • full tradeability • strict due diligence • no pioneer's preference • use it or lose it	• service specific • duration service specific • not tradeable • no pioneer's preference • use it or lose it
Competition policy	• free entry to operator and service markets • EC/national competition rules rigorously enforced • no ISO non competition covenants	• free entry to operator and service markets • EC/national competition rules rigorously enforced • no ISO non-competition covenants	• entry to service markets initially limited • EC/national competition rules rigorously enforced • ISO barriers to entry phased out	• competition enforcement as present • no change in treatment of "hot birds" • ISO barriers to entry phased out
Technical policies	• no limitation on spacing • no limitation on frequency sharing/reuse	• no limitation on spacing • no limitation on frequency sharing/reuse	• no limitation on spacing • no limitation on frequency sharing/reuse	• no limitation on spacing • frequency sharing/reuse unchanged
Recoup spectrum	satellite allocations recouped at World/Regional levels plus grandfathering	satellite allocations recouped at European level plus grandfathering	satellite allocations recouped at European level plus grandfathering	Increased flexibility in BSS. New pan-European allocations
Likely welfare and market impact	——————————> Most change Most liberal market impact	——————————>	——————————>	——————————> Little change Little market liberalisation

The possible economic effects on the satellite industry of all the regulatory measures already identified are summarised in Table E3 below. In the upper part of the table, in the first column of each Scenario we present the "Base Case" values over a five year period for price, cost and quantity under the assumption of no regulatory change - the status quo. The second column of each scenario gives the values for the same variables when deregulation is implemented and the third one provides the percentage changes.

In the lower part of the table, we present the extra gain to consumers, producers and society as a result of deregulation, compared with the "Base Case" (no regulatory change). In some of the alternatives considered the industry as a whole could be loss making as a result of large falls in prices not accompanied by equivalent reduction in costs. In these cases it will therefore be necessary for the governments/regulatory authorities to introduce a mechanism which would cover the shortfall in revenue for the industry by transferring part of the gain of consumers back to the operators. The maximum amount of such a transfer is given in the last row of the table.

The range of possible outcomes, even within each scenario, is quite large, depending on:

- how significant the effect of any regulatory change is, and
- whether it affects the competitive environment, the efficiency of production or both.

E8 Results

The key conclusions that emerge from the modelling analysis are the following:

- the potential benefits to producers and consumers from deregulation are very significant and could realistically exceed 1000 million ECUs a year; this is true for the maximum gain achievable for society in two out of the four scenarios considered: in the third scenario the maximum achievable gain could approach 800 million ECUs a year. It should be noted that the gain achievable by society is not directly related to the GSOSR market size. Lower prices and increased demand for satellite services will always lead to a gain for consumers and producers if efficiency improves sufficiently. The market size will not necessarily increase since more will be sold but at a lower price. Since lower prices are likely to attract more consumers into the market, however, market size will most probably also increase. Welfare gain could also have benefits in upstream or downstream markets;
- the 1000 million ECU estimate assumes that benefits from deregulation can and will be passed on to final consumers. It assumes also that deregulation will facilitate or in any case will not prevent consolidation in the industry so that operators also realise a significant gain; this will enable the achievement of the maximum "society gain" possible by more efficient production. It will also facilitate the implementation of regulatory change, since it should reduce opposition by the established large operators in the industry;
- the 1000 million ECU estimate does not include the likely benefits from deregulation resulting in the "competing" terrestrial industries and the possibility of further feedback through increasing demand for satellite services..

TABLE E3

THE EFFECTS OF DEREGULATION IN THE SATELLITE INDUSTRY

ALL VARIABLES AND CHANGES ARE AVERAGED OVER A PERIOD OF FIVE YEARS.
THE EFFECTS OF REGULATORY CHANGES ARE COMPARED WITH THE BASE CASE ie NO REGULATORY CHANGE

	SCENARIOS											
	92–96 Status Quo	1 – FULL LIBERALISATION Market approach in Region 1		92–96 Status Quo	2 – EUROPE Market approach in Europe		92–96 Status Quo	3 – PARTIAL MARKETS Limited Market Approach in Europe		92–96 Status Quo	4 – MINIMAL CHANGE Institutional and Allocation Reforms in Europe	
			% change			% change			% change			% change
PRICE /TRANSPONDER (ECU m)	2.70			2.80			2.80			2.80		
Limited regulatory impact		1.50	-44.4		2.10	-25.0		2.50	-10.7		2.60	-7.1
Significant regulatory impact		0.00	66.7		1.80	-35.7		2.30	-17.9		2.80	0.0
COST/SATELLITE (ECU m)	32.00			32.80			32.80			32.80		
Limited regulatory impact		21.90	31.6		25.40	-22.6		32.80	0.0		33.90	3.4
Significant regulatory impact		13.50	-57.8		16.30	-50.3		18.20	-44.5		32.80	0.0
NUMBER OF TRANSPONDERS	1614.00			1454.00			1454.00			1454.00		
Significant regulatory impact		2951.00	82.8		2182.00	50.1		1832.00	26.0		1600.00	10.0
Limited regulatory impact		2496.00	54.6		1935.00	33.1		1702.00	17.1			
CONSUMERS GAIN (ECU m)												
max *		1856.80			829.40			388.00			138.10	
min		1100.30			508.50			243.00			0.00	
PRODUCERS GAIN (ECU m)												
max		172.50			353.50			400.90			-106.60	
min		-483.60			-299.30			-199.00			-152.00	
SOCIETY GAINS (ECU m)												
max		1373.20			1015.60			788.90			31.00	
min		701.20			438.40			44.50			-13.90	
REQUIRED TRANSFER (ECU m) (only if operation is loss making)												
max		260.50			20.60			0.00			0.00	
min		0.00			0.00			0.00			0.00	

* 'max' denotes the maximum amount of gain achievable in the Scenario considered.
'min' denotes the minimum amount of gain achievable in the Scenario considered.

The overall results therefore support strongly the case for deregulation along the lines of Scenarios 1-3. Although a precise figure for the cost of implementing the regulatory package and setting-up and running the relevant regulatory authority can only be determined from subsequent work, the potential gains seem significant enough to justify such costs. Furthermore, unlike deregulation and privatisation in monopoly markets in a number of sectors in European countries where a single incumbent stood to lose significantly from the implementation of deregulation, the European satellite operation industry seems to offer significant potential benefits for most or all of the current incumbents because of currently unexploited economies of scale.

Scenario 4, although attractive because of its gradual nature seems to offer very little potential for welfare gains. If not accompanied by reasonable evidence that national authorities are determined to proceed with further deregulation, it could also lead to welfare losses through more inefficient production. It seems to be therefore a very risky option. The choice between all the scenarios however will depend largely on a detailed cost analysis of implementing them, which should include tangible and non tangible/pecuniary and non-pecuniary costs and can only be determined with precision in subsequent research.

E9 Policy Implications

The preceding analysis provides compelling evidence that the existing system of regulating GSOSR requires significant reform. Introducing more economic considerations into the regulation of the GSOSR would yield significant economic benefits to the geographical areas covered by the reforms.

It is clear that the greater the geographical area covered by the reforms the greater will be the overall improvement in the economic efficiency of the resulting regulatory environment. The optimum solution, therefore, would be for reform to take place at the level of the ITU, encompassing Regions 1, 2 and 3. Such regulatory reform would be very difficult to introduce as it would involve extensive multilateral negotiations, changes to UN conventions and fundamental reform of the structure and responsibilities of the ITU. However, there is an opportunity for Europe to provide a model for changes which should take place at a wider level. It is very important, therefore, that there is a clear understanding of the principles that are behind changes in the regulation of the GSOSR that could yield a more efficient market for geo-stationary satellite services.

These principles would be as follows:

- that as much of the GSOSR as is possible should be subject to free market conditions, and care should be taken to ensure that any GSOSR resource reserved for non market applications should not be allowed to distort the operation of market forces outside the reserved area;

- there should be ease of entry to, and exit from the market. This will ensure that inefficient operators could be replaced by efficient operators. The realistic threat of entry to markets should act as an important incentive for existing operators to maintain their competitiveness;

- there should be no barriers to entry or operation of services except for the absolute minimum of regulation required to ensure the technical integrity of the services being offered;

- the existing principles of EC competition policy should apply, so prohibiting practices such as predatory pricing, cross-subsidisation, abuse of a dominant position.

These principles, which require formal elaboration, should become enshrined in the articles of association of any European agency responsible for the coordination and regulation of GSOSR. Again the broader the coverage of such an agency the greater its potential beneficial impact.

The following regulatory principles would be crucial to achieving greater market orientation and the associated improvements in economic efficiency:

- in perpetuity rights of use combined with transferability of the right to use, or long duration licences combined with a high expectation of renewal and transferability of licences. These measures would allow flexibility in use of the GSOSR, which would be more responsive to changes in patterns of demand;

- due diligence of those applying to use GSOSR to ensure they have the technological, management and financial resources to implement proposals;

- due diligence during the period leading up to and following the placing of a satellite in space - use it as intended or lose it. This would require active monitoring;

- introduce an economic method of determining who uses which GSOSR. New licenses should involve open tenders. Price, other things being equal, should be the final arbitrator;

- ensure that the regulatory regime applies to all operators delivering services to the geographical area covered by the agency.

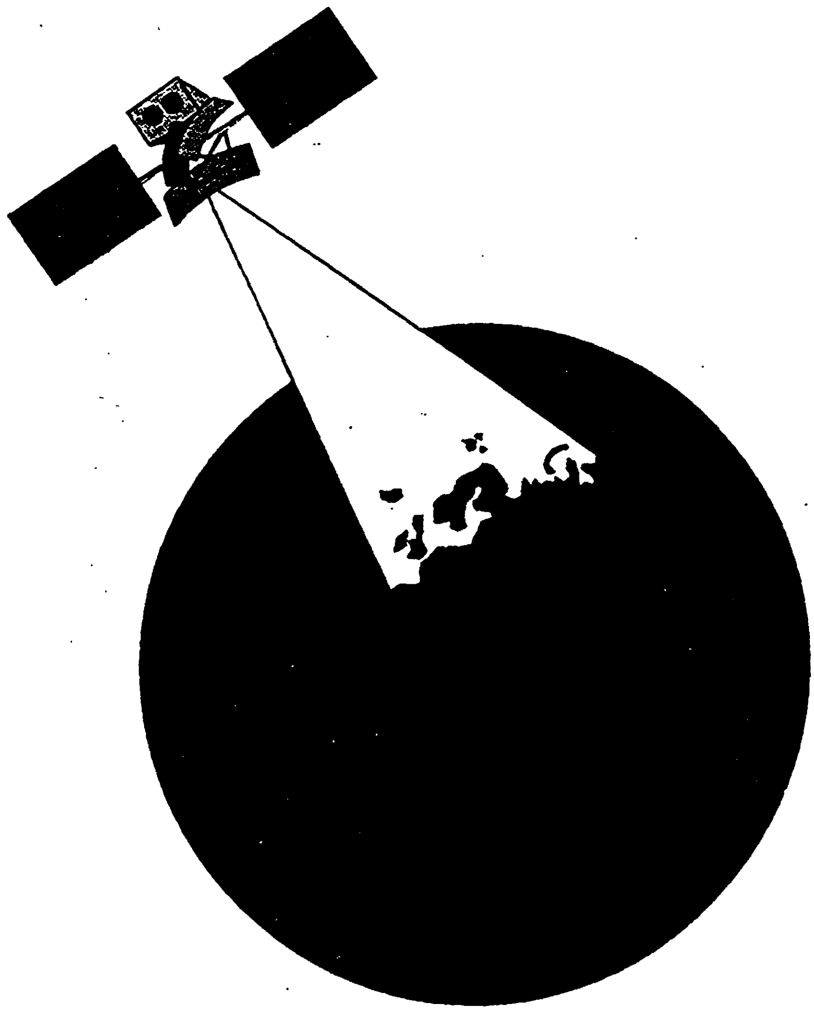
A new agency should either administer these regulations directly, or it should coordinate their uniform introduction and implementation across all participating member states. The precise structure and responsibilities of different regulatory authorities should be addressed as a matter of urgency.

Action is required because the satellite industry and its consumers are suffering from the economic inefficiencies that exist under the current regulatory system. The benefits of greater efficiency could potentially spread to a very wide range of consumers both inside and outside Europe. Such stimulation of the industry would also provide it with a greater chance of competing effectively, both outside Europe and with terrestrial substitutes - thus spreading the benefits of competition even further through society.

KPMG Consortium

An Economic Assessment of European Satellite Orbit and Spectrum Resources

Final Report - Appendices



European Commission

Appendix 1

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HISTORY AND DEVELOPMENT OF SATELLITE TECHNOLOGIES

MANAGEMENT SUMMARY

INTRODUCTION

This summary is intended as an introduction to the history and development of satellite technologies. It places particular emphasis on the impact of these technologies on the key physical resources used in satellite communications; the orbital slots into which satellites are placed, and the RF frequencies (and associated bandwidths) by means of which they communicate. However, it is important to note the link between the two, since a communications satellite is inextricably linked with a set of RF frequencies.

The key technologies and the trends in those technologies (both current and future) are discussed, focusing on satellite orbits, signal processing techniques, intelligent satellites and broadband services. The effects of these technologies on the orbit and frequency resources will also be assessed.

This report deals with the technological pressures on regulation, but other pressures—and the relationship between technological and other pressures—must also be recognised.

HISTORY

The worldwide satellite communications infrastructure was originally developed by Intelsat during the 1960s, and provided a limited number of telephony and TV channels. Communication was entirely between PTTs (the signatories to Intelsat), with national distribution by the relevant PTT.

Satellites increased in number and sophistication during the 1970s, and spectrum efficiency was improved by the use of dual polarisation. It became possible to lease a transponder from Intelsat, allowing closed, private networks to be created, though country distribution was still carried out by the PTTs.

The 1980s saw an exponential rise in the use of satellites and the range of services supported. Data services were developed, and for the first time earth stations were allowed to be placed on customers' premises. The rise of regional systems, such as Eutelsat and Arabsat, increased pressure on both orbital slots and the RF spectrum. Other developments which increased the pressure on the RF spectrum were:

- Satellite TV broadcast direct to home (TV-DTH) services
- Business/VSAT services
- Mobile communications, both personal telephony and store and forward messaging systems

  Inmarsat became operational in 1982, and now offers a wide range of mobile communication services.

The 1990s are likely to see the rise of low- and mid-earth orbit (LEO and MEO) satellites, which will decrease the pressure on orbital slots, particularly in the geosynchronous orbit (GEO), but which will only serve to increase the pressure on the RF spectrum.

RESOURCES

There are two physical resources which limit the worldwide capacity for satellite communications. These are:

- the potential orbits for satellites
- the frequencies used to communicate with the satellites, the available range of which is limited by technology (the techniques for exploiting higher and higher frequencies require constant development) and physics (only certain frequency ranges penetrate the earth's ionosphere).

The dominant orbit for communications satellites has always been the geosynchronous orbit (GEO), since it allows a satellite to remain apparently motionless above a point on the Earth's equator. Technological constraints have meant that satellites in this orbit cannot be placed less than 2° apart, thus severely limiting the potential number of orbital slots. This is particularly the case in popular positions, such as over the US, the Atlantic and Western Europe.

This situation will soon be eased by the growing trend towards the use of LEO and MEO orbits, in which the coverage of a single GEO satellite is provided by a constellation of LEO/MEO satellites (which, since they are not geosynchronous, also provide worldwide coverage, including the poles, which a GEO satellite cannot address).

Although the pressure on the orbit resource may be eased by the use of LEO/MEO satellites, this will not affect the problem of the crowded RF spectrum. Satellite communications uses the microwave frequencies, from 0.9 GHz upwards. However, not all frequencies above 0.9 GHz are available, since the earth's ionosphere is impenetrable at many frequencies. There are a number of windows, and these windows (bands) are named and divided between civil and military satellite communications. The bands used in civil satellite communications are:

- L band (1 - 2 GHz), which is used for mobile services
- S band (2 - 4 GHz), which is used for mobile services and for telemetric control of the satellite itself
- C band (4 - 6 GHz), which is used for general telecommunications services
- Ku band (10 - 14 GHz), which is used for both general and broadcast telecommunications services
- Ka band (20 - 30 GHz), which is used for general telecommunications services.

Exploitation of higher frequencies is the subject of research. As frequencies increase, so the signals are increasingly subject to fade, so that the exploitation of higher frequencies is highly dependent on the development of fade countermeasures (FCMs).

The allocation of frequency bands to services is carried out by World Administrative Radio Conferences, the most recent of which, WARC '92, allocated bandwidth to LEO/MEO mobile satellite services (such as Motorola's proposed Iridium system) and to satellite sound broadcasting.

The RF signals must be modulated if they are to carry data. The two principal modulation schemes currently in use are variations on Phase Shift Keying (PSK):

- Binary PSK (BPSK), which offers the best resilience to phase noise, but is not as spectrally efficient (offers lower transmission speeds) as other schemes
- Quadraphase PSK (QPSK), which offers double the spectral efficiency of BPSK, but is more sensitive to phase variations and additive noise. Consequently, it is more difficult and expensive to implement.

More spectrally-efficient modulation schemes are now being developed, in particular for use in broadband transmission and for mobile communication with LEO/MEO satellites.

Older, analogue technology (both on board satellites and in earth stations) does not make efficient use of the portion of the spectrum allocated for a particular transponder. This is being addressed by means of Digital Signal Processing (DSP) techniques, which are being used to implement modems; this will allow better performance and a degree of flexibility in changes between modulation schemes.

Finally, a large proportion of the RF spectrum has been allocated to users who do not make full use of it; in particular the blocks set aside for military use are not efficiently used, though they are unlikely to be released.

TECHNOLOGIES

The principal satellite communications services are:

- Telephony services, which are likely to become more prevalent because of a number of technical advances:
  - DSP techniques and VLSI implementation will reduce the cost of the earth stations
  - Digital compression techniques reduce the bandwidth required from what was once 64 kb/s to (currently) 16 kb/s, with a potential reduction to 2.4 kb/s for mobiles
  - Digital speech interpolation (DSI) further reduces the bandwidth required for the transmission of speech by removing the redundancy, the gaps, from the speech.

  Taken together, these factors have the potential to make satellite telephony a viable option; the proposed LEO/MEO personal telephony networks, such as Motorola's Iridium, will all use a handheld earth station, much as today's terrestrial cellular telephone networks do, and promise to be only slightly more expensive to use. This is in contrast to the current telephony networks, which are expensive to use and require a much bulkier earth station (normally a VSAT), so that their mobility is limited.

  The well–developed terrestrial telephony infrastructure in developed countries clearly limits the potential of satellite telephony, so that its principal application in those countries is in rural development. Another potential use of satellite telephony is in links with areas where the terrestrial infrastructure is far less developed, such as links with Eastern Europe. However, these limited uses meant that Europe and Japan, with their limited rural development opportunities, were opposed to the allocation of bands to LEO/MEO satellite telephony systems at WARC '92.

- TV-DTH and TV Direct Broadcast by Satellite (DBS) services, which currently generate more than half of the European satellite communications revenue. These services have seen a phenomenal growth since the beginning of the 1980s, and although their dominance is set to decline (to about a third of the total European revenues), they will still grow significantly over the next ten years.

  The Multiplexed Analogue Component (MAC) system has been introduced as a replacement for the older PAL system. There are two European variations of the system, D-MAC and D2-MAC (which uses half the bandwidth of D-MAC, with some sacrifice of picture quality). Note that, although D- and D2-MAC have some digital characteristics (notably digital sound and digital data), they do not offer digital TV, as the signal is still transmitted using FM. No pure digital TV is yet available via satellite.

  Although pure digital TV (such as High Definition TV (HDTV)) via satellite is likely to be commercially available by 2000, it is debatable what impact it will have; since most TV transmissions are either to cable heads (for distribution via cable) or direct to home, existing standards (PAL, D-MAC) will be preserved for a significant time to come, and it is likely that initial users of digital TV will be limited to "occasional" users, such as satellite news gathering (SNG), video conferencing, distance learning and business television.

  Digital radio broadcasting, using the Digital Audio Broadcasting (DAB) standard, is likely to suffer from the same problem of existing standards.

  Thus the digitisation of television and radio broadcasting is unlikely to have a significant effect on the pressure on the RF spectrum over the next ten years.

- Data; business services have been available since the early 1980s, using Very Small Aperture Terminals (VSATs) for both one way and two way data communications. Although the resources dedicated to business services is a small proportion of the total at the moment, this sector is set to see the greatest growth over the next ten years.

- Broadband services, currently under development, are an important target as regards integration with terrestrial networks. They will allow the integration of telephony, TV and data into a single, digital service, thus achieving the emerging target of multi-service support by a single transponder.

  Broadband services will require support for the ATM and SDH protocols, which will require significant development in the areas of modulation and coding.

The evolution of these satellite services has been supported by a number of technological developments:

- Earth stations have undergone a lot of developments, particularly the RF portion. However, in bands above Ku band, there has been very little development, which clearly needs to be redressed if the higher frequency bands are to be exploited in the future

- Circuit Multiplication Equipment (CME), which allows a greater number of circuits to be carried within the same bandwidth by means of compression techniques
- Access Schemes, which allow multiple users to access the same satellite transponder
- Satellites, in particular the development of co-ordination and networking techniques for constellations of LEO/MEO satellites.

FUTURE TRENDS

There are a number of technological trends which will have an influence on the orbit and frequency resources, principally in the following areas:

- digital signal processing (DSP) makes efficient use of the RF spectrum allocated, thus making available significantly greater potential bandwidth at a stroke
- the use of LEO/MEO satellites will greatly reduce the pressure on the orbits resource, but will only serve to increase pressure on the RF spectrum
- new modulation techniques currently under development will considerably improve spectral efficiency, in terms of the bandwidth required to carry a certain throughput of data
- on-board processing (OBP) will allow satellites to exist in a higher interference environment, so that they can be placed in closer orbits (allowing GEO satellites, for example, to be placed closer than 2° apart), thus increasing the potential number of satellites and therefore the pressure on the RF spectrum
- inter-satellite links (ISLs) will allow communication between satellites, thereby reducing the number of satellites necessary and so easing the pressure on the RF spectrum. ISLs, which will also rely on developments in OBP, are likely to have most impact on LEO and MEO satellites.

The main technological development is, of course, digitisation of transmission for RF services (*e.g.*: DAB, GSM and digital HDTV) leading to a convergence of telecommunications, broadcasting and other services. Such convergence would be supported by means of broadband ATM/SDH protocols, though the full bandwidth required to support ATM will not be available for at least ten years.

This convergence calls into question the concepts of separate service categories applied in current regulatory frameworks. Often technology evolution and market-led developments combine to demolish these artificial barriers, the classic example being the use of the FSS bands for DTH satellite TV broadcasting and the consequent convergence of the FSS and BSS service types.

There are some limitations to this convergence. Satellite transponders that come into service over the next ten years will offer increasing OBP capabilities, so that increasingly complex personal telephony and business/data services can be supported with ease. However, the use of such sophisticated transponders is not justified for TV-DTH and DBS services, and so they are likely to remain separate, leading (in the short/medium term only) to specialised transponders; some specialised for TV, others for integrated (broadband) services. In the longer term, with increased market penetration of digital TV services and their consequent integration with personal telephony and business/data services, the use of sophisticated transponders for TV will become justified since the TV signal will require only a fraction of the (integrated) bandwidth.

Therefore, the convergence of TV and, to a lesser extent (due to the lower capital investment in equipment) radio with other satellite services is likely to be well behind the technical capability, and is not likely in the next ten years.

SUMMARY

It can be seen that there is increasing pressure on both orbit and frequency resources. Although exploitation of LEO/MEO orbits will decrease the orbital slot pressure, the problem of scarcity of RF spectrum is not going to go away; it can, however, be eased by suitable application of technology:

- DSP techniques will allow efficient use of the RF spectrum allocated
- digital compression will increase the number of circuits that can be carried within a certain physical bandwidth
- new modulation techniques will further increase the spectral efficiency, making broadband technologies such as ATM and SDH feasible.

Against such technological developments are the growing importance and acceptance of standards, which is likely to slow down the introduction of innovative technology. The convergence of satellite services, using broadband technologies and the digitisation of TV and radio, may eventually greatly simplify the Radio Regulations by removing the distinctions between services. However, this is a long term aim, since it is unlikely that broadcast TV will converge in the next ten years. Until it does, the best that can be hoped for is the convergence into two types of service; TV and the rest. The one exception to this is the "occasional" user of TV, such as SNG, which will go digital in the short term (since there is no existing standards base which must be supported), and so can converge with the other digital services.

Increasing pressure on the orbit and frequency resources, then, is being addressed by a number of technological means both in isolation and in concert. Most of these technologies are expected to be in operational use in the late 1990s-2000.

1 INTRODUCTION

1.1 OVERVIEW

This document is intended as a briefing note on the history and development of satellite technologies, and places particular emphasis on the impact of these technologies on the key physical resources used in satellite communications; the orbital slots into which satellites are placed, and the RF frequencies (and associated bandwidths) by means of which they communicate. However, it is important to note the link between the two, since a communications satellite is inextricably linked with a set of RF frequencies.

The International Telecommunications Union's (ITU's) method of allocation of orbits and RF frequencies is discussed. The importance of the ITU-organised World Administrative Radio Conferences (WARCs) is also addressed; in particular, the most recent of these, WARC '92, is discussed, notably with respect to the allocation of bandwidth for networks of low earth orbit (LEO) personal communications satellites.

The key technologies and the trends in those technologies (both current and future) are discussed, focusing on satellite orbits, signal processing techniques, intelligent satellites and broadband services. The effects of these technologies on the orbit and frequency resources are also assessed.

1.2 PURPOSE AND SCOPE

The purpose of this document is to provide background material on the history and development of satellite technologies for non–technical readers, their impact on frequency and orbit resources, the allocation of those resources, and to identify key technological and application trends.

This document does not form a comprehensive description of the applications of satellite communications; nor does it attempt to specify how the EC could influence the allocation of the key resources; nor does it attempt to model the development of satellite communications or predict trends: the document's function is to report these trends.

1.3 RELATED DOCUMENTS

There are no related documents, other than the reference material outlined in the bibliography contained in this document.

1.4 STRUCTURE

This document is divided into five main sections, a summary of the document contents, a glossary of terms and a bibliography. The main sections are as follows:

- INTRODUCTION, providing a brief overview of the document and its subject, describing its purpose and scope, listing related documents and providing a glossary of terms
- HISTORY, providing the historical context for the remainder of the document

- **RESOURCES**, defining the frequency and orbit resources of satellite communications, with a brief description of the market allocation
- **TECHNOLOGIES**, describing the current trends in the technologies used in satellite communications and the services they support
- **FUTURE TRENDS**, identifying the key future trends in applications and technologies brought out from the previous sections and assessing their impact on the frequency and orbit resources.

1.5 GLOSSARY

There are a number of terms and abbreviations used in this document:

ACTS	Advanced Communications Technology Satellite, NASA's experimental satellite for the development of GSS transponders, OBP and DSP techniques.
Aloha	A technique whereby multiple users can access the same communications channel, by transmitting whenever the channel is clear, listening for collisions and re-transmitting (after a random period) when a collision is detected.
AOR	Atlantic Ocean Region, one of the three worldwide telecommunications regions defined by the ITU.
Apogee	The point in an elliptical orbit at which a satellite is farthest away from the earth.
Arpanet	One of the first major networks, developed by the Advanced Research Projects Agency of the US Department of Defense and which links may computers (particularly in research institutes and universities) from Hawaii to Sweden.
ATM	Asynchronous Transfer Mode, a broadband networking/switching technology, usually layered on top of SDH.
Bandwidth	A measure of the total transmission capacity of a device; in this case, a measure of the total RF capacity of a transponder.
BPSK	Binary PSK, an RF modulation technique in which a two-symbol alphabet is used, thus achieving lower susceptibility to interference than alphabets with more symbols, such as QPSK, but at the expense of lower data transfer rates.
Broadband	High bandwidth, high data rate.
BSB	British Satellite Broadcasting.
BSS	Broadcast Satellite Service, a type of transponder reserved for the broadcast of signals to multiple users.
CDMA	Code Division Multiple Access, a multiple access method using spread spectrum techniques.

CES	Coastal Earth Station, an earth station on the coast through which signals to/from an SES are transmitted to/received from a satellite. This term is extensively used by Inmarsat.
CME	Circuit Multiplication Equipment, which allows a greater number of circuits to be carried within the same bandwidth by means of compression techniques.
CME	Circuit Multiplication Equipment. Techniques, such as compression, which increase the apparent number of channels supported by the same bandwidth.
DAB	Digital Audio Broadcasting, a system for the transmission of very high quality audio signals using spread spectrum techniques.
DAMA	Demand Assigned Multiple Access, an access technique where bandwidth is assigned to a user, for access by, for example, TDMA or FDMA techniques, when the user demands it. The assignment is requested on a single channel, using a technique such as Aloha, and is assigned for a fixed period.
DBS	Direct Broadcast by Satellite, the broadcast of data (using a BSS transponder) directly to multiple users, rather than via a central terminal for distribution via cable. Used for satellite television. See also DTH.
Downlink	The communications link through which RF signals are transmitted to an earth station from the satellite.
DRS	Data Relay System, ESA's proposed DRSS.
DRSS	Data Relay System Satellite, a system of GEO satellites whose purpose is to relay signals from other satellites in, for example, LEO/MEO orbits, or from space vehicles such as ESA's Hermes or Ariane, or NASA's space shuttle.
DRTS	Data Relay & Tracking System, Japan's proposed DRSS.
DSI	Digital Speech Interpolation, a speech compression technique in which the redundancy (the gaps) is removed from speech channels.
DSP	Digital Signal Processing, digital RF modulation techniques which replace analogue techniques, such as BPSK, QPSK and FSK, and allow much greater bandwidth efficiency.
DTH	Direct To Home, the transmission of TV signals directly from the satellite to a terminal at the home of the viewer, rather than to a central terminal for distribution via cable. This term is used, rather than DBS, when an FSS transponder is used (as is the case on the Astra satellite), rather than a BSS transponder.
Earth Station	The piece of equipment by means of which a user carries out communication with the satellite.
ESA	European Space Agency.

ETSI	European Technical Standards Institute.
FCM	Fade Countermeasures, techniques for combating the effects of rain fade at higher RF frequencies.
FDDI	Fiber Distributed Data Interface, a networking standard based on fiber optics.
FDMA	Frequency Division Multiple Access, a satellite access technique in which multiple users access a single satellite transponder by each accessing it at a different frequency (within the bandwidth of the transponder).
FLMPTS	Future Land Mobile Public Telephone System, a terrestrial mobile communications system that will not be fully defined until the year 2000, and which is in direct competition with satellite mobile telephone systems using LEO satellites.
FM	Frequency Modulation, a modulation technique in which data is transmitted by modulating the frequency of the carrier.
Footprint	The area of the earth's surface that a satellite's transmissions can reach, as defined by its orbit, the transponder power used and the antenna direction (and any shaping resulting from the use of an advanced antenna).
FSK	Frequency Shift Keying, an RF modulation technique in which symbols are used to represent the data being transmitted, with each symbol being represented by a frequency shift.
FSS	Fixed Satellite Service, a type of transponder reserved for point to point communication between fixed earth stations.
GEO	Geostationary Orbit, an orbit with an altitude of 35786 km, in which a satellite appears to be stationary over a single equatorial point on the earth's surface.
GSS	General Satellite Service, a newly defined type of transponder, initially for experimental use on NASA's ACTS satellite, which offers integrated multiple services.
HDTV	High Definition Television, an emerging set of television standards.
HEO	Highly Elliptical Orbit, an elliptical orbit, such as the molnya orbit, whose apogee is 46300 km and whose perigee is 1000 km.
IDR	Intermediate Data Rate, a satellite access technique in which multiple users access a single satellite transponder using digital carriers separated by frequency division.
IFRB	International Frequencies Registration Board, part of the ITU, responsible for the allocation of orbits and frequencies to satellites.
IOL	Inter Orbit Link, a communications channel between satellites in different orbits, for example LEO to DRSS/GEO.

IP	Internet Protocol, the network layer protocol originally developed in the early 1980s for use on the Arpanet, and since adopted by many other networks and network standards (including FDDI).
ISDN	Integrated Services Digital Network, a networking technique which unifies data and voice communication into a single medium.
ISL	Inter-Satellite Link, a technique using either RF or lasers for communication between satellites.
ITU	International Telecommunications Union, the UN agency responsible for the worldwide regulation of satellite communications.
LEO	Low Earth Orbit, a satellite orbit between 500 and 1500 km.
LOS	Line of Sight, which needs to be maintained between a satellite and an earthbound terminal if communication is to be carried out.
MAC	Multiplexed Analogue Components, a family of TV signal transmission standards which includes C-MAC, D-MAC and D2-MAC (a half-bandwidth version of D-MAC, requiring some sacrifice in picture quality but more suitable for existing cable systems, particularly in France and Germany).
MBA	Multi-Beam Antenna, an advanced antenna in which the beam is split into several sub-beams, each covering a specific geographical area and accessible separately by using a different frequency.
MEO	Mid Earth Orbit, an orbit higher than LEO, but not as high as GEO.
MSS	Mobile Satellite Service, a type of transponder reserved for mobile communications.
NASA	National Aeronautics and Space Administration.
OBP	On Board Processing, an emerging technology in which much of the routing of data takes place on board the satellite, rather than being carried on the earth.
PCN	Personal Communication Network, usually a personal telephony network.
Perigee	The point in an elliptical orbit at which a satellite is closest to the earth.
PSK	Phase Shift Keying, an RF modulation technique in which symbols are used to represent the data being transmitted, with each symbol being represented by a phase shift.
PTO	Public Telecommunications Operator. A PTT that only deals in telecommunications. There might be more than one PTO in a country, as is the case in the UK.

PTT Post, Telegraph and Telephone, the national, normally state-owned organisations that, until recently, controlled all satellite communications.

QPSK Quadraphase PSK, an RF modulation technique in which a four-symbol alphabet is used, thus allowing greater data transfer rates than alphabets with fewer symbols, such as BPSK, but at the expense of greater susceptibility to interference.

RA Radiocommunications Agency, the UK licensing authority for the operation of telecommunications equipment and services (including satellite-based systems) within the UK.

RF Radio Frequency.

SCPC Single Channel Per Carrier, a technique whereby multiple users can share a transponder by each being allocated a separate channel within the total bandwidth.

SDH Synchronous Digital Hierarchy, a high speed networking architecture.

SES Ship Earth Station, an earth station aboard a ship. This term is extensively used by Inmarsat.

SMS Satellite Multi Service, a type of transponder, with very limited availability, capable of handling multiple services.

SNG Satellite News Gathering, the use of satellites for the transmission of news pictures from a camera to (for example) the home studio.

SONET Synchronous Optical NETwork, the American equivalent to the international SDH.

Spread Spectrum A technique for the transmission of signals by spreading them over the entire bandwidth of the receiver/transponder, with the signal only recoverable by means of a key, identifying those parts of the total bandwidth which make up the signal.

SSSO Specialised Satellite Service Operator, a type of UK licence granted for the operation of satellite services. Now largely bypassed by deregulation.

TCM Trelliss Coded Modulation, an RF modulation technique which offers superior spectral efficiency to mobile systems.

TDMA Time Division Multiple Access, a satellite access technique in which multiple users access a single satellite transponder by each accessing it at a different time.

TDRSS Tracking and Data Relay Satellite System, NASA's implementation of a DRSS.

Terminal An earth station.

TES	Telephony Earth Station, an earth station used for telephony, Used as a product name by Hughes.
Transponder	The piece of satellite equipment which receives signals from an earth station on the uplink, amplifies them, changes their frequency (normally a downshift) and re-transmits them on the downlink.
Uplink	The communications link through which RF signals are transmitted to the satellite from an earth station.
VR	Virtual Reality, which can be described as being inside a computer genereated world. Once there, a user interacts with objects and/or other users, the latter by means of broadband networks.
VSAT	Very Small Aperture Terminal, a terminal which uses a small (say 1m) dish.
WARC	World Administrative Radio Conference, the ITU-organised forum at which decisions about the allocations of the RF spectrum are made.
WATTC	World Administrative Telephone and Telegraph Conference, the ITU-organised forum at which decisions about international terrestrial telecommunications are made.

2 HISTORY

2.1 OVERVIEW

A number of technological terms and abbreviations are used in this section, which are briefly explained in the glossary (§1.5) and more fully explained and analysed in later sections.

2.1.1 Primitive Era

Communication via satellite was first achieved in 1958, with a satellite called Score. This satellite is best described as a delayed repeater, a voice message being received by the satellite from the earth and stored on tape for re-transmission. President Eisenhower was the first person to use this technique, for a worldwide Christmas greeting.

In 1960 Echo I was launched. This was a 30 metre diameter passive reflector used to test propagation and transmission techniques. However, such passive satellites had no commercial future because of the very high powers needed and the low capacity achievable.

Telstar, the first true active communication satellite, was launched in 1962. It was able to receive a signal transmitted to it in the 6 GHz band for downconversion, amplification and re-transmission in the 4 GHz band. Soon after this satellite, Relay and then a further Telstar were launched. All of these satellites were placed in low or medium altitude elliptical orbits, so that they were only visible across the Atlantic Ocean for less than one hour during each pass.

The breakthrough in satellite communications came in July 1963, when Syncom II became the first satellite in near geostationary orbit (Syncom I having failed before it reached its orbital position). Since its orbit had a 33 degree inclination, Syncom II was not truly geostationary. However, Syncom III achieved a true geostationary orbit in August 1964.

These early satellites paved the way for the subsequent fully commercial satellites.

2.1.2 International Global Era

1964-1970s

Intelsat, the International Telecommunications Satellite Organisation, was set up by the world's Post, Telegraph and Telephone administrations (PTTs) in order to facilitate the commercial exploitation of space in a co-operative manner. It is important to note the PTTs' domination of the organisation, since this has, for many years, affected both the services offered by Intelsat and who they are available to.

Soon after the formation of Intelsat, in 1965, the first commercial satellite, Early Bird (later renamed Intelsat I) was launched to form the initial space segment for Intelsat. This satellite could support 240 telephone circuits, tripling the trans-Atlantic telephony capacity and made possible the first trans-Atlantic transmission of live television signals.

At that time, satellite communications was PTT-dominated, with earth stations requiring 30m dishes forming gateways into the PTTs' networks. Intelsat dominated the geosynchronous satellites. Their satellites were above the major oceans only, and were low power, with a global beam coverage (the beam covering the whole of the earth's hemisphere visible from the satellite's orbit, rather than with beams focused on the intended areas of communication, such as continental land masses). They also operated only in C band (radio frequency (RF) bands are described in §3.2).

The Intelsat satellites offered multiple telephony channels, accessed by means of frequency division multiple access (FDMA) techniques, and TV frequency modulation (FM) transmission.

Since that time, Intelsat satellites have gone through a number of generations (the latest being Intelsat VII), expanding from 240 telephony circuits or one TV channel on Intelsat I to some 30000 digital 64 kb/s bearer circuits plus a number of TV channels on Intelsat VI.

The commercial and regulatory challenges facing Intelsat will have an effect on the technical and operational characteristics of Intelsat services. The economic harm co-ordination procedures have been effectively abandoned for non-public switched services. Further deregulation and competition from other satellites will raise traffic. The main economic impact on Intelsat will be to reduce the non-public switched traffic on Intelsat.

Current predictions are that Intelsat will run out of Atlantic Ocean region (AOR) bandwidth by 2003, even if all orbital slots were used. This may lead to separate (and different) satellites for public switched and other services (though this situation may be eased by expansion of Ka band services).

There will be 5 VIs in orbit soon and there are 7 VII/VII-As on order. A single Ku-band only satellite was launched in 1992. A least two more (probably VII-As) will be ordered.

The technical developments (described in more detail in §4 and §5) likely to affect Intelsat are: bandwidth efficient modulation, channel coding and processing, additional frequency bands, more frequency reuse, more orbital slots, greater use of time division multiple access (TDMA), greater effective power, on-board processing (OBP), inter-satellite links (ISLs) and beam hopping.(Jefferis, 1992)

2.1.3 Domestic Era

1970s-1980

Just after Early Bird (Intelsat I) was launched, Russia launched their first communications satellite in the Molnya series, so establishing the first regional satellite communications system. This was followed by the Russian Stationsar system and the Indonesian Palapa system, followed by domestic systems, of which the Canadian Anik was the first, followed shortly by numerous US systems and others in various parts of the world. All of these systems owned their own satellites, and were quite independent of Intelsat.

During this period, Intelsat earth stations became smaller (10-13m), with networks being closed (private). Country transmission distribution was the norm, with data being transmitted within a country by the relevant PTT. It became possible to lease a transponder from Intelsat, thus allowing greater flexibility. Further, the global beam coverage of transponders was replaced by shaped beams, and the use of dual-polarisation allowed frequency re-use, thus doubling the previous transmission capacity.

The principal services available were 1/2 transponder TV (FM) and single channel per carrier (SCPC) telephony, though some data services were starting.

2.1.4 Business

Early 1980s

Earth stations further reduced in size, to 3m. Again, networks remained closed, though usage was expanded to include TDMA and FDMA access techniques. TDMA was introduced into the international network.

For the first time, earth stations were allowed to be placed on customer's premises, rather than customers being required to access the services via the PTT, using the PTT's earth station.

Additional regional systems came into being, including the European Eutelsat systems and the Middle Eastern Arabsat, which owned their own satellites.

The use of Ku band (RF bands are described in §3.2) frequencies, together with split beams, allowed the use of smaller dishes, down to 3m in size. Such stations could be located on users' premises, thus eliminating the terrstrial links associated with previous systems, and allowing closed networks to be set up outside the control of PTTs. The extension into Ku band did bring with it more problems, such as higher rain fade.

2.1.5 Television

1980s

Eutelsat and Intelsat transponders became taken up with TV, principally with distribution to cable heads, with distribution to consumers being via cable systems. However, Astra in Europe launched a TV-Direct To Home (TV-DTH) service from fixed satellite service (FSS) transponders, using 60cm dishes.

Direct Broadcast by Satellite (DBS) services using broadcast satellite service (BSS) transponders were launched by British Satellite Broadcasting (BSB), TV-SAT and TDF1. BSB's service, which was later to be taken over and terminated by a competitor using the Astra satellite, used a 30cm squarial (square aerial).

The Multiplexed Analogue Component (MAC) system was introduced, and heralded as a replacement for the older PAL system. There are two European variations of this system, called D-MAC and D2-MAC (which uses half the bandwidth of D-MAC, with come sacrifice of picture quality). The EEC was later to try to make all TV-DTH services MAC; so far, this has failed.

Note that, although D- and D2-MAC have some digital characteristics (notably digital sound and digital data), they do not offer digital TV, as the signal is still transmitted using FM. No pure digital TV is yet available via satellite, all current transmissions are 27 MHz wide. Further, although pure digital TV (such as High Definition TV (HDTV)) via satellite is likely to be commercially available by 2000, it is debatable what impact it will have; since most TV transmissions are either to cable heads (for distribution via cable) or direct to home, existing standards (PAL, D-MAC) will be preserved for a significant time to come, and it is likely that initial users of digital TV will be limited to "occasional" users, such as satellite news gathering (SNG), video conferencing, distance learning and business television (Rogers, 1992).

2.1.6 Business/VSAT

Late 1980s-1990s

During this period, international services became more digital, using Intermediate Data Rate (IDR) and TDMA techniques for access by multiple users simultaneously. IDR uses separate digital channels sharing a transponder by frequency division, whilst TDMA requires users to each access the transponder at a different, pre-assigned time. Like IDR, TDMA uses a digital baseband.

The 3m size of earth stations failed in Europe, due to the strict regulatory environment. Meanwhile, dish sizes for very small aperture terminal (VSAT) services were falling in the USA, and most were in the range 1-3m.

Deregulation began in Europe with the issuing of Special Satellite Service Operator (SSSO) licences in the UK to six operators, plus BT and Mercury. These licences allowed the holders to transmit data. However, the passing of time has seen significant deregulation, and an SSSO licence is now largely irrelevant, and there are now 15 European satellite service operators, including Eutelsat and Intelsat. **Figure 2-1**, below, indicates the revenue split between these operators, which, in 1991, amounted to a total of 600 MECU. According to a report by CIT Research, it is anticipated that this will rise to approximately 1340 MECU over the next ten years.

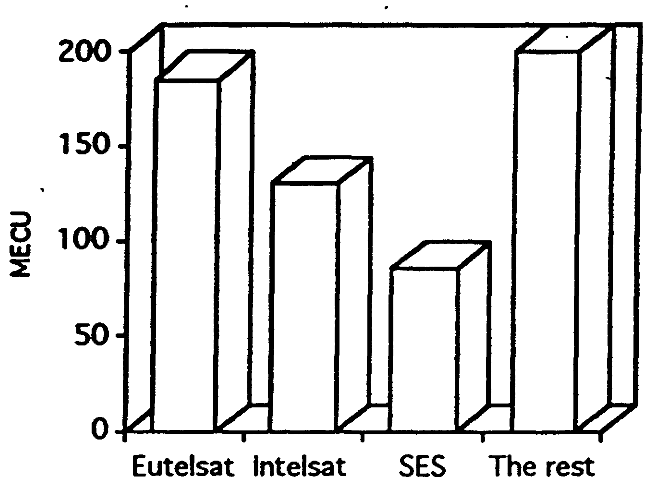


Figure 2-1: European Satellite Operator Revenues (1991)

The division of this revenue into the various service types is addressed in section 2.2, below.

At this time, transponder access was opened up to any signatory in Europe. The PTTs (Eutelsat) did introduce the Satellite Multi-Service (SMS) satellite system, but basically as a way to offer leased lines where ground circuits were not available, and with no serious promotion to attract users, no useful discounts for off-peak hour use, no real encouragement for potential users to join in large scale experiments in the way some computer firms will give computers to laboratories as contributions to joint research projects (Hine, 1989).

VSAT services, using 1-2m dishes, started in Europe. Despite regulatory problems, VSATs are gradually becoming established. VSATs are mainly used for business services, particularly data and private telephony (since regulatory restrictions have largely forbidden connection with the public networks). Experience has shown that VSAT use in Europe follows that in the US, with a suitable lag, with the result that the use of VSATs in the US is widely seen as a useful predictor for Europe. Further, the regulatory situation in Europe is highly fluid, with a quickening pace of liberalisation in many countries allowing a greater range of services to be realistically envisaged.

Eastern Germany is expected to account for more than half of all installed VSAT networks in Europe by the year 2000. Renault installed a VSAT network in eastern Germany and found it to be so successful that they are now planning to link all of their dealers in Europe with a satellite system carrying data and business television.

At present, Austria, Belgium, Ireland, Italy, Norway, Portugal, Spain and Switzerland refuse to licence private VSAT networks. The situation is changing and Spain, Italy and Greece are expected to liberalise shortly. Today, it is estimated that there are 65–70 operational networks in Europe comprising 2,500 interactive terminals. This is expected to grow to 130,000 in the next ten years (Newman, 1992).

Digital operation, using Digital Signal Processing (DSP) techniques, were first used for satellite communications during this period.

2.1.7 Mobiles

Late 1980s-1990s

The International Maritime Satellite Organisation, Inmarsat, introduced the global maritime system in 1984, which initially used dedicated Marecs satellites and special payloads added to some of the Intelsat V satellites to provide voice and data communications with ships using FM. The services were expanded to serve aircraft during the mid-1980s, offering 9.6 kb/s voice and data, and a service was launched for land mobiles in the 1990s. A new service, Inmarsat's Standard C service, offering a low bit rate (600 - 1200 b/s) was introduced for messaging applications. Inmarsat have recently launched the Standard M service, offering speech at 4.8 kb/s and data using a briefcase-sized telephony earth station.

Inmarsat became operational in 1982 and attracted 1,500 customers in its first year. This grew to 18,000 in 1991 and is expected to reach 1m by the turn of the century. Until 1989, Inmarsat operated only analogue telephone and telex services (Inmarsat–A), but then introduced the fully digital Inmarsat–C and Aeronautical services. Over the next couple of years, the digital replacement for Inmarsat–A (Inmarsat–B) and the cheaper and smaller Inmarsat–M services will be introduced. Inmarsat has now embarked on Project 21, aimed at introducing a lower cost, hand portable, service. This service, the Inmarsat–P service, will compete with the Motorola Iridium and TRW Odyssey services, and is discussed further in §2.1.8.

The services will be provided by means of Inmarsat's own satellites. Communication with Ship Earth Stations (SESs) is via spot beams, offering global coverage, using L band (RF bands are described in §3.2). Communication with the Coastal Earth Stations (CESs) uses C band.

Inmarsat contracted for its 3rd generation of spacecraft in January 1991. The satellites are under construction with first launch scheduled for 1994. The prime contractor is GE–

Astro with the payload from Matra–Marconi. The main design innovations are spot beam reconfigurability and reconfigurable channelisation.

There are three new capabilities being built in to the payload: C band–C band communication for administration, L band–L band communication for single hop mobile communications (for search and rescue), and an L–band navigation channel for new radiodetermination services.

2.1.8 PCNs and LEO/MEO

1990s

There is also an increasing R&D trend away from Geostationary (GEO) satellites towards Low Earth Orbit (LEO) satellites and eventually to Mid Earth Orbit (MEO) satellites, using constellations of satellites and techniques such as inter-satellite communication to provide the same services as GEO satellites more cheaply and with greater capacity (for reasons discussed in §3.1.1). This trend will inevitably be followed by commercial systems.

Such LEO / MEO satellites particularly lend themselves to services such as personal telephony (PCNs) and store-and-forward messaging systems. Services such as TV-DTH and broadcast / interactive data are clearly better provided by GEO satellites, with their larger, static footprint.

There are a number of proposals for both worldwide and regional personal communications system using the L/S bands and LEOs. The so-called "big LEOs" are mainly US-proposed (Iridium, Odyssey, Globalcomm etc) whilst a number of "little LEOs," offering low-rate data, have been proposed by various organisations to operate at 140 / 150 MHz.

According to the original proposal, Iridium is a worldwide, digital, satellite–based, cellular, personal communications system primarily intended to provide commercial, low–density, mobile service via portable, mobile, or transportable user units, employing low–profile antennas, to millions of users throughout the world. Calls can be made and received anywhere in the world with a personal, portable unit. Sixty-six small (320 Kg), smart satellites are internetted to form the network's backbone. Small, battery–powered, cellular–telephone–like user units communicate directly with the satellites. Gateways (earth stations) interface from the satellites to the terrestrial networks.

The L–Band links are dictated by the available technology that can provide link closure between the small satellites and the portable user units. The L–Band network employes a 37–hexagonal cell pattern from each satellite. The cells are designed for independent operation and each employs a different amount of power to close the links.

This reuse pattern offers part of the spectral efficiency realized with Iridium — worldwide, the same channel can be reused over 200 times. The modulation form is QPSK and the L–Band multiplexing scheme is a combination of TDMA and FDMA. Over an area the size of the United States' 48 contiguous states, forty cells are formed with an average of 2 KHz of spectrum needed per usable channel (Leopold, 1990).

Further, in response to Iridium, Inmarsat has proposed the Standard P system for personal communication via satellite, with an in-service date of 2000. This system will use either MEO or GEO satellites.

Such new "Satellite PCN" systems may offer synergy with the terrestrial mobile systems, such as:

- Pan–European digital cellular radio system (GSM)
- UK Personal Communication Network (PCN)
- CT2 and DECT cordless telephone
- ERMES paging network
- Digital pan–European PMR trunking
- Standard C
- Prodat and EutelTRACS, satellite-based pan-European mobile messaging systems
- EMS.

Although at first sight it would appear that all of these systems are in competition, in truth each has special features which makes it distinct from the others so that they should be viewed as complementary. Together, they provide an integrated, global, mobile PCN, offering a wide range of services from store and forward messaging to personal telephony, at a range of costs that can be related to the flexibility of the system.

The synergy with these systems will certainly influence the development of these third generation systems. The LEO satellites will be very complex, requiring on-board processing (OBP), inter-satellite links (ISLs) and a much increased spectral efficiency. The latter will be achieved by the use of DSP and code division multiple acess (CDMA) techniques. Although one can never be absolutely certain that a system will work until it flies, there is little doubt of the potential success of LEO systems. The development of suitable CDMA multiple access schemes may be key.

2.1.9 Intelligent Satellites

1990s-2000

Recent developments in satellite technology indicate a trend to OBP, which will greatly enhance the capacity for and the sophistication of the services offered. This will be accompanied by the use of DSP techniques in space, as well as on-board switching and ISLs.

These technological advances will significantly change the network concepts, merging fixed and mobile services into one, supporting multi-rate digital communication systems and carrying out the switching on the satellite. Further, the interference affecting the signals will become much less of a problem as a result of the use of OBP and CDMA techniques.

2.2 SERVICES

As the satellites have developed, so too has the range of services supported. Initially, these were limited to trunk telephony, linking PTTs, and live TV links. This has been expanded to cover a wide range, including:

- personal telephony

- Very Small Aperture Terminals (VSAT). Currently there are approximately 17 000 terminals installed; according to a report by CIT Research, this is predicted to rise to 130 000 over the next ten years
- Satellite News Gathering (SNG)
- TV-Direct To Home (TV-DTH)
- mobile data
- broadband data.

CIT Research has recently published figures for the revenues generated by satellite commmunications in Europe. The total revenue in 1991 was 600 MECU, which is predicted to rise to 1340 MECU over the next ten years. The split between the various services is illustrated in **Figure 2-2**; note the anticipated decline in the dominance of TV, although total TV-related revenues are still expected to rise.

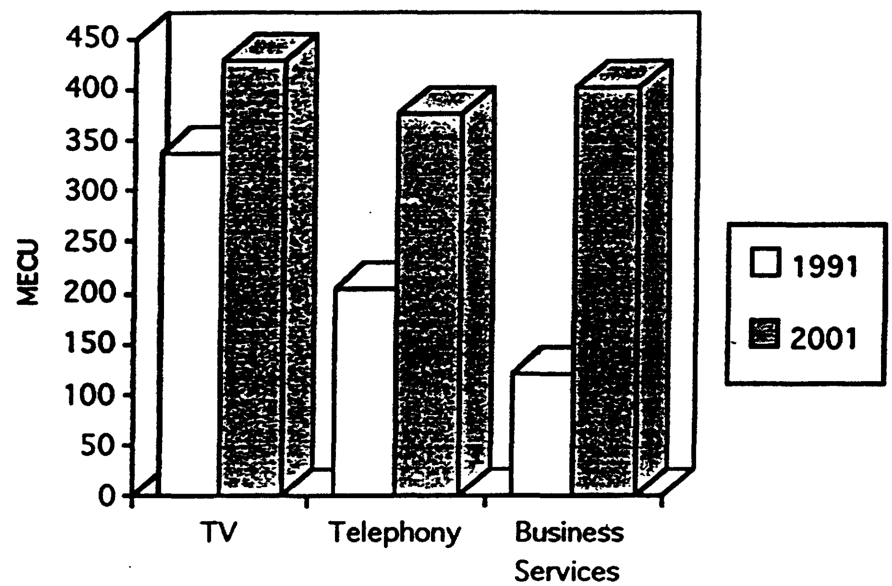


Figure 2-2: Revenue Distribution

All of these satellite services, in total, are only a tiny fraction of the telecommunications market, which is dominated by terrestrial telecommunications. Public Telecommunications Operator (PTO) revenue from Eutelsat is less than 1% of total PTO revenue. Satellite communications revenues in Europe will rise to no more than 2–3% of the total by the year 2000. Even in the USA, where use of satellite communications is far more established, satellite communications revenues are only 3.5% of the total (Milman, 1991).

Satellite communications services all make use of satellite transponders, which are of one of the following (WARC-defined) types:

- Fixed Satellite Services (FSS)
- Mobile Satellite Services (MSS)
- Broadcast Satellite Services (BSS).

While it had been intended at a global level that a service such as TV-DTH would use a BSS transponder, this is not, however, a cast-iron rule; for example, the FSS transponders on the Astra satellite are used for TV-DTH services. Such practices give rise to potential interference problems, as described in a later section. Strictly speaking, it may be argued that this use of an FSS transponder is prohibited by the provisions of the ITU Convention and the ITU Radio Regulations, whereby DTH reception of FSS services would be said to consitute "unauthorised interception of radiocommunications not intended for the use of the general public"; but the distinction between BSS and FSS has become blurred, and the two can be said to be converging (Raison, 1992). Indeed, there can be little doubt but that a DTH facility such as the Astra system intends direct reception.

These services all fall into one of three classes:

- point-to-point, used, for example, in personal telephony
- point-to-multipoint, used for TV and multimedia services, such as education and training
- multipoint-to-point, used in data collection.

2.3 REGULATION

2.3.1 Global

The regulation of the use of satellite communications obviously needs to be undertaken on a worldwide basis, and this is done by the International Telecommunications Union (ITU). The ITU has 164 member states and was founded in 1865; consequently, it has been involved in the regulation of telecommunications since its earliest days.

The ITU became an agency of the United Nations in 1947, with the following stated objectives:

- to maintain and extend international co-operation for the improvement and rational use of telecommunications
- to promote the development of technical facilities and their most efficient operation, and to improve the efficiency of telecommunications and increase their usefulness
- to harmonise the actions of nations in attaining these common goals.

The structure of the ITU was changed on 1st March 1993, in order to reflect the needs of the modern, more commercially-oriented environment. This includes allowing commercial membership. However, the rôle of such an intergovernmental organisation in a global business that is overwhelmingly a private sector business has been questioned by senior industry figures.

The new structure of the ITU is shown in **Figure 2-3**, below.

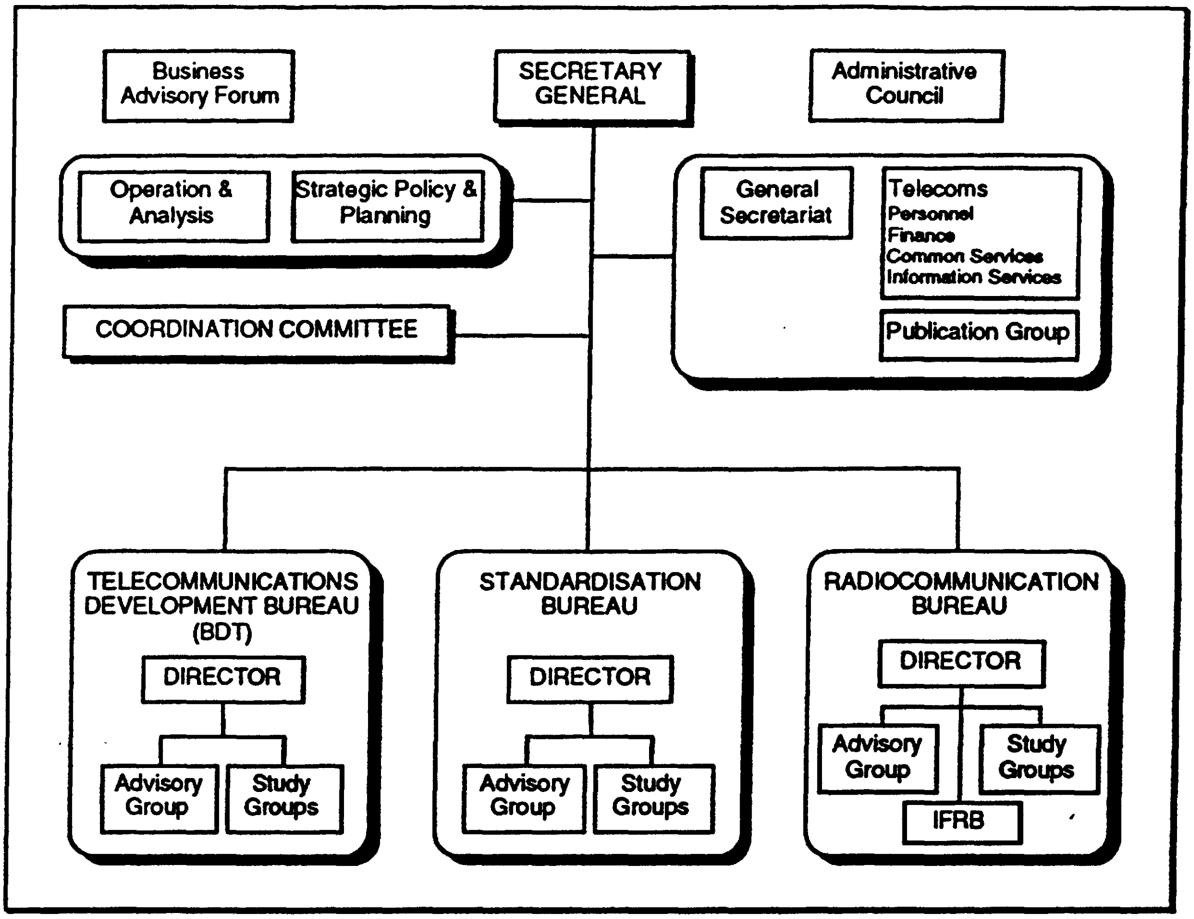


Figure 2-3: ITU Structure

Of the various entities making up the ITU, a number are of particular relevance to this report:

- The Administrative Council, which reviews and sets the agenda for the Administrative Conferences:

  - WARC, the World Administrative Radio Conference, which allocates bands of RF frequencies to services, including satellite services

  - WATTC, the World Administrative Telephone and Telegraphy Conference.

  WARCs are now held every two years. The most recent WARC conference, WARC 92, held in February 1992 in Torremolinos, will be discussed later in this document.

- The Telecommunications Development Bureau (BDT), which is made up of development conferences and the activities of the bureau itself. Emphasis is placed on presenting to developing countries the range of policy and structural options that would lead to greater resources for telecommunications development.

- TheStandardisation Bureau studies technical, operating and tariff questions and issues recommendations on them, with a view to standardising telecommunications on a worldwide basis.

- The Radiocommunication Bureau has integrated the CCIR activities relating to the efficient management of the radio-frequency spectrum in terrestrial and space radiocommunications, along with the activities of the International Frequency Registration Board (IFRB). The IFRB continues to exist as an independent entity within the Radiocommunication Bureau, though it has become a part-time body.

  The IFRB allocates frequencies, within the WARC-defined bands, to particular services. Technically, IFRB adjudicates on new frequency allocations to decide if they conform to ITU regulations. The IFRB has divided the world into three regions, as shown in Figure 2–4:

Region 1	Europe, Middle East, Africa, USSR, Mongolia
Region 2	North/South America, Greenland
Region 3	India, Iran, SE Asia, Australasia, Japan, China, Pacific.

  The IFRB is also responsible for the daily management of the frequency spectrum, as applied to satellite communications and the various services to be provided worldwide. Every country submits applications for frequency allocations, which are checked by the IFRB to see if they conform to regional agreements as well as the ITU regulations; as part of this work, the IFRB co-ordinates information about current interference problems.

  Finally, the IFRB, on behalf of the ITU, is responsible for the allocation of orbits to satellites. For example, the geosynchronous orbit (GEO) is clearly a limited resource, since satellites must, with current technology, be spaced at least 2° apart in order to limit interference, and so the co-ordinated allocation of orbits is vital. Over the next ten years, technological advances are likely to allow the closer placement of satellites in the geosynchronous orbit, thus increasing the overall capacity. However, it is difficult to be precise about how close they might be placed, and this is not felt to be a vital point, due to the decreasing dominance of the GEO orbit and the rise of the low- and mid-earth orbits (LEO / MEO).

Note that although the WARC allocates generic bands, users still need licences to operate in these bands from the countries that they wish to operate to and from; for example, in the USA, licences must be obtained from the FCC, and in the UK from the Radiocommunications Agency (RA). The FCC has recently allocated US mobile satellite service ("MSS") spectrum consistent with WARC 92; and is presently deciding a licensing regime for "big LEOs".

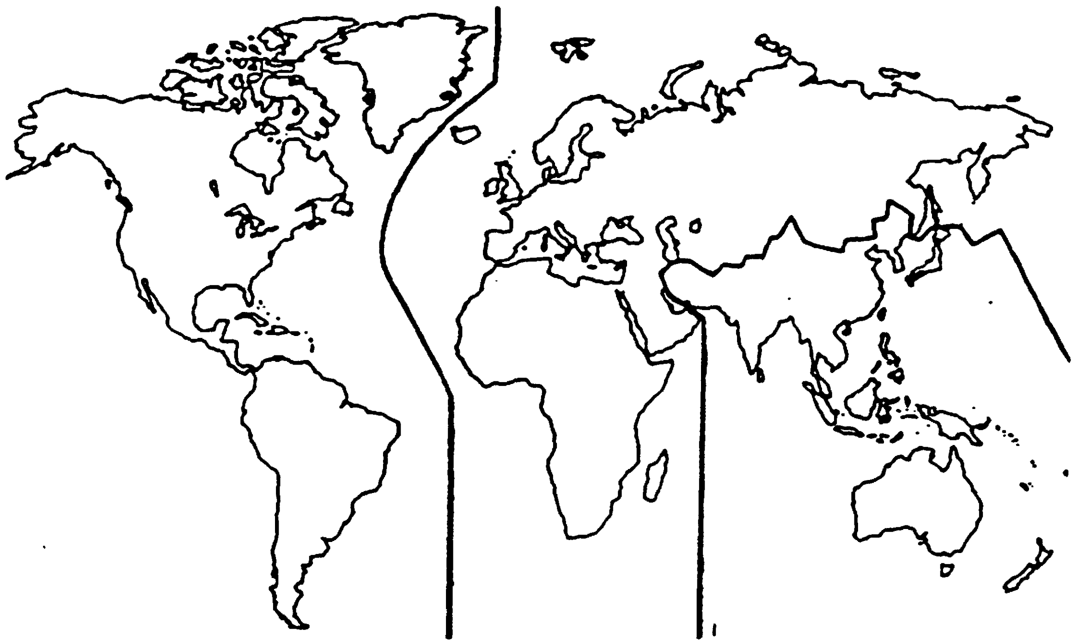


Figure 2–4. ITU Regions

2.3.2 Regional/National

In many parts of the world, including Europe, a major barrier to development of satellite services has been the local regulatory environment. A restrictive regulatory environment has been maintained by governments both for their own purposes (governments like to have control over cross–border telecommunications) and under pressure from the PTTs (cross–border traffic is historically the most profitable). It appears that this restraint is now being relaxed, particularly throughout Europe, so that the level of use of the technology may be set to escalate rapidly.

3 RESOURCES

The principal components of a satellite communications system are:

- the **satellite**, consisting of the platform and a number of **transponders**
- the **earth stations**, which transmit to the satellite via the uplink and receive from the satellite via the downlink.

Note that the downlink frequency is normally lower than the uplink frequency.

There are a number of physical resources which limit the worldwide capacity for satellite communications. These are:

- the satellites, the potential orbits for which are clearly limited (since, using current technology, GEO satellites must be separated by a minimum of 2° if interference is to be minimised, thus giving a potential of 360° / 2° = 180 slots), together with the number and types of transponder carried by each
- the frequencies used to communicate with the satellites, the available range of which is limited by technology (the techniques for exploiting higher and higher frequencies require constant development) and physics (only certain frequency ranges penetrate the earth's ionosphere; these are described in §3.2).

These resources and the factors affecting their availability are discussed in the following sections.

3.1 SATELLITE RESOURCES

3.1.1 Orbit Resources

The orbits used by communications satellites are illustrated in **Figure 3-1**, below, and are described in the following sub-sections.

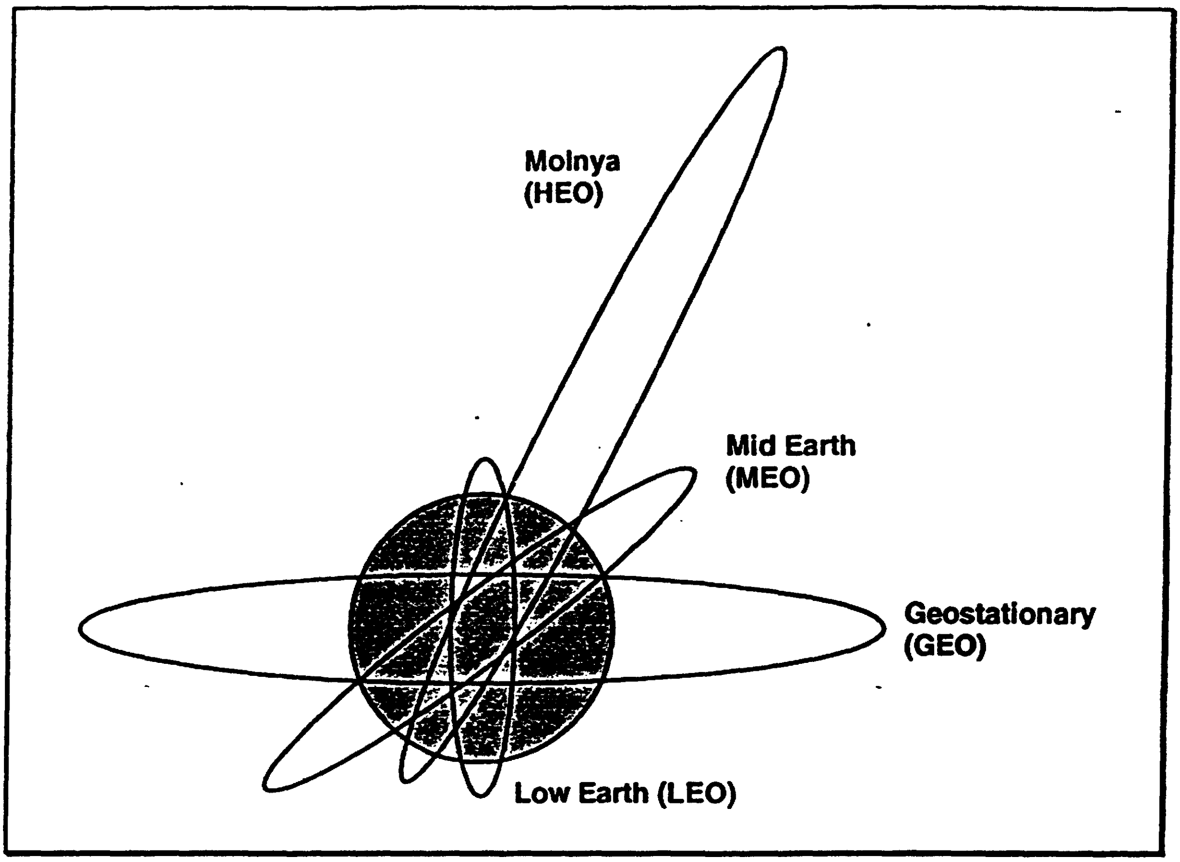


Figure 3-1: Satellite Orbits

The geostationary orbit (GEO), in which a satellite has a 24 hour period (so that it remains over the same equatorial point on the earth's surface), has an altitude of 35786 km. This is the most common orbit for telecommunications satellites, since it provides continuous coverage of a particular geographical area. However, it is impossible to cover the high latitudes from this orbit.

The molnya orbit, an example of a highly elliptical orbit (HEO), allows the high latitudes to be covered. It is an eccentric orbit, with an apogee of 40000 km and a perigee of 1000 km. Satellites placed in this orbit have an 8 - 12 hour period, so that three satellites suitably phased (in the same orbit) can provide 24 hour coverage for the high latitudes. This orbit was extensively used by the old Soviet Union, to allow coverage of the extreme north of the country, by the Molnya series satellites.

HEOs are actively under study in Europe; Archimedes is an ESA programme concerning the use of HEOs to provide voice communications in Europe. To date, feasibility studies have been conducted and these indicate technical and economic viability. By using HEO orbits an LOS path between the user and the satellite can be maintained even at northerly latitudes. BAe has led all of the key studies and has recently been concerned with the extension of the service from mobile telephony to include satellite sound broadcasting (Stuart, 1992).

A variant of the molnya orbit is the tundra orbit, with an apogee of 46300 km and a perigee of 25250 km. However, this orbit is rarely used.

The low earth orbits (LEOs), with an altitude of between 500 and 1500 km, are used by telecommunications satellites for specific purposes, such as navigation, store and forward, and increasingly for personal communications (for example, the Iridium system for personal telephony). Satellites placed in these orbits have a short period, and, if they are placed at an angle to the earth's equator, will be visible from any point on the earth's surface for a short time.

An additional orbit type, the mid earth orbit (MEO), is likely to find similar uses to the LEO orbit in the near future. Comparing satellites in LEO/MEO orbits with those in GEO orbits, we find that:

- LEO/MEO satellites are smaller and cheaper (for example, because lower RF power is needed, since they are closer to the earth) they are cheaper to launch (a lower orbit requires less energy to reach, plus multiple satellites can be launched at once because they are smaller) and launch insurance is cheaper. However, there are a lot of them - more in LEO than in MEO
- Because GEO satellites are mature, they are lower risk, and fewer satellites are required to provide the same coverage.

The GEO orbit is now extremely crowded, with 2° spacing between satellites. The ITU have a well-established procedure for allocating GEO orbit position which requires co-operation between parties, so that, for example, a European lobby could effectively kill any proposal. However, it is fair to say that orbits have never really been looked at as a resource, despite several suggestions to this effect, probably because there has never been a shortage before.

There are no mechanisms as yet for the allocation of orbits for LEO and MEO satellites. It is unlikely that progress on this point will be made before the next WARC conference.

Although Appendices 28 and 29 of the ITU Radio Regulations allow reasonable interference planning at the moment, there are potential problems in TV-Direct to Home (TV-DTH) services using Fixed Satellite Services (FSS) satellites, such as Astra. The expansion into LEO and MEO orbits will require new interference planning which is not currently in place, for example, within and between orbits (such as between systems of LEO satellites, or between LEO and GEO satellites).

3.1.2 Transponder Resources

The traditional satellite transponder is a conceptually simple device. It takes a signal received from the uplink, amplifies it, changes the frequency (normally a downshift) and re-transmits it on the downlink.

However, developments in technology are gradually changing this picture. For example, greater numbers of users can be accommodated through the use of spot beams. Spot beams replace a transponder's wide footprint on the earth's surface with a number of much smaller spots, which together cover the same area of the earth as the single transponder. A transponder therefore becomes a collection of a number of receivers and a number of transmitters, rather than one of each. In this way, different groups of users can use the same frequencies (frequency reuse), provided they are in different spots, thus increasing the overall capacity of the system and the overall spectral efficiency.

Other developments in satellite technology include on-board processing (OBP), which clearly will be needed in order to implement, amongst other services, spot beams (since users can move between spots, any data for specific users must be routed to a particular spot); and the replacement of RF modulation techniques with digital signal processing (DSP). OBP allows flexible routing between spot beams and the regeneration of digital signals (analgous to the amplification and removal of intereference in analogue signals) on the satellite., whilst DSP will be used on board satellites for networking, modems and codecs, and for on-board switches.

3.2 FREQUENCY RESOURCES

3.2.1 Bands

3.2.1.1 Description

Satellite communications uses the microwave frequencies, from 0.9 GHz upwards. However, not all frequencies above 0.9 GHz are available, since the earth's ionosphere is impenetrable at many frequencies. There are, however, a number of windows, and these windows (bands) are named and divided between civil and military satellite communications.

The frequency bands currently used in civil satellite communications are as follows (the use of each is addressed later, and is summarised in terms of service type in Appendix B, and in terms of application in Appendix C):

Name	Frequency
L band	1 - 2 GHz
S band	2 - 4 GHz
C band	4 - 6 GHz
Ku band	10 - 14 GHz
Ka band	20 - 30 GHz

The capacity of each of these bands can generally be said to be increasing, since it depends principally on technological developments.

The C, Ku and Ka bands are intended for general telecommunications applications (FSS), although BSS transponders also use the Ku band and are dedicated to broadcast applications.

MSS services use the L and S bands, though S-band is also used for telemetric control of the satellite itself. The communication characteristics in these bands are not well known over all elevation angles, which is clearly a consideration for LEO and MEO satellites. Further, there has been no analysis of the wideband performance characteristics, which is needed for CDMA and Digital Audio Broadcasting (DAB).

Consideration needs to be given to the extension of the bands within these areas and on new bands above Ka band. This is the subject of current research, as described in §4.2. Note that exploitation of higher frequencies has always been limited by technology, so that it has always been the lower frequencies that have been exploited first. Good knowledge of propagation up to 30/40 GHz is now available; fade countermeasures are currently being researched and should be operational by the mid 1990s. Little data is available on the use of Ka bands for mobiles; again, this is the subject of research and experimentation.

In this context, NASA is developing the Advanced Communications Technology Satellite (ACTS), which is expected to offer multiple communications services via a single platform. At WARC '92, the US instigated the definition of the General Satellite Service (GSS), to match the characteristics of ACTS, with uplink frequencies of 29.5-30 GHz, and downlink frequencies of 19.7-20.2 GHz.

As is described in a following section, the lower frequencies are more subject to terrestrial interference, whilst the higher frequencies are more subject to atmospheric interference. For this reason, the choice of band to be used in a particular geographical area depends on the physical characteristics of that area. Consequently, many models of satellite communication are not generally applicable.

3.2.1.2 Allocation

The allocation of frequency bands to services is carried out by the various WARCs. The most recent of these was WARC '92, held in Torremolinos, Spain, where it was felt that the key challenge was to protect existing services, whilst enabling new technologies to secure frequencies. The key points of the conference were:

- the allocation of spectrum to mobile satellite services, particularly for the new LEO/MEO satellite systems such as Motorola's proposed Iridium mobile telephony system, which is to use 66 LEO satellites to provide worldwide coverage, and similar systems planned by a number of organisations, including Loral, Qualcomm, TRW and Inmarsat.

  Frequencies in the band 1.5 - 2.5 GHz were allocated for use by these new LEO/MEO systems, with some bands not being available before 2005. Limited spectrum in the band 1.61-1.6265 GHz was made available for systems that are intended to enter service during the 1990s, such as Iridium. Since this could cause interference with the Russian Glasnoss satellite navigation system, it is likely that such systems will be required to use lower power than desirable. The desire of other nations to develop other systems could also cause problems. European nations and Japan were unenthusiastic about the US proposal, since they have no large, sparsely populated regions that could not be served by conventional mobile cellular phones.

- the "earmarking", rather than allocation, of spectrum for the Future Land Mobile Public Telephone System (FLMPTS) above 1.9 GHz. This earmarking does not preclude the use of the spectrum by other technologies, should they need it. This approach was taken because of the speculative nature of FLMPTS, whose system specifications are not likely to be fully developed before the year 2000

- satellite sound broadcasting (by systems such as DAB) received new allocations

- the definition of GSS, as described above.

3.2.2 Modulation

Clearly, if the signal is to carry data, it must be modulated. The two principal methods currently in use are Phase Shift Keying (PSK) and Frequency Shift Keying (FSK). Since FSK is rather less power efficient, PSK is used, in one of two variants:

- Binary PSK (BPSK)

- Quadraphase PSK (QPSK).

Although PSK variants with more phase states exist, they are more prone to degradation, and so far have not been used.

BPSK has a two symbol alphabet (using one bit per phase symbol) where both symbols have the same frequency, but have a relative phase shift of 180 degrees with respect to each other. Because it spreads the transmitted energy over a wider bandwidth, BPSK offers the best resilience to phase noise, but it is not as spectrally efficient as the larger symbol alphabet schemes such as QPSK.

QPSK uses two bits per symbol and has four phase states. It offers double the bandwidth efficiency of BPSK, but is more sensitive to phase variations and additive noise. Consequently, it is more difficult and expensive to implement successfully, though it is still used extensively.

Within Europe, Eutelsat have nominated a small number of transponders as Satellite Multi Service (SMS) transponders, which can be accessed using either BPSK or QPSK. Aside from these restrictions, there are a number of technical reasons, relating to power, interference and intermodulation, that mean that not all transponders are suitable for access using BPSK or QPSK.

Mobile systems require more spectrally efficient modulation schemes and, despite the greater use of linear amplifiers in mobiles, also require modulation schemes that will not regenerate the sidebands to cause adjacent channel interference when used with non-linear amplifiers. Such schemes as O-QPSK and MSK are in use, as well as $\pi/4$ shifted PSK.

More spectrally-efficient modulation schemes, such as multi-bit QAM, are needed for broadband transmission (for example, SDH over ATM) that have not yet been developed for use with satellite systems.

For mobile systems, the greater spectral efficiency needed will come from using Trellis-coded modulation (TCM).

Modems are increasingly being implemented using digital signal processing (DSP) techniques, which allow better performance and a degree of flexibility in changes between schemes.

3.2.3 Interference

There are three primary sources of interference which affect the RF signals to and from the satellite:

- Cosmic noise, the general background RF noise of the universe, which reduces the signal-to-noise ratio of the signal
- Terrestrial RF noise, which is entirely the result of human activities. The principal sources are:
    - terrestrial radio transmissions, sharing the frequency bands used by communications satellites
    - electric motors, such as those in various domestic appliances
    - sparks, as used in car engines

- direct RF emissions, such as those from the cathode ray tubes of televisions.

Thus it is clear that terrestrial RF noise is likely to be worst near cities. For this reason, the lower frequency bands (L-band and below), which are particularly susceptible to terrestrial RF noise, can be difficult to use in areas of high population density.

The use of C-band in the UK is a problem due to the large number of closely packed C-band terrestrial radio links and satellite uplinks; in the USA, where C-band is widely used, they are not so closely packed, and radio relays use higher frequencies.

- Atmospheric effects, principally caused by water vapour (including cloud) and rain. This can result in:

  - attenuation of the signal
  - refraction
  - depolarisation.

  There are other atmospheric affects, including those caused by airborne dust from volcanic eruptions, dust storms etc. However, these have been found to have a relatively minor affect on the signal.

  The higher frequency bands are more susceptible to the effects of rain and water vapour, so that, for example, Ka band may not be appropriate for use in areas of heavy and prolonged rain. Fade countermeasures (FCMs) are currently being researched, and should be operational by the middle of the 1990s in order to combat rain fade at the higher Ka band frequencies.

It is therefore clear that the choice of frequency band to be used in a particular geographical area is principally dependent on the characteristics of that area; specifically, its population density and its rainfall/cloud cover. The choice of band is the result of trade-offs between these factors, within the constraints of the WARC-allocated bands as regards the services that may be offered within those bands.

For example, in Japan, which endures periods of heavy rainfall and cloud cover, Ka band is widely used. C-band services are used for communications with remote islands. Ka-band services are integrated to improve the terrestrial networks, for example to provide capacity for sudden increases in demand. Ten of the 14 Ka-band transponders are used to link 62 zone centres in Japan; each zone centre is equipped with one earth station to carry overflow calls. Ka band is used because Japan's many small islands results in tightly packed radio systems, which need to use Ka band in order to avoid interference. For this reason, the Japanese pioneer the use of higher frequencies; the fact is, we must address the rain fade problems by means of developments in FCM.

4 TECHNOLOGIES

4.1 SERVICES

4.1.1 Telephony

Telephony by satellite suggests high cost earth stations and high cost satellite bandwidth. However, there are a number of factors which belie this impression:

- Increased use of digital signal processing (DSP) techniques and VLSI implementation reduce the cost of the earth stations
- Digital compression techniques reduce the bandwidth required from what was once 64 kb/s to (currently) 16 kb/s, with a potential reduction to 2.4 kb/s for mobiles
- Digital speech interpolation (DSI) further reduces the bandwidth required for the transmission of speech by removing the redundancy, the gaps, from the speech.

Taken together, these factors have the potential to make satellite telephony a viable option; the proposed LEO/MEO personal telephony networks, such as Motorola's Iridium, will all use a handheld earth station, much as today's terrestrial cellular telephone networks do, and promise to be only slightly more expensive to use. This is in contrast to the current networks, including those provided by Inmarsat and the newly launched Telephony Earth Station (TES) from Hughes, which are expensive to use and require a much bulkier earth station (normally a VSAT), so that their mobility is limited.

The well-developed terrestrial telephony infrastructure in developed countries clearly limits the potential of satellite telephony, so that its principal application in those countries is in rural development. Another potential use of satellite telephony is in links with areas where the terrestrial infrastructure is far less developed, such as links with Eastern Europe. However, these limited uses meant that Europe and Japan, with their limited rural development opportunities, were opposed to the allocation of bands to LEO/MEO satellite telephony systems at WARC '92.

4.1.2 TV

Currently, the TV signals carried by satellite use FM transmission, with a bandwidth of 27 MHz. The most significant advance that is likely to take place is the change to digital TV, which will allow a major bandwidth saving. It is widely seen that a digital TV transmission system, using compression, provides best performance in terms of transmit power, bandwidth and robustness (Fischer & Grassman, 1992). The digital TV system could be based on a true digital standard, such as those emerging for High Definition TV (HDTV), or a partially digital standard, such as the MAC suite. In any case, broadcast quality TV will require approximately 30 Mb/s.

There are three main approaches to compression: standard compression (e.g. MPEG, H261) without special transport, standard MPEG with satellite-specific transport and error concealment, modified MPEG with custom transport and error concealment (Zdepski, Raychaudhuri, & Schiff, 1992).

Such advances could potentially release a great deal of spare capacity, thus increasing the total capacity available (in terms of the total number of channels) at a stroke and possibly causing a transponder glut. This is particularly the case because, as described in section 2.2, TV is currently such a major user of worldwide satellite bandwidth, and is likely to remain so.

However, most TV transmissions are either DTH or intended for cable heads, so that existing standards (for example, PAL and MAC) will be preserved, since it is unlikely that home viewers will readily change their equipment. Hence the impact of TV compression may be limited. Nevertheless, casual users of TV, for example, satellite news gathering (SNG), teleconferencing, business TV etc, can make use of digital compression techniques.

4.1.3 Multi-Media

Multi-media services, combining video, text, sound and still pictures and aimed at the education market, is an example of a multi-service requirement. Clearly, it will require broader bandwidth; broadband services are addressed in a following sub-section.

4.1.4 Data

Data services have been available since the beginning of the 1980s, by means of, amongst others, VSAT technology. It is likely that these services will gradually be subsumed into broadband services, as discussed in a later section.

4.1.5 Broadband

The integration of telephony, TV and data into broadband digital services, thus achieving the emerging target of multi-service support by a single transponder, is also an important target as regards integration with terrestrial networks.

The various broadband technologies are compared in **Table 4-1**. Such technologies offer an immense amount of bandwidth, so that it is difficult to imagine there ever being a widespread demand. However, experience has shown that applications always arrive to fill the bandwidth available, and one application that will require vast amounts of bandwidth is virtual reality (VR); by theyear 2000, VR will no longer be a news story in its own right - it will be well on the way to becoming just another computer technique. Many VR applications will be heavily communications dependent, with all that entails for demand for broadband services. For example, networked VR means that children in one place can be taught, person to person, by a specialist teacher in a totally different place.

Service	Main Strengths	Main Weaknesses
ATM virtual private lines	Provides variable-rate circuits for high speed data (45, 155 or 622 Mb/s)	Handles data only (or anything else, such as telephony or TV, provided it is presented as data); not optimised for connectionless links; initial services offer private connectivity only
ISDN	Standard interfaces; E.164 addressing	Relatively low speed; handles connection-oriented links only; requires time for call setup
Broadband ISDN (BISDN)	High speed links available; variable rate circuits; E.164 addressing	Handles data only; not optimised for connectionless links
Frame relay virtual private lines	Fewer access lines needed; lower cost per packet	Long time from ordering to becoming available; low speed; prone to packet loss and delay; handles data only; private connections only
Fiber Distributed Data Interface (FDDI)	Connectionless service; operates at 100 Mb/s; relatively low cost; based on established standard; ring design offers route protection	Internet Protocol (IP) address limitations; limited geographical coverage; handles data only; delay under heavy network load
FDDI II	Offers both connectionless links for data and connection-oriented links for isochronous traffic	Standard is incomplete
Switched Multimegabit Data Service (SMDS)	Provides connectionless links; relatively low cost; global connectivity at speeds up to 155 Mb/s; CCITT E.164 addressing	Handles data only
IEEE 802.6 Metropolitan Area Networks	Offers both connectionless links for data and connection-oriented links for isochronous traffic; CCITT E.164 addressing and IP addressing; route protection by folded bus	Not widely available in the US
Private lines (DS-0, T1, T3)	No packet loss; no packet switching delay; handles isochronous traffic; reliable	High cost; long provisioning time; private networking only
Switched circuits (DS-0, T1, T3)	Dial-ip links on demand; lower cost; no packet loss; no packet switching delay; handles isochronous traffic	No global connectivity; point-to-point connections only; connection setup takes seconds
SDH	Offers bandwidth from 155 Mb/s to 622 Mb/s	Relatively high cost; fixed rate circuits are not well suited to handling bursty data transmissions

Table 4-1: High Speed Services

The emerging Asynchronous Transfer Mode (ATM) services, aimed at high speed networking, will form the underlying infrastructure for broadband satellite communications. Further, the key players in terrestrial telecommunications and networking have now formed the ATM Forum, with the aim of driving ATM through to the desktop, thus forming a continuous broadband, multi-service networking technology right from international trunks through to office systems. Thus it is apparent that the integration of satellites into broadband networks will require support for ATM.

The one exception to this global picture is Japan, where the N-Star system of satellites, to be launched in 1995, will support broadband ISDN (B-ISDN) directly, rather than ATM or B-ISDN layered on top of ATM. N-Star will offer data transmission rates of up to 1.56 Mbps.

There is a growing tendency for ATM services to be layered on Synchronous Digital Hierarchy (SDH - the international equivalent of the USA's Sonet standard) transmission systems. ATM maps easily on to SDH, which has the advantage of scalability, from a speed of 51.84 Mb/s through to 2.4 Gb/s using multiple optical fibres.

It is clear, then, that broadband, multi-service support by satellites is going to require support for ATM and SDH. However, neither of these have yet been demonstrated; in particular, SDH will require the development of new modulation and coding techniques, and possibly wider bandwidth transponders than currently exist, whilst ATM will require demonstration over a satellite (and will potentially need even higher bandwidth transponders), with the consequent transmission delays. Gateways for ATM are also likely to prove difficult. §4.2.2 addresses the technological advances necessary for SDH / ATM support.

4.2 SERVICE SUPPORT

4.2.1 Earth Stations

The RF portion of earth stations has undergone a lot of developments for all bands up to Ku band; there has been very little development above this band. This clearly needs to be redressed if the higher frequency bands are to be of use in the future.

There is a lack of off–the–shelf equipment above Ku–band and in Ka–band in particular. The ESA Olympus Ka–band experiments have improved the situation in Europe slightly but the lack of Ka–band work in the US (where there is no lack of Ku–band capacity) means that there has been no commercial pressure to bring Ka–band equipment to the market. Europe currently has something of a lead in Ka–band technology because ESA has been exploring Ka–band from the technological side: Italy, in particular, has been looking in this direction and ITALSAT carries Ka–band packages. Also in Europe, the pressure from HDTV for wider–band transponders has increased interest in Ka–band because there is simply not enough Ku–band spectrum available.

In terms of transponders, the effect of these trends will be higher bandwidth. There is a whole generation of 36/40MHz transponders in operation which were optimised for FM television even though many of them are not carrying TV at present. Now 54/72MHz transponders are in widespread operation and the next generation will be in the region of 140MHz to accomodate SDH. This would apparently mean an explosion in frequency spectrum requirements, but it must be remembered that it is accompanied by improvements in Circuit Multiplication Equipment (CME) technology which is pushing in the other direction.

Above Ka–band the picture is very different. The Japanese have been experimenting at 40/50 GHz but most usage in these bands is military (imaging and so on rather than communications), not civil. It is possible that the changing requirements of the military mean that some of this spectrum will be released in the future but this is far from certain.

Further, if the full potential of mobiles and PCNs is to be realised, then significant advances in the necessary earth stations are required, particularly in the areas of modulation and CDMA multiple access schemes. Most mobile services are in the L/S–bands but other (higher frequency) bands could be exploited in the future. MSS bands, for example, are already allocated in the Ka–band but no development has yet taken place. In the UK, the British National Space Centre (BNSC) has just awarded a study contract to begin research into exploiting mobile Ka–band services.

4.2.2 Circuit Multiplication Equipment

Circuit Multiplication Equipment (CME) allows a greater number of circuits to be carried within the same bandwidth by means of compression techniques. For example, speech circuits, which once required 64 kb/s were compressed to 32, then 16 kb/s, thus allowing 4 circuits in the same bandwidth. Further reductions are in the pipeline and additional technologies—such as Digital Speech Interpolation (DSI), which removes redundancy (*i.e.*: gaps in speech) from channels—allow still more voice, data or image circuits to be carried over the same channels.

Similar improvements are coming in the compression of video. The CCITT standard is 64 kb/s, though 365 kb/s and 2 Mb/s are industry standards, with 30 Mb/s for broadcast quality. As the bandwidth requirement goes up, so does the corresponding codec expense. However, digital compressed TV, as outlined in a previous section, will need significantly lower bandwidth.

The use of CME allows the bandwidth requirements of an application to be much reduced, potentially giving rise to a transponder glut. To balance this, though, lower bandwidth also means lower prices and therefore a greater demand for services.

Some advances in transponder technology will be required to take full advantage of CME techniques, though this is by no means true of all of them. However, DSP, which is probably the most significant advance, will require new transponders.

4.2.2.1 Components

The techniques of CME involve two types of equipment: the *coding* of the (voice, image or data traffic) into a digital stream and the *modulation* of the digital stream into radio (or other analogue) signals. The primary trend to note here in the satellite field is the integration of these components. In the past, coding and modulation were separate disciplines which resulted in the development of discrete components whereas they are now being integrated with much better results.

4.2.2.2 Modulation

Modulation, necessary if an RF signal is to carry data, is moving away from the traditional techniques and towards digital techniques. The PSK implementation in FSS modems will have a DSP implementation. Now, as described in an earlier section, the broadband developments will require the development of SDH/ATM modems, requiring the use of higher level QAM modulation.

The use of 155Mb/s SDH has been studied extensively for satellite communications and 16–QAM is emerging as the current leading modulation technique. Current proposed implementations still need a lot of power however. Intelsat have a major research programme under way in this field. A 16–QAM SDH channel might just fit into an existing 72MHz transponder but it is unlikely that such transponders could provide enough power. This is not a great technical problem, and it is only a matter of time (say, 5 years) before more powerful wideband transponders make this practical. Higher speed services—such as ATM at around 300Mb/s—are much further away in terms of practical implementation because new modulation techniques will need to be developed.

The growing importance of mobiles will require the use of suitable modulation techniques, including O-QPSK, MSK, π/4 shifted PSK, linear modulation schemes and Trellis coding. The continual changes in technology in this area are steadily reducing the bandwidth requirements for MSS but the shortage of frequency resources is more acute. The requirements for MSS coding (see §4.2.2.3) are quite different to the well–developed techniques for FSS coding so much work remains to be done in this field. To take the example of voice modulation, a CCITT standard for good quality voice at 8Kb/s is already on the horizon but this is only appropriate to FSS. Lower rate systems, such as adequate quality 2.4Kb/s voice, suffer from delay problems when dealing with GEO services and Doppler problems when dealing with LEO services. At the time of writing, 4Kb/s (6Kb/s with channel coding) voice is probably the lowest practical rate for MSS.

As has been already emphasised, spectral efficiency is now very important, significantly influencing the choice of modulation techniques.

4.2.2.3 Coding

A channel coding scheme modifies the digital data stream that is to be modulated in order to improve the quality of the channel. In general, it does this by adding redundant information to the bit stream to allow the receiver to recover from errors in the digital channel.

A number of channel coding schemes have been defined. For FSS, coding has been standardised (around convolutional codes such as the Vitterbi code) and has reached the point where chips to carry out the encoding and decoding are readily available off–the–shelf. For MSS, the types of errors encountered—burst rather than random errors—mean that these codes are not appropriate. There are basically two ways to handle burst errors:

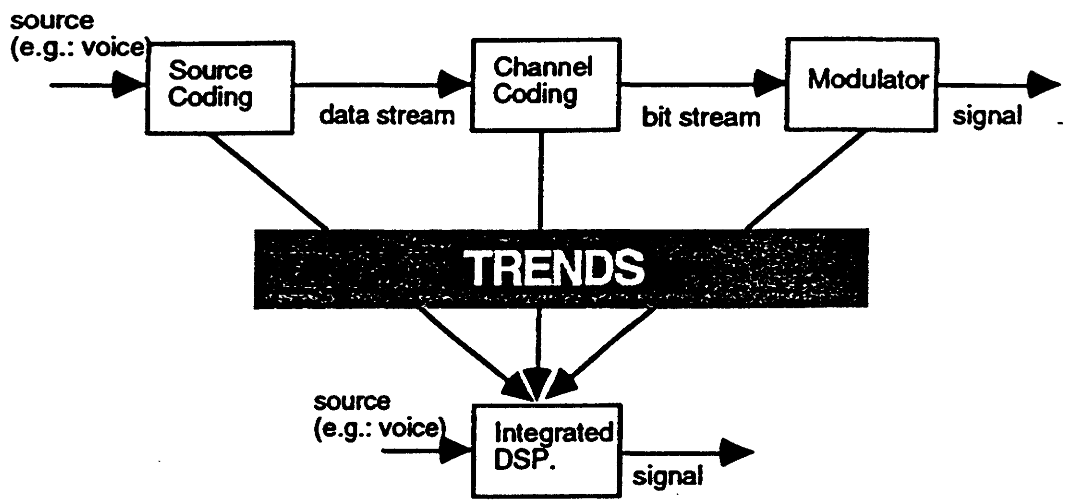
- by interleaving the channel to spread burst errors (so that they approximate random errors) and then applying a convolutional code, or
- by using block codes (such as Reed–Solomon codes) designed to recover burst errors.

The latter method is gaining favour and in the last year or so the first commercial R–S coders with "soft decision" implementations have appeared on the market. These can provide a significant gain.

It is very important that any coding gain translates into an improvement in other system parameters; for example, smaller dishes, less interference, less power.

4.2.2.4 Modems

Modem technology is undergoing significant transition at present. In the past, analogue modulators were combined with digital coders to provide the CME. Now, the use of DSP for modulation in software and the integration of (and sharing of information between) coding and modulation equipment heralds major improvements in modem technology. Furthermore, since the DSP modulation and coding implementations are now in software, they are more flexible and effective than traditional analogue techniques. It is difficult to see, at present, how Europe will catcch up in the field of DSP implementations. Both the US and Japan are very advanced in this field and the Japanese have recently done a lot work in DSP implementations for the new Inmarsat-M services.



4.2.3 Access Schemes

The highly developed access schemes, FDMA and TDMA, were originally developed for FSS services.

For VSATs, a number of access schemes have been developed, such as Aloha, RA Schemes and various modified Aloha schemes. These first-generation schemes will need to be replaced with more sophisticated second-generation, multi-service schemes which have yet to be developed. This is because the first–generation schemes were designed for low–rate data services but the requirements are now changing towards integrated voice, data and image services. These multi–service systems—such as multimedia systems—have very different design requirements from the "traditional" single service communications links implemented via VSATs.

The current access techniques for mobiles are FDMA and TDMA. However, for a number of reasons including bandwidth efficiency and resilience, CDMA may be required for new systems and will require further development. In fact, CDMA is in the acendant at present because of its better theoretical spectral utilisation—note that this is theoretical and it is not obvious at present that it will be possible to obtain such utilisations in practice. It is reasonable to assume that some sort of hybrid FD/TD/CD multiple access sheme will emerge to get better utilisation in practice.

4.2.4 Satellites

The major area of development in satellites is likely to be the co-ordination and networking of LEO and MEO satellite constellations. Clearly, this will require significant developments in ISLs and OBP. NASA's Tracking and Data Relay Satellite System (TDRSS), a network of GEO satellites which allow ground stations to communicate with LEO satellites, manned space vehicles etc., has allowed significant technological advances to be made in ISLs. Similarly, ESA Olympus, an experimental Data Relay Satellite (DRS), is intended to demonstrate ISL communication with the Eureca LEO platform, using Ka band.

ISLs are interesting in the context of this study because they significantly simplify the number of MSS orbital slots required and the terrestrial networking needed to support them. For FSS they are much less important. A number of Intelsat studies have shown that the expense of ISLs is not economic for FSS services. Originally, optical (very wideband) ISLs were considered for GEO satellites. This is feasible because GEOs are outside the atmosphere. For LEO/MEO satellites operating inside the Earth's atmosphere, lower bandwidth millimetre wave ISLs will be used.

Optical ISL technology is well advanced, but expensive. Integrated optics will reduce costs, but still the acquisition and tracking systems have larger mass and volume than competing systems. It is believed, therefore, that millimetre wave ISLs are the answer, and these should be operational sooner rather than later.

For FSS systems, the major areas of development are likely to be in OBP (in order to improve services) and multi-beam antennas (MBAs), which allow multiple spots to be covered through a single antenna. This allows for frequency re–use (in separate, unadjacent spot beams) and thus reduces the demand for frequency resources. Antenna technology is allowing a move to larger reflectors, and therefore smaller spots which multiply the frequency re–use factor.

5 FUTURE TRENDS

There are a number of technological trends which will have an influence on the orbit and frequency resources, principally in the areas of signal processing techniques, the use of different orbit types, and OBP. In addition, changes in the regulatory environment will have a profound effect on demand and therefore the resources themselves. These trends are discussed in the following sections.

5.1 SIGNAL PROCESSING

The principal technological trend in the field of signal processing is the move from RF techniques to DSP. Until now, the advances in signal processing have been in the RF interface, in order to accommodate services, but DSP (both in earth stations and on-board the satellite) will have a profound effect on the orbit and frequency resources.

DSP will allow such compression in all services, especially in video, that no larger satellites will be required, and perhaps no additional bandwidth, so that, although a shortage of Ku-band capacity in Europe is currently predicted, it is anticipated that digital compression technology will lead to a TV transponder glut.

5.2 ORBITS

There is a trend away from more traditional GEO satellites to networks of LEO/MEO satellites. The industry is at a major crossroads in making this change; it has an effect in worldwide mobile communications (the difficulties here are in getting the necessary frequency resources allocated worldwide), and raises a number of questions:

- how will orbits be allocated?
- how will they be managed?
- how will interference (between satellites, between networks of satellites and between orbits eg GEO and LEO) be minimised, monitored and managed?

Note that sound broadcasting, using Digital Audio Broadcasting (DAB) will use LEO/MEO orbits, as well as personal communications satellites, for which the avoidance of the transmission delay on speech circuits is a key advantage of LEO.

A comparison of the advantages and disadvantages of LEO and GEO satellite communications systems raises the following points;

For GEO:

- Mature architecture; familiarity of manufacturers and investors; fewer satellites

Against GEO:

- Long transmission delay; poorer spectrum efficiency; no high latitude coverage; inferior positioning performance; huge satellites; large, complex conventional antennae

For LEO:

- Shorter distance, lower power; smaller cells, more frequency reuse, more channels; improved redundancy; cheaper launch insurance; phased array antennae; worldwide coverage

Against LEO:

- Complex, unproved architecture; complicated networking; greater risks, development schedule and budget; multiple launches required; higher break-even point.

5.3 OBP

On board processing transforms a satellite from an essentially passive system to a switchboard in the sky. This is a key technological trend, since it will revolutionise networking, by:

- impacting heavily on terrestrial networks by allowing more sophisticated, unique services
- allowing smaller, cheaper earth stations
- giving an improved interface
- allowing satellites to be placed in closer orbits
- improving connectivity in LEO/MEO orbits.

OBP satellites will fly in experimental stages in the mid-to-end 1990s. Hardware/firmware developments are mostly complete but software/reliability studies are lagging and will constrain their use in operational systems. Expectations are that the first operational OBP satellites will fly around the year 2000, and by 2005 will be having a major impact.

5.4 SPACECRAFT

New developments in ion engines and in the use of new electric power systems will increase the efficiency and lifetime of satellites. New research will lead to the mini satellites necessary for the LEO constellations for mobile and personal communications around the mid to late 1990s.

Launchers are still a problem, and apart from Ariane, ASAP and Pegasus, we do not have low cost launchers. Multiple launch schemes for LEO satellites are currently under investigation and are expected to be available by the mid 1990s.

5.5 DEREGULATION

Deregulation of satellite communications, freeing it from PTT dominance, will, of course, increase the availability of satellite services and therefore the demand, since experience in the US has shown that, once access to satellite services becomes freely available throughout the geographical area of interest, users see it as a realistic alternative to terrestrial communications.

This increase in demand is in addition to that arising from the technological advances previously noted.

However, deregulation also raises a number of problems and questions, such as:

- the management of both orbits and frequencies (bandwidth) becomes significantly more difficult, as there are many more players
- who regulates certain services - for example, mobile via satellite?
- should Eutelsat become a commercial organisation?
- should satellites be designed to give preferential coverage - for example, of Eastern Europe?
- what should ETSI's rôle be in standardisation and type approval?

5.6 SERVICES

The wide expansion of services, as outlined in section 4 of this document, is made possible by DSP technology, freeing bandwidth and increasing spectral efficiency. The key step is in the integration of services using broadband technologies. However, future broadband services will need further reductions in costs before they become viable, and they are highly dependent on the development of key broadband technologies, particularly an SDH/ATM modem for satellites.

It is likely that education, particularly multi-media, will play a much larger rôle in the future of satellite communications than hitherto.

There are a number of services which will directly benefit from these technological advances; in particular, Satellite News Gathering (SNG), private data networks and digital compressed TV (though, as previously discussed, the requirement to maintain existing standards, such as PAL and D-MAC, will limit the penetration of the latter). It is important to note that the level of demand for these services is related to trends outside satellite communications: for example, the increased number of TV channels in Europe means more demand for SNG, whilst a trend to distributed offices and telecommuting means more demand for private networks.

APPENDIX A TECHNOLOGY AVAILABILITY

Diagram A-1, on the following page, illustrates the trends in technology availability, by plotting against time the availability of research systems, pilot commercial systems and fully commercial systems in the key technologies identified in this document:

- Digital Signal Processing (DSP), except for TV
- DSP for TV
- Inter-Satellite Links (ISLs)
- On Board Processing (OBP)
- Modulation and coding techniques for broadband applications (ATM/SDH)
- Multiple access techniques, using CDMA, for networks (constellations) of low earth orbit (LEO) satellites
- Deployable antennas, for which the scale of development refers to the size of deployable antennas (which is inversely proportional to the spot size achievable and therefore the level of frequency re-use).

As can be seen from the diagram, most of these technologies are expected to be in full commercial operation by the year 2000. The remaining technologies (OBP, ISLs and modulation & coding techniques) will not be in full commercial operation until 2005.

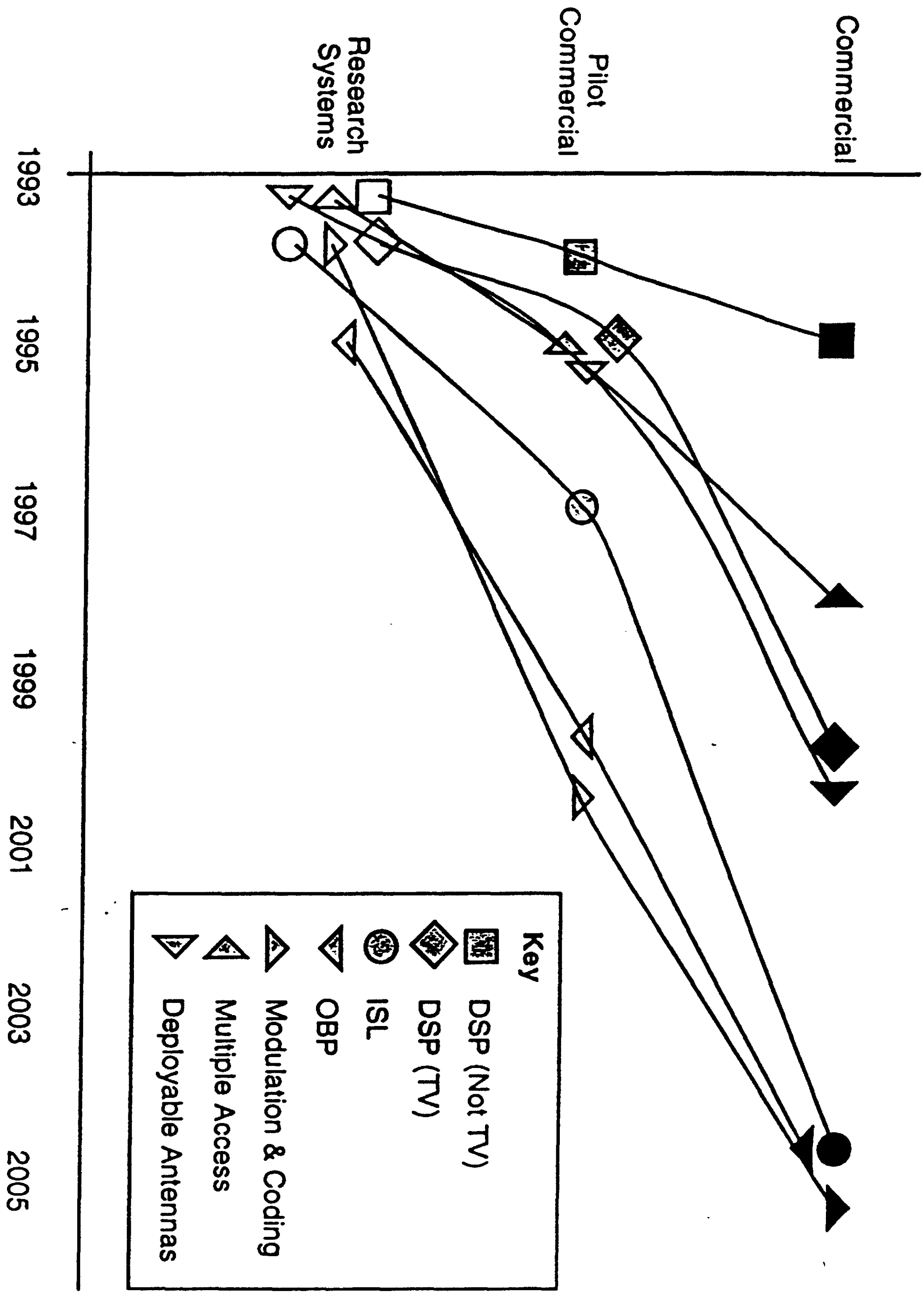


Diagram A-1: Technology Availability

APPENDIX B—SPECTRUM USAGE

Diagram B-1 summarises the applications of the L, S, C, Ku and Ka bands. The possible uses considered are:

- telemetric control of the satellite itself
- mobile satellite services (MSS)
- fixed satellite services (FSS)
- broadcast satellite services (BSS).

Specific applications within these service types are addressed in Appendix C.

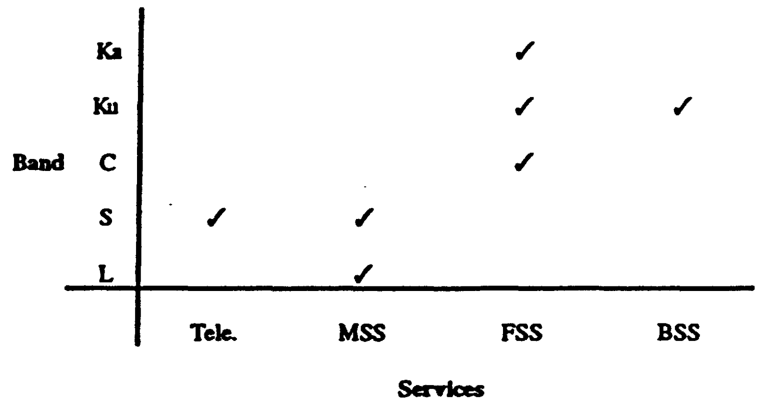


Diagram B-1: Band Uses

Diagram B–2 shows how the FSS and BSS bands, which are of most interest in the context of this report, are allocated.

Spectrum (GHz)	MHz	Band	Allocation	Direction	Use
2.500— 2.690	190	S	BSS	Down	Commercial
2.690— 3.400	710				
3.400— 4.200	800	C	FSS	Down	Commercial
4.200— 4.500	300				
4.500— 4.800	300		FSS	Down	Commercial
4.800— 5.725	925				
5.725— 7.075	1350		FSS	Up	Commercial
7.075— 7.250	175				
7.250— 7.750	500	X	FSS	Down	Military
7.750— 7.900	150				
7.900— 8.400	500		FSS	Up	Military
8.400— 10.700	2300				
10.700— 11.700	1000	Ku	FSS	Up/Down	Commercial
11.700— 12.500	800		BSS	Down	Commercial
12.500— 12.750	250		FSS	Up/Down	Commercial
12.750— 13.250	500		FSS	Up	Commercial
13.250— 14.000	750				
14.000— 14.500	500		FSS	Up	Commercial
14.500— 14.800	300		FSS	Up	Commercial
14.800— 17.300	2500				
17.300— 18.100	800	K	FSS	Up	Commercial
18.100— 20.200	2100		FSS	Down	Commercial
20.200— 21.200	1000		FSS	Down	Military
21.200— 27.500	6300				
27.500— 30.000	2500	Ka	FSS	Up	Commercial
30.000— 31.000	1000		FSS	Up	Military

Diagram B–2. Spectrum Usage

The more detailed breakdown of the spectrum usage depends on the country in question, because so much of the spectrum allocation is still handled at a national level. Diagram B–3 shows the C to Ka–band breakdown for the UK.

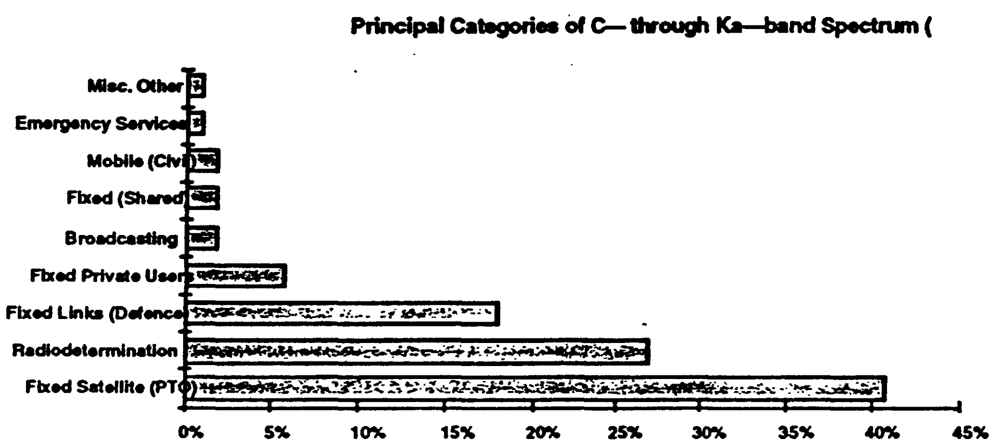


Diagram B–3. Spectrum Categories for the UK

APPENDIX C APPLICATION SUMMARY TABLES

The following tables summarise the application demand for frequency (F) and bandwidth (B) in the L/S, Ku and Ka bands. **Table C-1** applies to 1993, whilst **Table C-2** applies to 2003. The demand for these resources for the following services is addressed in these tables:

- fixed telephony
- broadcast TV
- other TV (SNG, teleconferencing etc.)
- business / VSAT
- aeronautical and maritime mobile
- land mobile
- mobile telephony (PCN).

The following key should be used in conjunction with these tables:

—	Not Applicable
F	Frequency
B	Bandwidth
+	Increasing demand
-	Decreasing, or no, demand
=	Static demand

	Fixed Telephony	Broadcast TV	Other TV (SNG etc)	Business / VSAT	Mobile: Aero, Maritime	Land Mobile	Mobile: PCN
L / S					F = B =	F = B =	F = B =
Ku	F = B +	F + B +	F = B =	F = B =		F - B -	
Ka	F - B -	F = B =	F - B -	F - B -	F - B -	F - B -	F - B -

Table B-1: 1993 Demand

	Fixed Telephony	Broadcast TV	Other TV (SNG etc)	Business / VSAT	Mobile: Aero, Maritime	Land Mobile	Mobile: PCN
L / S					F = B =	F + B +	F + B +
Ku	F + B +	F + B +	F = B =	F + B +		F = B =	
Ka	F = B =	F + B +	F = B =	F + B +	F = B =	F = B =	F + B +

Table B-2: 2003 Demand

Appendix 3

GEOSTATIONARY ORBIT AND SPECTRUM RESOURCES

THE WAY FORWARD FOR REGULATION

- Report to Participants -

Workshop Friday 8 October 1993
KPMG European Business Centre, Brussels

The workshop comprised an interim presentation of results to date of a study on geostationary orbit and spectrum resources commissioned by the EC, at which comments from participants were invited. There follows a summary of the main points raised during the above workshop. The points are itemised under the headings used during the day.

Shortcomings

- There are complexities associated with identifying the degree of scarcity that exists in the FSS, these difficulties should be addressed at some stage in the future.

- Polarisation and geographic discrimination are issues that need to be considered when looking at the issue of scarcity.

- 80% of satellites in the United States serve the US domestic market and 60% of European satellites are international in nature.

- The issue of scarcity and the regulations affecting the allocations of frequency resources and the access to the orbit is a world-wide issue, not confined to any particular ITU region. Because many satellites serve several regions simultaneously, this problem cannot be entirely solved in one region without affecting the other regions. Nonetheless, significant improvements are possible if effective reforms are implemented within particular regions.

- The current system of allocation in the unplanned bands and the current operational characteristics of satellites represent a very delicate balance. It is very difficult to change the current regime without making the situation worse. It would be necessary to take very detailed technical advice before any changes were proposed.

- Both the WARC 77 and 88 plans (Planned BSS and Planned FSS, respectively) were cited as examples of misconceived modification to existing regulations, although the intent of these plans was to improve the situation.

- In the 77 plan the rules of allotment provided five channels per country in the Ku-band (downlinks in the 11.7 - 12.5 GHz band) for domestic coverage, with orbital locations spaced every 6°. This took up significant amounts of resource without each country requiring such resource. In the 88 plan there was an attempt to introduce more flexibility by making the orbital location somewhat flexible. The idea was that allotments might be moved around, but in practice, as a result of ongoing modifications, nobody knows at any given time what is the exact state in terms of implementation of the plan. This makes it very difficult to implement the 88 plan in practice.

- It was agreed that fixing the technical parameters for use of orbit and frequency resource is very inefficient.

- There was agreement with the general view that the use of the plans is difficult in practice.

- It was pointed out that both plans were nationally orientated and this represents a significant problem when it comes to assessing the economic efficiency of the use of orbit and frequency resources. The national orientation of the plans is somewhat inevitable given that the ITU is an ensemble of countries under the auspices of the United Nations, which has around 180 members. A major principle is that any country is as entitled as any other to orbital spectrum. This applies equally to, for example, an African state or a European state. It is a political requirement that countries should have equal rights to the geostationary orbit and frequency resource. This is a significant problem for introducing market orientation.

- It was pointed out that the 88 plan for FSS was very nationally orientated and that this did not match the ability to develop services on a European basis, or the logic of pan-European services.

- The provision of set bands was asserted to be more efficient from the point of view of the use of orbit and frequency resources. This contention was disputed to an extent by a counter-assertion that allocation of such set bands did not very significantly improve efficiency of use of orbit/frequency resources. In addition, it will be difficult to locate bands for pan-European use (eg. VSAT uplinks).

- It was stated that the ITU was not one regulator but, rather, the sum of 180 country regulators. The system whilst equitable leads to many countries not using vested rights. A major point is that the intent behind the planned bands is being flouted by countries using their allotments for non-national uses.

- The regulatory shortcomings identified in the KPMG presentation were generally recognised. It was pointed out however that if one should go outside the GSOSR then at least some of the problem might be relieved (eg. LEOs). It was further pointed out that it would be necessary for any regulatory regime to cope with the provision of satellite services from other than the GSOSR. Technologies that would permit the provision of services from locations closer to the earth's surface are being developed under the ESA's Archimedes project.

- It was pointed out that the interference calculations being used by operators were very pessimistic and therefore contributed to the problem of artificial scarcity.
- It was felt that it might be possible to use the existing plans to pool resource for a combination of countries. In this way it would be possible for Europe to pool its allotments. It was pointed out that the ability to do this was analysed in scenario 2.
- It was pointed out that a threat from substitute services existed. It was asserted that satellites were often more expensive than terrestrial alternatives. Another alternative view was that until more efficient regulation was introduced into the satellite area the potential for providing services more efficiently could not be tested fully.
- A final suggestion in this part of the debate was that allocation tables should be redesigned around systems rather than services.
- KPMG concluded that inefficiencies with the current allocation system arose mostly because of its nationalistic and bureaucratic nature. These shortcomings could mostly disappear with an appropriately regulated market orientated system.

The Scenarios

- The KPMG scenarios included a distinction between deregulation at ITU Region 1 level and at the European (only) level.
- A question was asked whether our scenarios were formalising the Tongasat situation. The reply was that Tongasat was an example of organisations and countries exploiting the existing regulations. Our proposal was not therefore for the formalisation of Tongasat per se but more for creating a rational framework within which leasing or sale of LDC rights could take place.
- The Tongasat example illustrates that quasi market forces are starting to circumvent the intent behind existing administrative procedures.

The Model

- There was a number of questions concerning the internal workings of the model. It was pointed out that these would be explained more fully in the main report. There was however explanation of the key principles of the model and it was pointed out that the model was based on sound and rigorous economic theory and practice.
- The model assumes that the distribution of footprints among satellites in the sky does not change over time.

- Regulation should be able to respond to changes in demand. It should not stifle adjustment.
- It was asked who would be the winners and who the losers under a scenario which led to the consolidation of satellite operators.
- There was discussion about an appropriate cost function. It was agreed that significant economies of scale accrued for a company to operate up to five satellites and then smaller economies accrued up to nine or ten satellites per operator. It was pointed out that this pattern of the economies of scale was included in our cost function.

Institutional Change

- It is key to determine whether any alternative supranational allocation and assignment regimes must inherently cover the whole world or just regions or sub-regions. One view is that anything below a worldwide regime would create problems. Any system within a region or sub-region could be exploited by organisations from outside of that region or sub-region.
- An alternative view was that pooling of national allotments in the planned bands would be a way of moving towards a more economically efficient usage of orbit and frequency resources.
- It was argued that a regional or sub-regional coordinator allocating orbit and frequency resources would be a very large and bureaucratic organisation.
- It was pointed out that the ERO detailed spectrum investigation could harmonise frequencies in Europe. It should be possible to have two or three key European orbital positions instead of twenty national orbital positions. This could become logical if individual countries were to delegate their rights over the access to the orbit and frequency resources.
- It was argued that pooling would not be possible outside the planned bands. It was argued that coordination would have to take place with too many other networks to be feasible.
- A question was asked as to whether Germany could give up its rights over the Copernicus assignment to another organisation such as Eutelsat. It was pointed out that it could not transfer the rights it has for the Copernicus satellite but it could reach an agreement with another organisation such as Eutelsat for it to use the resources for other purposes. It was pointed out however that the alternative use ought to be in conformity with the technical specifications of the original assignment.
- A view emerged that in the planned bands the pooling of resources was not a problem as long as the individual countries retained underlying international rights of use.

Procedural Changes

- It was pointed out that in Germany it will be possible for any organisation to apply for access to GSOSR. The German authorities intend levying a fee for this service. It will be the German authorities that interface with ITU but the coordination work would have to be undertaken by the applicants.

- There was debate as to the ability to auction resources to private organisations. It was suggested that if an auction was for the right of access rather than the ownership of resource then this would be consistent with the current regulations. It was pointed out that if any sub-region or region auctioned the right to use any combination of orbit and frequency resource the resultant user would still have to be coordinated along traditional ITU regulatory lines.

- There was discussion whether it might be made contingent by a sub-region coordinator that the right to supply a service to their area was dependent upon proceeding through the auction procedure. This was accepted as a possibility.

- Planned bands were favoured by less developed countries to ensure that they had equitable rights to the geostationary and spectrum resources.

Terms and Conditions Changes

- Due diligence ("use it or lose it") would have to be applied on a world-wide basis in order for it to be most effective. If due diligence was only applied at a European level by a European coordinator it could be more difficult for the Europeans to implement new systems than for others. It was pointed out, however, that as most Region 1 satellites operated within the European area then the problem of coordination could be reduced by changing conditions at a European level. It would not be possible to eliminate the problem of tying up orbit and frequency resources for up to a nine year period when dealing with organisations outside the jurisdiction of the sub-regional coordinator, but coordinations with the organisations within its jurisdiction could be significantly speeded up. An acknowledged risk is that a local due diligence would drive operators to seek licences to operate from countries outside the sub-region. Hence it would be important to develop measures geared to addressing this risk.

- Transparency of parameters and consistency of criteria would be of paramount importance in the application of due diligence procedures.

- Auto-compatibility was a concept explained to represent the principle of not imposing constraints on other networks that those networks would not be prepared to accept themselves. It was pointed out that this technical method would be consistent with the economic principles underlying the modelling and scenario development.

Competition Policy

- It was asserted that Eutelsat Article 16 has never been applied as a tool to deny access to other users. It was also pointed out that at least the procedural requirement to coordinate with Eutelsat persists in the current environment.

Technical Policy

- It was felt that reform of the planned bands would significantly improve the ability of operators to provide space segment. It would be possible for fewer satellites to use more frequency so as to provide more capacity from any given location, therefore improving the efficiency of operation and the efficiency of use of geostationary orbit and frequency resources.

- Military bands were of marginal interest as they were generally either in too low or too high frequency bands.

- The issue of scarcity is not uniform across the spectrum. There are certain parts of the spectrum which are particularly scarce. An example was given of the bands for feeder links to serve mobile which were very difficult to find.

- Digitisation will help to remove problems of scarcity but not to the extent of a five-fold improvement.

KPMG Conclusions

- There seemed to be broad agreement at the meeting that greatest efficiency would be achieved by reforming the method of allocating and assigning geostationary orbit and frequency resources at the world-wide scale. There also seems to be consensus however that getting agreement on such change would politically be very difficult. There was no opinion expressed as to whether it was worth attempting to gain reform at the world-wide level. It was pointed out, however, that it would be necessary to give less developed countries an incentive to reform existing regulations. Such an incentive might be the potential of realising some revenue by formalising a method for leasing rights to access their allotments. It might be by promoting the fact that changes in regulations would be very likely to reduce the cost and therefore the price of provision of satellite services. This would potentially lead to the greater accessibility of telephony and broadcasting and other satellite services in less developed countries. This would be a potentially very cost effective method of introducing advanced communications into these countries.

- Some participants felt that pooling in the planned bands offered significant potential for improving the efficiency with which resources were allocated. Other participants however felt that the difficulties of coordinating under existing regulations with organisations outside the jurisdiction of the sub-region or regional body would significantly reduce and potentially undermine any benefits that might accrue. With regard to other regulatory changes there was some agreement that the introduction of due diligence procedures did hold out a potential for improving efficiency of use of geostationary orbit and frequency resources. There was again, however, a dispute as to whether this would have to be applied on a world-wide scale or whether it could also yield benefits if applied at a regional or sub-regional level.

- There was consensus that releasing resources tied up in the planned bands would yield practical benefits to operators in the industry.
- The needs and positions of developing countries need to be taken into account.
- It is the rights to *usage* of the resources with which we are concerned, rather than the resources per se.

Appendix 4

ECONOMIC PRINCIPLES TO BE FOLLOWED IN REGULATING THE SATELLITE INDUSTRY

This section describes the broad principles that might be adopted in developing the regulation of the GSOSR resource along economic lines rather than the existing administrative regulation. These address the main shortcomings of the current system that were described in Section 2. They are also the key principles underlying the development of the regulatory options described in Section 5 and form the basis for the fundamental relationships incorporated in the model, described in the Phase 1 Working Paper and in Section 6. These key principles were developed in consultation with the external economics advisers to the study.

In an ideal world, if all these principles applied and market forces were allowed free reign, this would lead to the position that economists refer to as "Pareto optimality". At this point there is no possible trade that would not make at least one party worse off than the current (equilibrium) position. This is a minimum condition for maximising welfare.

"Recognise and use competition and competitive markets as the cheapest, most efficient, least arbitrary and bureaucratic, and most decentralised information system."

The importance of information to the implementation of competitive markets was highlighted above. In a competitive market, all the information available on a particular product is summarised in its price. In general the closer you get to a competitive market, the more accurately prices reflect the information available and the more efficient it becomes. This is in contrast to efforts by regulatory authorities to "second guess" the market, as in the case of estimating the auction value of bandwidth or spectrum without actually holding an auction.

"Allow supply and demand to determine price and quantity."

This is the key requirement for the functioning of a proper market in any commodity and could be viewed as the defining characteristic of a market. In terms of GSOSR, this requires the free interaction of the demand for transponders by service providers and the provision of transponder capacity by operators.

The current framework for allocating GSOSR resources is far removed from the market solution. To the extent that there is scarcity in GSOSR, this suggests that price and/or quantity are unable to shift sufficiently to adjust to market conditions. This is further supported by reports that transponder prices are significantly affected by the influence of the Tos as shareholders in the satellite operators, service providers and competitors.

"Recognise scarcity as a result of a controlled price or a fixed supply relative to the free market solutions."

Scarcity/surplus are not absolute factors inherent in the products being considered (in this case, GSOSR). The extent to which there is scarcity can only be measured relative to the market (or equilibrium) solution. The existence of scarcity or surplus is a sign that markets are not allowed to operate freely or are adjusting to new conditions. Scarcity depends on a number of factors.

In the satellite industry, price, technology and regulation all significantly restrict supply. For example:

- the price of an operating licence is currently effectively zero. This has resulted in artificially high demand for slots and the "paper satellite" problem, as there is no "opportunity cost" to holding a licence and not doing anything with it. If operators paid the full market value for the licences, they would be under pressure from their shareholders or financiers to earn a return on the resource, either by using it or selling it on,

- while satellite technology is evolving rapidly, the long lead times, high start up cost and low operating cost of space segment mean that it is introduced only gradually. The lag in the implementation of new technology can create temporary scarcities,

- the current regulatory framework allocates blocks of spectrum to specific services (eg BSS). This creates artificial scarcity by removing these blocks from other uses and reserving them for services for which there is insufficient demand. The various regulatory frameworks for competing terrestrial services can also give them a competitive advantage vis a vis the satellite alternative.

If prices were freely allowed to adjust to shifts in market conditions, scarcity would become at best a transitory occurrence. The market would shift to a new equilibrium at which there was no excess supply or demand.

"Optimally, pricing should be based on marginal cost and price elasticity of demand of different user groups."

This states that the equilibrium price in a free market will depend on (for the supply side) the sensitivity of costs and therefore profits, and (for the demand side) on the sensitivity of demand to changes in price, that is, on consumers' willingness to pay.

The marginal cost to a supplier is the cost of providing an additional unit of the product, for example, an additional transponder. If this is lower than the market price, the supplier therefore has an incentive to sell more in order to increase profits. Conversely, if the marginal cost exceeds the price there is an incentive to cut back on supply.

In the case of demand, the price elasticity measures the sensitivity of consumers to shifts in the price. If demand is elastic, then a small change in price can have a large impact on the quantity demanded. Demand for many satellite applications (eg telephony) is likely to be elastic, because there are normally better terrestrial substitutes. A small increase in the price of the satellite service relative to the terrestrial competition will therefore lead to a large shift in demand away from the satellite option. Where demand is inelastic (eg in VSAT or SNG services for which terrestrial alternatives are poor substitutes, or for services where the satellite cost is a very small part of the total) then shifts in the price will have little impact on the quantity demanded. Elasticity can also differ between user groups. For example, business users are likely to be less sensitive than domestic customers to the price of a satellite mobile telephone.

The interaction of these two factors helps to determine the equilibrium price and quantity at which demand meets supply.

"Recognise the existence and role of economic rents"

Economic rent arises not from the replacement cost of the resource but the value of its use in relation to alternatives. Users of satellite facilities buy a service package which includes:

- the cost of the physical resource, including R&D, manufacture, launch, maintenance and marketing,
- the right for it to be in a particular orbit,
- the right to use particular frequencies.

The value they attach to the package depends on the price and availability of alternatives. The price of these alternatives depends on:

- the cost of alternative physical resources, especially optical fibre cables,
- the cost of wayleaves and other rights to use particular physical routes,
- the regulatory structure and what it allows profits to be.

The relative cost of cable versus satellite as a physical resource has varied over the years. Currently cables are cheaper for most of the distances found in Europe and hence are the preferred choice for TOs. Satellites may have a cost advantage on certain intercontinental routes. Quality differences can be important. Geostationary satellites have disadvantages for voice telephony even over long distances because of speech delay, although low earth orbit (LEO) satellites are substantially free of this. Satellites are a relatively flexible resource capable of being brought into operation or redeployed without the need for time-consuming and costly expenditure on terrestrial infrastructure. In some parts of the world (eg Eastern Europe, Southeast Asia) this makes them a viable commercial alternative. Satellites may have other niches where they are cost-effective against fibre cables, for example in point to multipoint data distribution and SNG.

The existence of specific technical advantages is not on its own sufficient to ensure that they sustain high satellite prices but they will tend to do so in conditions where competition between satellite operators is imperfect.

In some cases satellite operators may be able to offer a range of competitive services to business users because of effective differences in regulations governing leased line and satellite use. Some of these services would not be viable if users were allowed the unrestricted use of leased lines at cost-based tariffs. Value added by the satellite operator offering a better network management service than the PTT will assist viability.

A potential value for GSOSR is created if regulation allows profit margins on international tariffs to be high and access to the physical cable resources is restricted. If international tariffs are driven down toward cost and free access to terrestrial (including undersea) cables is allowed, the most that GSOSR should be worth is the difference between the physical resource cost of satellite and terrestrial resources. If satellites are more expensive in these circumstances, no operator will be willing to pay anything at all for GSOSR because there is a cheaper alternative.

Economic rents exist in other parts of the communications industry. American cable TV operators have at times been valued at a considerable premium to the value of their physical assets because of the value of their local infrastructure in a monopolistic environment. Profit regulation is being tightened up to reflect this. The high price paid for some mobile licences, notably in Greece, reflects an expectation that restricted market entry and weak regulation will allow high profits to be made.

For a cetain set of applications, it may be that satellites have such a large cost advantage against alternative means of provision that they must create a shortage in GSOSR. Perhaps the best indicator that this might be the case is the demand from Third World countries, where ground infrastructure could be unduly costly to construct and maintain. The rapidly expanding TV markets of Asia and the Pacific region could also lead to such a demand.

Spectrum is essential for mobile communications and there is ample evidence that customers are prepared to pay a premium for mobility, in a market that ranges from the level of the domestic cordless phone upwards through cellular systems to the global roaming systems being devised for the top slice of the market by Motorola, Inmarsat and others.

It is factors like these which create economic rents. They also provide a basis for charging more than the administrative cost of the resource to:

- allocate spectrum efficiently,
- increase the efficiency of its use.

"The economically appropriate technology should be used - no gold-plating for technology's sake alone."

From an economics point of view the optimum technology is the one that generates the most output from a given set of inputs. The adoption of this technology is a natural result of free markets - a company using less efficient old technology will lose its customers to one using the latest equipment that is able to set a lower price. The phenomenon of "gold-plating", where companies use equipment with capabilities beyond market requirements, is common in industries that are insulated from market prices. This occurs, for example with the US utilities, where price is related to return on capital, and with some TOs, where management is dominated by engineers and there is little or no competition. The use of the wrong level of technology and quality levels, driven beyond what consumers would be happy to pay for in the case of, for example, water and some US utilities, or falling below what the market would like to buy if they were allowed to such as in Eastern Europe or Greece, is inefficient from an economic point of view.

Any technology that uses more inputs (including financial) than necessary to satisfy demand is economically inefficient. However, in the satellite industry high start-up costs and long lead times, as well as techniques to extend the lifetimes of satellites, mean that there is a considerable lag before new technology becomes widely adopted. The lack of exposure to the market exacerbates the problem. Even in the US, where the industry is more exposed to market forces, the FCC had to urge the industry to adopt 2° spacing as a response to scarcity in orbit resources.

"The use of property rights is vital for a functioning market in transponders, orbit and spectrum."

The property rights that are inherent in the enjoyment of rights to exploit GSOSR are important in defining the scope of the market. The less flexible the licence and the narrower the rights allowed to the licensee, the less likely it will be that the optimal market solution will be reached.

Property rights are also necessary to ensure "fair play", ie, that all users and potential users play by common rules. These can be enforced by recourse to some higher authority. The fact that the ITU members generally abide by the Radio Regulations is vital to international frequency coordination. Even though the ITU lacks enforcement powers, until now at least rational self-interest (in mutual non-interference) has dictated mutual respect for assigned rights.

At national level, it is essential that special or exclusive rights to enjoy GSOSR assignments be abolished, such that national PTOs and other dominant incumbent space segment providers become subject to the same licensing regime as any other player; and that appropriate licence selection procedures be elaborated based on objective, transparent, non-discriminatory criteria. At present, the presumptive eligibility of favoured national players to provide space segment -- in their own right or via the ISOs -- severely distorts the European market for space segment provision by creating a class of specially privileged rights holders. It is necessary that the playing field be levelled to assure equal opportunities to qualify for access to GSOSR. Otherwise the market for space segment provision in Europe will remain fundamentally distorted.

Another fundamental issue in terms of creating a market in GSOSR concerns the tradeability of licences. Allowing licences to be freely tradeable (or what is effectively the same thing, allowing the companies holding them to be freely bought and sold) would allow any company that thinks it can make a better profit to buy either the licence itself or the current operator/space segment provider. This knowledge puts pressure on the incumbent to operate efficiently. When assignments are enjoyed by major players, such as the dominant European PTOs, tradability of licences is essential because it would be irrational (not to mention politically problematical) to purchase a PTO in order to obtain a relatively marginal asset.

Other areas where definition of property rights is important in relation to the market for space segment provision are:

- scope of licence: should the licence provide broad rights to use a particular orbit/frequency to provide any service, or should it specify the particular uses to which the resource can be put? The former is more flexible and therefore likely to lead to more efficient resource utilisation - a company providing a service for which there is little demand can either switch services or (providing there is tradeability) have its rights bought out by another company providing a more appropriate service,

- duration of the licence: a very short duration licence bestows limited property rights on the holder. This can inhibit investment, particularly towards the end of the licence period. The longer the duration, the greater the incentive to invest, in the knowledge that there will be sufficient time to earn a return. The most efficient solution would be to give licences in perpetuity (which is not inconsistent with the current model typical of most EC member states). However, it is often argued that because the GSOSR is a limited resource there are moral difficulties in giving away the rights to exploit it forever. There is a close parallel with land, which is also in fixed supply and where the owner has property rights in perpetuity.

"Recognise the unavoidable existence of imperfect competition in telecommunications, whether land or satellite-based"

Telecommunications is an industry characterised by significant economies of scale, creating barriers to entry through the existence of fixed costs. Marginal costs tend to fall as output expands, so that they are generally below average costs. Under such conditions there is no market solution where setting price equal to marginal costs creates an optimal solution from a welfare point of view. All operators have to sell at prices in excess of marginal cost if they are to cover their costs, including the cost of capital.

The industry would be a natural monopoly if it were not for the existence of moderating factors:

- technological change makes existing assets obsolescent and creates openings for new entrants,
- most firms operate with less than perfect levels of competence,
- no firm has perfect knowledge of the future, creating planning opportunities for others.

Any equilibrium that exists depends on the balance of these forces, barriers to entry and the extent to which regulation creates or removes other opportunities.

Imperfect competition creates the opportunity for firms to make more than 'normal' profits by restricting output and raising prices but it does not ensure that they can. Some telecommunications operators make low profits because political pressures keep the tariffs down. Others, especially in the international area, have been able to exploit their position very successfully.

One consequence of these factors is that market prices may be poor representations of the economic cost of alternatives and may lead to wasteful resource allocation if used for this purpose.

A second consequence is that, since marginal costs cannot be used as market prices, there is a need to find the 'second best' prices which maximise public welfare within the constraint that the industry must make adequate profits. This applies to GSOSR and other satellite resources as much as it does to general TO services.

"The sum of producer and consumer surplus is a generally accepted measure of overall social welfare."

Consumer surplus refers to the economic benefit which accrues to consumers from the opportunity to acquire goods at prices lower than they would be prepared to pay. This arises because individual tastes differ. Just as at any particular price a number of consumers are not willing to buy the product, there are also consumers that would still buy if it were a higher price. The difference between what the consumer would be prepared to pay and what they actually do pay is therefore a measure of their "profit"; and this can be used to measure the welfare benefit to consumers.

Producer surplus measures the benefit which producers secure when market conditions allow them to sell their output at prices higher than the minimum they would require as an incentive to supply. This occurs in cases where the price is higher than the average cost of production. This situation is generally associated with markets where there is limited competition, as is the case in many telecommunications sub-sectors including satellite communications. Producer surplus is therefore equivalent to "excess" or "supernormal" profit and measures the welfare benefit to suppliers.

The total of consumer and producer surplus is therefore a measure of the welfare benefit to society as a whole. This is the measure that we have adopted in the modelling work. It should be noted that this measure can be weighted to reflect society's views on political issues, such as income distribution or the relative importance of consumer and producer welfare benefits.

"Where possible all externalities should be internalised in the price system."

Externalities can be viewed as spillover effects from the production of a good or service that have an impact on other firms or consumers. A typical example is pollution, where a manufacturer maximising its own profit causes harm to others through reducing the quality of the air or water.

In the satellite industry, interference is an externality. This is addressed through the administrative mechanism of the Radio Regulations. Another example is the spillover from R&D carried out in the satellite industry into other industries. For example, other high technology industries may benefit from improvements in miniaturisation arising from satellite R&D, without contributing to the costs of that R&D. Economic theory says the externality will be internalised where possible by creating a market whereby one side compensates the other. The final outcome will depend on who has the associated property rights. Under the current system, the existing operators (even of "paper satellites") have the right not to be interfered with by new entrants. Introducing a market with appropriate property rights would mean that new entrants could either design their systems so as not to interfere or could compensate incumbents.

Similar market mechanisms have begun to be introduced in the area of pollution. Countries are beginning to adopt the "polluter pays" principle and the US has introduced tradeable pollution rights.

"Eliminate asymmetric or imperfect information to the extent possible."

Markets work best when information on prices, quality, etc, is widely available to all potential consumers. Asymmetrics arise when one party has access to information that the other party does not. Imperfect and incomplete information arises when no parties have all the necessary information to reach the equilibrium trade. Where there is asymmetric or imperfect information, the market fails to function properly. A typical example of this is the market for used cars. The seller knows whether the car has been treated well or whether it is a "lemon", but the buyer does not. As a result, prices of all used cars, both good and bad, are substantially lower than new, with the reduction far more than would be expected to arise from purely physical depreciation. This is also the case where competitors have to provide information to operators such as Eutelsat (with anti-competitive covenants) on their future planned filings, but the reverse flow of information is not required.

In the satellite market, the limited number of trades, the rapid pace of technological change, and the presence of large monopolistic companies (such as the TOs and the ISOs) all serve to limit the free availability of information. At the very least they attach a high cost to obtaining it. The lack of information creates uncertainty and risk, which has a cost which will be reflected in the cost of capital and through that into market prices; it also worsens investment decisions.

An example of the distortions caused by information asymmetries is the reported problem that Eutelsat experienced with its Signatories when it informed potential purchasers of its transponder prices. As purchasers have to go through a Signatory in order to buy transponder capacity, this provided them with information on the Signatories' markups which might have assisted in the negotiations. The Signatories in this case were acting to preserve the information imperfection to enable them to price substantially above cost.

"Use economic notions of sunk costs and opportunity costs rather than accounting costs. Likewise for economic vs accounting profits."

Accounting definitions of costs and profits generally differ substantially from economic definitions. This is understandable given that they have different objectives. In particular, economic theory places considerable weight on the concept of the "opportunity cost". This is the cost or value of the next best alternative, as being the opportunity that the agent foregoes in undertaking a particular option. Economic profits, which exclude return to capital, are usually lower than accounting profits, which are calculated by deducting costs (excluding interest payments) from sales.

The "paper satellites" phenomenon can be used to illustrate this. As assignments are typically free, the cost of having a slot and not doing anything with it is zero. There is therefore a strong incentive to hold licences, either for future use or to limit competition. If, however, licences were valued at their market rates (which would depend on the expected returns from the use of the resource), the opportunity cost of holding the licence and not doing anything with it would be much higher. This could be measured either in terms of the return that the company could have made if it had invested the money elsewhere or in terms of the financing cost of borrowing the money to buy the licence.

In terms of profits, economic theory includes the notion of "normal" profit which is the level at which no new firms are attracted into the industry and no existing firms leave it. This would correspond to the total market return on the capital employed in the business. As indicated above, where competition is restricted, firms can make more than normal profit over the long term without it being eroded by competition from new entrants. This situation exists in the satellite industry where there are considerable barriers to entry, few firms and the presence of large monopoly TOs.

"Operational and allocative efficiency should be encouraged."

Efficiency has two aspects:

- operational, or 'X' efficiency, defined as minimising the cost of a given output,
- allocative efficiency, whereby resources are allocated between alternative uses in the most efficient way.

Operational Efficiency

In economics, efficiency is defined in absolute terms, either minimising the cost of producing a given output or (what is essentially the same thing but measured in physical terms) maximising the production from a given set of inputs. Not using the resource at all (eg, "paper satellites") is generally likely to be inefficient. However there may be situations when it is better to hold on to the resource now in anticipation of more efficient uses in the future. The decision to do this would weigh the opportunity cost of not using the resource against the potential future returns.

The economically efficient position depends on the technology available. The high initial capital costs, rapid pace of technological change and barriers to entry suggest that an economically efficient use of the GSOSR resource is extremely unlikely in practice. The implication for the regulatory regime is that it should provide incentives to utilise GSOSR efficiently. One way of doing this is to ensure that operators face the true opportunity cost of the resource. However, an alternative that is often used is to use licence conditions to impose technically efficient solutions, ie, limiting the amount of GSOSR used. This has been used in the US, for example:

- the adoption of 2° spacing,
- limiting cellular licences to 2 x 25 MHz and HDTV to the existing UHF bands which were opposed by the industry but ultimately stimulated appropriate technical change.

These need not necessarily be the economically efficient solutions, however. A solution that uses the least amount of spectrum to provide a service may actually require more of other resources and cost more than one that uses a different combination of resources including more GSOSR.

Allocative Efficiency

Under conditions of perfect condition market prices equal marginal cost, which maximises welfare because otherwise:

- for goods priced below marginal cost, marginal demand is being satisfied at a cost greater than the goods are worth to the marginal buyer,

- for goods priced above marginal cost, users who are prepared to pay more than the marginal production cost but less than the market price are being denied the product.

In such a case aggregate welfare would be improved by producing less of the underpriced goods and using the resources to produce more of the overpriced goods, prices being adjusted to market clearing levels in both cases.

Under imperfect competition arising from scale economies this position cannot be reached but there will be a second best set of prices which maximise welfare subject to an adequate level of profits being made.

"If monopoly or anticompetitive situations and behaviour exist, follow modern principles of economic regulation."

This principle basically means that to the extent competition is limited, then regulation is necessary and the regulatory framework should attempt to replicate the pressures of competition. The shift in many government policies towards an increased role for the private sector in recent years has been accompanied by developments in regulatory economics to provide appropriate tools for regulators to deal with public and private sector monopolies. These include:

- price caps, which generally limit the percentage by which the company can raise prices to the rate of inflation, less an amount to stimulate efficiency improvements. Price caps are administratively and theoretically superior to the rate of return regulatory criteria that are still common in the US and elsewhere;

- non-linear tariffs allowing, for example, discounts for bulk purchases and in general more accurately reflecting the underlying cost realities such as the distinction between network access and usage;

- pressure for cost-based pricing;

- limitation of monopoly rights to "essential" areas;

- Ramsey pricing, which relates tariffs to demand elasticities, that is, to the willingness to pay of various user groups.

Price caps in particular are becoming increasingly used to regulate large, privatised utilities, for example in the regulation of BT in the UK.

"Let the Coase Theorem work - allow optimising arrangements to evolve freely rather than imposing them or attempting to anticipate them."

The Coase Theorem basically says that if property rights are well defined and the costs of reaching an agreement are relatively low, then an optimal (efficient) market solution will develop, that is, the market will find a way without outside regulatory intervention. Coase argued strongly for deregulation of the radio spectrum on these grounds. Even in the highly regulated, anticompetitive satellite industry, quasi-markets are developing. These attempt to find a way around the artificial barriers to entry and trading imposed by competition. Levin[15] highlighted a number of such developments. Examples from Levin's article and elsewhere include:

- leasing of transponder capacity by Intelsat, Hughes and Palapa of Indonesia;
- RCA-GTE paying $2 m a year to Telesat Canada for use of transponder capacity on ANIK-C until required in Canada;
- a proposed joint venture between Pacific Satellite Inc. (PSI) and the government of Papua New Guinea (PNG) that would allow PSI to use PNG orbit assignments in return for providing free domestic circuits. This is similar to the current controversy over Tongasat;
- SES/Astra's use of FSS spectrum to provide DTH services.

"Give due consideration to the concepts of public good, common property resources and intellectual property."

It is often claimed that the nature of the GSOSR resource should preclude it from the free market solution, as this would not be an equitable allocation of welfare. This is usually used to support arguments for administrative planning type regulation and argue against competitive solutions. In particular, it is argued that the GSOSR is a public good, and that its global nature means that it should be treated as a common property resource and under these conditions market solutions may not maximise social welfare. These concepts can be described as follows:

- a public good is defined as one where consumption by one individual does not reduce its availability to others, for example, street lighting, a lighthouse, defence, radio or TV broadcasts. The problem arises because individual consumers have an incentive to understate the price they would be prepared to pay for the product in the belief that someone else will pay. It is therefore argued that regulation is required to reach the optimum provision of the good,

- a common property resource is one which is not owned by an individual, for example, fisheries. This can lead to problems of over exploitation as individual users have little incentive to utilise it efficiently. It is therefore argued that regulation is required to prevent over-exploitation of the resource. This argument can be used to defend the position of LDCs, which argue that without regulation, by the time they are ready to make use of the GSOSR it will have been taken up by the developed countries. However, this could be addressed by appropriate definition of property rights and introduction of markets. For example, the LDCs could sell or lease rights to their BSS allotments until they are ready to use them.

Intellectual property rights are a particular issue in a rapidly changing industry which is at the forefront of new technology, such as satellites. The introduction of Pioneers' preference in the US was justified by the need to stimulate innovation. However, as indicated in Section 2, this

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[15]Emergent markets for orbit spectrum arrangements - H. Levin, Telecommunications Policy 1988.

is primarily a result of the regulatory procedures adopted in the US, and there are other methods available for protecting intellectual property.

"Use criteria and procedures that are objective, transparent and non-discriminatory."

These principles apply to any regulatory situation. The more objective and transparent the regulation, the less uncertainty the players face and the more likely they are to reach the optimal solution. It is therefore important to minimise the level of regulatory risk to companies in the industry.

It should be noted that there may be situations where discrimination is necessary. For example in UK telecommunications the old monopoly TO (BT) is price controlled while the newer competitor (Mercury) is not in order to provide an incentive for the new entrant. At present, however, in the satellite industry the regulations tend to discriminate in favour of the incumbent monopoly or quasi-monopoly organisations.

Appendix 5

Modelling Theory

The exposition of the basic assumptions, the modelling of the deregulation and the outside parameters is done in a non-technical manner because of the readership of this report. Details on the technical aspects of the model are available on request from KPMG Management Consulting in London. It should be noted that the model and the results have been checked, approved and fully agreed upon by two of the leading experts in the field: Europe based Professor Damien Neven (Lausanne University) and US based Professor Marcellus Snow (Hawaii University).

Basic assumptions of the modelling structure

The model assumes that there is one service offered at a single common price. The price and quantity (number of transponder equivalents) of the service made available is determined as if the whole industry was operated by a single firm. In that way the benefits (profits) for all participants are maximised. This implies that price exceeds marginal cost, and in the satellite industry average cost also.

We provide here a brief non-technical summary of all the assumptions made in the final version of the model used:

Determination of price and quantity

The model assumes that there is one service offered at a single common price, following consultation with our economic advisers. Altering this assumption would complicate the results and presentation considerably without adding to the basic insights of the analysis. The rationale for this assumption is that on the supply side transponders can be treated as homogeneous. Demand is of course for different uses and our aggregate demand estimates take into account the varying demand types. For the purpose of the modelling exercise however, the demand for different types of services is assumed to have similar characteristics and it is therefore possible to consider total demand for transponder equivalents in the satellite industry.

The price and quantity (number of transponder equivalents) of the service made available is determined as if the whole industry was operated by a single firm. In that way the benefits (profits) for all participants are maximised. This implies that price exceeds marginal cost, and in the satellite industry average cost also.

Average cost pricing

A number of operators, notably Intelsat and Eutelsat, are forced to price in a way that guarantees a given return to capital. In economic modelling terms this would be approximated by assuming that these operators are setting price per transponder equal to the average cost per transponder, so that turnover just covers costs and profits (economic) are zero.

Our model however is analysing the industry in terms of final services offered. This includes purely commercial operators (eg. Astra) and the PTTs (who are the major buyers of the Eutelsat and Intelsat). Very few, if any, of these final service providers are subject to any of the constraints faced by Eutelsat and Intelsat. We therefore maintain the assumption that the whole industry sets price as if it was a single firm, trying to maximise profits rather than setting price at average cost. This of course implies that the profits that Eutelsat and Intelsat could be making if they were free to price like the other operators, are distributed amongst the other players in the industry and the final service providers.

Determination of costs and number of operators

The satellite operating industry in Europe and Region 1 is quite fragmented and we therefore assume that the costs of operating the total number of satellites is distributed amongst a relatively large number of operators. This implies that the benefits of economies of scale are not exploited and operation is not carried at the minimum (average) cost possible.

Utilisation

We assume in the "Base Case" that all available transponders are fully utilised. The reason is that the model aims to assess regulatory changes rather than describe in detail short run fluctuations in demand. We recognise however that utilisation may and does fall short of 100%. As an indication of the effects of lower utilisation, we provide an estimate of the prices per transponder that would prevail if utilisation was 80% in the "Base Case".

We also examine the full effects of significant falls in the utilisation of new satellites launched when operators proceed with their plans (this is the "optimistic" scenario for Region 1 and the only scenario considered for Europe as the "Alternative Case"). In that case the number of satellites launched exceeds significantly the expected demand for their services and therefore the level of utilisation can fall to nearly around 50%. In the alternative case the implications of such a development for the profitability of the whole industry are examined.

Technical parameters

In order to calculate prices per transponder we assume that there are two "typical" satellites:

- the first type of satellite has only Ku transponders, assumed to be 15 per satellite (our 1992 data suggests that the actual number of Ku transponder equivalents per satellite is around 17. This figure is then reduced by 10% to 15, in order to allow for the spare capacity necessary for security reasons ie. if a satellite fails),
- the second type of satellite has all types of transponders (ie Ku, C band and others), a total of between 33 and 37 transponders per satellite. This is derived directly from the plans of the operators.

This allows us to reflect the much higher price charged for Ku transponders relative to C band.

Other assumptions made

- in order to reduce year to year fluctuations in the number of satellites launched we assume that the number of satellites launched every year is a 3-year moving average (MA). This takes into account therefore the possibility that a satellite might be launched but not operated for some time and the fact that there are different launch dates, and

- the number of transponders for 1993-96 depends on the expected demand growth.

Modelling Deregulation

Deregulation is modelled as a "move" of the industry towards the fully competitive outcome. The fully competitive outcome implies a significantly lower price and significantly higher demand (and supply) of transponders. In economic terms this is also the most efficient outcome, since the benefits for both producers and consumers are maximised.

Formally deregulation is modelled as a movement from a monopolistic structure, where the industry operates as if all satellites are operated by one firm, to an oligopolistic structure where the industry operates as if all satellites are operated by X firms, where X is larger than one (this is formally known in economic terms as an X player Cournot-Nash oligopoly). The demand and supply of transponders under an oligopolistic structure would normally approach the fully competitive outcome as X - ie the *assumed* number of operators - increases (the price also falls and approaches the fully competitive price as the *assumed* number of operators increase).

As an indication, with a linear demand curve and linear cost curve, the number of transponders demanded and supplied with a monopolistic industry structure is 50% of the number demanded and supplied under a fully competitive structure. The number of transponders demanded and supplied with an oligopolistic industry structure where X=2, is 66% of the number demanded and supplied under a fully competitive structure. When X is 3, the oligopolistic outcome is 75% of the fully competitive one and when X is 4, the oligopolistic outcome is 80% of the fully competitive one. In our modelling of deregulation, the assumed number of players under each scenario is given below:

SCENARIO	ASSUMED NUMBER OF PLAYERS - X
1 (Market approach in Region 1)	VERY LARGE
2 (Market approach in Europe)	2-3
3 (Partial Markets)	2-3

The "outside parameters"

A number of parameters are taken as given from outside the model:

- costs, the function relating the cost of operating satellites to the number of satellites per "producer" is assumed to be cubic and is derived from the latest Eutelsat data available on total operating costs. It is then adjusted to take into account the fact that there is at least another major operator in the industry (Intelsat). The resulting relationship implies that the efficient number of satellites to be operated (ie where the average cost is at a minimum) is 9,

- **elasticity of demand**, we estimate a linear demand function. In order to derive this function we assume that the elasticity of demand is between 1.1 and 1.2 in 1992 (this is an average of independent forecasts available). We assume that the elasticity is marginally higher for Europe, to reflect the more significant competition faced by satellite operators in that region. We also assume a relatively higher elasticity over the forecast period 1993-96 (between 1.25 and 1.4) compared to 1992, assuming that competition from terrestrial services intensifies,

- **demand growth**, the assumptions made about growth in demand for transponders are taken from independent estimates of the demand level and the market size in the year 2,000, by each service category. These are aggregated into demand for transponder equivalents and then adjusted for Region 1 and Europe, to reflect the relative maturity of the European market,

- **number of satellites**, the 1992 starting figure for number of existing satellites and the number of new satellites launched in 1992. These include all satellites known to be operational at the end of 1992. Where the lifespan of a satellite was unknown it was assumed to be between 4 and 8.5 years depending on the operator (see Appendix 7 for the full list of filings for region 1 satellites and the list of satellites included in the economic analysis),

- **launch plans**, the number of satellites/transponders planned to be launched by all operators every year.. This includes all satellites (ordered and under construction).

- **transponder types**, the number of Ku and total (ie including C-Band and other) transponders in 1992,

Appendix 6

Glossary of Abbreviations

There are a number of terms and abbreviations used in this report.

ACTS	Advanced Communications Technology Satellite, NASA's experimental satellite for the development of GSS transponders, OBP and DSP techniques.
Aloha	A technique whereby multiple users can access the same communications channel, by transmitting wherever the channel is clear, listening for collisions and re-transmitting (after a random period) when a collision is detected.
AOR	Atlantic Ocean Region, one of the three worldwide telecommunications regions defined by the ITU.
Apogee	The point in an elliptical orbit at which a satellite is farthest away from the earth.
Arpanet	One of the first major networks, developed by the Advanced Research Projects Agency of the US Department of Defense and which links many computers (particularly in research institutes and universities) from Hawaii to Sweden.
ATM	Asynchronous Transfer Mode, a broadband networking/switching technology, usually layered on top of SDH.
Bandwidth	A measure of the total transmission capacity of a device; in this case, a measure of the total RF capacity of a transponder.
BPSK	Binary PSK, an RF modulation technique in which a two-symbol alphabet is used, thus achieving lower susceptibility to interference than alphabets with more symbols, such as QPSK, but at the expense of lower data transfer rates.
Broadband	High bandwidth, high data rate.
BSB	British Satellite Broadcasting.
BSS	Broadcast Satellite Service, a type of transponder reserved for the broadcast of signals to multiple users.
CDMA	Code Division Multiple Access, a multiple access method using spread spectrum techniques.
CES	Coastal Earth Station, an earth station on the coast through which signals to/from an SES are transmitted to/received from a satellite. This term is extensively used by Inmarsat.
CME	Circuit Multiplication Equipment, which allows a greater number of circuits to be carried within the same bandwidth by means of compression techniques.

CME	Circuit Multiplication Equipment. Techniques, such as compression, which increase the apparent number of channels supported by the same bandwidth.
DAB	Digital Audio Broadcasting, a system for the transmission of very high quality audio signals using spread spectrum techniques.
DAMA	Demand Assigned Multiple Access, an access technique where bandwidth is assigned to a user, for access by, for example, TDMA or FDMA techniques, when the user demands it. The assignment is requested on a single channel, using a technique such as Aloha, and is assigned for a fixed period.
DBS	Direct Broadcast by Satellite, the broadcast of data (using a BSS transponder) directly to multiple users, rather than via a central terminal for distribution via cable. Used for satellite television. See also DTH.
Downlink	The communications link through which RF signals are transmitted to an earth station from the satellite.
DRS	Data Relay System, ESA's proposed DRSS.
DRSS	Data Relay System Satellite, a system of GEO satellites whose purpose is to relay signals from other satellites in, for example, LEO/MEO orbits, or from space vehicles such as ESA's Hermes or Ariane, or NASA's space shuttle.
DRTS	Data Relay & Tracking System, Japan's proposed DRSS.
DSI	Digital Speech Interpolation, a speech compression technique in which the redundancy (the gaps) is removed from speech channels.
DSP	Digital Signal Processing, digital RF modulation techniques which replace analogue techniques, such as BPSK, QPSK and FSK, and allow much greater bandwidth efficiency.
DTH	Direct To Home, the transmission of TV signals directly from the satellite to a terminal at the home of the viewer, rather than to a central terminal for distribution via cable. This term is used, rather than DBS, when an FSS transponder is used (as is the case on the Astra satellite), rather than a BSS transponder.
Earth Station	The piece of equipment by means of which a user carries out communication with the satellite.
ESA	European Space Agency.
ETSI	European Technical Standards Institute.
FCM	Fade Countermeasures, techniques for combating the effects of rain fade at higher RF frequencies.

FDDI	Fiber Distributed Data Interface, a networking standard based on fiber optics.
FDMA	Frequency Division Multiple Access, a satellite access technique is which multiple users access a single satellite transponder by each accessing it at a different frequency (within the bandwidth of the transponder).
FLMPTS	Future Land Mobile Public Telephone System, a terrestrial mobile communications system that will not be fully defined until the year 2000, and which is in direct competition with satellite mobile telephone systems using LEO satellites.
FM	Frequency Modulation, a modulation technique in which data is transmitted by modulating the frequency of the carrier.
Footprint	The area of the earth's surface that a satellite's transmissions can reach, as defined by its orbit, the transponder power used and the antenna direction (and any shaping resulting from the use of an advanced antenna).
FSK	Frequency Shift Keying, an RF modulation technique in which symbols are used to represent the data being transmitted, with each symbol being represented by a frequency shift.
FSS	Fixed Satellite Service, a type of transponder reserved for point to point communication between fixed earth stations.
GEO	Geostationary Orbit, an orbit with an altitude of 35786km, in which a satellite appears to be stationary over a single equatorial point on the earth's surface.
GSS	General Satellite Service, a newly defined type of transponder, initially experimental use on NASA's ACTS satellite, which offers integrated multiple services.
HDTV	High Definition Television, an emerging set of television standards.
HEO	Highly Elliptical Orbit, an elliptical orbit, such as molnya orbit, whose apogee is 46300km and whose perigee is 1000km.
IDR	Intermediate Data Rate, a satellite access technique in which multiple users access a single satellite transponder using digital carriers separated by frequency division.
IFRB	International Frequencies Registration Board, part of the ITU, responsible for the allocation of orbits and frequencies to satellites.
IOL	Inter Orbit Link, a communications channel between satellites in different orbits, for example LEO to DRSS/GEO.

IP	Internet Protocol, the network layer protocol originally developed in the early 1980s for use on the Arpanet, and since adopted by many other networks and network standards (including FDDI).
ISDN	Integrated Services Digital Network, a networking technique which unifies data and voice communication into a single medium.
ISL	Inter-Satellite Link, a technique using either RF or lasers for communication between satellites.
ITU	International Telecommunications Union, the UN agency responsible for the worldwide regulation of satellite communications.
LEO	Low Earth Orbit, a satellite orbit between 500 and 1500km.
LOS	Line of Sight, which needs to be maintained between a satellite and an earthbound terminal if communication is to be carried out.
MAC	Multiplexed Analogue Components, a family of TV signal transmission standards which includes C-MAC, D-MAC and D2-MAC (a half bandwidth version of D-MAC, requiring some sacrifice in picture quality but more suitable for existing cable systems, particularly in France and Germany).
MBA	Multi-Beam Antenna, an advanced antenna in which the beam is split into several sub-beams, each covering a specific geographical area and accessible separately by using a different frequency.
MEO	Mid Earth Orbit, an orbit higher than LEO, but not as high as GEO.
MSS	Mobile Satellite Service, a type of transponder reserved for mobile communications.
NASA	National Aeronautics and Space Administration.
OBP	On Board Processing, an emerging technology in which much of the routing of data takes place on board the satellite, rather than being carried on the earth.
PCN	Personal Communication Network, usually a personal telephony network.
Perigee	The point in an elliptical orbit at which a satellite is closest to the earth.
PSK	Phase Shift Keying, an RF modulation technique in which symbols are used to represent the data being transmitted, with each symbol being represented by a phase shift.
PTO	Public Telecommunications Operator. A PTT that only deals in telecommunications. There might be more than one PTO in a country, as is the case in the UK.

PTT	Post, Telegraph and Telephone, the national, normally state-owned organisations that, until recently, controlled all satellite communications.
QPSK	Quadraphase PSK, an RF modulation technique in which a four-symbol alphabet is used, thus allowing greater data transfer rates than alphabets with fewer symbols, such as BPSK, but at the expense of greater susceptibility to interference.
RA	Radiocommunications Agency, the UK licensing authority for the operation of telecommunications equipment and services (including satellite-based systems) within the UK.
RF	Radio Frequency.
SCPC	Single Channel Per Carrier, a technique whereby multiple users can share a transponder by each being allocated a separate channel within the total bandwidth.
SDH	Synchronous Digital Hierarchy, a high speed networking architecture.
SES	Ship Earth Station, an earth station aboard a ship. This term is extensively used by Inmarsat.
SMS	Satellite Multi Service, a type of transponder, with very limited availability, capable of handling multiple services.
SNG	Satellite News Gathering, the use of satellites for the transmission of news pictures from a camera to (for example) the home studio.
SONET	Synchronous Optical NETwork, the American equivalent to the international SDH.
Spread Spectrum	A technique for the transmission of signals by spreading them over the entire bandwidth of the receiver/transponder, with the signal only recoverable by means of a key, identifying those parts of the total bandwidth which make up the signal.
SSSO	Specialised Satellite Service Operator, a type of UK licence granted for the operation of satellite services. Now largely bypassed by deregulation.
TCM	Trellis Coded Modulation, an RF modulation technique which offers superior spectral efficiency to mobile systems.
TDMA	Time Division Multiple Access, a satellite access technique in which multiple users access a single satellite transponder by each accessing it at a different time.
TDRSS	Tracking and Data Relay Satellite System, NASA's implementation of a DRSS.
Terminal	An earth station.

TES	Telephony Earth Station, an earth station used for telephony. Used as a product name by Hughes.
Transponder	The piece of satellite equipment which receives signals from an earth station on the uplink, amplifies them, changes their frequency (normally a downshift) and re-transmits them on the downlink.
Uplink	The communications link through which RF signals are transmitted to the satellite from an earth station.
VR	Virtual Reality, which can be described as being inside a computer generated world. Once there, a user interacts with objects and/or other users, the latter by means of broadband networks.
VSAT	Very Small Aperture Terminal, a terminal which uses a small (say 1m) dish.
WARC	World Administrative Radio Conference, the ITU-organised forum at which decisions about the allocations of the RF spectrum are made.
WATTC	World Administrative Telephone and Telegraph Conference, the ITU-organised forum at which decisions about international terrestrial telecommunications are made.

Appendix 7

Orbital Locations of Region 1 Geostationary Satellite Filings

Name	Position °E
EUTELSAT I-F2	1
TELE-X	5
EUTELSAT II-F4	7
EUTELSAT II-F2	10
EUTELSAT II-F1	13
EUTELSAT II-F6	13
ITALSAT 2	13
ITALSAT 2	13.2
AMOS 1 & 2	15
EUTELSAT II-F3	16
ASTRA 1A	19.2
ASTRA 1B	19.2
ASTRA 1C	19.2
ASTRA 1D	19.2
EUTELSAT I-F5	21.5
GALS (3 at 23 °E)	23
DFS KOPERNIKUS 1	23.5
EUTELSAT I-F1	25.5
DFS KOPERNIKUS 2	28.5
ARABSAT 1-C	31
TURKSAT -1B	31
DFS KOPERNIKUS 3	33.5
STATSIONAR-02 (RADUGA 22)	35
EUTELSAT I-F4	36
EUTELSAT II-F5	36
STATSIONAR-12 (GORIZONT-12)	40

TURKSAT-1A	42
GALS (2 AT 44 °E)	44
STATSIONAR-09 (RADUGA 19)	45
STATSIONAR-24 (RADUGA 1-1)	49
TURKSAT -1C	50
STATSIONAR-05 (GORIZONT-17)	53
INTELSAT 507	57
INTELSAT 604	60
INTELSAT 602	63
INMARSAT 2 - F1 (INDIAN OCEAN)	64.5
INTELSAT 505	66
PANSAMSAT (PAS-4)	72
INSAT-2A	74
ASIASAT 2	77.5
STATSIONAR-13 (GORIZONT-16)	80
STATSIONAR-03 (RADUGA-20)	85
STATSIONAR-06 (GORIZONT-20)	90
INSAT-2B	91
INTELSAT 501	91.5
STATSIONAR-14 (GORIZONT-19)	95
STATSIONAR-T (EKRAN-19)	99
ASIASAT 1	105.5
STATSIONAR-15 (RADUGA 21)	128
GMS-4 (HIMAWARI-4)	140
STATSIONAR-07 (GORIZONT-18)	140
SOVCANSTAR	145
INTELSAT 511	177
INMARSAT 2-F3 (PACIFIC OCEAN)	178
STATSIONAR-10 (RADUGA-18)	190
ATLANTIC SATELLITES (2)	229

Satellites: Final

EKRAN 15	297
USASAT 13E	302
USASAT 13D	304
INMARSAT 2-F4	306
INTELSAT 513	307
INTELSAT 506	310
ORION F-2	313
PANAMSAT (PAS-1)	315
PANAMSAT (PAS-3)	317
COLUMBIA (TDRSS ATLANTIC)	319
INTELSAT 504	319.5
ORION F-1	322.5
INTELSAT 603	325.5
MARCOPOLO 1	329
STATSIONAR-D5 (RADUGA-16)	329.1
HISPASAT 1A	330
HISPASAT 1B	330
HISPASAT 1C	330
INTELSAT 601	332.5
STATSIONAR-08 (RADUGA 23)	335
INTELSAT 605	335.5
INTELSAT 502	338.5
INTELSAT K	338.5
TV SAT 2	340.8
EUROPESAT 1	341
EUROPESAT 2 & 3	341
OLYMPUS 1 (L-SAT)	341
TDF-1	341.2
TDF-2	341.2
INTELSAT 515	342

INMARSAT 2-F2	344.5
SOVCANSTAR	346
STATSIONAR-04 (GORIZONT-20)	346
STATIONAR-11 (GORIZONT- 15)	349
TELECOM 2A	352
TELECOM 2B	355
TELECOM 1C	357
INTELSAT 512	359
MARCOPOLO 2	359.2

REGION 1: SATELLITES
Existing in 1992

Asiasat	1	Astra	1	Columbia	1	3
DFS	3	Eutelsat	4	Inmarsat	1	8
Intelsat	7	Marco Polo	2	Olympus	1	10
Panamsat	1	Statsionar	4	TDF	2	7
Telecom	2	Tele-x	1	TV-Sat	1	4
TOTAL						**32**

(of which Europe are 26)

NEW LAUNCHES IN 1992

Astra	1	Eutelsat	1
Inmarsat	2	Intelsat	2
Italsat	1	Telecom	1
TOTAL			**8**

RETIREMENTS IN 1992

Statsionar	-1
TOTAL	**-1**

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