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LEOS

HEARINGS ON NON-GEOSTATIONARY MOBILE SATELLITE SYSTEMS (LOW EARTH ORBITING SATELLITE SYSTEMS : LEOS) BRUSSELS, 9-10 NOVEMBER 1992

RAPPORTEURS' REPORT

COMMISSION OF THE EUROPEAN COMMUNITIES

HEARINGS ON NON-GEOSTATIONARY MOBILE SATELLITE SYSTEMS (LOW EARTH ORBITING SATELLITE SYSTEMS : LEOS)

BRUSSELS
9-10 NOVEMBER 1992

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The views expressed in this report are based on Hearings on Non-Geostationary Mobile Satellite Telecommunications Systems held in Brussels on 9-10 November 1992 and may not necessarily be the views of the Commission of the European Communities, nor of the organisations with which the Rapporteurs are affiliated.

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PREFACE

During the past year, various proposals, mostly from US-led consortia, have been presented for mobile communications concepts which are planned to be introduced for global implementation in the latter half of the decade, based on direct communications between mobile terminals (including hand-held equipment) and non-geostationary satellites.

It is becoming increasingly evident that in addition to the question of spectrum allocation the types of service which are envisaged give rise to a range of policy issues relating to several elements of the Community's telecommunications and space policies which merit early consideration.

The major shift towards personal mobile communications rather than fixed communications which will be introduced by non-geostationary satellite systems and services on a global scale might bring about a revolution, not only in satellite communications but in telecommunications in general as well as in the way of regulating telecommunications services at a global level.

The strategic importance of these systems and services is therefore not to be underestimated and at this early stage, a strategic assessment of all aspects is necessary as input to an overall effort to come to a coherent evaluation of the importance of this type of service for the European market and the European industry, as well as to be able to assess the required efforts in the regulatory and standardisation fields with regard to these systems.

The European Commission has consequently initiated several activities to increase the awareness of the proposals for these systems and to contribute to a policy decision in Europe.

First of all, the Commission delegation to the ITU WARC 92 conference paid particular attention to this question.

Secondly, a European Delegation, led by DG XIII with participation from CEPT, met with the United States Government (Departments of State and Commerce, and the Federal Communications Commission) to discuss the current proposals and to gain a better insight in the US licensing process.

This mission confirmed that a more thorough European discussion is necessary to come to a full appraisal of these systems within the wider scope of the overall service introduction of satellite personal communications systems.

On the basis of this background and experience DG XIII therefore decided to organise the hearings on which this document reports.

1. THE HEARINGS: ORGANISATION AND PROCEDURES

This is a report of the Hearings on Non-Geostationary Mobile Satellite Telecommunications Systems[1], held in Brussels on 9-10 November 1992. The report was prepared by independent experts appointed by the Commission.

The Hearings were called at the initiative of the EC Commission, notably the DG XIII's international affairs division and the division dealing with space-related regulatory issues. In addition to the presenters, the Rapporteurs and CEC staff, some 130 representatives of European telecommunications operators, satellite organisations, equipment manufacturers as well as national regulatory authorities (NRAs) and standards bodies attended the Hearings. (See Annex)

In order of appearance, the following systems were presented:

- ODYSSEY (TRW)
- GLOBALSTAR
- IRIDIUM (Motorola)
- ELLIPSO (Ellipsat)
- PROJECT 21 (Inmarsat)
- CONSTELLATION

Each organisation was permitted to make an oral presentation of one hour. A 45-minute question-and-answer session followed. The presenters were not permitted to question each other. There was a one-hour plenary session at the conclusion of the Hearings during which all parties were allowed to raise questions.

The Commission had asked the presenters to cover seven subjects:

- architecture and organisation of the proposed system: satellite configuration, frequencies and communications plans;

- ownership and structure of the proposed operator: participation, financial and commercial relationships and industrial organisation;

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[1] For the purpose of this report the satellite-based personal communcations systems are called LEOS although not all proposals are LEOS in the strict sense of the word.

- development and implementation of the system: technology and intellectual property rights (IPRs), procurement and sourcing, launching plans;

- frequency allocation and frequency sharing, compatibility with different modulation techniques, interoperability;

- interrelationships between the proposed system and existing or proposed fixed and mobile networks;

- markets for services: voice/non-voice, advanced services, geographical distribution of prospective markets, with particular reference to the market in Europe and European demand for international mobile satellite services;

- status of the proposal with the International Telecommunications Union (ITU), the Federal Communications Commission (FCC), European national regulatory authorities (NRAs), etc.

This Report is organised as follows. Chapter 2 provides the background, setting LEOS in the context of regulatory and technical developments in the overall mobile communications sector. Chapter 3 summarises the individual presentations and the questions raised in subsequent discussion. Chapter 4 compares the six systems, using the rapporteurs' best judgment. The final chapter considers some of the policy issues raised for the Community and the new contenders in the mobile communications market.

2. LEOS AND ALTERNATIVES

Satellites in Low Earth Orbits (LEOS, and their Medium-Orbit and Highly Elliptical cousins, MEOS and HEOS) seek to combine some of the functions of current cellular communication - mobile telephony and paging - with those of present communications satellites: potential global coverage and positioning service. They promise to improve the geographical coverage of cellular and improve the cost and convenience of satellite communications.

The six proposals presented at the Hearings are becoming the subject of increasing international interest and debate. Some of them were important topics at the World Administrative Radio Conference (WARC 92) of the International Telecommunications Union (ITU), held in Torremolinos, Spain in February 1992. The allocation of global frequencies for this new technology represented an important first regulatory step to their global introduction.

The emergence of LEOS as an advanced solution to mobile communications problems owes much to certain particularly American factors on the demand and the supply side.

On the demand side, the existence of large, thinly populated areas poorly covered by cellular services on the one hand, and the limited roaming facilities provided by proprietary, non-standardised digital cellular systems - in contrast with Europe's GSM system - provide a promising potential market. *Nota bene* the same would apply to Western Europe if the build-up of GSM were to be delayed or remain patchy.

On the supply side, the availability of military technologies developed for the communications needs of a global and space power is not matched in Europe.

Mobile Communication Using Satellites

Mobile (voice) communications by satellite were first provided to the maritime world, where the need for reliable links to ships on the high seas was most pressing. For this application, geostationary satellites of modest performance were perfectly adequate since users could install large, expensive terminals on their vessels in exchange for a new service of excellent quality.

As technology progressed, it became possible to design increasingly small terminals, to the point of making them briefcase size, and hence portable. However, providing mobile services to users with hand-held terminals on a quasi-universal basis stretches the technical capacities of geostationary satellites to the limit if not beyond.

To compensate for the very small size of the user terminal, the transmission power and the receiver sensitivity of the satellite would have to be increased significantly, and this can only be done at considerable expense.

Geostationary satellites have two further disadvantages which cannot be alleviated:

- they cannot serve polar regions; and their elevation above the horizon can be fairly low in regions such as Northern Europe. Therefore the link between the satellite and the mobile user is liable to be frequently obstructed by natural obstacles such as buildings and trees;

- the relatively long transmission time due to the length of the trip to and from the satellite may cause objectionable delays in a telephone conversation and in computer-to-computer links.

Resorting to satellites placed in orbits lower than geostationary enables these problems to be solved at once. As the distance between the satellite and the Earth's surface is reduced, less radio-frequency (RF) power is needed at both ends of the link and the transmission delay is shortened. Since the satellite is no longer bound to the equatorial plane, a suitably high elevation angle can be obtained by selecting the orbits properly. The price to pay is that more satellites are now necessary to ensure service continuity and their number increases as the height of the orbit decreases.

Despite the above-mentioned drawbacks, geostationary satellites are already used by operators who will have captured some of the markets targeted by LEOS.

On a global scale, Inmarsat will be offering its Standard M shortly (digital transmission and briefcase size terminal). With the deployment of its third generation of satellite in 1995, this service should appeal to both mobile and fixed users in all regions of the world where the terrestrial infrastructure does not meet user needs.

The two American and Canadian MSAT satellites will be available in 1995 in North America and Mexico to support services similar to those offered by Inmarsat.

In Europe, the space segment for EMS (European Mobile Service) developed by ESA will be in place in 1995. It will cover Eastern Europe and will support the operation of MSBN (Mobile Satellite Business Networks) also developed as part of ESA's telecom programme.

The market of fixed users in regions where the terrestrial infrastructure is underdeveloped or non-existent is already being addressed by many operators of VSAT networks using 'traditional' satellites such as INTELSAT, EUTELSAT and PanAmsat. All forecasts show that activities in this sector will grow rapidly in the coming years.

GSM - Europe's Terrestrial System

The present generation of analogue cellular systems provides no cross-border roaming facilities. With GSM, Europe has now made a strong commitment to a single standard digital system allowing continent-wide, high-quality mobile

telephony, paging and fax services. The integration properties on the user side are matched by market integration (and competition) offered by a single standard on the supply side.

In fact, GSM - Global System for Mobiles, formerly Groupe Spécial Mobile - is the first pan-European communications standard. Commitments to 27 GSM networks in 17 European countries have now been made: 16 by established TOs, and the rest by competitors. The GSM standard has already been adopted in countries worldwide, including Australia, New Zealand, Ukraine, Russia, Singapore, India, Hong Kong and the Gulf States.

GSM services were launched in many European countries during 1992. Mannesmann Mobilfunk in Germany was the first to begin, in July. It was soon followed by Radiolinja in Finland, Deutsche Telekom, Sonofon in Denmark and France Telecom. Many others have since switched on their networks.

3. THE SIX PRESENTATIONS

The presentations, made under the rules described in Chapter 1, frequently covered similar ground. Some of this information is covered in Chapters 4 and 5. Here, we merely summarise the distinguishing characteristics of each of the systems presented.

ODYSSEY

Summary

(1) TECHNICAL

No of satellites Altitude (km) Mass (kg)	6→9→12 10 354 1 200
Multiple access	CDMA

(2) ECONOMIC

A. BUSINESS	
Investment	$ 800 million
Market forecast Fee structure	1.5% of cellular capacity: 2 million worldwide $ 0.65/min (shared) $ 24/month service charge
Geographic	Northern hemisphere Full system: global
B. INDUSTRIAL	
Key investor/technology provider	TRW Matra Marconi Space
Other	Cellular companies as 'strategic partners' (JVs) (Hitachi)
European value-added opportunities: industrial	• Satellites (MMS; TRW in US) • Launch services • Gateways • Local procurement of handsets
European value-added: services	• Resale & distribution • Equity participation, esp. by TOs

Technically, the distinguishing characteristic of this system is the choice of a medium rather than low orbit - 10 000 km rather than the ± 1000 km

preferred by most other systems. Odyssey claims life-cycle costs of one third of its other low-cost competitors.

The advantages claimed for this particular choice are:

- savings on the number of satellites required. This advantage is partially offset, however, by a satellite mass (1200 kg) three to six times those of the true LEOS;
- capacity can be expanded gradually, from 6→9→12 satellites, serving northern land masses initially and expanding to true global coverage;
- high elevation, hence fewer obstructions by houses, trees, etc.

In response to a question, it was admitted that the high elevation caused by the ME orbit seems to require some 'customer cooperation' inside buildings. This is partially compensated by high penetration paging.

Questioned on the health and safety aspects of the output wattage of the handset, the presenter stated that US studies had indicated that 1 W was safe, so 0.5 W presented no problems.

The Odyssey proposal calls for much of the switching function to be done by TOs and/or mobile operators rather than in the space segment. This raised the issue of interconnection arrangements with the TOs for wholesale telecommunications services, cost factors, assumptions about retail prices and billing to end users.

Arrangements with terrestrial mobile operators for retailing Odyssey services were noted as another critical factor which will affect the realisation of business plans.

This was all the more important since, in response to a question regarding the share of the European market in the company's business plan, the presenters gave the figure of 30% of total traffic.

A question was raised, if not answered, as to what Odyssey's fall-back plan will be if no business arrangements are possible with the required range of European TOs and/or mobile operators.

GLOBALSTAR

Summary

(1) TECHNICAL

No of satellites Altitude (km) Mass (kg)	48 1 389 300-350
Multiple access	CDMA

(2) ECONOMIC

A. BUSINESS	
Investment	$ 1 500 million
Market forecast Fee structure	0.7%/2% of cellular by 2001/2006 $ 20/month service charge
Geographic	Northern hemisphere Full system: global Europe: 25% (inferred) Global roaming with special terminals
B. INDUSTRIAL	
Key investor/technology provider	Loral Qualcomm
Other	Alcatel Aerospatiale Alenia DASA
European value-added opportunities: industrial	- Satellites: sole source contract - Launchers: limited competition - Gateways: 2 sources, locally negotiated contracts - Terminals: open under Globalstar type approval or: - Space segment: 50-60% - Terrestrial segment: 50% - Terminals 25-35%
European value-added: services	• Gateway operation • Resale & distribution

Globalstar is a relatively ambitious system giving full global coverage and allowing, at extra cost, global roaming. More than most others, Globalstar bases its market forecast on reaching countries with underdeveloped infrastructure, lacking cellular systems or adequate telephony in general.

Globalstar presenters stressed the decentralized nature of the system, with 100 to 150 gateways requiring only a 'simple addition' to existing cellular or PSTN infrastructure.

Terminals will be either single mode (for countries without cellular), bi-modal, or multi-mode (several cellular + Globalstar). Interfaces will be provided not just for digital but also existing analogue systems.

Globalstar forecasts gaining 37% of the global roaming market, or 150 000 subscribers of this high-value market by 2006. Total predicted subscriber base is 1.5 million by 2001, and 5.2 million by 2006.

IRIDIUM

Summary

(1) TECHNICAL

No of satellites altitude (km) mass (kg)	66 765 400
Multiple Access	TDMA
Gateways	

(2) ECONOMIC

A. BUSINESS	
Investment	$ 3.4 billion
Market forecast	1% of cellular/PCN by 2002 1/2% of paging call charge: $ 3
Geographic	Global coverage Global roaming
B. INDUSTRIAL	
Key investor/technology provider	Motorola
Other main technology providers	Lockheed (satellites) Raytheon
European value-added opportunities: industrial	• Launch services • GSM gateway switch • Local production of handsets by Motorola and licensees
European value-added: services	• Gateway operation • Resale & distribution

The key technical characteristic of this (the most ambitious) system is its stress on maximum user convenience achieved at the expense of greater technical complexity.

Intended to provide true global roaming facility via a lightweight, universally useable handset, the Iridium project is the only one to require intra-satellite communication and hence substantial on-board processing.

One commercial implication of this choice - evident in a projected call charge of three dollars, against around 0.65c for other LEOS and cellular - is that long-distance service is provided by Iridium rather than existing international carriers.

Technical Description

The space segment of the system consists of 66 satellites in circular orbit at the lowest altitude[2] - 765 km - of any of the proposed systems. This accounts for the large number of satellites. Given this constellation, and the marketing concept of global roaming, the system must be installed all at once.

Intersatellite links are seen as the most reliable and cost-effective means to link all elements of a global distributed network. They are claimed to reduce ground infrastructure costs, although the system requires call set-up gateways and terrestrial GSM or other PSTN gateways at the receiving end. The built-in geo-location facility (needed both for purposes of national control and to find any roaming subscriber worldwide) also requires substantial signal processing capacity.

A major claim, and crucial to the user-friendliness of the design, is that communication can be guaranteed at all times, e.g. from a car (basically because of a large number of satellites in low orbit permitting line-of-sight contact in most cases, except deep inside buildings).

Market Concept

Iridium will both complement and compete with existing cellular services. It expects to account for 1% of the cellular/PCN market by the year 2002, and less than 1/2% of the paging market.

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[2] Ellipso reaches an altitude of 426 km at its lowest point, but the apogee of 2900 km over its operational area in the northern hemisphere is more relevant for comparison.

Handsets are to be dual mode, with preference given to terrestrial (GSM) cellular services when and where available, or where no compatible cellular coverage exists for a visiting subscriber.

Multiple access will be via the TDMA rather than the CDMA mode.

Corporate Structure and European Participation

Iridium Inc. is an internationally held private corporation under US law.

Motorola Inc. is presently the only major shareholder in Iridium Inc., although it plans to reduce its share holding to 15%. Discussions are underway to form a politically balanced consortium of between 5-8 members from Europe, Asia and North and South America. Other equity investors will be the gateway operators - some 20 worldwide.

Motorola is to be the prime contractor for the first generation of the space system and will retain intellectual property rights for the system as a whole. Lockheed and Raytheon are likely to be chief subcontractors. Launch services may be procured in Europe.

The core switch may be supplied, *inter alia*, by a European supplier. Handsets, including for export, will be manufactured in Europe, with additional manufacturers to be licensed by Motorola.

Iridium sees itself as complementary to Inmarsat's present services and has offered Inmarsat capacity on an exclusive (international air and waters) and non-exclusive basis.

During the debate the question was raised whether Motorola was assuming the entire risk in this venture. The answer was 'no'. There is an appropriate 'escape clause'.

A delegate questioned the 16 dB link margin proposed.

Motorola said that it will make available its intellectual property rights (IPRs) to others at commercial rates. It was pointed out that most of the 'sophisticated costs' would be in the earth segment with the terrestrial TOs and mobile operators.

It stated that Inmarsat had been approached to be part of the Iridium venture. In this regard, it was Iridium which noted that Inmarsat has an unfair competitive advantage due to its status as a treaty-based International Satellite Organisation (ISO).

There was some question about Iridium's claim to use 'proven technology', notably as regards the intersatellite link, with Iridium arguing that on-board switching was essentially limited to a packet switching application.

ELLIPSO

Summary

(1) TECHNICAL

No of satellites Altitude (km) Mass (kg)	12→18→24 426/2903 200
Multiple access	CDMA

(2) ECONOMIC

A. BUSINESS	
Investment	$ 280 million
Market forecast	min. 250 000 600 000 worldwide $ 60c/min = 42 + 18 TO margin
Geographic	US/northern hemisphere Southern system later
B. INDUSTRIAL	
Key investor/technology provider	Mobile Communications Holdings, Inc. Matra Group Fairchild
European value-added opportunities: industrial	- Space segment via components sourced in Matra Group - Local gateways ?
	• Resale & distribution

Ellipso is a low-cost system with - initially - partial rather than global coverage. The key characteristic of this system - its elliptical orbit - is designed to meet financial as well as technical optimisation criteria.

Technical cost advantages of this particular design stem from the ability to concentrate capacity in areas of effective demand, saving on the number and size of satellites required. Satellites will be 'simple radio relays' with a short lifetime (5 years) to allow upgrading.

The 12 (later 18) satellites to be deployed in the first phase will have their apogee over the northern hemisphere. This means a larger proportion of total orbiting time is available for the markets which are to provide revenue for the first years. Indeed, the company expects the US market alone to assure profitability, which is expected to be achieved - at 'cellular prices' - with only 250 000 subscribers. Ellipso expects a total 600 000 subscribers worldwide.

The design does not provide continuous high quality coverage in the southern hemisphere until the third phase, when an additional 6 satellites (for a total of 24) will be deployed with their apogee over the southern hemisphere.

The drawback of partial coverage extending only gradually from the US is thought to be offset by the low-risk advantages, with initial financing limited to the requirements of the launch and core market, the US.

The large footprint resulting from high altitude reduces the number of earth stations required.

Corporate Structure and European Participation

Mobile Communications Holdings, Inc. (MCHI) is the parent of Ellipsat Corporation (for US operations) and Ellipsat International.

Its major technology partner is Fairchild, a US subsidiary of the Matra Group. European value-added for the space segment seems limited to components procurement from Matra subsidiaries on this side of the Atlantic. Matra's involvement in two systems (it also participates in Odyssey) is noteworthy.

Given Ellipso's reliance on terrestrial operators which will bear the lion's share of the switching and signalling functions associated with reaching end users, the importance of the interconnection arrangements with TOs was discussed and the retail arrangements with mobile service providers was raised once again. Ellipsat did not think it would have a problem reaching agreements with European operators on the same basis as they hope to achieve with those in the US.

As regards regional and international regulatory issues, Ellipso is content to abide by whatever rules are formulated and as yet does not seem to take an active part in the debate.

PROJECT 21

Unlike the other systems presented at the Hearings, Inmarsat's Project 21 is at an early definition stage. The technology, notably the satellite (LEO, MEO, GEO?) has not been chosen, and the markets to be targeted are still the subject of research and discussion among Inmarsat's shareholders, the national TOs. The one element which now links Project 21 with the other systems presented is the ambition to provide global telephony with hand-held receivers.

While Project 21 is behind the others in terms of planning for hand-held mobile, Inmarsat is well ahead in terms of actual presence in space-based mobile communications and telephony. Indeed, for most of its civilian satellite services, it has a global monopoly at present. On the other hand, Inmarsat's current customer base of 20 000 can be compared to Iridium's target of two million subscribers early in the next decade.

Inmarsat's essentially evolutionary strategy rests on a family of services built on successive generations of satellites:

1. Inmarsat-C, for portable mobile data, introduced in 1991

2. Inmarsat-M, briefcase telephone, from late 1992

3. Satellite paging to pocket receivers (1994)

4. Inmarsat-P, global hand-held phone, end decade ?

The parameters underlying present planning for Project 21 include

- hand-held terminal,
  dual-mode (cellular) and single mode models;
- telephony in line of sight of satellite, requiring 'customer cooperation'
  (e.g., moving near windows, leaving car);
- integrated, high penetration paging;
- global roaming via customer smart card;
- built-in position determination.

The space segment has not been specified. LEOS, enhanced GEOS and ICO (intermediate circular orbit) satellite overlay are being considered. Some mixed solutions under consideration call for intersatellite links (cf. Iridium).

Corporate Structure and Procurement

Inmarsat is an international organisation (ISO-status), a partnership of 65 countries. Signatories (national TOs or satellite service provider) hold investment shares and use the space capacity to provide mobile services. The customer base is 135 countries.

Inmarsat stressed its worldwide links with suppliers and service providers, covering the entire chain of value-added involved in space-based mobile communications and its terrestrial distribution.

Major procurement is carried out via open international tender. The manufacture and sale of mobile terminals is also totally liberated, subject to Inmarsat type approval.

During the question-and-answer session, Inmarsat was asked about the status and significance of an offer by Iridium to lease to Inmarsat on an exclusive basis capacity over international waters and international airspace, and on a non-exclusive basis elsewhere. The presenter stated that the offer 'was still on the table' and all options still open.

A question was raised as to the terms under which Inmarsat was allowed to operate in the US market. In response, the presenter hinted at the non-Inmarsat standard required to access Inmarsat capacity via the US Signatory, Comsat.

A questioner raised the issue - hinted at in some of the presentations by referring to 'a level playing field' - of Inmarsat's potentially privileged treaty-based ISO status. Was Inmarsat decision-making sufficiently transparent and accountable? Were there cross-subsidies? The response was that on balance Inmarsat was disadvantaged in the international arena.

A questioner noted that Inmarsat's original mandate is to provide the space segment for communications between ships in non-territorial waters and specific Member States, but not international cross-border communications. There was no clear response as to whether the Inmarsat Convention would have to be amended to cover international land mobile services.

The issue of link margins was raised again in relation to qualitative aspects and signal propagation. Inmarsat pointed out that these matters were under active study.

Health and safety issues were raised. Inmarsat's specification of a comparatively low quarter watt normal output power for handsets (peak power

of 0.5 W) was explained by sensitivity to health matters, especially in Europe. The impact of radio signals from sets held close to the brain is still under study.

CONSTELLATION

Summary

(1) TECHNICAL

No of satellites Altitude (km) Weight (kg)	48 1 020 200
Multiple access	CDMA

(2) ECONOMIC

A. BUSINESS	
Investment	$ 500 million
Market forecast	by 2002
Geographic	Global coverage No global roaming
B. INDUSTRIAL	
Key investor/technology provider	CTA/DSI Inc. (Systems engineer; satellite manuf.) Pacific Communications Sciences (cellular networks)
Other main technology providers	International MicroSpace, Inc. (launchers)
European value-added opportunities: industrial	Although general open procurement announced, partners include a micro-satellite and a launch vehicle manufacturer. Gateways will be procured through national partner. Ditto terminals.
Services	- Gateway operation - Resale & distribution

Constellation Communication Inc. presents its system as primarily business driven, aiming to provide a low cost, low risk service based on proven technology. An early service start-up is planned in order to gain market share.

The system design calls for full global coverage via 48 satellites in a low circular orbit.

In addition to mobile voice telephony, services include fax through PSTN or private network, data connection to packet network, and remote sensor data collection and forwarding.

Corporate Structure and European Participation

Constellation Communications Inc. is at present a partnership of primarily military communications specialists - CTA/DSI, a systems engineering and a microsatellite manufacturer; Pacific Communications Inc., a telecom specialist with satellite and cellular experience; and International MicroSpace, Inc., created to develop a low-cost launcher for micro-satellites.

The intention is to create an international corporation to own and operate the space segment, with European (and Asian) equity participation sought.

There is to be open procurement of space and ground segment. Procurement of gateways and user terminals will be carried out by national TOs.

Debate

The presentation's stress on general open procurement was queried, given the role of hardware providers as 'advisors' and specifications writers, notably for the space segment.

TABLE 1 - MAIN CHARACTERISTICS OF LEOS SYSTEMS (plus Inmarsat 3)

	ODYSSEY	GLOBALSTAR	IRIDIUM	ELLIPSO	CONSTELLATION	INMARSAT 3
Total number of satellites	6→9→12	48	66	12→18→24	48	-
Number of orbit planes	3	8	6	2→3→4	4	1
Type of orbit	Circular 55° incl.	Circular 52° incl.	Circular 87° incl.	Elliptical 64° incl.	Circular 90° incl.	Geo
Altitude of orbit (km)	10354	1389	765	426/2903	1020	35785
Number of satellites per orbital plane	2→3→4	6	11	6	12	4
Orbital period	6 hr	113 min	100 min	2 hr	105 min	24 hr
Satellite life time (years)	10 to 15	8	?	5	5	-
Satellite mass at launch (kg)	1200	350	400	200	200	-
Number of antenna beams per satellite	19	8	48	4	7	7
Frequency bands (GHz)						
- User to satellite	1.6	1.6	1.6	1.6	1.6	1.6
- Satellite to user	2.5	2.5	1.6	2.5	2.5	1.5
- Feeder links	30/20	6/5	30/20	30/20	6/4	6/4
- Inter satellite	n/a	n/a	23	n/a	n/a	n/a
Multiple-access mode	CDMA	CDMA	TDMA	CDMA	CDMA	-
Coverage	Up to global	Global	Global	Up to global	Global	Nearly global
One-hop delay (ms)	Up to 90	Up to 30	Up to 20	Up to 50	Up to 25	250
Start of service	1997	1999	1998	1996	1998	
Additional services	Paging, RDSS DBS-Radio		Paging		RDSS	
Capital invest. (MUSD)	800	1500	3370	280	500	-
FCC experimental license	yes	no	yes	yes	yes	-

4. COMPARATIVE ASSESSMENT

The main characteristics of the proposals are summarised in Table 1. Since Inmarsat has not yet selected any particular configuration for their Project 21, the characteristics of Inmarsat 3 have been included in this table for easy reference.

Optimisation

Although all proposed systems pursue the same broad objective - that is, to provide a digital communications service to mobile users equipped with hand-held terminals - they have opted for quite different configurations. The choice of an optimum configuration is the result of complex trade-offs which take into account many parameters. These include:

- space segment: satellite numbers, lifetime, launch costs
- cost, weight and function of the user terminal
- range and quality of the services offered
- areas to be served
- speed of the implementation of the system
- technical and financial risks.

Coming down from geostationary height to orbits closer to the Earth, the satellites decrease in size and become less expensive to build and to launch. The total cost of the space segment diminishes, but as the number of satellites needed increases, costs reach a minimum before climbing again.

Another element explaining different choices is the extent to which financial and business considerations are paramount, notably shortening the inevitable negative cashflow period and reducing risks. Both Odyssey and Ellipso can start operations with half the complement of satellites needed for full global operations and concentrate on the most promising initial markets in the US and/or the northern hemisphere.

One additional advantage of this flexibility seems to be early market entry. Given that even the US market will be too small to support more than two or three systems, those able to offer service early have an advantage.

Two further technical considerations were stressed in the presentations. The four systems using satellites essentially as frequency shifting transponders - leaving most of the data processing to the ground segment - stressed the advantages of this choice for easy reprogramming. The two systems - Odyssey and Ellipso - which build up the number of satellites gradually also stressed

the potential for technology upgrading. Constellation can claim to share this advantage through the short planned lifetime (5 years) of its satellites.

Last, but perhaps not least, the constellations chosen may also depend on the technologies available to the 'sponsoring' members of the consortia and the markets for hardware and software which space-based mobile telephony promises.

Corporate Structure and Interests

Indeed, given the economic uncertainty (see also below) of introducing commercially and technically untested services on a global scale, it is perhaps legitimate to ask whether the motivation behind these projects stems from market prospects or other reasons. In other words, do these projects offer a solution to well identified needs or, as is often the case, are they 'solutions in search of a problem'?

An analysis of the corporate structure suggests that with the exception of Iridium, all US projects are driven by industrial consortia which include space companies among their major partners:

- Odyssey: TRW, Matra Marconi Space (MMS)
- Globalstar: Loral, Alcatel Espace, Aerospatiale, Alenia, DASA
- Ellipsat: Fairchild, the Matra Group
- Constellation: CTA/DSI (Satellites), International Microspace (Launchers).

It can reasonably be assumed that in these four cases an important motivation is the prospect of creating more business for the space partners.

Iridium, on the other hand, is driven by Motorola, which is the world leader in personal communications and has an obvious interest in expanding its activities in this area. Motorola is also active in space, particularly communications payload as in the ACTS project of NASA. However, Iridium claims that, for them, satellites just happen to be a convenient means of achieving their business objectives.

As for Inmarsat, they are already engaged in the mobile communications field and are naturally looking for new markets.

Market Strategy and Expectations

All proponents offer the same basic telephone service as well as other value-added services compatible with the same data rate, in much the same way as GSM. None of them, except Iridium, hopes to be competitive with terrestrial cellular systems; hence, they expect to find a market in the fringe areas of regions which are developed but not entirely covered by cellular systems, and in less developed regions where there are no alternatives. Beyond the commonality of these broad objectives, the approaches differ in at least two respects.

There is first the *quality and scale* of the service offered. At one end of the range, Iridium aims to guarantee delivery to the end user wherever he is on Earth and regardless of his environment, e.g., even inside a car. At the other end, Inmarsat assumes some 'user cooperation', implying that the user will accept some constraints and tolerate that the service is liable to fail him under certain conditions. All others seem to be confident that their service will be continuous and reliable without, however, making the same claims as Iridium or being as candid about the limits of space-based telephony as Inmarsat.

The second aspect is the *magnitude of the area* served. Here again, Iridium clearly claims universal coverage, at least from a technical point of view, since they recognise that there might be limitations raised by national sovereignties beyond their control. Ellipsat takes the most cautious approach, saying they will start with a minimum configuration aimed at the US market only. Odyssey also proposes to proceed step by step and concentrate initially on the most populated areas of the northern hemisphere.

Even if and when Iridium's four US competitors achieve global coverage, true global *roaming* (a subscriber using his personal handset to access the system anywhere on earth) is a key design feature only for Iridium and Inmarsat's Project 21. Globalstar also promises global roaming with a multi-mode handset able to communicate with several cellular systems. Global roaming is already possible, albeit with a larger terminal, by Inmarsat's system M, now being introduced.

All proponents presented their own forecast of the markets they wish to capture. They assumed that they will have to share these markets with (only) one other LEO operator. Several are competing for same number of subscribers while others are seeking a niche within the total potential market.

One potentially important element is the negotiations underway by several systems to become the supplier for Inmarsat, raising the possibility of Inmarsat plus one or more others merging into a single system.

Telephony

Third world markets are deemed important by Constellation, which stresses a 'huge demand' for remote data collection (sensor monitoring).

All US proponents stated that they will rely on local telecom operators (TO) to promote and provide the service in the various regions where they expect to find a market. All but Iridium stress their role as 'wholesalers', leaving the retail side to their local partners. They will conclude some kind of partnership with each of them on a case-by-case basis. Inmarsat has an obvious advantage here since they already have a natural partnership with many international operators, most of whom hold a *de jure* or *de facto* monopoly in their country.

It is not clear how the US proponents propose to overcome this potential handicap and obtain 'landing rights' outside the US. Neither is it clear why traditional TOs, whose main line of activity is terrestrial communications, would go out of their way to promote a new type of business which would never account for more than a few percent of their total sales.

The Hearings did not bring any real clarification on these points. The particularly European dimension of these problems is raised in the final chapter on policy issues.

Procurement Policy

Given the principle that competitive procurement is a key to cost minimisation, it is useful to examine how the proponents intend to apply this principle.

All US consortia except Iridium include one or more satellite manufacturers among them, as shown earlier. Only one of them, Constellation, has stated that they will follow an open international procurement policy for all segments of their system. DTI, one of their partners, will bid for the space segment along with the rest of the world.

Iridium favours the sole source approach although they have no structural ties with any space company. For the space segment, they have selected Lockheed, which they consider to be the world leader in small LEO satellites.

Except for Inmarsat, which has a long tradition of open procurement, all others will rely on 'internal' procurement, at least at the satellite level, accepting competition for subsystems, equipment, components, and gateways and launchers. Odyssey stated that their satellites would be co-produced by TRW in the USA and Matra Marconi Space in Europe.

All announced that user terminals would be built to open standards without stating clearly how these standards would be determined.

Reliance on Terrestrial Operators

All systems offer to interconnect mobile subscribers via satellite with some terrestrial network to which the other party has access. This implies extensive use of the switching and signalling capacity of terrestrial operators for routing of calls, a key cost factor for all forms of switched telephony. All except Iridium propose a single hop by satellite to the gateway nearest to the mobile user and rely on the terrestrial infrastructure for the rest of the trip. In the extreme case of a call between antipodes, the signal may have to travel along 20 000 km of cables.

Iridium, for their part, propose to route the signal all the way via intersatellite links in space, if the two ends of the call are not in line of sight of the same satellite. This minimises reliance on terrestrial infrastructure.

In doing so, Iridium reduce their dependence on TOs and protect themselves against the impact of TOs' charges on the price of the service offered to the end user. To achieve this goal, they introduce switching facilities on board their satellites, which they claim implies no particular technological risk. They also claim that the management of a complete switching network involving nodes on board a constellation of 66 LEOS raises no specific problem. It must be noted, however, that no other system has ever attempted to do this before. The projects coming closest to it is ACTS, a single satellite with on-board switching but no intersatellite links; and MILSTAR, a military multiple satellite system with ISL (Inter Satellite Links). Neither has as yet been launched. It is therefore difficult to dismiss this issue as a trivial technological question.

The problem of networking is particularly acute in the Iridium case but in fact exists in all systems. It is generally overlooked because one tends to consider only calls originated by mobile users and destined for well-identified fixed subscribers. However, the system must also cope with calls originating from fixed users and destined for mobile users whose position is unknown to the calling party. To be able to route such a call properly to its final destination, the system operator must have access to the Home Location Registers (HLR) and Visitor Location Registers (VLR) of all TOs concerned. He must therefore ascertain their unrestricted cooperation. For those who, like Iridium, aim at global coverage, this is quite a challenging task.

As none of the proponents claims to have come anywhere near this state of affairs, this aspect of the problem remains very uncertain, with the level of uncertainty proportional to the ambitions of the proponent.

5. POLICY ISSUES

During the Hearings a number of questions were put to individual presenters which raise issues common to all or at least most of them. Further issues were highlighted in the Chairman's concluding remarks. Given the rapporteurs' brief, these issues can only be presented as questions. To find the answers will take half a decade and more.

The issues left open fall into three groups:

- problems of compatibility between the proposals and the emerging European regulatory framework and between US, international (ITU), and EC rulemaking;

- European industrial policy interests, both as regards hardware and telecom services.

- queries about the business plans and technological maturity of the proposals;

As regards business plans, the presenters, except Inmarsat, were at pains to stress the well-proven nature of most of the technology to be used. Yet dual-mode handsets do not exist, nor have the complex problems of networking on a mass scale - quite unlike that required for the military prototypes - been tested. Last but not least, the assumptions being made about market potential remain, in the opinion of some independent analysts, highly optimistic. For Europe, the relevant policy questions arising from the economic uncertainties relate to:

- competition: will there be room for one, two, or more LEOS and, if not, how can potential duo- or monopoly problems be tackled ?

- frequency allocation: Should scarce spectrum be allocated, and for how long, for systems which may only prove themselves - in a race with rapidly improving cellular - in the next decade?

LEOS and the ITU's WARC 92

At WARC 92, held in Torremolinos in the early part of 1992, a number of important Resolutions were agreed upon which affect the future development of mobile and mobile-satellite services. In particular, Resolution COM5/11 on the *Establishment of Standards for the Operation of Low-Orbit Satellite Systems* now provides a framework within which the many issues raised by the LEOS proposals can be addressed by the Members of the ITU.

The ITU is required to coordinate and foster among its Members efforts to harmonise telecommunications developments, including those using space-related technology 'with a view to taking utmost advantage of their possibilities'. It should be noted that Resolutions of the ITU, while binding on its Members, are not enforceable, as no sanctions are provided for non-compliance.

In formulating the Resolution, WARC 92 addressed a number of key issues, including:

- the limited nature of the radio-frequency spectrum and that all Members should have equitable and standard conditions of access to it;
- establishment of rates as low as possible consistent with efficient service and independent and sound financial administration;
- apportionment of accounting revenues from international traffic on an equitable basis;
- signalling and operational interfaces between terrestrial and satellite radio systems and the public telecommunications networks;
- the need for standards governing the coordination, sharing and operation of LEOS worldwide services within the telecommunication network;
- the need to guarantee worldwide protection to existing services and networks, including sharing frequency bands with services already using bands which may be allocated to LEOS;
- the fact that only a few LEOS can co-exist in any given frequency band.

The two basic types of LEOS proposed at WARC 92 were:

- the small 50-100 kilogram class systems, to be used for data communications and store-and-forward messaging services;

- the larger 350-500 kilogram class system, which is also used for data communications but is capable of real-time voice communication into hand-held mobile units worldwide, as well. (The mass of one of the systems proposed at the Hearing is 1 200 kg.)

At WARC 92, the United States delegation proposed a new allocation of radio-frequency spectrum between 1610 and 1626.5 MHz for the large LEOS. This spectrum was allocated to the aeronautical radio-navigation service (on a primary basis) and to the radio determination service (RDSS) in Europe. The Russian Federation and the United States operate their GLONASS and GPS military radio-determination systems in these bands. The WARC-92 agreed to allocation of these services in the major part of these indicated bands on a co-primary basis, subject to various footnotes and restrictions, the effect of which will still need to be analysed.

The small LEO systems were proposed for the bands 137-138 MHz and 400.15-401 MHz for the downlinks (Space-to-Earth) and 148-149.9 MHz for the uplink (Earth-to-Space). The indicated bands have been - and will continue to be - used for meteorological satellite space research and space operation services, but also by mobile and fixed services. The WARC-92 agreed to allocation of these services on a partly co-primary and partly secondary basis, also subject to footnotes (restrictions).

FCC Rulemaking and European Interests

Now that an international spectrum has been allocated for these purposes, the United States' Federal Communications Commission (FCC) has begun a rulemaking process for LEOS. This is likely to result in licences being issued under United States law as early as the fourth quarter of 1993. The European Community does not as yet have a policy for LEOS, although representatives from all Member States attended WARC 92 and agreed with the Resolutions. Thus, there are no licensing procedures and regulations designated expressly for LEOS-based mobile services, either by the Member Nations or at the Community level.

The Hearings had a strong US flavour. This is not a criticism: it reflects the fact that five of the six presentations were US-based and were, to a great extent, US-led. Therefore, it is natural for them to have initiated their regulatory and licensing steps with the FCC. This is particularly understandable when one considers that regulatory frameworks and licensing procedures for these services simply do not exist elsewhere. However, before LEOS-based mobile services can become truly global, other regulators will need to be involved.

While five of the presenting organisations at the Hearings were actively engaged in the FCC licensing procedure, there was far less awareness of the relevant policy and regulatory developments in Europe. Two relevant examples are the Commission's current review of competition in telecommunications services and the proposed EC Directive regarding mutual recognition of telecommunications licences, the creation of a Single Community Telecommunications Licence (SCTL) and a Community Telecommunications Committee (CTC) regulatory body.

Iridium appears to be the most active in dealing with the regulatory and licensing issues. All, with the exception of Ellipso, are already participating in the regional committee work of the ITU, seeking, amongst other things, to implement Resolution 5/11 of WARC 92. Ellipso, at least at this stage, seems content to abide by whatever rules are made without participating in the regional and international rulemaking process.

It was recognised, not least by the Commission, that the policy and regulatory situation in Europe was unclear and would continue to be in a state of flux. Those wishing to introduce new systems were thus facing a regulatory 'moving target'. This adds a regrettable if unavoidable element of uncertainty for these bold attempts to introduce new technology and new global services. Given the very high investment costs of some systems and the financial risks incurred by others, especially those not relying mainly on the US market, LEOS proponents need to have a measure of predictability as to the policy and regulatory environment in order to develop their business plans.

The ITU has laid out the framework within which many of the issues can be dealt with, but it remains a fact that individual jurisdictions ultimately will have to be satisfied that the proposals meet with their approval. Hopefully, the Members of the ITU can deal with a great number of the 'macro' issues in these deliberations, but we believe it remains a fact that even this will require detailed 'micro' work at both the regional (including Community) and domestic levels.

The Community Dimension

Since the publication of the 'Green Paper on a Common Approach in the Field of Satellite Communications in the European Community' of November 1990, the EC Commission has been working towards a Community licensing regime, including new satellite services. This work is in line with the general principles laid out in Directive 90/338/EEC on competition in markets for telecommunication services now being extended to satellite services.

A single Community-wide licence for satellite services would facilitate implementation of some of the principles laid out in the ITU Resolutions referred to as a common and harmonised approach. A Community Telecommunications Committee will be constituted specifically to assist the Commission in implementing the recognised procedure for satellite services.

However, given the scope of LEO proposals and the fact that a majority ownership of the systems will be non-EEC, it is not clear whether these systems will be able to take full advantage of a single Community licensing approach. Even recourse to national licensing applications would require coordination with a number of other important pan-European bodies.

Substantial work will need to be carried out by the European Conference of Postal and Telecommunications Administrations (CEPT)[3]. CEPT should facilitate future licensing of LEOS services in the broader European context, allowing national licensing procedures to be expedited by the setting common conditions and harmonising procedures.

It is envisaged that the specialised body within the CEPT will also need to be consulted: the European Radio Committee (ERC) on frequency matters; the European Radio Office on certain aspects of frequencies; and the planned European Numbering Office (ENO).

Standards

There needs to be agreement on a whole range of technical standards. In the past, the International Satellite Organisations (ISOs) have developed their own detailed specifications for the infrastructure of earth stations, etc. These specifications are well established, but they cannot be defined as 'standards' as we are defining them. Rather, they were specifications designed to ensure interoperability within the confines of the then-existing technical systems.

In Europe, ETSI will be required to carry out detailed work to ensure rapid type approval for the equipment needed to ensure that LEOS networks are established and can operate across Europe. Such standards will be designed to assure, *inter alia*:

- interoperability;
- compliance with the characteristics of the proposed network and existing networks;

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[3] Currently composed of 35 members, including the twelve EC Member States.

- technical compatibility;
- health and safety.

As regards the vexed question of frequencies referred to in the WARC Resolutions, the ERC/ERO would probably need to be given a pan-European mandate to harmonise the frequency bands for LEOS. Otherwise, these matters would have to be dealt with on a country-by-country basis. Furthermore, the ERC/ERO will also need to deal with the sharing of frequency bands. Proposals concerning shared use may further delay the coordination of new services; such delays are often beyond the control of individual national regulatory authorities.

To facilitate licensing of LEOS services, the European Committee for Telecommunications and Regulatory Affairs (ECTRA) could be asked to introduce harmonised conditions for the introduction of a pan-European LEOS licensing regime within the framework of the Mutual Recognition proposals that the Commission is expected to publish shortly.

Each of the applicants will to some degree rely on interconnection arrangements with existing TOs in order to facilitate expansion of their services. Such interconnection arrangements obviously raise significant issues of Community competition law. It may well be that in order to facilitate pan-European interconnection arrangements, these should be the subject of the Mutual Recognition regime referred to above, and in particular of close scrutiny by the NRAs to ensure their timely and efficient implementation. Indeed, under the Commission's proposals, the NRAs would be responsible for granting licences within the framework of the single Community satellite communications licence and for monitoring authorisations to introduce new satellite services.

Objections to granting Mutual Recognition to such licences will have to have an objective and non-discriminatory basis. However, as long as there are no harmonised Community-wide licensing conditions for LEOS, applications for Community licences will have to be dealt with on a case-by-case basis.

There are significant environmental and health and safety issues to be considered. These must be adequately defined as quickly as possible, so that handsets and other equipment can be introduced without adversely affecting the environment or the health and safety of users.

Network Protection

WARC 92 paid particular attention to the need to guarantee worldwide protection to existing services and networks. In particular, the sharing of

frequency bands needs to be resolved, in terms of both frequency spectrum and 'site clearance'. The introduction of LEOS will probably require a number of facilities such as large antennas and microwave installations, whose placement must take account of possible interference with existing services, sensitive areas such as airports or military and government installations, and national monuments and historical sites.

The United Kingdom sets down detailed procedures and contact points for site clearance around airports in a national 'code of practice'. France, for its part, is currently carrying out analyses of the immunity of systems to be protected and how site clearance procedures should function in future.

While site clearance may often be a matter for local authorities, NRAs should continue to play a strong role in assessing the potential for technical interference and the need for efficient and safe site clearance.

These issues relate to the physical protection of existing networks. But there is also the protection of existing network *services*. This a matter of regulation and policy, including competition policy.

Competition

In liberalised telecommunications markets, interconnection arrangements between TOs and their competitors are a central issue. These arrangements cover the linking of different networks and the conveyance of messages between them. They require agreement on technical interfaces on the one hand and revenue sharing on the other. 'Wholesaling' - the provision of switching and network facilities - provide significant business opportunities for TOs. Depending on interconnection arrangements, competitors may share in part of this business. At any rate, the terms of access to (other) networks are a critical cost factor. Hence both the EC Commission and national regulators have identified interconnection arrangements as critical for achieving competition in telecommunication.

LEOS-based mobile operators are dependent on the public switched networks operated by terrestrial TOs to reach the vast majority of end users. To gain access to this infrastructure - switches, local loops and customer access lines - built over decades, LEOS operators must enter into interconnection arrangements worldwide. These include some form of 'retail' arrangement, including billing, marketing, end-user obligations and complaints. All these give rise to potential problems of competition policy.

Obviously, negotiations over territorial fees for 'landing rights' will need to be negotiated with local administrations and TOs. These rates will probably require scrutiny by local competition authorities and, if necessary, by DG IV in the Community context.

Equitable apportionment of accounting revenues on international traffic must also be considered. This was not discussed in any detail in the Hearings or in plenary session, but it remains an important issue, which will have to be resolved between the LEOS and the TOs with whom they are dealing. This question also raises the difficult issue of network 'by-pass', with important regulatory implications.

Competition-related issues are touched on in the WARC 92 Resolution dealing with tariffs. The resolution calls for tariffs to be set as low as possible while continuing to be consistent with efficient service and independent sound financial information. Both national and regional competition authorities will have to monitor compliance with this Resolution.

Other competition-related issues arise from potential equity participation in LEOS by existing TOs. While such participation may make commercial sense, potential anti-competitive effects will need to be examined.

Similar issues arise in relation to intellectual property rights - in particular, whether networks will be 'open' or the technical interfaces need to be licensed.

Industrial Issues

The impact of a comparatively large-scale introduction of space-based mobile telephony on the European aerospace and telecommunications manufacturing industries needs to be considered.

A number of systems, notably Globalstar, already depend on significant European participation in the construction of the global system. As noted above, except for Inmarsat and Constellation, the other proponents envisage 'internal' procurement at least at the satellite level, while accepting competition for sub-systems, equipment components and in most cases, launchers. This will obviously have an impact on the European aerospace and telecommunications equipment manufacturing industries; consideration should be given to maximising the opportunities for European participation wherever possible.

ANNEX

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