Utility Use of Satellite Technology in Emergency Response

An Examination for European and North American Utilities

Prepared for the benefit of members of the

United Telecom Council
By
Joint Radio Company, Ltd.

October 2006

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The Joint Radio Company (JRC) is a joint venture company of National Grid, the UK gas pipeline and electricity transmission operator, and the Energy Networks Association which holds a share on behalf of the electricity transmission and distribution industry. JRC represents member companies in all aspects of radio communications within the UK, to both the European Telecommunications Standards Institute (ETSI) and the Conference of European Posts and Telecommunications Authorities (CEPT) within Europe, as well as within the International Telecommunication Union's Radiocommunication Sector (ITU-R) internationally. JRC manages the block allocations of scarce spectrum for utilities so that it is used efficiently. JRC is engaged in research and serves as technical adviser to the European UTC.

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Executive Summary

0.1 In their response to emergencies of all sizes, utility communications systems have proven themselves among the most robust of any, often providing voice and data communications at times and in places where no other services were available. The principal drivers that have operated since the early adoption of internal communications networks – safety, reliable service to the user and operational efficiency – have not changed. However, in some markets the vulnerability of utility communications systems, especially their mobile communications systems, have come under intense scrutiny in recent years, based on a variety of incidents caused by nature, human error and malicious intent,. This has been compounded in Europe, where many utilities have migrated to public wireless systems to take advantage of cost reductions and a vastly increased variety of services and infrastructure. In the USA, utilities have been less quick to abandon private systems in favour of public networks, but North American utilities' private networks have been subjected to stresses unlike anything seen before.

0.2 These new paradigms, and the increased public scrutiny of the reasons for a failure to deliver up to expectations, have led utilities and similar public safety users to explore alternatives, or supplementary communications systems. In the US, the same explorations have been driven by a search for additional tools to provide reliable communications, especially during emergency response activities.

0.3 A number of options exist to mitigate dependency on the public cellular networks and even on a single, self-provided mobile radio network. One option is to complement public terrestrial mobile telephony services with mobile satellite communications. This report examines the vulnerability of public mobile satellite systems to similar effects as those which prejudice dependence on terrestrial networks, both public and private. While a secondary focus, this report also examines the benefits of satellite data communications, such as advanced telemetry and Supervisory Control and Data Acquisition (SCADA). Our findings: satellite technology provides a useful adjunct to a diverse resilient communications strategy. It is a valuable tool in any communication manager's toolbox. However, satellite technology is not a complete solution, and any deployment for emergency use must be carefully planned and executed to meet response goals.

0.4 Although originally conceived to provide resilient world-wide communications, because of deficiencies in their financial model, most satellite networks have been unsuccessful commercially, and therefore never developed to achieve their complete design capacity, resilience and redundancy.

0.5 For understandable commercial reasons and technical complexity, it is difficult to evaluate precisely the capacity of individual satellite networks, and their predicted availability in a severe crisis. Apart from variable capacity limitations dependent on a large number of conditions, modelling the access protocol to predict possible interactions when loading becomes significant would require a range of assumptions which would be open to challenge. A summary and comparison of satellite services reveal salient points with respect to selection for emergency contingency planning. Some of these include:

- Global satellite communications companies, including Globalstar, offer dual-mode (satellite and terrestrial digital cellular) in order to reduce costs and improve service. In Europe, call translation services (national numbering plans) must be carefully considered as there may be conflicts during emergencies;
- Iridium handsets are comparatively expensive but the technology has the unique ability to route calls between satellites in orbit, without dependency on ground-based infrastructure;
- Iridium has further plans for the development of a portable gateway device capable of interconnecting a variety of communications networks, including public safety. This will allow seamless access to anyone tied to the Iridium network (including land mobile radio), regardless of the destruction of terrestrial infrastructure in an area;
- Inmarsat's primary drawback is that the does not support hand-held devices but the company's BAGN (Broadband Global Area Network) offers universal broadband at very competitive prices.

0.6 In spite of what might appear to be a catalogue of failings and vulnerabilities listed in this report, satellite communications may have a vital part to play in ensuring resilient communications in a crisis. Because they are substantially independent of main electricity supplies and have a separate telecommunication infrastructure, they provide a worthwhile complementary service to ground-based telecommunications networks.

0.7 A significant vulnerability of satellite phones is that they inherently have much greater limitations than fixed or mobile networks, and may be swamped if there is a major widespread crisis which disrupts parts of the strategic national infrastructure over a wide area.

0.8 Call termination requirements for satellite 'phones may make them useless in a crisis unless the called party also has a resilient communications pathway, or is outside of the affected area.

0.9 Failure of satellite communications in an emergency often has more to do with administrative and management failings than deficiencies in the core technology.

0.10 The changing global environment encourages provider companies to address limitations by such actions as constructing new ground stations to increase capacity and expanding their portfolios of services. Recognising a new market emerging for resilient communications in the face of the vulnerability of terrestrial networks, the satellite operators are responding to this lucrative new opportunity. Among new offerings are a Static IP (Internet Protocol) address modem and virtual private network (VPN) capability, potentially useful to utilities for Supervisory Control and Data Acquisition (SCADA) and telemetry to monitor remote assets.

0.11 This report advises that further work is necessary by any interested party to identify the most appropriate solutions for emergency communications in their environment. Once a decision has been reached on the preferred option, it must be rigorously examined and tests conducted where possible to ensure that if needed in a crisis, it performs as anticipated. There is no 'one size fits all' recommendation. Certainly, satellite usage is highly recommended as an integral part of a utility's emergency communications planning, but as utilities have learned in other cases, it is unwise to put all your eggs in one basket.

1. Background

1.1. Mobile communications are a vital ingredient for all utility operations. In the past, pre 1990, utility and other organisations depended on their own mobile communications systems for operational purposes. They owned and operated their own private Mobile Radio Systems (PMR, or LMR), in some cases becoming intimately involved in the design of networks. Utilities were also heavily involved in the development of radio standards to ensure the end product met their exacting standards. The benefits of these systems were that they could be designed with a price/performance ratio to suit the user's specific requirements, and coverage tailored to match the utility's operational area. The only alternatives were car telephones designed for senior business executives and prohibitively expensive, or the use of fixed phones at strategic points. Older industry specialists may remember specially designed phones booths by the road-side provided by the breakdown recovery services in some countries [The Automobile Association (AA) and Royal Automobile Club (RAC) in the UK], and the blue Police Telephone boxes immortalised by the BBC's children's science fiction character "Dr Who" who had a time machine in the form of a British Police telephone box called the "Tardis".

1.2 In the late 1980s, a new system of public mobile phones was developed based on a cellular structure for allocation of radio frequencies. The early system – called TACS (Total Access Communications System) – had limited coverage and reliability, but created a mass market for mobile telephony in the US and subsequently Europe. In the 1990s, the analogue American TACS standard was superseded in Europe by a standard called GSM (Groupe Spéciale Mobile, later renamed Global Standard for Mobiles), whereas the US followed a different path using CDMA (Code Division Multiple Access) technology. As the worldwide mobile phone market has grown, coverage has improved to encompass most of the populated landmass in the USA and Europe, and major cities worldwide. In parallel, prices have fallen well below what anyone might have forecast in 1990. Multi-frequency band GSM phones have subsequently been developed that can provide service from the same handset in most countries throughout the world, provided the correct service provider agreements are in place.

1.3 As the public cellular systems improved and their cost fell, the majority of organisations (in Europe) that previously had owned and operated their own private mobile radio systems gradually migrated to the public cellular networks. The digital standards also heralded a new facility not previously extensively used on non-trunked PMR systems – the short text messaging service – 'SMS'. As the use of data started to grow, mobile phone standards were enhanced to improve their data capability – in particular the GPRS (General Packet Radio System) for GSM. As a result, separate data and paging networks, both public and private have closed with the inexorable rise of the mobile phone.

1.4. The public telephone networks, whilst excellent in what they deliver, still leave un-addressed three major concerns which drove the original cost justification for PMR:

- **Coverage** – private networks can be designed to cover those areas where the requirement for communications exists, including remote geographic areas where little commercial justification exists for public operators, large private sites, inside specialist buildings, etc,

- **Access** – the system can be scaled for the largest emergency requirement, but if the capacity of the network is approached or exceeded, management can be exercised to ensure high priority use is optimised and lower priority usage curtailed.

- **Resilience** – the availability of the network, in particular dependence on mains electrical power can be eliminated, and the back-bone communications bearer circuits and switches can have resilience defined by the operational requirement.

1.5 To fill a perceived gap in the market, in the early 1990s, Public Access Mobile Radio Networks (PAMR) emerged in Europe, based initially on analogue technology (using the MPT1327 trunked radio standard), and subsequently TETRA (TErrestrial Trunked RAdio) digital technology. However, because of the established position of public mobile telephony, these PAMR systems ultimately failed financially and most have closed.

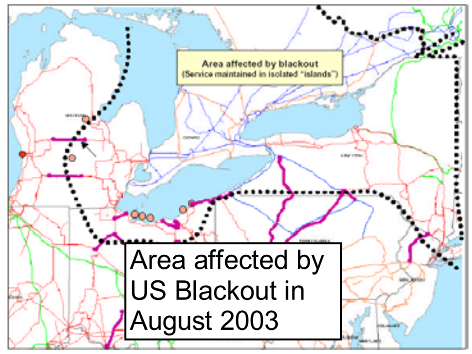
1.6 In the US, the regulatory structure was more amenable to shared private radio systems than in Europe, so a more appropriate concept of shared private mobile radio systems emerged, facilitated by proprietary standards such as the Motorola iDEN system.

1.7 For organisations that can never totally depend on public cellular networks, principally the Police and similar public safety services, to avoid the high cost of operating a number of similar PMR networks with national coverage, in Europe, these organisations are increasingly being cajoled by Governments into sharing networks.

1.8 In Great Britain, the Government has engaged a commercial organisation to design, build and operate a single highly resilient network designed for all the public safety organisations. This network, called "Airwave" is based on TETRA digital technology, operated by O2 (now owned by the Spanish telecoms operator Telefonica) under a 19-year contract. Similar arrangements have been adopted by a number of other European Administrations.

1.9 Although the Airwave network in Great Britain is intended to be a highly resilient network, a number of deficiencies have been recognised; primarily lack of power resilience, inadequate switch back-up, and redundant back-bone communications. Contracts have been placed by the UK Home Office to remedy these deficiencies, which should be completed by the end of 2007.

1.10 Resilience of vital communications networks, both fixed and mobile has been become an issue in many countries following the spectacular power outages experienced by several countries in 2003 (Italy, London & Birmingham in the UK, South of Sweden/North of Denmark, North-Eastern USA and Canada) which raised the profile of the dependence of developed countries on their communications networks.



1.11 In parallel with the growth of cellular telephony, technological advances enabled satellite systems, previously restricted to large, expensive fixed dishes to begin to compete with terrestrial mobile systems. However, whilst the satellite systems designed to deliver large bandwidth services to fixed dishes have flourished, most satellite systems designed to deliver services to mobile terminals have been through bankruptcy and refinancing at least once, and remain marginal in viability terms (with the notable exception of Inmarsat).

1.12 Thus, organisations crucially dependent on mobile communications, who had been migrating in large numbers to public mobile phone networks, began to assess their vulnerability. One provision which public safety users were tending to rely on to gain access to public GSM systems in an emergency was a system called ACCOLC. Although designed as a load management system for public networks through 14-layer systems of priorities, it has the spin-off benefit that it can be used to permit privileged access to the network in an emergency. Although the details of ACCOLC (ACCess OverLoad Control) and its implementation are beyond the scope of this report, experience with dependence on ACCOLC has taught some important lessons for emergency response communications. Ultimately however, mobile phones and ACCOLC do not provide a great deal of assistance in a crisis.

1.13 Similarly, organisations have explored the potential for obtaining SIM cards (Subscriber Identity Module) which enable the user to roam across any public mobile phone network in one's home country in the same way as a user is able to do when in a foreign country. This has the attraction of having one mobile handset that can obtain service on any network in an area when one's 'parent' network has failed, or is simply not available at that geographic location. Although attractive in principle, the implementation has not been seamless, and this alternative still does not overcome the common mode failure of loss of electricity supply to a wide area, flooding, etc.

1.14 The issue of priority access to networks in an emergency is not restricted to public networks, but is also a feature of private networks. Although for a self-provided sole-use network it can be managed internally by an organisation, shared networks (such as the British Airwave network) will still raise issues of the allocation of priorities in emergency situations.

1.15 Although this report raises the issue of priority access to telecommunications facilities in respect of mobile networks, the same issues arise in relation fixed networks, but have less visibility.

1.16 Although a large number of options exist to mitigate dependency on the public cellular networks, the favoured option of the moment is to complement public terrestrial mobile telephony services with mobile satellite communications. The major purpose of this report is to examine the vulnerability of public mobile satellite systems to similar effects as those that prejudice dependence on terrestrial public networks.


Madrid train bombing.
(picture courtesy of Londonist)

1.17 In parallel with severe weather – mainly the recent two severe hurricane seasons in the USA – and major power outages in recent years in a number of European countries and the USA, terrorism has also become a driver for diverse, secure and resilient communications. Recent major terrorist incidents – 9/11 in the US, the Madrid train bombs and 7 July 2005 in London have all highlighted the need for effective and reliable mobile communications.

1.18 The magnitude and duration of the 2005 hurricane season in the USA prompted intense national discussions concerning the survivability of commercial and private communications networks - in the popular press, in Congress and among utilities. The appropriate use of satellite communications for emergency response has been an integral part of these discussions. On June 12, 2006, an Independent Panel submitted a review of the impact of Hurricane Katrina upon the telecommunication and media infrastructure in the areas affected by the hurricane to the US Federal Communications Commission (FCC). The findings of the investigations make clear that the lack of power or fuel was among three contributing factors to disruption of (public) communications service to an extended geographic area for a prolonged period of time. This in turn severely impacted rescue operations and the recovery of nearly all other infrastructure services dependent on electric power restoration. This serves to underscore the critical importance of the private internal communications networks of energy utilities.


Path of Hurricane Katrina
August 2005
Imagery provided by
NOAA

1.19 The Independent Panel concluded that satellite service was the communications service least disrupted by Hurricane Katrina. Aside from independence from regional infrastructure, satellite networks are not affected by wind, rain or flooding. Users of satellite data networks observed that they were more robust than wireline T1 services and that there were fewer difficulties in obtaining and maintaining communications with a satellite network than other voice services. Mobile satellite operators reported great increases in satellite traffic without network/infrastructure issues. (More than 20,000 satellite phones were shipped to the Gulf coast region during the post-Katrina recovery period.)

1.20 This is not to say that satellite communication is without challenges; the Independent Panel concluded that functionality issues associated with satellite usage were largely due to lack of user training and equipment preparation, but these can be addressed. For instance, lack of familiarity with specialized dialling required by some satellite services and uncharged handsets could be avoided with proper pre-planning. The Panel's observations about lack of "in-building" satellite coverage may now be addressed by newer arrangements in which a satellite "box" mounted on the outside of a building connects to the in-building communications network. The FCC Independent Panel recommends that satellite service be developed as an adjunct or backup to primary communications channels in order to mitigate the effects of "single point of failure" in any communications scheme. [Ref 1]

2. Context

2.1. In assessing the value of mobile satellite communications in emergency response, their use must be placed in the context of a comprehensive telecommunications strategy. Any strategy that places total faith in any one system is likely to be flawed in a world where a software bug can bring down entire resilient networks whatever their level of redundancy, or terrorist action can be targeted at multiple specified installations.

2.2 Thus diversity is the key to ensuring resilient communications, aiming to avoid common points of failure in the mix of facilities employed. Recent emergency planning exercises in a number of countries have revealed surprising interdependencies, and common modes of failure that may not have been previously exposed. An exhaustive list might include such items as:

<u>Disease</u>
Pandemics, such as caused in the past by influenza and potential new threats such as Asian Bird Flu can reduce the availability of key personnel to maintain and operate critical communications systems.

<u>Terrorist attack</u>
Not simply the destruction of major facilities, but potentially ‘dirty’ bombs, which would deny access to large areas and contaminate equipment.

<u>Loss of electricity supply</u>
As modern telecommunications networks become more complex, although alternative routing can provide a degree of resilience, it is correspondingly more difficult to guarantee resilience of an entire network which embraces widely distributed infrastructure, key components of which may be vulnerable.

<u>Loss of water supply</u>
Large systems may require water based cooling systems to operate correctly, but any major facility employing significant numbers of staff will rapidly become uninhabitable if water is not available for sanitation.

<u>Flooding</u>
Severe flooding inhibits movement by maintenance and repair staff, disables equipment and floods underground ducts and cable joints. Replacement of damaged equipment can be lengthy.

<u>Storms</u>
Storms, mainly high winds, can destroy radio towers, move microwave and satellite dishes off beam, and bring down overhead power and telecommunications lines. Even underground cables are not immune as the roots of falling trees can tear out cables in the process.

Transportation disruption

In Europe, major cities are dependent on public transportation systems, which are essential for staff getting to and from facilities, and these can be compromised by a diverse range of causes. Severe weather, especially fallen trees can disrupt all forms of land-based transportation, whereas fuel crises can cause total transportation failure.

2.3 Against such a multiplicity and variety of threats, a telecommunications strategy employing a diverse range of options appears the optimum response. Within this strategy, mobile satellite systems would appear to offer contingency against a number of threats.

2.4 However, in developing any resilient telecommunications strategy, one has to take cognisance of similar organisations undertaking identical reviews, and ensure that all public safety organisations are not depending on the same limited pool of alternative provision, such that in a crisis, excessive and conflicting demands will be made of bearer services unable to meet the need. Mobile satellite services may fall under this heading, and care has to be taken to ensure that, when the facility is required in an emergency rather than during an exercise, it will fulfil expectations.

2.5 One consequence of globalisation not greatly tested to date is that utilities can expect governments to provide prioritisation of facilities in a national emergency. As telecommunications becomes more of a global commodity, individual governments have less ability to influence allocation of resources in an emergency. Commercial contract terms then become more important where access to emergency and priority facilities will be determined by negotiations undertaken in advance of the emergency situation. This will present fresh challenges in Europe where utilities have traditionally been able to rely on Government to obtain additional resources in times of crisis. This may be less of an issue in the USA where suppliers tend to be American owned and operated, and the government will have more leverage than in other countries.

3. Technical Parameters

3.1 Not all satellite systems are the same. Satellite based networks are grouped into families defined by the technical description of their satellites' orbit. A further significant difference in this context is whether traffic switching is ground-based or orbit-based, and consideration has to be given to whether communications can be satellite terminal to satellite terminal, or whether part of the pathway will be via another network (possibly terrestrial mobile phone, PSTN or internet-based).

3.2 The families and their associated orbits, advantages and disadvantages are shown in Table1 and Figure 1. The term 'Satellite Personal Communications Services' (S-PCS) is the service definition adopted by the European Commission to describe this newer generation of satellite constellations with the equipment providing access to the network in the form of handheld devices. The previous generation of satellites, typified by the maritime organisation INMARSAT, was designed with a limited number of geostationary satellites operating with transportable ground-stations, on ships, trucks and briefcase models as often seen being used by television reporters in remote locations.

Table 1: Satellite-based Networks

Family	Altitude	Advantages	Disadvantages
Low Earth Orbit (LEO)	500-1500 miles	Very low latency (Approximately 0.03s round trip)	Requires a large number of satellites to provide global coverage
Medium Earth Orbit (MEO)	6250-13,000 miles	Relatively low latency (0.06-0.14s round trip). Requires few satellites for global coverage.	Trade-off between the number of satellites and the latency time.
Geostationary Earth Orbit (GEO)	22,300 miles	Requires very few satellites for global coverage – a minimum of three effectively giving world-wide coverage.	High latency (0.24s round trip, more if multiple hops are used). In Northern latitudes, low elevation angles to geostationary orbit can give rise to blocking.
High Earth Orbit (HEO)	13,000 -22,000 miles	Coverage of the entire earth's surface at all latitudes achievable with a minimal number of satellites	Latency of the GEO satellites with the cost and complexity of MEOs.
Highly Elliptical Orbit (HEO)	n/a	Three satellites can provide continuous high elevation angles for coverage at higher latitudes.	Long path lengths would generate excessive latency for two-way communications.

3.3 This report focuses on what are generally thought of as mobile satellite phones. However, as in many areas of technology today, the boundaries have become blurred.

3.4 The main distinction drawn between ‘mobile’ and ‘fixed’ satellite services is the location of the satellite in orbit, and whether it is necessary to point the ground terminal at the satellite to obtain a satisfactory service (though the ‘pointing’ may be through an electrically steerable antenna rather than physically moving the dish).

3.5 ‘Fixed’ satellite services operate to satellites situated in geostationary (or geosynchronous to be more precise) orbit, located 22,300 (35,600 km) perpendicularly above the equator. At this height, the satellites rotate synchronously with the rotation of the earth, thus appearing to be ‘stationary’ above a given point on the equator. This enables dish antenna with high gain to be pointed at a given satellite and high bandwidth communication established relatively easily and reliably.

3.6 Thus, in the equatorial plane, the elevation angle for a dish antenna pointing at a satellite can be up to 90 degrees, reducing problems caused by ground clutter – buildings and vegetation, and with only a minimal portion of the path length passing through the earth’s atmosphere where most of the signal attenuation occurs.

3.7 As you move away from the equator, the maximum elevation angle decreases from 90 degrees on the equator to effectively zero in the Polar Regions. This not only increases the likelihood that local clutter will obstruct the path, but the radio signal has to travel through a greater portion of the earth’s atmosphere, increasing the attenuation of the wanted signal.

3.8 ‘Slots’ in the geostationary orbit are managed by the International Telecommunication Union (ITU) in Geneva, and as demand has increased, the orbital separation between satellites operating in the same frequency band has been progressively reduced to accommodate more services. This places a higher premium on the angular discrimination of satellite antennas and the accuracy with which they must be pointed.

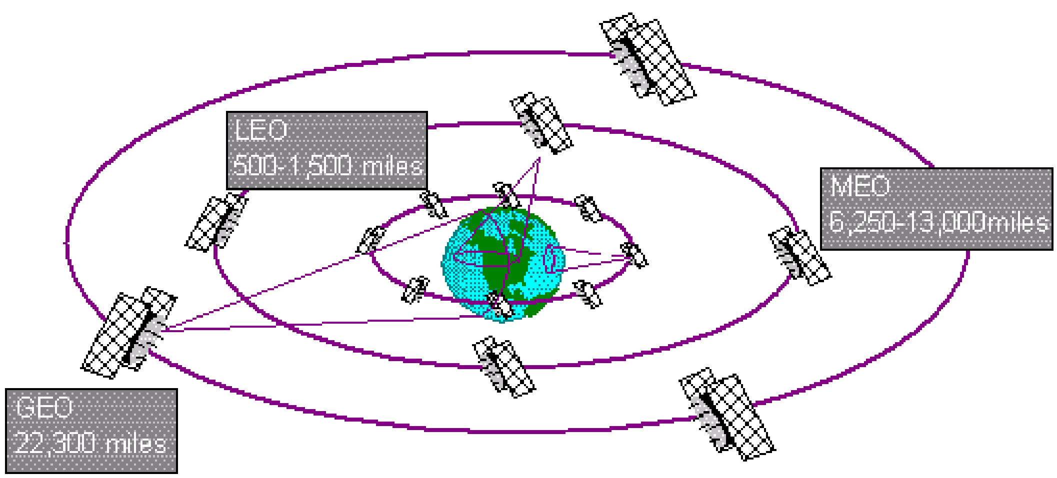


Figure 1: Satellite Orbits

3.9 The original concept of achieving global coverage to handheld terminals with a satellite network was through the deployment of LEO and MEO networks. These could work to terminals with omnidirectional antenna (or hemispherical or other complex pattern), but because these satellites appeared at many locations in the sky, the concept was that a handheld terminal would always be able to 'see' at least one satellite when used outside of a building.

3.10 The reduced link distance eliminates the long signal delay normally experienced in fixed satellite communications, making them more acceptable to two-way voice communications. In addition, the shorter radio path enables the use of small (<500g) terminals with low-power (<1W, rising to 8W eirp) transmitters and small linear antennas (<0.3m, or up to half a wave-length). Early network offerings tended to focus on either voice or data, but network enhancements mean that mixed voice and data are now possible. Care has to be taken however as the mix of data and voice is not as comprehensive as with terrestrial mobile phone services. (See Table 2).

3.11 Unfortunately (for the investors in the satellite networks), their original concept of mass-market global mobile communications has failed to materialise due the more rapid than expected deployment of terrestrial mobile phone networks. All the networks (with the exception of Inmarsat) have been through bankruptcy at least once, and the MEO networks have not yet made it to market.

3.12 The consequence of these bankruptcies is that the networks have not been developed to their originally designed capacity, coverage and resilience but, because of the low take-up, there can be adequate capacity for emergency communications.

3.13 Alternative orbit patterns using high earth orbits and highly elliptical orbits (both confusingly abbreviated to 'HEO') are included in Annex A, but are not a major focus of this report as they are more suited to delivering locational and broadcasting services (respectively) than fixed or mobile communications.

Table 2: Satellite Personal Communication Services Network Development

System Name	Orbit	Main Partners	Services		Launch-ed
			Voice	Data	
Iridium	LEO	Motorola, RV Telecommunications (formerly Vebacom), Sprint	Yes (2.4 kbit/s)	2.4 kbit/s	1998
Globalstar	LEO	Loral, Qualcomm	Yes (2.4 kbit/s)	9.6 kbit/s	1999
ICO	MEO	ICO Global Communications (Holdings) Limited	Yes (4.8 kbit/s)	38.4 kbit/s	2000
Thuraya	GEO	Private joint stock company: the shareholders comprise 21 prominent national telecommunications operators and investment houses, mainly drawn from Middle Eastern Arabic telecoms operators	Yes (2.4 kbits unconfirmed)	9.6 kbit/s	2001
Inmarsat	GEO	Original inter-governmental, but now privately owned	Yes (64 kbit/s)	144 kbit/s	1980

4. Comparisons among satellite systems

4.1 General

Table 3: Comparison of Satellite Services

	Iridium	Globalstar	Thuraya	Inmarsat Fleet	Inmarsat RBGAN	Inmarsat M4
Coverage	Global	Most parts of the globe	Europe, North Africa, Middle East & Indian Sub Continent	Global – excluding polar region		
Voice service	Yes	Yes	Yes	Yes	No	Yes
Data service	Yes	Yes	Yes	Yes	Yes	Yes
Max data rate	2.4k (9.6k compressed)	9.6k	9.6k	64k	144k (contended)	64k
Text message receive	Yes	Yes	Yes	N/A	N/A	N/A
Text message send	Yes	No	No	N/A	N/A	N/A
Prepay tariff	Yes	No	Yes	Yes	No	Yes
Postpay tariff	Yes	Yes	Yes	Yes	Yes	Yes

4.1.1 Global satellite communications companies tend to price in Euros (Globalstar) or US Dollars (Iridium). To reduce costs and improve service, terminals supporting speech calls are often dual mode (satellite and terrestrial digital cellular). This allows the terminal to use the lower cost terrestrial networks where available and satellite in all other outdoor locations.

4.1.2 PSTN calls to a satellite phone on a standard tariff may cost more than $5/5 Euros (£3.50) a minute, possibly up to $10/10Euros (£7) per minute. It is therefore important to establish a commercially viable communications plan before a crisis if exceptionally high call charges are not to be incurred. 1$/1 Euro (£1) per minute should be achievable through a negotiated arrangement.

4.1.3 The two original S-PCS LEO operators who have survived have been joined by two players which have developed mobile satellite systems based on satellites located in geostationary orbit - namely Inmarsat and Thuraya. Thuraya is a relative newcomer to the market based on a desire by Middle Eastern Arab nations to have their own mobile satellite communications. Inmarsat has continued to develop its range of services based on its original maritime market. Whilst others have stumbled from crisis to crisis, Inmarsat has always had a solid customer base from which to growth.

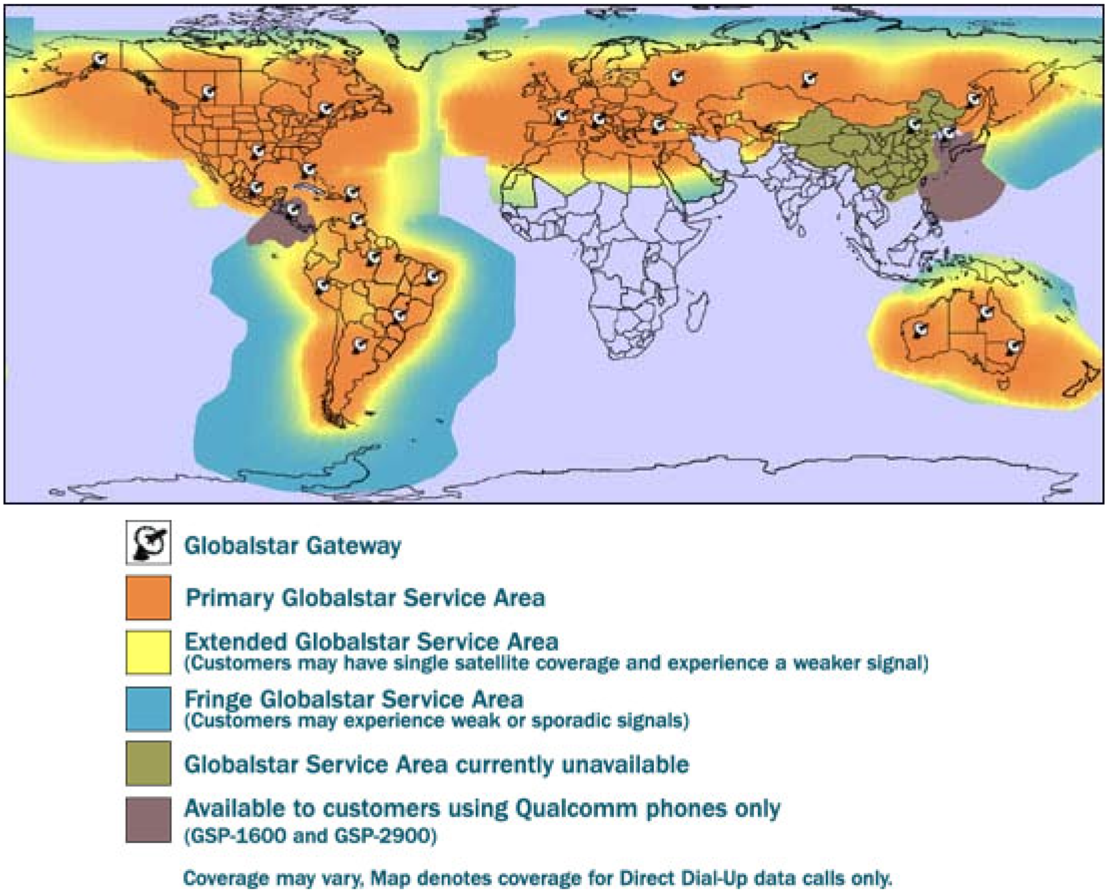
4.1.4 It is only in the last 5 years or so that handheld terminals have been able to work to geostationary satellites. They operate more effectively the closer you are to the Equator, but they have been found to be surprisingly good in northern latitudes.

4.1.5 ICO Global has persevered with the concept of the MEO satellite orbit. ICO does not have an operational service at present, but they are still raising capital in order to launch a service. In order to differentiate themselves in a highly competitive market, they have focused on providing a terrestrial segment for their service. The concept is that the satellite provider would operate terrestrial fill-in cells in major cities at the same frequency as the satellite system so that their terminals could function inside buildings where they would otherwise not work. This has raised a regulatory issue in that conventional terrestrial mobile phone operators who have paid large sums of money for their operating licences do not see why the mobile satellite operators, who effectively do not pay any licence fee for access to the mobile portion of their spectrum should be able to compete in lucrative city areas by deploying terrestrial networks.

4.1.6 The temperature of the debate has been raised further by a request from potential mobile satellite operators to be able to offer their service terrestrially, using the designated mobile satellite spectrum, before their satellite network has been deployed.

4.1.7 Annex B contains more general details of satellite systems.

4.2 Globalstar



4.2.1 Globalstar supports voice, fax and other data telecommunications services on a worldwide basis. SMS messages of up to 160 characters can be sent to and received from other Globalstar and GSM terminals. Globalstar provides a data bearer service of up to 9.6 kbits/s which can be used to provide connectivity between PCs and PDAs for use to communicate by fax, file transfer, internet and email services.

4.2.2 Some Globalstar mobile phones function as both cellular and satellite phones. This dual mode enables a single handset to operate in environments where a satellite only handset could not operate – for example, inside buildings, and to reduce call costs, but can create conflicts in emergency conditions.

4.2.3 By way of example, UK registered terminals link into a French ground station, which has limited connectivity into the France Telecom network. Ironically, it is reported that on 6 & 7 July 2005, around the time of the London Bombing, the Globalstar connection into the French network experienced a high level of faults, although Globalstar to Globalstar calls avoided the problem. It has not been possible to obtain any verifiable data to confirm or otherwise qualify these accounts.

4.2.4 Although Globalstar terminals sold in the UK usually have a French SIM (Subscriber Identification Module) card and number identity, it is possible to use a UK numbering plan and number translation (to allow calls originating in the UK from other networks to avoid international call bars). Care has to be taken that in an emergency this call translation service would not be affected.

4.2.5 During the 2005 hurricane season in the USA where several hurricanes struck the south-eastern states, satellite phones were used extensively when land-based communications failed. Globalstar reports that within the first 36 hours after Hurricane Katrina struck thousands of handsets were deployed to the Gulf region for emergency responders, a total of over 10,000 with seven days.

4.2.6 In the response to Katrina, Globalstar doubled the capacity for passing calls to landline phones, and increased network capacity by 60% within 24 hours. Overall, Globalstar phone usage in the Gulf region was reported as increasing by 560%, maintaining a 95% call completion rate, although it is not possible to establish call set-up success rates.

4.2.7 Utility experience of satellite phones during the hurricane season referred to them as “choppy”, but most had PMR on which to depend so evidence of problems is largely anecdotal. Several utilities did have or rented a small number of handsets. However, where telephone circuits were down, these did not function well, as the terrestrial side of the network depends on landlines just as other networks do. In areas where they did function, they were helpful, as long as crews didn’t try to use them inside buildings. There were reports of spectrum congestion issues, but no evidence of whether that was a concern or actually happened. Anecdotal utility experience in the UK has similarly reported inexplicably poor performance on occasions.

Restoring electricity supplies to New Orleans after Hurricane Katrina.
(picture courtesy of USA Today.)

4.2.8 US utility experience with mobile satellites concluded that they are one tool of an arsenal in post-disaster response, but should not be the only one.

4.2.9 In response to hurricane Katrina, Globalstar introduced a number of emergency measures to increase ground-based telecoms to their network, and reconfigured their spectrum plans to assign more radio channels to the affected region. The relevance of this US experience to incidents in Europe is limited, as the area covered by Hurricane Katrina was of a similar magnitude to the UK, but this is a useful example of Globalstar’s ability to increase capacity in a region when necessary.

4.2.10 More information on the Globalstar satellite network is included in Annex C, and can be downloaded from www.globalstar.com.

4.3 Iridium

4.3.1 The Iridium Satellite System provides global satellite voice and data solutions with complete coverage of the Earth (including oceans, airways and Polar regions) through a constellation of 66 low-earth orbiting (LEO) satellites operated by Boeing. Although Iridium's call charges are currently similar to Globalstar, the handsets are more expensive. Iridium handsets are not compatible with the GSM or CDMA networks.

4.3.2 Iridium offers conventional voice telephony features, with both contract and pre-payment facilities. Iridium provides an SMS for messages up to 160 characters that can be sent to and received from other Iridium terminals and to GSM terminals via earth station gateways. Iridium provides a data bearer for communications up to a speed 2.4 kbits/s. This is a dial-up service that can be used to provide connectivity between PCs and PDAs using an appropriate physical interface for fax, file transfer, Internet and e mail services. Iridium also offers an alternative service called "Direct Internet Data" whereby Iridium acts as an ISP. Using this service bandwidth of up to 9.6 kbits is available using compression applied at the Iridium earth station gateway.

4.3.3 The Iridium satellite system is based on a constellation of 66 satellites (reduced from an original design concept of 77 – the atomic number of the metallic element 'Iridium'). Iridium has the unique feature of switching calls between satellites in orbit, so it can easily route calls between Iridium handsets without any dependency on ground-based infrastructure (assuming handsets are authenticated). This also reduces latency in transmissions by avoiding multiple hops. All calls to or from the Iridium network are uplinked to the constellation using an earth station gateway.

4.3.4 Iridium currently provides services to the United States Department of Defense (DoD), which gives confidence that it will remain in service for the foreseeable future. Previously, there had been concerns about the limited number of ground stations, but this has now been rectified.

4.3.5 In August 2006, Iridium commissioned a new ground based Telemetry, Tracking, Command & Control (TT&CC) station in Fairbanks, Alaska to complement three other existing ground stations in the US, Canada and Iceland. This provides a fully redundant ground segment for TT&CC associated with 16 gateways stations positioned around the globe to uplink and downlink telecommunications traffic.

Opening ceremony for the Alaskan Iridium Ground Station, with one of the distinctive large white radomes visible in the background.
(picture courtesy of Iridium Satellite LLC.)

4.3.6 The nearest gateways for the UK are in Düsseldorf and Rome. The positions of the remaining ground stations are not known.

4.3.7 Iridium also offers an Enhanced Mobile Satellite Services (EMSS) as an emerging technology with capability to support low rate voice and data services from a mobile, lightweight terminal. EMSS services will be commercially provided with a few modifications necessary to allow for unique DoD features, such as end-to-end encryption and protection of sensitive user information. DoD has established a dedicated Government EMSS gateway in Wahiawa, Hawaii for government use through the Defense Switched Network (DSN). Through this gateway, EMSS subscribers will have direct connection into Defense Information Systems Network (DISN), which is capable of providing secure services, in addition to non-secure access to commercial telephone services. A commercially available user terminal will support secure communications by adding a removable National Security Agency (NSA) approved Type I Communications Security (COMSEC) sleeve which fits onto the commercial user terminal.

Restoring electricity supplies to New Orleans after Hurricane Katrina.
(picture courtesy of USA Today.)

4.3.7 In the aftermath of Hurricane Katrina, the Iridium network provided invaluable support. In the first 72 hours after Katrina hit, Iridium traffic in the affected area increased more than 3,000 percent, and the number of subscribers increased more than 500 percent. Iridium responded to the increased demand, moving to a 24-hour-a-day manufacturing schedule and seeking and receiving special temporary authority from the FCC to use an additional 2.25 MHz of spectrum.

4.3.8 Since Hurricane Katrina, Iridium has taken additional steps to ensure continued communications during an emergency. Iridium has arranged with Raytheon for the development of a portable gateway device to interconnect a variety of communications networks. Through this gateway device, public safety agencies can use their day-to-day communications networks to connect to Iridium's satellite network and place calls to any other communications network, including land mobile radio networks, through the Iridium system.

4.3.9 By connecting a public safety network to this gateway, the gateway manager can link that public safety network to any other network connected to the same gateway, including other public safety agencies and the Iridium network. Once connected together, individuals operating on separate public safety networks will be able to communicate seamlessly and will be able to access anyone via the Iridium network, including landline and wireless customers in other parts of the world. This is true even if the underlying terrestrial infrastructure in the affected area has been destroyed.

4.3.10 Iridium provided a more detailed analysis of its ability to support emergency communications in its testimony to the Federal Communications Committee in August 2006 (FCC) [Ref 2].

4.3.11 Additional information on the Iridium network is contained in Annex D and can be downloaded from the company website on www.iridium.com .

4.4 Thuraya

4.4.1 Thuraya was launched in 2001 to offer affordable communications to areas of high population, where coverage of GSM did not exist or was limited. This includes North and Central Africa, Middle East, India, Central Asia and Europe.

4.4.2 Thuraya is a geo-synchronous mobile satellite system providing access to Satellite and GSM900 services from the same Handset. It offers the facility for voice communications, a range of voice related services and SMS as standard, together with an in-built GPS. Data/fax facilities are available through an optional data kit with speeds up to 9.6kbit/s, which enables limited email and web browsing.

4.4.3 Thuraya's footprint covers the UK but because it uses a geo-synchronous orbit, the elevation angle from the UK is approximately 20 degrees, making a clear view of the horizon essential. (This is not a problem for its prime home market in the Middle East and Africa). It has been reported that Thuraya currently depends on a single satellite, as the in-orbit back-up satellite is defective, but it has not been possible to verify the validity of this assertion.

4.4.4 A Thuraya handset can be used in GSM mode, through a Thuraya

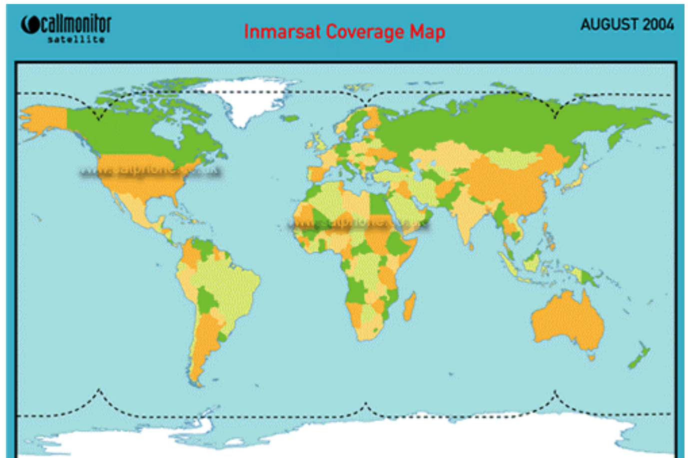
GSM roaming partner. The handset can be used as a Satellite only, GSM only, or auto switching between the two.

4.4.5 It would appear that for regulatory reasons, the 'phone must know where it is', which is why it has built-in GPS. Under normal conditions, it can take up to 2 minutes to acquire the network if the terminal is out of service for any reason; user reports have indicated that it can take up to 15 minutes to register and acquire a service when first switched on, which may be associated with need to acquire GPS before the handset can register. These registration times may be dependent on location as acquisition of satellite data can be more difficult in northern latitudes.

4.4.6 Thuraya satellites route terminal-to-terminal calls directly between terminals on the satellite independently of the earth station, making these calls 'one-hop'. Calls from the Thuraya network to other networks are routed through the earth station gateway located in the United Arab Emirates.

4.4.7 Additional information on the Thuraya network is contained in Annex E and can be downloaded from the company website on www.thuraya.com .

4.5 Inmarsat



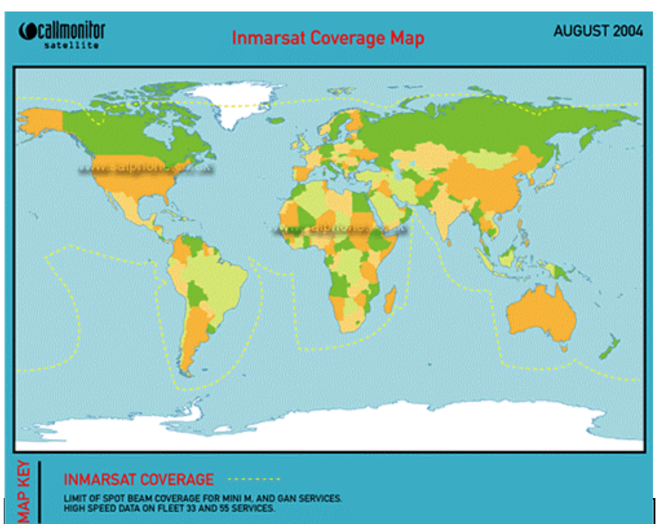
Map illustrating the coverage of the Inmarsat Fleet voice services.

4.5.1 Inmarsat was the world's first global mobile satellite communications operator and offers communications services to maritime, land-mobile, aeronautical and other users. Formed as a maritime-focused intergovernmental organization over 20 years ago, Inmarsat has been a limited company since 1999, serving a broad range of markets. Starting with a user base of 900 ships in the early 1980s, it now supports links for phone, fax and data communications at up to 64kbit/s to more than 240,000 ship, vehicle, aircraft and portable terminals.

4.5.2 Inmarsat Ltd is a subsidiary of the Inmarsat Ventures plc holding company. It operates a constellation of geostationary satellites that comprises five third-generation satellites backed up by four earlier spacecraft. The satellites are controlled from Inmarsat's headquarters in London. The Inmarsat system is used by independent service providers to offer a range of voice and multimedia communications.

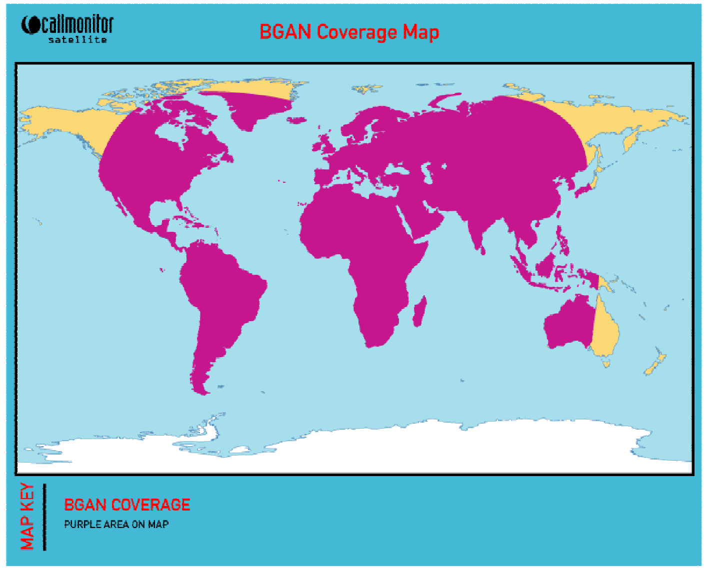
4.5.3 Inmarsat business strategy is to pursue a range of opportunities at the convergence of information technology, telecoms and mobility while continuing to serve traditional maritime, aeronautical, land-mobile and remote-area markets. Central to the strategy is the new Inmarsat I-4 satellite system, which supports Inmarsat Broadband Global Area Network (BGAN) - mobile data communications at up to 432kbit/s for Internet access, mobile multimedia and other applications.

4.5.4 The key drawback to Inmarsat is that it does not support hand-held devices, all products being transportable devices which need to be set up to look at geostationary orbit.



coverage for Mini-M and high speed data services.

4.5.5 Additional information on the Inmarsat network is contained in Annex F and can be downloaded from the company website on www.inmarsat.com .



4.5.6 The new BGAN (Broadband Global Area Network) service is designed to provide universal broadband at a competitive cost and was planned to launch in May 2006. Inmarsat experienced some delays due to difficulties transferring some existing services and customers from the old I-3 to the new I-4 satellite, but it is reported that these have now been resolved. The current M-4 64 kbit/s service prices have not changed, in spite of the advent of the new less expensive BGAN hardware and air-time. Each M-4 terminal costs about $7.5k and the cost to use a 64 kbit/s channels is about $6.50 per minute.

4.5.7 Although the BGAN service is described as 492kbit/s, this is a maximum/peak rate; the service plans do not guarantee 492 kbit/s. There are several "full channel" (called "Streaming Service", "committed information rate" or CIR rate, somewhat similar to the way Frame Relay service is sold) offerings that guarantee a channel of xxx kilobits per second. To get this service you subscribe to the Inmarsat "Standard Package" that is expected to cost $40 per month. In addition, they will apply the following charges per unit of data (1 Megabyte = 8 Megabits)

- 32 kbit/s Streaming Channel $1.95 per Megabyte
- 64 kbit/s Streaming Channel $5.84 per Megabyte
- 128 kbit/s Streaming Channel $9.70 per Megabyte
- 256 kbit/s Streaming Channel $14.24 per Megabyte

4.5.8 The above applies to the Standard Package costing $40 per month per BGAN terminal. There is also a basic package offered at $45 per month, but does not offer any Streaming Channels. A shared BGAN channel offers similar terms, up to the theoretical maximum of 492 kbit/s, depending on how many other users are on the same channel at the same time. BGAN might not be cost effective to deploy for VOIP telephone services, although each BGAN terminal comes with one standard 4 kHz voice channel that costs $1 minute to use.

4.5.9 There are three major hardware vendors: Hughes Networks Systems (USA), Thrane & Thrane (Europe) and NERA (Norway). The Hughes BGAN can be used on streaming channels of up to 256 kbit/s and costs $3,250. The Thrane & Thrane BGAN can be used on streaming channels of up to 128kbit/s and costs $3,100. The NERA BGAN can be used on streaming channels of up to 64 kbit/s and costs $2,500.

4.6 ICO Global

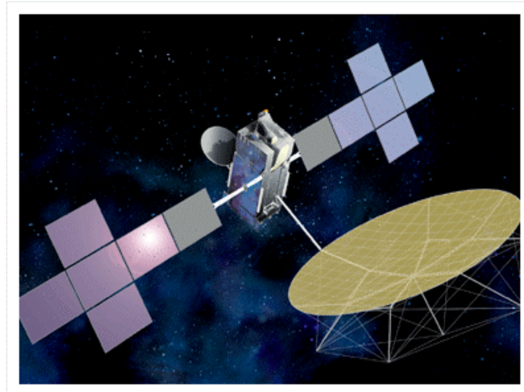
4.6.1 ICO Global Communications (Holdings) Limited is a next-generation satellite communications company based in Reston, Virginia, USA. ICO is developing an advanced hybrid system, combining both satellite and terrestrial communications capabilities, in order to offer wireless voice, data, and Internet services with handsets similar in size to existing cellular phones.

4.6.2 ICO has been authorized to operate a medium earth orbit (MEO) satellite system globally through a registration filed via the United Kingdom with the International Telecommunication Union (ITU). ICO has also been authorized to offer Mobile Satellite Services (MSS) throughout the United States using a geostationary earth orbit (GEO) satellite. ICO has the opportunity in the future to seek authorization from the U.S. Federal Communications Commission (FCC) to integrate an Ancillary Terrestrial Component (ATC) into their MSS system in order to provide integrated satellite and terrestrial services. Unlike satellite-only MSS systems, ICO believe that integrated MSS/ATC services may be more likely to appeal to a mass market of consumers and businesses. At the present time, ICO is focusing most of their resources on developing a US MSS system.

4.6.3 ICO is working with several industrial partners to design and build their MSS/ATC System. To date, they have certified the first seven FCC milestones. These milestones are designed to measure progress toward having their MSS system certified as operational by 17 July 2007 in accordance with the FCC milestone schedule.

4.6.4 On May 24, 2005 the FCC granted ICO's request to modify their reservation of spectrum for the provision of MSS service in the United States using a GEO satellite system, rather than a MEO satellite system. In anticipation of this approval, on January 10, 2005, they entered into a contract with Loral for construction of a GEO satellite with the contract mirroring the prescribed milestone dates set by the FCC, including completion of the GEO satellite in May 2007 and availability for launch by 1 July 2007. Physical construction of the satellite is currently underway.

4.6.5 The GEO satellite is designed to enable ICO to provide continuous service coverage primarily in all 50 states in the United States, as well as Puerto Rico and the US Virgin Islands. If other countries grant appropriate regulatory approval, the GEO satellite is capable of providing service outside of the United States, throughout North America.



4.6.6 In addition to their planned MSS/ATC System, ICO have been authorized by the UK administration to operate a global MEO satellite system. Under ITU rules, their MEO system is deemed to have been brought into use and therefore is entitled to international recognition and legal protection. ICO is working to benefit from their investment in an international MEO satellite system as they expect the regulatory regime which governs their MEO system to change in the next year.

4.6.7 ICO have in orbit one MEO satellite launched in June 2001, referred to as "F2," which currently provides data gathering services. Primary satellite control is provided under an agreement with PanAmSat Corporation, and they have a network management centre and a backup satellite control centre at Slough in the United Kingdom. ICO are required to have the capability of controlling F2 from the UK as part of their authorization. ICO are currently using one gateway ground station equipped with five antennas, located in the United States, to monitor F2. ICO also own a facility in Itaborai, Brazil, on which certain gateway equipment for the MEO system is located. In addition, ICO have ten MEO satellites in storage under an agreement with Boeing Satellite Systems International, most of which were in advanced stages of completion prior to the termination of work under the satellite agreements. The MEO satellites, including F2, are a modified Hughes 601 and Hughes 702 design and have a designed in-orbit life of 12 years. The satellites feature active S-band antennas capable of forming up to 490 beams for satellite-user links and C-band hardware for satellite-ground station links.

4.6.8 Additional information on the proposed ICO network is contained in Annex G and can be downloaded from the company website on www.ico.com .

5. Limitations of mobile satellite systems

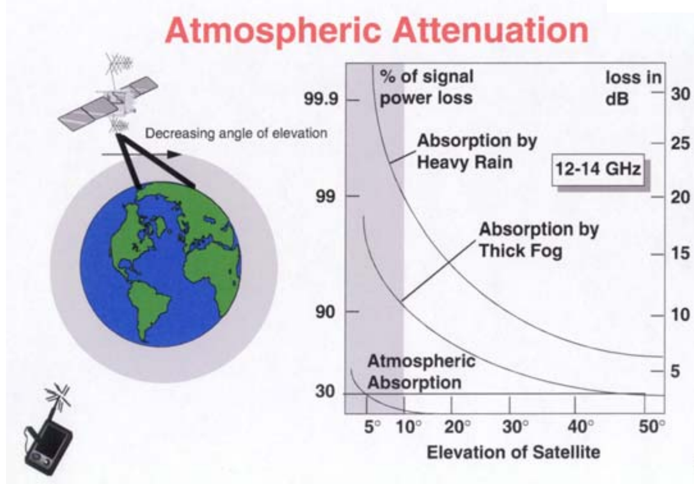
5.1 Limitations on mobile satellite systems as a resilient back-up for use in times of crisis are being examined by a number of organisations, including governments. Below is a summary of the most prominent concerns, although extensive, the list is not exhaustive.

Coverage:

5.2 Although in principle a satellite system has global coverage, in practice there are limitations. In general, **it is necessary to be out of doors**, or at least by a window without any electromagnetic attenuation for them to work at all. In fixed locations or in vehicles, this can be overcome by the use of an external antenna.

5.3 For geostationary systems, in Northern European Countries, the **elevation angles of the satellite are only in the order of 20 degrees,** (i.e. about the same as a domestic satellite TV dish which lies in the same orbital plane) and thus terrain or urban canyons can obstruct a clear path to the satellite and affect coverage.

[Ref 3]



5.4 For LEO and MEO systems, elevation angles are higher, but the consequence is that for a call lasting more than a few minutes, the **handset will have to hand-over to another satellite** to continue the call, a process which does not always appear to proceed smoothly in an urban environment.

5.5 The available signal strength for mobile satellite systems is always much less than a terrestrial system, and thus in urban and industrial areas, the possibility of reduction in sensitivity of the handset due to a **harsh surrounding electromagnetic environment** will always be greater than with a terrestrial system. [However, in some disaster recovery scenarios, electrical power systems have also failed, hence the electromagnetic environment is exceptionally benign.]

Access:

5.6 Satellite systems are normally operated by international consortia, and are relatively **immune to pressures from national governments** for priorities to be accorded to particular sets of users. This means that priority access systems such as the ACCOLC (ACCess OverLoad Control) scheme for according priority in the use of terrestrial cellular networks in GSM cannot be mandated by national governments in times of crisis. Any preferential treatment of one user as against another will be a contractual term to be negotiated prior to its need. In this area, it is likely that the US Federal Administration may have more influence than other national administrations.

5.7 It is understood that Inmarsat, being a service designed originally for maritime and other safety related communications systems, has a **pre-emption** capability by design, but it is not known how realistic it would be to use such a feature for unforeseen emergencies. It is not thought that the other mobile satellite systems have a similar facility designed in.

5.8 Satellite systems have relatively large footprints for their beams, which makes re-use of frequencies much less effective than corresponding terrestrial systems. This translates into much less capacity than terrestrial cellular networks for a given spectrum allocation. Satellite operators are reluctant to disclose precise details of their capacity limitation, but it is reported that one major mobile satellite operator has only **1000-1200 circuits available** in the European area. If this capacity were all committed to satellite-to-satellite calls (as in a 'Black Start' Scenario when a country loses its entire electricity grid), this would be reduced to 600 simultaneous calls.

5.9 In practice, there is no way to be certain precisely **how much capacity would be available in any given area during an emergency**. Section 7 contains a useful case study by Globalstar on capacity calculations for the US. From this it can be seen that the capacity varies continuously dependent on how many satellites are visible in the designated area, and the power capability of those satellites (which will vary over their lifetime, especially the condition of the batteries on which the satellite depends when solar cells are in the earth's shadow).

5.10 Every satellite system will have optimised its design parameters for certain conditions, which will have an impact on its **performance under non-idealised circumstances**. In terms of capacity, a large number of relatively small beams will be more susceptible to localised congestion than a smaller number of large beams, but the link budget is better the smaller the beam, leading to better coverage of obstructed locations.

5.11 Because of the limited number of circuits available in any given area, there is concern that in a major emergency, such a widespread loss of main electrical power, all the satellite phones would be brought into service, and the system will congest. Because of the relatively high cost of satellite phone charges when contrasted with the ubiquitous GSM, it is likely that **most satellite phones purchased for use in Europe are for emergency communications in a crisis**.

5.12 Compared to a terrestrial mobile phone, the **acquisition time for a satellite phone to gain access to the network is very long**. Although in training modes this is an irritation rather than an impediment, in a crisis, it is not known how the satellite system will respond to large numbers of simultaneous requests for service. In one modelling JRC undertook to simulate this effect for one satellite system, access to the satellite network was highlighted it as a potential problem under heavy loading. Although this did not appear to be an important issue in dealing with the US hurricane disasters in 2005, the Gulf region of the US appears to be beneficially served by satellite ground stations, and its proximity to the equator creates a more positive environment for satellite communications than the northern latitudes of Europe, Canada, and Alaska.

<u>Denial of Service:</u>

5.13 It is relatively easy to **block** a satellite network, either intentionally or accidentally. A high sited emitter in the same frequency band as the satellite communications can 'blind' the satellite(s) over a large geographic area. Detecting and removing the source of such interference, which may be in another unco-operative country, could be very difficult.

5.14 Such a **Denial of Service** attack is relatively easy for the smaller satellite systems such as little LEOs which share spectrum with other services. However, the bigger LEOs – which include Globalstar and Iridium, operating in designated mobile satellite spectrum and with robust protocols designed for a hostile environment are likely to be less vulnerable. The increasing number of government users of these services globally also generates more confidence that any denial of service attack would be given serious attention.

5.15 **GEO satellites** have been known to suffer interference accidentally, and are potentially more vulnerable to attack as a transportable, steerable dish can be pointed at a particular satellite to block it, a situation which is causing radio regulatory authorities world-wide to take notice.

<u>Resilience:</u>

5.16 **The resilience of a satellite system is difficult to define precisely**, and depends heavily on the exact manor in which the satellite system operates. The analysis below starts with the simple issues, before moving on to more complex analysis. In assessing the resilience of the system, it is important to fully understand all the processes in the authentication procedure. It must be remembered that the utmost priority of a commercial network is generation of revenue from call traffic; hence, even if a call can be connected technically, the call will not be set up without a billing mechanism in place. The issues raised below are often specific to the particular way in which a given service is set up.

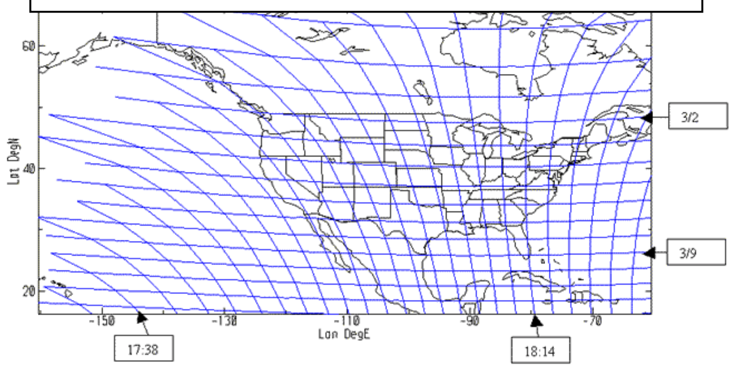
5.17 Dual terrestrial/satellite systems are usually configured to use the terrestrial system when available, only switching to satellite system when no terrestrial network is detected. Thus, if **the satellite phone detects a terrestrial network**, it will keep trying to place calls on the terrestrial network even when the network is congested and the calls are unsuccessful. The configuration may not allow the user to force the phone to use the satellite network, or may have an extended timeout period (30 minutes) before the user is authorised to default to satellite mode.

5.18 Before a call can be connected, the network has to **authenticate the handset** and ensure that the type of call requested is authorised. Satellite phones control this process using SIM cards in the same way as terrestrial mobile phones. Registration on the network usually requires interrogation of the 'home location register' for the terminal on

which this data is stored. Because of the international nature of the satellite networks, validating data may require international calls to be placed over the fixed telephone network. In times of crisis, these networks themselves are subject to congestion, and one strategy adopted by the fixed telephony network may be to restrict international call traffic, making it impossible for the satellite network to authenticate a given handset. The implication is that the precise working of the satellite system and its dependencies must be fully understood before taking decisions such as to use SIM cards from one country rather than another, bearing in mind that each operator will have a defined amount of capacity between each country.

5.19 Although **Home Location Registers** themselves are a vulnerability – sometimes causing loss of service to a group of handsets for an extended period, possibly more than a day – there is no reason to suspect that failure in home location registers would correlate to other incidents. However, for added resilience, it may be wise to ensure that all of an organisations' satellite phones are not registered on the same home location register, but spread across two or three different registers if possible to ensure that the whole group of phones does not fail at the same time because of the loss of one register.

Diagram indicating eclipse zones over USA. [Ref 3]



5.20 For geostationary satellite systems, there may be times of the year when the sun is directly behind the satellite in use (**the eclipse period**), which may restrict services at certain times. The effect is usually manifested in for 2-10 days in spring and autumn when the service will be interrupted for between 3-15 minutes depending on a range of factors such as orbital slot of satellite, radio frequency, antenna size, etc.

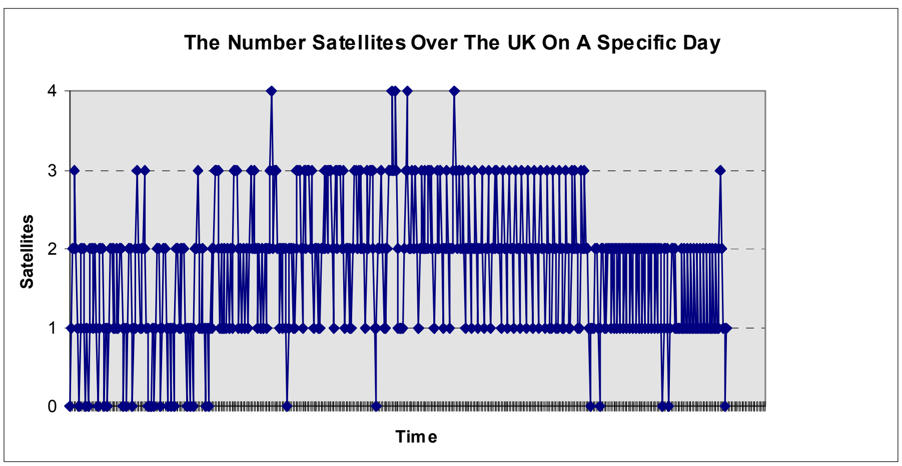
5.21 Apart from the Iridium network where calls are routed between satellites, the other networks are all dependent on ground-based infrastructure. As the viability of the mobile satellite networks has been marginal, or possibly negative, the **ground based switching infrastructures** initially did not have the desired resilience. However, the continuous tide of major incidents where failure of communications has been an issue has generated more business for the satellite phone business. Ground based infrastructures for Globalstar, Iridium and Inmarsat have all been strengthened recently leading to less concern over this aspect of their performance.

5.22 Satellite to satellite calls on the same infrastructure will be handled by the operator, but if the desired call path is satellite to fixed or satellite to terrestrial mobile, the resilience of the **complete path must be assured**, which may not be self-evident if the ground station for the satellite system is based at a hub a thousand miles away. In Europe, there is an added complexity in that the ground station may be located in another country, with transit through a number of intermediary countries.

5.23 In the case of satellite mobile phones based on geostationary orbits, for **satellite phone to satellite phone calls**, a double two way hop may be required, having a radio path of approximately 140,000km plus processing delay, yielding a total delay in the region of one second. This can make dialogue difficult, especially in stressful situations. A two-way hop may still be necessary for LEO networks if the handsets are registered on different satellites, even though they may be in the same geographic area, although the time delay is less significant for LEOs.

5.24 **Orbital stability** can be an issue mainly for geostationary satellites, but also affects other orbits to a lesser extent. For GEO orbits, satellites can drift in and out of position, causing the earth station link to drop in and out of service. This destabilises the network. For LEO and MEO orbits, spacecraft have limited fuel and station-keeping capability, and can drift out of their planned orbit, leaving gaps in coverage (on a time dependant basis).

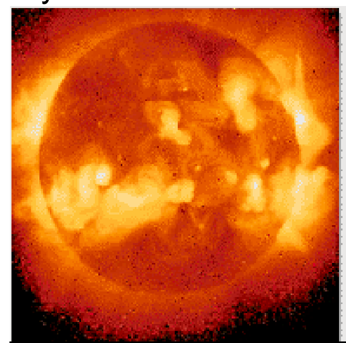
5.25 The capacity of MEO and LEO networks is likely to vary according to **how many satellites are visible at any one time**. Taking a worked example from a LEO satellite network at 800km altitude, it is possible to determine the amount of time each satellite's footprint covers a specific point on the ground on a particular day. The example below is based on a minimum 40 degree 'look angle' (an angle of elevation above the horizon) for each satellite. In this example, in the UK, the footprint of a satellite could take up to fifteen minutes to pass over a specific point. Depending on the precise location and the particular day, the number of satellites over the UK varies as shown in the following graph:



5.26 For this particular network of 36 LEO satellites, the graph displays that the **number of satellites visible** over the UK varies between zero and four satellites in a typical day. A similar assessment can be made for other networks. This is achieved most effectively if the network provider can supply a terminal with an engineering mode enabled.

5.27 Satellites have a limited **lifetime**, with virtually no ability to repair defects. Geostationary satellites, because of their relatively benign orbit (see annex B and section on Van Allen Belts), have a life expectancy of 15+ years. MEO and big LEOs reduce towards 10 years, with little LEOs having only a 7 year life on average. Lifetime is dependent on station-keeping fuel, electronics failure due to radiation damage, technological obsolescence and progressive deterioration of the batteries. Thus although satellites may fail completely, the more common problem is progressive deterioration over their life-time reducing performance. Because of the extensive period it has taken for satellite communications to mature, some networks already have a relatively high level of defective hardware, with limited incentives or ability to launch replacement equipment.

5.28 **Weather conditions** on the link path between the handset and the satellite will attenuate the signal strength. At the radio frequencies at which mobile satellite systems operate, and because of the length of the path, a significant proportion of which may be through rain-laden clouds, the signal can be significantly degraded during severe weather reducing the number of satellites visible at any given location.



Sunspot activity and solar storms

5.29 Satellite systems, operating outside the protective envelope of the earth's atmosphere, are vulnerable to **electromagnetic storms**, in particular solar flares which have a 13 year cycle associated with sunspot activity. Sunspots are areas of intense magnetic energy. They act like temporary caps on upwelling matter, and they are the sites of occasional ferocious eruptions of light and ionised gas. More sunspots generally means increased solar activity, which can damage or ultimately destroy delicate satellite systems.

5.30 Recognising a **new market emerging for resilient communications** in the face of the vulnerability of terrestrial networks, the satellite operators are responding to this lucrative new opportunity. For example, Globalstar launched a new handheld phone for satellite enterprise data customers featuring a Static IP (Internet Protocol) address modem and virtual private network (VPN) capability. The new equipment, launched in January 2006, is designed for large corporate customers who require VPN email access. Globalstar claim that potential customers include the utility industry, which might use it for SCADA (Supervisory Control and Data Acquisition) and telemetry monitoring to access remote assets.

5.31 **The changing global environment** has encouraged Iridium to construct a new ground station in Alaska for control of its network as reported in section 4.3, and Inmarsat continues to grow its portfolio of services as recorded in section 4.5.

<u>Other issues</u>

5.32 **Training** is particularly important as some aspects of a satellite mobile phone may be different to the familiar mobile phone. Use of international dial codes even for domestic calls can confuse some users. Aerials having to be deployed and then stowed after use is unfamiliar to the modern mobile phone user, also sometimes with microphones in different places on the phone. Evidence from operations in the UK, and evidence submitted to the FCC review of the impact of Hurricane Katrina (example in reference [4]) highlight this as a major – but soluble – problem.

5.32 Some terminals **cannot be carried with the antenna deployed**; hence staff cannot always be contacted when on the move.

5.33 **Battery life** for satellite phones, when used in satellite mode is more akin to PMR than mobile phones, being in the order of 2-3 hours talk time and 10-30 hours in stand-by mode. This is because whereas a mobile phone can 'sleep' when in stand-by mode, the satellite phone has to continually listen for calls. In these circumstances, where a satellite phone is in use because of loss of mains power supplies over a wide area, provision must be made for recharging where power cuts or severe weather have deprived people of mains electrical power for extended periods.

5.34 **Spare batteries** may also be an advantage for satellite phones as it may not be possible to use the phone while being recharged (e.g. it's inside a motor vehicle or control room). It would be frustrating in the extreme to have a working phone during an emergency incident, but not be able to use it as it was sitting on a charger unable to get service at that location.

5.35 Satellite networks have a **limited range** of handsets available, and a similarly limited range of accessories that can inhibit their application for specialist utility task, e.g. intrinsically safe models, headsets, etc.

5.36 Because of the different mode in which the satellite systems operate, and their high call charges, they are unlikely to be used routinely. Telephone numbers will therefore be unfamiliar and directories can become out of date. It is therefore important that **Directory Services** are provided in a way that is accessible if a satellite phone is needed in times of emergency. That extends both inside and outside of the organisation where abbreviated dialling codes may mean that users have only limited exposure and knowledge of the full PSTN number.

6. Alternative options

7.5 metre satellite dish serving as a hub for a private VSAT network in a UK utility.

6.1 Although in principle beyond the remit of this report, convergence in telecommunications services is opening new avenues. An area of increasing interest for mobile field force communication is VSAT (Very Small Aperture Terminal – i.e. small dishes) and VoIP (Voice over Internet Protocol) technology.

6.2 As more utilities deploy VSAT technology for information gathering across geographically dispersed networks, the opportunity emerges for using these points, widely distributed across the utility's service area as communications nodes. Although VSAT technology has a number of drawbacks for voice communications, these are not dissimilar to the mobile satellite networks based on GEO satellite orbits as the VSAT service uses the same GEO orbit.

6.3 In the first instance, these VSAT hubs, married to VoIP technology can provide fixed voice telephony – as well as data - from substations and other infrastructure. The logical extension of this fixed node is to install secure wireless technology at the local fixed node, employing WiFi, WiMax, Bluetooth or even PMR technology to extend the range of the fixed node to include wireless voice and data in the area surrounding the facility.

6.4 Another recent development in the UK has seen the Communications Regulator OFCOM auctioning rights to use low power radio channels adjacent to the public mobile phone spectrum, but within the tuning range of most domestic GSM-standard handsets (1781.7-1785 MHz paired with 1876.7-1880 MHz). This is creating a market for private GSM networks that can be deployed for use by a restricted group of users when the public networks are either unavailable or congested. It is therefore conceivable that a utility could deploy a resilient private mobile phone network covering a range of a few miles around each of their substations for use by their own staff when the public networks are not available.

Forward command and control unit of Strathclyde Fire Service incorporating a satellite communications to link back to the Control Room and Corporate data network.
(Picture courtesy of Excelerate Technology)

6.5 These developments are now being brought together by the emergency services in the UK through the provision of rapidly deployable incident control vehicles incorporating a steerable roof mounted VSAT dish to establish a broadband connection from the scene of an incident back into the corporate data network.

6.6 These vehicles usually also include remotely controlled CCTV cameras to permit the control room to independently assess an incident.

6.7 Applications in this market are still emerging, but the emergency services in the UK are investigating marrying the VSAT technology, VoIP and mobile communications to extend the communications capability of their mobile incident control rooms. The units are being equipped with PMR base stations to communicate with field staff in the vicinity of the incident support vehicle, and additionally may be equipped with private GSM mobile phone networks. The PMR system and private Mobile Phone network can then be linked directly back into the organisation's own network, and into a mobile phone gateway outside of the area affected by the incident.

Forward command and control unit of a UK Ambulance Service incorporating a pump-up mast housing dual radio antenna and remotely controlled optical and infrared cameras with satellite back-haul to the control room. (Picture courtesy of Excelerate Technology)

6.8 Since these incident support vehicles may already have an extendable mast for CCTV monitoring, it is relatively easy to get a high sited antenna for good radio coverage at the scene of the incident.

6.9 As well as mobile voice communications, the mobile units can be equipped with WiFi, WiMax and Bluetooth nodes to enable field staff dealing with the incident to have direct access to private broadband internet connections using the incident control unit as a mobile gateway.

6.10 The incident control units are fully equipped with stand-by power generation to enable them to operate independently at an incident for an extended period.

6.11 Satellite communications usage as an adjunct during emergency response is also useful to the personal communications service (PCS) or cellular industry. The US FCC's Independent Panel report indicated that over 100 cellular base stations on wheels ("COWS") were deployed during the post-Katrina Hurricane recovery period. [Ref 1]. In order to properly establish cellular communications through the mobile tower, there must be communications back to headquarters. Therefore, some US companies are using satellite trailers to support COWs in the field. [Ref 8]

6.12 Satellite Telemetry systems are sometimes termed TSATs (Telemetry and data transfer via SATellite) to differentiate telemetry applications from more general VSAT technology. In essence they use the same technology, but TSAT is normally used to describe lower data rate VSAT services.

7. Post-Hurricane Katrina case studies

7.1 While satellite usage by utility companies was certainly a reality in the USA prior to 2005, the intense hurricane season that year prompted executive management teams to dedicate additional time and resources to projects already underway, as was the case for Southern Company and Baltimore Gas & Electric companies, and to initiate new investigations into satellite emergency response programs. With an invigorated sense of urgency the mantra became "Just get it done…" We are at this juncture presented with the opportunity to review real-life implementations of satellite system solutions in preparation for emergency response. The appropriate focus of these initiatives is the provisioning of transportable satellite VPNs (Virtual Private Networks) that enable rapid connection to the internet and the utility's own server(s) or LAN.

Baltimore Gas and Electric (BGE)

7.2 Baltimore Gas and Electric (BGE) is an investor owned subsidiary of the Constellation Energy Group that serves 1.2 million business and residential electric customers and 625,000 gas customers in a 2,300-square-mile area of Central Maryland. As a member of a utility Mutual Assistance program, BGE assists fellow utilities with supplemental overhead line restoration and contract tree trimming crews during times of severe thunderstorms, hurricanes, snow, or ice storms. Positioned well away from the centre-points of last years' hurricanes, the company provided emergency assistance in the ravaged south eastern areas of the United States. BGE is equipped not only for rapid communications restoration in the event of storms but is considering all types of emergency situations including Pandemic Contingency Planning, in which the communications requirements of personnel working from home are addressed (business continuity).

7.3 BGE's 800 MHz voice network does not operate outside its service territory therefore limiting truck-to-truck work coordination during emergency response scenarios in host utility areas. In order to facilitate critical off-system communications, in 2004 the company designed a portable communications trailer equipped with a collapsible 100 foot lattice tower, 800 MHz repeater, and an on-board generator to support remote, stand-alone, truck-to-truck voice communications for overhead crews. As the need for enhanced communications abilities became apparent, satellite internet capabilities were added. According to James P. Garrett, Sr., BGE's Lead Wide Area Network Analyst, this allows,

> "…email and office applications data to be remotely available to supervisory and logistical workers. Workers' time sheets, outage and restoration reports (to) be electronically exchanged with host and home utilities. Other uses found for the internet access (are): locating parts and supplies for vehicle maintenance support, printing maps and directions for travel, food and hotel reservations, etc…the reception of news, weather, or other local conditions…"

Cellular and satellite phones and cellular FAX were incorporated along with voice over IP (VOIP) facilities -necessary where cellular coverage was poor or nonexistent. When Hurricane Katrina hit New Orleans, IEEE 802.11b/g capabilities were added to allow BGE and other outside utility workers wireless access to the internet to send timesheets and other reports back to home offices. In 2005, a second trailer was designed with all the capabilities of the first, but, with a pneumatically operated 60 foot tower and reduced footprint to facilitate easier deployment. [Ref 5]

Portable Emergency Communications trailer as deployed in New Orleans, Louisiana following Hurricane Katrina in September, 2005. Data and voice resources were fed from the trailer to BGE's Mobile Operations Centre. [Ref 5]

A "storm drill" was conducted in October of 2006 in which a third mobile self-contained communications van with video teleconferencing capabilities was put through its paces.

7.4 BGE found that the geographic impact of local storms is the loss of commercial cellular service therefore BGE is in the process of changing to a privately owned Harmony System, an IDEN system, within its own territory. The 800 MHz analogue system is migrating to an 800 MHz digital one; this entails changing out all equipment. In the process, the critical need has become providing intelligence so that overhead and emergency personnel can “talk” to the home network in Baltimore. Satellite communications is an integral part of the solution and its use effectively eliminates “islands of communication”, negates the requirement for VoIP and now long distance calls are no longer an issue. [Ref 5]

7.5 The net results of BGE’s 2005 use of self-contained, mobile, communications is the demonstrated ability to transfer data between home offices and remotely located restoration crews in a timely and accurate manner where little or no infrastructure exists. Effective communications increases the efficiency and helps reduce the costs of local and remote restoration efforts.

Southern Company

7.6 Southern Company was directly impacted by the 2005 hurricanes as its 3.9 million customers are throughout a service territory that extends across the south-eastern United States, including the States of Alabama, Florida, Georgia and Mississippi. The company’s response to a post-storm survey last year indicated that private internal networks, which includes land mobile radio, microwave and radios stood up very well to the hurricanes. Satellite systems and satellite phones were deployed immediately after the storm to assist in providing voice and data communications. This is testimony to the fact that Southern Company is very well prepared for the worst contingencies. This also makes Southern Company’s expedited planning for the expanded use of satellite communications during emergency response particularly significant to this study.

7.7 Southern Company is driven by the need to be totally self-sufficient in times of emergency. Towards this end, they have in tow seven 8’ X 16’ communication trailers outfitted for emergency response (and seven storm teams) and are so impressed with satellite communications that another eight trailers are in full-time daily operation for field and construction crews. Two additional command centre trailers equipped with automated satellite downlink systems, providing voice and data connectivity back to Southern Company’s network.

7.8 Mississippi Power Chief Information Officer, Ms. Aline Ward, emphasizes that everything comes back to the core corporate network. That is, with satellite transmissions, Southern Company is concerned about where the satellite signals go up and where they come back down, where the hub is located and how the signals tie into the fibre running to the company’s corporate network in Atlanta. From a business perspective, the voice and data quality associated with satellites are found to be very good, latency is minimal and bandwidth capacity is only limited by the amount the company is willing to spend on the system. Satellite phones are plentiful and can be leased. Southern Company has pre-arranged contracts with both satellite downlink and satellite phone vendors to quickly provide resources in an emergency. In short, Ms. Ward highly recommends satellite communications as an integral part of a utility's emergency communications planning. [Ref 7]

SDN Global offers data continuity solutions that connect directly to the customer's Local Area Network (LAN), Picture provided courtesy of SDN Global, www.sdnglobal.com

7.9 Mr. Allen White of Southern Company explains that the satellite company utilized by Southern Company is SDN Global. Southern Company enjoys an advantage in that SDN has an earth station located just a few blocks from the Southern Company corporate headquarters in Atlanta and is able to lease dark fibre between the two locations. When asked about system redundancy, Mr. White said the SDN earth station has redundancy in routing facilities located in Charlotte, N.C.

7.10 The two command centre trailers are semi-trailer sized units which are fully equipped offices. The seven communications trailers outfitted for emergency response are used to support seven separate "storm teams", ensuring truly independent operations. Since time is of the essence during a crisis, each trailer has a generator and an auto-point satellite system. Data connectivity and telephone connectivity is available within a matter of minutes. The data speeds are approximately 2 Mbits/s downstream and 512 kb upstream. Once every three months the emergency response trailers are tested just to make sure everything is in working order – the generator is cranked and dishes are checked. The eight operational units used full time by construction crews are manual point systems. Manual point satellite systems are significantly less expensive than auto-point systems; however, they can require one to three hours to set up as the satellite dish must be manually aligned.

7.11 Money spent on emergency satellite communications trailers is considered to be very much like insurance premiums. It is hoped that the service is never necessary, but if it is, you are certainly glad that the service is available. [Ref 8]

Globalstar LLC

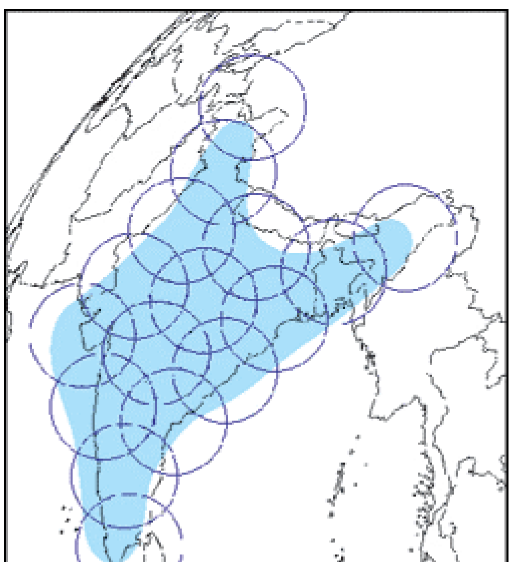
7.12. During and after Hurricane Katrina, Globalstar activated:

- dual-mode Globalstar/CDMA handsets;
- dual-mode Globalstar/CDMA fixed phones;
- dual-mode Globalstar/CDMA satellite data modems;
- dual-mode Globalstar/GSM handsets;
- dual-mode Globalstar/GSM fixed phones; and
- Globalstar simplex data modems.

7.13 In the US/Caribbean region, Globalstar activated 3,384 new subscriptions in August 2005, and in September 12,297 subscriptions, of which 11.087 (90%) were dual-mode Globalstar/CDMA handsets. In addition, in September 2005 Globalstar activated 2,002 simplex data modems, which are primarily used for asset monitoring and tracking. For comparison, in the same region for the six months from February to July 2005, Globalstar activated an average of 1,267 new phone and satellite data modem subscriptions per month.

7.14 In the two weeks following hurricane Katrina, Globalstar hand-built and sent to the Federal Emergency Management Agency (FEMA) four transportable emergency communications gateways. These units contained five or six Globalstar fixed phones and a GSM picocell. Users are able to plug up to six standard telephones into these units using standard RJ45 connectors. Up to 15 GSM cell phones can communicate simultaneously with each other through the picocell. The cellphone uses can also conduct five or six simultaneous calls through the emergency communications gateway via the Globalstar satellites over the public switched telephone network.

7.15 In terms of capacity on the Globalstar network, they have reported to the FCC [Ref 9] that there is no precise answer to this question. Call capacity is contingent on many variables related to both the satellites and the gateways. Each satellite has 16 spot beams which together cover a 3,500 mile diameter coverage area beneath the satellite. Each spot beam has 16.5 MHz of downlink spectrum which supports up to thirteen 1.23 MHz channels. Each 1.23 MHz channel can support up to 60 circuits. However, the satellite is power-limited, which prevents each satellite from supporting the theoretical maximum of 60 x 13 x 16 = 12,480 simultaneous voice calls. On the other hand, multiple satellites cover a point on the earth at



Concept of overlapping spot beams to provide continuous coverage [illustration is not to scale for Globalstar] any time (for instance, four to six satellites cover the continental US at any one time), so that capacity of multiple satellites contributes to the total system capacity.

7.16 The call capacity also depends on resource allocation decisions made by Globalstar's control centre and a gateway's physical configuration. Globalstar has the ability to change service coverage and to reassign or add communications channels in their gateways and satellite beams as demand warrants. These networks configuration changes can be implemented dynamically and remotely for their control centre in California. The capacity of each gateway to interconnect traffic to the public switched telephone network is matched to calling patterns through that gateway, and can be augmented reasonably promptly, and at modest cost – dependent on the ability of Globalstar's service providers being able to also respond quickly to a request for network enhancement. Finally, the circuit capacity of the gateway depends on the hardware that has been installed. Adding new hardware to expand capacity takes some time and is relatively expensive. For these reasons, Globalstar would not normally add hardware to meet short-term changes in demand.

7.17 Clearly the U.S. hurricane season of 2005 prompted critical infrastructure companies and satellite equipment/service suppliers to strengthen reliance upon satellite communications for future emergency response. UTC sources advise that during the past twelve months many U.S. utilities have been through a period of review it which the non-existence of integrated voice and data communications plans are revealed, and certainly in many companies, there is no strategy with regards to the use of LEO or MEO satellite communications in crisis. Yet a change in this trend is indicated as multiple proposals have been recently considered for deployment satellite voice communications as an emergency contingency and these plans further address combined high speed/low speed strategies with integrated SCADA and advanced telemetry functions. Such proposals are indicative of the increased attention utilities are giving to satellite communications, not only for emergency response, as a means to reach into remote and underserved areas and to "fill-in the gaps" in existing communications. It is fully expected that within a year, many more U.S. based utilities will have complemented existing internal communications with satellite service.

8. Conclusions

8.1 Although from the catalogue of vulnerabilities and failures listed earlier in the report one could draw a negative impression, mobile satellite communications have demonstrated their ability to play a vital role in providing resilient communications in a number of high profile incidents. Because they are substantially independent of main electricity supplies and local telecommunications infrastructure, they provide a worthwhile complementary service to public ground-based telecommunications networks, and even on occasion resilient private mobile communications networks.

8.2 The vulnerability of satellite phones is that they inherently have much greater limitations than fixed or mobile networks, and are likely to be swamped if there were a major widespread crisis which disrupted major elements of the strategic national infrastructure over a wide area. Their strength is that their failure modes are substantially different to terrestrial networks, making them very complementary.

8.3 One weakness in the deployment of satellite phones in an emergency is that users have not realised that call termination may make them useless unless the called party also has a resilient communications pathway, or is outside of the affected area.

8.4 A further conflict has emerged when telecommunications managers have equipped staff with satellite phones without alerting them to the differences in mode of operation. Control room staff and emergency planning managers have expected satellite phones to work in the same way as conventional mobile phones – i.e. inside conference rooms and at the control desk in a control room.

8.5 Major problems have emerged because of staff unfamiliarity with the handset when asked to operate it in what is already most probably the highest stress situation they have ever experienced in their working lives.

8.6 Directory structures are vital in that substantial feedback from incidents highlights the frustration of having a valuable working communications tool, but not having the correct telephone number of the called party – or the network barring the number because it is outside the normal numbering range.

8.7 Satellite phones are not a panacea and any deployment for emergency use must be carefully planned and executed if the reliance is to be more than illusory.

8.8 Chosen carefully, satellite mobile phones can provide a useful adjunct to any diverse resilient communications strategy.

8.9 This is a rapidly developing area both technically and commercially, and it is likely that some of the information in this report is already out of date.

9. Recommendations

9.1 **Further detailed work will be necessary** by any organisation wishing to identify the optimum communications options for their entity.

9.2 Once a decision has been reached on the preferred option, it must be **rigorously examined and tests conducted** where possible to ensure that if needed in a crisis, it performs as anticipated.

9.3 It may be worthwhile establishing a mechanism to **exchange telephone numbers with other organisations** using satellite mobile phones to manage their own emergencies so that, in a crisis, key personnel can exchange information.

9.4 This area **of technology is still developing**. In places, data (especially costs and call tariffs) may have been overtaken by developments of the networks, and should be re-validated before any firm conclusions are reached.

9.5 A **comprehensive communications strategy** will incorporate:

- **Flexibility** - adaptable to an ever changing environment and technologies;
- **Co-operation** - working with other users to ensure you can all communicate with one another in an emergency;
- **Diversity** – never depending excessively on one solution;
- **Current data** – ensuring all the data records are correct in terms of telephone number, staff functions and locations;
- **Information** – disseminating vital information clearly, simply and regularly to those who need to know; and
- **Luck** – in spite of all the best laid plans and exercises, life will always be full of surprises.

10. Disclaimer

10.1 Although JRC has used its best endeavours to produce work of only the highest quality, as an SME (Small and Medium sized Enterprises), JRC does not warrant the accuracy or authenticity of any of the data contained herein, and cannot accept any consequential liability for this report.

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12. Abbreviations

AA	Automobile Association
ACCOLC	ACCess OverLoad Control
ATC	Ancillary Terrestrial Component
BBC	British Broadcasting Corporation
B-GAN	Broadband Global Area Network
CCTV	Closed-Circuit Television
CDMA	Code Division Multiple Access
CII	Critical Infrastructure Industries
COMSEC	COMmunications SERurity
CNI	Critical National Infrastructure
DISN	Defense Information Systems Network
DoD	Department of Defense
DSN	Defense Switched Network
EIRP	Equivalent Isotropically Radiated Power
EMSS	Enhanced Mobile Satellite Service
FCC	Federal Communications Commission
FEMA	Federal Emergency Management Agency
g	gram (or gramme)
GEO	Geosynchronous (or Geostationary) Earth Orbit
GPRS	General Packet Radio System
GPS	Global Positioning System
GSM	Groupe Spéciale Mobile or Global Standard for Mobiles
HEO	High Earth Orbit or Highly Elliptical Orbit (different meanings)
HF	High Frequency
IP	Internet Protocol
ITU	International Telecommunication Union
JRC	Joint Radio Company Ltd
kbit	kilobit
km	kilometre
LEO	Low Earth Orbit
LMR	Land Mobile Radio

m	Metres
MEO	Medium Earth Orbit
MHz	Megahertz
MPT	Ministry of Posts and Telecommunications
MSS	Mobile Satellite Service
NSA	National Security Agency
OFCOM	Office of Communications
PC	Personal Computer
PDA	Personal Digital Assistant
PMR	Private Mobile Radio
PSTN	Public Switched Telephone Network
RAC	Royal Automobile Club
s	Second
SCADA	Supervisory Control And Data Acquisition
SIM	Subscriber Identity Module
SMS	Short Message Service
S-PCS	Satellite Personal Communications System
TACS	Total Access Communications System
TETRA	TErrestrial Trunked Radio
TSAT	Telemetry & data transfer via SATellite employing VSAT technology
TT&CC	Telemetry, Tracking & Command & Control
UK	United Kingdom
US	United States
USA	United States of America
UTC	United Telecom Council

VoIP	Voice over Internet Protocol
VPN	Virtual Private Network
VSAT	Very Small Aperture Terminal
W	Watts

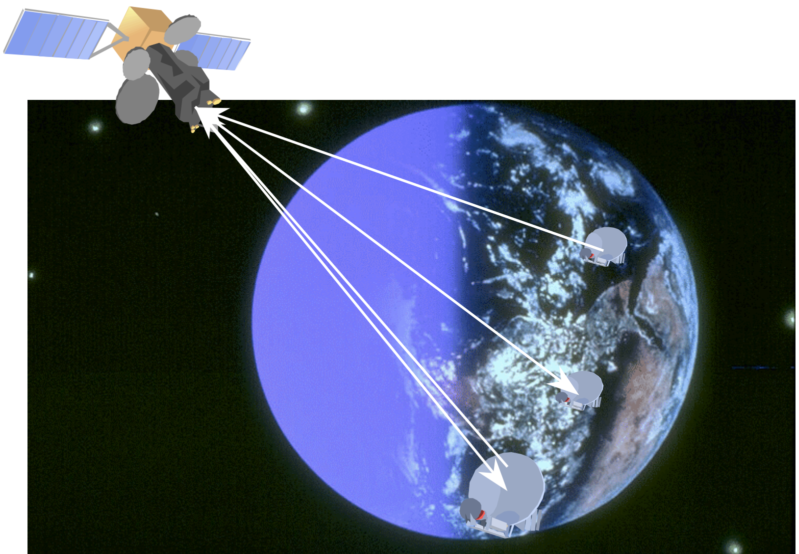

Illustration of VSAT technology [Ref 3]

13. Glossary

ACCOLC ACCess and OverLoad Control: a system designed to give priority access to mobile networks in times of stress.

Bluetooth Bluetooth is a specification for wireless personal area networks (PANs), also known as IEEE 802.15.1. Bluetooth provides a way to connect and exchange information between devices like personal digital assistants (PDAs), mobile phones, laptops, PCs, printers, digital cameras and video game consoles via a secure, globally unlicensed short-range radio frequency.

E1 A 1.5 MHz circuit (or 24 channel pulse code modulation voice circuit)

GPS Global Positioning System; usually refers to a US DoD system based on a constellation of satellites which transmit highly accurate time signals as they trace a known path around the earth. By comparing the time at which signals from a number of satellites arrive at a terminal, it is possible to calculate your precise position at any point on the earth’s surface, or even above it.

GPRS General Packet Radio Service: an enhancement of the GSM mobile phone standard to facilitate the transmission and reception of high speed data (theoretically up to 170 kbits/s) using a packet data protocol. Sometimes referred to as 2.5G – an intermediate step between circuit-switched data of second generation mobile phone systems (such as GSM), which operated at 9,6 kbits /s, and third generation systems such as UMTS & CDMA2000 which are capable of much higher data rates.

Hand-over Hand-over is a process where-by a telephone call is established using one transmission path, but due to the movement of the transmitter and/or the receiver, the communication path has to be transferred to another route during the progress of the call without a noticeable interruption to the parties making the call.

IP Internet Protocol: the basic protocol used for sending information over the Internet.

ITU International Telecommunication Union: an intergovernmental agency of the United Nations, based in Geneva, and charged with managing international aspects of telecommunications, including supervision of the radio spectrum, international telephone numbering and allocation of orbital slots for satellites.

L-band A range of frequencies typically considered to be between 1000 MHz and 2000 MHz which are in great demand due to their ability to be used for both terrestrial and satellite applications in fields of mobile telephony, broadcasting, position fixing, navigation and many niche applications.

Link budget A link budget is the accounting of all of the gains and losses from the transmitter, through the medium (free space, cable, waveguide, fibre, etc.) to the receiver in a telecommunication system. It takes into account the attenuation of the transmitted signal due to propagation, as well as the loss, or gain, due to the antenna. Random attenuations such as fading are not taken into account in link budget calculations with the assumption that fading will be handled with diversity techniques.

Milestones When referring to the development of satellite systems, a registration by the regulatory authorities to establish a timetable for the development and deployment of satellite systems to ensure that valuable spectrum and orbital positions are not reserved indefinitely for satellite systems which may never ultimately get to the market.

Picocell A Picocell is a low-power cellular base station designed to serve a very small area, such as part of a building, a street corner, a railway carriage or an airplane cabin. A picocell is generally smaller than a microcell, although there is no definitive distinction.

S-band The S band of the radio spectrum ranges from 2.0 to 4.0 GHz. crossing the imaginary boundary between UHF and SHF at 3 GHz. It is part of the microwave band of the electromagnetic spectrum. S band is used by weather radar and some communications satellites, especially those used by NASA to communicate with the Space Shuttle and the International Space Station.

Slant angle The angle subtended between a ground-based satellite terminal and the orbiting satellite with which it is communicating. When at 90 degrees, the radio path has a minimum amount of the earth's atmosphere through which to pass, hence a minimal amount of signal energy is lost through attenuation by the earth's atmosphere. When the slant angle approaches zero, the path through the atmosphere is significantly longer, resulting in much greater attenuation of the radio signals.

SMS Short Message Service (SMS) is a service available on most digital mobile phones (and other mobile devices, e.g. Pocket PCs, or occasionally even desktop computers) that permits the sending of short messages (also known as text messages, or more colloquially SMSes, texts or even txts) between mobile phones, other handheld devices and even landline telephones. They conventionally comprise 160 characters and are transmitted on the signalling channel, guaranteeing a more reliable and rapid service than if the same message were to be transmitted using the conventional data channel.

Trunked Radio System: a spectrally efficient system of allocating radio channels to successive users from a pool of available channels to avoid dedicating individual radio channels to a single user or block of users.

VoIP Voice over Internet Protocol, also called IP Telephony, Internet telephony, Broadband telephony, Broadband Phone and Voice over Broadband is the routing of voice conversations over the Internet or through any other IP-based network. Continuous analogue voice traffic it broken up into packets, transmitted over the internet and then re-assembled back into a voice stream at the recipient end.

Virtual private network (VPN): This is a private communications network often used within a company, or by several companies or organizations, to communicate confidentially over a publicly accessible network. VPN message traffic can be carried over a public networking infrastructure (e.g. the Internet) on top of standard protocols, or over a service provider's private network with a defined Service Level Agreement (SLA) between the VPN customer and the VPN service provider.

WiFi Wireless Fidelity: a radio system for connection computers and computer-like devices (e.g. intelligent mobile phones) together over short distances in homes, offices and public WiFi hotspots such as cafes and hotels; uses standard in the series IEEE 802.11 operating in unlicensed radio spectrum.

WiMax WiMAX is defined as Worldwide Interoperability for Microwave Access by the WiMAX Forum, formed in April 2001 to promote conformance and interoperability of the IEEE 802.16 standard, officially known as Wireless MAN. The Forum describes WiMAX as "a standards-based technology enabling the delivery of last mile wireless broadband access as an alternative to cable and DSL (Digital Subscriber Line)".

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Annexes

Annex A. History

A1. Reliable communications have been recognised as a key success factor for several millennia. One of the hallmarks of the Roman empire, more than two thousand years ago, was their system of roads to facilitate movement of troops and supplies efficiently and effectively throughout the Empire. So successful was this road system that, to this day, many roads in Europe still follow these ancient pathways.

The ancient 'Fosse Way' an old Roman Road still much used today by motorists in Leicestershire in the UK today.

A2 In parallel with the need for transport communication routes, systems were devised to convey information rapidly over large distances, mainly for military purposes. Despatch riders, carrier pigeons, signallers with flags, heliographs, fire beacons and watch towers formed the essential ingredients of successful defence and offensive military campaigns. Even with these early systems of communications, the essential elements of a communication system can be discerned, most notably:

- Speed – How long it takes for the message to get through?
- Bandwidth – How much information can be conveyed in a single message?
- Availability – How reliable is the means of communication?
- Security – How easy is it to intercept or block the communication?
- Confirmation – Has the message got through?
- Response – Will the medium support two-way communication?
- Capacity – How many messages can I send using the system?
- Cost - How much does it cost to establish, operate and maintain?

A3 If one looks at these basic historical systems of communications, the same elements of concern arise as has been the stimulus for this current study on use of mobile satellite communications in emergency response. In the 19th Century, optical telegraphs could transmit the midday time signal from London to the main British naval base at Portsmouth – some 70 miles in half-a-minute. But in fog, it must have taken a little longer for the time signal to get through. In the First World War in Europe, carrier pigeons were a favourite choice, though it is likely that many ended up on the table of the enemy – and the system lacked any confirmation of receipt and there was no return channel. In the US, native Indian smoke signals were legendary; they were more effective than open fires on sunny days, but possessed little security.

A4 Mobile communications came of age after Marconi conducted his experiments with radio in England. The benefits of radiocommunications were not obvious to the military from the start but this attitude rapidly changed as the possibilities became clear and the technology improved. During the First World War, the Royal Flying Corps, fed up with their pigeons being intercepted, started taking experimental radio transmitters up in the air allowing real-time gunnery spotting to take place. In peace-time the benefits of radio-based mobile communications were obvious to the civil arena. The Police were the first to deploy mobile radio in their patrol cars, followed rapidly by the utilities – mainly the electricity sector, which could see the benefits of this new technology.

Marconi Memorial in Alum Bay, Isle of Wight, England recounting Guglielmo Marconi's experiments in 1897 signalling to the opposite shore. Subsequently he established link between the Prince of Wales, on the Royal Yacht *Osborne* and Queen Victoria at Osborne House.

A5 Terrestrial mobile radio was obviously the technology that emerged in the 1950s, giving birth eventually to cellular mobile phone technology whereby in Western Nations, we are now reaching the situation where there are as many mobile phone connections as head of population.

A6 As land-based mobile radio communications became more reliable, offered higher voice quality, adopted data technologies (principally fax in the early days), and increased capacity, long range maritime communications were restricted to the specialist and 'quirky' HF (High Frequency) bands in order to achieve the desired range when on the high seas.

A7 In the 1960s, satellite communications emerged, commencing with large antennas – 30m or so in diameter – which operated between fixed locations. However, the rapid strides in the technology enabled smaller dishes to be increasingly used, enabling the technology to be deployed on mobile platforms, especially ships. This market, with a demonstrable need and the financial resources to adopt the technology, drove development until ultimately satellites could communicate with portable handsets, albeit with limited bandwidth. The mobile satellite sector was born!

A8 However, the birth of the mobile satellite sector has not been without pain. The majority of mobile satellite operations have been through bankruptcy and re-financing, some several times. The original vision of universal mobile voice communications has been undermined by the 'double whammy' of the global deployment of low cost terrestrial mobile phone services using a single standard - GSM - on an international scale; and the inability of those who would really benefit from the true global nature of mobile satellite phones to afford the technology.

A9 If one adds to the scenario regulatory constraints which, have restricted the ability of the mobile satellite operators to provide service in certain countries, plus the difficulty in some cases of establishing the necessary ground stations to terminate the calls, one can see how the mobile satellite industry has struggled to attract the finance necessary to deliver the required service levels.

A10 Thus the issues identified in paragraph 1.2 above in relation to ancient signalling systems remain the key issues to be addressed today. The prime purpose of this report is to assist utility telecoms managers when assessing the risks and costs of the alternative communications technologies, and to place mobile satellite systems in perspective.

A11 The Report by the London Assembly on the suicide bombing of the Capital on 7 July 2005 [Ref 10], commenting on the poor performance of the emergency services communications said "...we ... know that the ability of the London Fire Brigade to establish what had happened at King's Cross was hampered by the fact that hand-held radios did not work effectively between the platform and a control position at the top of the escalator, nor between the top of the escalator and outside the station. The Fire Brigade therefore had to use runners – individuals running up and down escalators – to communicate from below ground to the surface.".

Images of the familiar red London Double-Decker Bus are a poignant reminder of the continuing terrorist threat and the importance of reliable communications in an emergency. (picture courtesy of BBC London)

A12 Later in the same report, again the London Assembly report comments "Communications between Great Ormond Street [hospital] and Russell Square [underground railway] station were non-existent, so medical students acted as runners between the two." For all the advances in electronic communications in the 20th Century, it seems sometimes we have to fall-back to the old tried and tested methods of our forefathers.

A13 Utility communications systems along the Gulf Coast of the United States were rigorously tested during the months of August, September and October of 2005 by a series of three devastating hurricanes: Katrina, Rita and Wilma. While utility land mobile radio (LMR), microwave and fibre networks stood up very well under the circumstances, there has been much subsequent discussion by critical infrastructure industries (CII) and government regarding ways in which communications emergency preparedness might be improved before the next, inevitable disaster strikes. The use of mobile satellite communications has been an important part of these discussions.

Annex B. General satellite data

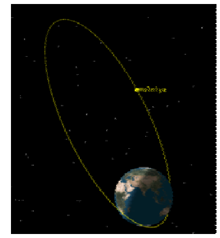
B1 Mobile satellite services have been in existence for over a decade, but their gestation period is usually long and painful. During this extended period, design parameters often change, and technological advances are incorporated. The international procedures for filing details are complex and changes are not always reflected in the satellite filings in the public domain for some time. Publicly available data can thus be out of date. Information in this section should therefore be treated as indicative of the systems rather than an authoritative specification and explanation of the mode of operation. It is also known that for commercial reasons, satellite operators do not find it in their interest to correct misleading explanations of the detailed operations of their systems in the public domain. Verifying data in these technical annexes is difficult, but the information is provided on that basis that, even if not precisely correct in every detail, it is indicative and of more value than no data.

B2. The satellite market remains buoyant, with systems still being planned, under construction, and with satellite constellations being assembled in orbit. Mobile Satellite Systems (MSS) provide a variety of personal and business communications on an individual country, regional or world-wide basis. The services offered range from messaging, paging, meter reading and asset tracking through to more broadband facilities, such as satellite based mobile telephony, multimedia and mobile data applications. Perhaps the largest investments globally at present are new ranges of military communications satellites and the European Global Positioning System ‘Galileo’.

B3. Satellite Services can be categorised both in terms of the service offered and the type of orbit employed.

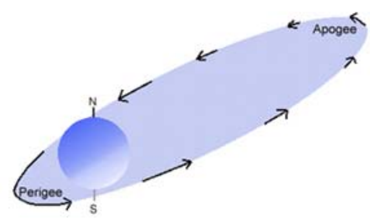
Generic Orbit	Orbital Height	Orbital Inclination	System Type	Comments
Low Earth Orbit	Up to 5,500 km	0 – 90º, circular	Little LEO	Less than 1 m³ in volume using frequencies below 1 GHz, operating in a ‘store and forward’ mode.
			Big LEO	Less than 10 m³ in volume, operating at frequencies above 1GHz, offering real-time services
			Broadband LEO	Multimedia services
Medium Earth Orbit: Intermediate Circular Orbit	Between 5,500 and 35,768 km	0 – 90º, circular	MEO	Multimedia & real-time services
Highly Elliptical Orbit	From 5,500 to 35,768 km	> 0 – < 90º	HEO	High latitude pseudo-stationary orbits
Geosynchronous Earth Orbit	35,768 km	~º, circular	GEO (Geo-synchronous or geostationary)	Real-time services

Molniya orbit



B4. Although the LEO, MEO and GEO satellite systems have been explained, for completeness it is important to mention the Molniya orbit. This is a class of a highly elliptic orbit with inclination of 63.4° and orbital period of about 12 hours. A satellite placed in this orbit spends most of its time over a designated area of the earth, a phenomenon known as apogee dwell. Molniya orbits are named after a series of Soviet/Russian Molniya communications satellites that have been using this class of orbits since the mid 1960s.

B5. For stationary apogees, the orbital period must divide 24 hours evenly. A 12 hour orbital period gives two apogees (that is, when the satellite reaches apogee it is always over one of two spots on the earth) and two perigees; a six hour period would give 4 of each type.



B6. A large inclination allows the apogee to be close to either the north or south pole (Russians, Canadians or Swedes would put it close to the north pole), where coverage for a geostationary satellite is poor or non-existent. In general, the oblateness of the earth perturbs the argument of perigee, so that even if the apogee started near the north pole, it would gradually move unless constantly corrected with "station keeping" thruster burns. To avoid this expenditure of fuel, the Molniya orbit uses an inclination of 63.4°, for which these perturbations are zero.

B7. Satellites placed in an highly elliptical orbit in such a way spend the greatest amount of time over a specific area of the earth. Broadcasting satellites intended to deliver services to mobile receivers in higher latitudes find these satellites the most effective. A constellation of three Molniya-orbit satellites can thus provide a broadcasting service at high elevation angles over areas such as Russia, Canada and Northern Europe more effectively than GEO satellites, but at lower cost than lower level circular orbits. The extended time delay for transmissions from the apogee of the Molniya orbit to reach the earth is not an issue for broadcasting as it is essentially a one-way service.

Mobile Satellite Services

B8. Proposed, planned and operational systems in the Mobile Satellite Services.

Name of System	Status	Nº of Satellite	Type of Service	First launch	Nº in Orbit	System finish
Globalstar	Operational	48 + 8	voice, data, fax, paging	1998	48 + 4 spare	2002
ICO	Planning	10 + 2	voice, data, fax, messaging	1998		
Iridium	Operational	77 + 11	voice, data, fax,	1997	66 + 9	2002

			paging		spare	

Frequency bands used by the MSS

B9. The frequency bands used are many and varied, but it is the mobile to satellite up and down link frequencies that are of significant interest as these are vying for the same spectrum as presently used by land mobile services in many cases. The frequencies used are shown in the following table:

System	Satellite to Mobile downlink	Mobile to Satellite uplink	Satellite to Gateway downlink	Gateway to Satellite uplink
Globalstar	2483·5 – 2500 MHz (S-band)	1610 - 1626·5 MHz (L-band) CDMA	6875 - 7055 MHz (C-band) FDMA	5091 - 5250 MHz (C-band) FDM
ICO	2 GHz	2 GHz	6825 - 7025 MHz (C-band)	5050 - 5250 MHz (C-band)
Iridium	1616 - 1626·5 MHz (L-band)	1616 - 1626·5 MHz (L-band)	19·4 – 19·6 GHz (Ka band)	29·1 – 29·3 GHz (Ka band)

Satellite Launch data Orbital and Payload Characteristics

Name of System	Orbital planes	SVs per plane	Altitude	Orbit inclin -ation	Orbital period	Latitude Cover-age	Footprint diameter	Power	Mass	Satell-ite life-time
Globalstar	8	6	1,414 km	52°	113min	±70°	16 x 2254km (5,850km)	1100 W	450 kg	7½ yrs
ICO	2	5	10,355 km	45°			163 x (11,000 km)	8700 W	2600 kg	12 years
Iridium	6	11	780 km	86°	100min	±90°	48 x 600 km (4,700km)	1400 W	700 kg	5 – 8 yrs

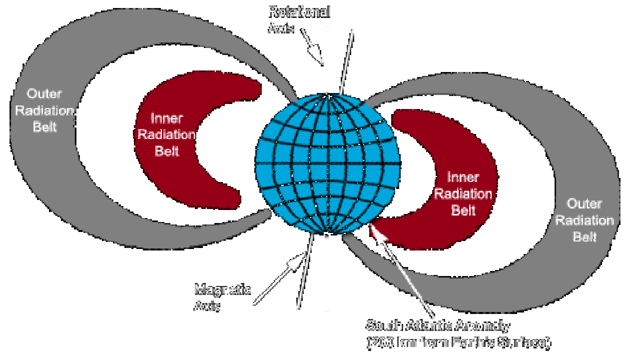
Higher Earth Orbit Satellite Services

B10. Confusion can arise between Highly Elliptical Orbits and Higher Earth Orbit satellites due to the use of the same abbreviation ‘HEO’. Global Positioning Satellite systems (GPS) use higher orbital slots. Two systems already exist: the US ‘GPS’ service and a similar Russian system called ‘Glonass’. Global Positioning Systems use a fleet of high Earth orbit satellites to provide constant coverage of the entire planet with high precision time signals to enable GPS receivers to compute their location to any point on the surface of the Earth. More complex receiver can also compute altitude.

B11. A new European GPS system is now in development called ‘Galileo’. It will complement the existing US and Russian systems by adding a further 30 satellites in three orbital planes at an altitude of 23,000 km. Each plane will contain nine operational satellites spaced at 40°

intervals plus in–orbit spares. Galileo has launch slots reserved between November 2007 and April 2008 for their first four operational satellites which have a scheduled life of 12 years.

Van Allen Radiation Belts

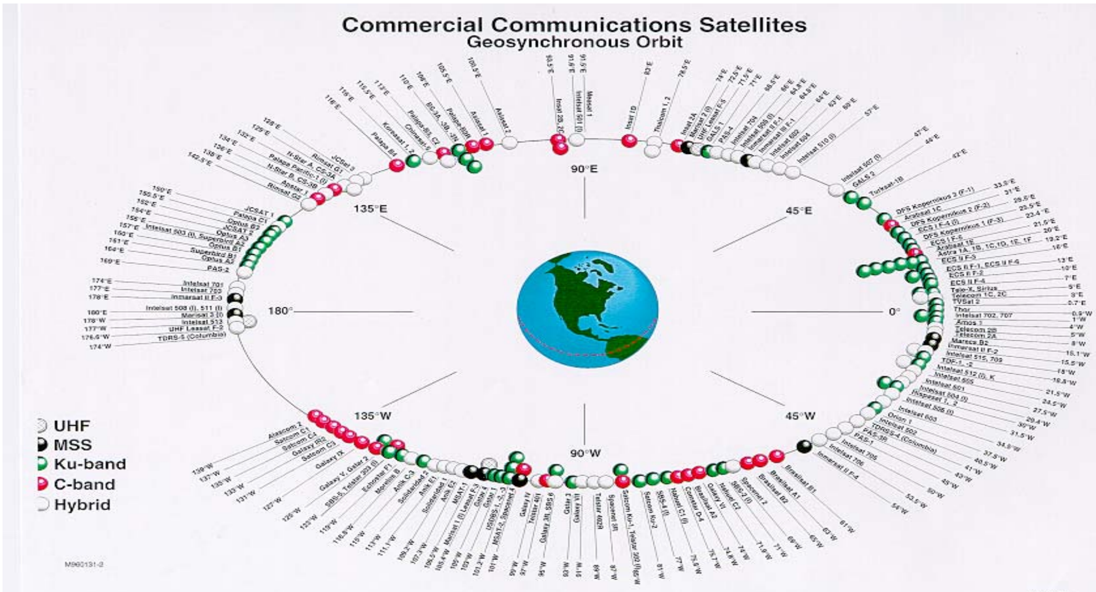


B12. The reason for the focus on specific altitudes for satellites circling the earth derives from a series of destructive belts of plasma around the earth, called 'Van Allen' belts named after the mission controller for the series of exploratory satellites which mapped them.

B13. The large outer radiation belt extends from an altitude of about 5,000–65,000 km and has its greatest intensity between 14,500 and 19,000 km. The inner Van Allen belt extends from roughly 7,000-21,000 km.

B14. Solar cells, integrated circuits, and sensors can be damaged by radiation. In 1962, the Van Allen belts were temporarily amplified by a high-altitude nuclear explosion and several satellites failed as a result of the increased radiation. Magnetic storms occasionally damage electronic components on spacecraft. Miniaturization and digitization of electronics and logic circuits have made satellites more vulnerable to radiation, as incoming ions may be as large as the circuit's charge. Electronics on satellites must be hardened against radiation to operate reliably. The Hubble Space Telescope, among other satellites, often has its sensors turned off when passing through regions of intense radiation.

Geostationary (Geosynchronous) Satellites



B15. In contrast to the mobile satellite market which has lacked financial certainty until recently, the fixed satellite market using geostationary satellites has flourished. The diagram below shows the relatively congested state of the geosynchronous orbit and the number of commercial satellites in use (in addition to unspecified numbers of military satellites).

Annex C. Globalstar technical annex

C1 Globalstar is a satellite-based, wireless telecommunications system designed to provide voice, data, fax, and other telecommunications services to users worldwide. Users of Globalstar make or receive calls using hand-held or vehicle mounted terminals similar to cellular phones. Most of the terminals are dual-mode, i.e. GSM/Globalstar or IS95/Globalstar. Consequently, when user terminals are in the terrestrial network coverage, they are intended to use the cellular network. When outside this coverage, they communicate via satellite. Calls are relayed through the Globalstar satellite constellation to a groundstation, and then through local terrestrial wireline and wireless systems to their end destinations.

C2. Globalstar satellites have been placed into low earth orbit, 48 of which were intended to be operational, with eight in-orbit spares. The satellites are placed in eight orbital planes of six satellites each with a circular orbit inclined at 52 degrees. The satellite mass is approximately 450 kilograms, and requires some 1,100 watts of power for normal operations. The satellites in the first-generation constellation are designed to operate at full performance for a minimum of 7 1/2 years.

C3. Globalstar's satellites orbit 1,414 km (878 miles) above the earth's surface, and take less than two hours to complete a full rotation. The LEO satellites communicate with Globalstar's devices using omni-directional antennas and need a clear line-of-sight to the sky to work.

Gateways

C4. Gateway facilities enable voice and data transfers to take place between Globalstar's wireless satellite network and the traditional public-switched telephone network (PSTN). Globalstar's call flow was designed to deliver high quality voice services. To achieve that result, outbound calls from Globalstar's phones are directly connected to a minimum of one and up to three LEO satellites at one time, and then delivered to the closest regional gateway for call completion through the PSTN. Incoming calls follow the same course, but in reverse.

Path Diversity™ & Coverage

C5. Globalstar uses a patented method of signal reception, called Path Diversity™, to achieve this connection of a single call with up to three satellites at one time. The design philosophy is to reduce voice delay and enhance voice quality. Path Diversity™ permits a digital receiver to combine multiple, relevant signals of varying strengths into a single, static-free signal. As satellites move in and out of view, they are added to and removed from a call in progress, thereby reducing the risk of call interruption. In principle, this enables Globalstar to provide broad coverage with less potential for signal blockage from buildings, terrain or other natural features.

C6. Multiple LEO satellites working in concert guarantee that if a single satellite temporarily fails, another one can respond and overall coverage will not be significantly impacted. Globalstar's service covers latitudes from 70° north to 70° south, which encompasses more than 75% of the world's surface area. The network was designed to service the temperate zones of the world where the majority of Globalstar's customers need coverage.

Wireless Technology

C7. Globalstar utilises a version of Code Division Multiple Access (CDMA) technology based upon the IS-95 CDMA standard. CDMA technology forms the foundation for 3G (Third Generation) wireless services, which are widely used around the world. This digital transmission technology allows a large number of wireless customers to simultaneously access a single radio frequency channel. The objective is less interference, and an increase in capacity when compared to analogue systems such as Frequency Division Multiple Access (FDMA).

Annex D. Iridium technical annex

D1. The Iridium communications service was launched on 1 November 1998 and went into Chapter 11 bankruptcy on 13 August 1999. The first Iridium call was made by then Vice President of the United States, Al Gore.

D2. Its financial failure was largely due to insufficient demand for the service. The increased coverage of terrestrial cellular networks (e.g. GSM) and the rise of roaming agreements between cellular providers proved to be fierce competition. The cost of service was also prohibitive for many users, despite the continuous world-wide coverage of the Iridium service. In addition, the bulkiness and expense of the handheld devices when compared to terrestrial cellular mobile phones discouraged adoption among users.

D3. The initial commercial failure of Iridium had a dampening effect on other proposed commercial satellite constellation projects, including Teledesic. Other schemes (Orbcomm, ICO Global Communications, and Globalstar) followed Iridium into bankruptcy protection, while a number of proposed schemes were never constructed.

D4. The Iridium satellites, however, remained in orbit, and their services were re-established in 2001 by the newly founded Iridium Satellite LLC, owned by a group of private investors. The system is being used extensively by the US Department of Defense for its communication purposes through the DoD Gateway in Hawaii. The commercial Gateway in Tempe, Arizona provides voice, data and paging services for commercial customers on a global basis. Typical customers include maritime, aviation, government, the petroleum industry, scientists, and frequent world travellers. Iridium Satellite LLC claims to have approximately 142,000 subscribers as of 31 December 2005, a 24% increase from the total as of 31 December 2004. Revenue for the calendar year 2005 was up 55% over 2004.

D5. US phone rates are reported as being in the region of, from land lines to Iridium phones $3 to $14 per minute, from Iridium to land lines about $1.50 per minute and between Iridium phones less than $1 per minute. Iridium and other satellite phones may be identifiable to the listener because of the particular "clipping" effect of the data compression and the latency (experienced as a noticeable lag or time delay) due to the distance the signal travels to and from the satellite, as well as the electronic equipment used. Iridium operates at a data rate of 2400 baud, which requires very aggressive voice compression and decompression algorithms. In particular, the voice coder used is called Advanced Multi-Band Excitation.

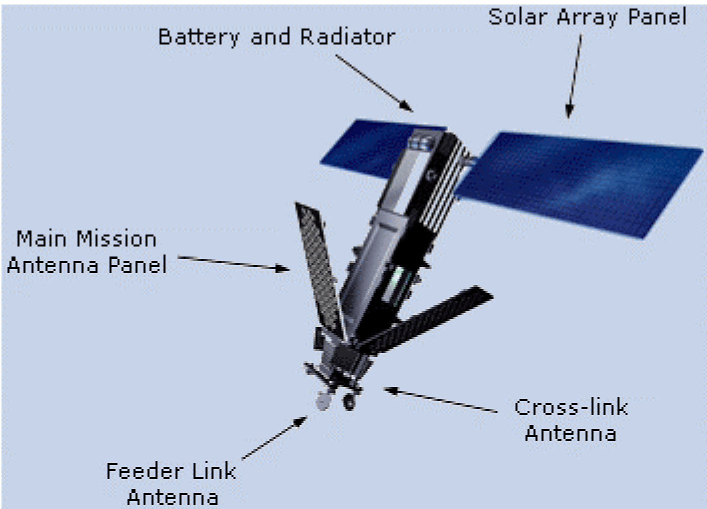
D6. The former Iridium provided phones from two vendors, Kyocera and Motorola. Kyocera phone models SS-66K and SD-66K are no longer in production, but still available in the second hand and surplus market. The Motorola phone 9500 is a design from the first commercial phase of Iridium, whereas the current 9505A model is a more modern design which is especially popular in military applications.

D7. Currently all equipment is provided by Iridium Satellite through its distribution partners. Motorola no longer manufactures equipment for Iridium. The 9505A is the most current version of the handset and the 9522A is the most current version of the OEM L-Band Transceiver module designed for integration into specific applications.

D8. Iridium phone numbers all start with +8816 or +8817 (which is like the country code for a virtual country) and the 8-digit phone number.

D9. Because of the satellites' peculiar shape with three polished door-sized antennas, 120 degrees apart and at 40 degree angles with the main bus, the Iridium satellites have a highly visible satellite flare, also called ‘Iridium flare’. The forward mirror faces the direction in which the satellite is travelling. On their orbits, the antennas directly reflect sunlight, creating a predictable and quickly moving illuminated spot of about 10 km diameter when the reflected beam hits the earth. To a spectator this looks like an extremely bright flare in the sky with a duration of only a couple of seconds. Some of the flares are so bright that they can be seen at daytime, but they are most impressive after dusk and before dawn. This flashing has been of extreme annoyance to astronomers in that the brightness of the satellites disturbs observations and can damage sensitive equipment.

The constellation



D10. The Iridium system requires 66 active satellites in orbit to complete its constellation, with spare satellites in orbit to substitute in case of failure. Each Iridium satellite is approximately 4 feet tall and weighs 670 kg fully fuelled. It is comprised of three L-band antenna panels providing the 48 beams of footprint. The satellite has four 23 GHz cross-links antennas. These antennas point to the nearest spacecraft in the same plane (fore and aft) and in the two adjacent co-rotating planes. The "feeder link" antennas relay information to the terrestrial gateways. The spacecraft payload is the dominant component with high-speed digital switching to handle complex telephony routing.

D11. The satellites are in 6 orbital planes separated by 31.6° at an altitude of 780km (485 miles) and 86.4° inclination. The Iridium network is designed to operate in the L-band of 1616 to 1626.5 MHz for ground user links, in the Ka-band of 19.4 to 19.6 GHz and 29.1 to 29.3 GHz for gateway down- and up-links and in the Ka-band of 23.18 to 23.38 GHz for inter-satellite links (ISL). The four intersatellite cross links on each satellite operate at 10 Mbit/s. The cross links were originally envisioned to be optical, but now use radio links. The exact L-band frequencies used depend on local regulating authorities and issued licenses in any particular region.

D12. Satellites communicate with neighbouring satellites via intersatellite links. Each satellite can have four intersatellite links: two to neighbours fore and aft in the same orbital plane, and two to satellites in neighbouring planes to either side. The satellites orbit from pole to pole with an orbit of roughly 100 minutes. This design means that there is excellent satellite visibility and service coverage at the North and South poles, where there are few customers. Because satellites use an over-the-pole orbital constellation design there is a "seam" where satellites in counter-rotating planes next to one another are travelling in opposite directions. Cross-seam intersatellite-link handoffs would have to happen very rapidly and cope with large Doppler shifts; Iridium only supports intersatellite links between satellites orbiting in the same direction.

D13. The cellular lookdown antenna has 48 spot beams arranged as 16 beams in three sectors. Each satellite projects 48 beams on the surface of the Earth, which may be viewed as providing coverage cells on the ground similar to terrestrial cellular systems. The size of each beam varies from 50-80 km in diameter depending on whether the satellite is directly overhead or at an oblique angle in which case the beam pattern is oblated. The 66-satellite constellation has the potential to support a total of 3,168 spot beams; however, as the satellite orbits converge at the poles, overlapping beams are shut down to prevent interference. Each satellite footprint is approximately 4,700 km in diameter. Under each beam's footprint, a satellite's power is limited to roughly 1,100 simultaneous circuits. A user is in view of a satellite for approximately 9 minutes, with about 1 minute under each beam, before being handed-off to the next satellite.

The satellites

D14. The satellite contains seven Motorola/FreeScale PowerPC 603E processors running at roughly 200 MHz. Processors are connected by a custom backplane network. One processor is dedicated to each cross-link antenna ("HVARC"), and two processors ("SVARC"s) are dedicated to satellite control — one being a spare. Late in the project an extra processor ("SAC") was added to perform resource management and phone call processing.

D15. The original design envisioned a completely static 1960s "dumb satellite" with a set of control messages and time-triggers for an entire orbit that would be uploaded as the satellite passed over the poles. It was found that this design did not have enough bandwidth in the space-based backhaul to upload each satellite quickly and reliably over the poles. Therefore, the design was scrapped in favour of a design that performed dynamic control of routing and channel selection late in the project, resulting in a one year delay in system delivery.

Earth base-stations

D16. Iridium routes phone calls through space. There are four Telemetry, Tracking, Command and Control earth stations, plus additional traffic-only earth stations. The space-based backhaul routes phone call packets through space to one of the downlinks ("feeder links"). Station-to-station calls can be routed directly through space with no downlink. As satellites leave the area of an Earth base station the routing tables change and frames are forwarded to the next satellite just coming into view of the Earth base station.

E. Inmarsat technical annex

Inmarsat Business Strategy

E1. Inmarsat was the pioneer of global mobile satellite communications, and operates several generations of satellite 'fleets' and provides a diverse range of services.

E2. Inmarsat operates a constellation of geostationary satellites that provide mobile phone, fax and data communications to every part of the world, except the poles. End-users can dial into the international telephone network and send data over the Internet by connecting to an Inmarsat satellite. Inmarsat's customer base includes shipowners, TV broadcasters, international aid workers, national governments, commercial airlines, banks and other financial institutions.

E3. Inmarsat-based services and solutions, including the mobile phones and other devices used to connect to its satellites, are sold by a network of Inmarsat Partners in more than 80 countries around the world. Inmarsat is the wholesaler, the provider of the satellite airtime.

E4. The satellites are controlled from Inmarsat's headquarters in London, which is also home to Inmarsat plc, Inmarsat's parent company, as well as a small intergovernmental organization (IGO), the International Mobile Satellite Organization (IMSO), created to supervise the company's public-service duties to support the Global Maritime Distress and Safety System (GMDSS) and satellite-aided air traffic control for the aviation community.

E5. Inmarsat came into being as an IGO in 1979 to provide global safety and other communications for the maritime community. Starting with a customer base of 900 ships in the early 1980s, it grew rapidly to offer similar services to other users on land and in the air, until in 1999 it became the first IGO to be transformed into a private company.

E6. It now supports links for phone, fax and data communications to more than 287,000 ship, vehicle, aircraft and other mobile users. Inmarsat's business strategy is to pursue a range of new data opportunities at the convergence of information technology, telecoms and mobility, while continuing to serve traditional maritime, aeronautical, land-mobile and remote-area markets.

E7. A cornerstone of this strategy is the new Inmarsat I-4 satellites, which are now entering service. They form the backbone of Inmarsat's Broadband Global Area Network (BGAN) services, offering simultaneous phone and mobile data communications at up to 492kbps for internet access, mobile multimedia and other advanced applications.

Inmarsat's 'Fourth Generation' Satellite fleet – I-4

E8. Eighty-five per cent of the world's landmass is now covered by Inmarsat's new satellite system - the Inmarsat-4 (I-4) series. The first two of three I-4 satellites are now in commercial operation in Inmarsat's Indian and Atlantic ocean regions, with coverage extending across North and South America, Europe, Africa, Asia and the Far East.

E9. Inmarsat's fourth-generation I-4 spacecraft are among the largest commercial communications satellites yet launched. They replace their highly successful predecessors - the Inmarsat-2 and Inmarsat-3 spacecraft - as the pillars of Inmarsat's new Broadband Global Area Network (BGAN) services.

E10. These new satellites deliver simultaneous voice and data at speeds of about half a megabit per second. The I-4 spacecraft have been built largely in the UK - the bus in Astrium's factory in Stevenage and the payload in Portsmouth. The two halves were then joined together in Toulouse, France, along with the US-built antenna and German-built solar arrays.

E11. The Inmarsat-4s, like their predecessors, are equipped with a single global beam that covers up to one-third of the Earth's surface, apart from the poles. Each satellite also generates 19 wide spot-beams that provide continuous coverage across the same region for Inmarsat's existing high-end services, including Fleet F77 128kbps, Fleet F55 and F33, and maritime mini-M.

E12. New to the I-4s are an additional 228 narrow spot-beams, designed to form the backbone of Inmarsat's broadband services, including the Broadband Global Area Network (BGAN), which was launched at the end of 2005. BGAN delivers Internet and intranet content and solutions, video-on-demand, videoconferencing, fax, e-mail, phone and LAN access at speeds of up to 492kbps.

E13. Together the first two I-4s serve about 98 per cent of the global population.

In-orbit operations

E14. The Inmarsat satellites are positioned in geostationary orbit. This means they follow a circular orbit in the plane of the Equator at a height of 35,600km, so they appear stationary relative to a point on the Earth's surface. The satellites are controlled from the Satellite Control Centre (SCC) at Inmarsat HQ in London, which is responsible for keeping the satellites in position and for ensuring the onboard systems are fully functional at all times.

E15. Data on the status of the Inmarsat satellites is supplied to the SCC by four tracking, telemetry and control (TT&C) stations located at Fucino, Italy; Beijing in China; Lake Cowichan, western Canada; and Pennant Point, eastern Canada. There are also back-up stations at Eik in Norway and Aukland, New Zealand.

E16. A call from an Inmarsat mobile terminal goes directly to the satellite overhead, which routes it back down to a gateway on the ground called a land earth station (LES). From there the call is passed into the public phone network.

E17. With the launch of BGAN, two new gateways, called Satellite Access Stations (SASs), have been introduced, both owned by Inmarsat. The first, in Burum, The Netherlands, is operated by Inmarsat partner Stratos / Xantic, and the other, in Fucino, Italy, by another partner, Telespazio.

Inmarsat I-3 satellite fleet

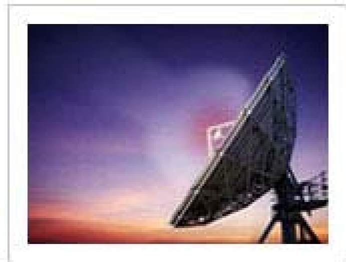
E18. Launched in 1996-8, the Inmarsat I-3s were built by Lockheed Martin Astro Space (now Lockheed Martin Missiles & Space) of the USA, responsible for the basic spacecraft, and the European Matra Marconi Space (now Astrium), which developed the communications payload. The Inmarsat I-3 communications payload generates a global beam and a maximum of seven spot-beams. Inmarsat I-3 F1 was launched in 1996 to cover the Indian Ocean Region. Over the next two years F2 entered service over Atlantic Ocean Region-East, followed by F3 (Pacific Ocean Region), F4 (Atlantic Ocean Region-West) and F5 (limited services on a single spot-beam, back-up and leased capacity).

Inmarsat I-2 satellite fleet

E19. Launched in the early 1990s, the four second-generation satellites were built to Inmarsat specification by an international group headed by British Aerospace (now BAE Systems). The three-axis-stabilized Inmarsat I-2s were designed for a 10-year life. Inmarsat-2 F1 was launched in 1990 and is now located over the Pacific, providing lease capacity. F2, launched in 1991, is over the western Atlantic, providing leased capacity and backing up Inmarsat I-3 F4.

E20. Also orbited in 1991, F3 was stationed over the Pacific Ocean until it became the first Inmarsat spacecraft to be decommissioned in early 2006. With the last of its remaining fuel, it has now been parked in a higher, so-called "graveyard orbit" where it will circle the Earth, safely out of the way of working satellites, for centuries to come.

E21. The fourth Inmarsat-2 was launched in 1992 and is used to provide leased capacity over the Indian Ocean and backing up Inmarsat I-3 F1 and Inmarsat I-3 F3.



Annex F. Thuraya technical annex

F1. Thuraya operates two satellites. Thuraya-1 satellite was launched on 21 October 2000; on board a Sea Launch Zenit-3SL rocket from the equator in the middle of the Pacific Ocean. It was the heaviest commercial payload ever launched and the first commercial satellite to employ digital beam forming. Thuraya's commercial services began in a gradual roll out in a number of countries in 2001. Thuraya's second satellite Thuraya 2 was launched on 10 June 2003 while a third satellite is being built by Boeing Satellite Systems to expand system capacity.

F2. The Thuraya mobile satellite system is a turnkey project built by Boeing Satellite Systems, formerly Hughes Space and Communications International, Inc. (HSCI), at the cost of US$ 1 billion. Designed for a 12-15 year lifespan, the Thuraya 2 satellite is positioned in Geosynchronous Orbit, 35,786 km (22,236 miles) above the Earth, at 44 degrees East Longitude and inclined at 6.3 degrees. The contract includes manufacture of two high power geo-synchronous satellites, the launch of the first satellite, manufacture and installation of the ground network equipment, the manufacture of nearly a quarter of a million mobile handsets and project insurance.

F3. Thuraya's system has been adapted for operation in both satellite and GSM environments. It provides flexibility in managing network resources through a re-programmable satellite payload. This supports modifications to the system's coverage area even in the post-launch period and optimises performance over high demand areas.

F4. Thuraya's satellites have been designed to achieve network capacity of about 13,750 telephone channels. Thuraya's hand held mobile terminals are comparable to GSM handsets in terms of size and appearance, as well as in voice quality.

Satellite features

F5. The satellites feature:

- 250-300 spot beams
- Digital beam forming (which provides for dynamic area coverage and optimises for changes in traffic demand)
- Single hop link for mobile-to-mobile communications
- High power capacity
- Dynamic satellite power control providing 10dB link margins

F6. The satellites provide voice telephony, fax, data, short messaging, location determination, emergency services, high power alerting and regulatory data. Thuraya Country Code is +88216.

F7. Radio frequencies for the system are:

Mobile Links

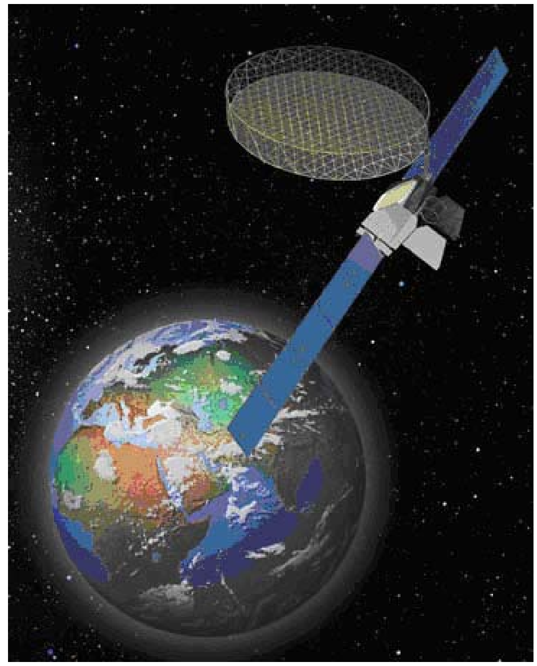
- Earth-to-space 1626.5-1660.5 MHz
- Space-to-Earth 1525.0-1559.0 MHz

Feeder Links

- Earth-to-space 6425.0-6725.0 MHz
- Space-to-Earth 3400.0-3625.0 MHz

Space Segment

F8. The Thuraya satellites are operated and managed by an integrated ground network which monitors and controls satellite movement, ensuring the overall and ongoing maintenance of satellites in geo-synchronous orbit.



F9. Satellite Overall Design:

- Number of satellites: 2
- Type of orbit: Geo-synchronous orbit with 6.3° inclination
- Orbital locations: 44° E and 28.5° E
- Service life of 12 years
- Compatible with Sea Launch and Ariane 5 launch vehicles and others
- Supplier: Hughes Space & Communications International, Inc.

F10. Payload Subsystem:

- 12.25 metre aperture deployable satellite antenna.
- On-board digital signal processing (DSP) to facilitate interconnectivity between the common feeder link coverage and the spot beams to make effective use of the feeder link band and to facilitate mobile to mobile links between any spot beams.
- Digital beam-forming capability which allows Thuraya to reconfigure beams in the coverage area, to enlarge beams and to activate new beams. It also allows the system to maximise coverage of "hot spots", or those areas where excess capacity is required.
- Flexibility to allocate 20% of the total power to any spot beam.
- Flexibility to reuse spectrum up to 30 times to improve spectrum efficiency.
- 8 time-multiplexed voice circuits:
- Modulation pi/4 QPSK
- FDMA carrier channel with a bandwidth of 27.7 kHz
- Channel bit rate is 46.8kbps
- Bus Subsystem
- Solar Power: beginning of life 13KW/End of life 11KW derived from panels on 2 wings, each having 4 panels of dual-junction gallium arsenide cells
- Batteries: 250 Ahr cells
- Dimensions: In orbit - solar arrays 34.5 m (113ft); antenna 17m (55.7 ft).
- Weight: 5350 kg (11,576 lb) at launch: 3200 kg (7,056 lb) in orbit (beginning of life.

User Segment

F11. The User Segment comprises the user terminals which enables subscribers to interface with the satellite system and obtain network access. Thuraya offers hand-held, vehicular and fixed terminals to cater to the needs of its subscribers. Thuraya's dual mode handsets -GSM and satellite integrate terrestrial and satellite services, allowing customers to roam without transmission interruption or failure.

F12. Two manufacturers, Hughes Network Systems and Ascom, are the contractors for the supply of the user terminals, supplying:

- Hand-held terminals, similar to GSM terminals in appearance, size and weight.
- Vehicular installations, consisting of a handheld terminal and vehicle installation kit.
- Fixed terminal, consisting of a handheld terminal and indoor fixing kit, using satellite mode only.

Ground Segment

F13. The Primary Gateway houses the Satellite Operation Centre, which monitors and controls satellite movement. Outside the Primary Gateway building are the primary dish (C-band antennae) and the back-up dish for controlling the satellites.

F14. The Primary Gateway is situated in Sharjah, United Arab Emirates and is responsible for Thuraya's entire network. It also serves as the MSS's main digital exchange. Individual Regional gateways may be established at a later date in other countries as necessary.

F15. The Primary Gateway comprises the satellite control facilities and the Gateway Station, including:

- SOC (Satellite Operations Centre)
- UBS (Uplink Beacon Station)
- SPCP (Satellite Payload Central Point)
- GSS (Gateway Station Subsystem)
- NSS (Network Switching Subsystem)
- AOC (Advanced Operations Centre)
- OSS (Operations Support Subsystem)

F16. Ground segment dimensions:

- 1,750,000 expected subscribers
- 13,750 Satellite Traffic Channels
- One Primary Gateway
- Regional Gateways as required
- Fax at 9.6 kbps
- Data at 9.6 kbps
- GSM Standard Supplementary Services
- Short Messages Service
- SMS Beam Broadcast
- Optimised Routing to provide most economic call routing
- Single hop for Thuraya-to-Thuraya anywhere in the coverage area
- Network Access and Call Tariff are based on caller terminal GPS position

Annex G. ICO Global technical annex

G1. ICO has been authorized to operate a medium earth orbit (MEO) satellite system globally through a registration filed via the United Kingdom with the International Telecommunication Union (ITU), an international organization within the United Nations system. ICO has also been authorized to offer MSS services throughout the United States using a geostationary earth orbit (GEO) satellite. ICO has the opportunity in the future to seek authorization from the U.S. Federal Communications Commission (FCC) to integrate an Ancillary Terrestrial Component (ATC) into their MSS system in order to provide integrated satellite and terrestrial services. Unlike satellite-only MSS systems, ICO believe that integrated MSS/ATC services may be more likely to appeal to a mass market of consumers and businesses. At the present time, ICO is focusing most of their resources on developing a US MSS system.

G2. ICO's MSS/ATC System infrastructure is expected to include the following:

- One orbiting GEO satellite, which will utilize a "bent pipe" architecture, where the satellite "reflects" the signals between the end-user equipment and the gateway ground station.
- Ground-based beam forming ("GBBF") equipment that is expected to be located at the gateway ground station.
- A land-based transmitting/receiving station utilizing large gateway feeder link antennas, with the gateway ground station connecting to their network through high-speed interconnection links and providing the interface between the satellite and the network.
- A core switching/routing segment, consisting of equipment used to route voice and data traffic between the ICO network and the public data, telephone, Internet and mobile network, and integrated with the satellite and ATC segments.
- An ancillary terrestrial component that will provide terrestrial wireless communications services that will be fully integrated with the satellite segment to provide ubiquitous national coverage to end-users.
- End-user equipment capable of supporting satellite-only and dual-mode (satellite/terrestrial) services.

G3. ICO's GEO satellite design is based on a Loral 1300 standard satellite platform that has been optimized for GEO MSS/ATC communications requirements. It features an expected 15-year service life and a 12-metre unfurlable reflector (antenna) that focuses the 2 GHz signals on North America. On 10 March 2006, ICO entered into an agreement with Lockheed Martin Commercial Launch Services, Inc. to provide launch services on an Atlas V launch vehicle, with a launch period commencing on 31 May 2007.

Utility Use of Satellite Technology in Emergency Response

Order Form

UTC Members and Non-Members may place an order as follows:

	Quantity	Price: Core and Associate Members	Price: Non-Members	Total
Utility Use of Satellite Technology in Emergency Response		$995		$
			$1,295	$
			Total	**$**

Name:____

Title:____

Company:____

Address:____

City:____

State and Zip Code:__________________________________

Country:____

Phone:____

Fax:____

E-Mail:____

Please charge the above fee to my credit card:

☐ American Express ☐ Visa ☐ MasterCard

Card #:____

Exp. Date:____

Name on Card:_______________________________________

Signature:____

☐ I will pay by corporate check. Please send me an invoice.

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