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Mobile Communications Via Satellite in the 1990s

O. Lundberg

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Mobile communications via satellite in the 1990s

By O. Lundberg
International Maritime Satellite Organization, 40 *Melton Street*, *London NW*1 2*EQ*, *U.K.*

The world's only satellite organization providing mobile communications on a commercial basis is the International Maritime Satellite Organization (Inmarsat). This paper reviews the origins of the organization and the needs of the shipping and offshore industry that led to its formation. The current system and its operations are described. The success achieved so far by Inmarsat in providing the satellite capacity for telephone, telex, facsimile and data communications to the maritime community makes it apparent that the system could also be used to provide capacity to the aeronautical community. Also, studies are now being made on future configurations of the system in which it may be possible to integrate a polar-orbiting satellite system, such as Sarsat–Cospas. Inmarsat is proceeding with the procurement of a new series of satellites that would come into operation from 1988. This paper reviews the enhanced capabilities that these new satellites will provide in the context of the requirements for mobile communications via satellite in the next decade.

Introduction

In the 1980s, satellites have become a mature technology. In the 1990s, the challenge, in part, may be the industrialization of space. More particularly, the challenge in the next decade will be to use that technology wisely, efficiently and in a way that serves the real needs of the end users in a vibrant marketplace.

Inmarsat sees its challenge in providing satellite communications capacity that best serves the mobile user in the international environment. This challenge is particularly important in view of the fact that Inmarsat is the world's only organization providing commercial mobile communications via satellite.

Although Inmarsat is a relatively young organization (it began operations in February 1982), the idea that impelled its creation is not. Indeed, maritime nations began to consider the possibility of a maritime communications satellite system as long ago as the launch of Early Bird in 1965.

The focus, then, of this paper will not be so much on the industrialization of space, but more on the future of mobile communications via satellite. Before embarking on that course, it would be appropriate to make reference to the origins of the maritime satellites.

Why Inmarsat was needed

Since the 1965 launch of the first commercial communications satellite, space-age technology has had a dramatic impact on the way the nations of the world communicate. Television, radio and telecommunications delivered via satellite now put people from around the globe in touch with each other in seconds. Until recently, however, this technological marvel was largely confined to the enjoyment of people on land, even though there has long been a need to extend the power of satellites to people at sea. It was for this reason that, soon after the launch of

Early Bird, maritime nations began to consider how satellites could be used to provide reliable communications to and from ships. They recognized that conventional radiocommunications on the m.f., h.f. and v.h.f. bands, although much improved over the years, cannot effectively meet all modern shipping requirements. They are still subject to the vagaries of ionospheric and other disturbances, as well as a lack of an adequate number of channels, making contact often difficult and sometimes impossible. Delays of many hours and even days occur, particularly in long-range communications. At times of maritime disaster, such delays have led in the past, and may in the future, to loss of life and property.

Table 1. Inmarsat member countries and signatories (December 1983)

U.S.A.	Communications Satellite Corporation (Comsat)
U.S.S.R.	Morsviazsputnik (includes initial investment share of Byelorussian and Ukranian S.S.Rs)
U.K.	British Telecom
Norway	Norwegian Telecommunications Administration
Japan	Kokusai Denshin Denwa Co., Ltd
Italy	Ministero delle Poste e Telecomunicazioni
France	Direction Générale des Télécommunications
F.R.G.	Bundesministerium für das Post und Fernmeldewesen
Greece	Hellenic Telecommunications Organization (O.T.E.)
Netherlands	Netherlands P.T.T. Administration
Canada	Teleglobe Canada
Kuwait	Ministry of Communications
Spain	Compañía Teléfonica Nacional de España
Sweden	Swedish Telecommunications Administration
Australia	Overseas Telecommunications Commission (O.T.C.)
Brazil	Empresa Brasileira de Telecomunicacoes S.A. (Embratel)
Denmark	Post and Telegraph Administration
India	Overseas Communications Service
Poland	Office of Maritime Economy
Saudi Arabia	Ministry of Posts, Telegraphs and Telephones
Singapore	Telecommunication Authority of Singapore
China (P.R.C.)	Beijing Marine Communications and Navigation Company
Argentina	Empresa Nacional de Telecomunicaciones (Entel)
Belgium	Régie des Télégraphes et des Téléphones
Finland	General Directorate of Posts and Telecommunications of Finland
New Zealand	Post Office Headquarters
Bulgaria	Shipping Corporation
Portugal	Companhia Portuguesa Radio Marconi
Algeria	Ministère des Postes et Télécommunications
Chile	Empresa Nacional de Telecomunicaciones S.A. (Entel-Chile)
Egypt	National Telecommunications Organization (Arento)
Iraq	Republic of Iraq
Liberia	Republic of Liberia
Oman	Sultanate of Oman
Philippines	Philippine Communications Satellite Corporation (Philcomsat)
Sri Lanka	Overseas Telecommunication Service
U.A.E.	Ministry of Communications
Tunisia	Republic of Tunisia

In 1971, the World Administrative Radio Conference for Space Telecommunications allocated frequency bands to the maritime mobile satellite service. Four years later, the International Maritime Organization (I.M.O.) convened the first of three sessions of the International Conference on the Establishment of an International Maritime Satellite Organization. I.M.O. identified several reasons why such a system should be established: to relieve congestion in the m.f. and h.f. bands; to improve reliability, quality and speed of communications; to improve geographical coverage and continuous availability of services; to permit automation of radiotelephone and teleprinter; to cater for services not possible in the m.f. and h.f. bands, such as high speed data transmission; to improve distress, urgency and safety communications.

I.M.O. held the final session on 3 September 1976, at which time the Conference unanimously adopted the Convention and Operating Agreement on the International Maritime Satellite Organization. With its headquarters in London, Inmarsat came into existence on 16 July 1979 and began operations on 1 February 1982. Forty countries have now joined the international organization (table 1).

Inmarsat's purpose

According to its Convention, Inmarsat's purpose is 'to make provision for the space segment necessary for improving maritime communications, thereby assisting in improving distress and safety of life at sea communications, efficiency and management of ships, maritime public correspondence services and radiodetermination capabilities.' The Convention also says that Inmarsat shall act exclusively for peaceful purposes, that it is open for membership by all States and that ships of all nations may use the space segment.

Structure and financing

Established to 'operate on a sound economic and financial basis, having regard to accepted commercial principles', Inmarsat is financed by the Signatories to its Operating Agreement. The Signatories have been designated as such by the member countries. For the most part, the Signatories are national telecommunications carriers.

The Signatories come from the rich and the developing nations, from East and West. Those Signatories with the largest investment shares are from the U.S.A., Soviet Union, the U.K., Norway and Japan. The investment share is intended to reflect the actual use of the Inmarsat system. The investment covers the costs of the space segment and the operating and administrative costs of the organization. The total of all capital invested by the Signatories, plus compounded compensation at 14% a year, is to be returned to Signatories as the system becomes profitable. Inmarsat could break even as early as 1984, much earlier than its original forecasts, in part because the number of users of the system is growing more rapidly than was expected.

Inmarsat has a three-tier organizational structure.

(1) The *Assembly* of Parties (or States) meets once every two years to review the activities and objectives of Inmarsat and to make recommendations to the Council. All member States are represented and have one vote each.

(2) The *Council* of Signatories is like a corporate board of directors; it is Inmarsat's policy-making body. It consists of 22 Signatories: 18 with the largest investment shares and four others elected by the Assembly on the principle of a just geographical representation and with due regard for the interest of developing countries. The Council meets at least three times a year and each Signatory has a voting power equal to its investment share.

(3) The *Directorate* achieves the day-to-day activities of the organization. The Director General is Inmarsat's Chief Executive Officer.

The Inmarsat system

The Inmarsat satellite system is somewhat different from those of other satellite organizations which provide a fixed service. Inmarsat interfaces directly to the end user's telephone on the mobile side of the satellite. It extends the terrestrial telecommunications networks to the oceans of the world. When someone on board a ship picks up the telephone, he is, in effect, using the ultimate in cordless telephones.

The maritime satellite system has three major components: the satellite capacity leased by the organization, the coast Earth stations and the ship Earth stations (figure 1).

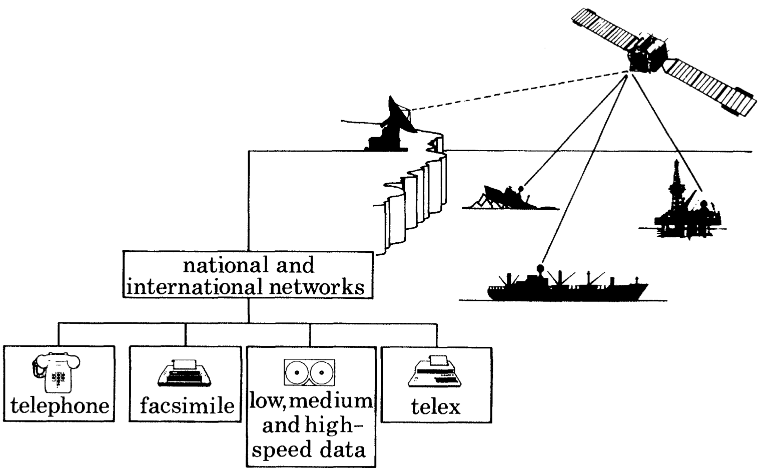

Figure 1. The Inmarsat system comprises three main elements: the satellites, the coast Earth stations and the ship Earth stations. The coast Earth station provides the link with the national and international telecommunications networks. The broken line represents transmissions to the satellite at 6 GHz and reception from the satellite at 4 GHz; the solid lines represent transmissions at 1.6 GHz and reception at 1.5 GHz.

The nerve centre of the system is the operations control centre (o.c.c.) at Inmarsat's headquarters. The o.c.c. is connected directly by its own ship Earth stations to the Atlantic and Indian Ocean satellites, and so to all coast Earth stations around the world. Operating continuously, it coordinates a wide range of activities. Should a serious problem arise with one satellite, putting it out of commission, the o.c.c. would be responsible for taking the necessary steps to transfer traffic to a spare satellite in orbit. The o.c.c. also handles all commissioning applications from ships that have just installed Inmarsat terminals.

The satellites

The Inmarsat satellites are in geostationary orbit, 36000 km above the equator, over the Atlantic, Indian and Pacific Oceans, and provide near-global coverage (figure 2). There are both operational and back-up satellites. Thus, if one satellite should fail, another spare in orbit will be able to take over immediately.

From December 1983, Inmarsat had leased two Marisat satellites, each with a capacity of about 10 telephone channels, from the Marisat Joint Venture (the principal shareholder of which is Comsat General of the U.S.A.); a Marecs A satellite, with a capacity of about 40 telephone channels, from the European Space Agency; and maritime communications subsystems (m.c.s.), each with a capacity of about 30 telephone channels, on the Intelsat V F-5 and F-6 satellites. In the next year or so, it plans to lease capacity on other satellites. The satellite configuration is given by ocean region in table 2.

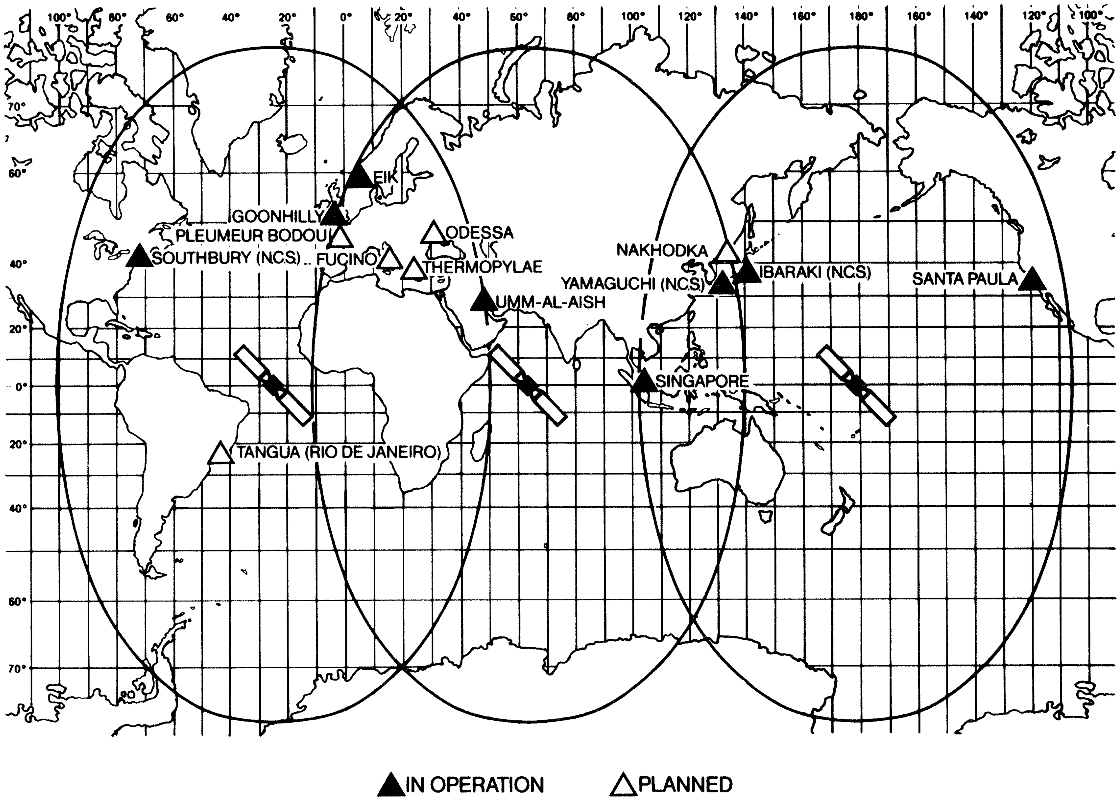

FIGURE 2. The Inmarsat satellites provide near global coverage (to about the 75° latitudes) so that a ship can communicate via satellite virtually anywhere. As of 1 December 1983, there were eight coast Earth stations in operation with several more scheduled to joint them in 1984. Three of these are Network Coordination Stations (N.C.S.), which assign telephone channels on demand to requesting ship Earth stations.

TABLE 2. SATELLITE CONFIGURATION

ocean	satellite	status
Atlantic	Marecs A	operational
	Intelsat V MCS-B	in-orbit spare
Indian	Intelsat V MCS-A	operational
	Marisat F-2	in-orbit spare
	Intelsat V MCS-C	available late in 1983
Pacific	Marisat F-3	operational
	Marecs B2	available early in 1985

Coast Earth stations

The coast Earth stations provide the link between the satellites and the telecommunications networks ashore. The coast Earth stations are owned and operated by Signatories, who are also responsible for the landline connections to the public switched telephone and telex networks. A typical coast Earth station consists of a parabolic antenna about 11–14 m in diameter, which is used for transmission of signals to the satellite at 6 GHz and for reception from the satellite at 4 GHz. The same antenna or another dedicated antenna is used for L-band transmission (1.6 GHz) and reception (1.5 GHz) of network control signals. Each coast Earth station provides, as a minimum, telex and telephone services. As well, three coast Earth stations – at Southbury, Connecticut, and at Yamaguchi and Ibaraki in Japan – serve as network co-ordination stations, which assign telephone channels, on demand, to ship Earth stations.

As of October 1983, eight Inmarsat coast Earth stations were in operation around the world, and their number is expected to more than double by the end of 1984.

The additional coast Earth stations will shorten the terrestrial distance a call has to travel to and from ships and offer the opportunity to reduce user charges. The cost of placing a call varies from country to country, as one might expect, since end-user charges for Inmarsat services are set by telecommunications administrations. For ship-to-shore calls, the Signatory operating the coast Earth station bills the user's designated accounting authority. Billing for shore-to-ship calls is the responsibility of the telecommunications administration providing service via Inmarsat, which in turn earns its revenues by billing the Signatories who operate the coast Earth stations for the use made of its satellite system.

Ship Earth stations

The ship Earth station, which puts the user on ship in instant contact with the rest of the world, consists of two parts, the hardware above deck and that below. That above consists of a parabolic antenna, typically between 0.8 m and 1.2 m in diameter, housed in a fibreglass radome, which protects the dish from the harsh maritime environment (figure 3). The antenna is mounted on a stabilized platform, which enables the antenna beam to remain pointed at the satellite regardless of ship course or movement. Signals are transmitted to the satellite at 1.6 GHz and received at 1.5 GHz.

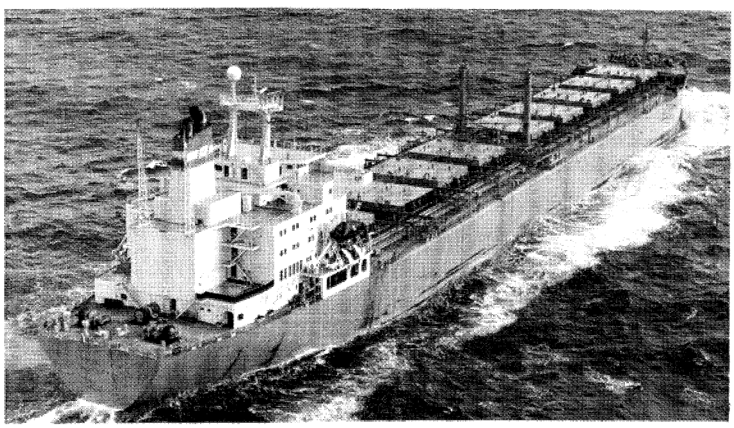

FIGURE 3. The ship Earth station, which enables a ship to communicate with other ships or with shore-based subscribers, consists of equipment both above and below deck. Above deck is a parabolic antenna on a stabilized platform covered in a radome. The radome on the bulk carrier *Ambia Fair* can be seen here as a white, distinctive mushroom shape mounted on a pedestal above the bridge. (Photograph by Skyfotos.)

The equipment below the deck consists of telex and telephone and a variety of optional equipment for facsimile, data and slow-scan television. Low and medium-speed data transmission are available via a voice channel at up to 4.8 kbit s^{-1} in both directions. With a specially prepared satellite channel in the ship-to-shore direction, high-speed data transmission at up to 56 kbit s^{-1} is available. Inmarsat has also agreed to make satellite capacity available in the ship-to-shore direction for a very high speed data service (v.h.s.d.), which would allow information to be transmitted at rates of 1 Mbit s^{-1} or more.

Calls are placed to and from ships in virtually the same way – and just as quickly – as one would make a call from the home or office. When a user on board a ship places a telephone call, he pushes a request button on his communications equipment below deck, which sends a signal via satellite to a network coordination station (n.c.s.). The n.c.s. then assigns a voice channel from a 'pool' of available circuits for use by the ship for that call. Telex channels, however, are assigned by the coast Earth station. In both cases, channels are assigned automatically and in a matter of seconds. The user then dials the number he wants. Each ocean region has the equivalent of a country code.

Inmarsat gives distress signals priority access to the spare segment. For distress calls, a special button on the ship station may be pressed to provide immediate telex or telephone communication to the desired coast Earth station, which then puts the ship into contact with the appropriate rescue coordination centre.

Ship Earth stations can be purchased from 10 different manufacturers around the world. Prices are competitive at about U.S. $35 000, which is about half as much as one cost two or three years ago. This technology will continue to evolve, as manufacturers of ship Earth stations are producing a new generation of equipment that is smaller and easier to use than earlier models. Until now, the antennas above deck have been of parabolic design, but now there is one manufacturer seeking approval from Inmarsat for a phased array antenna. Most of the current systems below deck are modular in design and can easily be upgraded by the addition of new capabilities. A typical unit below deck consists of a microcomputer with a visual display unit (v.d.u.) and alphanumeric keyboard, hard copy printer and telephone with a modem.

For the time being and probably until the early 1990s, the standard A ship Earth station, an analog terminal, is likely to remain the all-purpose workhorse of the Inmarsat system. Development work is, however, proceeding on other possible standards to meet the needs of high- and low-volume-communication users. One of these could be a multi-channel variant of the standard A, which currently has a one telephone–one telex channel capability. Inmarsat recently approved new technical requirements that would permit up to three simultaneous telephone or telex calls, a capability that would be of interest to heavy users of the system such as the oil industry. Other standards would include a smaller, digital version of Standard A and an even smaller terminal, which would be used for telex or low-speed data communications. These new standards could reach the market at about the same time as Inmarsat's second-generation satellite system, in 1988.

Applications and users

The number of ships, offshore drilling rigs and others using the satellite system increased by about 60 % in Inmarsat's first year of operations (figure 4). On 1 December 1983, there were about 2200 users, including oil tankers, liquid natural gas carriers, offshore drilling rigs, seismic survey vessels, fishing boats, cargo and container vessels, passenger ships, ice breakers, tugs, cable-laying ships and even a replica of a Viking ship. The maritime satellite system is also used by research teams in the Antarctic, a weather station in northern Greenland and, on an exceptional basis, by oil production platforms. As might be expected from such a range of users, the range of applications of satellite communications is equally wide. Some examples are given.

(1) Offshore oil rigs equipped with satellite terminals can transmit well log data to land-based computers for rapid analysis.

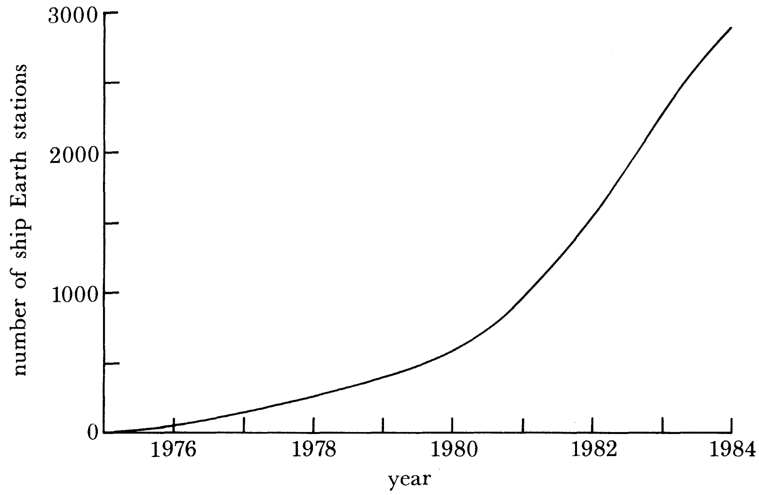

FIGURE 4. In its first year of operations, Inmarsat witnessed a 60% increase in the number of ships fitted with ship Earth stations, despite the prolonged recession in the shipping industry.

(2) Ship operators can use the system for the rapid transmission of data on engine performance, fuel consumption, position-reporting, weather conditions and provisioning. Their vessels can obtain berthing and scheduling information in advance of arrival in port. If there are delays in port, the ship can adjust its estimated time of arrival or be diverted to another port.

(3) If a vessel breaks down at sea, engineering drawings can be transmitted by facsimile to enable repairs to be made. If necessary, spare parts can be ordered by satellite and be waiting in the next port to minimize the time spent waiting for the repairs to be done.

(4) Ships of a particular fleet or national group can receive a common telex message through Inmarsat's facility for shore-to-ship group ('broadcast') calls. Facilities also exist for group calls to ships in a defined geographical area within each ocean region, which is particularly useful for broadcasting weather forecasts and navigational warnings.

THE FUTURE OF MOBILE COMMUNICATIONS VIA SATELLITE

Since 1979, Inmarsat's preoccupation has been to establish its satellite system. Now, with a proven, reliable system in place, one that is attracting a rapidly growing number of users, Inmarsat has been devoting an increasing amount of its time to the future. In the maritime world, a milestone will be reached in 1990 when the Future Global Maritime Distress and Safety System (F.G.M.D.S.S.) is introduced by the International Maritime Organization (I.M.O.).

Future Global Maritime Distress and Safety System

F.G.M.D.S.S. will also be a milestone for Inmarsat, because one of its major objectives is to provide improved facilities for distress calls and communications to improve safety of life at sea. The immediacy and reliability of Inmarsat communications have already led some countries to include the ship Earth station as an alternative main transmitter for mandatory carriage on ships covered by the I.M.O. Safety of Life at Sea (SOLAS) Convention. Many more countries are expected to follow suit as I.M.O. prepares its new SOLAS requirements and its proposals for the F.G.M.D.S.S. According to I.M.O., the F.G.M.D.S.S. is intended to be 'a comprehensive system to improve distress and safety communications and procedures which, in conjunction with a coordinated search and rescue infrastructure, will incorporate recent technical developments'.

One objective of the future system is to enable any properly equipped ship to achieve automatic distress alerting and be located with minimum delay. Although most countries have some sort of search and rescue facilities for aiding ships at sea, these facilities vary and their efforts are not coordinated on a global basis. Hence, the system would also provide for the establishment of rescue coordination centres where they do not exist and for a set of procedures for responding to distress alerts and for making rescue missions. As well, it is expected that most rescue centres will be equipped with satellite communications so that they can have direct access to the Inmarsat system and will, as a consequence, be able to contact vessels similarly equipped in seconds in the event of a distress or emergency at sea. In November 1983, Argentina became the first country to equip a rescue centre with maritime satellite communications.

Inmarsat is expected to play a major role in the F.G.M.D.S.S. I.M.O. has said 'The F.G.M.D.S.S. will use both satellite and terrestrial communications. Satellite communications will be provided by Inmarsat. A distress capability for alerting by satellite EPIRB will be provided by Inmarsat geostationary satellites as well as polar orbiting satellites. Terrestrial communications will use frequencies in the m.f., h.f. and v.h.f. bands. Terrestrial communications will no longer use Morse code radiotelegraphy but will employ digital selective calling, radiotelephony and narrow band direct printing.' All equipment carried on ships will be designed for simple operation and will be largely automated.

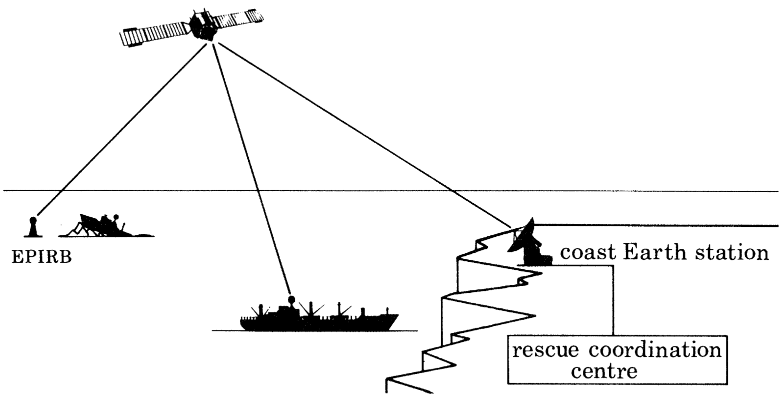

FIGURE 5. An emergency position-indicating radio beacon is a transmitter fitted on a buoy designed to float free from a sinking ship and to transmit a distress signal via satellite to a coast Earth station, which would then relay the message to the nearest rescue coordination centre. The Inmarsat system has been used in recent trials of such EPIRBS.

The satellite EPIRB (emergency position-indicating radio beacon) will be capable of sending a message via satellite by giving the ship's identity number and its position coordinates (figure 5). It could be carried on a ship or lifeboat, fitted in a buoy designed to float free and be activated should a ship sink. I.M.O. is preparing the operational requirements, while the International Radio Consultative Committee (C.C.I.R.) is developing the technical provisions for a satellite EPIRB system. In 1982–83, a working group of the C.C.I.R. coordinated a series of trials using the Inmarsat system aimed at developing the technical specifications for a EPIRB, operating at L-band, the same frequency bandwidth used by Inmarsat.

Polar-orbiting satellites

There is, of course, another search and rescue satellite system operating, called Sarsat–Cospas, which has been developed by Canada, the United States, France and the Soviet Union. The Soviet Union was the first to launch a satellite under this scheme, the Cosmos 1383, in June 1982. Two months after its launch, the satellite picked up signals transmitted from an aircraft that had crashed in northern British Columbia. By measuring the Doppler shift in the received signals, a rescue team was able to pinpoint the location of the aircraft. The speedy rescue that followed resulted in three lives being saved. Since then, two Cosmos satellites and an American NOAA satellite carrying similar payloads have been credited with saving more than 60 lives.

These satellites operate in a polar orbit up to 1000 km above the Earth and detect signals in the 121.5 and 243 MHz band, the international distress frequencies, as well as in the 406 MHz band, which was recently allocated specifically for low power emergency beacons capable of being detected and located by satellites.

There are pros and cons to be said for satellite EPIRBS operating at 406 MHz or L-band. For its part, Inmarsat has said that it does not intend to carry a 406 MHz payload on its second-generation satellite system, as we have not yet identified any customer who is willing to pay for the extra expense involved. In any event, the trials using our satellites have shown that the emergency beacons can operate effectively at L-band.

I.M.O. has said that it would like to see a single international distress frequency for satellite emergency beacons. That would certainly be desirable from the perspective of the user whose equipment is likely to be cheaper than would be the case if it had to operate at two or more frequencies. It may well be that the optimum system would integrate both polar-orbiting and geostationary satellites in one scheme (figure 6). Polar-orbiting satellites could carry additional payloads as well, perhaps capabilities for navigation and thin-route communications, which would be especially valuable over the polar regions.

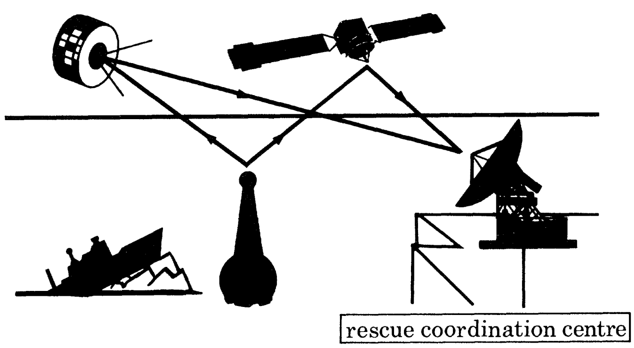

FIGURE 6. In the next decade, it is possible that a polar-orbiting satellite system such as Sarsat–Cospas could be integrated with the geostationary Inmarsat satellite system. This combination would principally be used for distress alerting, but polar-orbiting satellites could carry other payloads as well, including thin-route communications for use over the polar regions.

It was recently decided by the Sarsat–Cospas member countries, which now also include the U.K. and Norway, to carry on with this demonstration satellite programme until the end of the 1980s. Until then, member countries will be giving some thought as to what sort of institutional structure should be established for managing this programme on a continuous basis. It has been suggested that one option would be to have Inmarsat procure and manage such a system. Probably among the reasons that Inmarsat might be considered are that it has the right sort of institutional structure, that it has the mandate to provide for distress and safety services and that Inmarsat itself has been participating in trials, organized by I.M.O. and the C.C.I.R., of satellite emergency beacons. Some of the Sarsat–Cospas nations have also been involved in these trials.

Inmarsat may be willing to manage a search and rescue satellite programme, if it could be financed. Someone would have to pay for such a programme; at present, it is the taxpayers in the participating countries. If the programme were managed by Inmarsat, it would be possible to spread the burden to all countries that benefit. While it's true that Inmarsat was created to provide such services, a formula for funding them is still needed.

Aeronautical communications

Although Inmarsat was created to serve maritime requirements, other possible applications were foreseen at the international conference that conceived the organization. One of these applications, the feasibility of which Inmarsat is exploring, relates to aeronautical communications via satellite. The international conference recommended that 'arrangements should be made to undertake at an early date the study, without prejudice to programmes in planning, of the institutional, financial, technical and operating consequences of the use by Inmarsat of multi-purpose satellites providing both a maritime mobile and an aeronautical mobile capability'.

The notion of aircraft using satellite communications is not a new one. In 1968, I.C.A.O. established a panel of experts to deal with the Application of Space Techniques Relating to Aviation (ASTRA). Over the next four years, the panel studied the technical characteristics for an aeronautical satellite system. Following a recommendation of an Air Navigation Conference held by I.C.A.O. in 1972, representatives from Canada, the United States and the European Space Agency set up the Aeronautical satellite (Aerosat) programme. Aerosat was intended to follow an international programme for research and development of an aeronautical satellite. The experimental Aerosat satellite was to determine the desired characteristics of an operational aeronautical satellite for mobile communications and position determination. The satellite was to be launched in 1979–80, but it never reached the launch pad. By the end of the decade, the aviation industry was in the financial doldrums, and airlines were reluctant to spend money on an expensive, dedicated satellite system; funding for the programme ceased. Fortunately, the interest in aeronautical satellite communications did not diminish. In fact, I.C.A.O. and the International Air Transport Association (I.A.T.A.) had even participated in some of the early discussions that eventually led to the establishment of Inmarsat.

In late 1982, I.C.A.O. said it intended to draft technical specifications for a future satellite system that could serve the mobile communication needs of international civil aviation. The service as envisaged by I.C.A.O. would be designed to improve air–ground communications and would make use of low-speed digital data transmission on the L-band frequencies (specifically, the aeronautical R-band) already exclusively allocated for the aeronautical mobile service by the I.T.U.

In the months that followed, Inmarsat continued its intensive discussions with I.C.A.O. and I.A.T.A. and others, which were aimed at defining the aviation community's requirements and exploring institutional arrangements wherein the Inmarsat system could be shared for aeronautical applications. Prompted by I.C.A.Os expression of interest in a satellite communica-

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tions facility, Inmarsat's 14th Council session in May 1983 approved an amendment to a request for proposals, which was released in August 1983, for the second-generation Inmarsat satellite system. The amendment meant that Inmarsat could provide an aeronautical capability with its new series of satellites, the first of which is scheduled for operation in late 1988. The amendment principally involved an extension of the upper end of the L-band bandwidth by about 1 MHz, and some changes to the C-band feeder link frequency bandwidths. The fact that Inmarsat's second generation satellites will incorporate a small part of the aeronautical L-band does not mean that Inmarsat is committed to providing an aeronautical service, nor that the aeronautical community is committed to using it. At this stage, it merely means that Inmarsat could provide one, subject to detailed consultations with the aeronautical community.

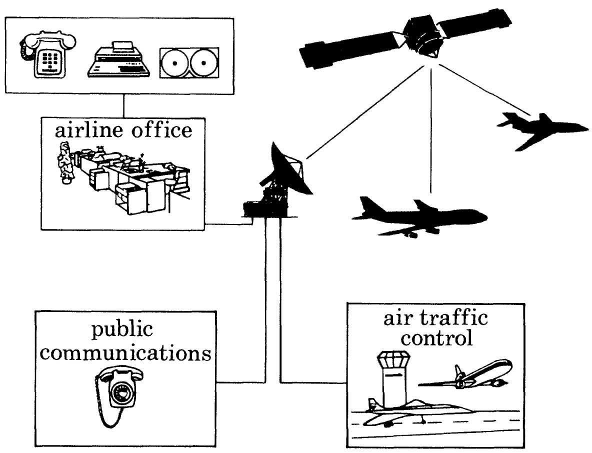

FIGURE 7. Aeronautical satellite communications. An expression of interest by the International Civil Aviation Organization in aeronautical communications via satellite prompted Inmarsat to amend its request for proposals for a new series of satellites to come into operation in 1988. The amendment means that aircraft could use the same satellite system now used by the maritime community.

The adjacency of the maritime and aeronautical frequency bands – and thereby the possibility of sharing the same satellites – would seem to be a powerful argument for cooperation between Inmarsat and the aeronautical community. It means that Aerosat capabilities could be provided at a cost orders of magnitude less than earlier assumed. While cooperation between the two user groups would seem to be logical, all solutions must be driven by user requirements. One requirement is for improvement in present radio links. Very high frequency radio leaves large parts of the globe uncovered and h.f. suffers from well known propagation peculiarities that make the medium unsuitable for modern communications. Additionally, existing links sometimes suffer from congestion and crowding of the air waves. Satellites, on the other hand, offer high quality, reliable and virtually instantaneous air–ground communications. Aircraft could use satellite communications for air–ground data links for air traffic control – particularly across the north Atlantic, where airline traffic is the heaviest – and for transmission of flight data and weather reports (figure 7). Satellites also have a communications range that extends to almost one-third of the world. Three would provide near global coverage, a fact that has considerable implications for system design; a satellite system would probably be far less expensive than any new terrestrial solutions.

Although a satellite communications terminal for civil aircraft has yet to be developed, Inmarsat is making various studies that could facilitate its development. One of these studies is being made under a contract that is aimed at defining certain technical aspects of providing aeronautical communications via the Inmarsat system. The contract encompasses the following areas: propagation effects on aeronautical satellite links; antenna systems; modulation and coding methods; overall aircraft Earth station (avionics) integration.

Another study is expected to lead to development of a compact, lightweight and relatively inexpensive type of Earth station, which could be used by ships or aircraft. This terminal, known as standard C, is initially intended to provide maritime users with medium speed digital telex-type communications. Standard C will be characterized by a low-gain, quasi-omni-directional antenna. Preliminary estimates indicate that highly reliable communications could be achieved with a G/T in the range of -17 to -26 dB K^{-1} and with a mobile terminal e.i.r.p. of about 20 dB (with respect to 1 W). An overall terminal mass of 15 kg or less is envisaged. Inmarsat estimates that standard C terminals could cost less than U.S. $10000, although an aircraft terminal of similar capabilities would require integration with other aircraft avionics and may prove to be more expensive as a result. Although a voice capability for such a satellite terminal is likely to be further into the future, Inmarsat is studying possible digital voice coding methods compatible with low data rates.

With development of a suitable terminal, aircraft could start using Inmarsat's existing satellite system on an experimental basis. It is more likely, however, that the aeronautical terminals would not start appearing in any substantial numbers until after 1988, when Inmarsat's second generation satellite system comes into operation.

Second-generation system

The satellites composing Inmarsat's first-generation satellite system will near the end of their design lives in the late 1980s, by which time the available capacity in the Atlantic Ocean region is expected to become saturated. In August 1983, Inmarsat issued a call for tenders on a new series of satellites, which could cost several hundred million dollars. Inmarsat requires new satellites from 1988 to handle expected increases in the numbers of users of its system and to offer new services.

Inmarsat's request for proposals, which was sent to leading satellite suppliers around the world, says that bidders could offer spacecraft to be leased or purchased by Inmarsat. Depending on which option is selected, Inmarsat could be ordering as many as nine satellites, which would be launched into geostationary orbit over a three-year period starting in the second quarter of 1988. The spacecraft must be compatible with more than one launcher of six listed in the request for proposals. Of the six, one (Ariane) is European, one (Proton) is Soviet and four (the Space Shuttle, Thor Delta, Atlas Centaur and Titan) are American.

Inmarsat's second-generation system is expected to have many more times the capacity of its existing system. The request for proposals calls for spacecraft with a minimum of 125 telephone channels, compared to the 40 channels provided by the Marecs satellite, the one with the greatest capacity in the current system. The channel capacity could be expanded to about 250 channels by using various techniques, notably carrier suppression. In the ship-to-shore direction, the spacecraft will provide four separate channel paths, which will allow better use of available capacity for working with new smaller types of ship Earth stations under development for the late 1980s, as well as with EPIRBS and aircraft.

Bidders are required to send their proposals to Inmarsat no later than 2 April 1984. The successful bidder or bidders will be chosen by the first quarter of 1985 and then, under the purchase option, will have 36 months to deliver the first in the new series of satellites. If it decides to purchase, rather than lease the satellites, Inmarsat would place contracts for the launch of the satellites.

As noted earlier in this paper, the request for proposals provides for the possibility that the second-generation system may be used for satellite communications to and from aircraft, as well as for new, smaller and more advanced ship Earth stations to be introduced in the future. The number of users of the system is expected to exceed 10000 by the mid-1990s, and it may be even more than that if Inmarsat is used to serve the aeronautical community and to manage a search and rescue satellite system.

Cooperation or failure

The realization of such a multi-purpose system in the 1990s will depend on the support and participation of all nations concerned. Any international system such as that required to support international aeronautical or maritime transport must be open for use by all nations on a non-discriminatory basis. This is not really a political requirement but is primarily based on common sense and a recognition of the fundamental role such a system would play in supporting international transport and improving safety.

The broad international base of Inmarsat suggests that it should be possible to develop institutional arrangements reasonably quickly for search and rescue satellites and for aeronautical satellite communications, following the model already set for maritime satellite communications. Indeed, steps are being taken in this direction already, following a decision by Inmarsat member states during the third Inmarsat Assembly in October 1983. The Assembly requested the Director General to study what amendments would be required to the Inmarsat Convention and Operating Agreement, to put the provision of aeronautical services via Inmarsat on a sound institutional footing. In addition, for an international system like Inmarsat to be successful, there is a need for technical standards to be agreed to achieve economies of scale and interconnectivity. Mobile users need only one system, one piece of equipment that can be used all over the world.

The next decade should be an exciting one for international mobile satellite communications. It is possible that the next decade will see such communications provided by a multi-purpose satellite system, in which geostationary and polar-orbiting satellites are integrated. Such a system, different in many respects from that of the 1980s, will probably be the only way in which various mobile communities can be served in an economic fashion.

'IGURE 3. The ship Earth station, which enables a ship to communicate with other ships or with shore-based subscribers, consists of equipment both above and below deck. Above deck is a parabolic antenna on a stabilized platform covered in a radome. The radome on the bulk carrier *Ambia Fair* can be seen here as a white, distinctive mushroom shape mounted on a pedestal above the bridge. (Photograph by Skyfotos.)